US 20090325065A1

(19) United States

(12) Patent Application Publication

Fujii et al.

(10) Pub. No.: US 2009/0325065 A1

(43) Pub. Date: Dec. 31, 2009

(54) **NON-AQUEOUS LIQUID ELECTROLYTE AND NON-AQUEOUS LIQUID ELECTROLYTE SECONDARY BATTERY**

(75) Inventors: **Takashi Fujii**, Ibaraki (JP); **Noriko Shima**, Ibaraki (JP); **Youichi Ohashi**, Ibaraki (JP); **Shinichi Kinoshita**, Ibaraki (JP)

Correspondence Address:
OBLON, SPIVAK, MCCLELLAND MAIER & NEUSTADT, L.L.P.
1940 DUKE STREET
ALEXANDRIA, VA 22314 (US)

(73) Assignee: **Mitsubishi Chemical Corporation**, Minato-ku, Tokyo (JP)

(21) Appl. No.: **12/298,440**

(22) PCT Filed: **Apr. 27, 2007**

(86) PCT No.: **PCT/JP07/59207**

§ 371 (c)(1), (2), (4) Date: **Feb. 11, 2009**

(30) **Foreign Application Priority Data**

Apr. 27, 2006	(JP)	2006-124041
Apr. 27, 2006	(JP)	2006-124042
Apr. 27, 2006	(JP)	2006-124043
Apr. 27, 2006	(JP)	2006-124044
Apr. 27, 2006	(JP)	2006-124045

Publication Classification

(51) **Int. Cl.**
H01M 6/14 (2006.01)
H01M 10/26 (2006.01)

(52) **U.S. Cl.** **429/199**; 429/207

(57) **ABSTRACT**

A non-aqueous liquid electrolyte secondary battery using negative-electrode active material having Si, Sn and/or Pb, with high charge-capacity, superior characteristics including discharge-capacity retention rate over long is provided. Its non-aqueous liquid electrolyte contains carbonate having unsaturated bond and/or halogen and compounds like $LiPF_6$ and/or $LiBF_4$ (first lithium salt) and lithium salt different from said first one, represented by formula below (second lithium salt).

$Li_l(\alpha_m X^a{}_n)$

NON-AQUEOUS LIQUID ELECTROLYTE AND NON-AQUEOUS LIQUID ELECTROLYTE SECONDARY BATTERY

TECHNICAL FIELD

[0001] The present invention relates to a non-aqueous liquid electrolyte and non-aqueous liquid electrolyte secondary battery using the same. Particularly, it relates to a non-aqueous liquid electrolyte, which shows superior charge-discharge cycle performance when used for a non-aqueous liquid electrolyte secondary battery utilizing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom, and also relates to a non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte.

BACKGROUND ART

[0002] In recent years, with the reduction in weight and size of electrical appliances, development of a non-aqueous liquid electrolyte secondary battery having high energy density, for example lithium secondary battery, has been advanced. Also, as application field of lithium secondary battery is expanded, further improvement in its battery characteristics has been desired.

[0003] In this situation, a secondary battery based on metal lithium as negative electrode has been studied as a battery capable of achieving higher capacity. However, there is a problem that metal lithium grows as dendrite on repeated charges and discharges, and when this reaches the positive electrode, short circuit in the battery occurs. This has been the greatest obstacle in putting a lithium secondary battery based on metal lithium as negative electrode to practical use.

[0004] On the other hand, a non-aqueous liquid electrolyte secondary battery has been proposed, in which carbonaceous material capable of intercalating and deintercalating lithium, such as coke, artificial graphite or natural graphite, is used for the negative electrode in place of metal lithium. In such a non-aqueous liquid electrolyte secondary battery, growth of metal lithium as dendrite can be avoided and therefore, battery life and safety can be improved. When graphite of this kind is used as negative electrode, capacity is known to be usually of the order of 300 $mAh \cdot g^{-1}$, 500 $mAh \cdot cm^{-3}$.

[0005] In recent years, proposals have been made for the negative-electrode active material based on simple metal element capable of forming an alloy with lithium such as silicon (Si), tin (Sn) and lead (Pb), an alloy containing at least one of these metal elements, or metal compound containing these metal elements (hereafter referred to as "negative-electrode active material containing Si, Sn, Pb and the like", as appropriate). The capacity of these materials per unit volume is of the order of 2000 $mAh \cdot cm^{-3}$ or larger, which is about 4 times that of graphites or even larger. Therefore, higher capacity can be obtained by using these materials.

[0006] Although a secondary battery using negative-electrode active material containing Si, Sn, Pb and the like is suitable for realizing higher capacity, there is a decrease in safety, and negative-electrode active material deteriorates on repeated charges and discharges, leading to reduced charge-discharge efficiency and deterioration of cycle performance.

[0007] Therefore, in order to secure safety and prevent a decrease in discharge capacity, a proposal has been made to include cyclic carbonate ester or a polymer of carbonate ester and phosphoric acid triester in the non-aqueous liquid electrolyte used for a secondary battery (refer to Patent Document 1). Furthermore, a proposal has been made to add, in the non-aqueous liquid electrolyte, a heterocyclic compound having sulfur atom and/or oxygen atom in the ring structure and to form a protective layer on the surface of the negative-electrode active material, thus improving charge-discharge cycle performance (refer to Patent Document 2). Moreover, another proposal has been made to add, in the non-aqueous liquid electrolyte, LiB $(C_2O_4)_2$ to form a protective layer on the negative electrode, thus improving cycle performance (refer to Patent Document 3).

[0008] [Patent Document 1] Japanese Patent Laid-Open Publication No. Hei 11-176470

[0009] [Patent Document 2] Japanese Patent Laid-Open Publication No. 2004-87284

[0010] [Patent Document 3] Japanese Patent Laid-Open Publication No. 2005-228565

DISCLOSURE OF THE INVENTION

Problem to Be Solved by the Invention

[0011] Previous secondary batteries described in Patent Documents 1 and 2 use an element such as silicon (Si) as negative electrode material. Although higher capacity was thereby obtained, they were inadequate with respect to performance on longer-term charge-discharge cycle and, especially, discharge capacity retention rate. In the secondary battery described in Patent Document 3, the cycle performance were inadequate either, maybe because a protective layer formed by LiB $(C_2O_4)_2$, which is a salt added to the non-aqueous liquid electrolyte, on the negative electrode heightend the negative-electrode resistance.

[0012] The present invention has been made in view of the above problems. Namely, the purpose of the present invention is to provide a non-aqueous liquid electrolyte secondary battery based on a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom, having high charging capacity and capable of maintaining excellent characteristics, especially discharge capacity retention rate, over a long period of time, and a non-aqueous liquid electrolyte to be used for it.

Means for Solving the Problem

[0013] The present inventors made an intensive effort to solve the above problems and have found that it is possible to solve the above problems by incorporating a carbonate having at least either an unsaturated bond or a halogen atom and at least one kind of a compound (specific compound) selected from the group consisting of (A), (B), (C), (D) and (E), to be described later, in the non-aqueous liquid electrolyte, of a non-aqueous liquid electrolyte secondary battery based on a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom. This finding led to the completion of the present invention.

[0014] Namely, the subject matter of the present invention lies in a non-aqueous liquid electrolyte to be used for a non-aqueous liquid electrolyte secondary battery comprising a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and the non-aqueous liquid electrolyte, the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom,

[0015] wherein said non-aqueous liquid electrolyte contains, at least, a carbonate having at least either an unsaturated bond or a halogen atom, and at least one kind selected from the group consisting of (A), (B), (C), (D) and (E) below. (claim **1**).

[0016] (A) At least one lithium salt of $LiPF_6$ and $LiBF_4$ (hereinafter referred to as "first lithium salt") and at least one kind of lithium salt, which is different from said first lithium salt, represented by the formula (A-1) below (hereinafter referred to as "second lithium salt").

[Chemical Formula 1]

$$Li_l(\alpha_m X^a{}_n) \quad \text{(A-1)}$$

(In the formula (A-1),

[0017] l represents an integer of 1 or larger and 10 or smaller,

[0018] m represents an integer of 1 or larger and 100 or smaller,

[0019] and n represents an integer of 1 or larger and 200 or smaller.

[0020] α represents any atom selected from the group consisting of boron atom, carbon atom, nitrogen atom, oxygen atom and phosphorus atom. When m is 2 or larger, the two or more of a may be the same as or different from each other.

[0021] X^a represents a functional group having at least one kind of atom selected from 14 group to 17 group of the periodic table at its binding position to the α. When n is 2 or larger, the two or more of X^a may be the same or different from each other. In addition, two or more X^a may be connected to each other to form a ring structure,

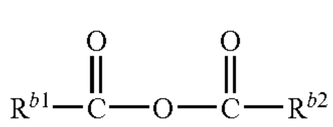
[0022] except such a compound that α is boron atom and X^a is represented by

$$(C_iH_{2(i-2)}O_4)(C_jH_{2(j-2)}O_4)$$

(in this context, i and j each represent, independently of each other, an integer of 2 or larger.)

[0023] (B) At least one kind of compound represented by the formula (B-1) below.

[Chemical Formula 2]



(B-1)

(In the formula (B-1), R^{b1} and R^{b2} represent, independently of each other, a hydrocarbon group, which may have a substituent, with carbon number of 15 or smaller. R^{b1} and R^{b2} may be connected to each other to form a ring structure.)

[0024] (C) At least one kind of chain compound having one or more sulfur-containing functional groups represented by the formula (C-1) below.

[Chemical Formula 3]

$$\text{-}(O)_m\text{-}[S(=O)_y]_x\text{-}(O)_n\text{-} \quad \text{(C-1)}$$

(In the formula (C-1),

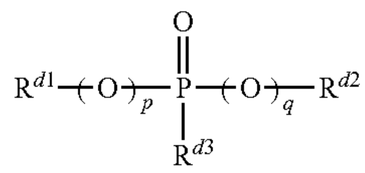
[0025] m and n represent, independently of each other, an integer of 0 or 1,

[0026] x represents an integer of 1 or 2, and

[0027] y represents an integer of 0 or larger and 2 or smaller.)

[0028] (D) At least one kind of organic phosphorous compound represented by the formula (D-1) below.

[Chemical Formula 4]



(D-1)

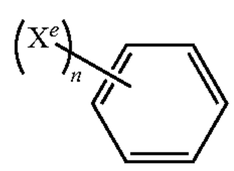
(In the formula (D-1),

[0029] p and q represent, independently of each other, an integer of 0 or 1, and

[0030] R^{d1}, R^{d2} and R^{d3} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller. Any two of R^{d1}, R^{d2} and R^{d3} may be connected to each other to form a ring structure.)

[0031] (E) At least one kind of compound represented by the formula (E-1) below.

[Chemical Formula 5]



(E-1)

(In the formula (E-1),

[0032] X^e represents a halogen atom, alkyl group or aryl group. When X^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group.

[0033] n represents an integer of 1 or larger and 6 or smaller.

[0034] When n is 2 or larger, the two or more of X^e may be the same or different from each other. In addition, two or more X^e may be connected to each other to form a ring structure or a cage structure.

[0035] In this case, it is preferable that, in the above formula (A-1), α is boron atom or phosphorus atom, and X^a is a substituent selected from the group consisting of fluorine atom, hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group and substituted sulfonyloxy group (in this context, when X^a is a hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group or substituted sulfonyloxy group, a part or all of the hydrogen atoms may be substituted with a fluorine atom. In addition, when X^a exists plurally, they may be different from or the same as each other and may be connected to each other to form a ring structure) (claim **2**).

[0036] Further, it is preferable that, in the above formula (A-1), α is carbon atom, nitrogen atom or oxygen atom, and X^a is a group represented by $—SO_2R^{a0}$ (in this context, R^{a0} represents fluorine atom or a hydrocarbon group. When R^{a0} is a hydrocarbon group, a part or all of the hydrogen atoms may be substituted with a fluorine atom. In addition, when the number of X^a is two or more, the two or more of R^{a0} may be the same or different from each other and further, the two or more of R^{a0} may be connected to each other to form a ring structure) (claim **3**).

[0037] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said first lithium salt is 0.5 mol/liter or higher and 2.5 mol/liter or lower, in said non-aqueous liquid electrolyte, the concentration of said second lithium salt is 0.001 mol/liter or higher and 1 mol/liter or lower, and the molar ratio of said second lithium salt relative to the first lithium salt is 1 or smaller (claim **4**).

[0038] Further, it is preferable that said compound represented by the above formula (B-1) is a compound in which R^{b1} and R^{b2} are connected to each other directly to form a ring structure (claim **5**).

[0039] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (B-1) is 0.01 weight % or higher and 5 weight % or lower (claim **6**).

[0040] Further, it is preferable that said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is a compound represented by the formula (C-2) below (claim **7**).

[Chemical Formula 6]

$$R^{c1}\text{-}A^{c}\text{-}R^{c2} \qquad \text{(C-2)}$$

(In the formula (C-2),

[0041] A^c represents a sulfur-containing functional group represented by the above formula (C-1), and

[0042] R^{c1} and R^{c2} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller.)

[0043] Further, it is preferable that said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is a compound represented by the formula (C-3) below (claim **8**).

[Chemical Formula 7]

$$(R^{c3}\text{-}A^{c}\text{-})_{z}R^{c4} \qquad \text{(C-3)}$$

(In the formula (C-3),

[0044] R^{c3} represents a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller,

[0045] A^c represents a sulfur-containing functional group represented by the above formula (1) [SIC],

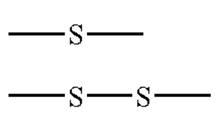
[0046] z represents an integer of 2 or larger and 4 or smaller, and

[0047] R^{c4} represents a hydrocarbon group, which may have a halogen atom, with z number of connection parts and with carbon number of 1 or larger and 20 or smaller.

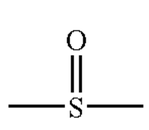
[0048] In this context, the z number of R^{c3} and A^c may be the same or different from each other, respectively.)

[0049] Further, it is preferable that said sulfur-containing functional group represented by the above formula (C-1) is any one of functional groups represented by the formulae (C-4) to (C-10) below (claim **9**).

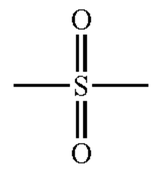
[Chemical Formula 8]

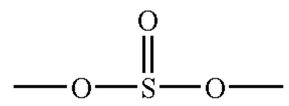

(C-4)

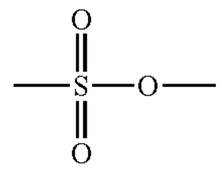
(C-5)

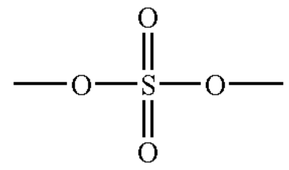

(C-6)

-continued


(C-7)


(C-8)


(C-9)


(C-10)

[0050] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is 0.01 weight % or higher and 10 weight % or lower (claim **10**).

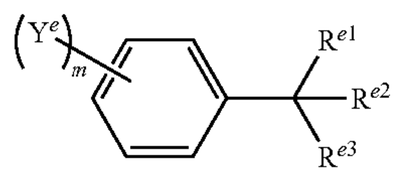
[0051] Further, it is preferable that, in the above formula (D-1), p+q is equal to 1 or 2 (claim **11**).

[0052] Further, it is preferable that, in the above formula (D-1), p+q is equal to 0 (claim **12**).

[0053] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (D-1) is 0.01 weight % or higher and 10 weight % or lower (claim **13**).

[0054] Further, it is preferable that said compound represented by the above formula (E-1) is the compound represented by the formula (E-2) below (claim **14**).

[Chemical Formula 9]


(E-2)

(In the formula (E-2),

[0055] R^{e1}, R^{e2} and R^{e3} represent, independently of each other, hydrogen atom, or an alkyl group that may be substituted with a halogen atom. In addition, two or three of R^{e1}, R^{e2} and R^{e3} may be connected to each other to form a ring structure or cage structure.

[0056] However, none of or one of R^{e1}, R^{e2} and R^{e3} is hydrogen atom.

[0057] Y^e represents a halogen atom, alkyl group or aryl group. When Y^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group.

[0058] m represents an integer of 0 or larger and 5 or smaller. When m is 2 or larger, the two or more of Y^e may be the same or different from each other. In addition, two or more Y^e may be connected to each other to form a ring structure or cage structure.)

[0059] Further, it is preferable that, in the above formula (E-1), at least one of X^e is halogen atom, or an aryl group that may be substituted with a halogen atom (claim **15**).

[0060] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (E-1) is 0.01 weight % or higher and 10 weight % or lower (claim **16**).

[0061] Further, it is preferable that, in said non-aqueous liquid electrolyte, the concentration of said carbonate having at least either an unsaturated bond or a halogen atom is 0.01 weight % or higher, and 70 weight % or lower (claim **17**).

[0062] Further, it is preferable that said carbonate having at least either an unsaturated bond or a halogen atom is one or more kinds of carbonates selected from the group consisting of vinylene carbonate, vinylethylene carbonate, fluoroethylene carbonate, difluoroethylene carbonate and derivatives of these carbonates (claim **18**).

[0063] Further, it is preferable to further contain ethylene carbonate and/or propylene carbonate (claim **19**).

[0064] Further, it is preferable to further contain at least one carbonate selected from the group consisting of dimethyl carbonate, ethylmethyl carbonate, diethyl carbonate, methyl-n-propyl carbonate, ethyl-n-propyl carbonate and di-n-propyl carbonate (claim **20**).

[0065] Another subject matter of the present invention lies in a non-aqueous liquid electrolyte secondary battery comprising a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and a non-aqueous liquid electrolyte, the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom, wherein said non-aqueous liquid electrolyte is a non-aqueous liquid electrolyte according to any one of claims **1** to **20** (claim **21**).

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0066] The non-aqueous liquid electrolyte secondary battery of the present invention has high charge capacity and maintains an excellent property over a long period. It is excellent especially in discharge capacity retention rate.

BEST MODES FOR CARRYING OUT THE INVENTION

[0067] An embodiment of the present invention will be explained in detail below. The explanation given below on constituent features indicates one example of each aspect of the present invention (representative example) and by no means restrictive. It is to be understood that the present invention is by no means limited by these examples insofar as they do not depart from the intent of the invention.

[I. Non-Aqueous Electrolyte Solution]

[0068] First, the non-aqueous liquid electrolyte of the present invention will be explained.

[0069] The non-aqueous liquid electrolyte of the present invention is a non-aqueous liquid electrolyte to be used for a non-aqueous liquid electrolyte secondary battery comprising a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and a non-aqueous liquid electrolyte, the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom.

[0070] The non-aqueous liquid electrolyte of the present invention usually comprises, as its main components, an electrolyte and non-aqueous solvent to dissolve it, similarly to a non-aqueous liquid electrolyte generally used. It further comprises at least one kind of compound selected from the group consisting of (A), (B), (C), (D) and (E) described later or a combination thereof (the compound and the combination thereof are hereafter referred to as "specific compound" as appropriate), and at least one kind of carbonate having at least either an unsaturated bond or a halogen atom (hereafter referred to as "specific carbonate" as appropriate). It may contain other components (such as an additive).

[0071] In the following description, explanation will be given, first, on the specific compound and specific carbonate, followed by the electrolyte and the non-aqueous solvent. Other components will also be touched upon.

[0072] [I-1. Specific Compound]

[0073] The specific compound according to the present invention is at least one kind selected from the group consisting of (A), (B), (C), (D) and (E) below.

[0074] (A) At least one lithium salt of $LiPF_6$ and $LiBF_4$ (hereinafter referred to as "first lithium salt") and at least one kind of lithium salt, which is different from the first lithium salt, represented by the formula (A-1) to be described later (hereinafter referred to as "second lithium salt"). (The combination of the first lithium salt and the second lithium salt will be referred to as "specific compound (A)" as appropriate.)

[0075] (B) At least one kind of compound represented by the formula (B-1) to be described later (hereinafter referred to as "specific compound (B)" as appropriate).

[0076] (C) At least one kind of chain compound having one or more sulfur-containing functional groups represented by the formula (C-1) to be described later (hereinafter referred to as "specific compound (C)" as appropriate).

[0077] (D) At least one kind of organic phosphorous compound represented by the formula (D-1) to be described later (hereinafter referred to as "specific compound (D)" as appropriate).

[0078] (E) At least one kind of compound represented by the formula (E-1) to be described later (hereinafter referred to as "specific compound (E)" as appropriate).

[0079] The non-aqueous liquid electrolyte of the present invention may contain any one kind of the above-mentioned specific compounds (A) to (E) as one kind, or two or more kinds of them in combination in any combination and in any ratio.

[0080] In the following, each of the specific compounds (A) to (E) will be explained in this order.

[0081] [I-1-A. Specific Compound (A)]

[0082] The specific compound (A) is a combination of the first lithium salt and the second lithium salt, which are explained below.

[0083] [I-1-A-1. First Lithium Salt]

[0084] The first lithium salt is at least one lithium salt of $LiPF_6$ and $LiBF_4$.

[0085] As first lithium salt, either one of $LiPF_6$ and $LiBF_4$ can be used alone, or both of them can be used in combination. Of these, it is preferable to use $LiPF_6$ alone or to use $LiPF_6$ and $LiBF_4$ in combination. The combined use of $LiPF_6$ and $LiBF_4$ is particularly preferable, since effect of prevent-

ing capacity decrease caused by a continuous charging can be achieved remarkably for the non-aqueous liquid electrolyte of the present invention, which contains comparatively large amount of carbonate compound in the form of specific carbonate or non-aqueous solvent to be described later.

[0086] The concentration of the first lithium salt in the non-aqueous liquid electrolyte is in the range of usually 0.5 mol/liter or higher, preferably 0.6 mol/liter or higher, more preferably 0.7 mol/liter or higher, and usually 2.5 mol/liter or lower, preferably 1.8 mol/liter or lower, more preferably 1.5 mol/liter or lower. Whether the concentration of the first lithium salt is too low or too high, the electric conductivity of the non-aqueous liquid electrolyte tends to be too low, leading possibly to decrease in battery characteristics. Incidentally, when both $LiPF_6$ and $LiBF_4$ are used in combination, total concentration of them should fall within the above-mentioned range.

[0087] In addition, when both $LiPF_6$ and $LiBF_4$ are used in combination as first lithium salt, the molar ratio of $LiBF_4$ relative to $LiPF_6$ is usually 0.005 or higher, preferably 0.01 or higher, particularly preferably 0.05 or higher, and usually 1 or lower. When the ratio of $LiBF_4$ relative to LiPF6 is too high, the electric conductivity of the liquid electrolyte may be too low, leading possibly to decrease in battery characteristics.

[0088] [I-1-A-2. Second Lithium Salt]

[0089] The second lithium salt is a lithium salt represented by the formula (A-1) below. However, it is assumed that the second lithium salt does not include the above-mentioned first lithium salt ($LiPF_6$, $LiBF_4$).

[Chemical Formula 10]

$$Li_l(\alpha_m X^a{}_n) \quad \text{(A-1)}$$

(In the formula (A-1),

[0090] l represents an integer of 1 or larger and 10 or smaller,

[0091] m represents an integer of 1 or larger and 100 or smaller,

[0092] and n represents an integer of 1 or larger and 200 or smaller.

[0093] α represents any atom selected from the group consisting of boron atom, carbon atom, nitrogen atom, oxygen atom and phosphorus atom. When m is 2 or larger, the two or more of a may be the same or different from each other.

[0094] X^a represents a functional group having at least one kind of atom selected from the 14 group to 17 group of the periodic table at its binding position to the α. When n is 2 or larger, the two or more of X^a may be the same or different from each other. In addition, two or more X^a may be connected to each other to form a ring structure, except such a compound that α is boron atom and X^a is $(C_iH_{2(i-2)}O_4)(C_jH_{2(j-2)}O_4)$ (in this context, i and j each represent, independently of each other, an integer of 2 or larger.)

[0095] More specifically, in the above-mentioned formula (A-1), l represents an integer of usually 1 or larger, and usually 10 or smaller, preferably 5 or smaller, particularly preferably 2 or smaller.

[0096] m represents an integer of usually 1 or larger, and usually 100 or smaller, preferably 50 or smaller, particularly preferably 20 or smaller.

[0097] n represents an integer of usually 1 or larger, and usually 200 or smaller, preferably 100 or smaller, particularly preferably 20 or smaller.

[0098] In the above formula (A-1), when α is boron atom or phosphorus atom, it is preferable that X^a is a substituent selected from the group consisting of fluorine atom, hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group and substituted sulfonyloxy group (in this context, when X^a is a hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group or substituted sulfonyloxy group, a part or all of the hydrogen atoms may be substituted with a fluorine atom. In addition, when X^a exists plurally, they may be different from or the same as each other and may be connected to each other to form a ring structure). Incidentally, the substituent which substituted carbonyloxy group, substituted sulfinyloxy group and substituted sulfonyloxy group possess is usually a hydrocarbon group.

[0099] In the above formula (A-1), when α is carbon atom, nitrogen atom or oxygen atom, it is preferable that X^a is a group represented by $—SO_2R^{a0}$ (in this context, R^{a0} represents fluorine atom or a hydrocarbon group. When R^{a0} is a hydrocarbon group, a part or all of the hydrogen atoms may be substituted with a fluorine atom. In addition, when the number of X^a is two or more, the two or more of R^{a0} may be the same or different from each other and further, the two or more of R^{a0} may be connected to each other to form a ring structure).

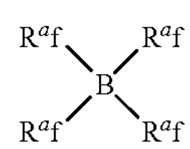
[0100] In the following, examples of the second lithium salt will be described for each kind of α.

[0101] Second Lithium Salt in Which α is Boron Atom

[0102] Examples of the second lithium salt, in which α in the above formula (A-1) is boron atom, include lithium salts having univalent anions represented by the following formulae (A-2-1) to (A-2-12).

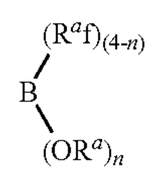
[Chemical Formula 11]

(A-2-1)



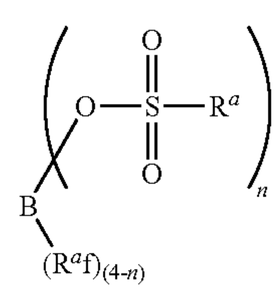
[Chemical Formula 12]

(A-2-2)



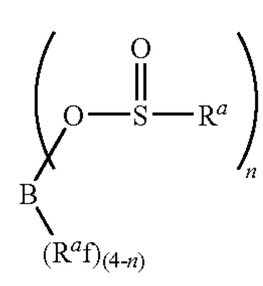
[Chemical Formula 13]

A-2-3)



[Chemical Formula 14]

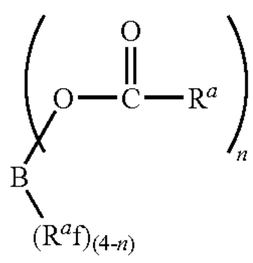
(A-2-4)



-continued

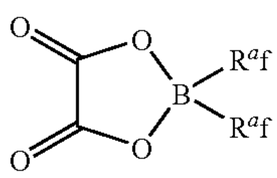
[Chemical Formula 15]

(A-2-5)



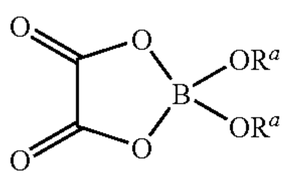
[Chemical Formula 16]

(A-2-6)



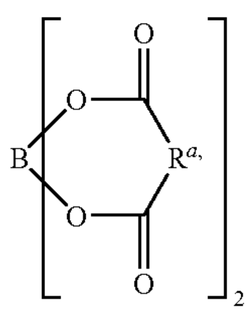
[Chemical Formula 17]

(A-2-7)



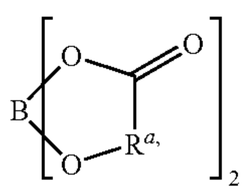
[Chemical Formula 18]

(A-2-8)



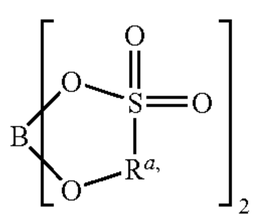
[Chemical Formula 19]

(A-2-9)



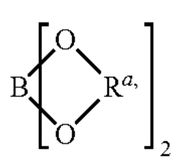
[Chemical Formula 20]

(A-2-10)



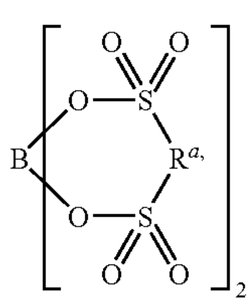
[Chemical Formula 21]

(A-2-11)



[Chemical Formula 22]

(A-2-12)



[0103] In the above formulae (A-2-1) to (A-2-12), R^a represents a univalent hydrocarbon group that may be substituted with a fluorine atom.

[0104] $R^{a'}$ represents a bivalent hydrocarbon group that may be substituted with a fluorine atom.

[0105] R^af represents fluorine atom or a univalent fluorinated carbon group. In the present Description, the term "fluorinated carbon group" indicates a hydrocarbon group in which all the hydrogen atoms are substituted with fluorine atoms.

[0106] When plural number of R^a, $R^{a'}$, and/or R^af are present in the same molecule, they may be the same or may be different from each other.

[0107] n represents an integer of 1 or larger, and 4 or smaller.

[0108] In the following, explanation will be given on R^a and $R^{a'}$ first.

[0109] R^a is to be a univalent hydrocarbon group and there is no other limitation on its kind. It may be, for example, a saturated hydrocarbon group, or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0110] $R^{a'}$ is to be a bivalent hydrocarbon group and there is no other limitation on its kind. It may be a saturated hydrocarbon group, or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0111] The number of carbon atoms of the univalent hydrocarbon group R^a is usually 1 or more, and usually 12 or less, preferably 8 or less.

[0112] The number of carbon atoms of the bivalent hydrocarbon group $R^{a'}$ is usually 1 or more, preferably 2 or more, and usually 24 or less, preferably 16 or less. When the number of carbon atoms of R^a and $R^{a'}$ is too many, solubility in solvents tends to decrease.

[0113] For the hydrocarbon groups of R^a and $R^{a'}$, a part or all of their hydrogen atoms may be substituted with a fluorine atom (a hydrocarbon group in which a part or all of its hydrogen atoms are substituted with a fluorine atom is hereinafter collectively referred to as "fluorine-substituted hydrocarbon group". Among them, a hydrocarbon group in which all of its hydrogen atoms are substituted with fluorine atoms is referred to as "fluorinated carbon group", as mentioned above). When R^a and $R^{a'}$ are a fluorine-substituted hydrocarbon group, the number of the fluorine atoms may be only one or two or more.

[0114] Concrete examples will be given first for R^a when it is an unsubstituted hydrocarbon group.

[0115] Examples of the chained saturated hydrocarbon group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group and tert-butyl group.

[0116] Examples of the cyclic saturated hydrocarbon group include cyclopropyl group, cyclopentyl group and cyclohexyl group.

[0117] Examples of the hydrocarbon group having one or more unsaturated bonds (hereinafter abbreviated as "unsaturated hydrocarbon group", as appropriate) include vinyl group, 1-propene-1-yl group, 1-propene-2-yl group, 2-propene-1-yl group, allyl group, crotyl group, ethynyl group,

propargyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, xylyl group, benzyl group and cinnamyl group.

[0118] Of these hydrocarbon groups, preferable for R^a from the standpoints of solubility in liquid electrolyte and ease of industrial availability are methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, tert-butyl group, cyclopentyl group, cyclohexyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, vinyl group, allyl group, ethynyl group, propargyl group, and benzyl group. Particularly preferable are methyl group, ethyl group, n-propyl group, n-butyl group, vinyl group and benzyl group.

[0119] Next, concrete examples will be given for R^a when it is a fluorine-substituted hydrocarbon group.

[0120] Examples of the fluorine-substituted chained saturated hydrocarbon group include fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 1,1-difluoroethyl group, 1,2-difluoroethyl group, 2,2-difluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 1-fluoro-n-propyl group, 2-fluoro-n-propyl group, 3-fluoro-n-propyl group, 1,1-difluoro-n-propyl group, 1,2-difluoro-n-propyl group, 1,3-difluoro-n-propyl group, 2,2-difluoro-n-propyl group, 2,3-difluoro-n-propyl group, 3,3-difluoro-n-propyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 1-fluoroisopropyl group, 2-fluoroisopropyl group, 1,2-difluoroisopropyl group, 2,2-difluoroisopropyl group, 2,2'-difluoroisopropyl group, 2,2,2,2',2',2'-hexafluoroisopropyl group, 1-fluoro-n-butyl group, 2-fluoro-n-butyl group, 3-fluoro-n-butyl group, 4-fluoro-n-butyl group, 4,4,4-trifluoro-n-butyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group and perfluoro-tert-butyl group.

[0121] Examples of the fluorine-substituted cyclic saturated hydrocarbon group include 1-fluorocyclopropyl group, 2-fluorocyclopropyl group, perfluorocyclopropyl group, 1-fluorocyclopentyl group, 2-fluorocyclopentyl group, 3-fluorocyclopentyl group, perfluorocyclopentyl group, 1-fluorocyclohexyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group and perfluorocyclohexyl group.

[0122] Examples of the fluorine-substituted unsaturated hydrocarbon group include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 3-fluoro-2-methylphenyl group, 4-fluoro-2-methylphenyl group, 5-fluoro-2-methylphenyl group, 6-fluoro-2-methylphenyl group, 2-fluoro-3-methylphenyl group, 4-fluoro-3-methylphenyl group, 5-fluoro-3-methylphenyl group, 6-fluoro-3-methylphenyl group, 2-fluoro-4-methylphenyl group, 3-fluoro-4-methylphenyl group, perfluorotoluyl group, 2-fluoronaphthalene-1-yl group, 3-fluoronaphthalene-1-yl group, 4-fluoronaphthalene-1-yl group, 5-fluoronaphthalene-1-yl group, 6-fluoronaphthalene-1-yl group, 7-fluoronaphthalene-1-yl group, 8-fluoronaphthalene-1-yl group, 1-fluoronaphthalene-2-yl group, 3-fluoronaphthalene-2-yl group, 4-fluoronaphthalene-2-yl group, 5-fluoronaphthalene-2-yl group, 6-fluoronaphthalene-2-yl group, 7-fluoronaphthalene-2-yl group, 8-fluoronaphthalene-2-yl group, perfluoronaphthyl group, 1-fluorovinyl group, 2-fluorovinyl group, 1,2-difluorovinyl group, 2,2-difluorovinyl group, perfluorovinyl group, 1-fluoroallyl group, 2-fluoroallyl group, 3-fluoroallyl group, perfluoroallyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group, (perfluorophenyl)methyl group and perfluorophenylmethyl group.

[0123] Of these fluorine-substituted hydrocarbon groups, preferable as R^a from the standpoints of chemical and electrochemical stability and ease of industrial availability are fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 2,2,2,2',2',2'-hexafluoroisopropyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group, perfluoro-tert-butyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group, perfluorocyclohexyl group, 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 1-fluorovinyl group, 2-fluorovinyl group, perfluorovinyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group, (perfluorophenyl)methyl group and perfluorophenylmethyl group.

[0124] Concrete examples of $R^{a'}$ include bivalent, unsubstituted or fluorine-substituted hydrocarbon groups which are obtained by removal of one arbitrary hydrogen atom or fluorine atom from the univalent unsubstituted or fluorine-substituted hydrocarbon groups mentioned above as concrete examples of R^a. Also concrete examples of $R^{a'}$ include bivalent unsubstituted or fluorine-substituted hydrocarbon groups which are obtained by bonding of two arbitrary groups of the univalent unsubstituted or fluorine-substituted hydrocarbon groups cited above as concrete examples of R^a.

[0125] Next, explanation will be given on R^af.

[0126] As mentioned above, R^af is fluorine atom or a univalent fluorinated carbon group. When R^af is a univalent fluorinated carbon group, there is no special limitation on the carbon skeleton structure of its molecule. For example, it may consist of only a saturated bond (carbon to carbon single bond), or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0127] When R^af is a univalent fluorinated carbon group, the number of its carbon atoms is usually 1 or more, and usually 12 or less, preferably 8 or less. When the number of carbon atoms of the fluorinated carbon group is too many, solubility in solvents tends to decrease.

[0128] Next, concrete examples will be given for R^af when it is a fluorinated carbon group.

[0129] Examples of the chained fluorinated carbon group include trifluoromethyl group, perfluoroethyl group, perfluoro-n-propyl group, perfluoroisopropyl group, perfluoro-n-butyl group and perfluoro-tert-butyl group.

[0130] Examples of the cyclic fluorinated carbon group include perfluorocyclopropyl group, perfluorocyclopentyl group and perfluorocyclohexyl group.

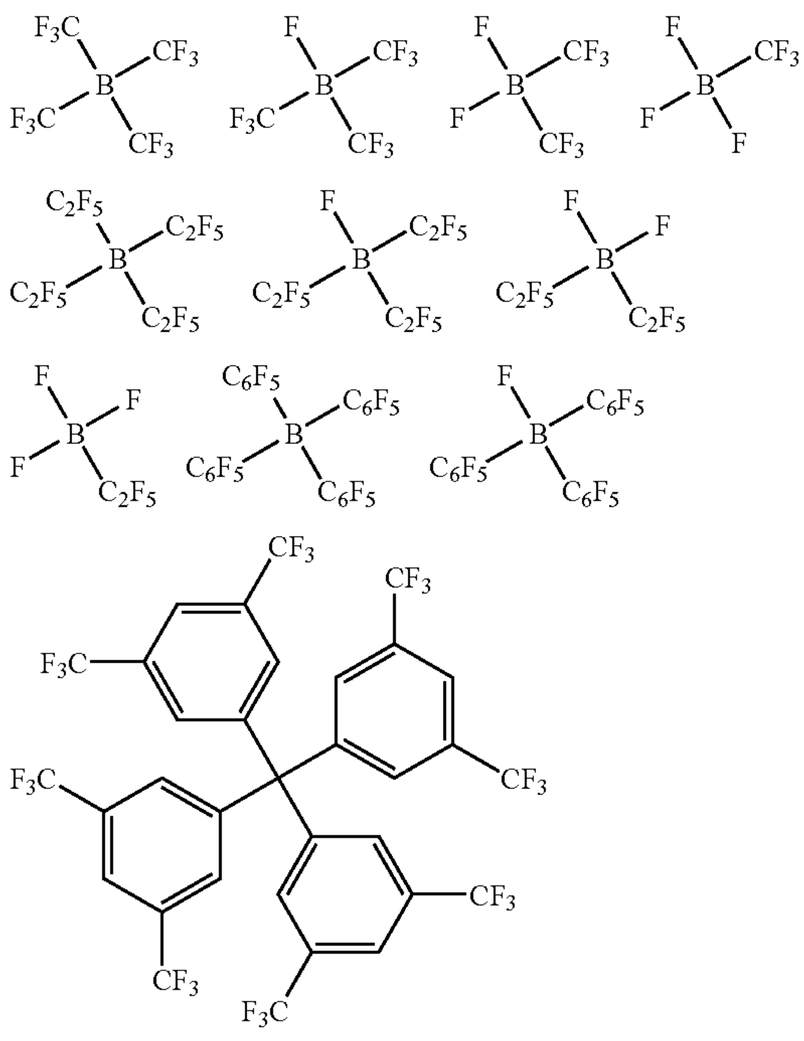
[0131] Examples of the fluorinated carbon group having one or more unsaturated bonds (hereinafter abbreviated as "unsaturated fluorinated carbon group", as appropriate) include perfluorophenyl group, perfluorotoluyl group, per-

fluoronaphthyl group, perfluorovinyl group, perfluoroallyl group, (perfluorophenyl)methyl group and perfluorophenylmethyl group.

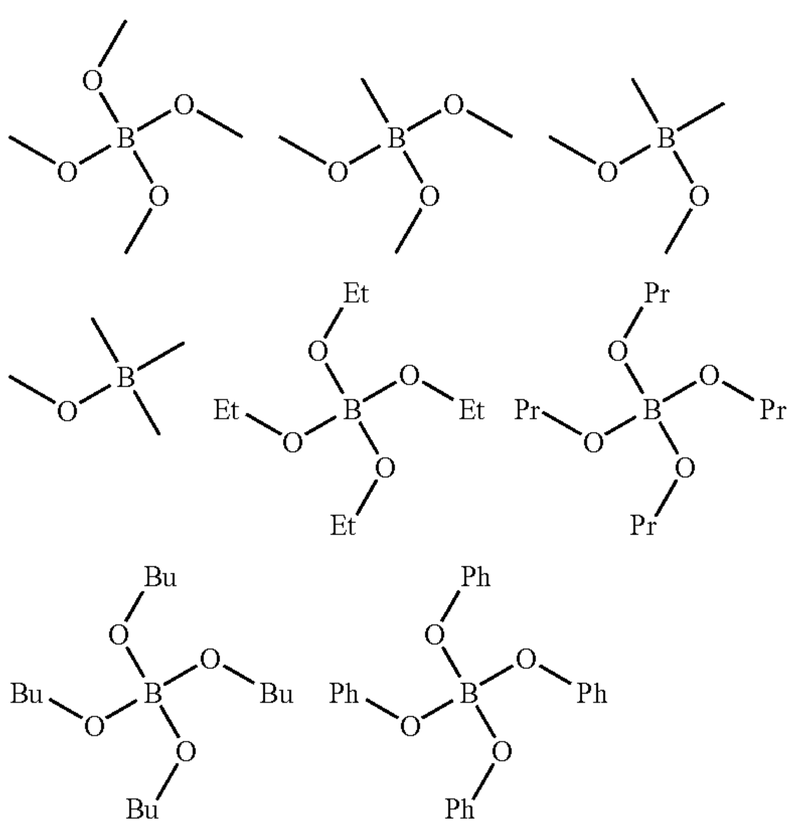
[0132] Of these fluorinated carbon groups, preferable as $R^a f$ from the standpoints of solubility of salts, electric conductivity characteristics, or the like are trifluoromethyl group, perfluoroethyl group, perfluoro-n-propyl group and perfluoroisopropyl group. Particularly preferable are trifluoromethyl group and perfluoroethyl group.

[0133] Next, concrete examples will be given for univalent anions represented by the above formulae (A-2-1) to (A-2-12).

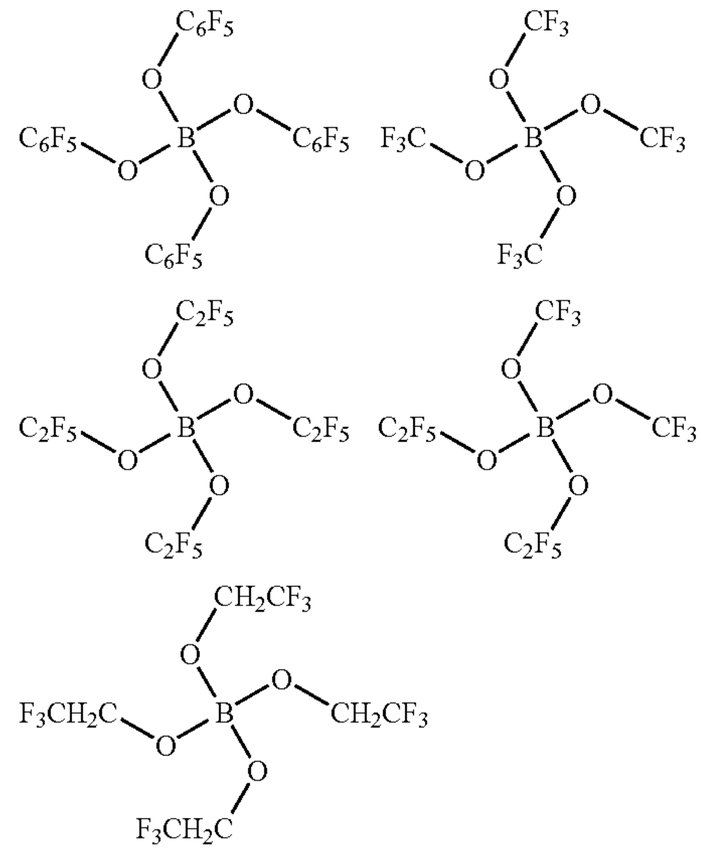
[Chemical Formula 23]



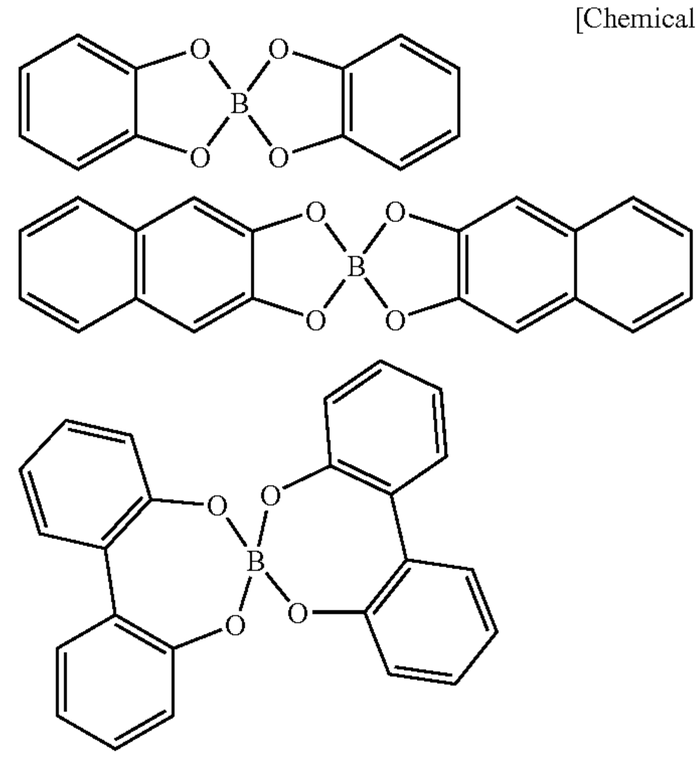
[Chemical Formula 24]



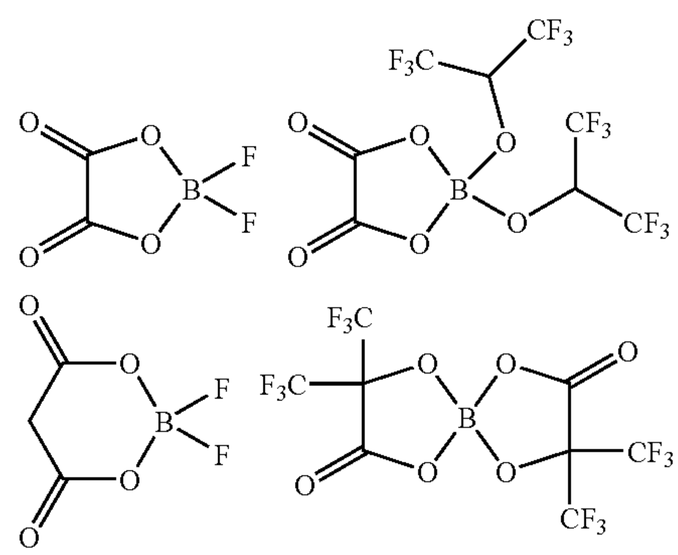
-continued



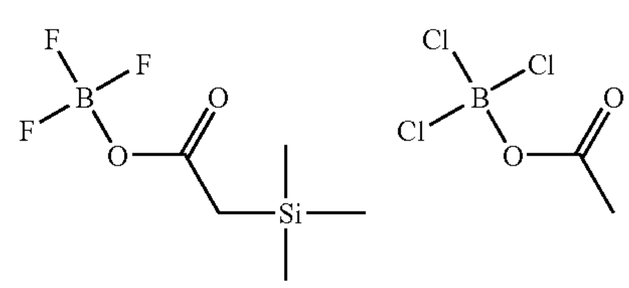
[Chemical Formula 25]



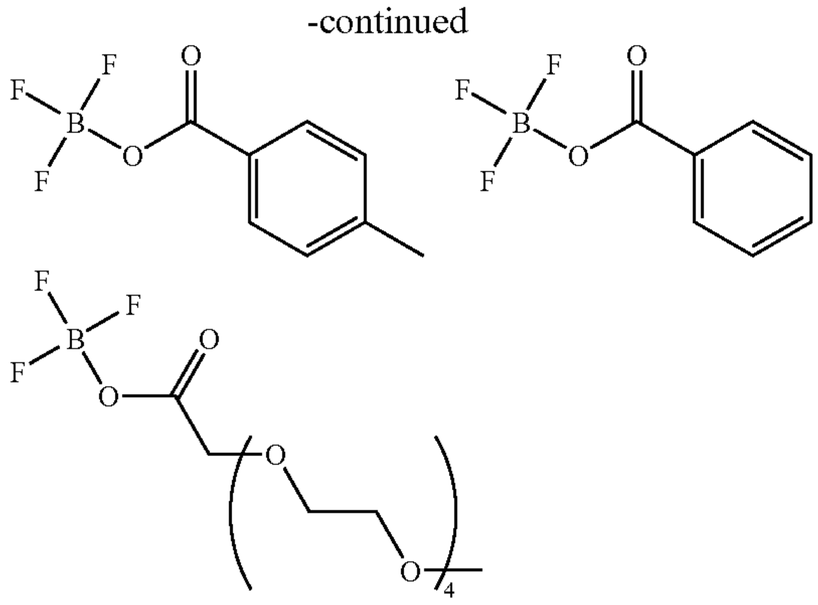
[Chemical Formula 26]



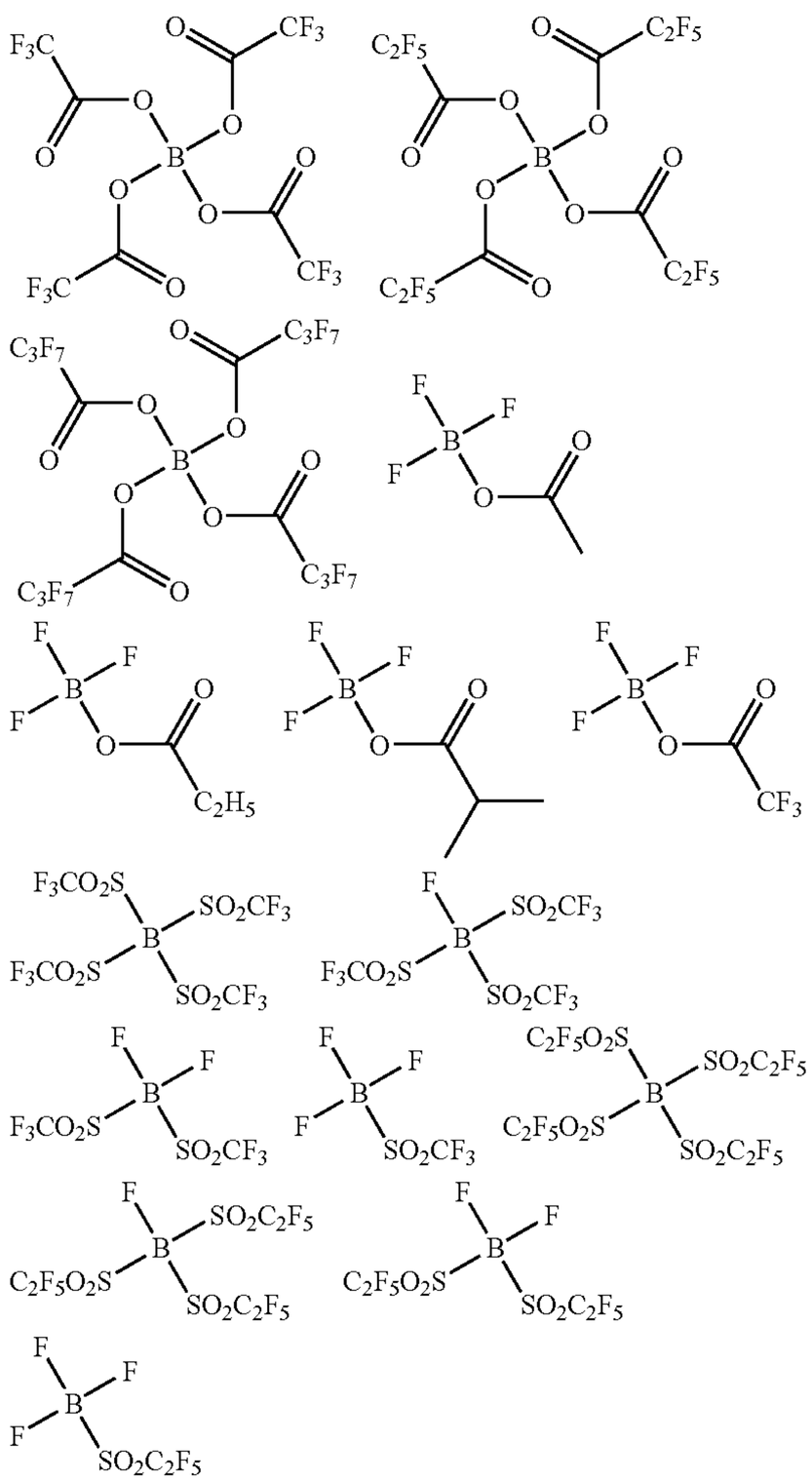
[Chemical Formula 27]



-continued



[Chemical Formula 28]



[0134] Examples of the second lithium salt, in which α is boron atom, include lithium salts having a cluster anion represented by the formula $B_{12}F_xZ_{12-x}$, in addition to lithium salts having univalent anions represented by the above formulae (A-2-1) to (A-2-12). X represents an integer of 5 or larger and 11 or smaller. Z represents H, Cl or Br.

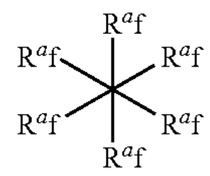
[0135] Concrete examples of the cluster anion represented by the formula $B_{12}F_xZ_{12-x}$ include $Li_2B_{12}F_5H_7$, $Li_2B_{12}F_6H_6$, $Li_2B_{12}F_7H_5$, $Li_2B_{12}F_8H_4$, $Li_2B_{12}F_9H_3$, $Li_2B_{12}F_{10}H_2$ and $Li_2B_{12}F_{11}H_1$.

[0136] Second Lithium Salt in Which α is Phosphorus Atom:

[0137] Examples of the second lithium salt, in which α in the above formula (A-1) is phosphorus atom, include lithium salts having univalent anions represented by the following formulae (A-3-1) to (A-3-18).

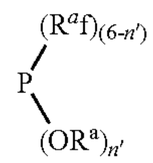
[Chemical Formula 29]

(A-3-1)



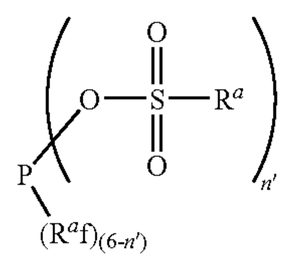
[Chemical Formula 30]

(A-3-2)



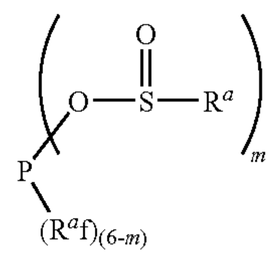
[Chemical Formula 31]

(A-3-3)



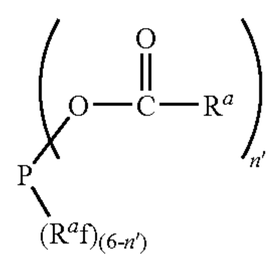
[Chemical Formula 32]

(A-3-4)



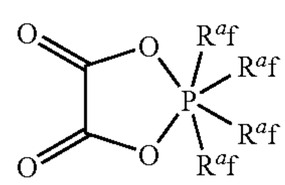
[Chemical Formula 33]

(A-3-5)



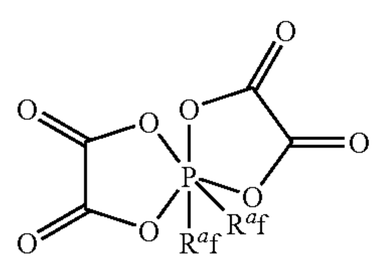
[Chemical Formula 34]

(A-3-6)



[Chemical Formula 35]

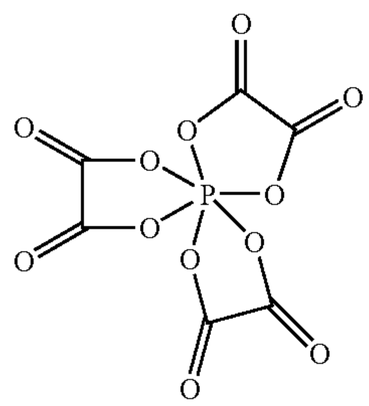
(A-3-7)



-continued

[Chemical Formula 36]

(A-3-8)



[0138] In the above formulae (A-3-1) to (A-3-18), R^a represents a univalent hydrocarbon group that may be substituted with a fluorine atom.

[0139] $R^{a'}$ represents a bivalent hydrocarbon group that may be substituted with a fluorine atom.

[0140] R^af represents fluorine atom or a univalent fluorinated carbon group.

[0141] When plural number of R^a, $R^{a'}$, and/or R^af are present in the same molecule, they may be the same or may be different from each other.

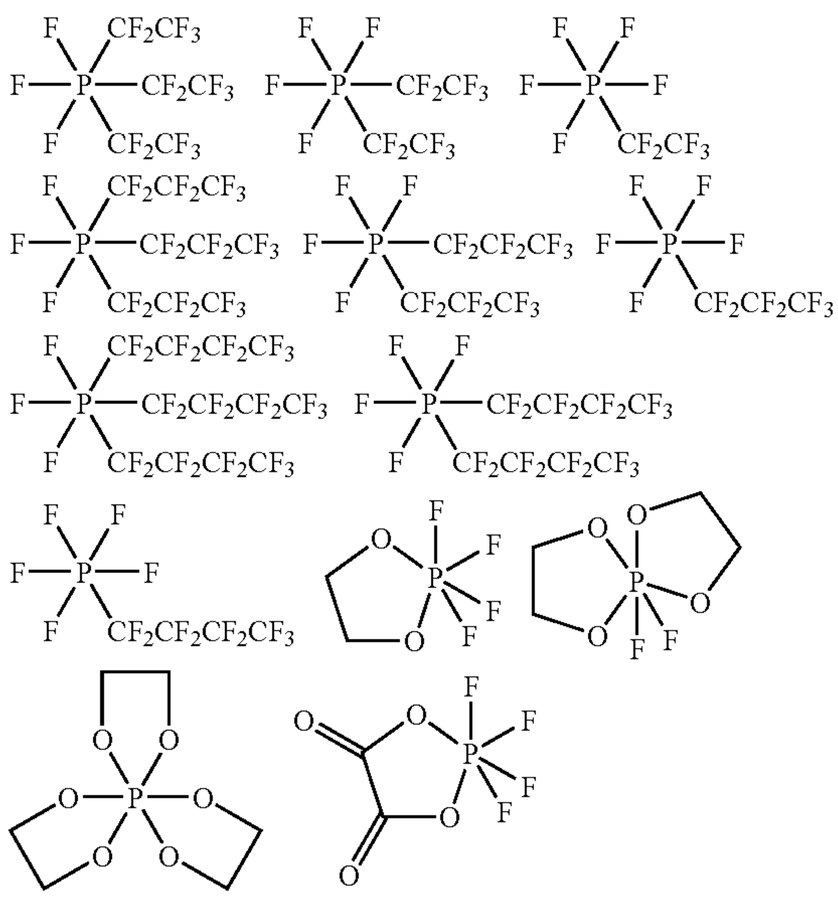
[0142] n' represents an integer of 1 or larger, and 6 or smaller.

[0143] m represents an integer of 1 or larger, and 3 or smaller.

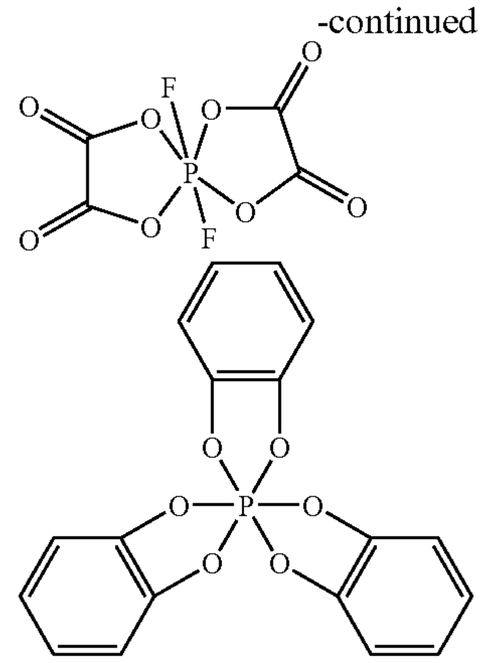
[0144] The details such as the kind and the number of carbon atoms of R^a, $R^{a'}$ and R^af are the same as described previously for R^a, R^a and R^af in the above formulae (A-2-1) to (A-2-12). Concrete examples of R^a, $R^{a'}$ and R^af include the same concrete examples cited earlier for R^a, $R^{a'}$ and R^af in the above formulae (A-2-1) to (A-2-12).

[0145] Next, concrete examples will be given for univalent anions represented by the above formulae (A-3-1) to (A-3-18).

[Chemical Formula 47]



-continued

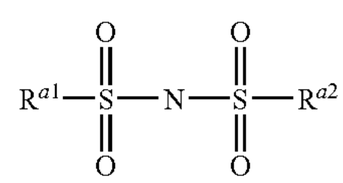


[0146] Second Lithium Salt in Which α is Nitrogen Atom:

[0147] Examples of the second lithium salt, in which α in the above formula (A-1) is nitrogen atom, include lithium salts having univalent anions represented by the following formula (A-4-1).

[Chemical Formula 49]

(A-4-1)



[0148] In the above formula (A-4-1), R^{a1} and R^{a2} are fluorine atom or a univalent hydrocarbon group that may be substituted with a fluorine atom. R^{a1} and R^{a2} may be the same or may be a different from each other.

[0149] In the above formula (A-4-1), no particular limitation is imposed on the kind of R^{a1} and R^{a2} when they are a univalent hydrocarbon group. It may be, for example, a saturated hydrocarbon group, or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0150] When R^{a1} and R^{a2} are a univalent hydrocarbon group, the number of their carbon atoms is usually 1 or more, and usually 9 or less, preferably 7 or less. When the number of carbon atoms of the hydrocarbon groups are too many, solubility in solvents tends to decrease.

[0151] As described above, when R^{a1} and R^{a2} are a hydrocarbon group, all or part of their hydrogen atoms may be substituted with a fluorine atom. When R^{a1} and R^{a2} are a fluorine-substituted hydrocarbon group, the number of the fluorine atom may be only one or two or more.

[0152] In the following, concrete examples will be given for R^{a1} and R^{a2} when they are an unsubstituted hydrocarbon group.

[0153] Examples of the chained saturated hydrocarbon group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group and tert-butyl group.

[0154] Examples of the cyclic saturated hydrocarbon group include cyclopropyl group, cyclopentyl group and cyclohexyl group.

[0155] Examples of the unsaturated hydrocarbon group include vinyl group, 1-propene-1-yl group, 1-propene-2-yl group, 2-propene-1-yl group, allyl group, crotyl group, ethynyl group, propargyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, xylyl group, benzyl group and cinnamyl group.

[0156] Of these unsubstituted hydrocarbon groups, preferable as R^{a1} and R^{a2} from the standpoints of solubility in liquid electrolyte and ease of industrial availability are methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, tert-butyl group, cyclopentyl group, cyclohexyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, vinyl group, allyl group, ethynyl group, propargyl group, and benzyl group. Particularly preferable are methyl group, ethyl group, n-propyl group, phenyl group, vinyl group and allyl group.

[0157] Next, concrete examples will be given for R^{a1} and R^{a2} when they are a fluorine-substituted hydrocarbon group.

[0158] Examples of the fluorine-substituted chained saturated hydrocarbon group include fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 1,1-difluoroethyl group, 1,2-difluoroethyl group, 2,2-difluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 1-fluoro-n-propyl group, 2-fluoro-n-propyl group, 3-fluoro-n-propyl group, 1,1-difluoro-n-propyl group, 1,2-difluoro-n-propyl group, 1,3-difluoro-n-propyl group, 2,2-difluoro-n-propyl group, 2,3-difluoro-n-propyl group, 3,3-difluoro-n-propyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 1-fluoroisopropyl group, 2-fluoroisopropyl group, 1,2-difluoroisopropyl group, 2,2-difluoroisopropyl group, 2,2'-difluoroisopropyl group, 2,2,2,2',2',2'-hexafluoroisopropyl group, 1-fluoro-n-butyl group, 2-fluoro-n-butyl group, 3-fluoro-n-butyl group, 4-fluoro-n-butyl group, 4,4,4-trifluoro-n-butyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group and perfluoro-tert-butyl group.

[0159] Examples of the fluorine-substituted chained [SIC] saturated hydrocarbon group include 1-fluorocyclopropyl group, 2-fluorocyclopropyl group, perfluorocyclopropyl group, 1-fluorocyclopentyl group, 2-fluorocyclopentyl group, 3-fluorocyclopentyl group, perfluorocyclopentyl group, 1-fluorocyclohexyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group and perfluorocyclohexyl group.

[0160] Example of the fluorine-substituted unsaturated hydrocarbon group include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 3-fluoro-2-methylphenyl group, 4-fluoro-2-methylphenyl group, 5-fluoro-2-methylphenyl group, 6-fluoro-2-methylphenyl group, 2-fluoro-3-methylphenyl group, 4-fluoro-3-methylphenyl group, 5-fluoro-3-methylphenyl group, 6-fluoro-3-methylphenyl group, 2-fluoro-4-methylphenyl group, 3-fluoro-4-methylphenyl group, perfluorotoluyl group, 2-fluoronaphthalene-1-yl group, 3-fluoronaphthalene-1-yl group, 4-fluoronaphthalene-1-yl group, 5-fluoronaphthalene-1-yl group, 6-fluoronaphthalene-1-yl group, 7-fluoronaphthalene-1-yl group, 8-fluoronaphthalene-1-yl group, 1-fluoronaphthalene-2-yl group, 3-fluoronaphthalene-2-yl group, 4-fluoronaphthalene-2-yl group, 5-fluoronaphthalene-2-yl group, 6-fluoronaphthalene-2-yl group, 7-fluoronaphthalene-2-yl group, 8-fluoronaphthalene-2-yl group, perfluoronaphthyl group, 1-fluorovinyl group, 2-fluorovinyl group, 1,2-difluorovinyl group, 2,2-difluorovinyl group, perfluorovinyl group, 1-fluoroallyl group, 2-fluoroallyl group, 3-fluoroallyl group, perfluoroallyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group, (perfluorophenyl)methyl group and perfluorophenylmethyl group.

[0161] Of these fluorine-substituted hydrocarbon groups, preferable as R^{a1} and R^{a2} from the standpoints of chemical and electrochemical stability and ease of industrial availability are fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 2,2,2,2'2'2'-hexafluoroisopropyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group, perfluoro-tert-butyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group, perfluorocyclohexyl group, 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 1-fluorovinyl group, 2-fluorovinyl group, perfluorovinyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group, (perfluorophenyl)methyl group and perfluorophenylmethyl group.

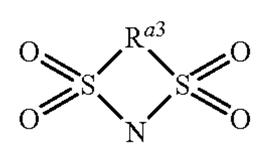
[0162] In particular, a univalent fluorinated carbon group is preferable as R^{a1} and R^{a2}. Examples of the univalent fluorinated hydrocarbon group include trifluoromethyl group, perfluoroethyl group, perfluoro-n-propyl group, perfluoroisopropyl group, perfluoro-n-butyl group and perfluoro-tert-butyl group.

[0163] When α is nitrogen atom, the following compounds include as concrete examples: $LiN(SO_2CF_3)_2$, $LiN(SO_2C_2F_5)_2$, $LiN(SO_2C_3F_7)_2$, $LiN(SO_2CF_3)(SO_2C_4F_9)$.

[0164] In the above formula (A-1), as other examples of the second lithium salt in which α is nitrogen atom, lithium salts having univalent cyclic anions represented by the formula (A-4-2) below include.

[Chemical Formula 50]

(A-4-2)



[0165] In the above formula (A-4-2), R^{a3} is a bivalent hydrocarbon group that may be substituted with a fluorine atom.

[0166] No particular limitation is imposed on the kind of the hydrocarbon group of R^{a3}. It may be a saturated hydrocarbon group, or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0167] For the hydrocarbon group of R^{a3}, a part or all of its hydrogen atom may be substituted with a fluorine atom. When R^{a3} is a fluorine-substituted hydrocarbon group, the number of the fluorine atom may be only one or two or more.

[0168] The number of carbon atoms of R^{a3} is usually 1 or more, preferably 2 or more, and usually 12 or less, preferably 8 or less. When the number of carbon atoms of R^{a3} are too many, solubility tends to decrease.

[0169] When R^{a3} is a bivalent hydrocarbon group, concrete examples thereof include ethylene group, trimethylene group, tetramethylene group, pentamethylene group, propylene group, 2-methyltrimethylene group and neopentylene group.

[0170] On the other hand, when R^{a3} is a fluorine-substituted hydrocarbon group, fluorinated carbon group is particularly preferable. Concrete examples thereof are perfluoroethylene group and perfluorotrimethylene group.

[0171] Concrete examples of the lithium salt having univalent cyclic anions represented by the formula (A-4-2) above include lithium cyclic 1,2-ethanedisulfonylimide, lithium cyclic 1,3-propanedisulfonylimide, lithium cyclic 1,2-perfluoroethanedisulfonylimide, lithium cyclic 1,3-perfluoropropanedisulfonylimide and lithium cyclic 1,4-perfluorobutanedisulfonylimide.

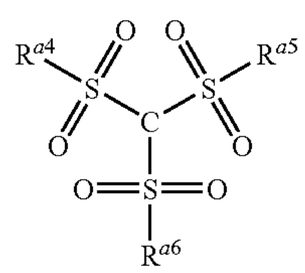
[0172] Of these, preferable are lithium cyclic 1,2-perfluoroethanedisulfonylimide and lithium cyclic 1,3-perfluoropropanedisulfonylimide.

[0173] Second Lithium Salt in Which α is Carbon Atom:

[0174] Examples of the second lithium salt, in which α in the above formula (A-1) is carbon atom, include univalent anions [SIC] represented by the following formula (A-5)

[Chemical Formula 51]

(A-5)



[0175] In the above formula (A-5), R^{a4}, R^{a5} and R^{a6} are fluorine atom or a univalent hydrocarbon group that may be substituted with a fluorine atom. R^{a4}, R^{a5} and R^{a6} may be the same or may be different from each other.

[0176] When R^{a4}, R^{a5} and R^{a6} are an unsubstituted or fluorine-substituted hydrocarbon group, the details such as its kind or the number of carbon atoms are the same as described previously for R^{a1} and R^{a2} in the above formula (A-4-1). Concrete examples of R^{a4}, R^{a5} and R^{a6}, when they are an unsubstituted or fluorine-substituted hydrocarbon group, include the same concrete examples cited for R^{a1} and R^{a2} in the above formula (A-4-1).

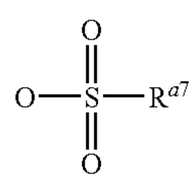
[0177] Concrete examples of the lithium salt having univalent anions represented by the above formula (A-5) include $LiC(SO_2CF_3)_3$, $LiC(SO_2C_2F_5)_3$ and $LiC(SO_2C_3F_7)_3$.

[0178] Second Lithium Salt in Which α is Oxygen Atom:

[0179] Examples of the second lithium salt, in which α in the above formula (A-1) is oxygen atom, include univalent anions [SIC] represented by the following formula (A-6).

[Chemical Formula 52]

(A-6)



[0180] In the above formula (A-6), R^{a7} is fluorine atom or a univalent hydrocarbon group that may be substituted with a fluorine atom.

[0181] When R^{a7} is an unsubstituted or fluorine-substituted hydrocarbon group, the details such as its kind or the number of carbon atoms are the same as described previously for R^{a1} and R^{a2} in the above formula (A-4-1). Concrete examples of R^{a7}, when it is an unsubstituted or fluorine-substituted hydrocarbon group, include the same concrete examples cited earlier for R^{a1} and R^{a2} in the above formula (A-4-1).

[0182] Of the lithium salts having univalent anions represented by the above formula (A-6), those containing sulfonyloxide are preferable because of easy availability and good solubility. Concrete examples include $LiSO_3CF_3$, $LiSO_3C_2F_5$, $LiSO_3C_3F_7$ and $LiSO_3C_4F_8$[SIC].

[0183] No particular limitation is imposed on the molecular weight of the second lithium salt, insofar as the advantage of the present invention is not significantly impaired. However, it is usually 50 or larger, preferably 100 or larger, and usually 600 or smaller, preferably 500 or smaller. When the molecular weight of the second lithium salt is too large, solubility in solvents tends to decrease.

[0184] There is no special limitation on the method of production of the second lithium salt and any known method can be selected and used.

[0185] The second lithium salt explained above may be included in the non-aqueous liquid electrolyte of the present invention either as a single one or as a combination of two or more kinds in any combination and in any ratio.

[0186] The concentration of the second lithium salt in the non-aqueous liquid electrolyte is in the range of usually 0.001 mol/liter or higher, preferably 0.01 mol/liter or higher, more preferably 0.02 mol/liter or higher, and usually 1 mol/liter or lower, preferably 0.5 mol/liter or lower, more preferably 0.3 mol/liter or lower, particularly preferably 0.2 mol/liter or lower. When the concentration of the second lithium salt is too low, it is difficult to suppress the gas evolution at the time of continuous charging and the capacity decrease sufficiently. On the contrary, when the concentration of the second lithium salt is too high, the battery characteristics after high-temperature storage tend to decrease. Incidentally, when two or more kinds of second lithium salts are used in combination, the total concentration of them should fall within the above-mentioned range.

[0187] [I-1-A-3. Others]

[0188] There is no special limitation on the ratio of the second lithium salt relative to the first lithium salt, in the non-aqueous liquid electrolyte of the present invention. The molar ratio of {(second lithium salt)/(first lithium salt)} is usually 0.005 or higher, preferably 0.01 or higher, particularly preferably 0.02 or higher, and usually 1 or lower, preferably 0.5 or lower, particularly preferably 0.2 or lower. When the molar ratio exceeds the upper limit, the battery characteristics after constant-temperature [SIC] storage tend to decrease. When it falls below the above lower limit, it is difficult to suppress the gas evolution at the time of continuous charging and the capacity decrease sufficiently.

[0189] By incorporating the above-mentioned first and second lithium salt (the specific compound (A)) and the specific carbonate in a non-aqueous liquid electrolyte, it is possible to improve the charge-discharge cycle performance of the non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte. The detailed reason is not clear, but inferred as follows. Namely, through the reaction between the first and second lithium salt (specific compound (A)) and the specific carbonate contained in the non-aqueous liquid electrolyte, an effective protective layer is formed on the

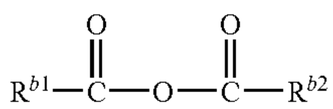
surface of the negative-electrode active material, leading to the suppression of side reactions. Cycle deterioration is thus inhibited. The details of this reaction is not clear, but it is inferred that coexistence of the first and second lithium salts and the specific carbonate in the liquid electrolyte can somehow contribute to enhancement in the protective layer characteristics.

[0190] [I-1-B. Specific Compound (B)]

[0191] Specific compound (B) is an acid anhydride represented by the formula (B-1) below.

[Chemical Formula 53]

(B-1)



(In the formula (B-1), R^{b1} and R^{b2} represent, independently of each other, a hydrocarbon group, which may have a substituent, with carbon number of 15 or smaller. R^{b1} and R^{b2} may be connected to each other to form a ring structure.)

[0192] No particular limitation is imposed on the kind of R^{b1} and R^{b2}, so long as they are a univalent hydrocarbon group. They may be, for example, an aliphatic hydrocarbon group or aromatic hydrocarbon group or a combination of aliphatic hydrocarbon group and aromatic hydrocarbon group. The aliphatic hydrocarbon group may be a saturated hydrocarbon group, or it may contain one or more unsaturated bonds (carbon to carbon double bond or carbon to carbon triple bond). In addition, the aliphatic hydrocarbon group may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other. R^{b1} and R^{b2} may be the same or different.

[0193] When R^{b1} and R^{b2} are bonded to each other to form a ring structure, R^{b1} and R^{b2} constitute a bivalent hydrocarbon group. No particular limitation is imposed on the kind of the bivalent hydrocarbon group. It may be an aliphatic group, aromatic group, or a combination of aliphatic group and aromatic group. When it is an aliphatic group, it may be a saturated group or unsaturated group. It may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain group and cyclic group may be connected together.

[0194] When the hydrocarbon group of R^{b1} and R^{b2} has a substituent, there is no special limitation on the kind of the substituent, insofar as the intent of the present invention is not significantly impaired. Examples include halogen atoms such as fluorine atom, chlorine atom, bromine atom and iodine atom, and a substituent containing a functional group such as ester group, cyano group, carbonyl group and ether group. The hydrocarbon group of R^{b1} and R^{b2} may have 1 of these substituent or 2 or more. When they have 2 or more substituents, they may be the same or different from each other.

[0195] The number of carbon atoms of each hydrocarbon group R^{b1} and R^{b2} is 15 or less, as described above. It is preferably 12 or less, more preferably 10 or less, and usually 1 or more. When R^{b1} and R^{b2} are bonded together to form a bivalent hydrocarbon group, the number of carbon atoms of the bivalent hydrocarbon group is usually 30 or less, preferably 15 or less, more preferably 10 or less, and usually it is 1 or more. When the hydrocarbon group of R^{b1} and R^{b2} has a substituent containing carbon atoms, the total number of carbon atoms including those of the substituent should preferably fall within the above range.

[0196] Concrete examples of the hydrocarbon groups constituting R^{b1} and R^{b2} will be given below.

[0197] First, examples of the aliphatic saturated hydrocarbon group include chained alkyl group and cyclic alkyl group.

[0198] Concrete examples of the chained alkyl group include methyl group, ethyl group, 1-propyl group, 1-methylethyl group, 1-butyl group, 1-methylpropyl group, 2-methylpropyl group, 1,1-dimethylethyl group, 1-pentyl group, 1-methylbutyl group, 1-ethylpropyl group, 2-methylbutyl group, 3-methylbutyl group, 2,2-dimethylpropyl group, 1,1-dimethylpropyl group, 1,2-dimethylpropyl group, 1-hexyl group, 1-methylpentyl group, 1-ethylbutyl group, 2-methylpentyl group, 3-methylpentyl group, 4-methylpentyl group, 2-ethylbutyl group, 2,2-dimethylbutyl group, 2,3-dimethylbutyl group, 3,3-dimethylbutyl group, 1,1-dimethylbutyl group, 1,2-dimethylbutyl group, 1,3-dimethylbutyl group, 1,1,2-trimethylpropyl group, 1,2,2-trimethylpropyl group, 1-ethyl-2-methylpropyl group and 1-ethyl-1-methylpropyl group.

[0199] Concrete examples of the cyclic alkyl group include cyclopentyl group, 2-methylcyclopentyl group, 3-methylcyclopentyl group, 2,2-dimethylcyclopentyl group, 2,3-dimethylcyclopentyl group, 2,4-dimethylcyclopentyl group, 2,5-dimethylcyclopentyl group, 3,3-dimethylcyclopentyl group, 3,4-dimethylcyclopentyl group, 2-ethylcyclopentyl group, 3-ethylcyclopentyl group, cyclohexyl group, 2-methylcyclohexyl group, 3-methylcyclohexyl group, 4-methylcyclohexyl group, 2,2-dimethylcyclohexyl group, 2,3-dimethylcyclohexyl group, 2,4-dimethylcyclohexyl group, 2,5-dimethylcyclohexyl group, 2,6-dimethylcyclohexyl group, 3,3-dimethylcyclohexyl group, 3,4-dimethylcyclohexyl group, 3,5-dimethylcyclohexyl group, 2-ethylcyclohexyl group, 3-ethylcyclohexyl group, 4-ethylcyclohexyl group, bicyclo[3,2,1]octa-1-yl group and bicyclo[3,2,1]octa-2-yl group.

[0200] On the other hand, examples of the aliphatic unsaturated hydrocarbon group include alkenyl group and alkynyl group. The number of the unsaturated bond included in an aliphatic unsaturated hydrocarbon group may be either only one or two or more.

[0201] Concrete examples of alkenyl group include vinyl group, allyl group, 1-methylvinyl group, 2-methylvinyl group, 1-butenyl group, 1-methylenepropyl group, 1-methyl-2-propenyl group, 3-butenyl group, 2-butenyl group, 1-methyl-1-propenyl group, 2-methyl-1-propenyl group, 2-methyl-2-propenyl group, 1-pentenyl group, 1-methylenebutyl group, 1-ethyl-2-propenyl group, 1-methyl-3-butene-1-yl group, 4-pentenyl group, 2-pentenyl group, 1-methyl-1-butenyl group, 1-ethyl-1-propenyl group, 1-methyl-2-butenyl group, 3-pentenyl group, 2-methyl-1-butenyl group, 2-methylenebutyl group, 1,2-dimethyl-2-propenyl group, 3-methyl-3-butenyl group, 2-methyl-2-butenyl group, 1,2-dimethyl-1-propenyl group, 3-methyl-2-butenyl group, 2-methyl-3-butenyl group, 1-methylene-2-methylpropyl group, 3-methyl-1-butenyl group, 1-hexenyl group, 1-methylenepentyl group, 1-allylbutyl group, 1-ethyl-3-butenyl group, 1-methyl-4-pentenyl group, 5-hexenyl group, 2-hexenyl group, 1-methyl-1-pentenyl group, 1-ethylidenebutyl group, 1-ethyl-2-butyl group, 1-methyl-3-pentenyl group, 4-hexenyl group, 3-hexenyl group, 1-methyl-2-pentenyl group, 1-ethyl-1-butenyl group, 2-methylenepentyl group, 2-methyl-1-pentenyl group, 1-ethyl-2-methyl-2-propenyl group, 1,3-dimethyl-3-butenyl group, 4-methyl-4-pentenyl group,

2-methyl-2-pentenyl group, 1-ethyl-2-methyl-1-propenyl group, 1,3-dimethyl-2-butenyl group, 4-methyl-3-pentenyl group, 2-methyl-3-pentenyl group, 1,1-dimethyl-2-butenyl group, 1-isopropyl-1-pentenyl group, 1,3-dimethyl-1-butenyl group, 4-methyl-2-pentenyl group, 2-methyl-4-pentenyl group, 1,1-dimethyl-3-butenyl group, 1-isopropyl-2-propenyl group, 3-methyl-1-methylenebutyl group, 4-methyl-1-pentenyl group, 2,3-dimethyl-1-butenyl group, 3-methyl-2-methylenebutyl group, 1,1,2-trimethyl-2-propenyl group, 2,3-dimethyl-3-butenyl group, 2,3-dimethyl-2-butenyl group, 2,2-dimethyl-3-butenyl group, 2,2-dimethyl-1-methylenepropyl group and 3,3-dimethyl-1-butenyl group.

[0202] Alkenyl group may exist as (E) to (Z) isomers depending on the configuration around carbon to carbon double bond. In the present invention, any of the isomers can be used.

[0203] Concrete examples of the alkynyl group include ethynyl group, 1-propynyl group, 2-propynyl group, 1-butynyl group, 1-methyl-2-propynyl group, 3-butynyl group, 2-butynyl group, 1-pentynyl group, 1-ethyl-2-propynyl group, 1-methyl-3-butynyl group, 4-pentynyl group, 2-pentynyl group, 1-methyl-2-butynyl group, 3-pentynyl group, 3-methyl-1-butynyl group, 1,1-dimethyl-2-propynyl group, 2-methyl-3-butynyl group, 1-hexynyl group, 1-ethynylbutyl group, 1-ethyl-3-butynyl group, 1-methyl-4-pentynyl group, 5-hexynyl group, 2-hexynyl group, 1-ethyl-2-butynyl group, 1-methyl-3-pentynyl group, 2-hexynyl group, 3-hexynyl group, 1-methyl-2-pentynyl group, 4-methyl-1-pentynyl group, 1-isopropyl-2-propynyl group, 1,1-dimethyl-3-butynyl group, 2-methyl-4pentynyl group, 4-methyl-2-pentynyl group, 1,1 dimethyl-2-butynyl group, 2-methyl-3-pentynyl group, 3-methyl-1-pentynyl group, 1-ethyl-1-methyl-2-propynyl group, 2-ethyl-3-butynyl group, 1,2-dimethyl-3-butynyl group and 3-methyl-4-pentynyl group.

[0204] Example of the aromatic hydrocarbon group include an aryl group.

[0205] Concrete examples of the aryl group are phenyl group, 2-methylphenyl group, 3-methylphenyl group, 4-methylphenyl group, 2,3-dimethylphenyl group, 2,4-dimethylphenyl group, 2,5-dimethylphenyl group, 2,6-dimethylphenyl group, 2,3,4-trimethylphenyl group, 2,3,5-trimethylphenyl group, 2,3,6-trimethylphenyl group, 2,4,5-trimethylphenyl group, 2,3,6-trimethylphenyl group, 2,5,6-trimethylphenyl group, 3,4,5-trimethylphenyl group, 2,3,4,5-tetramethylphenyl group, 2,3,4,6-tetramethylphenyl group, 2,4,5,6-tetramethylphenyl group, pentamethylphenyl group, 1-naphthyl group and 2-naphthyl group.

[0206] Concrete examples of the bivalent hydrocarbon group formed by bonding of R^{b1} and R^{b2} include methylene group, ethylene group, propane-1,2-diyl group, propane-1,3-diyl group, butane-1,2-diyl group, butane-1,3-diyl group, butane-1,4-diyl group, butane-2,3-diyl group, ethene-1,2-diyl group, propene-1,2-diyl group, propene-1,3-diyl group, propene-2,3-diyl group, 1-butene-1,2-diyl group, 1-butene-1,3-diyl group, 1-butene-1,4-diyl group, 1-butene-2,3-diyl group, 1-butene-2,4-diyl group, 1-butene-3,4-diyl group, 2-butene-1,2-diyl group, 2-butene-1,3-diyl group, 2-butene-1,4-diyl group and 2-butene-2,3-diyl group.

[0207] Examples of the hydrocarbon group having a substituent include halogen atom-substituted hydrocarbon groups, and hydrocarbon groups having a substituent containing a functional group such as ester group, cyano group, carbonyl group and ether group.

[0208] Examples of the halogen atom include fluorine atom, chlorine atom, bromine atom and iodine atom. Of these, fluorine atom, chlorine atom and bromine atom are preferable from the standpoint of capacity retention effect. Fluorine atom and chlorine atom are more preferable. Most preferable is fluorine atom. In the examples below, hydrocarbon groups substituted with fluorine atom are mainly presented as examples. It is to be understood that hydrocarbon groups in which a part or all of these fluorine atoms are replaced by chlorine atom, bromine atom or iodine atom are also included in the example groups.

[0209] Concrete examples of the chained alkyl group that are substituted with halogen atom include: fluorine-substituted alkyl group such as fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 1,1-difluoroethyl group, 1,2-difluoroethyl group, 2,2-difluoroethyl group, 1,1,2-trifluoroethyl group, 1,2,2-trifluoroethyl group, 2,2,2-trifluoroethyl group, 1,1,2,2-tetrafluoroethyl group, 1,2,2,2-tetrafluoroethyl group and perfluoroethyl group; chlorine-substituted alkyl group such as chloromethyl group, dichloromethyl group, trichloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 1,1-dichloroethyl group, 1,2-dichloroethyl group, 2,2-dichloroethyl group, 1,1,2-trichloroethyl group, 1,2,2-trichloroethyl group, 2,2,2-trichloroethyl group, 1,1,2,2-tetrachloroethyl group, 1,2,2,2-tetrachloroethyl group and perchloroethyl group.

[0210] Concrete examples of the cyclic alkyl group that is substituted with a halogen atom include 2-fluorocyclopentyl group, 3-fluorocyclopentyl group, 2,3-difluorocyclopentyl group, 2,4-difluorocyclopentyl group, 2,5-difluorocyclopentyl group, 3,4-difluorocyclopentyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group, 2,3-difluorocyclohexyl group, 2,4-difluorocyclohexyl group, 2,5-difluorocyclohexyl group, 2,6-difluorocyclohexyl group, 3,4-difluorocyclohexyl group, 3,5-difluorocyclohexyl group, 2,3,4-trifluorocyclohexyl group, 2,3,5-trifluorocyclohexyl group, 2,3,6-trifluorocyclohexyl group, 2,4,5-trifluorocyclohexyl group, 2,4,6-trifluorocyclohexyl group, 2,5,6-trifluorocyclohexyl group, 3,4,5-trifluorocyclohexyl group, 2,3,4,5-tetrafluorocyclohexyl group, 2,3,4,6-tetrafluorocyclohexyl group, 2,3,5,6-tetrafluorocyclohexyl group and pentafluorocyclohexyl group.

[0211] Concrete examples of the alkenyl group that is substituted with a halogen atom include 1-fluorovinyl group, 2-fluorovinyl group, 1,2-difluorovinyl group, 2,2-difluorovinyl group, 1,2,2-trifluorovinyl group, 1-fluoro-1-propenyl group, 2-fluoro-1-propenyl group, 3-fluoro-1-propenyl group, 1,2-difluoro-1-propenyl group, 1,3-difluoro-1-propenyl group, 2,3-difluoro-1-propenyl group, 3,3-difluoro-1-propenyl group, 1,2,3-trifluoro-1-propenyl group, 1,3,3-trifluoro-1-propenyl group, 2,3,3-trifluoro-1-propenyl group, 3,3,3-trifluoro-1-propenyl group, 1,2,3,3-tetrafluoro-1-propenyl group, 1,3,3,3-tetrafluoro-1-propenyl group, 2,3,3,3-tetrafluoro-1-propenyl group, 1,2,3,3,3-pentafluoro-1-propenyl group, 2-fluoro-1-methylvinyl group, 1-fluoromethylvinyl group, 2-fluoro-1-fluoromethylvinyl group, 1-difluoromethylvinyl group, 2,2-difluoro-1-methylvinyl group, 2,2-difluoro-1-fluoromethylvinyl group, 2-fluoro-1-difluoromethylvinyl group, 1-trifluoromethylvinyl group, 2-fluoro-1-trifluoromethylvinyl group, 2,2-difluoro-1-difluoromethylvinyl group, 2,2-difluoro-1-trifluoromethylvinyl group, 1-fluoroallyl group, 2-fluoroallyl group, 3-fluoroallyl group, 1,1-difluoroallyl group, 1,2-difluoroallyl group, 1,3-difluoroallyl group, 2,3-difluoroallyl

group, 3,3-difluoroallyl group, 1,1,2-trifluoroallyl group, 1,1,3-trifluoroallyl group, 1,2,3-trifluoroallyl group, 1,3,3-trifluoroallyl group, 2,3,3-trifluoroallyl group, 1,1,1,2-tetrafluoroallyl group, 1,1,1,3-tetrafluoroallyl group, 1,1,2,3-tetrafluoroallyl group, 1,1,3,3-tetrafluoroallyl group, 1,2,3,3-tetrafluoroallyl group, 1,1,1,2,3-pentafluoroallyl group, 1,1,1,3,3-pentafluoroallyl group, 1,1,2,3,3-pentafluoroallyl group and 1,1,1,2,3,3-hexafluoroallyl group.

[0212] Concrete examples of the alkynyl group that is substituted with a halogen atom include 2-fluoroethynyl group, 3-fluoro-1-propynyl group, 3,3-difluoro-1-propynyl group, 3,3,3-trifluoro-1-propynyl group, 3-fluoro-2-propynyl group, 1-fluoro-2-propynyl group, 1,1-difluoro-2-propynyl group, 1,3-difluoro-2-propynyl group and 1,1,3-trifluoro-2-propynyl group.

[0213] Concrete examples of the aryl group that is substituted with a halogen atom include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 2,5-difluorophenyl group, 2,6-difluorophenyl group, 2,3,4-trifluorophenyl group, 2,3,5-trifluorophenyl group, 2,3,6-trifluorophenyl group, 2,4,5-trifluorophenyl group, 2,3,6-trifluorophenyl group, 2,5,6-trifluorophenyl group, 3,4,5-trifluorophenyl group, 2,3,4,5-tetrafluorophenyl group, 2,3,4,6-tetrafluorophenyl group, 2,4,5,6-tetrafluorophenyl group and pentafluorophenyl group.

[0214] Concrete examples of the hydrocarbon group having a substituent containing an ester group include methoxycarbonylmethyl group, ethoxycarbonylmethyl group, 1-ethoxycarbonylethyl group and 2-ethoxycarbonylethyl group.

[0215] Concrete examples of the hydrocarbon group that is substituted with a cyano group include cyanomethyl group, 1-cyanoethyl group and 2-cyanoethyl group.

[0216] Concrete examples of the hydrocarbon group having a substituent containing a carbonyl group include 1-oxymethyl group, 1-oxypropyl group and methylcarbonylmethyl group.

[0217] Concrete examples of the hydrocarbon group having a substituent containing an ether group include methoxymethyl group, ethoxymethyl group, 1-methoxyethyl group and 2-methoxyethyl group.

[0218] Next, explanation will be given on the concrete examples of acid anhydride represented by the above formula (B-1). In the following examples, the term "analogous compound" means an acid anhydride obtained by replacing a part of the structure of exemplified acid anhydrides with another structure within the scope of the present invention.

[0219] First, examples will be given for the acid anhydride in which R^{b1} and R^{b2} are the same group.

[0220] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are a chained alkyl group include acetic acid anhydride, propionic acid anhydride, butanoic acid anhydride, 2-methylpropionic acid anhydride, 2,2-dimethylpropionic acid anhydride, 2-methylbutanoic acid anhydride, 3-methylbutanoic acid anhydride, 2,2-dimethylbutanoic acid anhydride, 2,3-dimethylbutanoic acid anhydride, 3,3-dimethylbutanoic acid anhydride, 2,2,3-trimethylbutanoic acid anhydride, 2,3,3-trimethylbutanoic acid anhydride, 2,2,3,3-teramethylbutanoic acid anhydride and 2-ethylbutanoic acid anhydride, and their analogous compounds.

[0221] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are a cyclic alkyl group include cyclopropane carboxylic acid anhydride, cyclopentane carboxylic acid anhydride and cyclohexane carboxylic acid anhydride and their analogous compounds.

[0222] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are an alkenyl group include acrylic acid anhydride, 2-methylacrylic acid anhydride, 3-methylacrylic acid anhydride, 2,3-dimethylacrylic acid anhydride, 3,3-dimethylacrylic acid anhydride, 2,3,3-trimethylacrylic acid anhydride, 2-phenylacrylic acid anhydride, 3-phenylacrylic acid anhydride, 2,3-diphenylacrylic acid anhydride, 3,3-diphenylacrylic acid anhydride, 3-butenoic acid anhydride, 2-methyl-3-butenoic acid anhydride, 2,2-dimethyl-3-butenoic acid anhydride, 3-methyl-3-butenoic acid anhydride, 2-methyl-3-methyl-3-butenoic acid anhydride, 2,2-dimethyl-3-methyl-3-butenoic acid anhydride, 3-pentenoic acid anhydride, 4-pentenoic acid anhydride, 2-cyclopentenecarboxylic acid anhydride, 3-cyclopentenecarboxylic acid anhydride and 4-cyclopentenecarboxylic acid anhydride and their analogous compounds.

[0223] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are an alkynyl group include propynic acid anhydride, 3-phenylpropynic acid anhydride, 2-butynic acid anhydride, 2-pentynic acid anhydride, 3-butynic acid anhydride, 3-pentynic acid anhydride and 4-pentynic acid anhydride and their analogous compounds.

[0224] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are an aryl group include benzoic acid anhydride, 4-methylbenzoic acid anhydride, 4-ethylbenzoic acid anhydride, 4-tert-butylbenzoic acid anhydride, 2-methylbenzoic acid anhydride, 2,4,6-trimethylbenzoic acid anhydride, 1-naphthalenecarboxylic acid anhydride and 2-naphthalenecarboxylic acid anhydride, and their analogous compounds.

[0225] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are substituted with a halogen atom include mainly compounds described below which are substituted with a fluorine atom. It is to be understood that acid anhydrides in which a part or all of these fluorine atoms are replaced by chlorine atom, bromine atom or iodine atom are also included in the example compounds.

[0226] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are a halogen-substituted chained alkyl group include fluoroacetic acid anhydride, difluoroacetic acid anhydride, trifluoroacetic acid anhydride, 2-fluoropropionic acid anhydride, 2,2-difluoropropionic acid anhydride, 2,3-difluoropropionic acid anhydride, 2,2,3-trifluoropropionic acid anhydride, 2,3,3-trifluoropropionic acid anhydride, 2,2,3,3-tetrapropionic acid [SIC] anhydride, 2,3,3,3-tetrapropionic acid [SIC] anhydride, 3-fluoropropionic acid anhydride, 3,3-difluoropropionic acid anhydride, 3,3,3-trifluoropropionic acid anhydride and perfluoropropionic acid anhydride, and their analogous compounds.

[0227] Concrete examples of the acid anhydride in which $R^{b1}$and R^{b2} are a halogen-substituted cyclic alkyl group include 2-fluorocyclopentanecarboxylic acid anhydride, 3-fluorocyclopentanecarboxylic acid anhydride and 4-fluorocyclopentanecarboxylic acid anhydride, and their analogous compounds.

[0228] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are a halogen-substituted alkenyl group include 2-fluoroacrylic acid anhydride, 3-fluoroacrylic acid anhydride, 2,3-difluoroacrylic acid anhydride, 3,3-difluoroacrylic acid anhydride, 2,3,3-trifluoroacrylic acid anhydride, 2-(trifluoromethyl)acrylic acid anhydride, 3-(trifluoromethyl) acrylic acid anhydride, 2,3-bis(trifluoromethyl)acrylic acid

anhydride, 2,3,3-tris(trifluoromethyl)acrylic acid anhydride, 2-(4-fluorophenyl)acrylic acid anhydride, 3-(4-fluorophenyl) acrylic acid anhydride, 2,3-bis(4-fluorophenyl)acrylic acid anhydride, 3,3-bis(4-fluorophenyl)acrylic acid anhydride, 2-fluoro-3-butenoic acid anhydride, 2,2-difluoro-3-butenolic acid anhydride, 3-fluoro-2-butenoic acid anhydride, 4-fluoro-3-butenoic acid anhydride, 3,4-difluoro-3-butenoic acid anhydride and 3,3,4-trifluoro-3-butenoic acid anhydride, and their analogous compounds.

[0229] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are a halogen-substituted alkynyl group include 3-fluoro-2-propynic acid anhydride, 3-(4-fluorophenyl)-2-propynic acid anhydride, 3-(2,3,4,5,6-pentafluorophenyl)-2-propynic acid anhydride, 4-fluoro-2-butynic acid anhydride, 4,4-difluoro-2-butynic acid anhydride and 4,4,4-trifluoro-2-butynic acid anhydride, and their analogous compounds.

[0230] Concrete examples of acid anhydride in which R^{b1} and R^{b2} are a halogen-substituted aryl group include 4-fluorobenzoic acid anhydride, 2,3,4,5,6-pentafluorobenzoic acid anhydride and 4-trifluoromethylbenzoic acid anhydride, and their anaologous compounds.

[0231] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} have substituents containing a functional group such as ester group, nitrile group, ketone group and ether group include alkyl oxalic acid anhydride, 2-cyanoacetic acid anhydride, 2-oxopropionic acid anhydride, 3-oxobutanoic acid anhydride, 4-acetylbenzoic acid anhydride, methoxyacetic acid anhydride and 4-methoxybenzoic acid anhydride, and their analogous compounds.

[0232] Next, examples will be given for the acid anhydride in which R^{b1} and R^{b2} are different groups.

[0233] All the combinations of R^{b1} and R^{b2}, shown above as examples including their analogous compounds, are possible. The representative examples will be shown below.

[0234] Examples of combination of plural number of chained alkyl groups include acetic acid propionic acid anhydride, acetic acid butanoic acid anhydride, butanoic acid propionic acid anhydride and acetic acid 2-methylpropionic acid anhydride.

[0235] Examples of combination of chained alkyl group and cyclic alkyl group include acetic acid cyclopentanecarboxylic acid anhydride, acetic acid cyclohexanecarboxylic acid anhydride and cyclopentanecarboxylic acid propionic acid anhydride.

[0236] Examples of combination of chained alkyl group and alkenyl group include acetic acid acrylic acid anhydride, acetic acid 3-methylacrylic acid anhydride, acetic acid 3-butenoic acid anhydride and acrylic acid propionic acid anhydride.

[0237] Examples of combination of chained alkyl group and alkynyl group include acetic acid propynic acid anhydride, acetic acid 2-butynic acid anhydride, acetic acid 3-butynic acid anhydride, acetic acid 3-phenylpropynic acid anhydride and propionic acid propynic acid anhydride.

[0238] Examples of combination of chained alkyl group and aryl group include acetic acid benzoic acid anhydride, acetic acid 4-methylbenzoic acid anhydride, acetic acid 1-naphthalenecarboxylic acid anhydride and benzoic acid propionic acid anhydride.

[0239] Examples of combination of chained alkyl group and hydrocarbon group having a functional group include acetic acid fluoroacetic acid anhydride, acetic acid trifluoroacetic acid anhydride, acetic acid 4-fluorobenzoic acid anhydride, fluoroacetic acid propionic acid anhydride, acetic acid alkyloxalic acid anhydride, acetic acid 2-cyanoacetic acid anhydride, acetic acid 2-oxopropionic acid anhydride, acetic acid methoxyacetic acid anhydride and methoxyacetic acid propionic acid anhydride.

[0240] Examples of combination of plural number of cyclic alkyl groups include cyclopentanecarboxylic acid cyclohexanecarboxylic acid anhydride.

[0241] Examples of combination of cyclic alkyl group and alkenyl group include acrylic acid cyclopentanecarboxylic acid anhydride, 3-methylacrylic acid cyclopentanecarboxylic acid anhydride, 3-butenoic acid cyclopentanecarboxylic acid anhydride and acrylic acid cyclohexanecarboxylic acid anhydride.

[0242] Examples of combination of cyclic alkyl group and alkynyl group include propynic acid cyclopentanecarboxylic acid anhydride, 2-butynic acid cyclopentanecarboxylic acid anhydride and propynic acid cyclohexanecarboxylic acid anhydride.

[0243] Examples of combination of cyclic alkyl group and aryl group include benzoic acid cyclopentanecarboxylic acid anhydride, 4-methylbenzoic acid cyclopentanecarboxylic acid anhydride and benzoic acid cyclohexanecarboxylic acid anhydride.

[0244] Examples of combination of cyclic alkyl group and hydrocarbon group containing a functional group include fluoroacetic acid cyclopentanecarboxylic acid anhydride, cyclopentanecarboxylic acid trifluoroacetic acid anhydride, cyclopentanecarboxylic acid 2-cyanoacetic acid anhydride, cyclopentanecarboxylic acid methoxyacetic acid anhydride and cyclohexanecarboxylic acid fluoroacetic acid anhydride.

[0245] Examples of combination of plural number of alkenyl groups include acrylic acid 2-methylacrylic acid anhydride, acrylic acid 3-methylacrylic acid anhydride, acrylic acid 3-butenoic acid anhydride and 2-methylacrylic acid 3-methylacrylic acid anhydride.

[0246] Examples of combination of alkenyl group and alkynyl group include acrylic acid propynic acid anhydride, acrylic acid 2-butynic acid anhydride and 2-methylacrylic acid propynic acid anhydride.

[0247] Examples of combination of alkenyl group and aryl group include acrylic acid benzoic acid anhydride, acrylic acid 4-methylbenzoic acid anhydride and 2-methylacrylic acid benzoic acid anhydride.

[0248] Examples of combination of alkenyl group and hydrocarbon group having a functional group include acrylic acid fluoroacetic acid anhydride, acrylic acid trifluoroacetic acid anhydride, acrylic acid 2-cyanoacetic acid anhydride, acrylic acid methoxyacetic acid anhydride and 2-methylacrylic acid fluoroacetic acid anhydride.

[0249] Examples of combination of alkynyl groups include propynic acid 2-butynic acid anhydride, propynic acid 3-butynic acid anhydride and 2-butynic acid 3-butynic acid anhydride.

[0250] Examples of combination of alkynyl group and aryl group include benzoic acid propynic acid anhydride, 4-methylbenzoic acid propynic acid anhydride and benzoic acid 2-butynic acid anhydride.

[0251] Examples of combination of alkynyl group and hydrocarbon group containing a functional group include propynic acid fluoroacetic acid anhydride, propynic acid trifluoroacetic acid anhydride, propynic acid 2-cyanoacetic acid anhydride, propynic acid methoxyacetic acid anhydride and 2-butynic acid fluoroacetic acid anhydride.

[0252] Examples of combination of plural number of aryl groups include benzoic acid 4-methylbenzoic acid anhydride, benzoic acid 1-naphthalenecarboxylic acid anhydride and 4-methylbenzoic acid 1-naphthalenecarboxylic acid anhydride.

[0253] Examples of combination of aryl group and hydrocarbon group containing a functional group include benzoic acid fluoroacetic acid anhydride, benzoic acid trifluoroacetic acid anhydride, benzoic acid 2-cyanoacetic acid anhydride, benzoic acid methoxyacetic acid anhydride and 4-methylbenzoic acid fluoroacetic acid anhydride.

[0254] Examples of combination of hydrocarbon groups containing a functional group include fluoroacetic acid trifluoroacetic acid anhydride, fluoroacetic acid 2-cyanoacetic acid anhydride, fluoroacetic acid methoxyacetic acid anhydride and trifluoroacetic acid 2-cyanoacetic acid anhydride.

[0255] Next, examples will be given for the acid anhydride in which R^{b1} and R^{b2} are bonded together to form a ring structure.

[0256] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are bonded together to form a 5-membered ring structure include succinic acid anhydride, 4-methylsuccinic acid anhydride, 4,4-dimethylsuccinic acid anhydride, 4,5-dimethylsuccinic acid anhydride, 4,4,5-trimethylsuccinic acid anhydride, 4,4,5,5-tetramethylsuccinic acid anhydride, 4-vinylsuccinic acid anhydride, 4,5-divinylsuccinic acid anhydride, 4-phenylsuccinic acid anhydride, 4,5-diphenylsuccinic acid anhydride, 4,4-diphenylsuccinic acid anhydride, citraconic acid anhydride, maleic acid anhydride, 4-methylmaleic acid anhydride, 4,5-dimethylmaleic acid anhydride, 4-phenylmaleic acid anhydride, 4,5-diphenylmaleic acid anhydride, itaconic acid anhydride, 5-methylitaconic acid anhydride, 5,5-dimethylitaconic acid anhydride, phthalic acid anhydride and 3,4,5,6-tetrahydrophthalic acid anhydride, and their analogous compounds.

[0257] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are bonded together to form a 6-membered ring structure include cyclohexane-1,2-dicarboxylic acid anhydride, 4-cyclohexene-1,2-dicarboxylic acid anhydride and glutaric acid anhydride, and their analogous compounds.

[0258] Concrete examples of the acid anhydride in which R^{b1} and R^{b2} are bonded together to form other type of ring structure include 5-norbornene-2,3-dicarboxylic acid anhydride, cyclopentanetetracarboxylic acid dianhydride, pyromellitic acid anhydride and diglycolic acid anhydride, and their analogous compounds.

[0259] Concrete examples of the acid anhydride, in which R^{b1} and R^{b2} are bonded together to form a ring structure and, at the same time, R^{b1} and R^{b2} are substituted with a halogen atom, include 4-fluorosuccinic acid anhydride, 4,4-difluorosuccinic acid anhydride, 4,5-difluorosuccinic acid anhydride, 4,4,5-trifluorosuccinic acid anhydride, 4,4,5,5-tetrafluorosuccinic acid anhydride, 4-fluoromaleic acid anhydride, 4,5-difluoromaleic acid anhydride, 5-fluoroitaconic acid anhydride and 5,5-difluoroitaconic acid anhydride, and their analogous compounds.

[0260] Among the acid anhydrides exemplified above, preferable as specific compound (B) are acid anhydrides in which R^{b1} and R^{b2} are connected to each other to form a ring structure, because they achieve particularly excellent battery characteristics by forming a good protective layer through a reaction with the specific carbonate. More specifically, acid anhydrides in which R^{b1} and R^{b2} are connected to each other to form a 5-membered ring structure or 6-membered ring structure, including acid anhydrides in which those R^{b1} and R^{b2} are substituted with a halogen atom, are preferable. Among them, particularly preferable are acid anhydrides in which R^{b1} and R^{b2} are connected to each other to form a 5-membered ring structure.

[0261] Among acid anhydrides in which R^{b1} and R^{b2} are bonded together to form a 5-membered ring structure, succinic acid anhydride and its derivatives, maleic acid anhydride and its derivatives, itaconic acid anhydride and its derivatives and phthalic acid anhydride and its derivatives have particularly superior characteristics, for example.

[0262] The concrete examples include succinic acid anhydride, 4-methylsuccinic acid anhydride, 4,4-dimethylsuccinic acid anhydride, 4,5-dimethylsuccinic acid anhydride, 4,4,5-trimethylsuccinic acid anhydride, 4,4,5,5-tetramethylsuccinic acid anhydride, 4-vinylsuccinic acid anhydride, 4,5-divinylsuccinic acid anhydride, 4-phenylsuccinic acid anhydride, 4,5-diphenylsuccinic acid anhydride, 4,4-diphenylsuccinic acid anhydride, citraconic acid anhydride, maleic acid anhydride, 4-methylmaleic acid anhydride, 4,5-dimethylmaleic acid anhydride, 4-phenylmaleic acid anhydride, 4,5-diphenylmaleic acid anhydride, itaconic acid anhydride, 5-methylitaconic acid anhydride, 5,5-dimethylitaconic acid anhydride, glutaric acid anhydride, phthalic acid anhydride and 3,4,5,6-tetrahydrophthalic acid anhydride, and their analogous compounds.

[0263] The acid anhydrides possessing a 5-membered ring structure shown above may be substituted with a halogen atom. The concrete examples are 4-fluorosuccinic acid anhydride, 4,4-difluorosuccinic acid anhydride, 4,5-difluorosuccinic acid anhydride, 4,4,5-trifluorosuccinic acid anhydride, 4,4,5,5-tetrafluorosuccinic acid anhydride, 4-fluoromaleic acid anhydride, 4,5-difluoromaleic acid anhydride, 5-fluoroitaconic acid anhydride and 5,5-difluoroitaconic acid anhydride, and their analogous compounds.

[0264] There is no special limitation on the molecular weight of the specific compound (B), insofar as the advantage of the present invention is not significantly impaired. However, it is usually 90 or larger. There is no special limitation on the upper limit, but when it is too high, viscosity tends to increase. Therefore, to be practical, it is usually 300 or smaller, preferably 200 or smaller.

[0265] No particular limitation is imposed on the method of production of the specific compound (B), either. Any known method can be adopted and used.

[0266] The specific compound (B) explained above can be included in the non-aqueous liquid electrolyte of the present invention either as a single kind or as a combination of two or more kinds in any combination and in any ratio.

[0267] There is no special limitation on the proportion of the specific compound (B) in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. However, it is preferable that the concentration in the non-aqueous liquid electrolyte of the present invention is usually 0.01 weight % or higher, preferably 0.1 weight % or higher, and usually 5 weight % or lower, preferably 3 weight % or lower. If the proportion is below the lower limit of the above range, an adequate effect of improving cycle performance of the non-aqueous liquid electrolyte secondary battery may not be guaranteed when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery. When it exceeds the upper limit, its chemical reactivity in the non-aqueous liquid electrolyte tends to

increase, leading possibly to decrease in battery characteristics of the above-mentioned non-aqueous liquid electrolyte secondary battery.

[0268] No limitation is imposed on the ratio of the specific compound (B) relative to the specific carbonate to be described later, in the non-aqueous liquid electrolyte of the present invention, either. However, it is preferable that the relative weight ratio, represented by "weight of the specific compound (B)/weight of the specific carbonate", is in the range of usually 0.0001 or higher, preferably 0.001 or higher, more preferably 0.01 or higher, and usually 1000 or lower, preferably 100 or lower, more preferably 10 or lower. If the above-mentioned relative weight ratio is too high or too low, the synergistic effect may not be obtained.

[0269] By incorporating the above-mentioned specific compound (B) and the specific carbonate in a non-aqueous liquid electrolyte, it is possible to improve the charge-discharge cycle performance of the non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte. The detailed reason is not clear, but inferred as follows. Namely, through the reaction between the specific compound (B) and the specific carbonate contained in the non-aqueous liquid electrolyte, an effective protective layer is formed on the surface of the negative-electrode active material, leading to the suppression of side reactions. Cycle deterioration is thus inhibited. The details of this reaction is not clear, but it is inferred that coexistence of the specific compound (B) and the specific carbonate in the liquid electrolyte can somehow contribute to enhancement in the protective layer characteristics.

[0270] [I-1-C. Specific Compound (C)]

[0271] <I-1-C-1. Sulfur-Containing Functional Group Represented by the Formula (C-1)>

[0272] Specific compound (C) is a chain compound having one or more sulfur-containing functional groups represented by the formula (C-1) below.

[Chemical Formula 54]

$$-(O)_m-[S(=O)_y]_x-(O)_n- \quad \text{(C-1)}$$

[0273] In the above formula (C-1), m and n represent, independently of each other, an integer of 0 or 1.

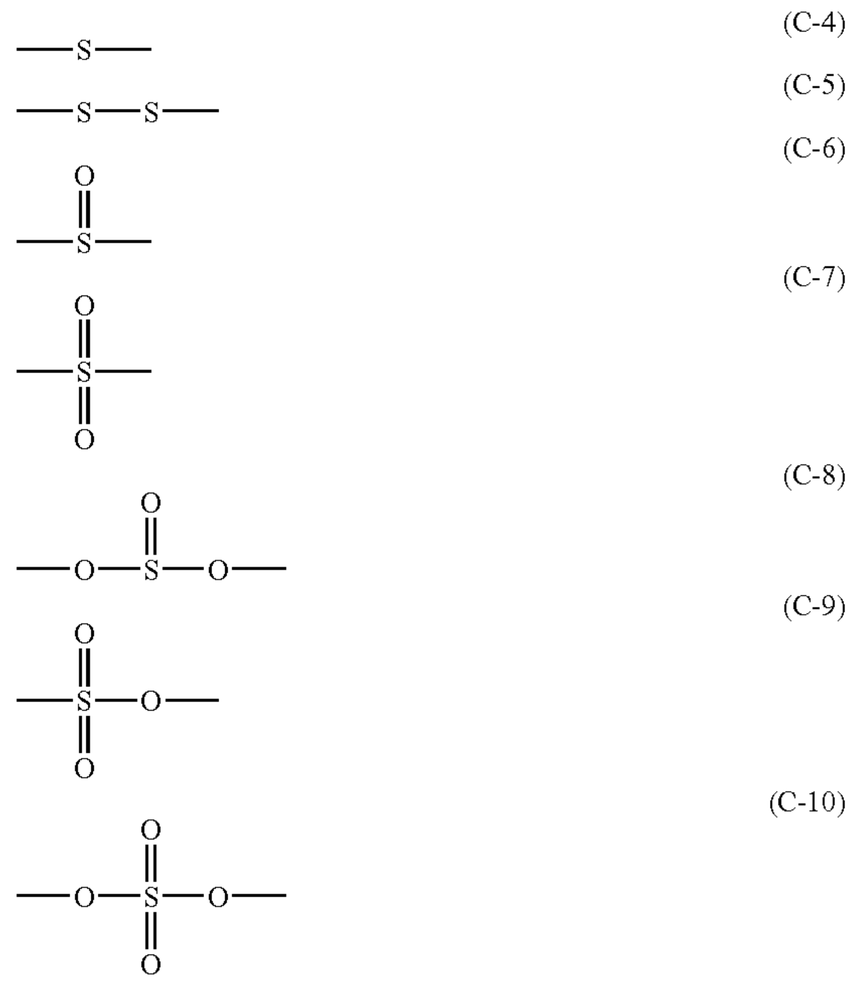
[0274] x represents an integer of 1 or 2.

[0275] y represents an integer of 0 or larger and 2 or smaller.

[0276] Concrete examples of the sulfur-containing functional group represented by the formula (C-1) above include —S—, —O—S—, —O—S—O—, —S(=O)—, —S(=O)$_2$—, —O—S(=O)—, —O—S(=O)$_2$—, —O—S(=O)—, —O—S(=O)$_2$—O—, —S—S—, —S(=O)—S—, —S(=O)$_2$—S—, —O—S—S—, —O—S(=O)—S—, —O—S(=O)$_2$—S—, —O—S—S—O—, —O—S(=O)—S—O—, —O—S(=O)$_2$—S—O—, —S(=O)—S(=O)—, —S(=O)$_2$—S(=O)—, —S(=O)$_2$—S(=O)$_2$—, —O—S(=O)—S(=O)—, —O—S(=O)$_2$—S(=O)—, —O—S(=O)$_2$—S(=O)$_2$—, —O—S(=O)—S(=O)—O—, —O—S(=O)$_2$—S(=O)—O— and —O—S(=O)$_2$—S(=O)$_2$—O—.

[0277] It is preferable, from the standpoint of ease of industrial availability and chemical stability, that the sulfur-containing functional group represented by the formula (C-1) is selected from among functional groups represented by the formulae (C-4) to (C-10) shown below.

[Chemical Formula 55]



[0278] The number of sulfur-containing functional group, represented by the above formula (C-1) and contained in the specific compound (C), needs to be 1 or more per molecule. There is no special upper limit, but it is preferable that it is usually 6 or less, particularly 4 or less.

[0279] There is no other particular limitation for the specific compound (C) insofar as the compound has at least one sulfur-containing functional group represented by the above formula (C-1). Among them, it is preferably a chain compound represented by the formula (C-2) below or chain compound represented by the formula (C-3) below.

[0280] <I-1-C-2. Chain Compound Represented by the Formula (C-2)>

[Chemical Formula 56]

$$R^{c1}\text{-}A^{c}\text{-}R^{c2} \quad \text{(C-2)}$$

[0281] In the above formula (C-2), A^c represents a sulfur-containing functional group represented by the formula (C-1).

[0282] R^{c1} and R^{c2} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 10 [SIC] or smaller.

[0283] In the above formula (C-2), no particular limitation is imposed on the kind of the hydrocarbon group of R^{c1} and R^{c2}. They may be an aliphatic hydrocarbon group or aromatic hydrocarbon group or a combination of aliphatic hydrocarbon group and aromatic hydrocarbon group. The aliphatic hydrocarbon group may be a saturated hydrocarbon group, or it may contain at least one unsaturated bond (carbon to carbon double bond or carbon to carbon triple bond). In addition, the aliphatic hydrocarbon group may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0284] The number of carbon atoms of the hydrocarbon groups R^{c1} and R^{c2} are usually 1 or more, and usually 20 or

less, preferably 10 or less, more preferably 6 or less. When the carbon number of the hydrocarbon groups R^{c1} and R^{c2} are too many, solubility in the non-aqueous liquid electrolyte tends to decrease.

[0285] Concrete examples of the hydrocarbon group which are preferable as R^{c1} and R^{c2} will be listed below.

[0286] Concrete examples of the saturated chained hydrocarbon group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group and tert-butyl group.

[0287] Concrete examples of the saturated cyclic hydrocarbon group include cyclopropyl group, cyclopentyl group and cyclohexyl group.

[0288] Concrete examples of the hydrocarbon group having an unsaturated bond (hereinafter abbreviated as "unsaturated hydrocarbon group", as appropriate) include vinyl group, 1-propene-1-yl group, 1-propene-2-yl group, allyl group, crotyl group, ethynyl group, propargyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, xylyl group, benzyl group and cinnamyl group.

[0289] Of these hydrocarbon groups, preferable as R^{c1} and R^{c2} from the standpoint of solubility in non-aqueous liquid electrolyte and ease of industrial availability are methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, tert-butyl group, cyclopentyl group, cyclohexyl group, phenyl group, 2-toluyl group, 3-toluyl group, 4-toluyl group, vinyl group, allyl group, ethynyl group, propargyl group and benzyl group. Particularly preferable are methyl group, ethyl group, n-propyl group, n-butyl group, cyclohexyl group and phenyl group.

[0290] In the hydrocarbon group of R^{c1} and R^{c2} in the above formula (C-2), a part or all of the hydrogen atoms bonded to the carbon atoms may be substituted with halogen atoms.

[0291] The halogen atom include fluorine atom, chlorine atom, bromine atom and iodine atom. Of these, fluorine atom, chlorine atom and bromine atom are preferable. Particularly preferable from the standpoint of chemical stability or electrochemical stability are fluorine atom and chlorine atom.

[0292] When the hydrocarbon group of R^{c1} and R^{c2} is substituted with halogen atoms, no particular limitation is imposed on the number of the halogen atoms. A part of the hydrogen atoms of the hydrocarbon group may be substituted with halogen atoms or all of the hydrogen atoms may be substituted with halogen atoms. When each of R^{c1} and R^{c2} has a plurality of halogen atoms, those halogen atoms may be the same as or different from each other.

[0293] Concrete examples of the halogen-substituted hydrocarbon group preferable as R^{c1} and R^{c2} will be cited below.

[0294] Concrete examples of the fluorine-substituted chained saturated hydrocarbon group include fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 1,1-difluoroethyl group, 1,2-difluoroethyl group, 2,2-difluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 1-fluoro-n-propyl group, 2-fluoro-n-propyl group, 3-fluoro-n-propyl group, 1,1-difluoro-n-propyl group, 1,2-difluoro-n-propyl group, 1,3-difluoro-n-propyl group, 2,2-difluoro-n-propyl group, 2,3-difluoro-n-propyl group, 3,3-difluoro-n-propyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 1-fluoroisopropyl group, 2-fluoroisopropyl group, 1,2-difluoroisopropyl group, 2,2-difluoroisopropyl group, 2,2'-difluoroisopropyl group, 2,2,2,2',2',2'-hexafluoroisopropyl group, 1-fluoro-n-butyl group, 2-fluoro-n-butyl group, 3-fluoro-n-butyl group, 4-fluoro-n-butyl group, 4,4,4-trifluoro-n-butyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group and perfluoro-tert-butyl group.

[0295] Concrete examples of the fluorine-substituted cyclic saturated hydrocarbon group include 1-fluorocyclopropyl group, 2-fluorocyclopropyl group, perfluorocyclopropyl group, 1-fluorocyclopentyl group, 2-fluorocyclopentyl group, 3-fluorocyclopentyl group, perfluorocyclopentyl group, 1-fluorocyclohexyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group and perfluorocyclohexyl group.

[0296] Concrete examples of the fluorine-substituted unsaturated hydrocarbon group include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 3-fluoro-2-methylphenyl group, 4-fluoro-2-methylphenyl group, 5-fluoro-2-methylphenyl group, 6-fluoro-2-methylphenyl group, 2-fluoro-3-methylphenyl group, 4-fluoro-3-methylphenyl group, 5-fluoro-3-methylphenyl group, 6-fluoro-3-methylphenyl group, 2-fluoro-4-methylphenyl group, 3-fluoro-4-methylphenyl group, perfluorotoluyl group, 2-fluoronaphthalene-1-yl group, 3-fluoronaphthalene-1-yl group, 4-fluoronaphthalene-1-yl group, 5-fluoronaphthalene-1-yl group, 6-fluoronaphthalene-1-yl group, 7-fluoronaphthalene-1-yl group, 8-fluoronaphthalene-1-yl group, 1-fluoronaphthalene-2-yl group, 3-fluoronaphthalene-2-yl group, 4-fluoronaphthalene-2-yl group, 5-fluoronaphthalene-2-yl group, 6-fluoronaphthalene-2-yl group, 7-fluoronaphthalene-2-yl group, 8-fluoronaphthalene-2-yl group, perfluoronaphthyl group, 1-fluorovinyl group, 2-fluorovinyl group, 1,2-difluorovinyl group, 2,2-difluorovinyl group, perfluorovinyl group, 1-fluoroallyl group, 2-fluoroallyl group, 3-fluoroallyl group, perfluoroallyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group, and (perfluorophenyl) methyl group.

[0297] Concrete examples of the chlorine-substituted chained saturated hydrocarbon group include chloromethyl group, dichloromethyl group, trichloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 1,1-dichloroethyl group, 1,2-dichloroethyl group, 2,2-dichloroethyl group, 2,2,2-trichloroethyl group, perchloroethyl group, 1-chloro-n-propyl group, 2-chloro-n-propyl group, 3-chloro-n-propyl group, 1,1-dichloro-n-propyl group, 1,2-dichloro-n-propyl group, 1,3-dichloro-n-propyl group, 2,2-dichloro-n-propyl group, 2,3-dichloro-n-propyl group, 3,3-dichloro-n-propyl group, 3,3,3-trichloro-n-propyl group, 2,2,3,3,3-pentachloro-n-propyl group, perchloro-n-propyl group, 1-chloroisopropyl group, 2-chloroisopropyl group, 1,2-dichloroisopropyl group, 2,2-dichloroisopropyl group, 2,2'-dichloroisopropyl group, 2,2,2,2',2',2'-hexachloroisopropyl group, 1-chloro-n-butyl group, 2-chloro-n-butyl group, 3-chloro-n-butyl group, 4-chloro-n-butyl group, 4,4,4-trichloro-n-butyl group, perchloro-n-butyl group, 2-chloro-tert-butyl group and perchloro-tert-butyl group.

[0298] Concrete examples of the chlorine-substituted cyclic saturated hydrocarbon group include 1-chlorocyclopropyl group, 2-chlorocyclopropyl group, perchlorocyclopropyl group, 1-chlorocyclopentyl group, 2-chlorocyclopentyl group, 3-chlorocyclopentyl group, perchlorocyclopentyl

group, 1-chlorocyclohexyl group, 2-chlorocyclohexyl group, 3-chlorocyclohexyl group, 4-chlorocyclohexyl group and perchlorocyclohexyl group.

[0299] Concrete example of the chlorine-substituted unsaturated hydrocarbon group include 2-chlorophenyl group, 3-chlorophenyl group, 4-chlorophenyl group, 2,3-dichlorophenyl group, 2,4-dichlorophenyl group, 3,5-dichlorophenyl group, 2,4,6-trichlorophenyl group, perchlorophenyl group, 3-chloro-2-methylphenyl group, 4-chloro-2-methylphenyl group, 5-chloro-2-methylphenyl group, 6-chloro-2-methylphenyl group, 2-chloro-3-methylphenyl group, 4-chloro-3-methylphenyl group, 5-chloro-3-methylphenyl group, 6-chloro-3-methylphenyl group, 2-chloro-4-methylphenyl group, 3-chloro-4-methylphenyl group, perchlorotoluyl group, 2-chloronaphthalene-1-yl group, 3-chloronaphthalene-1-yl group, 4-chloronaphthalene-1-yl group, 5-chloronaphthalene-1-yl group, 6-chloronaphthalene-1-yl group, 7-chloronaphthalene-1-yl group, 8-chloronaphthalene-1-yl group, 1-chloronaphthalene-2-yl group, 3-chloronaphthalene-2-yl group, 4-chloronaphthalene-2-yl group, 5-chloronaphthalene-2-yl group, 6-chloronaphthalene-2-yl group, 7-chloronaphthalene-2-yl group, 8-chloronaphthalene-2-yl group, perchloronaphthyl group, 1-chlorovinyl group, 2-chlorovinyl group, 1,2-dichlorovinyl group, 2,2-dichlorovinyl group, perchlorovinyl group, 1-chloroallyl group, 2-chloroallyl group, 3-chloroallyl group, perchloroallyl group, (2-chlorophenyl)methyl group, (3-chlorophenyl)methyl group, (4-chlorophenyl)methyl group and (perchlorophenyl)methyl group.

[0300] Of these groups, the fluorine-substituted hydrocarbon groups are preferable from the standpoint of chemical and electrochemical stability, ease of industrial availability or the like. The concrete examples include fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 3,3,3-trifluoro-n-propyl group, 2,2,3,3,3-pentafluoro-n-propyl group, perfluoro-n-propyl group, 2,2,2,2',2',2'-hexafluoroisopropyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group, perfluoro-tert-butyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group, perfluorocyclohexyl group, 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 3,5-difluorophenyl group, 2,4,6-trifluorophenyl group, perfluorophenyl group, 1-fluorovinyl group, 2-fluorovinyl group, perfluorovinyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group, (4-fluorophenyl)methyl group and (perfluorophenyl)methyl group.

[0301] Next, concrete examples of the compound represented by the above formula (C-2), as classified according to the sulfur-containing functional group represented by the formula (C-1), will be listed below.

[0302] Chain Compound Possessing a Functional Group of the Formula (C-4):

[0303] Chain compound possessing a functional group represented by the above formula (C-4) include the following.

[0304] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl sulfide, diethyl sulfide, di-n-propyl sulfide, diisopropyl sulfide, di-n-butyl sulfide, diisobutyl sulfide and di-tert-butyl sulfide.

[0305] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl sulfide and dicyclohexyl sulfide.

[0306] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl sulfide, di(2-toluyl)sulfide, di(3-toluyl)sulfide, di(4-toluyl)sulfide, divinyl sulfide, diallyl sulfide and dibenzyl sulfide.

[0307] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)sulfide, bis(difluoromethyl)sulfide, bis(trifluoromethyl)sulfide, di(1-fluoroethyl)sulfide, di(2-fluoroethyl)sulfide, bis(2,2,2-trifluoroethyl)sulfide, bis(perfluoroethyl)sulfide, bis(3,3,3-trifluoro-n-propyl)sulfide, bis(2,2,3,3,3-pentafluoro-n-propyl)sulfide, bis(perfluoro-n-propyl)sulfide, di(2-fluoroisopropyl)sulfide, bis(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, bis(perfluoro-n-butyl)sulfide, di(2-fluoro-tert-butyl)sulfide and bis(perfluoro-tert-butyl)sulfide.

[0308] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)sulfide, di(3-fluorocyclohexyl)sulfide, di(4-fluorocyclohexyl)sulfide and bis(perfluorocyclohexyl)sulfide.

[0309] Concrete examples of the compound possessing a fluorine-substituted unsaturated hydrocarbon group include di(2-fluorophenyl)sulfide, di(3-fluorophenyl)sulfide, di(4-fluorophenyl)sulfide, bis(2,3-difluorophenyl)sulfide, bis(2,4-difluorophenyl)sulfide, bis(3,5-difluorophenyl)sulfide, bis(2,4,6-trifluorophenyl)sulfide, bis(perfluorophenyl)sulfide, di(1-fluorovinyl)sulfide, di(2-fluorovinyl)sulfide, bis(perfluorovinyl)sulfide, bis[(2-fluorophenyl)methyl] sulfide, bis[(3-fluorophenyl)methyl] sulfide, bis[(4-fluorophenyl)methyl] sulfide and bis[(perfluorophenyl)methyl] sulfide.

[0310] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl sulfide, methylpropyl sulfide, methylisopropyl sulfide, methyl-n-butyl sulfide, methylisobutyl sulfide, methyl-tert-butyl sulfide, methylcyclopentyl sulfide, methylcyclohexyl sulfide, methylphenyl sulfide, methyl(2-toluyl)sulfide, methyl(3-toluyl)sulfide, methyl(4-toluyl)sulfide, methylvinyl sulfide, methylallyl sulfide, methylbenzyl sulfide, ethylpropyl sulfide, ethylisopropyl sulfide, ethyl-n-butyl sulfide, ethylisobutyl sulfide, ethyl-tert-butyl sulfide, ethylcyclopentyl sulfide, ethylcyclohexyl sulfide, ethylphenyl sulfide, ethyl(2-toluyl)sulfide, ethyl(3-toluyl)sulfide, ethyl(4-toluyl)sulfide, ethylvinyl sulfide, ethylallyl sulfide, ethylbenzyl sulfide, phenylpropyl sulfide, phenylisopropyl sulfide, phenyl-n-butyl sulfide, phenylisobutyl sulfide, phenyl-tert-butyl sulfide, phenylcyclopentyl sulfide, phenylcyclohexyl sulfide, phenyl(2-toluyl)sulfide, phenyl(3-toluyl)sulfide, phenyl(4-toluyl)sulfide, phenylvinyl sulfide, phenylallyl sulfide and phenylbenzyl sulfide.

[0311] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluoromethyl)sulfide, methyl(difluoromethyl)sulfide, methyl(trifluoromethyl)sulfide, methyl(1-fluoroethyl)sulfide, methyl(2-fluoroethyl)sulfide, methyl(2,2,2-trifluoroethyl)sulfide, methyl(perfluoroethyl)sulfide, methyl(3,3,3-trifluoro-n-propyl)sulfide, methyl(2,2,3,3,3-pentafluoro-n-propyl)sulfide, methyl(perfluoro-n-propyl)sulfide, methyl(2-fluoroisopropyl)sulfide, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, methyl(perfluoro-n-butyl)sulfide, methyl(2-fluoro-tert-butyl)sulfide, methyl(perfluoro-tert-butyl)sulfide, methyl(2-fluorocyclohexyl)sulfide, methyl(3-fluorocyclohexyl)sulfide, methyl(4-fluorocyclohexyl)sulfide, methyl(perfluorocyclohexyl)sulfide, methyl(2-fluorophenyl)

sulfide, methyl(3-fluorophenyl)sulfide, methyl(4-fluorophenyl)sulfide, methyl(2,3-difluorophenyl)sulfide, methyl(2,4-difluorophenyl)sulfide, methyl(3,5-difluorophenyl)sulfide, methyl(2,4,6-trifluorophenyl)sulfide, methyl(perfluorophenyl)sulfide, methyl(1-fluorovinyl)sulfide, methyl(2-fluorovinyl)sulfide, methyl(perfluorovinyl)sulfide, methyl[(2-fluorophenyl)methyl] sulfide, methyl[(3-fluorophenyl)methyl] sulfide, methyl[(4-fluorophenyl)methyl] sulfide, methyl[(perfluorophenyl)methyl] sulfide, ethyl(fluoromethyl)sulfide, ethyl(difluoromethyl)sulfide, ethyl(trifluoromethyl)sulfide, ethyl(1-fluoroethyl)sulfide, ethyl(2-fluoroethyl)sulfide, ethyl(2,2,2-trifluoroethyl)sulfide, ethyl(perfluoroethyl)sulfide, ethyl(3,3,3-trifluoro-n-propyl)sulfide, ethyl(2,2,3,3,3-pentafluoro-n-propyl)sulfide, ethyl(perfluoro-n-propyl)sulfide, ethyl(2-fluoroisopropyl)sulfide, ethyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, ethyl(perfluoro-n-butyl)sulfide, ethyl(2-fluoro-tert-butyl)sulfide, ethyl(perfluoro-tert-butyl)sulfide, ethyl(2-fluorocyclohexyl)sulfide, ethyl(3-fluorocyclohexyl)sulfide, ethyl(4-fluorocyclohexyl)sulfide, ethyl(perfluorocyclohexyl)sulfide, ethyl(2-fluorophenyl)sulfide, ethyl(3-fluorophenyl)sulfide, ethyl(4-fluorophenyl)sulfide, ethyl(2,3-difluorophenyl)sulfide, ethyl(2,4-difluorophenyl)sulfide, ethyl(3,5-difluorophenyl)sulfide, ethyl(2,4,6-trifluorophenyl)sulfide, ethyl(perfluorophenyl)sulfide, ethyl(1-fluorovinyl)sulfide, ethyl(2-fluorovinyl)sulfide, ethyl(perfluorovinyl)sulfide, ethyl[(2-fluorophenyl)methyl] sulfide, ethyl[(3-fluorophenyl)ethyl] sulfide, ethyl[(4-fluorophenyl)methyl] sulfide, ethyl[(perfluorophenyl)methyl] sulfide, phenyl(fluoromethyl)sulfide, phenyl(difluoromethyl)sulfide, phenyl(trifluoromethyl)sulfide, phenyl(1-fluoroethyl)sulfide, phenyl(2-fluoroethyl)sulfide, phenyl(2,2,2-trifluoroethyl)sulfide, phenyl(perfluoroethyl)sulfide, phenyl(3,3,3-trifluoro-n-propyl)sulfide, phenyl(2,2,3,3,3-pentafluoro-n-propyl)sulfide, phenyl(perfluoro-n-propyl)sulfide, phenyl(2-fluoroisopropyl)sulfide, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, phenyl(perfluoro-n-butyl)sulfide, phenyl(2-fluoro-tert-butyl)sulfide, phenyl(perfluoro-tert-butyl)sulfide, phenyl(2-fluorocyclohexyl)sulfide, phenyl(3-fluorocyclohexyl)sulfide, phenyl(4-fluorocyclohexyl)sulfide, phenyl(perfluorocyclohexyl)sulfide, phenyl(2-fluorophenyl)sulfide, phenyl(3-fluorophenyl)sulfide, phenyl(4-fluorophenyl)sulfide, phenyl(2,3-difluorophenyl)sulfide, phenyl(2,4-difluorophenyl)sulfide, phenyl(3,5-difluorophenyl)sulfide, phenyl(2,4,6-trifluorophenyl)sulfide, phenyl(perfluorophenyl)sulfide, phenyl(1-fluorovinyl)sulfide, phenyl(2-fluorovinyl)sulfide, phenyl(perfluorovinyl)sulfide, phenyl[(2-fluorophenyl)methyl] sulfide, phenyl[(3-fluorophenyl)methyl] sulfide, phenyl[(4-fluorophenyl)methyl] sulfide and phenyl[(perfluorophenyl)methyl] sulfide.

[0312] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)sulfide, (2,2,2-trifluoroethyl)(difluoromethyl)sulfide, (2,2,2-trifluoroethyl)(trifluoromethyl)sulfide, (2,2,2-trifluoroethyl)(1-fluoroethyl)sulfide, (2,2,2-trifluoroethyl)(2-fluoroethyl)sulfide, (2,2,2-trifluoroethyl)(perfluoroethyl)sulfide, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)sulfide, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)sulfide, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)sulfide, (2,2,2-trifluoroethyl)(2-fluoroisopropyl)sulfide, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, (2,2,2-trifluoroethyl)(perfluoro-n-butyl)sulfide, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl)sulfide, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl)sulfide, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl)sulfide, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)sulfide, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)sulfide, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)sulfide, (2,2,2-trifluoroethyl)(2-fluorophenyl)sulfide, (2,2,2-trifluoroethyl)(3-fluorophenyl)sulfide, (2,2,2-trifluoroethyl)(4-fluorophenyl)sulfide, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)sulfide, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)sulfide, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)sulfide, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)sulfide, (2,2,2-trifluoroethyl)(perfluorophenyl)sulfide, (2,2,2-trifluoroethyl)(1-fluorovinyl)sulfide, (2,2,2-trifluoroethyl)(2-fluorovinyl)sulfide, (2,2,2-trifluoroethyl)(perfluorovinyl)sulfide, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] sulfide, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] sulfide, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] sulfide and (2,2,2-trifluoroethyl)[(perfluorophenyl)methyl] sulfide.

[0313] Chain Compound Possessing a Functional Group of the Formula (C-5):

[0314] Chain compound possessing a functional group represented by the above formula (C-5) include the following.

[0315] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl disulfide, diethyl disulfide, di-n-propyl disulfide, diisopropyl disulfide, di-n-butyl disulfide, diisobutyl disulfide and di-tert-butyl disulfide.

[0316] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl disulfide and dicyclohexyl disulfide.

[0317] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl disulfide, di(2-toluyl)disulfide, di(3-toluyl)disulfide, di(4-toluyl)disulfide, divinyl disulfide, diallyl disulfide and dibenzyl disulfide.

[0318] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)disulfide, bis(difluoromethyl)disulfide, bis(trifluoromethyl)disulfide, di(1-fluoroethyl)disulfide, di(2-fluoroethyl)disulfide, bis(2,2,2-trifluoroethyl)disulfide, bis(perfluoroethyl)disulfide, bis(3,3,3-trifluoro-n-propyl)disulfide, bis(2,2,3,3,3-pentafluoro-n-propyl)disulfide, bis(perfluoro-n-propyl)disulfide, di(2-fluoroisopropyl)disulfide, bis(2,2,2,2',2',2'-hexafluoroisopropyl)disulfide, bis(perfluoro-n-butyl)disulfide, di(2-fluoro-tert-butyl)disulfide and bis(perfluoro-tert-butyl)disulfide.

[0319] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)disulfide, di(3-fluorocyclohexyl)disulfide, di(4-fluorocyclohexyl)disulfide and bis(perfluorocyclohexyl)disulfide.

[0320] Concrete examples of the compound possessing a fluorine-substituted unsaturated hydrocarbon group include di(2-fluorophenyl)disulfide, di(3-fluorophenyl)disulfide, di(4-fluorophenyl)disulfide, bis(2,3-difluorophenyl)disulfide, bis(2,4-difluorophenyl)disulfide, bis(3,5-difluorophenyl)disulfide, bis(2,4,6-trifluorophenyl)disulfide, bis(perfluorophenyl)disulfide, di(1-fluorovinyl)disulfide, di(2-fluorovinyl)disulfide, bis(perfluorovinyl)disulfide, bis[(2-fluorophenyl)methyl] disulfide, bis[(3-fluorophenyl)methyl] disulfide, bis[(4-fluorophenyl)methyl] disulfide and bis[(perfluorophenyl)methyl] disulfide.

[0321] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl

disulfide, methylpropyl disulfide, methylisopropyl disulfide, methyl n-butyl disulfide, methylisobutyl disulfide, methyl tert-butyl disulfide, methylcyclopentyl disulfide, methylcyclohexyl disulfide, methylphenyl disulfide, methyl(2-toluyl) disulfide, methyl(3-toluyl)disulfide, methyl(4-toluyl)disulfide, methylvinyl disulfide, methylallyl disulfide, methylbenzyl disulfide, ethylpropyl disulfide, ethylisopropyl disulfide, ethyl n-butyl disulfide, ethylisobutyl disulfide, ethyl tert-butyl disulfide, ethylcyclopentyl disulfide, ethylcyclohexyl disulfide, ethylphenyl disulfide, ethyl(2-toluyl)disulfide, ethyl(3-toluyl)disulfide, ethyl(4-toluyl)disulfide, ethylvinyl disulfide, ethylallyl disulfide, ethylbenzyl disulfide, phenylpropyl disulfide, phenylisopropyl disulfide, phenyl-n-butyl disulfide, phenylisobutyl disulfide, phenyl-tert-butyl disulfide, phenylcyclopentyl disulfide, phenylcyclohexyl disulfide, phenyl(2-toluyl)disulfide, phenyl(3-toluyl)disulfide, phenyl(4-toluyl)disulfide, phenylvinyl disulfide, phenylallyl disulfide and phenylbenzyl disulfide.

[0322] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluoromethyl)disulfide, methyl(difluoromethyl)disulfide, methyl(trifluoromethyl)disulfide, methyl(1-fluoroethyl)disulfide, methyl(2-fluoroethyl)disulfide, methyl(2,2,2-trifluoroethyl) disulfide, methyl(perfluoroethyl)disulfide, methyl(3,3,3-trifluoro-n-propyl)disulfide, methyl(2,2,3,3,3-pentafluoro-n-propyl)disulfide, methyl(perfluoro-n-propyl)disulfide, methyl(2-fluoroisopropyl)disulfide, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)disulfide, methyl(perfluoro-n-butyl) disulfide, methyl(2-fluoro-tert-butyl)disulfide, methyl(perfluoro-tert-butyl)disulfide, methyl(2-fluorocyclohexyl) disulfide, methyl(3-fluorocyclohexyl)disulfide, methyl(4-fluorocyclohexyl)disulfide, methyl(perfluorocyclohexyl) disulfide, methyl(2-fluorophenyl)disulfide, methyl(3-fluorophenyl)disulfide, methyl(4-fluorophenyl)disulfide, methyl(2,3-difluorophenyl)disulfide, methyl(2,4-difluorophenyl)disulfide, methyl(3,5-difluorophenyl)disulfide, methyl(2,4,6-trifluorophenyl)disulfide, methyl(perfluorophenyl)disulfide, methyl(1-fluorovinyl)disulfide, methyl (2-fluorovinyl)disulfide, methyl(perfluorovinyl)disulfide, methyl[(2-fluorophenyl)methyl] disulfide, methyl[(3-fluorophenyl)methyl] disulfide, methyl[(4-fluorophenyl)methyl] disulfide, methyl[(perfluorophenyl)methyl] disulfide, ethyl (fluoromethyl)disulfide, ethyl(difluoromethyl)disulfide, ethyl(trifluoromethyl)disulfide, ethyl(1-fluoroethyl)disulfide, ethyl(2-fluoroethyl)disulfide, ethyl(2,2,2-trifluoroethyl)disulfide, ethyl(perfluoroethyl)disulfide, ethyl(3,3,3-trifluoro-n-propyl)disulfide, ethyl(2,2,3,3,3-pentafluoro-n-propyl)disulfide, ethyl(perfluoro-n-propyl)disulfide, ethyl(2-fluoroisopropyl)disulfide, ethyl(2,2,2,2',2',2'-hexafluoroisopropyl)disulfide, ethyl(perfluoro-n-butyl) disulfide, ethyl(2-fluoro-tert-butyl)disulfide, ethyl(perfluoro-tert-butyl)disulfide, ethyl(2-fluorocyclohexyl)disulfide, ethyl (3-fluorocyclohexyl)disulfide, ethyl(4-fluorocyclohexyl) disulfide, ethyl(perfluorocyclohexyl)disulfide, ethyl(2-fluorophenyl)disulfide, ethyl(3-fluorophenyl)disulfide, ethyl (4-fluorophenyl)disulfide, ethyl(2,3-difluorophenyl) disulfide, ethyl(2,4-difluorophenyl)disulfide, ethyl(3,5-difluorophenyl)disulfide, ethyl(2,4,6-trifluorophenyl) disulfide, ethyl(perfluorophenyl)disulfide, ethyl(1-fluorovinyl)disulfide, ethyl(2-fluorovinyl)disulfide, ethyl (perfluorovinyl)disulfide, ethyl[(2-fluorophenyl)ethyl] disulfide, ethyl[(3-fluorophenyl)methyl] disulfide, ethyl[(4-fluorophenyl)methyl] disulfide, ethyl[(perfluorophenyl)methyl] disulfide, phenyl(fluoromethyl)disulfide, phenyl(difluoromethyl)disulfide, phenyl(trifluoromethyl)disulfide, phenyl(1-fluoroethyl)disulfide, phenyl(2-fluoroethyl)disulfide, phenyl(2,2,2-trifluoroethyl)disulfide, phenyl(perfluoroethyl)disulfide, phenyl(3,3,3-trifluoro-n-propyl)disulfide, phenyl(2,2,3,3,3-pentafluoro-n-propyl)disulfide, phenyl(perfluoro-n-propyl)disulfide, phenyl(2-fluoroisopropyl)disulfide, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)disulfide, phenyl(perfluoro-n-butyl)disulfide, phenyl(2-fluoro-tert-butyl)disulfide, phenyl(perfluoro-tert-butyl)disulfide, phenyl (2-fluorocyclohexyl)disulfide, phenyl(3-fluorocyclohexyl) disulfide, phenyl(4-fluorocyclohexyl)disulfide, phenyl (perfluorocyclohexyl)disulfide, phenyl(2-fluorophenyl) disulfide, phenyl(3-fluorophenyl)disulfide, phenyl(4-fluorophenyl)disulfide, phenyl(2,3-difluorophenyl)disulfide, phenyl(2,4-difluorophenyl)disulfide, phenyl(3,5-difluorophenyl)disulfide, phenyl(2,4,6-trifluorophenyl)disulfide, phenyl, phenyl(perfluorophenyl)disulfide, phenyl(1-fluorovinyl)disulfide, phenyl (2-fluorovinyl)disulfide, phenyl(perfluorovinyl)disulfide, phenyl[(2-fluorophenyl)methyl] disulfide, phenyl[(3-fluorophenyl)methyl] disulfide, phenyl[(4-fluorophenyl)methyl] disulfide, phenyl[(perfluorophenyl) methyl] disulfide

[0323] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)disulfide, (2,2,2-trifluoroethyl) (difluoromethyl)disulfide, (2,2,2-trifluoroethyl)(trifluoromethyl)disulfide, (2,2,2-trifluoroethyl)(1-fluoroethyl) disulfide, (2,2,2-trifluoroethyl)(2-fluoroethyl)disulfide, (2,2,2-trifluoroethyl)(perfluoroethyl)disulfide, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)disulfide, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)disulfide, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)disulfide, (2,2,2-trifluoroethyl)(2-fluoroisopropyl)disulfide, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)disulfide, (2,2,2-trifluoroethyl)(perfluoro-n-butyl)disulfide, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl)disulfide, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl)disulfide, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl)disulfide, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)disulfide, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)disulfide, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)disulfide, (2,2,2-trifluoroethyl)(2-fluorophenyl)disulfide, (2,2,2-trifluoroethyl)(3-fluorophenyl)disulfide, (2,2,2-trifluoroethyl)(4-fluorophenyl)disulfide, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)disulfide, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)disulfide, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)disulfide, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)disulfide, (2,2,2-trifluoroethyl)(perfluorophenyl)disulfide, (2,2,2-trifluoroethyl)(1-fluorovinyl)disulfide, (2,2,2-trifluoroethyl) (2-fluorovinyl)disulfide, (2,2,2-trifluoroethyl) (perfluorovinyl)disulfide, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] disulfide, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] disulfide, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] disulfide and (2,2,2-trifluoroethyl) [(perfluorophenyl)methyl] disulfide.

[0324] Chain Compound Possessing a Functional Group of the Formula (C-6):

[0325] As chain compound possessing a functional group represented by the above formula (C-6) include the following.

[0326] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl sul-

foxide, diethyl sulfoxide, di-n-propyl sulfoxide, diisopropyl sulfoxide, di-n-butyl sulfoxide, diisobutyl sulfoxide and di-tert-butyl sulfoxide.

[0327] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl sulfoxide and dicyclohexyl sulfoxide.

[0328] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl sulfoxide, di(2-toluyl)sulfoxide, di(3-toluyl)sulfoxide, di(4-toluyl)sulfoxide, divinyl sulfoxide, diallyl sulfoxide and dibenzyl sulfoxide.

[0329] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)sulfoxide, bis(difluoromethyl)sulfoxide, bis(trifluoromethyl)sulfoxide, di(1-fluoroethyl)sulfoxide, di(2-fluoroethyl)sulfoxide, bis(2,2,2-trifluoroethyl) sulfoxide, bis(perfluoroethyl)sulfoxide, bis(3,3,3-trifluoro-n-propyl)sulfoxide, bis(2,2,3,3,3-pentafluoro-n-propyl) sulfoxide, bis(perfluoro-n-propyl)sulfoxide, di(2-fluoroisopropyl)sulfoxide, bis(2,2,2,2',2',2'-hexafluoroisopropyl)sulfoxide, bis(perfluoro-n-butyl) sulfoxide, di(2-fluoro-tert-butyl)sulfoxide and bis(perfluoro-tert-butyl)sulfoxide.

[0330] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)sulfoxide, di(3-fluorocyclohexyl)sulfoxide, di(4-fluorocyclohexyl)sulfoxide, bis(perfluorocyclohexyl)sulfoxide, di(2-fluorophenyl)sulfoxide, di(3-fluorophenyl)sulfoxide, di(4-fluorophenyl)sulfoxide, bis(2,3-difluorophenyl)sulfoxide, bis(2,4-difluorophenyl) sulfoxide, bis(3,5-difluorophenyl)sulfoxide, bis(2,4,6-trifluorophenyl)sulfoxide, bis(perfluorophenyl)sulfoxide, di(1-fluorovinyl)sulfoxide, di(2-fluorovinyl)sulfoxide, bis (perfluorovinyl)sulfoxide, bis[(2-fluorophenyl)methyl] sulfoxide, bis[(3-fluorophenyl)methyl] sulfoxide, bis[(4-fluorophenyl)methyl] sulfoxide and bis[(perfluorophenyl) methyl] sulfoxide.

[0331] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl sulfoxide, methylpropyl sulfoxide, methylisopropyl sulfoxide, methyl-n-butyl sulfoxide, methylisobutyl sulfoxide, methyl-tert-butyl sulfoxide, methylcyclopentyl sulfoxide, methylcyclohexyl sulfoxide, methylphenyl sulfoxide, methyl (2-toluyl)sulfoxide, methyl(3-toluyl)sulfoxide, methyl(4-toluyl)sulfoxide, methylvinyl sulfoxide, methylallyl sulfoxide, methylbenzyl sulfoxide, ethylpropyl sulfoxide, ethylisopropyl sulfoxide, ethyl-n-butyl sulfoxide, ethylisobutyl sulfoxide, ethyl-tert-butyl sulfoxide, ethylcyclopentyl sulfoxide, ethylcyclohexyl sulfoxide, ethylphenyl sulfoxide, ethyl(2-toluyl)sulfoxide, ethyl(3-toluyl)sulfoxide, ethyl(4-toluyl)sulfoxide, ethylvinyl sulfoxide, ethylallyl sulfoxide, ethylbenzyl sulfoxide, phenylpropyl sulfoxide, phenylisopropyl sulfoxide, phenyl-n-butyl sulfoxide, phenylisobutyl sulfoxide, phenyl-tert-butyl sulfoxide, phenylcyclopentyl sulfoxide, phenylcyclohexyl sulfoxide, phenyl(2-toluyl)sulfoxide, phenyl(3-toluyl)sulfoxide, phenyl(4-toluyl)sulfoxide, phenylvinyl sulfoxide, phenylallyl sulfoxide and phenylbenzyl sulfoxide.

[0332] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluoromethyl)sulfoxide, methyl(difluoromethyl)sulfoxide, methyl (trifluoromethyl)sulfoxide, methyl(1-fluoroethyl)sulfoxide, methyl(2-fluoroethyl)sulfoxide, methyl(2,2,2-trifluoroethyl) sulfoxide, methyl(perfluoroethyl)sulfoxide, methyl(3,3,3-trifluoro-n-propyl)sulfoxide, methyl(2,2,3,3,3-pentafluoro-n-propyl)sulfoxide, methyl(perfluoro-n-propyl)sulfoxide, methyl(2-fluoroisopropyl)sulfoxide, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfoxide, methyl(perfluoro-n-butyl) sulfoxide, methyl(2-fluoro-tert-butyl)sulfoxide, methyl(perfluoro-tert-butyl)sulfoxide, methyl(2-fluorocyclohexyl) sulfoxide, methyl(3-fluorocyclohexyl)sulfoxide, methyl(4-fluorocyclohexyl)sulfoxide, methyl(perfluorocyclohexyl) sulfoxide, methyl(2-fluorophenyl)sulfoxide, methyl(3-fluorophenyl)sulfoxide, methyl(4-fluorophenyl)sulfoxide, methyl(2,3-difluorophenyl)sulfoxide, methyl(2,4-difluorophenyl)sulfoxide, methyl(3,5-difluorophenyl)sulfoxide, methyl(2,4,6-trifluorophenyl)sulfoxide, methyl(perfluorophenyl)sulfoxide, methyl(1-fluorovinyl)sulfoxide, methyl (2-fluorovinyl)sulfoxide, methyl(perfluorovinyl)sulfoxide, methyl[(2-fluorophenyl)methyl] sulfoxide, methyl[(3-fluorophenyl)methyl] sulfoxide, methyl[(4-fluorophenyl)methyl] sulfoxide, methyl[(perfluorophenyl)methyl] sulfoxide, ethyl(fluoromethyl)sulfoxide, ethyl(difluoromethyl)sulfoxide, ethyl(trifluoromethyl)sulfoxide, ethyl(1-fluoroethyl)sulfoxide, ethyl(2-fluoroethyl)sulfoxide, ethyl(2,2,2-trifluoroethyl)sulfoxide, ethyl(perfluoroethyl)sulfoxide, ethyl(3,3,3-trifluoro-n-propyl)sulfoxide, ethyl(2,2,3,3,3-pentafluoro-n-propyl)sulfoxide, ethyl(perfluoro-n-propyl)sulfoxide, ethyl (2-fluoroisopropyl)sulfoxide, ethyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfoxide, ethyl(perfluoro-n-butyl) sulfoxide, ethyl(2-fluoro-tert-butyl)sulfoxide, ethyl (perfluoro-tert-butyl)sulfoxide, ethyl(2-fluorocyclohexyl) sulfoxide, ethyl(3-fluorocyclohexyl)sulfoxide, ethyl(4-fluorocyclohexyl)sulfoxide, ethyl(perfluorocyclohexyl) sulfoxide, ethyl(2-fluorophenyl)sulfoxide, ethyl(3-fluorophenyl)sulfoxide, ethyl(4-fluorophenyl)sulfoxide, ethyl(2,3-difluorophenyl)sulfoxide, ethyl(2,4-difluorophenyl)sulfoxide, ethyl(3,5-difluorophenyl)sulfoxide, ethyl(2,4,6-trifluorophenyl)sulfoxide, ethyl(perfluorophenyl)sulfoxide, ethyl(1-fluorovinyl)sulfoxide, ethyl(2-fluorovinyl) sulfoxide, ethyl(perfluorovinyl)sulfoxide, ethyl[(2-fluorophenyl)ethyl] sulfoxide, ethyl[(3-fluorophenyl) methyl] sulfoxide, ethyl[(4-fluorophenyl)methyl] sulfoxide, ethyl[(perfluorophenyl)methyl] sulfoxide, phenyl(fluoromethyl)sulfoxide, phenyl(difluoromethyl)sulfoxide, phenyl (trifluoromethyl)sulfoxide, phenyl(1-fluoroethyl)sulfoxide, phenyl(2-fluoroethyl)sulfoxide, phenyl(2,2,2-trifluoroethyl) sulfoxide, phenyl(perfluoroethyl)sulfoxide, phenyl(3,3,3-trifluoro-n-propyl)sulfoxide, phenyl(2,2,3,3,3-pentafluoro-n-propyl)sulfoxide, phenyl(perfluoro-n-propyl)sulfoxide, phenyl(2-fluoroisopropyl)sulfoxide, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfoxide, phenyl(perfluoro-n-butyl) sulfoxide, phenyl(2-fluoro-tert-butyl)sulfoxide, phenyl(perfluoro-tert-butyl)sulfoxide, phenyl(2-fluorocyclohexyl) sulfoxide, phenyl(3-fluorocyclohexyl)sulfoxide, phenyl(4-fluorocyclohexyl)sulfoxide, phenyl(perfluorocyclohexyl) sulfoxide, phenyl(2-fluorophenyl)sulfoxide, phenyl(3-fluorophenyl)sulfoxide, phenyl(4-fluorophenyl)sulfoxide, phenyl(2,3-difluorophenyl)sulfoxide, phenyl(2,4-difluorophenyl)sulfoxide, phenyl(3,5-difluorophenyl)sulfoxide, phenyl(2,4,6-trifluorophenyl)sulfoxide, phenyl(perfluorophenyl)sulfoxide, phenyl(1-fluorovinyl)sulfoxide, phenyl (2-fluorovinyl)sulfoxide, phenyl(perfluorovinyl)sulfoxide, phenyl[(2-fluorophenyl)methyl] sulfoxide, phenyl[(3-fluorophenyl)methyl] sulfoxide, phenyl[(4-fluorophenyl)methyl] sulfoxide and phenyl[(perfluorophenyl)methyl] sulfoxide.

[0333] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)sulfoxide, (2,2,2-trifluoroethyl)(difluoromethyl)sulfoxide, (2,2,2-trifluoroethyl)(trifluoromethyl)sulfoxide, (2,2,2-trifluoroethyl)(1-fluoroethyl)sulfoxide, (2,2,2-trifluoroethyl)(2-fluoroethyl)sulfoxide, (2,2,2-trifluoroethyl)(perfluoroethyl)sulfoxide, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)sulfoxide, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)sulfide, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)sulfide, (2,2,2-trifluoroethyl)(2-fluoroisopropyl)sulfide, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)sulfide, (2,2,2-trifluoroethyl)(perfluoro-n-butyl)sulfide, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl)sulfoxide, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl)sulfide, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl)sulfide, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)sulfoxide, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)sulfoxide, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)sulfoxide, (2,2,2-trifluoroethyl)(2-fluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(3-fluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(4-fluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(perfluorophenyl)sulfoxide, (2,2,2-trifluoroethyl)(1-fluorovinyl)sulfoxide, (2,2,2-trifluoroethyl)(2-fluorovinyl)sulfoxide, (2,2,2-trifluoroethyl)(perfluorovinyl)sulfoxide, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] sulfoxide, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] sulfoxide, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] sulfoxide and (2,2,2-trifluoroethyl)[(perfluorophenyl)methyl] sulfoxide.

[0334] Chain Compound Possessing a Functional Group of the Formula (C-7):

[0335] As chain compound possessing a functional group represented by the above formula (C-7) include the following.

[0336] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl sulfone, diethyl sulfone, di-n-propyl sulfone, diisopropyl sulfone, di-n-butyl sulfone, diisobutyl sulfone and di-tert-butyl sulfone.

[0337] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl sulfone and dicyclohexyl sulfone.

[0338] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl sulfone, di(2-toluyl)sulfone, di(3-toluyl)sulfone, di(4-toluyl)sulfone, divinyl sulfone, diallyl sulfone and dibenzyl sulfone.

[0339] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)sulfone, bis(difluoromethyl)sulfone, bis(trifluoromethyl)sulfone, di(1-fluoroethyl)sulfone, di(2-fluoroethyl)sulfone, bis(2,2,2-trifluoroethyl)sulfone, bis(perfluoroethyl)sulfone, bis(3,3,3-trifluoro-n-propyl)sulfone, bis(2,2,3,3,3-pentafluoro-n-propyl)sulfone, bis(perfluoro-n-propyl)sulfone, di(2-fluoroisopropyl)sulfone, bis(2,2,2,2',2',2'-hexafluoroisopropyl)sulfone, bis(perfluoro-n-butyl)sulfone, di(2-fluoro-tert-butyl)sulfone and bis(perfluoro-tert-butyl)sulfone.

[0340] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)sulfone, di(3-fluorocyclohexyl)sulfone, di(4-fluorocyclohexyl)sulfone and bis(perfluorocyclohexyl)sulfone.

[0341] Concrete examples of the compound possessing a fluorine-substituted unsaturated hydrocarbon group include di(2-fluorophenyl)sulfone, di(3-fluorophenyl)sulfone, di(4-fluorophenyl)sulfone, bis(2,3-difluorophenyl)sulfone, bis(2,4-difluorophenyl)sulfone, bis(3,5-difluorophenyl)sulfone, bis(2,4,6-trifluorophenyl)sulfone, bis(perfluorophenyl)sulfone, di(1-fluorovinyl)sulfone, di(2-fluorovinyl)sulfone, bis(perfluorovinyl)sulfone, bis[(2-fluorophenyl)methyl] sulfone, bis[(3-fluorophenyl)methyl] sulfone, bis[(4-fluorophenyl)methyl] sulfone and bis[(perfluorophenyl)methyl] sulfone.

[0342] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl sulfone, methylpropyl sulfone, methylisopropyl sulfone, methyl-n-butyl sulfone, methylisobutyl sulfone, methyltert-butyl sulfone, methylcyclopentyl sulfone, methylcyclohexyl sulfone, methylphenyl sulfone, methyl(2-toluyl)sulfone, methyl(3-toluyl)sulfone, methyl(4-toluyl)sulfone, methylvinyl sulfone, methylallyl sulfone, methylbenzyl sulfone, ethylpropyl sulfone, ethylisopropyl sulfone, ethyl n-butyl sulfone, ethylisobutyl sulfone, ethyl tert-butyl sulfone, ethylcyclopentyl sulfone, ethylcyclohexyl sulfone, ethylphenyl sulfone, ethyl(2-toluyl)sulfone, ethyl(3-toluyl)sulfone, ethyl(4-toluyl)sulfone, ethylvinyl sulfone, ethylallyl sulfone, ethylbenzyl sulfone, phenylpropyl sulfone, phenylisopropyl sulfone, phenyl n-butyl sulfone, phenylisobutyl sulfone, phenyl tert-butyl sulfone, phenylcyclopentyl sulfone, phenylcyclohexyl sulfone, phenyl(2-toluyl)sulfone, phenyl(3-toluyl)sulfone, phenyl(4-toluyl)sulfone, phenylvinyl sulfone, phenylallyl sulfone and phenylbenzyl sulfone.

[0343] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluoromethyl)sulfone, methyl(difluoromethyl)sulfone, methyl(trifluoromethyl)sulfone, methyl(1-fluoroethyl)sulfone, methyl(2-fluoroethyl)sulfone, methyl(2,2,2-trifluoroethyl)sulfone, methyl(perfluoroethyl)sulfone, methyl(3,3,3-trifluoro-n-propyl)sulfone, methyl(2,2,3,3,3-pentafluoro-n-propyl)sulfone, methyl(perfluoro-n-propyl)sulfone, methyl(2-fluoroisopropyl)sulfone, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfone, methyl(perfluoro-n-butyl)sulfone, methyl(2-fluoro-tert-butyl)sulfone, methyl(perfluoro-tert-butyl)sulfone, methyl(2-fluorocyclohexyl)sulfone, methyl(3-fluorocyclohexyl)sulfone, methyl(4-fluorocyclohexyl)sulfone, methyl(perfluorocyclohexyl)sulfone, methyl(2-fluorophenyl)sulfone, methyl(3-fluorophenyl)sulfone, methyl(4-fluorophenyl)sulfone, methyl(2,3-difluorophenyl)sulfone, methyl(2,4-difluorophenyl)sulfone, methyl(3,5-difluorophenyl)sulfone, methyl(2,4,6-trifluorophenyl)sulfone, methyl(perfluorophenyl)sulfone, methyl(1-fluorovinyl)sulfone, methyl(2-fluorovinyl)sulfone, methyl(perfluorovinyl)sulfone, methyl[(2-fluorophenyl)methyl] sulfone, methyl[(3-fluorophenyl)methyl] sulfone, methyl[(4-fluorophenyl)methyl] sulfone, methyl[(perfluorophenyl)methyl] sulfone, ethyl(fluoromethyl)sulfone, ethyl(difluoromethyl)sulfone, ethyl(trifluoromethyl)sulfone, ethyl(1-fluoroethyl)sulfone, ethyl(2-fluoroethyl)sulfone, ethyl(2,2,2-trifluoroethyl)sulfone, ethyl(perfluoroethyl)sulfone, ethyl(3,3,3-trifluoro-n-propyl)sulfone, ethyl(2,2,3,3,3-pentafluoro-n-propyl)sulfone, ethyl(perfluoro-n-propyl)sulfone, ethyl(2-fluoroisopropyl)sulfone, ethyl(2,2,2,2',2',2'-hexaflu-

oroisopropyl)sulfone, ethyl(perfluoro-n-butyl)sulfone, ethyl (2-fluoro-tert-butyl)sulfone, ethyl(perfluoro-tert-butyl)sulfone, ethyl(2-fluorocyclohexyl)sulfone, ethyl(3-fluorocyclohexyl)sulfone, ethyl(4-fluorocyclohexyl)sulfone, ethyl(perfluorocyclohexyl)sulfone, ethyl(2-fluorophenyl) sulfone, ethyl(3-fluorophenyl)sulfone, ethyl(4-fluorophenyl) sulfone, ethyl(2,3-difluorophenyl)sulfone, ethyl(2,4-difluorophenyl)sulfone, ethyl(3,5-difluorophenyl)sulfone, ethyl(2,4,6-trifluorophenyl)sulfone, ethyl(perfluorophenyl)sulfone, ethyl(1-fluorovinyl)sulfone, ethyl(2-fluorovinyl)sulfone, ethyl(perfluorovinyl)sulfone, ethyl[(2-fluorophenyl)ethyl] sulfone, ethyl[(3-fluorophenyl)methyl] sulfone, ethyl[(4-fluorophenyl)methyl] sulfone, ethyl[(perfluorophenyl)methyl] sulfone, phenyl(fluoromethyl)sulfone, phenyl(difluoromethyl)sulfone, phenyl(trifluoromethyl)sulfone, phenyl(1-fluoroethyl)sulfone, phenyl(2-fluoroethyl)sulfone, phenyl(2,2,2-trifluoroethyl)sulfone, phenyl(perfluoroethyl)sulfone, phenyl(3,3,3-trifluoro-n-propyl)sulfone, phenyl(2,2,3,3,3-pentafluoro-n-propyl)sulfone, phenyl(perfluoro-n-propyl) sulfone, phenyl(2-fluoroisopropyl)sulfone, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfone, phenyl(perfluoro-n-butyl) sulfone, phenyl(2-fluoro-tert-butyl)sulfone, phenyl (perfluoro-tert-butyl)sulfone, phenyl(2-fluorocyclohexyl) sulfone, phenyl(3-fluorocyclohexyl)sulfone, phenyl(4-fluorocyclohexyl)sulfone, phenyl(perfluorocyclohexyl) sulfone, phenyl(2-fluorophenyl)sulfone, phenyl(3-fluorophenyl)sulfone, phenyl(4-fluorophenyl)sulfone, phenyl(2,3-difluorophenyl)sulfone, phenyl(2,4-difluorophenyl)sulfone, phenyl(3,5-difluorophenyl)sulfone, phenyl(2,4,6-trifluorophenyl)sulfone, phenyl(perfluorophenyl)sulfone, phenyl(1-fluorovinyl)sulfone, phenyl(2-fluorovinyl)sulfone, phenyl(perfluorovinyl)sulfone, phenyl[(2-fluorophenyl)methyl] sulfone, phenyl[(3-fluorophenyl)methyl] sulfone, phenyl[(4-fluorophenyl)methyl] sulfone and phenyl[(perfluorophenyl)methyl] sulfone.

[0344] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)sulfone, (2,2,2-trifluoroethyl) (difluoromethyl)sulfone, (2,2,2-trifluoroethyl)(trifluoromethyl)sulfone, (2,2,2-trifluoroethyl)(1-fluoroethyl)sulfone, (2,2,2-trifluoroethyl)(perfluoroethyl)sulfone, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)sulfone, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)sulfone, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)sulfone, (2,2,2-trifluoroethyl) (2-fluoroisopropyl)sulfone, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)sulfone, (2,2,2-trifluoroethyl) (perfluoro-n-butyl)sulfone, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl)sulfone, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl)sulfone, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl) sulfone, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)sulfone, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)sulfone, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)sulfone, (2,2,2-trifluoroethyl)(2-fluorophenyl)sulfone, (2,2,2-trifluoroethyl)(3-fluorophenyl)sulfone, (2,2,2-trifluoroethyl)(4-fluorophenyl) sulfone, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)sulfone, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)sulfone, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)sulfone, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)sulfone, (2,2,2-trifluoroethyl) (perfluorophenyl)sulfone, (2,2,2-trifluoroethyl)(1-fluorovinyl)sulfone, (2,2,2-trifluoroethyl)(2-fluorovinyl) sulfone, (2,2,2-trifluoroethyl)(perfluorovinyl)sulfone, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] sulfone, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] sulfone, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] sulfone and (2,2,2-trifluoroethyl)[(perfluorophenyl)methyl] sulfone.

[0345] Chain Compound Possessing a Functional Group of the Formula (C-8):

[0346] As chain compound possessing a functional group represented by the above formula (C-8) include the following.

[0347] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl sulfite, diethyl sulfite, di-n-propyl sulfite, diisopropyl sulfite, di-n-butyl sulfite, diisobutyl sulfite and di-tert-butyl sulfite.

[0348] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl sulfite and dicyclohexyl sulfite.

[0349] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl sulfite, di(2-toluyl)sulfite, di(3-toluyl)sulfite, di(4-toluyl)sulfite, divinyl sulfite, diallyl sulfite and dibenzyl sulfite.

[0350] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)sulfite, bis(difluoromethyl)sulfite, bis(trifluoromethyl)sulfite, di(1-fluoroethyl)sulfite, di(2-fluoroethyl)sulfite, bis(2,2,2-trifluoroethyl)sulfite, bis(perfluoroethyl)sulfite, bis(3,3,3-trifluoro-n-propyl)sulfite, bis(2,2,3,3,3-pentafluoro-n-propyl)sulfite, bis(perfluoro-n-propyl) sulfite, di(2-fluoroisopropyl)sulfite, bis(2,2,2,2',2',2'-hexafluoroisopropyl)sulfite, bis(perfluoro-n-butyl)sulfite, di(2-fluoro-tert-butyl)sulfite and bis(perfluoro-tert-butyl) sulfite.

[0351] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)sulfite, di(3-fluorocyclohexyl)sulfite, di(4-fluorocyclohexyl)sulfite and bis(perfluorocyclohexyl)sulfite.

[0352] Concrete examples of the compound possessing a fluorine-substituted unsaturated hydrocarbon group include di(2-fluorophenyl)sulfite, di(3-fluorophenyl)sulfite, di(4-fluorophenyl)sulfite, bis(2,3-difluorophenyl)sulfite, bis(2,4-difluorophenyl)sulfite, bis(3,5-difluorophenyl)sulfite, bis(2,4,6-trifluorophenyl)sulfite, bis(perfluorophenyl)sulfite, di(1-fluorovinyl)sulfite, di(2-fluorovinyl)sulfite, bis (perfluorovinyl)sulfite, bis[(2-fluorophenyl)methyl] sulfite, bis[(3-fluorophenyl)methyl] sulfite, bis[(4-fluorophenyl)methyl] sulfite and bis[(perfluorophenyl)methyl] sulfite.

[0353] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl sulfite, methylpropyl sulfite, methylisopropyl sulfite, methyl-n-butyl sulfite, methylisobutyl sulfite, methyl-tert-butyl sulfite, methylcyclopentyl sulfite, methylcyclohexyl sulfite, methylphenyl sulfite, methyl(2-toluyl)sulfite, methyl(3-toluyl)sulfite, methyl(4-toluyl)sulfite, methylvinyl sulfite, methylallyl sulfite, methylbenzyl sulfite, ethylpropyl sulfite, ethylisopropyl sulfite, ethyl-n-butyl sulfite, ethylisobutyl sulfite, ethyl-tert-butyl sulfite, ethylcyclopentyl sulfite, ethylcyclohexyl sulfite, ethylphenyl sulfite, ethyl(2-toluyl)sulfite, ethyl(3-toluyl)sulfite, ethyl(4-toluyl)sulfite, ethylvinyl sulfite, ethylallyl sulfite, ethylbenzyl sulfite, phenylpropyl sulfite, phenylisopropyl sulfite, phenyl-n-butyl sulfite, phenylisobutyl sulfite, phenyl-tert-butyl sulfite, phenylcyclopentyl sulfite, phenylcyclohexyl sulfite, phenyl(2-toluyl)sulfite, phenyl(3-toluyl)sulfite, phenyl(4-toluyl)sulfite, phenylvinyl sulfite, phenylallyl sulfite and phenylbenzyl sulfite.

[0354] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluorom-

ethyl)sulfite, methyl(difluoromethyl)sulfite, methyl(trifluoromethyl)sulfite, methyl(1-fluoroethyl)sulfite, methyl(2-fluoroethyl)sulfite, methyl(2,2,2-trifluoroethyl)sulfite, methyl(perfluoroethyl)sulfite, methyl(3,3,3-trifluoro-n-propyl)sulfite, methyl(2,2,3,3,3-pentafluoro-n-propyl)sulfite, methyl(perfluoro-n-propyl)sulfite, methyl(2-fluoroisopropyl)sulfite, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfite, methyl(perfluoro-n-butyl)sulfite, methyl(2-fluoro-tert-butyl) sulfite, methyl(perfluoro-tert-butyl)sulfite, methyl(2-fluorocyclohexyl)sulfite, methyl(3-fluorocyclohexyl)sulfite, methyl(4-fluorocyclohexyl)sulfite, methyl(perfluorocyclohexyl)sulfite, methyl(2-fluorophenyl)sulfite, methyl(3-fluorophenyl)sulfite, methyl(4-fluorophenyl)sulfite, methyl(2,3-difluorophenyl)sulfite, methyl(2,4-difluorophenyl)sulfite, methyl(3,5-difluorophenyl)sulfite, methyl(2,4,6-trifluorophenyl)sulfite, methyl(perfluorophenyl)sulfite, methyl(1-fluorovinyl)sulfite, methyl(2-fluorovinyl)sulfite, methyl(perfluorovinyl)sulfite, methyl[(2-fluorophenyl)methyl] sulfite, methyl[(3-fluorophenyl)methyl] sulfite, methyl[(4-fluorophenyl)methyl] sulfite, methyl[(perfluorophenyl)methyl] sulfite, ethyl(fluoromethyl)sulfite, ethyl(difluoromethyl) sulfite, ethyl(trifluoromethyl)sulfite, ethyl(1-fluoroethyl) sulfite, ethyl(2-fluoroethyl)sulfite, ethyl(2,2,2-trifluoroethyl) sulfite, ethyl(perfluoroethyl)sulfite, ethyl(3,3,3-trifluoro-n-propyl)sulfite, ethyl(2,2,3,3,3-pentafluoro-n-propyl)sulfite, ethyl(perfluoro-n-propyl)sulfite, ethyl(2-fluoroisopropyl) sulfite, ethyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfite, ethyl (perfluoro-n-butyl)sulfite, ethyl(2-fluoro-tert-butyl)sulfite, ethyl(perfluoro-tert-butyl)sulfite, ethyl(2-fluorocyclohexyl) sulfite, ethyl(3-fluorocyclohexyl)sulfite, ethyl(4-fluorocyclohexyl)sulfite, ethyl(perfluorocyclohexyl)sulfite, ethyl(2-fluorophenyl)sulfite, ethyl(3-fluorophenyl)sulfite, ethyl(4-fluorophenyl)sulfite, ethyl(2,3-difluorophenyl)sulfite, ethyl (2,4-difluorophenyl)sulfite, ethyl(3,5-difluorophenyl)sulfite, ethyl(2,4,6-trifluorophenyl)sulfite, ethyl(perfluorophenyl) sulfite, ethyl(1-fluorovinyl)sulfite, ethyl(2-fluorovinyl) sulfite, ethyl(perfluorovinyl)sulfite, ethyl[(2-fluorophenyl) ethyl] sulfite, ethyl[(3-fluorophenyl)methyl] sulfite, ethyl[(4-fluorophenyl)methyl] sulfite, ethyl[(perfluorophenyl)methyl] sulfite, phenyl(fluoromethyl)sulfite, phenyl(difluoromethyl) sulfite, phenyl(trifluoromethyl)sulfite, phenyl(1-fluoroethyl) sulfite, phenyl(2-fluoroethyl)sulfite, phenyl(2,2,2-trifluoroethyl)sulfite, phenyl(perfluoroethyl)sulfite, phenyl(3,3,3-trifluoro-n-propyl)sulfite, phenyl(2,2,3,3,3-pentafluoro-n-propyl)sulfite, phenyl(perfluoro-n-propyl)sulfite, phenyl(2-fluoroisopropyl)sulfite, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfite, phenyl(perfluoro-n-butyl) sulfite, phenyl(2-fluoro-tert-butyl)sulfite, phenyl(perfluoro-tert-butyl)sulfite, phenyl(2-fluorocyclohexyl)sulfite, phenyl (3-fluorocyclohexyl)sulfite, phenyl(4-fluorocyclohexyl) sulfite, phenyl(perfluorocyclohexyl)sulfite, phenyl(2-fluorophenyl)sulfite, phenyl(3-fluorophenyl)sulfite, phenyl (4-fluorophenyl)sulfite, phenyl(2,3-difluorophenyl)sulfite, phenyl(2,4-difluorophenyl)sulfite, phenyl(3,5-difluorophenyl)sulfite, phenyl(2,4,6-trifluorophenyl)sulfite, phenyl(perfluorophenyl)sulfite, phenyl(1-fluorovinyl)sulfite, phenyl(2-fluorovinyl)sulfite, phenyl(perfluorovinyl)sulfite, phenyl[(2-fluorophenyl)methyl] sulfite, phenyl[(3-fluorophenyl) methyl] sulfite, phenyl[(4-fluorophenyl)methyl] sulfite and phenyl[(perfluorophenyl)methyl] sulfite.

[0355] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)sulfite, (2,2,2-trifluoroethyl)(difluoromethyl)sulfite, (2,2,2-trifluoroethyl)(trifluoromethyl)sulfite, (2,2,2-trifluoroethyl)(1-fluoroethyl)sulfite, (2,2,2-trifluoroethyl)(2-fluoroethyl)sulfite, (2,2,2-trifluoroethyl)(perfluoroethyl)sulfite, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)sulfite, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)sulfite, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)sulfite, (2,2,2-trifluoroethyl)(2-fluoroisopropyl)sulfite, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)sulfite, (2,2,2-trifluoroethyl)(perfluoro-n-butyl)sulfite, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl) sulfite, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl)sulfite, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl)sulfite, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)sulfite, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)sulfite, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)sulfite, (2,2,2-trifluoroethyl)(2-fluorophenyl) sulfite, (2,2,2-trifluoroethyl)(3-fluorophenyl)sulfite, (2,2,2-trifluoroethyl)(4-fluorophenyl)sulfite, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)sulfite, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)sulfite, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)sulfite, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)sulfite, (2,2,2-trifluoroethyl)(perfluorophenyl)sulfite, (2,2,2-trifluoroethyl)(1-fluorovinyl)sulfite, (2,2,2-trifluoroethyl)(2-fluorovinyl) sulfite, (2,2,2-trifluoroethyl)(perfluorovinyl)sulfite, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] sulfite, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] sulfite, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] sulfite and (2,2,2-trifluoroethyl)[(perfluorophenyl)methyl] sulfite.

[0356] Chain Compound Possessing a Functional Group of the Formula (C-9):

[0357] As chain compound possessing a functional group represented by the above formula (C-9) include the following.

[0358] Concrete examples of the aliphatic sulfonic acid ester possessing a chained saturated hydrocarbon group include methyl methanesulfonate, ethyl methanesulfonate, n-propyl methanesulfonate, isopropyl methanesulfonate, n-butyl methanesulfonate, isobutyl methanesulfonate, tert-butyl methanesulfonate, methyl ethanesulfonate, ethyl ethanesulfonate, n-propyl ethanesulfonate, isopropyl ethanesulfonate, n-butyl ethanesulfonate, isobutyl ethanesulfonate and tert-butyl ethanesulfonate.

[0359] Concrete examples of the aliphatic sulfonic acid ester possessing a cyclic saturated hydrocarbon group include cyclopentyl methanesulfonate, cyclohexyl methanesulfonate, cyclopentyl ethanesulfonate and cyclohexyl ethanesulfonate.

[0360] Concrete examples of the aliphatic sulfonic acid ester possessing an unsaturated hydrocarbon group include phenyl methanesulfonate, (2-toluyl)methanesulfonate, (3-toluyl)methanesulfonate, (4-toluyl)methanesulfonate, vinyl methanesulfonate, allyl methanesulfonate, benzyl methanesulfonate, phenyl ethanesulfonate, (2-toluyl)ethanesulfonate, (3-toluyl)ethanesulfonate, (4-toluyl)ethanesulfonate, vinyl ethanesulfonate, allyl ethanesulfonate and benzyl ethanesulfonate.

[0361] Concrete examples of the aliphatic sulfonic acid ester derivative that is substituted with a fluorine atom include methyl trifluoromethane sulfonate, ethyl trifluoromethane sulfonate, n-propyl trifluoromethane sulfonate, isopropyl trifluoromethane sulfonate, n-butyl trifluoromethane sulfonate, isobutyl trifluoromethane sulfonate, tert-butyl trifluoromethane sulfonate, cyclopentyl trifluoromethane sulfonate, cyclohexyl trifluoromethane sulfonate, phenyl trifluoromethane sulfonate, (2-toluyl)trifluoromethane sulfonate,

(3-toluyl)trifluoromethane sulfonate, (4-toluyl)trifluoromethane sulfonate, vinyl trifluoromethane sulfonate, allyl trifluoromethane sulfonate, benzyl trifluoromethane sulfonate, (fluoromethyl)trifluoromethane sulfonate, (difluoromethyl)trifluoromethane sulfonate, (trifluoromethyl)trifluoromethane sulfonate, (1-fluoroethyl)trifluoromethane sulfonate, (2-fluoroethyl)trifluoromethane sulfonate, (2,2,2-trifluoroethyl)trifluoromethane sulfonate, (perfluoroethyl) trifluoromethane sulfonate, (3,3,3-trifluoro-n-propyl)trifluoromethane sulfonate, (2,2,3,3,3-pentafluoro-n-propyl) trifluoromethane sulfonate, (perfluoro-n-propyl) trifluoromethane sulfonate, (2-fluoroisopropyl) trifluoromethane sulfonate, (2,2,2,2',2',2'-hexafluoroisopropyl)trifluoromethane sulfonate, (perfluoro-n-butyl)trifluoromethane sulfonate, (2-fluoro-tert-butyl) trifluoromethane sulfonate, (perfluoro-tert-butyl) trifluoromethane sulfonate, (2-fluorocyclohexyl) trifluoromethane sulfonate, (3-fluorocyclohexyl) trifluoromethane sulfonate, (4-fluorocyclohexyl) trifluoromethane sulfonate, (perfluorocyclohexyl) trifluoromethane sulfonate, (2-fluorophenyl) trifluoromethane sulfonate, (3-fluorophenyl) trifluoromethane sulfonate, (4-fluorophenyl) trifluoromethane sulfonate, (2,3-difluorophenyl) trifluoromethane sulfonate, (2,4-difluorophenyl) trifluoromethane sulfonate, (3,5-difluorophenyl) trifluoromethane sulfonate, (2,4,6-trifluorophenyl) trifluoromethane sulfonate, (perfluorophenyl) trifluoromethane sulfonate, (1-fluorovinyl)trifluoromethane sulfonate, (2-fluorovinyl)trifluoromethane sulfonate, (perfluorovinyl)trifluoromethane sulfonate, (2-fluorophenyl)methyl trifluoromethane sulfonate, (3-fluorophenyl)methyl trifluoromethane sulfonate, (4-fluorophenyl)methyl trifluoromethane sulfonate and (perfluorophenyl)methyl trifluoromethane sulfonate.

[0362] Concrete examples of the aliphatic sulfonic acid ester derivative in which hydrogen atom in the ester moiety is substituted by fluorine atom include (fluoromethyl)methanesulfonate, (difluoromethyl)methanesulfonate, (trifluoromethyl)methanesulfonate, (1-fluoroethyl)methanesulfonate, (2-fluoroethyl)methanesulfonate, (2,2,2-trifluoroethyl)methanesulfonate, (perfluoroethyl)methanesulfonate, (3,3,3-trifluoro-n-propyl)methanesulfonate, (2,2,3,3,3-pentafluoro-n-propyl)methanesulfonate, (perfluoro-n-propyl) methanesulfonate, (2-fluoroisopropyl)methanesulfonate, (2,2,2,2',2',2'-hexafluoroisopropyl)methanesulfonate, (perfluoro-n-butyl)methanesulfonate, (2-fluoro-tert-butyl)methanesulfonate, (perfluoro-tert-butyl)methanesulfonate, (fluoromethyl)ethanesulfonate, (difluoromethyl)ethanesulfonate, (trifluoromethyl)ethanesulfonate, (1-fluoroethyl)ethanesulfonate, (2-fluoroethyl)ethanesulfonate, (2,2,2-trifluoroethyl)ethanesulfonate, (perfluoroethyl)ethanesulfonate, (3,3,3-trifluoro-n-propyl)ethanesulfonate, (2,2,3,3,3-pentafluoro-n-propyl)ethanesulfonate, (perfluoro-n-propyl) ethanesulfonate, (2-fluoroisopropyl)ethanesulfonate, (2,2,2,2',2',2'-hexafluoroisopropyl)ethanesulfonate, (perfluoro-n-butyl)ethanesulfonate, (2-fluoro-tert-butyl)ethanesulfonate and (perfluoro-tert-butyl)ethanesulfonate.

[0363] Concrete examples of the aliphatic sulfonic acid ester possessing a cyclic saturated hydrocarbon group that is substituted with a fluorine atom include (2-fluorocyclohexyl) methanesulfonate, (3-fluorocyclohexyl)methanesulfonate, (4-fluorocyclohexyl)methanesulfonate, (perfluorocyclohexyl)methanesulfonate, (2-fluorocyclohexyl)ethanesulfonate, (3-fluorocyclohexyl)ethanesulfonate, (4-fluorocyclohexyl)ethanesulfonate and (perfluorocyclohexyl) ethanesulfonate.

[0364] Concrete examples of the aliphatic sulfonic acid ester possessing an unsaturated hydrocarbon group that is substituted with a fluorine atom include (2-fluorophenyl) methanesulfonate, (3-fluorophenyl)methanesulfonate, (4-fluorophenyl)methanesulfonate, (2,3-difluorophenyl) methanesulfonate, (2,4-difluorophenyl)methanesulfonate, (3,5-difluorophenyl)methanesulfonate, (2,4,6-trifluorophenyl)methanesulfonate, (perfluorophenyl)methanesulfonate, (1-fluorovinyl)methanesulfonate, (2-fluorovinyl)methanesulfonate, (perfluorovinyl)methanesulfonate, (2-fluorophenyl)methyl methanesulfonate, (3-fluorophenyl)methyl methanesulfonate, (4-fluorophenyl)methyl methanesulfonate, (perfluorophenyl)methyl methanesulfonate, (2-fluorophenyl)ethanesulfonate, (3-fluorophenyl)ethanesulfonate, (4-fluorophenyl)ethanesulfonate, (2,3-difluorophenyl) ethanesulfonate, (2,4-difluorophenyl)ethanesulfonate, (3,5-difluorophenyl)ethanesulfonate, (2,4,6-trifluorophenyl) ethanesulfonate, (perfluorophenyl)ethanesulfonate, (1-fluorovinyl)ethanesulfonate, (2-fluorovinyl)ethanesulfonate, (perfluorovinyl)ethanesulfonate, (2-fluorophenyl) methyl ethanesulfonate, (3-fluorophenyl)methyl ethanesulfonate, (4-fluorophenyl)methyl ethanesulfonate and (perfluorophenyl)methyl ethanesulfonate.

[0365] Concrete examples of the aromatic sulfonic acid ester possessing a chained saturated hydrocarbon group include methyl benzenesulfonate, ethyl benzenesulfonate, n-propyl benzenesulfonate, isopropyl benzenesulfonate, n-butyl benzenesulfonate, isobutyl benzenesulfonate, tert-butyl benzenesulfonate, methyl p-toluenesulfonate, ethyl p-toluenesulfonate, n-propyl p-toluenesulfonate, isopropyl p-toluenesulfonate, n-butyl p-toluenesulfonate, isobutyl p-toluenesulfonate and tert-butyl p-toluenesulfonate.

[0366] Concrete examples of the aromatic sulfonic acid ester possessing a cyclic saturated hydrocarbon group include cyclopentyl benzenesulfonate, cyclohexyl benzenesulfonate, cyclopentyl p-toluenesulfonate and cyclohexyl p-toluenesulfonate.

[0367] Concrete examples of the aromatic sulfonic acid ester possessing an unsaturated hydrocarbon group include phenyl benzenesulfonate, (2-toluyl)benzenesulfonate, (3-toluyl)benzenesulfonate, (4-toluyl)benzenesulfonate, vinyl benzenesulfonate, allyl benzenesulfonate, benzyl benzenesulfonate, phenyl p-toluenesulfonate, (2-toluyl)p-toluenesulfonate, (3-toluyl)p-toluenesulfonate, (4-toluyl)p-toluenesulfonate, vinyl p-toluenesulfonate, allyl p-toluenesulfonate and benzyl p-toluenesulfonate.

[0368] Concrete examples of the aromatic sulfonic acid ester possessing a chained saturated hydrocarbon group that is substituted with a fluorine atom include (fluoromethyl) benzenesulfonate, (difluoromethyl)benzenesulfonate, (trifluoromethyl)benzenesulfonate, (1-fluoroethyl)benzenesulfonate, (2-fluoroethyl)benzenesulfonate, (2,2,2-trifluoroethyl)benzenesulfonate, (perfluoroethyl) benzenesulfonate, (3,3,3-trifluoro-n-propyl) benzenesulfonate, (2,2,3,3,3-pentafluoro-n-propyl) benzenesulfonate, (perfluoro-n-propyl)benzenesulfonate, (2-fluoroisopropyl)benzenesulfonate, (2,2,2,2',2',2'-hexafluoroisopropyl)benzenesulfonate, (perfluoro-n-butyl)benzenesulfonate, (2-fluoro-tert-butyl)benzenesulfonate, (perfluoro-tert-butyl)benzenesulfonate, (fluoromethyl)p-toluenesulfonate, (difluoromethyl)p-toluenesulfonate,

(trifluoromethyl)p-toluenesulfonate, (1-fluoroethyl)p-toluenesulfonate, (2-fluoroethyl)p-toluenesulfonate, (2,2,2-trifluoroethyl)p-toluenesulfonate, (perfluoroethyl)p-toluenesulfonate, (3,3,3-trifluoro-n-propyl)p-toluenesulfonate, (2,2,3,3,3-pentafluoro-n-propyl)p-toluenesulfonate, (perfluoro-n-propyl)p-toluenesulfonate, (2-fluoroisopropyl)p-toluenesulfonate, (2,2,2,2',2',2'-hexafluoroisopropyl)p-toluenesulfonate, (perfluoro-n-butyl)p-toluenesulfonate, (2-fluoro-tert-butyl)p-toluenesulfonate and (perfluoro-tert-butyl)p-toluenesulfonate.

[0369] Concrete examples of the aromatic sulfonic acid ester possessing a cyclic saturated hydrocarbon group that is substituted with a fluorine atom include (2-fluorocyclohexyl) benzenesulfonate, (3-fluorocyclohexyl)benzenesulfonate, (4-fluorocyclohexyl)benzenesulfonate, (perfluorocyclohexyl)benzenesulfonate, (2-fluorocyclohexyl)p-toluenesulfonate, (3-fluorocyclohexyl)p-toluenesulfonate, (4-fluorocyclohexyl)p-toluenesulfonate and (perfluorocyclohexyl) p-toluenesulfonate.

[0370] Concrete examples of the aromatic sulfonic acid ester possessing an unsaturated hydrocarbon group that is substituted with a fluorine substituent include (2-fluorophenyl)benzenesulfonate, (3-fluorophenyl)benzenesulfonate, (4-fluorophenyl)benzenesulfonate, (2,3-difluorophenyl)benzenesulfonate, (2,4-difluorophenyl)benzenesulfonate, (3,5-difluorophenyl)benzenesulfonate, (2,4,6-trifluorophenyl) benzenesulfonate, (perfluorophenyl)benzenesulfonate, (1-fluorovinyl)benzenesulfonate, (2-fluorovinyl)benzenesulfonate, (perfluorovinyl)benzenesulfonate, (2-fluorophenyl)methyl benzenesulfonate, (3-fluorophenyl)methyl benzenesulfonate, (4-fluorophenyl)methyl benzenesulfonate, (perfluorophenyl)methyl benzenesulfonate, (2-fluorophenyl) p-toluenesulfonate, (3-fluorophenyl)p-toluenesulfonate, (4-fluorophenyl)p-toluenesulfonate, (2,3-difluorophenyl)p-toluenesulfonate, (2,4-difluorophenyl)p-toluenesulfonate, (3,5-difluorophenyl)p-toluenesulfonate, (2,4,6-trifluorophenyl)p-toluenesulfonate, (perfluorophenyl)p-toluenesulfonate, (1-fluorovinyl)p-toluenesulfonate, (2-fluorovinyl) p-toluenesulfonate, (perfluorovinyl)p-toluenesulfonate, (2-fluorophenyl)methyl p-toluenesulfonate, (3-fluorophenyl)methyl p-toluenesulfonate, (4-fluorophenyl)methyl p-toluenesulfonate and (perfluorophenyl)methyl p-toluenesulfonate.

[0371] Chain Compound Possessing a Functional Group of the Formula (C-10):

[0372] As chain compound possessing a functional group represented by the above formula (C-10) include the following.

[0373] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl sulfate, diethyl sulfate, di-n-propyl sulfate, diisopropyl sulfate, di-n-butyl sulfate, diisobutyl sulfate and di-tert-butyl sulfate.

[0374] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include dicyclopentyl sulfate and dicyclohexyl sulfate.

[0375] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl sulfate, di(2-toluyl)sulfate, di(3-toluyl)sulfate, di(4-toluyl)sulfate, divinyl sulfate, diallyl sulfate and dibenzyl sulfate.

[0376] Concrete examples of the compound possessing a fluorine-substituted chained saturated hydrocarbon group include bis(fluoromethyl)sulfate, bis(difluoromethyl)sulfate, bis(trifluoromethyl)sulfate, di(1-fluoroethyl)sulfate, di(2-fluoroethyl)sulfate, bis(2,2,2-trifluoroethyl)sulfate, bis(perfluoroethyl)sulfate, bis(3,3,3-trifluoro-n-propyl)sulfate, bis (2,2,3,3,3-pentafluoro-n-propyl)sulfate, bis(perfluoro-n-propyl)sulfate, di(2-fluoroisopropyl)sulfate, bis(2,2,2,2',2',2'-hexafluoroisopropyl)sulfate, bis(perfluoro-n-butyl) sulfate, di(2-fluoro-tert-butyl)sulfate and bis(perfluoro-tert-butyl)sulfate.

[0377] Concrete examples of the compound possessing a fluorine-substituted cyclic saturated hydrocarbon group include di(2-fluorocyclohexyl)sulfate, di(3-fluorocyclohexyl)sulfate, di(4-fluorocyclohexyl)sulfate and bis(perfluorocyclohexyl)sulfate.

[0378] Concrete examples of the compound possessing a fluorine-substituted unsaturated hydrocarbon group include di(2-fluorophenyl)sulfate, di(3-fluorophenyl)sulfate, di(4-fluorophenyl)sulfate, bis(2,3-difluorophenyl)sulfate, bis(2,4-difluorophenyl)sulfate, bis(3,5-difluorophenyl)sulfate, bis(2,4,6-trifluorophenyl)sulfate, bis(perfluorophenyl)sulfate, di(1-fluorovinyl)sulfate, di(2-fluorovinyl)sulfate, bis(perfluorovinyl)sulfate, bis[(2-fluorophenyl)methyl] sulfate, bis [(3-fluorophenyl)methyl] sulfate, bis[(4-fluorophenyl)methyl] sulfate and bis[(perfluorophenyl)methyl] sulfate.

[0379] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups include ethylmethyl sulfate, methylpropyl sulfate, methylisopropyl sulfate, methyl-n-butyl sulfate, methylisobutyl sulfate, methyl-tert-butyl sulfate, methylcyclopentyl sulfate, methylcyclohexyl sulfate, methylphenyl sulfate, methyl(2-toluyl)sulfate, methyl(3-toluyl)sulfate, methyl(4-toluyl)sulfate, methylvinyl sulfate, methylallyl sulfate, methylbenzyl sulfate, ethylpropyl sulfate, ethylisopropyl sulfate, ethyl-n-butyl sulfate, ethylisobutyl sulfate, ethyl-tert-butyl sulfate, ethylcyclopentyl sulfate, ethylcyclohexyl sulfate, ethylphenyl sulfate, ethyl (2-toluyl)sulfate, ethyl(3-toluyl)sulfate, ethyl(4-toluyl)sulfate, ethylvinyl sulfate, ethylallyl sulfate, ethylbenzyl sulfate, phenylpropyl sulfate, phenylisopropyl sulfate, phenyl n-butyl sulfate, phenylisobutyl sulfate, phenyl tert-butyl sulfate, phenylcyclopentyl sulfate, phenylcyclohexyl sulfate, phenyl(2-toluyl)sulfate, phenyl(3-toluyl)sulfate, phenyl(4-toluyl)sulfate, phenylvinyl sulfate, phenylallyl sulfate and phenylbenzyl sulfate.

[0380] Concrete examples of the compound in which R^{c1} and R^{c2} are different hydrocarbon groups and at least one of them contains a fluorine substituent include methyl(fluoromethyl)sulfate, methyl(difluoromethyl)sulfate, methyl(trifluoromethyl)sulfate, methyl(1-fluoroethyl)sulfate, methyl(2-fluoroethyl)sulfate, methyl(2,2,2-trifluoroethyl)sulfate, methyl(perfluoroethyl)sulfate, methyl(3,3,3-trifluoro-n-propyl)sulfate, methyl(2,2,3,3,3-pentafluoro-n-propyl)sulfate, methyl(perfluoro-n-propyl)sulfate, methyl(2-fluoroisopropyl)sulfate, methyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfate, methyl(perfluoro-n-butyl)sulfate, methyl(2-fluoro-tert-butyl)sulfate, methyl(perfluoro-tert-butyl)sulfate, methyl(2-fluorocyclohexyl)sulfate, methyl(3-fluorocyclohexyl) sulfate, methyl(4-fluorocyclohexyl)sulfate, methyl (perfluorocyclohexyl)sulfate, methyl(2-fluorophenyl) sulfate, methyl(3-fluorophenyl)sulfate, methyl(4-fluorophenyl)sulfate, methyl(2,3-difluorophenyl)sulfate, methyl(2,4-difluorophenyl)sulfate, methyl(3,5-difluorophenyl)sulfate, methyl(2,4,6-trifluorophenyl)sulfate, methyl (perfluorophenyl)sulfate, methyl(1-fluorovinyl)sulfate, methyl(2-fluorovinyl)sulfate, methyl(perfluorovinyl)sulfate, methyl[(2-fluorophenyl)methyl] sulfate, methyl[(3-fluorophenyl)methyl] sulfate, methyl[(4-fluorophenyl)methyl] sulfate, methyl[(perfluorophenyl)methyl] sulfate, ethyl(fluo-

romethyl)sulfate, ethyl(difluoromethyl)sulfate, ethyl(trifluoromethyl)sulfate, ethyl(1-fluoroethyl)sulfate, ethyl(2-fluoroethyl)sulfate, ethyl(2,2,2-trifluoroethyl)sulfate, ethyl (perfluoroethyl)sulfate, ethyl(3,3,3-trifluoro-n-propyl) sulfate, ethyl(2,2,3,3,3-pentafluoro-n-propyl)sulfate, ethyl (perfluoro-n-propyl)sulfate, ethyl(2-fluoroisopropyl)sulfate, ethyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfate, ethyl(perfluoro-n-butyl)sulfate, ethyl(2-fluoro-tert-butyl)sulfate, ethyl (perfluoro-tert-butyl)sulfate, ethyl(2-fluorocyclohexyl)sulfate, ethyl(3-fluorocyclohexyl)sulfate, ethyl(4-fluorocyclohexyl)sulfate, ethyl(perfluorocyclohexyl)sulfate, ethyl(2-fluorophenyl)sulfate, ethyl(3-fluorophenyl)sulfate, ethyl(4-fluorophenyl)sulfate, ethyl(2,3-difluorophenyl)sulfate, ethyl(2,4-difluorophenyl)sulfate, ethyl(3,5-difluorophenyl)sulfate, ethyl(2,4,6-trifluorophenyl)sulfate, ethyl(perfluorophenyl)sulfate, ethyl(1-fluorovinyl)sulfate, ethyl(2-fluorovinyl)sulfate, ethyl(perfluorovinyl)sulfate, ethyl[(2-fluorophenyl)ethyl] sulfate, ethyl[(3-fluorophenyl)methyl] sulfate, ethyl[(4-fluorophenyl)methyl] sulfate, ethyl[(perfluorophenyl)methyl] sulfate, phenyl(fluoromethyl)sulfate, phenyl(difluoromethyl)sulfate, phenyl(trifluoromethyl)sulfate, phenyl(1-fluoroethyl)sulfate, phenyl(2-fluoroethyl)sulfate, phenyl(2,2,2-trifluoroethyl)sulfate, phenyl(perfluoroethyl)sulfate, phenyl(3,3,3-trifluoro-n-propyl)sulfate, phenyl (2,2,3,3,3-pentafluoro-n-propyl)sulfate, phenyl(perfluoro-n-propyl)sulfate, phenyl(2-fluoroisopropyl)sulfate, phenyl(2,2,2,2',2',2'-hexafluoroisopropyl)sulfate, phenyl(perfluoro-n-butyl)sulfate, phenyl(2-fluoro-tert-butyl)sulfate, phenyl (perfluoro-tert-butyl)sulfate, phenyl(2-fluorocyclohexyl) sulfate, phenyl(3-fluorocyclohexyl)sulfate, phenyl(4-fluorocyclohexyl)sulfate, phenyl(perfluorocyclohexyl) sulfate, phenyl(2-fluorophenyl)sulfate, phenyl(3-fluorophenyl)sulfate, phenyl(4-fluorophenyl)sulfate, phenyl (2,3-difluorophenyl)sulfate, phenyl(2,4-difluorophenyl) sulfate, phenyl(3,5-difluorophenyl)sulfate, phenyl(2,4,6-trifluorophenyl)sulfate, phenyl(perfluorophenyl)sulfate, phenyl(1-fluorovinyl)sulfate, phenyl(2-fluorovinyl)sulfate, phenyl(perfluorovinyl)sulfate, phenyl[(2-fluorophenyl)methyl] sulfate, phenyl[(3-fluorophenyl)methyl] sulfate, phenyl [(4-fluorophenyl)methyl] sulfate and phenyl[(perfluorophenyl)methyl] sulfate.

[0381] Concrete examples of the compound in which R^{c1} and R^{c2} are different chained saturated hydrocarbon groups and both of them have a fluorine substituent include (2,2,2-trifluoroethyl)(fluoromethyl)sulfate, (2,2,2-trifluoroethyl) (difluoromethyl)sulfate, (2,2,2-trifluoroethyl)(trifluoromethyl)sulfate, (2,2,2-trifluoroethyl)(1-fluoroethyl)sulfate, (2,2,2-trifluoroethyl)(2-fluoroethyl)sulfate, (2,2,2-trifluoroethyl)(perfluoroethyl)sulfate, (2,2,2-trifluoroethyl)(3,3,3-trifluoro-n-propyl)sulfate, (2,2,2-trifluoroethyl)(2,2,3,3,3-pentafluoro-n-propyl)sulfate, (2,2,2-trifluoroethyl)(perfluoro-n-propyl)sulfate, (2,2,2-trifluoroethyl)(2-fluoroisopropyl) sulfate, (2,2,2-trifluoroethyl)(2,2,2,2',2',2'-hexafluoroisopropyl)sulfate, (2,2,2-trifluoroethyl) (perfluoro-n-butyl)sulfate, (2,2,2-trifluoroethyl)(2-fluoro-tert-butyl)sulfate, (2,2,2-trifluoroethyl)(perfluoro-tert-butyl) sulfate, (2,2,2-trifluoroethyl)(2-fluorocyclohexyl)sulfate, (2,2,2-trifluoroethyl)(3-fluorocyclohexyl)sulfate, (2,2,2-trifluoroethyl)(4-fluorocyclohexyl)sulfate, (2,2,2-trifluoroethyl)(perfluorocyclohexyl)sulfate, (2,2,2-trifluoroethyl)(2-fluorophenyl)sulfate, (2,2,2-trifluoroethyl)(3-fluorophenyl) sulfate, (2,2,2-trifluoroethyl)(4-fluorophenyl)sulfate, (2,2,2-trifluoroethyl)(2,3-difluorophenyl)sulfate, (2,2,2-trifluoroethyl)(2,4-difluorophenyl)sulfate, (2,2,2-trifluoroethyl)(3,5-difluorophenyl)sulfate, (2,2,2-trifluoroethyl)(2,4,6-trifluorophenyl)sulfate, (2,2,2-trifluoroethyl)(perfluorophenyl)sulfate, (2,2,2-trifluoroethyl)(1-fluorovinyl)sulfate, (2,2,2-trifluoroethyl) (2-fluorovinyl)sulfate, (2,2,2-trifluoroethyl)(perfluorovinyl) sulfate, (2,2,2-trifluoroethyl)[(2-fluorophenyl)methyl] sulfate, (2,2,2-trifluoroethyl)[(3-fluorophenyl)methyl] sulfate, (2,2,2-trifluoroethyl)[(4-fluorophenyl)methyl] sulfate and (2,2,2-trifluoroethyl)[(perfluorophenyl)methyl] sulfate.

[0382] Of the compounds represented by the above formula (C-2), preferable as specific compound (C) from the standpoint of ease of synthesis and industrial availability are dimethylsulfide, diethylsulfide, dibutylsulfide, diphenylsulfide, dibenzylsulfide, diallylsulfide, butylmethylsulfide, butylethylsulfide, methylphenylsulfide, ethylphenylsulfide, dimethyldisulfide, diethyldisulfide, dibutyldisulfide, diphenyldisulfide, dibenzyldisulfide, diallyldisulfide, butylmethyldisulfide, butylethyldisulfide, methylphenyldisulfide, ethylphenyldisulfide, dimethylsulfoxide, dibutylsulfoxide, diphenylsulfoxide, dibenzylsulfoxide, methylphenylsulfoxide, phenylvinylsulfoxide, dimethylsulfone, diethylsulfone, dibutylsulfone, diphenylsulfone, divinylsulfone, methylphenylsulfone, ethylphenylsulfone, allylphenylsulfone, fluoromethylphenylsulfone, phenylvinylsulfone, bis (4-fluorophenyl)sulfone, dimethylsulfite, diethylsulfite, di-n-propylsulfite, dipropargylsulfite, diphenylsulfite, bis(2,2,2-trifluoromethyl)sulfite, ethylmethylsulfite, 1-fluoroethylmethylsulfite, 2-fluoroethylmethylsulfite, trifluoroethylmethylsulfite, methyl methanesulfonate, ethyl methanesulfonate, phenyl methanesulfonate, (2,2,2-trifluoroethyl)methanesulfonate, methyl 2,2,2-trifluoroethanesulfonate, methyl benzenesulfonate, ethyl benzenesulfonate, phenyl benzenesulfonate, methyl p-toluylsulfonate, ethyl p-toluylsulfonate, phenyl p-toluylsulfonate, dimethylsulfate, diethylsulfate, diisopropylsulfate and bis(2,2,2-trifluoroethyl)sulfate.

[0383] <I-1-C-3. Chain Compound Represented by the Formula (C-3)>

[Chemical Formula 57]

$$(R^{c3}\text{-}A)_z\text{-}R^{c4} \qquad \text{(C-3)}$$

[0384] In the above formula (C-3), R^{c3} represents a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller.

[0385] A^c represents a sulfur-containing functional group represented by the above formula (C-1).

[0386] z represents an integer of 2 or larger and 4 or smaller.

[0387] R^{c4} represents a hydrocarbon group, which may have a halogen atom, with z number of connection parts and with carbon number of 1 or larger and 20 or smaller.

[0388] In this context, the z number of R^{c3} and A^c may be the same as or different from each other, respectively.

[0389] The chain compound represented by the above formula (C-3) contains a sulfur-containing functional group A^c, the number of which is equal to z (namely 2 or more, and 4 or less). Combination of this sulfur-containing functional group A^c include the following.

[0390] In the case that z=2:

[0391] The following can be listed: formula (C-4) and formula (C-4), formula (C-5) and formula (C-5), formula (C-6) and formula (C-6), formula (C-7) and formula (C-7), formula (C-8) and formula (C-8), formula (C-9) and formula (C-9), formula (C-10) and formula (C-10), formula (C-4) and formula (C-5), formula (C-4) and formula (C-6), formula (C-4)

and formula (C-7), formula (C-4) and formula (C-8), formula (C-4) and formula (C-9), formula (C-4) and formula (C-10), formula (C-5) and formula (C-6), formula (C-5) and formula (C-7), formula (C-5) and formula (C-8), formula (C-5) and formula (C-9), formula (C-5) and formula (C-10), formula (C-6) and formula (C-7), formula (C-6) and formula (C-8), formula (C-6) and formula (C-9), formula (C-6) and formula (C-10), formula (C-7) and formula (C-8), formula (C-7) and formula (C-9), formula (C-7) and formula (C-10), formula (C-8) and formula (C-9), formula (C-8) and formula (C-10), and formula (C-9) and formula (C-10).

[0392] In the case that z=3:

[0393] The following can be listed: formula (C-4) and formula (C-4) and formula (C-4), formula (C-5) and formula (C-5) and formula (C-5), formula (C-6) and formula (C-6) and formula (C-6), formula (C-7) and formula (C-7) and formula (C-7), formula (C-8) and formula (C-8) and formula (C-8), formula (C-9) and formula (C-9) and formula (C-9), formula (C-10) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-5), formula (C-4) and formula (C-4) and formula (6)[SIC], formula (C-4) and formula (C-4) and formula (C-7), formula (C-4) and formula (C-4) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-5), formula (C-4) and formula (C-5) and formula (6) [SIC], formula (C-4) and formula (C-5) and formula (C-7), formula (C-4) and formula (C-5) and formula (C-8), formula (C-4) and formula (C-5) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-10), formula (C-4) and formula (C-6) and formula (6) [SIC], formula (C-4) and formula (C-6) and formula (C-7), formula (C-4) and formula (C-6) and formula (C-8), formula (C-4) and formula (C-6) and formula (C-9), formula (C-4) and formula (C-6) and formula (C-10), formula (C-4) and formula (C-7) and formula (C-7), formula (C-4) and formula (C-7) and formula (C-8), formula (C-4) and formula (C-7) and formula (C-9), formula (C-4) and formula (C-7) and formula (C-10), formula (C-4) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-5) and formula (6) [SIC], formula (C-5) and formula (C-5) and formula (C-7), formula (C-5) and formula (C-5) and formula (C-8), formula (C-5) and formula (C-5) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-10), formula (C-5) and formula (C-6) and formula (6) [SIC], formula (C-5) and formula (C-6) and formula (C-7), formula (C-5) and formula (C-6) and formula (C-8), formula (C-5) and formula (C-6) and formula (C-9), formula (C-5) and formula (C-6) and formula (C-10), formula (C-5) and formula (C-7) and formula (C-7), formula (C-5) and formula (C-7) and formula (C-8), formula (C-5) and formula (C-7) and formula (C-9), formula (C-5) and formula (C-7) and formula (C-10), formula (C-5) and formula (C-8) and formula (C-8), formula (C-5) and formula (C-8) and formula (C-9), formula (C-5) and formula (C-8) and formula (C-10), formula (C-5) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-7), formula (C-6) and formula (C-6) and formula (C-8), formula (C-6) and formula (C-6) and formula (C-9), formula (C-6) and formula (C-6) and formula (C-10), formula (C-6) and formula (C-7) and formula (C-7), formula (C-6) and formula (C-7) and formula (C-8), formula (C-6) and formula (C-7) and formula (C-9), formula (C-6) and formula (C-7) and formula (C-10), formula (C-6) and formula (C-8) and formula (C-8), formula (C-6) and formula (C-8) and formula (C-9), formula (C-6) and formula (C-8) and formula (C-10), formula (C-6) and formula (C-9) and formula (C-9), formula (C-6) and formula (C-9) and formula (C-10), formula (C-6) and formula (C-10) and formula (C-10), formula (C-7) and formula (C-7) and formula (C-8), formula (C-7) and formula (C-7) and formula (C-9), formula (C-7) and formula (C-7) and formula (C-10), formula (C-7) and formula (C-8) and formula (C-8), formula (C-7) and formula (C-8) and formula (C-9), formula (C-7) and formula (C-8) and formula (C-10), formula (C-7) and formula (C-9) and formula (C-9), formula (C-7) and formula (C-9) and formula (C-10), formula (C-7) and formula (C-10) and formula (C-10), formula (C-8) and formula (C-8) and formula (C-9), formula (C-8) and formula (C-8) and formula (C-10), formula (C-8) and formula (C-9) and formula (C-9), formula (C-8) and formula (C-9) and formula (C-10), formula (C-8) and formula (C-10) and formula (C-10), formula (C-9) and formula (C-9) and formula (C-10), and formula (C-9) and formula (C-10) and formula (C-10).

[0394] In the case that z=4:

[0395] The following can be listed: formula (C-4) and formula (C-4) and formula (C-4) and formula (C-4), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-5), formula (C-6) and formula (C-6) and formula (C-6) and formula (C-6), formula (C-7) and formula (C-7) and formula (C-7) and (7), formula (C-8) and formula (C-8) and formula (C-8) and formula (C-8), formula (C-9) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-10) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-5), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-6), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-7), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-4) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-5), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-6), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-7), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-5) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-6) and formula (C-6), formula (C-4) and formula (C-4) and formula (C-6) and formula (C-7), formula (C-4) and formula (C-4) and formula (C-6) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-6) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-6) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-7) and formula (C-7), formula (C-4) and formula (C-4) and formula (C-7) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-7) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-7) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-4) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-8) and formula (C-10)

and formula (C-10), formula (C-4) and formula (C-4) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-4) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-4) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-5), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-6), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-7), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-8), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-5) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-6) and formula (C-6), formula (C-4) and formula (C-5) and formula (C-6) and formula (C-7), formula (C-4) and formula (C-5) and formula (C-6) and formula (C-8), formula (C-4) and formula (C-5) and formula (C-6) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-6) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-7) and formula (C-7), formula (C-4) and formula (C-5) and formula (C-7) and formula (C-8), formula (C-4) and formula (C-5) and formula (C-7) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-7) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-5) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-5) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-5) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-6) and formula (C-6) and formula (C-6), formula (C-4) and formula (C-6) and formula (C-6) and formula (C-7), formula (C-4) and formula (C-6) and formula (C-6) and formula (C-8), formula (C-4) and formula (C-6) and formula (C-6) and formula (C-9), formula (C-4) and formula (C-6) and formula (C-6) and formula (C-10), formula (C-4) and formula (C-6) and formula (C-7) and formula (C-7), formula (C-4) and formula (C-6) and formula (C-7) and formula (C-8), formula (C-4) and formula (C-6) and formula (C-7) and formula (C-9), formula (C-4) and formula (C-6) and formula (C-7) and formula (C-10), formula (C-4) and formula (C-6) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-6) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-6) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-6) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-6) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-6) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-7) and formula (C-7) and formula (C-7), formula (C-4) and formula (C-7) and formula (C-7) and formula (C-8), formula (C-4) and formula (C-7) and formula (C-7) and formula (C-9), formula (C-4) and formula (C-7) and formula (C-7) and formula (C-10), formula (C-4) and formula (C-7) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-7) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-7) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-7) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-7) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-7) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-8) and formula (C-8) and formula (C-8), formula (C-4) and formula (C-8) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-8) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-8) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-8) and formula (C-9), formula (C-4) and formula (C-8) and formula (C-10), formula (C-4) and formula (C-8) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-4) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-4) and formula (C-9) and formula (C-10) and formula (C-10), formula (C-4) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-6), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-7), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-8), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-5) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-6) and formula (C-6), formula (C-5) and formula (C-5) and formula (C-6) and formula (C-7), formula (C-5) and formula (C-5) and formula (C-6) and formula (C-8), formula (C-5) and formula (C-5) and formula (C-6) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-6) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-7) and formula (C-7), formula (C-5) and formula (C-5) and formula (C-7) and formula (C-8), formula (C-5) and formula (C-5) and formula (C-7) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-7) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-8) and formula (C-8), formula (C-5) and formula (C-5) and formula (C-8) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-8) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-5) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-5) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-6) and formula (C-6) and formula (C-6), formula (C-5) and formula (C-6) and formula (C-7), formula (C-5) and formula (C-6) and formula (C-8), formula (C-5) and formula (C-6) and formula (C-6) and formula (C-9), formula (C-5) and formula (C-6) and formula (C-6) and formula (C-10), formula (C-5) and formula (C-6) and formula (C-7) and formula (C-7), formula (C-5) and formula (C-6) and formula (C-7) and formula (C-8), formula (C-5) and formula (C-6) and formula (C-8) and formula (C-8), formula (C-5) and formula (C-6) and formula (C-8) and formula (C-9), formula (C-5) and formula (C-6) and formula (C-8) and formula (C-10), formula (C-5) and formula (C-6) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-6) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-6) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-7) and formula (C-7) and formula (C-7), formula (C-5) and formula (C-7) and formula (C-7) and formula (C-8), formula (C-5) and formula (C-7) and formula (C-7) and formula (C-9), formula (C-5) and formula (C-7) and formula (C-7) and formula (C-10), formula (C-5) and formula (C-7) and formula (C-8) and formula (C-8), formula (C-5) and formula (C-7) and formula (C-8) and formula (C-9), formula (C-5) and formula (C-7) and formula (C-8) and formula (C-10), formula (C-5) and formula (C-7) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-7) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-7) and formula (C-10) and formula (C-10), formula (C-5) and

formula (C-8) and formula (C-8) and formula (C-8), formula (C-5) and formula (C-8) and formula (C-8) and formula (C-9), formula (C-5) and formula (C-8) and formula (C-8) and formula (C-10), formula (C-5) and formula (C-8) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-8) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-8) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-5) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-5) and formula (C-9) and formula (C-10) and formula (C-10), formula (C-5) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-6) and formula (C-7), formula (C-6) and formula (C-6) and formula (C-6) and formula (C-8), formula (C-6) and formula (C-6) and formula (C-6) and formula (C-9), formula (C-6) and formula (C-6) and formula (C-6) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-7) and formula (C-7), formula (C-6) and formula (C-6) and formula (C-7) and formula (C-8), formula (C-6) and formula (C-6) and formula (C-7) and formula (C-9), formula (C-6) and formula (C-6) and formula (C-7) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-8) and formula (C-8), formula (C-6) and formula (C-6) and formula (C-8) and formula (C-9), formula (C-6) and formula (C-6) and formula (C-8) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-9) and formula (C-9), formula (C-6) and formula (C-6) and formula (C-9) and formula (C-10), formula (C-6) and formula (C-6) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-7) and formula (C-7) and formula (C-7), formula (C-6) and formula (C-7) and formula (C-7) and formula (C-8), formula (C-6) and formula (C-7) and formula (C-7) and formula (C-9), formula (C-6) and formula (C-7) and formula (C-7) and formula (C-10), formula (C-6) and formula (C-7) and formula (C-8) and formula (C-8), formula (C-6) and formula (C-7) and formula (C-8) and formula (C-9), formula (C-6) and formula (C-7) and formula (C-8) and formula (C-10), formula (C-6) and formula (C-7) and formula (C-9) and formula (C-9), formula (C-6) and formula (C-7) and formula (C-9) and formula (C-10), formula (C-6) and formula (C-7) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-8) and formula (C-8) and formula (C-8), formula (C-6) and formula (C-8) and formula (C-8) and formula (C-9), formula (C-6) and formula (C-8) and formula (C-8) and formula (C-10), formula (C-6) and formula (C-8) and formula (C-9) and formula (C-9), formula (C-6) and formula (C-8) and formula (C-9) and formula (C-10), formula (C-6) and formula (C-8) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-6) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-6) and formula (C-9) and formula (C-10) and formula (C-10), formula (C-6) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-7) and formula (C-7) and formula (C-7) and formula (C-8), formula (C-7) and formula (C-7) and formula (C-7) and formula (C-9), formula (C-7) and formula (C-7) and formula (C-7) and formula (C-10), formula (C-7) and formula (C-7) and formula (C-8) and formula (C-8), formula (C-7) and formula (C-7) and formula (C-8) and formula (C-9), formula (C-7) and formula (C-7) and formula (C-8) and formula (C-10), formula (C-7) and formula (C-7) and formula (C-9) and formula (C-9), formula (C-7) and formula (C-7) and formula (C-9) and formula (C-10), formula (C-7) and formula (C-7) and formula (C-10) and formula (C-10), formula (C-7) and formula (C-8) and formula (C-8) and formula (C-8), formula (C-7) and formula (C-8) and formula (C-8) and formula (C-9), formula (C-7) and formula (C-8) and formula (C-8) and formula (C-10), formula (C-7) and formula (C-8) and formula (C-9) and formula (C-9), formula (C-7) and formula (C-8) and formula (C-9) and formula (C-10), formula (C-7) and formula (C-8) and formula (C-10) and formula (C-10), formula (C-7) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-7) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-7) and formula (C-9) and formula (C-10) and formula (C-10), formula (C-7) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-8) and formula (C-8) and formula (C-8) and formula (C-9), formula (C-8) and formula (C-8) and formula (C-8) and formula (C-10), formula (C-8) and formula (C-8) and formula (C-9) and formula (C-9), formula (C-8) and formula (C-8) and formula (C-9) and formula (C-10), formula (C-8) and formula (C-8) and formula (C-10) and formula (C-10), formula (C-8) and formula (C-9) and formula (C-9) and formula (C-9), formula (C-8) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-8) and formula (C-9) and formula (C-10) and formula (C-10), formula (C-8) and formula (C-10) and formula (C-10) and formula (C-10), formula (C-9) and formula (C-9) and formula (C-9) and formula (C-10), formula (C-9) and formula (C-9) and formula (C-10) and formula (C-10), and formula (C-9) and formula (C-10) and formula (C-10) and formula (C-10).

[0396] Of these combinations, preferable from the standpoints of ease of synthesis, industrial availability and the like are combinations of formula (C-4) and formula (C-4), formula (C-4) and formula (C-6), formula (C-7) and formula (C-7), formula (C-8) and formula (C-8), formula (C-9) and formula (C-9), and formula (C-9) and formula (C-9) and formula (C-9).

[0397] The details such as the kind of the hydrocarbon group, the number of carbon atoms and concrete examples of R^{c3} of the above formula (C-3) are the same as described previously for R^{c1} and R^{c2} in the above formula (C-2). The details where the hydrocarbon group of R^{c3} is substituted with a halogen atom are also the same as described previously for R^{c1} and R^{c2} in the above formula (C-2).

[0398] R^{c4} in the above formula (C-3) is a hydrocarbon group with a valency value of z (namely, bivalent or more, and tetravalent or less), which can be obtained by removal of z number of hydrogen atoms (namely, 2 or more and 4 or less) from an arbitrary hydrocarbon with 20 or less carbon number. There is no special limitation on the kind of the hydrocarbon group. They may be an aliphatic hydrocarbon group or aromatic hydrocarbon group or a combination of aliphatic hydrocarbon group and aromatic hydrocarbon group. The aliphatic hydrocarbon group may be a saturated hydrocarbon group, or it may contain an unsaturated bond (carbon to carbon double bond or carbon to carbon triple bond). In addition, the aliphatic hydrocarbon group may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0399] The number of carbon atoms of the hydrocarbon group R^{c4} is usually 1 or more, and usually 20 or less, preferably 10 or less, more preferably 6 or less. When the carbon number of the hydrocarbon group R^{c4} is too many, solubility in the non-aqueous liquid electrolyte tends to decrease.

[0400] Concrete examples of the hydrocarbon group which are preferable as R^{c4} will be listed below.

[0401] Concrete examples of R^{c4} possessing two bonding sites include 1,1-disubstituted methane, 1,1-disubstituted ethane, 1,2-disubstituted ethane, 1,1-disubstituted propane, 1,2-disubstituted propane, 1,3-disubstituted propane, 1,1-disubstituted butane, 1,2-disubstituted butane, 1,3-disubstituted butane, 1,4-disubstituted butane, 2,3-disubstituted butane, 2,2-dimethyl-1,3-disubstituted propane, 1,1-disubstituted ethylene, 1,2-disubstituted ethylene, 1,1-disubstituted propylene, 1,2-disubstituted propylene, 1,3-disubstituted propylene, 2,2-disubstituted propylene, 2,3-disubstituted propylene, 3,3-disubstituted propylene, 1,1-disubstituted-1-butylene, 1,2-disubstituted-1-butylene, 1,3-disubstituted-1-butylene, 1,4-disubstituted-1-butylene, 2,3-disubstituted-1-butylene, 2,4-disubstituted-1-butylene, 3,3-disubstituted-1-butylene, 3,4-disubstituted-1-butylene, 4,4-disubstituted-1-butylene, 1,1-disubstituted-2-butylene, 1,2-disubstituted-2-butylene, 1,3-disubstituted-2-butylene, 1,4-disubstituted-2-butylene, 2,3-disubstituted-2-butylene, 1,1-disubstituted-2-butine and 1,4-disubstituted-2-butine.

[0402] Concrete examples of R^{c4} possessing three bonding sites include 1,1,1-trisubstituted methane, 1,1,2-trisubstituted ethane, 1,1,3-trisubstituted propane, 1,2,2-trisubstituted propane, 1,2,3-trisubstituted propane, 1,1,1-trisubstituted butane, 1,1,2-trisubstituted butane, 1,1,3-trisubstituted butane, 1,1,4-trisubstituted butane, 1,2,2-trisubstituted butane, 1,2,3-trisubstituted butane, 1,2,4-trisubstituted butane, 1,3,3-trisubstituted butane and 2,2,3-trisubstituted butane.

[0403] Concrete examples of R^{c4} possessing four bonding sites include 1,1,1,1-tetrasubstituted methane, 1,1,1,2-tetrasubstituted ethane, 1,1,2,2-tetrasubstituted ethane, 1,1,1,2-tetrasubstituted propane, 1,1,1,3-tetrasubstituted propane, 1,1,2,2-tetrasubstituted propane, 1,1,2,3-tetrasubstituted propane, 1,2,2,3-tetrasubstituted propane, 1,1,1,2-tetrasubstituted butane, 1,1,1,3-tetrasubstituted butane, 1,1,1,4-tetrasubstituted butane, 1,1,2,2-tetrasubstituted butane, 1,1,2,3-tetrasubstituted butane, 1,1,2,4-tetrasubstituted butane, 1,1,3,3-tetrasubstituted butane, 1,1,3,4-tetrasubstituted butane, 1,2,2,3-tetrasubstituted butane, 1,2,2,4-tetrasubstituted butane, 1,2,3,4-tetrasubstituted butane, 1,3,3,4-tetrasubstituted butane and 2,2,3,3-tetrasubstituted butane.

[0404] Of these compounds, preferable from the standpoints of chemical stability and ease of industrial availability are 1,2-disubstituted ethane, 1,2-disubstituted propane, 1,3-disubstituted propane, 1,2-disubstituted butane, 1,3-disubstituted butane, 1,4-disubstituted butane, 2,3-disubstituted butane, 2,2-dimethyl-1,3-disubstituted propane, 1,2-disubstituted ethylene, 1,4-disubstituted-2-butylene, 1,2,3-trisubstituted propane, 1,2,3-trisubstituted butane, 1,2,4-trisubstituted butane and 1,2,3,4-tetrasubstituted butane.

[0405] In the hydrocarbon group of R^{c4} in the above formula (C-3), a part or all of the hydrogen atoms bonded to the carbon atoms may be substituted with halogen atoms.

[0406] The halogen atom include fluorine atom, chlorine atom, bromine atom and iodine atom. Particularly preferable are fluorine atom, chlorine atom and bromine atom. From the standpoint of chemical stability or electrochemical stability, fluorine atom and chlorine atom are more preferable.

[0407] When the hydrocarbon group of R^{c4} is substituted with a halogen atom, no particular limitation is imposed on the number of the halogen atoms. A part of the hydrogen atoms of the hydrocarbon group may be substituted with halogen atoms or all of the hydrogen atoms may be substituted with halogen atoms. When the hydrocarbon group R^{c4} has a plurality of halogen atoms, those halogen atoms may be the same as or different from each other.

[0408] Next, concrete examples of the compound represented by the above formula (C-3), as classified according to the sulfur-containing functional group represented by the formula (C-1), will be listed below.

[0409] Chain Compound Possessing Two Functional Groups of the Formula (C-4):

[0410] Chain compound possessing two functional groups represented by the above formula (C-4) include the following.

[0411] Concrete examples of the compound possessing a chained saturated hydrocarbon group include bis(methylthio)methane, benzaldehydediethylmercaptal, bis(phenylthio)methane, 1,2-bis(ethylthio)ethane and 1-{[2-(propylthio)ethyl]thio}propane.

[0412] Concrete example of the compound possessing a cyclic saturated hydrocarbon group include bis(cyclopentylthio)methane, bis(cyclohexylthio)methane and 1,2-bis(cyclohexylthio)ethane.

[0413] Concrete example of the compound possessing an unsaturated hydrocarbon group include {[2-(phenylthio)ethyl]thio}benzene.

[0414] Concrete examples of the compound possessing a hydrocarbon group containing a fluorine atom include bis(2,2,2-trifluoroethylthio)methane, bis(2-fluorophenylthio)methane, bis(3-fluorophenylthio)methane and bis(4-fluorophenylthio)methane.

[0415] Chain Compound Possessing a Functional Group of the Formula (C-4) and Functional Group of the Formula (C-6):

[0416] Chain compound possessing a functional group represented by the formula (C-4) and a functional group represented by the formula (C-6) include the following.

[0417] Concrete examples of the compound possessing a chained saturated hydrocarbon group include methyl(methylsulfinylmethyl)sulfide and ethyl(ethylsulfinylmethyl)sulfide.

[0418] Chain Compound Possessing Two Functional Groups of the Formula (C-7):

[0419] Chain compound possessing two functional groups represented by the above formula (C-7) include the following.

[0420] Concrete examples of the compound possessing a chained saturated hydrocarbon group include 1,4-bis(methylsulfonyl)butane, 1,4-bis(ethylsulfonyl)butane and 1,4-bis(tert-butylsulfonyl)butane.

[0421] Concrete examples of the compound possessing a cyclic saturated hydrocarbon group include 1,4-bis(cyclopentylsulfonyl)butane, 1,4-bis(cyclohexylsulfonyl)butane and 1,4-bis(2-fluorocyclohexylsulfonyl)butane.

[0422] Concrete examples of the compound possessing an unsaturated hydrocarbon group include 1,2-bis(phenylsulfonyl)ethane and 1-{[4-(vinylsulfonyl)butyl]sulfonyl}ethylene.

[0423] Chain Compound Possessing Two Functional Groups of the Formula (C-8):

[0424] Chain compound possessing two functional groups represented by the above formula (C-8) include the following.

[0425] Concrete examples of the compound possessing a chained saturated hydrocarbon group include 1,2-bis(methoxysulfinyloxy)ethane, 1,2-bis(ethoxysulfinyloxy)ethane,

(methoxysulfinyloxyethyl)ethylsulfite, 1,2-bis(cyclohexyloxysulfinyloxy)ethane and 1,2-bis(2,2,2-trifluoroethoxysulfinyloxy)ethane.

[0426] Chain Compound Possessing Two Functional Groups of the Formula (C-9):

[0427] Chain compound possessing two functional groups represented by the above formula (C-9) include the following.

[0428] Concrete examples of the compound possessing a chained saturated hydrocarbon group include dimethyl 1,2-ethanedisulfonate, diethyl 1,2-ethanedisulfonate, bis(2,2,2-trifluoroethyl) 1,2-ethanedisulfonate, dimethyl 1,3-propanedisulfonate, diethyl 1,3-propanedisulfonate, bis(2,2,2-trifluoroethyl) 1,3-propanedisulfonate, dimethyl 1,3-perfluoropropanedisulfonate, diethyl 1,3-perfluoropropanedisulfonate, bis(2,2,2-trifluoroethyl) 1,3-perfluoropropanedisulfonate, busulfan, dimethyl 1,4-butanedisulfonate, 1,4-bis(trifluoromethanesulfonyloxy) butane and 1,4-bis(2,2,2-trifluoroethanesulfonyloxy)butane.

[0429] Concrete examples of the compound possessing a chained saturated hydrocarbon group include 1,2-bis(methoxysulfonyl)cyclohexane, 1,3-bis(methoxysulfonyl)cyclohexane, 1,4-bis(methoxysulfonyl)cyclohexane, 1,4-bis(2,2,2-trifluoroethoxysulfonyl)cyclohexane, dimethyl cyclohexane-1,2-disulfonate, diethyl cyclohexane-1,2-disulfonate, bis(2,2,2-trifluoroethyl)cyclohexane-1,2-disulfonate, dimethyl cyclohexane-1,3-disulfonate and dimethyl cyclohexane-1,4-disulfonate.

[0430] Concrete examples of the compound possessing an unsaturated hydrocarbon group include diphenyl 1,2-ethanedisulfonate, 1,3-propanediol-di-p-tosylate, 2,2-dimethyl-1,3-propanediol-di-p-tosylate, dimethyl 1,2-benzenedisulfonate, diethyl 1,2-benzenedisulfonate, bis(2,2,2-trifluoroethyl) 1,2-benzenedisulfonate, dimethyl 1,3-benzenedisulfonate and dimethyl 1,4-benzenedisulfonate.

[0431] Chain Compound Possessing Three Functional Groups of the Formula (C-9):

[0432] Chain compound possessing three functional groups represented by the above formula (C-9) include 1,2,4-tris(methanesulfonyloxy)butane, 1,2,4-tris(trifluoro methanesulfonyloxy)butane and 1,2,4-tris(2,2,2-trifluoro ethanesulfonyloxy)butane.

[0433] Of the compounds exemplified above, represented by the formula (C-3), preferable as specific compound (C) from the standpoint of ease of availability, chemical stability or the like are bis(methylthio)methane, bis(phenylthio)methane, busulfan, 1,4-bis(2,2,2-trifluoro ethanesulfonyloxy)butane and 1,2,4-tris(methanesulfonyloxy)butane.

[0434] <I-1-C-4. Others>

[0435] There is no special limitation on the molecular weight of the specific compound (C), insofar as the advantage of the present invention is not significantly impaired. However, it is usually 60 or larger, and preferably 90 or larger. There is no special limitation on the upper limit, but when it is too high, viscosity tends to increase. Therefore, to be practical, it is usually 600 or smaller, preferably 400 or smaller.

[0436] There is no special limitation on the method of producing the specific compound (C), either, and any known method can be selected and used.

[0437] The specific compound (C) explained above can be included in the non-aqueous liquid electrolyte of the present invention either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0438] There is no special limitation on the proportion of the specific compound (C) in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. However, it is preferable that the concentration in the non-aqueous liquid electrolyte of the present invention is usually 0.01 weight % or higher, preferably 0.1 weight % or higher, and usually 10 weight % or lower, preferably 5 weight % or lower. If the proportion is below the lower limit of the above range, an adequate effect of improving cycle performance of the non-aqueous liquid electrolyte secondary battery may not be guaranteed when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery. On the other hand, when it exceeds the upper limit of the above range, its chemical reactivity in the non-aqueous liquid electrolyte may increase, leading possibly to decrease in battery characteristics of the above-mentioned non-aqueous liquid electrolyte secondary battery.

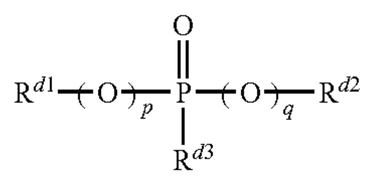
[0439] No limitation is imposed on the ratio of the specific compound (C) relative to the specific carbonate, in the non-aqueous liquid electrolyte of the present invention, either. However, it is preferable that the relative weight ratio, represented by "weight of the specific compound (C)/weight of the specific carbonate", is in the range of usually 0.0001 or higher, preferably 0.001 or higher, more preferably 0.01 or higher, and usually 1000 or lower, preferably 100 or lower, more preferably 10 or lower. If the above-mentioned relative weight ratio is too high or too low, the synergistic effect may not be obtained.

[0440] By incorporating the above-mentioned specific compound (C) and the specific carbonate in a non-aqueous liquid electrolyte, it is possible to improve the charge-discharge cycle performance of the non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte. The detailed reason is not clear, but inferred as follows. Namely, through the reaction between the specific compound (C) and the specific carbonate contained in the non-aqueous liquid electrolyte, an effective protective layer is formed on the surface of the negative-electrode active material, leading to the suppression of side reactions. Cycle deterioration is thus inhibited. The details of this reaction is not clear, but it is inferred that coexistence of the specific compound (C) and the specific carbonate in the liquid electrolyte can somehow contribute to enhancement in the protective layer characteristics.

[0441] [I-1-D. Specific Compound (D)]

[0442] Specific compound (D) is an organic phosphorus compound represented by the formula (D-1) below.

[Chemical Formula 58]



(D-1)

(In the above formula (D-1), p and q represent, independently of each other, an integer of 0 or 1,

[0443] R^{d1}, R^{d2} and R^{d3} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller.

[0444] Any two or more of R^{d1}, R^{d2} and R^{d3} may be connected to each other to form a ring structure.)

[0445] No particular limitation is imposed on the kind of the hydrocarbon group of R^{d1}, R^{d2} and R^{d3}. They may be an aliphatic hydrocarbon group or aromatic hydrocarbon group

or a combination of aliphatic hydrocarbon group and aromatic hydrocarbon group. The aliphatic hydrocarbon group may be a saturated hydrocarbon group, or it may contain an unsaturated bond (carbon to carbon double bond or carbon to carbon triple bond). In addition, the aliphatic hydrocarbon group may be chained or cyclic. When it is chained, the chain may be straight or branched. Further, the chain and ring may be connected with each other.

[0446] The number of carbon atoms of the hydrocarbon groups R^{d1}, R^{d2} and R^{d3} is usually 1 or more, and usually 20 or less, preferably 10 or less, more preferably 6 or less. When the carbon number of the hydrocarbon groups R^{d1}, R^{d2} and R^{d3} is too many, solubility in the non-aqueous liquid electrolyte tends to decrease.

[0447] Concrete examples of the hydrocarbon group which are preferable as R^{d1}, R^{d2} and R^{d3} will be listed below.

[0448] Concrete examples of the chained saturated aliphatic hydrocarbon group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group and 2-ethylhexyl group.

[0449] Concrete examples of the cyclic saturated aliphatic hydrocarbon group include cyclopropyl group, cyclopentyl group and cyclohexyl group.

[0450] Concrete examples of the aliphatic hydrocarbon group having an unsaturated bond (hereinafter abbreviated as "unsaturated aliphatic hydrocarbon group", as appropriate) include vinyl group, 1-propene-1-yl group, allyl group and crotyl group.

[0451] Concrete examples of the aromatic hydrocarbon group, or hydrocarbon group formed by bonding of aromatic hydrocarbon group and aliphatic hydrocarbon group include phenyl group, toluyl group, xylyl group, cinnamyl group and benzyl group.

[0452] Of the hydrocarbon groups exemplified above, preferable as R^{d1}, R^{d2} and R^{d3} from the standpoints of solubility in the liquid electrolyte and ease of industrial availability are methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, tert-butyl group, 2-ethylhexyl group, cyclopentyl group, cyclohexyl group, phenyl group, toluyl group, vinyl group, allyl group and benzyl group.

[0453] Two of R^{d1}, R^{d2} and R^{d3} may be bonded together to form a ring structure. Possible combinations include R^{d1} and R^{d2}, R^{d1} and R^{d3}, and R^{d2} and R^{d3}. It is preferable that the member of the ring formed, of the ring structure, is usually 4 or more, preferably 5 or more, and usually 10 or less, preferably 7 or less, from the standpoints of chemical stability and ease of industrial availability.

[0454] When any two of R^{d1}, R^{d2} and R^{d3} are bonded together to form a ring structure, the hydrocarbon groups bonded constitute a bivalent hydrocarbon group. Concrete examples of such a bivalent hydrocarbon group include —CH_2CH_2— group, —$CH_2CH_2CH_2$— group, —$CH_2CH(CH_3)$— group, —$CH_2CH(C_2H_5)$— group, —$CH(CH_3)CH(CH_3)$— group, —$CH_2CH_2CH(CH_3)$— group, —$CH_2CH_2CH_2CH_2$— group, —$CH_2C(CH_3)_2CH_2$— group, —CH═CH— group, —CH═$CHCH_2$— group, —CH═$C(CH_3)$— group, —$CH_2C(═CH_2)$— group, —CH═$C(C_2H_5)$— group, —$C(CH_3)═C(CH_3)$— group, —CH═$CHCH(CH_3)$— group, —$CH_2CH═C(CH_3)$— group, —CH═$CHCH_2CH_2$— group, —$CH_2CH═CHCH_2$— group and —$CH_2C≡CCH_2$— group.

[0455] Of these, preferable as the bivalent hydrocarbon group from the standpoints of chemical stability and ease of industrial availability are —CH_2CH_2— group, —$CH_2CH_2CH_2$— group, —$CH_2CH(CH_3)$— group, —$CH(CH_3)CH(CH_3)$— group, —$CH_2CH_2CH_2CH_2$— group, —CH═CH— group, —CH═$CHCH_2$— group, —CH═$C(CH_3)$— group, —CH═$C(C_2H_5)$— group, —$C(CH_3)═C(CH_3)$— group and —$CH_2CH═CHCH_2$— group.

[0456] In the hydrocarbon groups of R^{d1}, R^{d2} and R^{d3} in the above formula (D-1), a part or all of the hydrogen atoms bonded to the carbon atoms may be substituted by halogen atoms.

[0457] The halogen atom include fluorine atom, chlorine atom, bromine atom and iodine atom. Of these, fluorine atom, chlorine atom and bromine atom are preferable. Particularly preferable from the standpoint of chemical stability or electrochemical stability are fluorine atom and chlorine atom.

[0458] When each of the hydrocarbon groups of R^{d1}, R^{d2} and R^{d3} is substituted with a halogen atom, no particular limitation is imposed on the number of the halogen atoms. A part of the hydrogen atoms of each hydrocarbon group may be substituted by halogen atoms or all hydrogen atoms of each hydrocarbon group may be substituted by halogen atoms. When each hydrocarbon group of R^{d1}, R^{d2} and R^{d3} has a plurality of halogen atoms, those halogen atoms may be the same or different from each other.

[0459] Concrete examples of the halogen-substituted hydrocarbon groups preferable as R^{d1}, R^{d2} and R^{d3} will be cited below.

[0460] Concrete examples of the fluorine-substituted chained saturated aliphatic hydrocarbon group include fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 2,2,2-trifluoroethyl group, perfluoroethyl group, 1-fluoro-n-propyl group, 2-fluoro-n-propyl group, 3-fluoro-n-propyl group, 3,3,3-trifluoro-n-propyl group, 1-fluoro-isopropyl group, perfluoro-n-propyl group, 1,1,1,3,3,3-hexafluoroisopropyl group, 4,4,4-trifluoro-n-butyl group, perfluoro-n-butyl group, 2-fluoro-tert-butyl group and perfluoro-tert-butyl group.

[0461] Concrete examples of the fluorine-substituted cyclic saturated aliphatic hydrocarbon group include 2-fluorocyclohexyl group, 3-fluorocyclohexyl group and 4-fluorocyclohexyl group.

[0462] Concrete examples of the fluorine-substituted unsaturated aliphatic hydrocarbon group include 1-fluorovinyl group, 2-fluorovinyl group, 2,2-difluorovinyl group, tetrafluorovinyl group, 2-fluoroallyl group and 3-fluoroallyl group.

[0463] Concrete examples of the fluorine-substituted, aromatic hydrocarbon group or hydrocarbon group formed by bonding of aromatic hydrocarbon group and aliphatic hydrocarbon group include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, difluorophenyl group, trifluorophenyl group, perfluorophenyl group, 2-fluorophenylmethyl group, 3-fluorophenylmethyl group and 4-fluorophenylmethyl group.

[0464] Concrete examples of the chlorine-substituted chained saturated aliphatic hydrocarbon group include chloromethyl group, dichloromethyl group, trichloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 2,2,2-trichloroethyl group, perchloroethyl group, 1-chloro-n-propyl group, 2-chloro-n-propyl group, 3-chloro-n-propyl group, perchloro-n-propyl group, 3,3,3-trichloro-n-propyl group, 1-chloro-isopropyl group, 1,1,1,3,3,3-hexachloroiso-

propyl group, 4,4,4-trichloro-n-butyl group, perchloro-n-butyl group, 2-chloro-tert-butyl group and perchloro-tert-butyl group.

[0465] Concrete examples of the chlorine-substituted chained [SIC] saturated aliphatic hydrocarbon group include 2-chlorocyclohexyl group, 3-chlorocyclohexyl group and 4-chlorocyclohexyl group.

[0466] Concrete examples of the chlorine-substituted unsaturated aliphatic hydrocarbon group include 1-chlorovinyl group, 2-chlorovinyl group, 2,2-dichlorovinyl group, tetrachlorovinyl group, 2-chloroallyl group and 3-chloroallyl group.

[0467] Concrete examples of the chlorine-substituted, aromatic hydrocarbon group or hydrocarbon group formed by bonding of aromatic hydrocarbon group and aliphatic hydrocarbon group include 2-chlorophenyl group, 3-chlorophenyl group, 4-chlorophenyl group, 2-chlorophenylmethyl group, 3-chlorophenylmethyl group, 4-chlorophenylmethyl group and chlorofluoromethyl [SIC] group.

[0468] Regarding the bivalent hydrocarbon group formed by bonding of any two of the R^{d1}, R^{d2} and R^{d3} groups, a part or all of its hydrogen atoms may be substituted by halogen atoms.

[0469] Concrete example of the bivalent hydrocarbon group containing a halogen atom include —CH_2CHF— group, —CHFCHF— group, —CH_2CF_2— group, —CH_2CH_2CHF— group, —CH_2CHFCH_2— group, —$CH_2CH(CF_3)$— group, —$CHFCH_2CH_2CH_2$— group, —$CH_2CHFCH_2CH_2$— group, —CH═CF— group, —CF═CF— group, —CH═$CFCH_2$— group, —CH═CHCHF— group, —CF═$C(CH_3)$— group, —CH═$C(CF_3)$— group, —CHFCH═$CHCH_2$— group, —CH_2CF=$CHCH_2$— group, —CH_2CHCl— group, —CHFCHCl— group, —CH_2CCl_2— group, —CH_2CH_2CHCl— group, —$CH_2CHClCH_2$— group, —$CH_2CH(CCl_3)$— group, —$CHClCH_2CH_2CH_2$— group, —$CH_2CHClCH_2CH_2$— group, —CH═CCl— group, —CCl═CCl— group, —CH═$CClCH_2$— group, —CH═CHCHCl— group, —CCl═$C(CH_3)$— group, —CH═$C(CCl_3)$— group, —CHClCH═$CHCH_2$— group, —CH_2CCl═$CHCH_2$— group and —CHFCHCl— group.

[0470] Next, concrete examples of the compound represented by the above-mentioned formula (D-1), as classified according to the combination of p and q, will be listed below.

[0471] As described above, in the above-mentioned formula (D-1), p and q represent, independently of each other, an integer of 0 or 1. Therefore, possible combinations of (p,q) are (1,1), (1,0), (0,1) and (0,0).

[0472] <Examples of the Compound When p+q=2>

[0473] When p+q=2, namely (p,g)=(1,1), the compound represented by the above formula (D-1) is a phosphonic acid ester.

[0474] Examples of the phosphonic acid ester include phosphonic acid diesters containing substituents such as alkyl group, unsaturated hydrocarbon group and aryl group.

[0475] Concrete examples of the alkylphosphonic acid diester containing an alkyl substituent include dimethyl methylphosphonate, diethyl ethylphosphonate, di-n-propyl n-propylphosphonate, diisopropyl isopropylphosphonate, di-n-butyl n-butylphosphonate, diisobutyl isobutylphosphonate, di-tert-butyl tert-butylphosphonate, dicyclopentyl cyclopentylphosphonate, dicyclohexyl cyclohexylphosphonate, diethyl methylphosphonate, di-n-propyl methylphosphonate, di-n-butyl methylphosphonate, dicyclopentyl methylphosphonate, dicyclohexyl methylphosphonate, di(2-cyclohexenyl) methylphosphonate, di(3-cyclohexenyl) methylphosphonate, divinyl methylphosphonate, diallyl methylphosphonate, dipropargyl methylphosphonate, diphenyl methylphosphonate, di(2-toluyl) methylphosphonate, di(3-toluyl)methylphosphonate, di(4-toluyl) methylphosphonate, dimethyl ethylphosphonate, di-n-propyl ethylphosphonate, di-n-butyl ethylphosphonate, dicyclopentyl ethylphosphonate, dicyclohexyl ethylphosphonate, di(2-cyclohexenyl) ethylphosphonate, di(3-cyclohexenyl) ethylphosphonate, divinyl ethylphosphonate, diallyl ethylphosphonate, dipropargyl ethylphosphonate, diphenyl ethylphosphonate, di(2-toluyl)ethylphosphonate, di(3-toluyl) ethylphosphonate, di(4-toluyl)ethylphosphonate, dimethyl n-butylphosphonate, diethyl n-butylphosphonate, dimethyl cyclohexylphosphonate, diethyl cyclohexylphosphonate, ethylmethyl methylphosphonate, methyl-n-propyl methylphosphonate, n-butylmethyl methylphosphonate, cyclopentylmethyl methylphosphonate, cyclohexylmethyl methylphosphonate, (2-cyclohexenyl)methyl methylphosphonate, (3-cyclohexenyl)methyl methylphosphonate, methylvinyl methylphosphonate, methylallyl methylphosphonate, methylpropargyl methylphosphonate, methylphenyl methylphosphonate, methyl(2-toluyl)methylphosphonate, methyl (3-toluyl)methylphosphonate, methyl(4-toluyl)methylphosphonate, ethyl-n-propyl methylphosphonate, cyclohexylethyl methylphosphonate, ethylphenyl methylphosphonate, cyclohexylphenyl methylphosphonate, vinylphenyl methylphosphonate, allylphenyl methylphosphonate, phenyl(2-toluyl)methylphosphonate, phenyl(4-toluyl) methylphosphonate, ethylmethyl ethylphosphonate, methyl-n-propyl ethylphosphonate, n-butylmethyl ethylphosphonate, cyclopentylmethyl ethylphosphonate, cyclohexylmethyl ethylphosphonate, (2-cyclohexenyl)methyl ethylphosphonate, (3-cyclohexenyl)methyl ethylphosphonate, methylvinyl ethylphosphonate, allylmethyl ethylphosphonate, methylpropargyl ethylphosphonate, methylphenyl ethylphosphonate, methyl(2-toluyl)ethylphosphonate, methyl (3-toluyl)ethylphosphonate, methyl(4-toluyl) ethylphosphonate, ethyl-n-propyl ethylphosphonate, cyclohexylethyl ethylphosphonate, ethylphenyl ethylphosphonate, cyclohexylphenyl ethylphosphonate, vinylphenyl ethylphosphonate, allylphenyl ethylphosphonate, phenyl(2-toluyl)ethylphosphonate, phenyl(4-toluyl)ethylphosphonate, ethylmethyl n-butylphosphonate, methyl-n-propyl n-butylphosphonate, n-butylmethyl n-butylphosphonate, cyclopentylmethyl n-butylphosphonate, cyclohexylmethyl n-butylphosphonate, (2-cyclohexenyl)methyl n-butylphosphonate, (3-cyclohexenyl)methyl n-butylphosphonate, methylvinyl n-butylphosphonate, allylmethyl n-butylphosphonate, methylpropargyl n-butylphosphonate, methylphenyl n-butylphosphonate, methyl(2-toluyl) n-butylphosphonate, methyl(3-toluyl) n-butylphosphonate, methyl(4-toluyl)n-butylphosphonate, ethyl-n-propyl n-butylphosphonate, cyclohexylethyl n-butylphosphonate, ethylphenyl n-butylphosphonate, cyclohexylphenyl n-butylphosphonate, vinylphenyl n-butylphosphonate, allylphenyl n-butylphosphonate, phenyl(2-toluyl)n-butylphosphonate, phenyl(4-toluyl)n-butylphosphonate, ethylmethyl cyclohexylphosphonate, methyl-n-propyl cyclohexylphosphonate, n-butylmethyl cyclohexylphosphonate, cyclopentylmethyl cyclohexylphosphonate, cyclohexylmethyl cyclohexylphosphonate, (2-cyclohexenyl)methyl cyclohexylphosphonate, (3-cyclohexenyl)methyl cyclohexy-

lphosphonate, methylvinyl cyclohexylphosphonate, allylmethyl cyclohexylphosphonate, methylpropargyl cyclohexylphosphonate, methylphenyl cyclohexylphosphonate, methyl (2-toluyl)cyclohexylphosphonate, methyl(3-toluyl) cyclohexylphosphonate, methyl(4-toluyl) cyclohexylphosphonate, ethyl-n-propyl cyclohexylphosphonate, cyclohexylethyl cyclohexylphosphonate, ethylphenyl cyclohexylphosphonate, cyclohexylphenyl cyclohexylphosphonate, vinylphenyl cyclohexylphosphonate, allylphenyl cyclohexylphosphonate, phenyl (2-toluyl)cyclohexylphosphonate and phenyl(4-toluyl) cyclohexylphosphonate.

[0476] Concrete examples of the phosphonic acid diester containing an alkyl substituent and also a fluorine atom-substituted site include diperfluoromethyl methylphosphonate, di(2,2,2-trifluoroethyl)methylphosphonate, diperfluoroethyl methylphosphonate, di(2-fluorocyclohexyl) methylphosphonate, di(3-fluorocyclohexyl) methylphosphonate, di(4-fluorocyclohexyl) methylphosphonate, di(2-fluorovinyl)methylphosphonate, di(2,2-difluorovinyl)methylphosphonate, di(2-fluorophenyl) methylphosphonate, di(3-fluorophenyl)methylphosphonate, di(4-fluorophenyl)methylphosphonate, diperfluoromethyl ethylphosphonate, di(2,2,2-trifluoroethyl)ethylphosphonate, diperfluoroethyl ethylphosphonate, di(2-fluorocyclohexyl) ethylphosphonate, di(3-fluorocyclohexyl)ethylphosphonate, di(4-fluorocyclohexyl)ethylphosphonate, di(2-fluorovinyl) ethylphosphonate, di(2,2-difluorovinyl)ethylphosphonate, di(2-fluorophenyl)ethylphosphonate, di(3-fluorophenyl)ethylphosphonate, di(4-fluorophenyl)ethylphosphonate, di(2,2,2-trifluoroethyl)n-butylphosphonate, diperfluoroethyl n-butylphosphonate, di(2-fluorophenyl)n-butylphosphonate, di(2,2,2-trifluoroethyl)cyclohexylphosphonate, diperfluoroethyl cyclohexylphosphonate, di(2-fluorophenyl)cyclohexylphosphonate, methylperfluoromethyl methylphosphonate, methyl(2,2,2-trifluoroethyl)methylphosphonate, methylperfluoroethyl methylphosphonate, (2-fluorocyclohexyl)methyl methylphosphonate, (3-fluorocyclohexyl)methyl methylphosphonate, (4-fluorocyclohexyl)methyl methylphosphonate, (2-fluorovinyl)methyl methylphosphonate, (2,2-difluorovinyl)methyl methylphosphonate, (2-fluorophenyl)methyl methylphosphonate, (3-fluorophenyl)methyl methylphosphonate, (4-fluorophenyl)methyl methylphosphonate, ethyl (2,2,2-trifluoroethyl)methylphosphonate, ethylperfluoroethyl methylphosphonate, (2-fluorophenyl)ethyl methylphosphonate, cyclohexyl(2,2,2-trifluoroethyl)methylphosphonate, cyclohexylperfluoroethyl methylphosphonate, cyclohexyl(2-fluorophenyl)methylphosphonate, vinyl (2,2,2-trifluoroethyl)methylphosphonate, vinyl(2-fluorophenyl)methylphosphonate, allyl(2,2,2-trifluoroethyl) methylphosphonate, allyl(2-fluorophenyl) methylphosphonate, phenyl(2,2,2-trifluoroethyl) methylphosphonate, phenylperfluoroethyl methylphosphonate, phenyl(2-fluorophenyl)methylphosphonate, perfluoroethyl(2,2,2-trifluoroethyl) methylphosphonate, perfluoroethyl(2-fluorophenyl) methylphosphonate, methylphosphonate(2-fluorocyclohexyl)(2,2,2-trifluoroethyl), (2-fluorocyclohexyl)(2-fluorophenyl) methylphosphonate, (2-fluorophenyl)(4-fluorophenyl) methylphosphonate, ethyl(2,2,2-trifluoroethyl) ethylphosphonate, ethylperfluoroethyl ethylphosphonate, (2-fluorophenyl)ethyl ethylphosphonate, cyclohexyl(2,2,2-trifluoroethyl)ethylphosphonate, cyclohexylperfluoroethyl ethylphosphonate, cyclohexyl(2-fluorophenyl)ethylphosphonate, vinyl(2,2,2-trifluoroethyl)ethylphosphonate, vinyl (2-fluorophenyl)ethylphosphonate, allyl(2,2,2-trifluoroethyl)ethylphosphonate, allyl(2-fluorophenyl) ethylphosphonate, phenyl(2,2,2-trifluoroethyl) ethylphosphonate, phenylperfluoroethyl ethylphosphonate, phenyl(2-fluorophenyl)ethylphosphonate, perfluoroethyl(2,2,2-trifluoroethyl)ethylphosphonate, perfluoroethyl(2-fluorophenyl)ethylphosphonate, (2-fluorocyclohexyl)(2,2,2-trifluoroethyl) ethylphosphonate, (2-fluorocyclohexyl)(2-fluorophenyl)ethylphosphonate, (2-fluorophenyl)(4-fluorophenyl)ethylphosphonate, ethyl(2,2,2-trifluoroethyl)) n-butylphosphonate, ethylperfluoroethyl n-butylphosphonate, (2-fluorophenyl)ethyl n-butylphosphonate, cyclohexyl(2,2,2-trifluoroethyl)n-butylphosphonate, cyclohexylperfluoroethyl n-butylphosphonate, cyclohexyl (2-fluorophenyl)n-butylphosphonate, vinyl(2,2,2-trifluoroethyl)n-butylphosphonate, vinyl(2-fluorophenyl)n-butylphosphonate, allyl(2,2,2-trifluoroethyl)n-butylphosphonate), allyl(2-fluorophenyl)n-butylphosphonate, phenyl(2,2,2-trifluoroethyl)n-butylphosphonate, phenylperfluoroethyl n-butylphosphonate, phenyl(2-fluorophenyl)n-butylphosphonate, perfluoroethyl(2,2,2-trifluoroethyl)n-butylphosphonate, perfluoroethyl(2-fluorophenyl)n-butylphosphonate, (2-fluorocyclohexyl)(2,2,2-trifluoroethyl)n-butylphosphonate, (2-fluorocyclohexyl)(2-fluorophenyl)n-butylphosphonate, (2-fluorophenyl)(4-fluorophenyl)n-butylphosphonate, ethyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, ethylperfluoroethyl cyclohexylphosphonate, (2-fluorophenyl)ethyl cyclohexylphosphonate, cyclohexyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, cyclohexylperfluoroethyl cyclohexylphosphonate, cyclohexyl(2-fluorophenyl)cyclohexylphosphonate, vinyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, vinyl(2-fluorophenyl)cyclohexylphosphonate, allyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, allyl(2-fluorophenyl) cyclohexylphosphonate, phenyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, phenylperfluoroethyl cyclohexylphosphonate, phenyl(2-fluorophenyl)cyclohexylphosphonate, perfluoroethyl(2,2,2-trifluoroethyl)cyclohexylphosphonate, perfluoroethyl(2-fluorophenyl)cyclohexylphosphonate, (2-fluorocyclohexyl)(2,2,2-trifluoroethyl)cyclohexylphosphonate, (2-fluorocyclohexyl) (2-fluorophenyl)cyclohexylphosphonate, (2-fluorophenyl) (4-fluorophenyl)cyclohexylphosphonate, diperfluoromethyl perfluoromethylphosphonate, di(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, diperfluoroethyl perfluoroethylphosphonate, di(2-fluorocyclohexyl)(2-fluorocyclohexyl) phosphonate, di(3-fluorocyclohexyl)(3-fluorocyclohexyl) phosphonate, di(4-fluorocyclohexyl)(4-fluorocyclohexyl) phosphonate, dimethyl(2,2,2-trifluoroethyl)phosphonate, diethyl (2,2,2-trifluoroethyl)phosphonate, di-n-butyl(2,2,2-trifluoroethyl)phosphonate, dicyclohexyl(2,2,2-trifluoroethyl)phosphonate, di(2-cyclohexenyl)(2,2,2-trifluoroethyl) phosphonate, divinyl(2,2,2-trifluoroethyl)phosphonate, diallyl(2,2,2-trifluoroethyl)phosphonate, dipropargyl(2,2,2-trifluoroethyl)phosphonate, diphenyl(2,2,2-trifluoroethyl) phosphonate, di(2-toluyl)(2,2,2-trifluoroethyl)phosphonate, di(4-toluyl)(2,2,2-trifluoroethyl)phosphonate, diperfluoroethyl(2,2,2-trifluoroethyl)phosphonate, di(2-fluorocyclohexyl)(2,2,2-trifluoroethyl)phosphonate, di(2-fluorovinyl) (2,2,2-trifluoroethyl)phosphonate, di(2-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, di(4-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, ethylmethyl (2,2,2-trifluoroethyl)phosphonate, n-butylmethyl (2,2,2-

trifluoroethyl)phosphonate, cyclohexylmethyl (2,2,2-trifluoroethyl)phosphonate, methylvinyl (2,2,2-trifluoroethyl)phosphonate, allylmethyl (2,2,2-trifluoroethyl)phosphonate, methylphenyl (2,2,2-trifluoroethyl)phosphonate, methyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, methylperfluoroethyl(2,2,2-trifluoroethyl)phosphonate, (2-fluorocyclohexyl)methyl(2,2,2-trifluoroethyl)phosphonate, (2-fluorovinyl)methyl (2,2,2-trifluoroethyl)phosphonate, (2-fluorophenyl)methyl(2,2,2-trifluoroethyl)phosphonate, cyclohexylethyl(2,2,2-trifluoroethyl)phosphonate, ethylphenyl(2,2,2-trifluoroethyl)phosphonate, ethyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, (2-fluorophenyl)ethyl(2,2,2-trifluoroethyl)phosphonate, cyclohexylphenyl(2,2,2-trifluoroethyl)phosphonate, cyclohexyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, cyclohexyl(2-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, vinyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, vinyl(2-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, allyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, allyl(2-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, phenyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, phenyl (2-fluorophenyl) (2,2,2-trifluoroethyl)phosphonate, (2,2,2-trifluoroethyl)(2-fluorophenyl)(2,2,2-trifluoroethyl) phosphonate, phenyl(2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phosphonate, phenyl(2-fluorophenyl)(2,2,2-trifluoroethyl)phosphonate, dimethyl(2-fluorocyclohexyl) phosphonate, diethyl(2-fluorocyclohexyl)phosphonate, dicyclohexyl(2-fluorocyclohexyl)phosphonate, diphenyl (2-fluorocyclohexyl)phosphonate, bis(2,2,2-trifluoroethyl) (2-fluorocyclohexyl)phosphonate, di(2-fluorophenyl)(2-fluorocyclohexyl)phosphonate, ethylmethyl(2-fluorocyclohexyl)phosphonate, cyclohexylmethyl(2-fluorocyclohexyl) phosphonate, methylphenyl(2-fluorocyclohexyl) phosphonate, methyl(2,2,2-trifluoroethyl)(2-fluorocyclohexyl)phosphonate and (2-fluorophenyl)methyl (2-fluorocyclohexyl)phosphonate.

[0477] Concrete examples of the phosphonic acid diester containing an unsaturated hydrocarbon group substituent include divinyl vinylphosphonate, diallyl allylphosphonate, dipropargyl propargylphosphonte, dimethyl vinylphosphonate, diethyl vinylphosphonate, di-n-butyl vinylphosphonate, dicyclohexyl vinylphosphonate, diphenyl vinylphosphonate, ethylmethyl vinylphosphonate, methyl-n-propyl vinylphosphonate, n-butylmethyl vinylphosphonate, cyclopentylmethyl vinylphosphonate, cyclohexylmethyl vinylphosphonate, (2-cyclohexenyl)methyl vinylphosphonate, (3-cyclohexenyl)methyl vinylphosphonate, methylvinyl vinylphosphonate, allylmethyl vinylphosphonate, methylpropargyl vinylphosphonate, methylphenyl vinylphosphonate, methyl(2-toluyl)vinylphosphonate, methyl(3-toluyl)vinylphosphonate, methyl(4-toluyl)vinylphosphonate, ethyl-n-propyl vinylphosphonate, cyclohexylethyl vinylphosphonate, ethylphenyl vinylphosphonate, cyclohexylphenyl vinylphosphonate, vinylphenyl vinylphosphonate, allylphenyl vinylphosphonate, phenyl(2-toluyl)vinylphosphonate, phenyl(4-toluyl) vinylphosphonate, dimethyl allylphosphonate, diethyl allylphosphonate, di-n-butyl allylphosphonate, dicyclohexyl allylphosphonate, diphenyl allylphosphonate, di(2,2,2-trifluoroethyl)allylphosphonate, di(2-fluorocyclohexyl)allylphosphonate, di(2-fluoroethyl)allylphosphonate, ethylmethyl allylphosphonate, methyl-n-propyl allylphosphonate, n-butylmethyl allylphosphonate, cyclopentylmethyl allylphosphonate, cyclohexylmethyl allylphosphonate, (2-cyclohexenyl)methyl allylphosphonate, (3-cyclohexenyl)methyl allylphosphonate, methylvinyl allylphosphonate, allylmethyl allylphosphonate, methylpropargyl allylphosphonate, methylphenyl allylphosphonate, methyl(2-toluyl)allylphosphonate, methyl(3-toluyl) allylphosphonate, methyl(4-toluyl)allylphosphonate, ethyl-n-propyl allylphosphonate, cyclohexylethyl allylphosphonate, ethylphenyl allylphosphonate, cyclohexylphenyl allylphosphonate, vinylphenyl allylphosphonate, allylphenyl allylphosphonate, phenyl(2-toluyl)allylphosphonate and phenyl(4-toluyl)allylphosphonate.

[0478] Concrete examples of the phosphonic acid diester containing an unsaturated hydrocarbon group substituent and also a fluorine atom-substituted site include di(2,2,2-trifluoroethyl)vinylphosphonate, di(2-fluorocyclohexyl) vinylphosphonate, di(2-fluorophenyl)vinylphosphonate, methyl(2,2,2-trifluoroethyl)vinylphosphonate, methyl(2-fluorocyclohexyl)vinylphosphonate, methyl(2-fluorophenyl) vinylphosphonate, di(2,2,2-trifluoroethyl)allylphosphonate, di(2-fluorocyclohexyl)allylphosphonate, di(2-fluorophenyl) allylphosphonate, methyl(2,2,2-trifluoroethyl)allylphosphonate, methyl(2-fluorocyclohexyl)allylphosphonate, methyl (2-fluorophenyl)allylphosphonate, dimethyl(2-fluorovinyl) phosphonate, diethyl (2-fluorovinyl)phosphonate, di-n-butyl (2-fluorovinyl)phosphonate, dicyclohexyl(2-fluorovinyl) phosphonate, di(2-fluorovinyl)(2-fluorovinyl)phosphonate, di(2,2-difluorovinyl)(2,-difluorovinyl)phosphonate, diphenyl(2-fluorovinyl)phosphonate, di(2,2,2-trifluoroethyl)(2-fluorovinyl)phosphonate, di(2-fluorocyclohexyl)(2-fluorovinyl)phosphonate, di(2-fluorophenyl)(2-fluorovinyl) phosphonate, ethylmethyl(2-fluorovinyl)phosphonate, cyclohexylmethyl(2-fluorovinyl)phosphonate, methylphenyl (2-fluorovinyl)phosphonate, methyl(2,2,2-trifluoroethyl)(2-fluorovinyl)phosphonate and (2-fluorophenyl)methyl(2-fluorovinyl)phosphonate.

[0479] Concrete examples of the phosphonic acid diester containing an aryl substituent include diphenyl phenylphosphonate, di(2-toluyl)(2-toluyl)phosphonate, di(3-toluyl)(3-toluyl)phosphonate, di(4-toluyl)(4-toluyl)phosphonate, di(2-fluorophenyl)(2-fluorophenyl)phosphonate, di(3-fluorophenyl)(3-fluorophenyl)phosphonate, di(4-fluorophenyl)(4-fluorophenyl)phosphonate, dimethyl phenylphosphonate, diethyl phenylphosphonate, di-n-butyl phenylphosphonate, dicyclohexyl phenylphosphonate, diphenyl phenylphosphonate, ethylmethyl phenylphosphonate, methyl-n-propyl phenylphosphonate, n-butylmethyl phenylphosphonate, cyclopentylmethyl phenylphosphonate, cyclohexylmethyl phenylphosphonate, (2-cyclohexenyl)methyl phenylphosphonate, (3-cyclohexenyl)methyl phenylphosphonate, methylvinyl phenylphosphonate, allylmethyl phenylphosphonate, methylpropargyl phenylphosphonate, methylphenyl phenylphosphonate, methyl(2-toluyl)phenylphosphonate, methyl(3-toluyl)phenylphosphonate, methyl(4-toluyl)phenylphosphonate, ethyl-n-propyl phenylphosphonate, cyclohexylethyl phenylphosphonate, ethylphenyl phenylphosphonate, cyclohexylphenyl phenylphosphonate, vinylphenyl phenylphosphonate, allylphenyl phenylphosphonate, phenyl(2-toluyl)phenylphosphonate, phenyl(4-toluyl)phenylphosphonate, dimethyl 2-toluylphosphonate, diethyl 2-toluylphosphonate, di-n-butyl 2-toluylphosphonate, dicyclohexyl 2-toluylphosphonate, diphenyl 2-toluylphosphonate, di(2,2,2-trifluoroethyl)2-toluylphosphonate, di(2-fluorocyclohexyl)2-toluylphosphonate, di(2-fluorophenyl)2-toluylphos-

phonate, ethylmethyl 2-toluylphosphonate, methyl-n-propyl 2-toluylphosphonate, n-butylmethyl 2-toluylphosphonate, cyclopentylmethyl 2-toluylphosphonate, cyclohexylmethyl 2-toluylphosphonate, (2-cyclohexenyl)methyl 2-toluylphosphonate, (3-cyclohexenyl)methyl 2-toluylphosphonate, methylvinyl 2-toluylphosphonate, allylmethyl 2-toluylphosphonate, methylpropargyl 2-toluylphosphonate, methylphenyl 2-toluylphosphonate, methyl(2-toluyl)2-toluylphosphonate, methyl(3-toluyl)2-toluylphosphonate, methyl(4-toluyl) 2-toluylphosphonate, ethyl-n-propyl 2-toluylphosphonate, cyclohexylethyl 2-toluylphosphonate, ethylphenyl 2-toluylphosphonate, cyclohexylphenyl 2-toluylphosphonate, vinylphenyl 2-toluylphosphonate, allylphenyl 2-toluylphosphonate, phenyl(2-toluyl)2-toluylphosphonate, phenyl(4-toluyl)2-toluylphosphonate, dimethyl 4-toluylphosphonate, diethyl 4-toluylphosphonate, di-n-butyl 4-toluylphosphonate, dicyclohexyl 4-toluylphosphonate, diphenyl 4-toluylphosphonate, di(2,2,2-trifluoroethyl)4-toluylphosphonate, di(2-fluorocyclohexyl)4-toluylphosphonate, di(2-fluorophenyl)4-toluylphosphonate, ethylmethyl 4-toluylphosphonate, methyl-n-propyl 4-toluylphosphonate, n-butylmethyl 4-toluylphosphonate, cyclopentylmethyl 4-toluylphosphonate, cyclohexylmethyl 4-toluylphosphonate, (2-cyclohexenyl)methyl 4-toluylphosphonate, (3-cyclohexenyl)methyl 4-toluylphosphonate, methylvinyl 4-toluylphosphonate, allylmethyl 4-toluylphosphonate, methylpropargyl 4-toluylphosphonate, methylphenyl 4-toluylphosphonate, methyl(2-toluyl)4-toluylphosphonate, methyl(3-toluyl)4-toluylphosphonate, methyl(4-toluyl)4-toluylphosphonate, ethyl-n-propyl 4-toluylphosphonate, cyclohexylethyl 4-toluylphosphonate, ethylphenyl 4-toluylphosphonate, cyclohexylphenyl 4-toluylphosphonate, vinylphenyl 4-toluylphosphonate, allylphenyl 4-toluylphosphonate, phenyl(2-toluyl)4-toluylphosphonate and phenyl(4-toluyl)4-toluylphosphonate.

[0480] Concrete examples of the phosphonic acid diester containing an aryl substituent and also a fluorine atom-substituted site include di(2,2,2-trifluoroethyl)phenylphosphonate, di(2-fluorocyclohexyl)phenylphosphonate, di(2-fluorophenyl)phenylphosphonate, methyl(2,2,2-trifluoroethyl) phenylphosphonate, methyl(2-fluorocyclohexyl) phenylphosphonate, methyl(2-fluorophenyl) phenylphosphonate, dimethyl(2-fluorophenyl)phosphonate, diethyl(2-fluorophenyl)phosphonate, dicyclohexyl(2-fluorophenyl)phosphonate, diphenyl (2-fluorophenyl)phosphonate, bis(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphonate, di(2-fluorophenyl)(2-fluorophenyl)phosphonate, ethylmethyl (2-fluorophenyl)phosphonate, cyclohexylmethyl (2-fluorophenyl)phosphonate, methylphenyl (2-fluorophenyl)phosphonate, methyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphonate and (2-fluorophenyl)methyl(2-fluorophenyl)phosphonate.

[0481] Concrete examples of the phosphonic acid ester in which any two of R^{d1}, R^{d2} and R^{d3} are connected to form a ring structure include 2-methyl-1,3,2-dioxaphosphorane-2-oxide, 2-methyl-1,3,2-dioxaphosphine-2-oxide, 2-ethyl-1,3,2-dioxaphosphorane-2-oxide, 2-butyl-1,3,2-dioxaphosphorane-2-oxide, 2-cyclohexyl-1,3,2-dioxaphosphorane-2-oxide, 2-vinyl-1,3,2-dioxaphosphorane-2-oxide, 2-phenyl-1,3,2-dioxaphosphorane-2-oxide, 2-(2,2,2-trifluoroethyl)-1,3,2-dioxaphosphorane-2-oxide, 2-perfluoroethyl-1,3,2-dioxaphosphorane-2-oxide, 2-(2-fluorophenyl)-1,3,2-dioxaphosphorane-2-oxide, 4-fluoro-2-methyl-1,3,2-dioxaphosphorane-2-oxide, 2-methoxy-1,2-oxaphosphorane-2-oxide, 2-ethoxy-1,2-oxaphosphorane-2-oxide, 2-phenoxy-1,2-oxaphosphorane-2-oxide and 2-methoxy-1,2-oxaphosphine-2-oxide.

[0482] Of these phosphonic acid esters, particularly preferable as specific compound (D) are dimethyl methylphosphonate, diethyl ethylphosphonate, di-n-butyl n-butylphosphonate, diisobutyl isobutylphosphonate, diethyl methylphosphonate, di-n-butyl methylphosphonate, diphenyl methylphosphonate, dimethyl ethylphosphonate, di-n-butyl ethylphosphonate, diphenyl ethylphosphonate, di(2,2,2-trifluoroethyl)methylphosphonate, di(2,2,2-trifluoroethyl) ethylphosphonate, diphenyl phenylphosphonate, dimethyl phenylphosphonate and diethyl phenylphosphonate.

[0483] <Examples of the Compound When p+q=1>

[0484] When p+q=1, namely (p, q)=(1,0) or (0,1), the compound represented by the above formula (D-1) is a phosphinic acid ester.

[0485] Examples of the phosphinic acid ester include those in which the ester moiety is an alkyl group, unsaturated hydrocarbon group and aryl group.

[0486] Concrete examples of the phosphinic acid ester in which the ester moiety is an alkyl group include methyl dimethylphosphinate, ethyl diethylphosphinate, n-propyl di-n-propylphosphinate, isopropyl diisopropylphosphinate, n-butyl di-n-butylphosphinate, isobutyl diisobutylphosphinate, tert-butyl di-tert-butylphosphinate, cyclopentyl dicyclopentylphosphinate, cyclohexyl dicyclohexylphosphinate, methyl diethylphosphinate, methyl di-n-propylphosphinate, methyl diisopropylphosphinate, methyl di-n-butylphosphinate, methyl diisobutylphosphinate, methyl di-tert-butylphosphinate, methyl dicyclopentylphosphinate, methyl dicyclohexylphosphinate, methyl di(2-cyclohexenyl)phosphinate, methyl di(3-cyclohexenyl)phosphinate, methyl divinylphosphinate, methyl diallylphosphinate, methyl dipropargylphosphinate, methyl diphenylphosphinate, methyl di(2-toluyl)phosphinate, methyl di(3-toluyl)phosphinate, methyl di(4-toluyl)phosphinate, ethyl dimethylphosphinate, ethyl di-n-propylphosphinate, ethyl diisopropylphosphinate, ethyl di-n-butylphosphinate, ethyl diisobutylphosphinate, ethyl di-tert-butylphosphinate, ethyl dicyclopentylphosphinate, ethyl dicyclohexylphosphinate, ethyl di(2-cyclohexenyl)phosphinate, ethyl di(3-cyclohexenyl)phosphinate, ethyl divinylphosphinate, ethyl diallylphosphinate, ethyl dipropargylphosphinate, ethyl diphenylphosphinate, ethyl di(2-toluyl)phosphinate, ethyl di(3-toluyl)phosphinate, ethyl di(4-toluyl)phosphinate, n-butyl dimethylphosphinate, n-butyl diethylphosphinate, n-butyl dicyclohexylphosphinate, n-butyl diphenylphosphinate, cyclohexyl dimethylphosphinate, cyclohexyl diethylphosphinate, cyclohexyl di-n-butylphosphinate, cyclohexyl divinylphosphinate, cyclohexyl diphenylphosphinate, methyl ethylmethylphosphinate, methyl methyl-n-butylphosphinate, methyl cyclohexylmethylphosphinate, methyl methylvinylphosphinate, methyl methylphenylphosphinate, methyl n-butylethylphosphinate, methyl cyclohexylethylphosphinate, methyl ethylvinylphosphinate, methyl ethylphenylphosphinate, methyl n-butylcyclohexylphosphinate, methyl n-butylvinylphosphinate, methyl n-butylphenylphosphinate, methyl cyclohexylvinylphosphinate, methyl cyclohexylphenylphosphinate, ethyl ethylmethylphosphinate, ethyl methyl-n-butylphosphinate, ethyl cyclohexylmethylphosphinate, ethyl methylvinylphosphinate, ethyl methylphenylphosphinate, ethyl n-butylethylphosphinate, ethyl cyclohexylethylphosphinate, ethyl ethylvinylphosphinate, ethyl ethylphenylphosphinate, ethyl n-butyl-

cyclohexylphosphinate, ethyl n-butylvinylphosphinate, ethyl n-butylphenylphosphinate, ethyl cyclohexylvinylphosphinate, ethyl, cyclohexylphenylphosphinate, ethyl phenylvinylphosphinate, n-butyl ethylmethylphosphinate, n-butyl methyl-n-butylphosphinate, n-butyl cyclohexylmethylphosphinate, n-butyl methylvinylphosphinate, n-butyl methylphenylphosphinate, n-butyl n-butylethylphosphinate, n-butyl cyclohexylethylphosphinate, n-butyl ethylvinylphosphinate, n-butyl ethylphenylphosphinate, n-butyl n-butylcyclohexylphosphinate, n-butyl n-butylvinylphosphinate, n-butyl n-butylphenylphosphinate, n-butyl cyclohexylvinylphosphinate, n-butyl cyclohexylphenylphosphinate, n-butyl phenylvinylphosphinate, ethylmethylphosphinatecyclohexyl, cyclohexyl methyl-n-butylphosphinate, cyclohexyl cyclohexylmethylphosphinate, cyclohexyl methylvinylphosphinate, cyclohexyl methylphenylphosphinate, cyclohexyl n-butylethylphosphinate, cyclohexyl cyclohexylethylphosphinate, cyclohexyl ethylvinylphosphinate, cyclohexyl ethylphenylphosphinate, cyclohexyl n-butylcyclohexylphosphinate, cyclohexyl n-butylvinylphosphinate, cyclohexyl n-butylphenylphosphinate, cyclohexyl cyclohexylvinylphosphinate, cyclohexyl cyclohexylphenylphosphinate and cyclohexyl phenylvinylphosphinate.

[0487] Concrete examples of the phosphinic acid ester, in which ester moiety is an alkyl group and which contains a fluorine atom-substituted site, include perfluoromethyl bisperfluoromethylphosphinate, (2,2,2-trifluoroethyl)bis(2,2,2-trifluoroethyl)phosphinate, perfluoroethyl bisperfluoroethylphosphinate, (2-fluorocyclohexyl)di(2-fluorocyclohexyl)phosphinate, (3-fluorocyclohexyl)di(3-fluorocyclohexyl)phosphinate, (4-fluorocyclohexyl)di(4-fluorocyclohexyl)phosphinate, methyl bisperfluoromethylphosphinate, methyl bis(2,2,2-trifluoroethyl)phosphinate, methyl bisperfluoroethylphosphinate, methyl di(2-fluorocyclohexyl)phosphinate, methyl di(3-fluorocyclohexyl)phosphinate, methyl di(4-fluorocyclohexyl)phosphinate, methyl di(2-fluorovinyl)phosphinate, methyl di(2,2-difluorovinyl)phosphinate, methyl di(2-fluorophenyl)phosphinate, methyl di(3-fluorophenyl)phosphinate, methyl di(4-fluorophenyl)phosphinate, ethyl bisperfluoromethylphosphinate, ethyl bis(2,2,2-trifluoroethyl)phosphinate, ethyl bisperfluoroethylphosphinate, ethyl di(2-fluorocyclohexyl)phosphinate, ethyl di(3-fluorocyclohexyl)phosphinate, ethyl di(4-fluorocyclohexyl)phosphinate, ethyl di(2-fluorovinyl)phosphinate, ethyl di(2,2-difluorovinyl)phosphinate, ethyl di(2-fluorophenyl)phosphinate, ethyl di(3-fluorophenyl)phosphinate, ethyl di(4-fluorophenyl)phosphinate, n-butyl bis(2,2,2-trifluoroethyl)phosphinate, n-butyl di(2-fluorophenyl)phosphinate, cyclohexyl bis(2,2,2-trifluoroethyl)phosphinate, cyclohexyl di(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)dimethylphosphinate, (2,2,2-trifluoroethyl)diethylphosphinate, (2,2,2-trifluoroethyl)di-n-butylphosphinate, (2,2,2-trifluoroethyl)dicyclohexylphosphinate, (2,2,2-trifluoroethyl divinylphosphinate, (2,2,2-trifluoroethyl)diphenylphosphinate, (2,2,2-trifluoroethyl)di(2-fluorophenyl)phosphinate, methyl methyl(2,2,2-trifluoroethyl)phosphinate, methyl methyl(2-fluorophenyl)phosphinate, methyl ethyl(2,2,2-trifluoroethyl)phosphinate, methyl ethyl(2-fluorophenyl)phosphinate, methyl n-butyl(2,2,2-trifluoroethyl)phosphinate, methyl n-butyl(2-fluorophenyl)phosphinate, methyl cyclohexyl(2,2,2-trifluoroethyl)phosphinate, methyl cyclohexyl(2-fluorophenyl)phosphinate, methyl phenylvinylphosphinate, methyl(2,2,2-trifluoroethyl)vinylphosphinate, methyl(2-fluorophenyl)vinylphosphinate, methyl(2,2,2-trifluoroethyl)phenylphosphinate, methyl(2-fluorophenyl)phenylphosphinate, methyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphinate, ethyl methyl(2,2,2-trifluoroethyl)phosphinate, ethyl methyl(2-fluorophenyl)phosphinate, ethyl ethyl(2,2,2-trifluoroethyl)phosphinate, ethyl ethyl(2-fluorophenyl)phosphinate, ethyl n-butyl(2,2,2-trifluoroethyl)phosphinate, ethyl n-butyl(2-fluorophenyl)phosphinate, ethyl cyclohexyl(2,2,2-trifluoroethyl)phosphinate, ethyl cyclohexyl(2-fluorophenyl)phosphinate, ethyl(2,2,2-trifluoroethyl)vinylphosphinate, ethyl(2-fluorophenyl)vinylphosphinate, ethyl(2,2,2-trifluoroethyl)phenylphosphinate, ethyl (2-fluorophenyl)phenylphosphinate, ethyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphinate, n-butyl methyl (2,2,2-trifluoroethyl)phosphinate, n-butyl methyl(2-fluorophenyl)phosphinate, n-butyl ethyl(2,2,2-trifluoroethyl)phosphinate, n-butyl ethyl(2-fluorophenyl)phosphinate, n-butyl n-butyl(2,2,2-trifluoroethyl)phosphinate, n-butyl n-butyl(2-fluorophenyl)phosphinate, n-butyl cyclohexyl(2,2,2-trifluoroethyl)phosphinate, n-butyl cyclohexyl(2-fluorophenyl)phosphinate, n-butyl (2,2,2-trifluoroethyl)vinylphosphinate, n-butyl(2-fluorophenyl)vinylphosphinate, n-butyl(2,2,2-trifluoroethyl)phenylphosphinate, n-butyl(2-fluorophenyl)phenylphosphinate, n-butyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphinate, cyclohexyl methyl(2,2,2-trifluoroethyl)phosphinate, cyclohexyl methyl(2-fluorophenyl)phosphinate, cyclohexyl ethyl(2,2,2-trifluoroethyl)phosphinate, cyclohexyl ethyl(2-fluorophenyl)phosphinate, cyclohexyl n-butyl(2,2,2-trifluoroethyl)phosphinate, cyclohexyl n-butyl(2-fluorophenyl)phosphinate, cyclohexyl cyclohexyl(2,2,2-trifluoroethyl)phosphinate, cyclohexyl cyclohexyl(2-fluorophenyl)phosphinate, cyclohexyl(2,2,2-trifluoroethyl)vinylphosphinate, cyclohexyl(2-fluorophenyl)vinylphosphinate, cyclohexyl(2,2,2-trifluoroethyl)phenylphosphinate, cyclohexyl(2-fluorophenyl)phenylphosphinate, cyclohexyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)ethylmethylphosphinate, (2,2,2-trifluoroethyl)methyl-n-butylphosphinate, (2,2,2-trifluoroethyl)cyclohexylmethylphosphinate, (2,2,2-trifluoroethyl)methylvinylphosphinate, (2,2,2-trifluoroethyl)methylphenylphosphinate, (2,2,2-trifluoroethyl)methyl(2,2,2-trifluoroethyl)phosphinate, (2,2,2-trifluoroethyl)methyl(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)n-butylethylphosphinate, (2,2,2-trifluoroethyl)cyclohexylethylphosphinate, (2,2,2-trifluoroethyl)ethylvinylphosphinate, (2,2,2-trifluoroethyl)ethylphenylphosphinate, (2,2,2-trifluoroethyl)ethyl(2,2,2-trifluoroethyl)phosphinate, (2,2,2-trifluoroethyl)ethyl(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)n-butylcyclohexylphosphinate, (2,2,2-trifluoroethyl)n-butylvinylphosphinate, (2,2,2-trifluoroethyl)n-butylphenylphosphinate, (2,2,2-trifluoroethyl)n-butyl(2,2,2-trifluoroethyl)phosphinate, (2,2,2-trifluoroethyl)n-butyl(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)cyclohexylvinylphosphinate, (2,2,2-trifluoroethyl)cyclohexylphenylphosphinate, (2,2,2-trifluoroethyl)cyclohexyl(2,2,2-trifluoroethyl)phosphinate, (2,2,2-trifluoroethyl)cyclohexyl(2-fluorophenyl)phosphinate, (2,2,2-trifluoroethyl)phenylvinylphosphinate, (2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)vinylphosphinate, (2,2,2-trifluoroethyl)(2-fluorophenyl)vinylphosphinate, (2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)phenylphosphinate, (2,2,

2-trifluoroethyl)(2-fluorophenyl)phenylphosphinate and (2,2,2-trifluoroethyl)(2,2,2-trifluoroethyl)(2-fluorophenyl) phosphinate.

[0488] Concrete examples of the phosphinic acid ester in which the ester moiety is unsaturated hydrocarbon group include (2-cyclohexenyl)di(2-cyclohexenyl)phosphinate, (3-cyclohexenyl)di(3-cyclohexenyl)phosphinate, vinyl divinylphosphinate, allyl diallylphosphinate, propargyl dipropargylphosphinate, vinyl dimethylphosphinate, vinyl diethylphosphinate, vinyl di-n-butylphosphinate, vinyl dicyclohexylphosphinate, vinyl diphenylphosphinate, vinyl bis(2,2,2-trifluoroethyl)phosphinate and vinyl di(2-fluorophenyl)phosphinate.

[0489] Concrete examples of the phosphinic acid ester, in which the ester moiety is an unsaturated hydrocarbon group and which contains a fluorine atom-substituted site, include (2-fluorovinyl)di(2-fluorovinyl)phosphinate, (2,2-difluorovinyl)di(2,2-difluorovinyl)phosphinate, vinyl bis(2,2,2-trifluoroethyl)phosphinate and vinyl di(2-fluorophenyl)phosphinate.

[0490] Concrete examples of the phosphinic acid ester in which the ester moiety is an aryl group include phenyl diphenylphosphinate, (2-toluyl)di(2-toluyl)phosphinate, (3-toluyl) di(3-toluyl)phosphinate, (4-toluyl)di(4-toluyl)phosphinate, phenyl dimethylphosphinate, phenyl diethylphosphinate, phenyl di-n-butylphosphinate, phenyl dicyclohexylphosphinate and phenyl divinylphosphinate.

[0491] Concrete examples of the phosphinic acid ester, in which the ester moiety is an unsaturated hydrocarbon group [SIC] and which contains a fluorine atom-substituted site, include (2-fluorophenyl)di(2-fluorophenyl)phosphinate, (3-fluorophenyl)di(3-fluorophenyl)phosphinate, (4-fluorophenyl)di(4-fluorophenyl)phosphinate, phenyl bis(2,2,2-trifluoroethyl)phosphinate, phenyl di(2-fluorophenyl)phosphinate, (2-fluorophenyl)dimethylphosphinate, (2-fluorophenyl)diethylphosphinate, (2-fluorophenyl)di-n-butylphosphinate, (2-fluorophenyl)dicyclohexylphosphinate, (2-fluorophenyl)divinylphosphinate, (2-fluorophenyl) diphenylphosphinate and (2-fluorophenyl)di(2,2,2-trifluoroethyl)phosphinate.

[0492] Concrete examples of the phosphinic acid ester in which any two of R^{d1}, R^{d2} and R^{d3} are connected to form a ring structure include 2-methyl-1,2-oxaphosphorane-2-oxide, 2-methyl-1,2-oxaphosphinane-2-oxide, 2-ethyl-1,2-oxaphosphorane-2-oxide, 2-butyl-1,2-oxaphosphorane-2-oxide, 2-cyclohexyl-1,2-oxaphosphorane-2-oxide, 2-vinyl-1,2-oxaphosphorane-2-oxide, 2-phenyl-1,2-oxaphosphorane-2-oxide, 2-(2,2,2-trifluoroethyl)-1,2-oxaphosphorane-2-oxide, 2-perfluoroethyl-1,2-oxaphosphorane-2-oxide, 2-(2-fluorophenyl)-1,2-oxaphosphorane-2-oxide, 4-fluoro-2-methyl-1,2-oxaphosphorane-2-oxide, 1-methoxyphosphorane-1-oxide, 1-ethoxyphosphorane-1-oxide, 1-phenoxyphosphorane-1-oxide and 1-methoxy-phosphinane-1-oxide.

[0493] Of the phosphinic acid esters exemplified above, particularly preferable as specific compound (D) are ethyl diethylphosphinate, n-butyl di-n-butylphosphinate, cyclohexyl dicyclohexylphosphinate, phenyl diphenylphosphinate, (2,2,2-trifluoroethyl)bis(2,2,2-trifluoroethyl)phosphinate, methyl methyl-n-butylphosphinate, methyl methylphenylphosphinate, methyl methyl(2,2,2-trifluoroethyl)phosphinate, ethyl ethylphenylphosphinate, ethyl ethyl (2,2,2-trifluoroethyl)phosphinate and n-butyl n-butylphenylphosphinate.

[0494] When the compounds represented by the above formula (D-1) are organic phosphorous compounds where p+q=1 or 2, combined use with the specific carbonate explained later makes it possible to offer a non-aqueous liquid electrolyte secondary battery with high capacity and with superior characteristics maintained for a long time, particularly with high discharge capacity retention rate.

[0495] Of the organic phosphorous compounds exemplified above, which are shown in the above formula (D-1) where p+q=1 or 2, particularly preferable are dimethyl methylphosphonate, diethyl ethylphosphonate, di-n-butyl n-butylphosphonate, dimethyl phenylphosphonate, diethyl phenylphosphonate, ethyl diethylphosphinate, n-butyl di-n-butylphosphinate, methyl methyl-n-butylphosphinate, methyl methylphenylphosphinate and ethyl ethylphenylphosphinate.

[0496] <Examples of the Compound When p+q=0>

[0497] When p+q=0, namely (p,q)=(0,0), the compound represented by the above formula (D-1) is a phosphine oxide.

[0498] Examples of the phosphine oxide include those consisting only of alkyl group, those possessing an unsaturated hydrocarbon group and those possessing an aryl group.

[0499] Concrete examples of the phosphine oxide consisting only of alkyl group include trimethylphosphine oxide, triethylphosphine oxide, tri-n-propylphosphine oxide, triisopropylphosphine oxide, tri-n-butylphosphine oxide, triisobutylphosphine oxide, tri-tert-butylphosphine oxide, tricyclopentylphosphine oxide, tricyclohexylphosphine oxide, ethyldimethylphosphine oxide, dimethyl-n-propylphosphine oxide, isopropyldimethylphosphine oxide, n-butyldimethylphosphine oxide, isobutyldimethylphosphine oxide, tert-butyldimethyiphosphine oxide, cyclopentyldimethylphosphine oxide, cyclohexyldimethylphosphine oxide, diethylmethylphosphine oxide, diethyl-n-butylphosphine oxide, cyclohexyldiethylphosphine oxide, di-n-butylmethylphosphine oxide, di-n-butylethylphosphine oxide, di-n-butylcyclohexylphosphine oxide, dicyclohexylmethylphosphine oxide, dicyclohexylethylphosphine oxide, n-butyldicyclohexylphosphine oxide, ethylmethyl-n-propylphosphine oxide, ethylmethylisopropylphosphine oxide, ethylmethyl-n-butylphosphine oxide, ethylmethylisobutylphosphine oxide, ethylmethyl-tert-butylphosphine oxide, ethylmethylcyclopentylphosphine oxide, ethylmethylcyclohexylphosphine oxide, n-butylmethyl-n-propylphosphine oxide, n-butylmethylcyclohexylphosphine oxide and cyclohexylmethyl(2,2,2-trifluoroethyl)phosphine oxide.

[0500] Concrete examples of the trialkylphosphine oxide containing a fluorine atom substituent include triperfluoromethylphosphine oxide, tri(2,2,2-trifluoroethyl)phosphine oxide, triperfluoroethylphosphine oxide, tri(2-fluorocyclohexyl)phosphine oxide, tri(3-fluorocyclohexyl)phosphine oxide, tri(4-fluorocyclohexyl)phosphine oxide, perfluoromethyldimethylphosphine oxide, (2,2,2-trifluoroethyl)dimethylphosphine oxide, perfluoroethyldimethylphosphine oxide, (2-fluorocyclohexyl)dimethylphosphine oxide, (3-fluorocyclohexyl)dimethylphosphine oxide, (4-fluorocyclohexyl) dimethylphosphine oxide, diethyl(2,2,2-trifluoroethyl)phosphine oxide, di-n-butyl(2,2,2-trifluoroethyl)phosphine oxide, dicyclohexyl(2,2,2-trifluoroethyl)phosphine oxide, di(2,2,2-trifluoroethyl)methylphosphine oxide, ethyl(2,2,2-trifluoroethyl)phosphine oxide, n-butyldi(2,2,2-trifluoroethyl)phosphine oxide, cyclohexyldi(2,2,2-trifluoroethyl)phosphine oxide, ethylmethylperfluoromethylphosphine oxide, ethylmethyl(2,2,2-trifluoroethyl)phosphine oxide, ethylmethylper-

fluoroethylphosphine oxide, ethylmethyl(2-fluorocyclohexyl)phosphine oxide, ethylmethyl(3-fluorocyclohexyl) phosphine oxide, ethylmethyl(4-fluorocyclohexyl) phosphine oxide, n-butylmethyl(2,2,2-trifluoroethyl) phosphine oxide, n-butylethyl-n-propylphosphine oxide, n-butylethylcyclohexylphosphine oxide, n-butylethyl(2,2,2-trifluoroethyl)phosphine oxide, cyclohexylethyl(2,2,2-trifluoroethyl)phosphine oxide and n-butylcyclohexyl(2,2,2-trifluoroethyl)phosphine oxide.

[0501] Concrete examples of the phosphine oxide possessing an unsaturated hydrocarbon group include tri(2-cyclohexenyl)phosphine oxide, tri(3-cyclohexenyl)phosphine oxide, trivinylphosphine oxide, triallylphosphine oxide, tripropargylphosphine oxide, (2-cyclohexenyl)dimethylphosphine oxide, (3-cyclohexenyl)dimethylphosphine oxide, dimethylvinylphosphine oxide, allyldimethylphosphine oxide, dimethylpropargylphosphine oxide, ethylmethyl(2-cyclohexenyl)phosphine oxide, ethylmethyl(3-cyclohexenyl)phosphine oxide, ethylmethylvinylphosphine oxide, ethylmethylallylphosphine oxide and ethylmethylpropargylphosphine oxide.

[0502] Concrete examples of the phosphine oxide possessing a fluorine atom-substituted unsaturated hydrocarbon group include tri(2-fluorovinyl)phosphine oxide, tri(2,2-difluorovinyl)phosphine oxide, (2-fluorovinyl)dimethylphosphine oxide, (2,2-difluorovinyl)dimethylphosphine oxide, ethylmethyl(2-fluorovinyl)phosphine oxide and ethylmethyl (2,2-difluorovinyl)phosphine oxide.

[0503] Concrete examples of the phosphine oxide possessing an aryl group include triphenylphosphine oxide, tri(2-toluyl)phosphine oxide, tri(3-toluyl)phosphine oxide, tri(4-toluyl)phosphine oxide, dimethylphenylphosphine oxide, dimethyl(2-toluyl)phosphine oxide, dimethyl(3-toluyl)phosphine oxide, dimethyl(4-toluyl)phosphine oxide, diethylphenylphosphine oxide, di-n-butylphenylphosphine oxide, dicyclohexylphenylphosphine oxide, diphenylmethylphosphine oxide, ethyldiphenylphosphine oxide, n-butyldiphenylphosphine oxide, cyclohexyldiphenylphosphine oxide, ethylmethylphenylphosphine oxide, ethylmethyl(2-toluyl)phosphine oxide, ethylmethyl(3-toluyl)phosphine oxide, ethylmethyl(4-toluyl)phosphine oxide, n-butylmethylphenylphosphine oxide, cyclohexylmethylphenylphosphine oxide, n-butylethylphenylphosphine oxide, cyclohexylethylphenylphosphine oxide and n-butylcyclohexylphenylphosphine oxide.

[0504] Concrete examples of the dialkylarylphosphine oxide [SIC] containing a fluorine atom substituent include tri(2-fluorophenyl)phosphine oxide, tri(3-fluorophenyl) phosphine oxide, tri(4-fluorophenyl)phosphine oxide, (2-fluorophenyl)dimethylphosphine oxide, (2-fluorophenyl) dimethylphosphine oxide, (3-fluorophenyl)dimethylphosphine oxide, (3-fluorophenyl)dimethylphosphine oxide [SIC], (4-fluorophenyl)dimethylphosphine oxide, (2-fluorophenyl)diethylphosphine oxide, (2-fluorophenyl)di-n-butylphosphine oxide, (2-fluorophenyl)dicyclohexylphosphine oxide, diphenyl(2,2,2-trifluoroethyl)phosphine oxide, (2-fluorophenyl)diphenylphosphine oxide, phenyldi(2,2,2-trifluoroethyl)phosphine oxide, (2-fluorophenyl)di(2,2,2-trifluoroethyl)phosphine oxide, di(2-fluorophenyl)methylphosphine oxide, ethyl(2-fluorophenyl)phosphine oxide, n-butyldi(2-fluorophenyl)phosphine oxide, cyclohexyldi(2-fluorophenyl)phosphine oxide, phenyldi(2-fluorophenyl) phosphine oxide, di(2-fluorophenyl)(2,2,2-trifluoroethyl) phosphine oxide, ethylmethyl(2-fluorophenyl)phosphine oxide, ethylmethyl(3-fluorophenyl)phosphine oxide, ethylmethyl(4-fluorophenyl)phosphine oxide, n-butylmethyl(2-fluorophenyl)phosphine oxide, cyclohexylmethyl(2-fluorophenyl)phosphine oxide, phenylmethyl(2,2,2-trifluoroethyl)phosphine oxide, phenylmethyl(2-fluorophenyl)phosphine oxide, (2,2,2-trifluoroethyl)methyl (2-fluorophenyl)phosphine oxide, n-butylethyl(2-fluorophenyl)phosphine oxide, cyclohexylethyl(2-fluorophenyl)phosphine oxide, ethylphenyl(2,2,2-trifluoroethyl)phosphine oxide, ethylphenyl(2-fluorophenyl) phosphine oxide, ethyl(2,2,2-trifluoroethyl)(2-fluorophenyl) phosphine oxide, n-butylcyclohexyl(2-fluorophenyl) phosphine oxide, n-butylphenyl(2,2,2-trifluoroethyl) phosphine oxide, n-butylphenyl(2-fluorophenyl)phosphine oxide, n-butyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphine oxide, cyclohexylphenyl(2,2,2-trifluoroethyl)phosphine oxide, cyclohexylphenyl(2-fluorophenyl)phosphine oxide, cyclohexylphenyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphine oxide, phenyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphine oxide and perfluoroethyl(2,2,2-trifluoroethyl)(2-fluorophenyl)phosphine oxide.

[0505] Concrete examples of the phosphine oxide in which any two of R^{d1}, R^{d2} and R^{d3} are bonded together to form a ring structure include 1-methylphosphorane-1-oxide, 1-ethylphosphorane-1-oxide, 1-n-butylphosphorane-1-oxide, 1-phenylphosphorane-1-oxide, 1-(2,2,2-trifluoroethyl)-1-oxide [SIC], 1-(2-fluphenyl)-1-oxide [SIC], 1,2-dimethylphosphorane-1-oxide, 1,3-dimethylphosphorane-1-oxide, 1-methyl-2-ethylphosphorane-1-oxide, 2-methyl-1-ethylphosphorane-1-oxide, 1-methylphosphinane-1-oxide and 1-ethylphosphinane-1-oxide.

[0506] Of the phosphine oxides exemplified above, particularly preferable as specific compound (D) are trimethyl phosphine oxide, triethyl phosphine oxide, tri-n-butyl phosphine oxide, tricyclohexyl phosphine oxide, tri(2,2,2-trifluoroethyl)phosphine oxide, triperfluoroethyl phosphine oxide, triallyl phosphine oxide and triphenyl phosphine oxide.

[0507] Even when the compounds represented by the formula (D-1) are organic phosphorous compounds where p+q=0, combined use with the specific carbonate explained later makes it possible to offer a non-aqueous liquid electrolyte secondary battery with high capacity and with superior characteristics maintained for a long time, particularly with high discharge capacity retention rate.

[0508] There is no special limitation on the molecular weight of the specific compound (D), insofar as the advantage of the present invention is not significantly impaired. However, it is usually 80 or larger, and preferably 90 or larger. There is no special limitation on the upper limit. But when it is too high, viscosity tends to increase. Therefore, to be practical, it is usually 400 or smaller, preferably 300 or smaller.

[0509] No particular limitation is imposed on the method of producing the specific compound (D), either. Any known method can be adopted and used.

[0510] The specific compound (D) explained above can be included in the non-aqueous liquid electrolyte of the present invention either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0511] There is no special limitation on the proportion of the specific compound (D) in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. However, it is preferable that the concentration in the non-aqueous liquid electrolyte of the present invention is usually 0.01 weight %

or higher, preferably 0.1 weight % or higher, and usually 10 weight % or lower, preferably 5 weight % or lower. If the proportion is below the lower limit of the above range, an adequate effect of improving cycle performance of the non-aqueous liquid electrolyte secondary battery may not be guaranteed when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery. On the other hand, when it exceeds the upper limit of the above range, its chemical reactivity in the non-aqueous liquid electrolyte tends to increase, leading possibly to decrease in battery characteristics of the above-mentioned non-aqueous liquid electrolyte secondary battery.

[0512] No limitation is imposed on the ratio of the specific compound (D) relative to the specific carbonate, in the non-aqueous liquid electrolyte of the present invention, either. However, it is preferable that the relative weight ratio, represented by "weight of the specific compound (D)/weight of the specific carbonate", is in the range of usually 0.0001 or higher, preferably 0.001 or higher, more preferably 0.01 or higher, and usually 1000 or lower, preferably 100 or lower, more preferably 10 or lower. If the above-mentioned relative weight ratio is too high or too low, the synergistic effect may not be obtained.

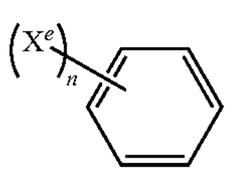
[0513] By incorporating the above-mentioned specific compound (D) and the specific carbonate in a non-aqueous liquid electrolyte, it is possible to improve the charge-discharge cycle performance of the non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte. The detailed reason is not clear, but inferred as follows. Namely, through the reaction between the specific compound (D) and the specific carbonate contained in the non-aqueous liquid electrolyte, an effective protective layer is formed on the surface of the negative-electrode active material, leading to the suppression of side reactions. Cycle deterioration is thus inhibited. The details of this reaction is not clear, but it is inferred that coexistence of the specific compound (D) and the specific carbonate in the liquid electrolyte can somehow contribute to enhancement in the protective layer characteristics.

[0514] [I-1-E. Specific Compound (E)]

[0515] Specific compound (E) is a compound represented by the formula (E-1) below.

[Chemical Formula 59]

(E-1)

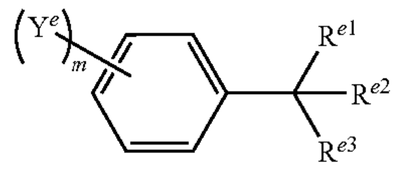


(In the formula (E-1), X^e represents a halogen atom, alkyl group or aryl group. When X^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group. n represents an integer of 1 or larger and 6 or smaller. When n is 2 or larger, the two or more of X^e may be the same or different from each other. In addition, two or more X^e may be connected to each other to form a ring structure or cage structure.)

[0516] Further, the specific compound (E) is preferably the compound represented by the formula (E-2) below.

[Chemical Formula 60]

(E-2)



(In the formula (E-2), R^{e1}, R^{e2} and R^{e3} represent, independently of each other, hydrogen atom, or an alkyl group that may be substituted with a halogen atom. In addition, two or three of R^{e1}, R^{e2} and R^{e3} may be connected to each other to form a ring structure or cage structure. However, none of or one of R^{e1}, R^{e2} and R^{e3} is hydrogen atom. Y^e represents a halogen atom, alkyl group or aryl group. When Y^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group. m represents an integer of 0 or larger and 5 or smaller. When m is 2 or larger, the two or more of Y^e may be the same or different from each other. In addition, two or more Y^e may be connected to each other to form a ring structure or cage structure.)

[0517] First, the substituent represented by X^e or Y^e in the above-mentioned formula (E-1) or (E-2).

[0518] When X^e or Y^e is a halogen atom, no particular limitation is imposed on the kind of the halogen atom. Examples of the halogen atom include fluorine atom, chlorine atom, bromine atom and iodine atom. Among them, preferable as the halogen atom is fluorine atom or chlorine atom, because the above-mentioned compound will then function also as overcharge-preventing agent when contained in a non-aqueous liquid electrolyte. Particularly preferable is fluorine atom.

[0519] When X^e or Y^e is an alkyl group, the kind thereof is not particularly limited. They can have any alkyl group structure such as chain structure, ring structure or cage structure. When they are of ring structure or cage structure, the number of the ring, the number of the member of each ring or the like is not particularly limited, either. The alkyl group may be substituted with one or more substituents. The substituent can be selected arbitrarily from the group consisting of halogen atom, alkyl group and aryl group. When the alkyl group has two or more substituents, these substituents may be the same or different from each other.

[0520] No particular limitation is imposed on the carbon number of the alkyl group. However, it is preferable to be in the range of usually 1 or more, and usually 50 or less, particularly 25 or less. When the carbon number of the alkyl group is too large, the solubility tends to decrease. When the alkyl group has a substituent of alkyl group or aryl group, the total carbon number of X^e or Y^e, including the substituents, should be adjusted to fall within the above-mentioned range.

[0521] In the following, concrete examples of the unsubstituted or substituted alkyl group are listed below.

[0522] Concrete examples of the "unsubstituted of alkyl group-substituted chain-structured alkyl group" include methyl group, ethyl group, 1-propyl group, 1-methylethyl group, 1-butyl group, 1-methylpropyl group, 2-methylpropyl group, 1,1-dimethylethyl group, 1-pentyl group, 1-methylbutyl group, 1-ethylpropyl group, 2-methylbutyl group, 3-methylbutyl group, 2,2-dimethylpropyl group, 1,1-dimethylpropyl group, 1,2-dimethylpropyl group, 1-hexyl group, 1-methylpentyl group, 1-ethylbutyl group, 2-methylpentyl group, 3-methylpentyl group, 4-methylpentyl group, 2-ethyl-

butyl group, 2,2-dimethylbutyl group, 2,3-dimethylbutyl group, 3,3-dimethylbutyl group, 1,1-dimethylbutyl group, 1,2-dimethylbutyl group, 1,1,2-trimethylpropyl group, 1,2,2-trimethylpropyl group, 1-ethyl-2-methylpropyl group and 1-ethyl-1-methylpropyl group.

[0523] Concrete examples of the "aryl group-substituted chain-structured alkyl group" include phenylmethyl group, diphenylmethyl group, triphenylmethyl group, 1-phenylethyl group, 2-phenylethyl group, (1-fluorophenyl)methyl group, (2-fluorophenyl)methyl group, (3-fluorophenyl)methyl group and (1,2-difluorophenyl)methyl group.

[0524] Concrete examples of the "halogen atom-substituted chain-structured alkyl group" include: fluorine-substituted alkyl groups such as fluoromethyl group, difluoromethyl group, trifluoromethyl group, 1-fluoroethyl group, 2-fluoroethyl group, 1,1-difluoroethyl group, 1,2-difluoroethyl group, 2,2-difluoroethyl group, and 1,1,2-trifluoroethyl group; and chlorine-substituted alkyl groups such as chloromethyl group, dichloromethyl group, trichloromethyl group, 1-chloroethyl group, 2-chloroethyl group, 1,1-dichloroethyl group, 1,2-dichloroethyl group, 2,2-dichloroethyl group, and 1,1,2-trichloroethyl group.

[0525] Concrete examples of the "unsubstituted or alkyl group-substituted cyclic-structured alkyl group" or the "cyclic-structured alkyl group" formed by bonding any two of the R^{e1}, R^{e2} and R^{e3} together include cyclopentyl group, 2-methylcyclopentyl group, 3-methylcyclopentyl group, 2,2-dimethylcyclopentyl group, 2,3-dimethylcyclopentyl group, 2,4-dimethylcyclopentyl group, 2,5-dimethylcyclopentyl group, 3,3-dimethylcyclopentyl group, 3,4-dimethylcyclopentyl group, 2-ethylcyclopentyl group, 3-ethylcyclopentyl group, cyclohexyl group, 2-methylcyclohexyl group, 3-methylcyclohexyl group, 4-methylcyclohexyl group, 2,2-dimethylcyclohexyl group, 2,3-dimethylcyclohexyl group, 2,4-dimethylcyclohexyl group, 2,5-dimethylcyclohexyl group, 2,6-dimethylcyclohexyl group, 3,4-dimethylcyclohexyl group, 3,5-dimethylcyclohexyl group, 2-ethylcyclohexyl group, 3-ethylcyclohexyl group, 4-ethylcyclohexyl group, bicyclo[3,2,1]octa-1-yl group, and bicyclo[3,2,1]octa-2-yl group.

[0526] "Unsubstituted of alkyl group-substituted cage-structured alkyl groups" or "cage-structured alkyl groups" in which R^{e1}, R^{e2} and R^{e3} are bonded together can be also exemplified. Concrete examples of the cage structure include adamantane structure and cubane structure.

[0527] Concrete examples of the "aryl group-substituted cyclic alkyl group" include 2-phenylcyclopentyl group, 3-phenylcyclopentyl group, 2,3-diphenylcyclohexyl group, 2,4-diphenylcyclohexyl group, 2,5-diphenylcyclohexyl group, 3,4-diphenylcyclohexyl group, 2-phenylcyclohexyl group, 3-phenylcyclohexyl group, 4-phenylcyclohexyl group, 2,3-diphenylcyclohexyl group, 2,4-diphenylcyclohexyl group, 2,5-diphenylcyclohexyl group, 2,6-diphenylcyclohexyl group, 3,4-diphenylcyclohexyl group, 3,5-diphenylcyclohexyl group, 2-(2-fluorophenyl)cyclohexyl group, 2-(3-fluorophenyl)cyclohexyl group, 2-(4-fluorophenyl)cyclohexyl group, 3-(2-fluorophenyl)cyclohexyl group, 4-(2-fluorophenyl)cyclohexyl group, and 2,3-bis(2-fluorophenyl) cyclohexyl group.

[0528] Concrete examples of the "halogen atom-substituted cyclic alkyl group" include 2-fluorocyclopentyl group, 3-fluorocyclopentyl group, 2,3-difluorocyclopentyl group, 2,4-difluorocyclopentyl group, 2,5-difluorocyclopentyl group, 3,4-difluorocyclopentyl group, 2-fluorocyclohexyl group, 3-fluorocyclohexyl group, 4-fluorocyclohexyl group, 2,3-difluorocyclohexyl group, 2,4-difluorocyclohexyl group, 2,5-difluorocyclohexyl group, 2,6-difluorocyclohexyl group, 3,4-difluorocyclohexyl group, 3,5-difluorocyclohexyl group, 2,3,4-triORocyclohexyl group [SIC], 2,3,5-trifluORocyclohexyl group [SIC], 2,3,6-triORocyclohexyl group [SIC], 2,4,5-triORocyclohexyl group [SIC], 2,4,6-triORocyclohexyl group [SIC], 2,5,6-triORocyclohexyl group [SIC], 3,4,5-triORocyclohexyl group [SIC], 2,3,4,5-tetraORocyclohexyl group [SIC], 2,3,4,6-tetraORocyclohexyl group [SIC], 2,3,5,6-tetraORocyclohexyl group [SIC]and pentafluorocyclohexyl group.

[0529] Of the unsubstituted or substituted alkyl groups exemplified above, preferable are unsubstituted, fluorine-substituted or chlorine-substituted alkyl groups, because the above-mentioned specific compound (E) will then react also as overcharge-preventing agent when contained in a non-aqueous liquid electrolyte. Particularly preferable are unsubstituted or fluorine-substituted alkyl groups.

[0530] On the other hand, when X^e or Y^e is an aryl group, the kind thereof is not particularly limited, either. They may be monocyclic or polycyclic. The number of the ring, the number of the member of each ring or the like is not particularly limited, either. The aryl group may be substituted with one or more substituents. The substituent can be selected arbitrarily from the group consisting of halogen atom, alkyl group and aryl group. When the aryl group has two or more substituents, these substituents may be the same or different from each other.

[0531] No particular limitation is imposed on the carbon number of the aryl group. It is preferable to be usually 6 or more. When the aryl group has a substituent of alkyl group or aryl group, the total carbon number of X^e or Y^e, including the substituents, should be adjusted to fall within the above-mentioned range.

[0532] In the following, concrete examples of the unsubstituted or substituted aryl group are listed below.

[0533] Concrete examples of the "unsubstituted or alkyl group-substituted aryl group" include phenyl group, 2-methylphenyl group, 3-methylphenyl group, 4-methylphenyl group, 2,3-dimethylphenyl group, 2,4-dimethylphenyl group, 2,5-dimethylphenyl group, 2,6-dimethylphenyl group, 2,3,4-trimethylphenyl group, 2,3,5-trimethylphenyl group, 2,3,6-trimethylphenyl group, 2,4,5-trimethylphenyl group, 2,3,6-trimethylphenyl group, 2,5,6-trimethylphenyl group, 3,4,5-trimethylphenyl group, 2,3,4,5-tetramethylphenyl group, 2,3,4,6-tetramethylphenyl group, 2,4,5,6-tetramethylphenyl group, pentamethylphenyl group, 1-naphthyl group and 2-naphthyl group.

[0534] Concrete examples of the "aryl group-substituted aryl group" include (2-phenyl)phenyl group, (3-phenyl)phenyl group, and (4-phenyl)phenyl group.

[0535] As concrete examples of the "halogen atom-substituted aryl group" include 2-fluorophenyl group, 3-fluorophenyl group, 4-fluorophenyl group, 2,3-difluorophenyl group, 2,4-difluorophenyl group, 2,5-difluorophenyl group, 2,6-difluorophenyl group, 2,3,4-trifluorophenyl group, 2,3,5-trifluorophenyl group, 2,3,6-trifluorophenyl group, 2,4,5-trifluorophenyl group, 2,3,6-trifluorophenyl group, 2,5,6-trifluorophenyl group, 3,4,5-trifluorophenyl group, 2,3,4,5-tetrafluorophenyl group, 2,3,4,6-tetrafluorophenyl group, 2,4,5,6-tetrafluorophenyl group and pentafluorophenyl group.

[0536] Of the unsubstituted or substituted aryl groups exemplified above, preferable are unsubstituted, fluorine-substituted or chlorine-substituted aryl groups, because the above-mentioned specific compound (E) will then react also as overcharge-preventing agent when contained in a non-aqueous liquid electrolyte. Particularly preferable are unsubstituted or fluorine-substituted alkyl groups.

[0537] In the above-mentioned formula (E-1), n represents an integer of usually 1 or larger, and usually 6 or smaller, preferably 3 or smaller. When n is 2 or larger, the two or more of X^e may be the same or different from each other. However, it is preferable that those X^e are the same as each other, from the standpoint of ease in the synthesis.

[0538] In the above-mentioned formula (E-2), m represents an integer of usually 0 or larger, and usually 5 or smaller, preferably 3 or smaller. When m is 2 or larger, the two or more of Y^e may be the same or different from each other. However, it is preferable that those Y^e are the same as each other, from the standpoint of ease in the synthesis.

[0539] In addition, two or more X^e or two or more Y^e may be connected to each other respectively to form a ring structure or cage structure. Concrete examples of the ring structure or cage structure in such cases include adamantane structure and cubane structure.

[0540] In the above-mentioned formula (E-2), R^{e1}, R^{e2} and R^{e3} represent, independently of each other, hydrogen atom or an alkyl group. However, none of or one of R^{e1}, R^{e2} and R^{e3} is hydrogen atom.

[0541] When R^{e1}, R^{e2} or R^{e3} is an alkyl group, the alkyl group may be substituted with one or more halogen atoms. In addition, two or three of R^{e1}, R^{e2} and R^{e3} may be connected to each other to form a ring structure or cage structure. Concrete examples of these unsubstituted or halogen-substituted alkyl group and concrete examples of the ring structure or cage structure are the same as those described above for X^e and Y^e.

[0542] The carbon numbers of R^{e1}, R^{e2} and R^{e3} are not particularly limited, either. However, it is preferable that the total carbon number of R^{e1}, R^{e2} and R^{e3} is usually 1 or larger, particularly 2 or larger.

[0543] Next, concrete examples of the compounds represented by the formulae (E-1) and (E-2) below.

[0544] As such concrete examples in which the substituents of X^e and Y^e are a halogen atom include monosubstituted compounds such as fluorobenzene, chlorobenzene, bromobenzene, and iodobenzene; disubstituted compounds such as difluorobenzene, dichlorobenzene, dibromobenzene, and diiodobenzene; and trisubstituted compounds such as trifluorobenzene, trichlorobenzene, tribromobenzene, and triiodobenzene.

[0545] Concrete examples of the compound in which the substituents of X^e and Y^e are an unsubstituted or alkyl group-substituted chained alkyl group include monosubstituted compounds such as (1-methylethyl)benzene, (1,1-dimethylethy)benzene, (1-methylpropyl)benzene, (1-methylbutyl)benzene, (1-ethylpropyl)benzene, and (1,1-dimethylpropyl)benzene; disubstituted compounds such as 1,2-bis(1-mehtylethyl)benzene, 1,2-bis(1,1-dimethylethyl)benzene, 1,2-bis(1,1-dimethylpropyl)benzene, 1,3-bis(1-methylethyl)benzene, 1,3-bis(1,1-dimethylethyl)benzene, 1,3-bis(1,1-dimethylpropyl)benzene, 1,4-bis(1-methylethyl)benzene, 1,4-bis(1,1-dimethylethyl)benzene, and 1,4-bis(1,1-dimethylpropyl)benzene; and trisubstituted compounds such as 1,2,3-tris(1-methylethyl)benzene, 1,2,3-tris(1,1-dimethylethyl)benzene, 1,2,3-tris(1,1-dimethylpropyl)benzene, 1,2,4-tris(1-methylethyl)benzene, 1,2,4-tris(1,1-dimethylethyl)benzene, 1,2,4-tris(1,1-dimethylpropyl)benzene, 1,2,5-tris(1-methylethyl)benzene, 1,2,5-tris(1,1-dimethylethyl)benzene, 1,2,5-tris(1,1-dimethylpropyl)benzene, 1,3,5-tris(1-methylethyl)benzene, 1,3,5-tris(1,1-dimethylethyl)benzene, and 1,3,5-tris(1,1-dimethylpropyl)benzene.

[0546] Concrete examples of the compound in which one of the substituents X^e and Y^e is a halogen atom and another of them is an unsubstituted or alkyl group-substituted chained alkyl group include 1-fluoro-2-(1-methylethyl)benzene, 1-(1,1-dimethylethyl)-2-fluorobenzene, 1-fluoro-2-(1-methylpropyl)benzene, 1-fluoro-2-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, 1-fluoro-2-(1,1-dimethylpropyl)benzene, 1-fluoro-3-(1-methylethyl)benzene, 1-(1,1-dimethylethyl)-3-fluorobenzene, 1-fluoro-3-(1-methylpropyl)benzene, 1-fluoro-3-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, 1-fluoro-3-(1,1-dimethylpropyl)benzene, 1-fluoro-4-(1-methylethyl)benzene, 1-(1,1-dimethylethyl)-4-fluorobenzene, 1-fluoro-4-(1-methylpropyl)benzene, 1-fluoro-4-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, and 1-fluoro-4-(1,1-dimethylpropyl)benzene.

[0547] Concrete examples of the compound in which the substituents of X^e and Y^e are an unsubstituted or alkyl group-substituted cyclic alkyl group, or in which the substituent of Y^e is a cyclic alkyl group formed by bonding any two of the R^{e1}, R^{e2} and R^{e3} together include monosubstituted compounds such as cyclopentylbenzene, cyclohexylbenzene, (2-cyclohexyl)cyclohexylbenzene, (3-cyclohexyl)cyclohexylbenzene, (4-cyclohexyl)cyclohexylbenzene, 1-cyclohexyl-2-phenylcyclohexane, 1-cyclohexyl-3-phenylcyclohexane, and 1-cyclohexyl-4-phenylcyclohexane; disubstituted compounds such as 1,2-dicyclopentylbenzene, 1,3-dicyclopentylbenzene, 1,4-dicyclopentylbenzene, 1,2-dicyclohexylbenzene, 1,3-dicyclohexylbenzene, and 1,4-dicyclohexylbenzene; and trisubsituted compounds such as 1,2,3-tricyclopentylbenzene, 1,2,4-tricyclopentylbenzene, 1,2,5-tricyclopentylbenzene, 1,3,5-tricyclopentylbenzene, 1,2,3-tricyclohexylbenzene, 1,2,4-tricyclohexylbenzene, 1,2,5-tricyclohexylbenzene, and 1,3,5-tricyclohexylbenzene.

[0548] Concrete examples of the compound in which one of the substituents X^e and Y^e is a halogen atom and another of them is an unsubstituted or alkyl group-substituted cyclic alkyl group include 1-cyclopentyl-2-fluorobenzene, 1-cyclohexyl-2-fluorobenzene, 1-cyclopentyl-3-fluorobenzene, 1-cyclohexyl-3-fluorobenzene, 1-cyclopentyl-4-fluorobenzene, and 1-cyclohexyl-4-fluorobenzene.

[0549] Concrete examples of the compound in which the substituents of X^e and Y^e are an unsubstituted or alkyl group-substituted aryl group include monosubstituted compounds such as phenylbenzene; disubstituted compounds such as 1,2-diphenylbenzene, 1,3-diphenylbenzene, and 1,4-diphenylbenzene; and trisubstituted compounds such as 1,2,3-triphenylbenzene, 1,2,4-triphenylbenzene, 1,2,5-triphenylbenzene, and 1,3,5-triphenylbenzene.

[0550] Concrete examples of the compound in which one of the substituents X^e and Y^e is a halogen atom and another of them is an unsubstituted, alkyl group-substituted or halogen atom-substituted aryl group include 1-fluoro-2-phenylbenzene, 1-fluoro-3-phenylbenzene, 1-fluoro-4-phenylbenzene, 1-fluoro-2-(2-fluorophenyl)benzene, 1-fluoro-3-(2-fluorophenyl)benzene, 1-fluoro-4-(2-fluorophenyl)benzene, 1-fluoro-2-(3-fluorophenyl)benzene, 1-fluoro-3-(3-fluorophenyl)benzene, 1-fluoro-4-(3-fluorophenyl)benzene,

1-fluoro-2-(4-fluorophenyl)benzene, 1-fluoro-3-(4-fluorophenyl)benzene, and 1-fluoro-4-(4-fluorophenyl)benzene.

[0551] Concrete examples of the compound in which one of the substituents of X^e and Y^e is an unsubstituted or alkyl group-substituted chained alkyl group and another of them is an aryl group include 1-(1,1-dimethylethyl)-2-phenylbenzene, 1-(1,1-dimethylethyl)-3-phenylbenzene, 1-(1,1-dimethylethyl)-4-phenylbenzene, 1-(1,1-dimethylpropyl)-2-phenylbenzene, 1-(1,1-dimethylpropyl)-3-phenylbenzene, and 1-(1,1-dimethylpropyl)-4-phenylbenzene.

[0552] Concrete examples of the compound in which one of the substituents of X^e and Y^e is an unsubstituted or alkyl group-substituted cyclic alkyl group and another of them is an aryl group include 1-cyclohexyl-2-phenylbenzene, 1-cyclohexyl-3-phenylbenzene, and 1-cyclohexyl-4-phenylbenzene.

[0553] Concrete examples of the compound in which the substituents of X^e and Y^e are an aryl group-substituted cyclic alkyl group include (2-phenyl)cyclohexylbenzene, (3-phenyl)cyclohexylbenzene, and (4-phenyl)cyclohexylbenzene.

[0554] Among the compounds exemplified above, preferable as the specific compound (E) are compounds represented by the above-mentioned formula (E-2), because they react also as overcharge-preventing agent.

[0555] Concrete examples of the compounds represented by the above-mentioned formula (E-2) will be listed below.

[0556] Concrete examples of the compound in which the substituent of Y^e is an unsubstituted or alkyl group-substituted chained alkyl group include monosubstituted compounds such as (1-methylethyl)benzene, (1,1-dimethylethy) benzene, (1-methylpropyl)benzene, (1-methylbutyl) benzene, (1-ethylpropyl)benzene, and (1,1-dimethylpropyl) benzene; disubstituted compounds such as 1,2-bis(1-mehtylethyl)benzene, 1,2-bis(1,1-dimethylethyl)benzene, 1,2-bis(1,1-dimethylpropyl)benzene, 1,3-bis(1-methylethyl) benzene, 1,3-bis(1,1-dimethylethyl)benzene, 1,3-bis(1,1-dimethylpropyl)benzene, 1,4-bis(1-methylethyl)benzene, 1,4-bis(1,1-dimethylethyl)benzene, and 1,4-bis(1,1-dimethylpropyl)benzene; and trisubstituted compounds such as 1,2,3-tris(1-methylethyl)benzene, 1,2,3-tris(1,1-dimethylethyl) benzene, 1,2,3-tris(1,1-dimethylpropyl)benzene, 1,2,4-tris (1-methylethyl)benzene, 1,2,4-tris(1,1-dimethylethyl) benzene, 1,2,4-tris(1,1-dimethylpropyl)benzene, 1,2,5-tris (1-methylethyl)benzene, 1,2,5-tris(1,1-dimethylethyl) benzene, 1,2,5-tris(1,1-dimethylpropyl)benzene, 1,3,5-tris (1-methylethyl)benzene, 1,3,5-tris(1,1-dimethylethyl) benzene, and 1,3,5-tris(1,1-dimethylpropyl)benzene.

[0557] Concrete examples of the compound in which one of the substituent Y^e is a halogen atom and another Y^e is an unsubstituted or alkyl group-substituted chained alkyl group include 1-fluoro-2-(1-methylethyl)benzene, 1-(1,1-dimethylethyl)-2-fluorobenzene, 1-fluoro-2-(1-methylpropyl)benzene, 1-fluoro-2-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, 1-fluoro-2-(1,1-dimethylpropyl)benzene, 1-fluoro-3-(1-methylbutyl)benzene, 1-(1,1-dimethylethyl)-3-fluorobenzene, 1-fluoro-3-(1-methylpropyl)benzene, 1-fluoro-3-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, 1-fluoro-3-(1,1-dimethylpropyl)benzene, 1-fluoro-4-(1-methylethyl)benzene, 1-(1,1-dimethylethyl)-4-fluorobenzene, 1-fluoro-4-(1-methylpropyl)benzene, 1-fluoro-4-(1-methylbutyl)benzene, 1-fluoro-(1-ethylpropyl)benzene, and 1-fluoro-4-(1,1-dimethylpropyl)benzene.

[0558] Concrete examples of the compound in which the substituent of Y^e is an unsubstituted or alkyl group-substituted cyclic alkyl group, or a cyclic-structured alkyl group formed by bonding any two of the R^{e1}, R^{e2} and R^{e3} together include monosubstituted compounds such as cyclopentylbenzene, cyclohexylbenzene, (2-cyclohexyl)cyclohexylbenzene, (3-cyclohexyl)cyclohexylbenzene, (4-cyclohexyl)cyclohexylbenzene, 1-cyclohexyl-2-phenylcyclohexane, 1-cyclohexyl-3-phenylcyclohexane, and 1-cyclohexyl-4-phenylcyclohexane; disubstituted compounds such as 1,2-dicyclopentylbenzene, 1,3-dicyclopentylbenzene, 1,4-dicyclopentylbenzene, 1,2-dicyclohexylbenzene, 1,3-dicyclohexylbenzene, and 1,4-dicyclohexylbenzene; and trisubsituted compounds such as 1,2,3-tricyclopentylbenzene, 1,2,4-tricyclopentylbenzene, 1,2,5-tricyclopentylbenzene, 1,3,5-tricyclopentylbenzene, 1,2,3-tricyclohexylbenzene, 1,2,4-tricyclohexylbenzene, 1,2,5-tricyclohexylbenzene, and 1,3,5-tricyclohexylbenzene.

[0559] Concrete examples of the compound in which one of the substituent Y^e is a halogen atom and another Y^e is an unsubstituted or alkyl group-substituted cyclic alkyl group include 1-cyclopentyl-2-fluorobenzene, 1-cyclohexyl-2-fluorobenzene, 1-cyclopentyl-3-fluorobenzene, 1-cyclohexyl-3-fluorobenzene, 1-cyclopentyl-4-fluorobenzene, and 1-cyclohexyl-4-fluorobenzene.

[0560] Among the compounds exemplified above, particularly preferable are (1,1-dimethylethyl)benzene, (1,1-dimethylpropyl)benzene, cyclohexylbenzene, 1-cyclopentyl-2-fluorobenzene, 1-cyclopentyl-3-fluorobenzene, 1-cyclopentyl-4-fluorobenzene, 1-cyclohexyl-2-phenylbenzene, 1-cyclohexyl-3-phenylbenzene, 1-cyclohexyl-4-phenylbenzene, (2-cyclohexyl)cyclohexylbenzene, (3-cyclohexyl)cyclohexylbenzene, (4-cyclohexyl) cyclohexylbenzene, (2-phenyl)cyclohexylbenzene, (3-phenyl)cyclohexylbenzene, and (4-phenyl)cyclohexylbenzene.

[0561] Also, compounds in which X^e in the formula (E-1) is a halogen atom, or an unsubstituted or halogen atom-substituted aryl group are preferable. Concrete examples include the following compounds.

[0562] Concrete examples in which the substituent X^e is a halogen atom include monosubstituted compounds such as fluorobenzene, chlorobenzene, bromobenzene, and iodobenzene; disubstituted compounds such as difluorobenzene, dichlorobenzene, dibromobenzene, and diiodobenzene; and trisubstituted compounds such as trifluorobenzene, trichlorobenzene, tribromobenzene, and triiodobenzene.

[0563] Concrete examples of the compound in which one of the substituent X^e is a halogen atom and another X^e is an unsubstituted, alkyl group-substituted or halogen atom-substituted aryl group include 1-fluoro-2-phenylbenzene, 1-fluoro-3-phenylbenzene, 1-fluoro-4-phenylbenzene, 1-fluoro-2-(2-fluorophenyl)benzene, 1-fluoro-3-(2-fluorophenyl)benzene, 1-fluoro-4-(2-fluorophenyl)benzene, 1-fluoro-2-(3-fluorophenyl)benzene, 1-fluoro-3-(3-fluorophenyl)benzene, 1-fluoro-4-(3-fluorophenyl)benzene, 1-fluoro-2-(4-fluorophenyl)benzene, 1-fluoro-3-(4-fluorophenyl)benzene, and 1-fluoro-4-(4-fluorophenyl)benzene.

[0564] Concrete examples of the compound in which one of the substituent X^e is an unsubstituted or alkyl group-substituted chained alkyl group and another X^e is an aryl group include 1-(1,1-dimethylethyl)-2-phenylbenzene, 1-(1,1-dimethylethyl)-3-phenylbenzene, 1-(1,1-dimethylethyl)-4-phenylbenzene, 1-(1,1-dimethylpropyl)-2-phenylbenzene, 1-(1,1-dimethylpropyl)-3-phenylbenzene, and 1-(1,1-dimethylpropyl)-4-phenylbenzene.

[0565] Concrete examples of the compound in which one of the substituent X^e is an unsubstituted or alkyl group-substituted cyclic alkyl group and another X^e is an aryl group include 1-cyclohexyl-2-phenylbenzene, 1-cyclohexyl-3-phenylbenzene, and 1-cyclohexyl-4-phenylbenzene.

[0566] Among the compounds exemplified above, particularly preferable are fluorobenzene, 1-cyclopentyl-2-fluorobenzene, 1-cyclopentyl-3-fluorobenzene, 1-cyclopentyl-4-fluorobenzene, phenylbenzene, 1,2-diphenylbenzene, 1,3-diphenylbenzene, 1,4-diphenylbenzene, 1-cyclohexyl-2-phenylbenzene, 1-cyclohexyl-3-phenylbenzene, and 1-cyclohexyl-4-phenylbenzene.

[0567] There is no special limitation on the molecular weight of the specific compound (E), insofar as the advantage of the present invention is not significantly impaired. However, it is usually 100 or more, and preferably 110 or more. There is no special limitation on the upper limit, but when it is too high, viscosity tends to increase. Therefore, to be practical, it is usually 400 or smaller, preferably 300 or smaller.

[0568] No particular limitation is imposed on the method of producing the specific compound (E), either. Any known method can be adopted and used.

[0569] The specific compound (E) explained above can be included in the non-aqueous liquid electrolyte of the present invention either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0570] There is no special limitation on the proportion of the specific compound (E) in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. However, it is preferable that the concentration in the non-aqueous liquid electrolyte of the present invention is usually 0.01 weight % or higher, preferably 0.1 weight % or higher, and usually 10 weight % or lower, preferably 5 weight % or lower. If the proportion is below the lower limit of the above range, an adequate effect of improving cycle performance of the non-aqueous liquid electrolyte secondary battery may not be guaranteed when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery. On the other hand, when it exceeds the upper limit of the above range, its chemical reactivity in the non-aqueous liquid electrolyte tends to increase, leading possibly to decrease in battery characteristics of the above-mentioned non-aqueous liquid electrolyte secondary battery.

[0571] No limitation is imposed on the ratio of the specific compound (E) relative to the specific carbonate, in the non-aqueous liquid electrolyte of the present invention, either. However, it is preferable that the relative weight ratio, represented by "weight of the specific compound (E) weight of the specific carbonate", is in the range of usually 0.0001 or higher, preferably 0.001 or higher, more preferably 0.01 or higher, and usually 1000 or lower, preferably 100 or lower, more preferably 10 or lower. If the above-mentioned relative weight ratio is too high or too low, the synergistic effect may not be obtained.

[0572] By incorporating the above-mentioned specific compound (E) and the specific carbonate in a non-aqueous liquid electrolyte, it is possible to improve the charge-discharge cycle performance of the non-aqueous liquid electrolyte secondary battery using the non-aqueous liquid electrolyte. The detailed reason is not clear, but inferred as follows. Namely, through the reaction between the specific compound (E) and the specific carbonate contained in the non-aqueous liquid electrolyte, an effective protective layer is formed on the surface of the negative-electrode active material, leading to the suppression of side reactions. Cycle deterioration is thus inhibited. The details of this reaction is not clear, but it is inferred that coexistence of the specific compound (E) and the specific carbonate in the liquid electrolyte can somehow contribute to enhancement in the protective layer characteristics.

[0573] [I-2. Specific Carbonate]

[0574] The specific carbonate according to the present invention indicates a carbonate having at least either an unsaturated bond or a halogen atom. Namely, the specific carbonate of the present invention may contain only an unsaturated bond or only a halogen atom. It may also contain both an unsaturated bond and a halogen atom.

[0575] There is no special limitation on the kind of the carbonate having an unsaturated bond (hereinafter abbreviated as "unsaturated carbonate" as appropriate) and any known unsaturated carbonate can be used, insofar as it is a carbonate having a carbon-to-carbon unsaturated bond such as carbon-to-carbon double bond or carbon-to-carbon triple bond. A carbonate having an aromatic ring can also be regarded as carbonate having an unsaturated bond.

[0576] Examples of the unsaturated carbonate include vinylene carbonate and its derivatives, ethylene carbonate substituted with a substituent having an aromatic ring or carbon-to-carbon unsaturated bond and its derivatives, phenyl carbonates, vinyl carbonates and allyl carbonates.

[0577] Concrete examples of the vinylene carbonate and its derivatives include: vinylene carbonate, methylvinylene carbonate, 4,5-dimethylvinylene carbonate, phenylvinylene carbonate, 4,5-diphenylvinylene carbonate and catechol carbonate.

[0578] Concrete examples of the ethylene carbonate substituted with a substituent containing an aromatic ring or a carbon-to-carbon unsaturated bond and its derivatives include: vinylethylene carbonate, 4,5-divinylethylene carbonate, phenylethylene carbonate and 4,5-diphenylethylene carbonate.

[0579] Concrete examples of the phenyl carbonates include: diphenyl carbonate, ethylphenyl carbonate, methylphenyl carbonate and t-butylphenyl carbonate.

[0580] Concrete examples of the vinyl carbonates include: divinyl carbonate and methylvinyl carbonate.

[0581] Concrete examples of the allyl carbonates include: diallyl carbonate and allylmethyl carbonate.

[0582] Of these unsaturated carbonates, preferable as specific carbonate are vinylene carbonate and its derivatives, and ethylene carbonate substituted with a substituent having an aromatic ring or carbon-to-carbon unsaturated bond and its derivatives. In particular, vinylene carbonate, 4,5-diphenylvinylene carbonate, 4,5-dimethylvinylene carbonate and vinylethylene carbonate can be preferably used, as they form a stable interface protective layer.

[0583] On the other hand, regarding the carbonate having a halogen atom (hereinafter abbreviated as "halogenated carbonate" as appropriate), no special limitation exists on its kind and any halogenated carbonate can be used, insofar as it contains a halogen atom.

[0584] Concrete examples of the halogen atom are fluorine atom, chlorine atom, bromine atom and iodine atom. Of these, preferable are fluorine atom and chlorine atom. Fluorine atom is particularly preferable. There is no special limitation on the number of the halogen atoms contained in the halogenated carbonate insofar as it is one or more. However, it is usually 6 or less, preferably 4 or less. When the haloge-

nated carbonate contains more than one halogen atoms, they can be identical to or different from each other.

[0585] Examples of the halogenated carbonate include ethylene carbonate and its derivatives, dimethyl carbonate and its derivatives, ethylmethyl carbonate and its derivatives and diethyl carbonate and its derivatives.

[0586] Concrete examples of the ethylene carbonate derivatives are: fluoroethylene carbonate, chloroethylene carbonate, 4,4-difluoroethylene carbonate, 4,5-difluoroethylene carbonate, 4,4-dichloroethylene carbonate, 4,5-dichloroethylene carbonate, 4-fluoro-4-methylethylene carbonate, 4-chloro-4-methylethylene carbonate, 4,5-difluoro-4-methylethylene carbonate, 4,5-dichloro-4-methylethylene carbonate, 4-fluoro-5-methylethylene carbonate, 4-chloro-5-methylethylene carbonate, 4,4-difluoro-5-methylethylene carbonate, 4,4-dichloro-5-methylethylene carbonate, 4-(fluoromethyl)-ethylene carbonate, 4-(chloromethyl)-ethylene carbonate, 4-(difluoromethyl)-ethylene carbonate, 4-(dichloromethyl)-ethylene carbonate, 4-(trifluoromethyl)-ethylene carbonate, 4-(trichloromethyl)-ethylene carbonate, 4-(fluoromethyl)-4-fluoroethylene carbonate, 4-(chloromethyl)-4-chloroethylene carbonate, 4-(fluoromethyl)-5-fluoroethylene carbonate, 4-(chloromethyl)-5-chloroethylene carbonate, 4-fluoro-4,5-dimethylethylene carbonate, 4-chloro-4,5-dimethylethylene carbonate, 4,5-difluoro-4,5-dimethylethylene carbonate, 4,5-dichloro-4,5-dimethylethylene carbonate, 4,4-difluoro-5,5-dimethylethylene carbonate and 4,4-dichloro-5,5-dimethylethylene carbonate.

[0587] Concrete examples of the dimethyl carbonate derivatives are: fluoromethyl methyl carbonate, difluoromethyl methyl carbonate, trifluoromethyl methyl carbonate, bis(fluoromethyl)carbonate, bis(difluoro)methyl carbonate, bis(trifluoro)methyl carbonate, chloromethylmethyl carbonate, dichloromethylmethyl carbonate, trichloromethylmethyl carbonate, bis(chloromethyl)carbonate, bis(dichloro)methyl carbonate and bis(trichloro)methyl carbonate.

[0588] Concrete examples of the ethylmethyl carbonate derivatives are: 2-fluoroethylmethyl carbonate, ethylfluoromethyl carbonate, 2,2-difluoroethylmethyl carbonate, 2-fluoroethylfluoromethyl carbonate, ethyldifluoromethyl carbonate, 2,2,2-trifluoroethylmethyl carbonate, 2,2-difluoroethylfluoromethyl carbonate, 2-fluoroethyldifluoromethyl carbonate, ethyltrifluoromethyl carbonate, 2-chloroethylmethyl carbonate, ethylchloromethyl carbonate, 2,2-dichloroethylmethyl carbonate, 2-chloroethylchloromethyl carbonate, ethyldichloromethyl carbonate, 2,2,2-trichloroethylmethyl carbonate, 2,2-dichloroethylchloromethyl carbonate, 2-chloroethyldichloromethyl carbonate and ethyltrichloromethyl carbonate.

[0589] Concrete examples of the diethyl carbonate derivatives are: ethyl-(2-fluoroethyl)carbonate, ethyl-(2,2-difluoroethyl)carbonate, bis(2-fluoroethyl)carbonate, ethyl-(2,2,2-trifluoroethyl)carbonate, 2,2-difluoroethyl-2'-fluoroethyl carbonate, bis(2,2-difluoroethyl)carbonate, 2,2,2-trifluoroethyl-2'-fluoroethyl carbonate, 2,2,2-trifluoroethyl-2',2'-difluoroethyl carbonate, bis(2,2,2-trifluoroethyl)carbonate, ethyl-(2-chloroethyl)carbonate, ethyl-(2,2-dichloroethyl) carbonate, bis(2-chloroethyl)carbonate, ethyl-(2,2,2-trichloroethyl)carbonate, 2,2-dichloroethyl-2'-chloroethyl carbonate, bis(2,2-dichloroethyl)carbonate, 2,2,2-trichloroethyl-2'-chloroethyl carbonate, 2,2,2-trichloroethyl-2',2'-dichloroethyl carbonate and bis(2,2,2-trichloroethyl) carbonate.

[0590] Of these halogenated carbonates, preferable are carbonates containing a fluorine atom. More preferable are ethylene carbonate and its derivatives containing a fluorine atom. In particular, fluoroethylene carbonate, 4-(fluoromethyl)-ethylene carbonate, 4,4-difluoroethylene carbonate and 4,5-difluoroethylene carbonate can preferably be used, as these compounds form an interface protective layer.

[0591] Furthermore, it is possible to use a carbonate containing both an unsaturated bond and a halogen atom (hereinafter abbreviated as "halogenated unsaturated carbonate" as appropriate) as specific carbonate. There is no special limitation on the halogenated unsaturated carbonate used and any such compounds can be used, insofar as the advantage of the present invention is not significantly impaired.

[0592] Examples of the halogenated unsaturated carbonates include vinylene carbonate and its derivatives, ethylene carbonate substituted with a substituent having an aromatic ring or carbon-to-carbon unsaturated bond and its derivatives, and allyl carbonates [SIC].

[0593] Concrete examples of the vinylene carbonate derivatives include: fluorovinylene carbonate, 4-fluoro-5-methylvinylene carbonate, 4-fluoro-5-phenylvinylene carbonate, chlorovinylene carbonate, 4-chloro-5-methylvinylene carbonate and 4-chloro-5-phenylvinylene carbonate.

[0594] Concrete examples of the ethylene carbonate substituted with a substituent having an aromatic ring or carbon-to-carbon unsaturated bond and its derivatives include: 4-fluoro-4-vinylethylene carbonate, 4-fluoro-5-vinylethylene carbonate, 4,4-difluoro-5-vinylethylene carbonate, 4,5-difluoro-4-vinylethylene carbonate, 4-chloro-5-vinylethylene carbonate, 4,4-dichloro-5-vinylethylene carbonate, 4,5-dichloro-4-vinylethylene carbonate, 4-fluoro-4,5-divinylethylene carbonate, 4,5-difluoro-4,5-divinylethylene carbonate, 4-chloro-4,5-divinylethylene carbonate, 4,5-dichloro-4,5-divinylethylene carbonate, 4-fluoro-4-phenylethylene carbonate, 4-fluoro-5-phenylethylene carbonate, 4,4-difluoro-5-phenylethylene carbonate, 4,5-difluoro-4-phenylethylene carbonate, 4-chloro-4-phenylethylene carbonate, 4-chloro-5-phenylethylene carbonate, 4,4-dichloro-5-phenylethylene carbonate, 4,5-dichloro-4-phenylethylene carbonate, 4,5-difluoro-4,5-diphenylethylene carbonate and 4,5-dichloro-4,5-diphenylethylene carbonate.

[0595] Concrete examples of the phenyl carbonates include: fluoromethylphenyl carbonate, 2-fluoroethylphenyl carbonate, 2,2-difluoroethylphenyl carbonate, 2,2,2-trifluoroethylphenyl carbonate, chloromethylphenyl carbonate, 2-chloroethylphenyl carbonate, 2,2-dichloroethylphenyl carbonate and 2,2,2-trichloroethylphenyl carbonate.

[0596] Concrete examples of the vinyl carbonates include: fluoromethylvinyl carbonate, 2-fluoroethylvinyl carbonate, 2,2-difluoroethylvinyl carbonate, 2,2,2-trifluoroethylvinyl carbonate, chloromethylvinyl carbonate, 2-chloroethylvinyl carbonate, 2,2-dichloroethylvinyl carbonate and 2,2,2-trichloroethylvinyl carbonate.

[0597] Concrete examples of the allyl carbonates include: fluoromethylallyl carbonate, 2-fluoroethylallyl carbonate, 2,2-difluoroethylallyl carbonate, 2,2,2-trifluoroethylallyl carbonate, chloromethylallyl carbonate, 2-chloroethylallyl carbonate, 2,2-dichloroethylallyl carbonate and 2,2,2-trichloroethylallyl carbonate.

[0598] Of the halogenated unsaturated carbonates mentioned above, particularly preferable as specific carbonate are one or more compounds selected from the group consisting of vinylene carbonate, vinylethylene carbonate, fluoroethylene

carbonate, 4,5-difluoroethylene carbonate, and derivatives of these carbonate compounds, which are highly effective when used alone.

[0599] There is no special limitation on the molecular weight of the specific carbonate, insofar as the advantage of the present invention is not significantly impaired. It is usually 50 or larger, preferably 80 or larger, and usually 250 or smaller, preferably 150 or smaller. When it is too large, the solubility of the specific carbonate in the non-aqueous liquid electrolyte decreases and the advantageous effect of the present invention may not be adequately achieved.

[0600] There is no special limitation on the method of producing the specific carbonate and any known method can be selected and used.

[0601] The specific carbonate, explained above, may be used in the non-aqueous liquid electrolyte of the present invention either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0602] There is no special limitation on the proportion of the specific carbonate in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. It is preferable that the proportion, relative to the non-aqueous liquid electrolyte of the present invention, is usually 0.01 weight % or larger, preferably 0.1 weight % or larger, more preferably 0.3 weight % or larger, and usually 70 weight % or smaller, preferably 50 weight % or smaller, more preferably 40 weight % or smaller. If the proportion is below the above-mentioned lower limit, adequate effect of improving cycle performance of the non-aqueous liquid electrolyte secondary battery may not be guaranteed when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery. On the other hand, if the proportion of the specific carbonate is too large, high-temperature storage characteristics and trickle charging characteristics of the non-aqueous liquid electrolyte secondary battery tend to deteriorate, leading particularly to increased gas evolution and deterioration of capacity retention rate, when the non-aqueous liquid electrolyte of the present invention is used for the non-aqueous liquid electrolyte secondary battery.

[0603] [I-3. Non-Aqueous Solvent]

[0604] As non-aqueous solvent contained in the non-aqueous liquid electrolyte of the present invention, any such solvent can be used, insofar as the advantageous effect of the present invention is not significantly impaired. Non-aqueous solvent may be used either one kind or as a combination of two or more kinds in any combination and in any ratio.

[0605] Examples of usually used non-aqueous solvent include: cyclic carbonate, chain carbonate, chain and cyclic carboxylic acid ester, chain and cyclic ether, phosphor-containing organic solvent and sulfur-containing organic solvent.

[0606] There is no special limitation on the kind of the cyclic carbonate. Examples of those usually used, except carbonates corresponding to the specific carbonates mentioned previously, include: ethylene carbonate, propylene carbonate and butylene carbonate.

[0607] Of these compounds, ethylene carbonate and propylene carbonate are preferable because they have high dielectric constant, which effects easy dissolution of the solute, and assures good cycle performance when used for the non-aqueous electrolyte solution secondary battery. Accordingly, it is preferable that the non-aqueous liquid electrolyte of the present invention contains, as non-aqueous solvent, ethylene carbonate and/or propylene carbonate, in addition to the carbonates corresponding to the specific carbonate mentioned before.

[0608] There is no special limitation on the kind of the chain carbonate, either. Examples of those usually used, except carbonates corresponding to the specific carbonates mentioned previously, include: dimethyl carbonate, ethylmethyl carbonate, diethyl carbonate, methyl-n-propyl carbonate, ethyl-n-propyl carbonate and di-n-propyl carbonate.

[0609] Therefore, it is preferable that the non-aqueous liquid electrolyte of the present invention contains, as non-aqueous solvent, at least one carbonate selected from the group consisting of dimethyl carbonate, ethylmethyl carbonate, diethyl carbonate, methyl-n-propyl carbonate, ethyl-n-propyl carbonate and di-n-propyl carbonate, in addition to the carbonates corresponding to the specific carbonate mentioned before. Of these, diethyl carbonate, methyl-n-propyl carbonate and ethyl-n-propyl carbonate are preferable, and diethyl carbonate is particularly preferable because of its excellent cycle performance when used for the non-aqueous liquid electrolyte secondary battery.

[0610] There is no special limitation on the kind of the chain carboxylic acid ester. Examples of those usually used include: methyl acetate, ethyl acetate, n-propyl acetate, i-propyl acetate, n-butyl acetate, i-butyl acetate, t-butyl acetate, methyl propionate, ethyl propionate, n-propyl propionate, i-propyl propionate, n-butyl propionate, i-butyl propionate and t-butyl propionate.

[0611] Of these compounds, preferable are ethyl acetate, methyl propionate and ethyl propionate.

[0612] There is no special limitation on the kind of the cyclic carboxylic acid ester, either. Examples of those usually used include: γ-butyrolactone, γ-valerolactone and δ-valerolactone.

[0613] Of these, γ-butyrolactone is preferable.

[0614] There is no special limitation on the kind of the chain ether. Examples of those usually used include: dimethoxymethane, dimethoxyethane, diethoxymethane, diethoxyethane, ethoxymethoxymethane and ethoxymethoxyethane.

[0615] Of these, dimethoxyethane and diethoxyethane are preferable.

[0616] There is no special limitation on the kind of the cyclic ether. Examples of those usually used include: tetrahydrofuran and 2-methyltetrahydrofuran.

[0617] There is no special limitation on the kind of the phosphor-containing organic solvent. Examples of those usually used include: phosphoric acid esters such as trimethyl phosphate, triethyl phosphate and triphenyl phosphate; phosphorous acid esters such as trimethyl phosphite, triethyl phosphite and triphenyl phosphite; and phosphine oxides such as trimethyl phosphine oxide, triethyl phosphine oxide and triphenyl phosphine oxide.

[0618] There is no special limitation on the kind of the sulfur-containing organic solvent. Examples of those usually used include: ethylene sulfite, 1,3-propane sultone, 1,4-butane sultone, methyl methane sulfonate, busulfan, sulfolane, sulforene, dimethyl sulfone, diphenyl sulfone, methyl phenyl sulfone, dibutyl disulfide, dicyclohexyl disulfide, tetramethyl thiuram monosulfide, N,N-dimethylmethane sulfonamide and N,N-diethylmethane sulfonamide.

[0619] Of these compounds, it is preferable to use ethylene carbonate and/or propylene carbonate, which belongs to

cyclic carbonate. It is further preferable to combine the chain carbonate with these cyclic carbonates.

[0620] When the cyclic carbonate and chain carbonate are used in combination as non-aqueous solvent, preferable content of the chain carbonate in the non-aqueous solvent of the non-aqueous liquid electrolyte of the present invention is usually 30 weight % or higher, preferably 50 weight % or higher, and usually 95 weight % or lower, preferably 90 weight % or lower. On the other hand, preferable content of the cyclic carbonate in the non-aqueous solvent of the non-aqueous liquid electrolyte of the present invention is usually 5 weight % or higher, preferably 10 weight % or higher, and usually 50 weight % or lower, preferably 40 weight % or lower. When the content of the chain carbonate is too low, the viscosity of the non-aqueous liquid electrolyte of the present invention may increase. When the content of the chain carbonate is too high, dissociation degree of electrolyte lithium salt becomes low, leading to a decrease in electric conductivity of the non-aqueous liquid electrolyte of the present invention.

[0621] [I-4. Electrolyte]

[0622] There is no special limitation on the kind of the electrolyte used for the non-aqueous liquid electrolyte of the present invention. Any electrolyte known to be used as electrolyte of the intended non-aqueous liquid electrolyte secondary battery can be used. When the non-aqueous liquid electrolyte of the present invention is used for the lithium secondary battery, a lithium salt is usually used as electrolyte.

[0623] Concrete examples of the electrolytes include: inorganic lithium salts such as $LiClO_4$, $LiAsF_6$, $LiPF_6$, Li_2CO_3 and $LiBF_4$; fluorine-containing organic lithium salt such as $LiCF_3SO_3$, $LiN(CF_3SO_2)_2$, $LiN(C_2F_5SO_{2)2}$, cyclic 1,3-hexafluoropropane disulfonylimide lithium salt, cyclic 1,2-tetrafluoroethane disulfonylimide lithium salt, $LiN(CF_3SO_2)(C_4F_9SO_2)$, $LiC(CF_3SO_2)_3$, $LiPF_4(CF_3)_2$, $LiPF_4(C_2F_5)_2$, $LiPF_4(CF_3SO_2)_2$, $LiPF_4(C_2F_5SO_2)_2$, $LiBF_2(CF_3)_2$, $LiBF_2(C_2F_5)_2$, $LiBF_2(CF_3SO_2)_2$ and $LiBF_2(C_2F_5SO_2)_2$; dicarboxylic acid-containing lithium salt complexes such as lithium bis(oxalato)borate, lithium tris(oxalato)phosphate and lithium difluorooxalatoborate; and sodium salts and potassium salts such as KPF_6, $NaPF_6$, $NaBF_4$ and $NaCF_3SO_3$.

[0624] Of these, preferable are $LiPF_6$, $LiBF_4$, $LiCF_3SO_3$, $LiN(CF_3SO_2)_2$, $LiN(C_2F_5SO_2)_2$ and cyclic 1,2-tetrafluoroethane disulfonylimide lithium salt. Particularly preferable are $LiPF_6$ and $LiBF_4$.

[0625] The electrolyte can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio. In particular, when two specific inorganic lithium salts are used in combination, or inorganic lithium salt and fluorine-containing organic lithium salt are used in combination, gas evolution at the time of trickle charging is suppressed or deterioration at the time of high-temperature storage is suppressed, which is desirable. Particularly preferable are combined use of $LiPF_6$ and $LiBF_4$, and combined use of inorganic lithium salt, such as $LiPF_6$ and $LiBF_4$, and fluorine-containing organic lithium salt, such as $LiCF_3SO_3$, $LiN(CF_3SO_2)_2$ and $LiN(C_2F_5SO_2)_2$.

[0626] When $LiPF_6$ and $LiBF_4$ are used in combination, it is preferable that the ratio of $LiBF_4$ in the whole electrolyte is usually 0.01 weight % or higher and 20 weight % or lower. Dissociation of $LiBF_4$ is not extensive and if the ratio is too high, resistance of the liquid electrolyte may become high.

[0627] On the other hand, when an inorganic lithium salt such as $LiPF_6$ and $LiBF_4$ and a fluorine-containing organic lithium salt such as $LiCF_3SO_3$, $LiN(CF_3SO_2)_2$ and $LiN(C_2F_5SO_2)_2$ are used in combination, it is preferable that the ratio of the inorganic lithium salt in the whole electrolyte is usually 70 weight % or higher and 99 weight % or lower. The molecular weight of a fluorine-containing organic lithium salt is generally higher than that of an inorganic lithium salt. Therefore, when that ratio is too high, the ratio of the solvent in the liquid electrolyte decreases, resulting possibly in high resistance of the liquid electrolyte.

[0628] No particular limitation is imposed on the concentration of the lithium salt in the non-aqueous liquid electrolyte of the present invention, insofar as the advantage of the present invention is not significantly impaired. It is usually 0.5 $mol \cdot dm^{-3}$ or higher, preferably 0.6 $mol \cdot dm^{-3}$ or higher, more preferably 0.8 $mol \cdot dm^{-3}$ or higher, and usually 3 $mol \cdot dm^{-3}$ or lower, preferably 2 $mol \cdot dm^{-3}$ or lower, more preferably 1.5 $mol \cdot dm^{-3}$ or lower. When the concentration is too low, the electric conductivity of the non-aqueous liquid electrolyte may be inadequate. When the concentration is too high, the electric conductivity may decrease due to high viscosity, resulting in low performance of the non-aqueous liquid electrolyte secondary battery based on the non-aqueous liquid electrolyte of the present invention.

[0629] When the non-aqueous liquid electrolyte of the present invention contains the above-mentioned specific compound (A), namely, the first and the second lithium salts, these lithium salts may serve as electrolytes, or another electrolyte may be contained additionally.

[0630] [I-5. Additive]

[0631] It is preferable that the non-aqueous liquid electrolyte of the present invention contains various additives to the extent that the advantage of the present invention is not significantly impaired. As the additive, any known ones can be used. The additive can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0632] Examples of the additives include overcharge-preventing agent and auxiliary agent used to improve capacity retention characteristics and cycle performance after high-temperature storage.

[0633] Concrete examples of the overcharge-preventing agent include: aromatic compounds such as biphenyl, alkyl biphenyl, terphenyl, partially hydrogenated terphenyl, cyclohexylbenzene, t-butylbenzene, t-amylbenzene, diphenylether and dibenzofuran; partially fluorinated above-mentioned aromatic compounds such as 2-fluorobiphenyl, o-cyclohexylfluorobenzene and p-cyclohexylfluorobenzene; fluorine-containing anisole compounds such as 2,4-difluoroanisole, 2,5-difluoroanislole and 2,6-difluoroaniole [SIC].

[0634] These overcharge-preventing agents can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0635] When the non-aqueous liquid electrolyte of the present invention contains an overcharge-preventing agent, no particular limitation is imposed on its concentration used, insofar as the advantage of the present invention is not significantly impaired. However, it is preferable that its content in the total non-aqueous liquid electrolyte is usually 0.1 weight % or more and 5 weight % or less. By incorporating the overcharge-preventing agent in a non-aqueous liquid electrolyte, it is possible to prevent rupture and ignition of the non-aqueous liquid electrolyte secondary battery caused by

overcharge, which preferably contributes to the enhancement of safety of the non-aqueous liquid electrolyte secondary battery.

[0636] On the other hand, concrete examples of the auxiliary agent used to improve capacity retention characteristics or cycle performance after the high-temperature storage are: anhydrides of dicarboxylic acid such as succinic acid, maleic acid and phthalic acid; carbonate compounds except those designated as the specific carbonates, such as erythritan carbonate and spiro-bis-dimethylene carbonate; sulfur-containing compounds such as ethylene sulfite, 1,3-propane sultone, 1,4-butane sultone, methyl methanesulfonate, busulfane, sulfolane, sulforene, dimethyl sulfone, diphenyl sulfone, methylphenyl sulfone, dibutyl disulfide, dicyclohexyl disulfide, tetramethylthiuram monosulfide, N,N-dimethylmethane sulfonamide and N,N-diethylmethane sulfonamide; nitrogen-containing compounds such as 1-methyl-2-pyrolidinone, 1-methyl-2-piperidone, 3-methyl-2-oxazolidinone, 1,3-dimethly-2-imidazolidinone and N-methylsuccinimide; hydrocarbon compounds such as heptane, octane and cycloheptane; and fluorine-containing aromatic compounds such as fluorobenzene, difluorobenzene and benzotrifluoride.

[0637] These auxiliary agents can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0638] When the non-aqueous liquid electrolyte of the present invention contains an auxiliary agent, no limitation is imposed on its concentration, insofar as the advantage of the present invention is not significantly impaired. Usually, it is preferable that its concentration in the entire non-aqueous liquid electrolyte is 0.1 weight % or higher and 5 weight % or lower.

[II. Lithium Secondary Battery]

[0639] The lithium secondary battery of the present invention comprises a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and a non-aqueous liquid electrolyte, the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom, wherein said non-aqueous liquid electrolyte is the non-aqueous liquid electrolyte of the present invention mentioned above.

[0640] [II-1. Constitution of Battery]

[0641] Constitution of the non-aqueous liquid electrolyte secondary battery of the present invention is similar to that of the known non-aqueous liquid electrolyte secondary battery except the constitution of the negative electrode and non-aqueous liquid electrolyte. Usually, the positive electrode and negative electrode are layered with a porous membrane (a separator) interposed therein, which is impregnated with the non-aqueous liquid electrolyte of the present invention, and the whole structure is stored in a case (an outer package). There is no special limitation on the shape of the non-aqueous liquid electrolyte secondary battery of the present invention. The shape may be cylindrical, prismatic, laminated, coin-like or large size-type.

[0642] [II-2. Non-Aqueous Liquid Electrolyte]

[0643] As non-aqueous liquid electrolyte, the non-aqueous liquid electrolyte of the present invention, described above, is used. Other non-aqueous liquid electrolyte can be added to the non-aqueous liquid electrolyte of the present invention to such an extent that it does not depart from the scope of the present invention.

[0644] [II-3. Negative Electrode]

[0645] The negative electrode of the non-aqueous liquid electrolyte secondary battery of the present invention comprises negative-electrode active material having at least one kind of atom selected from the group consisting of Si (silicon) atom, Sn (tin) atom and Pb (lead) atom (these are hereafter referred to as "specific metal elements" as appropriate).

[0646] Examples of the negative-electrode active material containing at least one element selected from the specific metal elements include: any one specific metal element alone; alloys consisting of two or more kinds of the specific metal elements; alloys consisting of one or more of the specific metal elements and one or more other metal elements; and compounds containing one or more of the specific metal elements. It is possible to realize higher capacity of the battery by using these metal elements, alloys or metal compounds as negative-electrode active material.

[0647] Examples of the compounds containing one or more of the specific metal elements include complex compounds, such as carbide, oxide, nitride, sulfide and phosphide, containing one or more of the specific metal elements.

[0648] Other examples include compounds in which these complex compounds are further connected to metal elements, alloys or several elements such as non-metal elements in a complicated manner. More concrete examples include alloys of Si or Sn with a metal not reacting as negative electrode. Also usable are complex compounds containing 5 or 6 elements, in which Sn, for example, is combined with a metal which is other than Si, Sn and Pb and is capable of acting as negative electrode, a metal not reacting as negative electrode and a non-metal element.

[0649] Of these negative-electrode active materials, preferable are: any one kind of the specific metal elements used alone, alloys of two or more kinds of the specific metal elements, and oxides, carbides or nitrides of the specific metal elements, as they have large capacity per unit weight when made into the battery. Particularly preferable are metal elements, alloys, oxides, carbides and nitrides of Si and/or Sn, from the standpoints of capacity per unit weight and small burden on the environment.

[0650] Also preferable are the following Si and/or Sn-containing compounds because of their excellent cycle performance, although they are inferior to metal alone or alloy in capacity per unit weight.

[0651] Oxides of Si and/or Sn in which the ratio of Si and/or Sn relative to oxygen is usually 0.5 to 1.5, preferably 0.7 to 1.3, more preferably 0.9 to 1.1.

[0652] Nitrides of Si and/or Sn in which the ratio of Si and/or Sn relative to nitrogen is usually 0.5 to 1.5, preferably 0.7 to 1.3, more preferably 0.9 to 1.1.

[0653] Carbides of Si and/or Sn in which the ratio of Si and/or Sn relative to carbon is usually 0.5 to 1.5, preferably 0.7 to 1.3, more preferably 0.9 to 1.1.

[0654] The above negative-electrode active material can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0655] The negative electrode of the non-aqueous liquid electrolyte secondary battery of the present invention can be produced according to a known method. Specifically, the negative electrode can be produced using the above-mentioned negative-electrode active material combined with binder, electroconductor or the like, directly by roll-molding into a sheet electrode, or by compression-molding into a pellet electrode, for example. However, it is usually produced

by forming a thin layer containing the above negative-electrode active material (negative-electrode active material layer) on a current collector for a negative-electrode (hereinafter, referred to as "negative-electrode current collector" as appropriate) by means of coating, vapor deposition, spattering, plating or the like. In this case, the above negative-electrode active material is mixed with, for example, binder, thickener, electroconductor, solvent or the like to be made into the form of slurry. Then the slurry is applied to the negative-electrode current collector, dried and pressed to increase its density, thereby the negative-electrode active material layer being formed on the negative-electrode current collector.

[0656] Materials of the negative-electrode current collector include: steel, copper alloy, nickel, nickel alloy and stainless steel. Of these materials, preferable is copper foil, because of its thin-layer formability and low cost.

[0657] The thickness of the negative-electrode current collector is usually 1 μm or larger, preferably 5 μm or larger, and usually 100 μm or smaller, preferably 50 μm or smaller. When the negative-electrode current collector is too thick, the capacity of the entire battery may become too low. On the other hand, when it is too thin, its handling is sometimes difficult.

[0658] In order to increase the bindability of the negative-electrode current collector to the negative-electrode active material layer formed thereon, it is preferable that the surface of the negative-electrode current collector is subjected to roughening procedure in advance. Examples of the surface roughening methods include: blasting procedure; rolling with a rough-surfaced roll; mechanical polishing in which the collector surface is polished with such means as an abrasive cloth or abrasive paper onto which abradant particles are adhered, a whetstone, an emery buff and a wire brush equipped with steel wire; electropolishing; and chemical polishing.

[0659] In order to decrease the weight of the negative-electrode current collector and increase energy density of the battery per unit weight, it is also possible to use a perforated-type negative-electrode current collector such as an expanded metal or a punched metal. This type of negative-electrode current collector is freely adjustable in its weight by means of adjusting its ratio of perforation. Besides, when the negative-electrode active material layers are formed on both sides of this perforated-type of negative-electrode current collector, the negative-electrode active material layers are riveted at these perforations and therefore become more resistant to exfoliation. However, if the ratio of perforation is too high, the bond strength may rather decrease because the contact area between the negative-electrode active material layer and the negative-electrode current collector becomes too small.

[0660] Slurry for making the negative-electrode active material layer is usually prepared by adding such agents as binder and thickener to the negative electrode material. Incidentally, in this Description, the term "negative electrode material" indicates a material containing both negative-electrode active material and electroconductor.

[0661] The content of the negative-electrode active material in the negative electrode material is usually 70 weight % or higher, preferably 75 weight % or higher, and usually 97 weight % or lower, preferably 95 weight % or lower. When the content of the negative-electrode active material is too low, the capacity of the secondary battery based on the resultant negative electrode tends to be insufficient. When the content is too high, the relative content of the binder etc. tends to become low, leading to insufficient strength of the negative electrode. When two or more kinds of negative-electrode active materials are used in combination, the sum of the negative-electrode active materials should fall within the above range.

[0662] Examples of the electroconductor to be used for the negative electrode include: metal materials such as copper and nickel; and carbon materials such as graphite and carbon black. These materials can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio. In particular, carbon material can be advantageously used as electroconductor, as this material can also function as active material. The content of the electroconductor in the negative electrode material is usually 3 weight % or higher, preferably 5 weight % or higher, and usually 30 weight % or lower, preferably 25 weight % or lower. When the content of the electroconductor is too low, the conductivity tends to be inadequate. When it is too high, the relative content of the negative-electrode active material tends to be inadequate, leading to decrease in battery capacity and mechanical strength. When two or more electroconductors are used in combination, the total content of the electroconductors should be adjusted to fall within the above range.

[0663] As binder to be used for the negative electrode, any such material can be used insofar as it is stable in the solvent used for the electrode production and in the liquid electrolyte. Examples include polyfluorinated vinylidene, polytetrafluoro ethylene, polyethylene, polypropylene, styrene butadiene rubber, isoprene rubber, butadiene rubber, ethylene acrylic acid copolymer and ethylene methacrylic acid copolymer. These may be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio. The content of the binder per 100 weight parts of the negative electrode material is usually 0.5 weight part or more, preferably 1 weight part or more, and usually 10 weight parts or less, preferably 8 weight parts or less. When the content of the binder is too small, mechanical strength of the resultant negative electrode tends to be insufficient. When the content is too high, the relative content of the negative-electrode active material tends to decrease, leading possibly to insufficient battery capacity and conductivity. When two or more binders are used in combination, the total content of the binders should be adjusted to fall within the above range.

[0664] Thickener to be used for the negative electrode include carboxymethyl cellulose, methyl cellulose, hydroxymethyl cellulose, ethyl cellulose, polyvinyl alcohol, oxidized starch, phosphorylated starch and casein. These may be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio. The thickener may be used when considered necessary. When the thickener is used, it is preferable that its content in the negative-electrode active material layer is usually held at 0.5 weight % or higher, and 5 weight % or lower.

[0665] Slurry for making the negative-electrode active material layer is prepared by mixing, as needed, electroconductor, binder or thickener with the above negative-electrode active material, using aqueous solvent or organic solvent as dispersion medium. As aqueous solvent, water is usually used. It is also possible to mix other solvent, e.g. alcohol such as ethanol or cyclic amide such as N-methylpyrrolidone, in a ratio not exceeding about 30 weight % relative to water. Examples of organic solvent usually used include: cyclic amides such as N-methylpyrrolidone; straight chain amides

such as N,N-dimethylformamide and N,N-dimethylacetamide; aromatic hydrocarbons such as anisole, toluene and xylene; and alcohols such as butanol and cyclohexanol. Of these, preferable are cyclic amides, such as N-methylpyrrolidone, and straight chain amides, such as N,N-dimethylformamide and N,N-dimethylacetamide. These can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0666] No particular limitation is imposed on the viscosity of the slurry, insofar as the slurry can be applied on the current collector. The amount of the solvent used at the time of slurry preparation can be adjusted appropriately to give a suitable viscosity for application.

[0667] Slurry obtained is applied on the above negative-electrode current collector, and after drying and pressing, negative-electrode active material layer is formed. No particular limitation is imposed on the method of the application and known methods can be used. No particular limitation is imposed on the method of drying either, and known methods such as air drying, heated drying and reduced-pressure drying can be used.

[0668] There is no special limitation on the electrode structure when negative-electrode active material is made into an electrode by the above-mentioned method. The density of the active material present on the current collector is preferably 1 $g \cdot cm^{-3}$ or higher, more preferably 1.2 $g \cdot cm^{-3}$ or higher, still more preferably 1.3 $g \cdot cm^{-3}$ or higher, and usually 2 $g \cdot cm^{-3}$ or lower, preferably 1.9 $g \cdot cm^{-3}$ or lower, more preferably 1.8 $g \cdot cm^{-3}$ or lower, still more preferably 1.7 $g \cdot cm^{-3}$ or lower. When the density exceeds the above-mentioned range, the active material particles are destroyed and an increase in initial irreversible capacity and deterioration in charge-discharge characteristic under high current densities, caused by decrease in immersibility of the non-aqueous liquid electrolyte near the interface between the current collector/active material, may result. When the density is below the above range, the conductivity in the active material may be poor, battery resistance may increase and capacity per unit volume may decrease.

[0669] [II-4. Positive Electrode]

[0670] The positive electrode of the non-aqueous liquid electrolyte secondary battery of the present invention contains positive-electrode active material, in the same way as a usual non-aqueous liquid electrolyte secondary battery.

[0671] Examples of the positive-electrode active material include inorganic compounds such as transition metal oxides, composite oxides of transition metal and lithium (lithium transition metal composite oxide), transition metal sulfides and metal oxides, and metal lithium, lithium alloys and their composites. Concrete examples include: transition metal oxides such as MnO, V_2O_5, V_6O_{13} and TiO_2; lithium transition metal composite oxides such as $LiCoO_2$ or lithium cobalt composite oxide whose basic composition is $LiCoO_2$, $LiNiO_2$ or lithium nickel composite oxide whose basic composition is $LiNiO_2$, $LiMn_2O_4$ or $LiMnO_2$ or lithium manganese composite oxide whose basic composition is $LiMn_2O_4$ or $LiMnO_2$, lithium nickel manganese cobalt composite oxide and lithium nickel cobalt aluminum composite oxide; transition metal sulfides such as TiS and FeS; and metal oxides such as SnO_2 and SiO_2. Of these compounds, preferable are lithium transition metal composite oxides, more concretely $LiCoO_2$ or lithium cobalt composite oxide whose basic composition is $LiCoO_2$, $LiNiO_2$ or lithium nickel composite oxide whose basic composition is $LiNiO_2$, $LiMn_2O_4$ or $LiMnO_2$ or lithium manganese composite oxide whose basic composition is $LiMn_2O_4$ or $LiMnO_2$, lithium nickel manganese cobalt composite oxide and lithium nickel cobalt aluminum composite oxide, because they can provide both high capacity and excellent cycle performance. Lithium transition metal composite oxides are preferable also because their chemical stability can be improved by replacing a part of cobalt, nickel or manganese in the lithium transition metal composite oxide with other metal such as Al, Ti, V, Cr, Mn, Fe, Co, Li, Ni, Cu, Zn, Mg, Ga or Zr. These positive-electrode active materials can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0672] The positive electrode of the non-aqueous liquid electrolyte secondary battery of the present invention can be produced according to a known method. Concretely, for example, the positive electrode can be produced using the above-mentioned positive-electrode active material combined with binder, electroconductor or the like, directly by roll-molding into a sheet electrode, by compression-molding into a pellet electrode, by means of forming a positive-electrode active material layer applying the active material on a current collector for a positive-electrode (hereinafter, referred to as "positive-electrode current collector" as appropriate) (coating method), or by means of forming a thin layer (positive-electrode active material layer) containing the above positive-electrode active material on the positive-electrode current collector by vapor deposition, spattering, plating or the like. Usually, it is produced by a coating method to form a positive-electrode active material layer.

[0673] When by a coating method, the above positive-electrode active material is mixed with, for example, binder, thickener, electroconductor, solvent or the like to be made into the form of slurry. Then the slurry is applied to the positive-electrode current collector, dried and pressed to increase its density, thereby the positive-electrode active material layer being formed on the positive-electrode current collector.

[0674] Examples of the material of positive-electrode current collector include aluminum, titanium, tantalum and alloys containing one or more of these metals. Of these, aluminum and its alloys are preferable.

[0675] The thickness of the positive-electrode current collector is usually 1 μm or larger, preferably 5 μm or larger, and usually 100 μm or smaller, preferably 50 μm or smaller. When the positive-electrode current collector is too thick, the capacity of the entire battery may become too low. On the other hand, when it is too thin, its handling is sometimes difficult.

[0676] In order to increase the bindability of the positive-electrode current collector to the positive-electrode active material layer formed thereon, it is preferable that the surface of the positive-electrode current collector is subjected to roughening procedure in advance. Examples of the surface roughening methods include: blasting procedure; rolling with a rough-surfaced roll; mechanical polishing in which the collector surface is polished with such means as an abrasive cloth or abrasive paper onto which abradant particles are adhered, a whetstone, an emery buff and a wire brush equipped with steel wire; electropolishing; and chemical polishing.

[0677] In order to decrease the weight of the positive-electrode current collector and increase energy density of the battery per unit weight, it is also possible to use a perforated-type positive-electrode current collector such as an expanded

metal or a punched metal. This type of positive-electrode current collector is freely adjustable in its weight by means of adjusting its ratio of perforation. Besides, when the positive-electrode active material layers are formed on both sides of this perforated-type of positive-electrode current collector, the positive-electrode active material layers are riveted at these perforations and therefore become more resistant to exfoliation. However, if the ratio of perforation is too high, the bond strength may rather decrease because the contact area between the positive-electrode active material layer and the positive-electrode current collector becomes too small.

[0678] Usually, an electroconductor is included in the positive-electrode active material layer in order to increase conductivity. There is no special limitation on the kind of the electroconductor used. Concrete examples thereof are metallic materials, such as copper and nickel, and carbonaceous material, e.g. graphite such as natural graphite and artificial graphite, carbon black such as acetylene black and amorphous carbon like needle coke. These materials can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0679] The content of the electroconductor in the positive-electrode active material layer is usually 0.01 weight % or higher, preferably 0.1 weight % or higher, more preferably 1 weight % or higher, and usually 50 weight % or lower, preferably 30 weight % or lower, more preferably 15 weight % or lower. When the content is too low, conductivity may be inadequate. When it is too high, capacity of the battery may decrease.

[0680] As binder to be used for the preparation of the positive-electrode active material layer, any such material can be used in the case of coating insofar as it is stable in the liquid medium to be used at the time of electrode preparation. Concrete examples thereof are: resin polymers such as polyethylene, polypropylene, polyethylene terephthalate, polymethyl metacrylate, aromatic polyamide, cellulose and nitrocellulose; rubber-type polymers such as SBR (styrene butadiene rubber), NBR (acrylonitrile butadiene rubber), fluorinated rubber, isoprene rubber, butadiene rubber and ethylene propylene rubber; thermoplastic elastomer-type polymers such as styrene-butadiene-styrene block copolymer and its hydrogenated products, EPDM (ethylene-propylene-diene terpolymer), styrene ethylene butadiene ethylene copolymer, styrene isoprene styrene block copolymer and its hydrogenated products; soft resin polymers such as syndiotactic-1,2-polybutadiene, polyvinyl acetate, ethylene vinyl acetate copolymer and propylene α-olefin copolymer; fluorinated polymers such as polyfluorinated vinylidene, polytetrafluoroethylene, fluorinated polyfluorovinylidene and polytetrafluoroethylene ethylene copolymer; and high molecular composite materials having ionic conductivity for alkali metal ion (especially lithium ion). These materials can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0681] The content of the binder in the positive-electrode active material layer is usually 0.1 weight % or higher, preferably 1 weight % or higher, more preferably 5 weight % or higher, and usually 80 weight % or lower, preferably 60 weight % or lower, more preferably 40 weight % or lower, most preferably 10 weight % or lower. When the content of the binder is too low, the positive-electrode active material can not be adequately retained and mechanical strength of the positive electrode may decrease, leading to deterioration of battery characteristics such as cycle performance. When the content is too high, the battery capacity and conductivity may deteriorate.

[0682] As liquid medium for preparing the slurry, any solvent can be used insofar as it can dissolve or disperse positive-electrode active material, electroconductor, binder and, as needed, thickener. Either an aqueous solvent or organic solvent can be used.

[0683] Examples of the aqueous solvent include water, and mixture of water and alcohol. Examples of the organic solvent include: aliphatic hydrocarbons such as hexane; aromatic hydrocarbons such as benzene, toluene, xylene and methylnaphthalene; heterocyclic compounds such as quinoline and pyridine; ketones such as acetone, methylethyl ketone and cyclohexanone; esters such as methyl acetate and methyl acrylate; amines such as diethylene triamine and N,N-dimethylaminopropylamine; ethers such as diethyl ether, propylene oxide and tetrahydrofuran (THF); amides such as N-methylpyrrolidone (NMP), dimethylformamide and dimethylacetamide; and non-protonic polar solvents such as hexamethylphosphoramide and dimethylsulfoxide.

[0684] Especially when an aqueous solvent is used, it is preferable to prepare the slurry using a thickener and latex such as styrene butadiene rubber (SBR). A thickener is usually used to adjust the viscosity of the slurry. There is no limitation on the kind of the thickner. Concrete examples thereof include carboxymethyl cellulose, methyl cellulose, hydroxymethyl cellulose, ethyl cellulose, polyvinyl alcohol, oxidized starch, phosphorylated starch, casein, and salts of these compounds. These can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio. When a thickener is used, the proportion of the thickener in the active material is usually 0.1 weight % or higher, preferably 0.5 weight % or higher, more preferably 0.6 weight % or higher, and usually 5 weight % or lower, preferably 3 weight % or lower, more preferably 2 weight % or lower. When the proportion is below the above range, the coatability may extremely decrease. When the proportion exceeds the above range, the ratio of the active material in the positive-electrode active material layer decreases and there is a possibility that the battery capacity decreases and the resistance in the positive-electrode active materials becomes large.

[0685] No particular limitation is imposed on the viscosity of the slurry, insofar as the slurry can be applied on the current collector. The amount of the solvent used at the time of slurry preparation can be adjusted appropriately to give a suitable viscosity for application.

[0686] The slurry obtained is applied on the above positive-electrode current collector, and after drying and pressing, the negative-electrode active material layer [SIC] is formed. No particular limitation is imposed on the method of application and per se known methods can be used. No particular limitation is imposed on the method of drying either, and known methods such as air drying, heated drying and reduced-pressure drying can be used.

[0687] It is preferable that the positive-electrode active material layer, obtained through the coating and drying, is subjected to consolidation process by such means as hand pressing or roller pressing, in order to increase packing density of the positive-electrode active material.

[0688] The density of the positive-electrode active material is preferably 1.5 $g \cdot cm^{-3}$ or higher, more preferably 2 $g \cdot cm^{-3}$ or higher, still more preferably 2.2 $g \cdot cm^{-3}$ or higher, and

preferably 3.5 $g \cdot cm^{-3}$ or lower, more preferably 3 $g \cdot cm^{-3}$ or lower, still more preferably 2.8 $g \cdot cm^{-3}$ or lower. When the density exceeds the above-mentioned upper limit, a decrease in immersibility of the non-aqueous liquid electrolyte near the interface between the current collector/active material may occur and deterioration in charge-discharge characteristic under high current densities may result. When the density is below the above range, the conductivity in the active material may decrease and the battery resistance may increase.

[0689] [II-5. Separator]

[0690] Usually, a separator is installed between the positive electrode and the negative electrode to prevent short circuit. In the case, the non-aqueous liquid electrolyte of the present invention is usually used in such a way that the separator is impregnated with this liquid electrolyte.

[0691] There is no special limitation on the material or shape of the separator. Any known ones can be used, insofar as the advantage of the present invention is not significantly impaired. It is particularly preferable to use a porous sheet or non-woven fabric, with good water-retaining characteristics, which is made of material stable in the non-aqueous liquid electrolyte of the present invention.

[0692] Examples of the materials of the separator include: polyolefins such as polyethylene and polypropylene, polytetrafluoroethylene, polyether sulfone and glass filter. Of these materials, preferable are glass filter and polyolefin. Particularly preferable is polyolefin. These materials can be used either as a single kind or as a mixture of two or more kinds in any combination and in any ratio.

[0693] No particular limitation is imposed on the thickness of the separator. It is usually 1 μm or larger, preferably 5 μm or larger, more preferably 10 μm or larger, and usually 50 μm or smaller, preferably 40 μm or smaller, more preferably 30 μm or smaller. When the separator is too thin, the insulation property and mechanical strength may deteriorate. When it is too thick, battery characteristics such as rate characteristics may deteriorate and also energy density of the entire non-aqueous liquid electrolyte secondary battery may decrease.

[0694] When porous material such as porous sheet or non-woven fabric is used as separator, there is no special limitation on the porosity of the separator. It is usually 20% or larger, preferably 35% or larger, more preferably 45% or larger, and usually 90% or smaller, preferably 85% or smaller, more preferably 75% or smaller. When the porosity is too small, the membrane resistance may become large and the rate characteristics tend to deteriorate. When it is too large, mechanical strength of the separator tend to decrease, leading possibly to poor insulation property.

[0695] No particular limitation is imposed on the average pore diameter of the separator, either. It is usually 0.5 μm or smaller, preferably 0.2 μm or smaller, and usually 0.05 μm or larger. When the average pore diameter is too large, short circuit is liable to occur. When it is too small, the membrane resistance may become large and the rate characteristics may deteriorate.

[0696] [II-6. Outer Package]

[0697] The non-aqueous liquid electrolyte secondary battery of the present invention is usually constituted by storing the above non-aqueous liquid electrolyte, negative electrode, positive electrode and separator or the like in an outer package. There is no special limitation on this outer package and any known one can be used insofar as the advantageous effect of the present invention is not significantly impaired.

[0698] Concretely, there is no special limitation on the material of the outer package. Usually, nickel-plated iron, stainless steel, aluminum and its alloys, nickel and titanium are used, for example.

[0699] There is no limitation on the shape of the outer package, either. The shape may be cylindrical, prismatic, laminated, coin-like or large-size type.

EXAMPLE

[0700] The present invention will be explained in further detail below referring to examples. It is to be understood that the present invention is by no means limited to these examples insofar as it does not depart from the scope of the invention.

Example•Comparative Example Group A: Examples A1 to A34 and Comparative Examples A1 to A10

[0701] Non-aqueous liquid electrolyte secondary batteries were assembled by the following procedure and their performances were evaluated. The results are shown in Tables 1 to 4.

[0702] [Preparation of Negative Electrode]

Preparation of Silicon Alloy Negative Electrode: Examples A1 to A34 and Comparative Examples A1 to A4 and A10

[0703] Negative-electrode active material used were 73.2 weight parts of silicon, which is a non-carbonaceous material, 8.1 weight parts of copper and 12.2 weight parts of artificial graphite powder (commercial name: "KS-6", manufactured by Timcal Co.). To the mixture were added 54.2 weight parts of N-methylpyrrolidone solution, containing 12 weight parts of poly(vinylidene fluoride) (hereafter abbreviated as "PVDF"), and 50 weight parts of N-methylpyrrolidone, and the mixture was made into slurry using a disperser. The slurry obtained was coated uniformly onto a copper foil of 18 μm thickness, which is a negative-electrode current collector. The coated film was first air-dried and finally reduced pressure-dried overnight at 85° C. And then, it was pressed to give an electrode density of about 1.5 $g \cdot cm^{-3}$. Then, a disk of 12.5 mm diameter was stamped out to prepare the negative electrode (silicon alloy negative electrode).

Preparation of Graphite Negative Electrode: Comparative Examples A5 to A9

[0704] Negative-electrode active material used was 100 weight parts of artificial graphite powder (commercial name: "KS-6", manufactured by Timcal Co.). To this were added 83.5 weight parts of N-methylpyrrolidone solution, containing 12 weight parts of PVDF, and 50 weight parts of N-methylpyrrolidone, and the mixture was made into slurry using a disperser. The slurry obtained was coated uniformly onto a copper foil of 18 μm thickness, which is a negative-electrode current collector. The coated film was first air-dried and finally reduced pressure-dried overnight at 85° C. And then, it was pressed to give an electrode density of about 1.5 $g \cdot cm^{-3}$. Then, a disk of 12.5 mm diameter was punched out to prepare the negative electrode (graphite negative electrode).

[0705] [Preparation of Positive Electrode]

[0706] Positive-electrode active material used was 85 weight parts of $LiCoO_2$ ("C5", manufactured by NIPPON CHEMICAL INDUSTRIAL CO., LTD.). To this were added 6 weight parts of carbon black (commercial name: "Denka Black", manufactured by Denki Kagaku Kogyo Kabushiki

Kaisha) and 9 weight parts of poly(vinylidene fluoride) KF-1000 (commercial name: "KF-1000", manufacturd by KUREHA CORPORATION). After mixing, the mixture was dispersed into slurry using N-methyl-2-pyrrolidone. The slurry obtained was coated uniformly onto an aluminum foil of 20 μm thickness, which is the positive-electrode current collector, so that its amount represents 90% of the theoretical capacity of the negative electrode. After drying at 100° C. for 12 hours, a disk of 12.5 mm diameter was stamped out to prepare the positive electrode.

[0707] [Preparation of Non-Aqueous Liquid Electrolyte]

[0708] Compounds of [Specific carbonate], [Other compound], [First lithium salt] and [Second lithium salt] described in each [Example] and [Comparative Example] of Tables 1 to 4 appearing later were mixed in a ratio specified in each column of the Tables, thereby to prepare the non-aqueous liquid electrolyte (non-aqueous liquid electrolyte of Examples A1 to A34 and Comparative Examples A1 to A10).

[0709] In the column of [Specific carbonate], the following abbreviations are used.

[0710] FEC: fluoroethylene carbonate

[0711] VC: vinylene carbonate

[0712] VEC: vinylethylene carbonate

[0713] EC: ethylene carbonate

[0714] DEC: diethyl carbonate

[0715] [Preparation of Coin-Type Cell]

[0716] By using the above-mentioned positive electrode and negative electrode, and each non-aqueous liquid electrolyte prepared by the above-mentioned procedures (non-aqueous liquid electrolytes of Examples A1 to A34 and Comparative Examples A1 to A10), the coin-type cells (non-aqueous liquid electrolyte secondary batteries of Examples A1 to A34 and Comparative Examples A1 to A10) were prepared by the following procedure. Namely, the positive electrode was installed in a stainless steel can body which also functions as positive-electrode current collector, and onto it, the negative electrode was placed with a separator, made of polyethylene and impregnated with the liquid electrolyte, interposed therebetween. Then the can body was sealed by caulking with a sealing pad, which also functions as negative-electrode current collector, with a gasket for insulation interposed therebetween, thereby the coin-type cell being prepared. As negative electrode, the above-mentioned silicon alloy negative electrode or graphite negative electrode was selected and used, according to the description of [Negative electrode] column in each [Example] and [Comparative Example] of Tables 1 to 4 appearing later.

[0717] [Evaluation of Coin-Type Cell (Discharge Capacity and Discharge Capacity Retention Rate)]

[0718] For the coin-type cells obtained by the above procedure (non-aqueous liquid electrolyte secondary batteries of Examples A1 to A34 and Comparative Examples A1 to A10), the discharge capacity and discharge capacity retention rate were evaluated by the following procedure. Namely, each coin-type cell was first charged with constant current and constant voltage at the charge termination voltage of 4.2V-3 mA and at the charge termination current of 0.15 μA, and then discharged with constant current at the discharge termination voltage of 3.0V-3 mA. This charge-discharge cycle was repeated 50 times. In the 50 cycles, discharge capacities were measured at the 1st and 10th cycles. Discharge capacity retention rate at each cycles was calculated according to the following formula.

Discharge capacity retention rate (%)=100*(discharge capacity at the 10th cycle)/(discharge capacity at the 1st cycle) [Mathematical Formula 1]

[0719] Discharge capacities at the 1st and 10th cycles and discharge capacity retention rate (%) obtained for the coin-type cell of each Examples and Comparative Examples are shown in the column of [Evaluation of the cell] of Tables 1 to 4 below. Each value of the discharge capacities shown in Tables 1 to 4 indicates capacity per unit weight of the negative-electrode active material ($mAh \cdot g^{-1}$). "Wt %" indicates "weight %".

TABLE 1

	Non-aqueous liquid electrolyte					Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example A1	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	635	572	90.1
Example A2	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.05 mol/l)	638	567	88.9
Example A3	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	637	601	94.4
Example A4	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6 + LiBF_4$ (0.5 mol/l + 0.5 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	634	600	94.7
Example A5	Silicon alloy	FEC (11 wt %)	EC + DEC (21 wt % + 68 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	633	586	92.6
Example A6	Silicon alloy	VC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	622	522	83.9
Example A7	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	645	607	94.8
Example A8	Silicon alloy	FEC + VEC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiBF_2(C_2O_4)$ (0.1 mol/l)	642	605	94.2
Example A9	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiB(OCOCF_3)_4$ (0.01 mol/l)	633	568	89.7

TABLE 1-continued

		Non-aqueous liquid electrolyte				Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example A10	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiB(OCOCF_3)_4$ (0.01 mol/l)	638	600	94.0
Example A11	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiB(OCOCF_3)_4$ (0.01 mol/l)	636	602	94.6
Example A12	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiB(SO_2CF_3)_4$ (0.1 mol/l)	629	563	89.5

TABLE 2

		Non-aqueous liquid electrolyte				Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example A13	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiB(SO_2CF_3)_4$ (0.1 mol/l)	633	594	93.8
Example A14	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiB(SO_2CF_3)_4$ (0.1 mol/l)	637	601	94.4
Example A15	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiPF_4(C_2O_4)$ (0.1 mol/l)	632	564	89.3
Example A16	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiPF_4(C_2O_4)$ (0.1 mol/l)	639	602	94.2
Example A17	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiPF_4(C_2O_4)$ (0.1 mol/l)	640	605	94.6
Example A18	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	632	569	90.0
Example A19	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.05 mol/l)	640	566	88.4
Example A20	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	642	607	94.6
Example A21	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6 + LiBF_4$ (0.5 mol/l + 0.5 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	637	604	94.8
Example A22	Silicon alloy	FEC (11 wt %)	EC + DEC (21 wt % + 68 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	636	590	92.8
Example A23	Silicon alloy	VC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	630	530	84.1
Example A24	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	646	611	94.9

TABLE 3

		Non-aqueous liquid electrolyte				Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example A25	Silicon alloy	FEC + VEC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	644	607	94.2
Example A26	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2C_2F_5)_2$ (0.1 mol/l)	629	563	89.5
Example A27	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2C_2F_5)_2$ (0.1 mol/l)	632	594	94.0
Example A28	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2C_2F_5)_2$ (0.1 mol/l)	636	602	94.6
Example A29	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiC(SO_2CF_3)_3$ (0.1 mol/l)	628	566	90.2
Example A30	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiC(SO_2CF_3)_3$ (0.1 mol/l)	633	596	94.2

TABLE 3-continued

		Non-aqueous liquid electrolyte				Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example A31	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiC(SO_2CF_3)_3$ (0.1 mol/l)	638	603	94.5
Example A32	Silicon alloy	FEC (5 wt %)	EC + DEC (22 wt % + 73 wt %)	$LiPF_6$ (1 mol/l)	$LiSO_3CF_3$ (0.1 mol/l)	630	563	89.3
Example A33	Silicon alloy	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiSO_3CF_3$ (0.1 mol/l)	635	598	94.2
Example A34	Silicon alloy	FEC + VC (39 wt % + 2 wt %)	DEC (59 wt %)	$LiPF_6$ (1 mol/l)	$LiSO_3CF_3$ (0.1 mol/l)	640	605	94.5

TABLE 4

		Non-aqueous liquid electrolyte				Evaluation of the cell		
	Negative electrode	Specific carbonate (Mixing ratio)	Other compound (Mixing ratio)	First lithium salt (Concentration)	Second lithium salt (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example A1	Silicon alloy	FEC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	none	615	494	80.3
Comparative Example A2	Silicon alloy	VC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	none	611	455	74.5
Comparative Example A3	Silicon alloy	none	EC + DEC (37 wt % + 63 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	600	336	56.0
Comparative Example A4	Silicon alloy	none	EC + DEC (37 wt % + 63 wt %)	$LiPF_6$ (1 mol/l)	none	601	341	56.7
Comparative Example A5	Graphite	none	EC + DEC (37 wt % + 63 wt %)	$LiPF_6$ (1 mol/l)	none	338	274	81.1
Comparative Example A6	Graphite	none	EC + DEC (37 wt % + 63 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	333	276	83.0
Comparative Example A7	Graphite	VC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	none	342	301	88.0
Comparative Example A8	Graphite	FEC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	332	247	74.4
Comparative Example A9	Graphite	FEC (40 wt %)	DEC (60 wt %)	$LiPF_6$ (1 mol/l)	$LiN(SO_2CF_3)_2$ (0.1 mol/l)	330	224	67.8
Comparative Example A10	Silicon alloy	FEC (5 wt %)	EC + DEC (35 wt % + 60 wt %)	$LiPF_6$ (1 mol/l)	$LiB(C_2O_4)_2$ (0.1 mol/l)	598	437	73.1

[0720] The results shown in Tables 1 to 4 above indicate the following.

[0721] In Examples A1 to A34, where non-aqueous liquid electrolyte containing the first and second lithium salts (specific compound (A)) and the specific carbonate was used, the discharge capacity retention rate is improved remarkably in comparison with Comparative Example A4, where non-aqueous liquid electrolyte containing neither the specific compound (A) nor the specific carbonate was used.

[0722] In contrast, in Comparative Example A3, where non-aqueous liquid electrolyte containing only the first and second lithium salts (specific compound (A)) and no specific carbonate was used, the capacity retention rate is not improved in comparison with Comparative Example A4. On the contrary, the capacity retentions of Comparative Examples A1 and A2, where non-aqueous liquid electrolyte containing only the first lithium salt and the specific carbonate and no second lithium salt was used, are improved but still far inferior to those of Examples A1 to A34.

[0723] On the other hand, in Comparative Examples A5 to A9, only carbon material was used as negative-electrode active material. The non-aqueous liquid electrolyte of Comparative Example A5 contained no second lithium salt or specific carbonate. The non-aqueous liquid electrolyte of Comparative Example A6 contained only the first and the second lithium salts (specific compound (A)). The non-aque-

ous liquid electrolyte of Comparative Example A7 contained only the first lithium salt and the specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples A8 and A9 contained the first and the second lithium salts (specific compound (A)) and the specific carbonate.

[0724] In Examples A1 to A34, where the negative-electrode active material was silicon alloy, the discharge capacity is high in comparison with Comparative Examples A5 to A9, where the negative-electrode active material consisted only of carbon material. When the negative-electrode active material was carbon material, comparison among Comparative Examples A5 to A9 indicates improvement in discharge capacity retention rate due to that the non-aqueous liquid electrolyte contained the specific carbonate, but the effect due to containing only the first and the second lithium salts (specific compound (A)) or the synergistic effect due to containing both the first and the second lithium salts (specific compound (A)) and the specific carbonate is not recognized.

[0725] In Comparative Example A10, where $LiB(C_2O_4)_2$ is contained in the non-aqueous liquid electrolyte in place of the second lithium salt, no better improvement effect of discharge capacity retention rate was not exhibited than in Examples A1 to A34. The reason is not clear, but it is inferred that the use of $LiB(C_2O_4)_2$ causes formation of protective layer on the electrode and it rises the resistance.

Example•Comparative Example Group B: Examples B1 to B26 and Comparative Examples B1to B9

[0726] Non-aqueous liquid electrolyte secondary batteries were assembled by the following procedure and their performances were evaluated. The results are shown in Tables 5 to 8.

[0727] [Preparation of Negative Electrode]

Preparation of Silicon Alloy Negative Electrode: Examples B1 to B26 and Comparative Examples B1 to B4

[0728] The silicon alloy negative electrode was prepared by the same method as described in the section <Preparation of silicon alloy negative electrode> of the above-mentioned [Example Comparative Example Group A].

Preparation of Graphite Negative Electrode: Comparative Examples B5 to B9

[0729] The graphite negative electrode was prepared by the same method as described in the section <Preparation of graphite negative electrode> of the above-mentioned [Example•Comparative Example Group A].

[0730] [Preparation of Positive Electrode]

[0731] The positive electrode was prepared by the same method as described in the section <Preparation of positive electrode> of the above-mentioned [Example•Comparative Example Group A].

[0732] [Preparation of Non-Aqueous Liquid Electrolyte]

[0733] Compounds of [Specific carbonate], [Other compound] and [Specific compound (B)] described in each [Example] and [Comparative Example] of Tables 5 to 8 appearing later were mixed in a ratio specified in each column of the Tables. $LiPF_6$ was dissolved further as electrolyte salt at a concentration of 1 $mol \cdot dm^{-3}$ to prepare the non-aqueous liquid electrolyte (non-aqueous liquid electrolyte of Examples B1 to B26 and Comparative Examples B1 to B9).

[0734] [Preparation of Coin-Type Cell]

[0735] By using the above-mentioned positive electrode and negative electrode, and the non-aqueous liquid electrolyte prepared by the above-mentioned procedure, the coin-type cells (non-aqueous liquid electrolyte secondary batteries of Examples B1 to B26 and Comparative Examples B1 to B9) were prepared by the same procedure as described in [Preparation of coin-type cell] of the above-mentioned [Example•Comparative Example Group A]. As negative electrode, the above-mentioned silicon alloy negative electrode or graphite negative electrode was selected and used, according to the description of [Negative electrode] column in each [Example] and [Comparative Example] of Tables 5 to 8 appearing later.

[0736] [Evaluation of Coin-Type Cell (Discharge Capacity and Discharge Capacity Retention Rate)]

[0737] For the coin-type cells obtained by the above procedure (non-aqueous liquid electrolyte secondary batteries of Examples B1 to B26 and Comparative Examples B1 to B9), the discharge capacity and discharge capacity retention rate were evaluated by the same procedure as described in [Preparation of coin-type cell] [SIC]of the above-mentioned [Example•Comparative Example Group A].

[0738] Discharge capacities at the 1st and 10th cycles and discharge capacity retention rate (%) obtained for the coin-type cell of each Example and Comparative Example are shown in the column of [Evaluation of the cell] of Tables 5 to 8 below. Each value of the discharge capacities shown in Tables 5 to 8 indicates capacity per unit weight of negative-electrode active material ($mAh \cdot g^{-1}$). "wt %" indicates "weight %".

TABLE 5

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (B) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example B1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Succinic anhydride (2 wt %)	635	584	92.0
Example B2	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Succinic anhydride (1 wt %)	636	584	91.8
Example B3	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Succinic anhydride (2 wt %)	636	601	94.5

TABLE 5-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (B) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example B4	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Succinic anhydride (2 wt %)	637	599	94.1
Example B5	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Succinic anhydride (2 wt %)	630	570	90.5
Example B6	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Succinic anhydride (2 wt %)	640	609	95.2
Example B7	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Succinic anhydride (2 wt %)	640	607	94.8
Example B8	Silicon alloy	Difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Succinic anhydride (2 wt %)	639	588	92.0
Example B9	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Maleic anhydride (2 wt %)	635	577	90.9

TABLE 6

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (B) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example B10	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Maleic anhydride (2 wt %)	638	598	93.7
Example B11	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Maleic anhydride (2 wt %)	638	600	94.0
Example B12	Silicon alloy	Difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Maleic anhydride (2 wt %)	640	582	90.9
Example B13	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Itaconic aid anhydride (2 wt %)	629	572	90.9
Example B14	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Itaconic acid anhydride (2 wt %)	638	595	93.3
Example B15	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Itaconic acid anhydride (2 wt %)	640	603	94.2
Example B16	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Phthalic anhydride (2 wt %)	638	574	90.0
Example B17	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Phthalic anhydride (1 wt %)	639	592	92.6
Example B18	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Phthalic anhydride (2 wt %)	637	596	93.6

TABLE 7

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (B) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example B19	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	4,4,5,5-tetrafluorosuccinic acid anhydride (2 wt %)	637	573	90.0
Example B20	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	4,4,5,5-tetrafluorosuccinic acid anhydride (1 wt %)	640	588	91.9
Example B21	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	4,4,5,5-tetrafluorosuccinic acid anhydride (2 wt %)	640	589	92.0
Example B22	Silicon alloy	Difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	4,4,5,5-tetrafluorosuccinic acid anhydride (2 wt %)	636	576	90.5
Example B23	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	diglycolic acid anhydride (2 wt %)	635	564	88.8
Example B24	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	diglycolic acid anhydride (1 wt %)	637	579	90.9
Example B25	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	diglycolic acid anhydride (2 wt %)	639	581	90.9
Example B26	Silicon alloy	Difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	diglycolic acid anhydride (2 wt %)	642	584	91.0

TABLE 8

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (B) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example B1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	615	494	80.3
Comparative Example B2	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	611	455	74.5
Comparative Example B3	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Succinic anhydride (2 wt %)	610	356	58.4
Comparative Example B4	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	601	341	56.7
Comparative Example B5	Graphite	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	342	301	88.0
Comparative Example B6	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Succinic anhydride (2 wt %)	340	276	81.2
Comparative Example B7	Graphite	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	338	274	81.1
Comparative Example B8	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Succinic anhydride (2 wt %)	336	252	75.0
Comparative Example B9	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Succinic anhydride (2 wt %)	333	234	70.3

[0739] The results shown in Tables 5 to 8 above indicate the following.

[0740] In Examples B1 to B26, where the specific compound (B) and the specific carbonate were contained, the discharge capacity retention rate is improved remarkably in comparison with Comparative Example B4, where neither the specific compound (B) nor the specific carbonate was contained.

[0741] In contrast, in Comparative Example B3, where only the specific compound (B) was contained, the discharge capacity retention rate is not improved in comparison with to Comparative Example B4. On the contrary, the discharge capacity retention rates of Comparative Examples B1 and B2, where only the specific carbonate was contained, are improved but still far inferior to those of Examples B1 to B26.

[0742] On the other hand, in Comparative Examples B5 to B9, only carbon material was used as negative-electrode active material. The non-aqueous liquid electrolyte of Comparative Example B7 contained no specific compound (B) or specific carbonate. The non-aqueous liquid electrolyte of Comparative Example B6 contained only the specific compound (B). The non-aqueous liquid electrolyte of Comparative Example B5 contained only the specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples B8 and B9 contained the specific compound (B) and the specific carbonate.

[0743] In Examples B1 to B26, where the negative-electrode active material was silicon alloy, the discharge capacity is high in comparison with Comparative Examples B5 to B9, where the negative-electrode active material consisted only of carbon material. When the negative-electrode active material was only carbon material, comparison among Comparative Examples B7, B5, B6, B8 and B9 indicates improvement in discharge capacity retention rate due to that the non-aqueous liquid electrolyte contained the specific carbonate, but the effect due to containing only the specific compound (B) or the synergistic effect due to containing both the specific compound (B) and the specific carbonate is not recognized.

Example•Comparative Example Group C: Examples C1 to C95 and Comparative Examples C1 to C33

[0744] Non-aqueous liquid electrolyte secondary batteries were assembled by the following procedure and their performances were evaluated. The results are shown in Tables 9 to 23.

[0745] [Preparation of Negative Electrode]

Preparation of Silicon Alloy Negative Electrode: Examples C1 to C95 and Comparative Examples C1 to C10

[0746] The silicon alloy negative electrode was prepared by the same method as described in the section <Preparation of silicon alloy negative electrode> of the above-mentioned [Example Comparative Example Group A].

Preparation of Graphite Negative Electrode: Comparative Examples C11 to C33

[0747] The graphite negative electrode was prepared by the same method as described in the section <Preparation of graphite negative electrode> of the above-mentioned [Example•Comparative Example Group A].

[0748] [Preparation of Positive Electrode]

[0749] The positive electrode was prepared by the same method as described in the section <Preparation of positive electrode> of the above-mentioned [Example Comparative Example Group A].

[0750] [Preparation of Non-Aqueous Liquid Electrolyte]

[0751] Compounds of [Specific carbonate], [Other compound] and [Specific compound (C)] described in each [Example] and [Comparative Example] of Tables 9 to 23 appearing later were mixed in a ratio specified in each column of the Tables. $LiPF_6$ was dissolved further as electrolyte salt at a concentration of 1 mol·dm^{-3} to prepare the non-aqueous liquid electrolyte (non-aqueous liquid electrolyte of Examples C1 to C95 and Comparative Examples C1 to C33).

[0752] [Preparation of Coin-Type Cell]

[0753] By using the above-mentioned positive electrode and negative electrode, and the non-aqueous liquid electrolyte prepared by the above-mentioned procedure, the coin-type cells (non-aqueous liquid electrolyte secondary batteries of Examples C1 to C95 and Comparative Examples C1 to C33) were prepared by the same procedure as described in [Preparation of coin-type cell] of the above-mentioned [Example•Comparative Example Group A]. As negative electrode, the above-mentioned silicon alloy negative electrode or graphite negative electrode was selected and used, according to the description of [Negative electrode] column in each [Example] and [Comparative Example] of Tables 9 to 23 appearing later.

[0754] [Evaluation of Coin-Type Cell (Discharge Capacity and Discharge Capacity Retention Rate)]

[0755] For the coin-type cells obtained by the above procedure (non-aqueous liquid electrolyte secondary batteries of Examples C1 to C95 and Comparative Examples C1 to C33), the discharge capacity and discharge capacity retention rate were evaluated by the same procedure as described in [Preparation of coin-type cell] [SIC]of the above-mentioned [Example•Comparative Example Group A].

[0756] Discharge capacities at the 1st and 10th cycles and discharge capacity retention rate (%) obtained for the coin-type cell of each Examples and Comparative Examples are shown in the column of [Evaluation of the cell] of Tables 9 to 23 below. Each value of the discharge capacities shown in Tables 9 to 23 indicates capacity per unit weight of negative-electrode active material (mAh·g^{-1}). "wt %" indicates "weight %".

TABLE 9

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example C1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl sulfide (2 wt %)	626	567	90.6

TABLE 9-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C2	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dibutyl sulfide (0.2 wt %)	629	565	89.8
Example C3	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dibutyl sulfide (2 wt %)	634	598	94.3
Example C4	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dibutyl sulfide (2 wt %)	631	585	92.7
Example C5	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl sulfide (2 wt %)	629	579	92.1
Example C6	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl sulfide (2 wt %)	619	519	83.8
Example C7	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dibutyl sulfide (2 wt %)	639	604	94.5
Example C8	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dibutyl sulfide (2 wt %)	636	599	94.2
Example C9	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl disulfide (2 wt %)	625	564	90.2

TABLE 10

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C10	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dibutyl disulfide (0.2 wt %)	627	562	89.6
Example C11	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dibutyl disulfide (2 wt %)	633	595	94.0
Example C12	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dibutyl disulfide (2 wt %)	629	584	92.8
Example C13	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl disulfide (2 wt %)	627	575	91.7
Example C14	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl disulfide (2 wt %)	616	520	84.4
Example C15	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dibutyl disulfide (2 wt %)	636	603	94.8
Example C16	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dibutyl disulfide (2 wt %)	632	597	94.5
Example C17	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfoxide (2 wt %)	630	578	91.7

TABLE 10-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C18	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dimethylsulfoxide (0.2 wt %)	625	555	88.8

TABLE 11

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{1}$)	Discharge capacity retention rate (%)
Example C19	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfoxide (2 wt %)	636	600	94.3
Example C20	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dimethylsulfoxide (2 wt %)	633	586	92.6
Example C21	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfoxide (2 wt %)	631	581	92.1
Example C22	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfoxide (2 wt %)	619	519	83.8
Example C23	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfoxide (2 wt %)	642	609	94.9
Example C24	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfoxide (2 wt %)	641	602	93.9
Example C25	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfone (2 wt %)	631	570	90.3
Example C26	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dimethylsulfone (0.2 wt %)	629	558	88.7
Example C27	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfone (2 wt %)	635	602	94.8

TABLE 12

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C28	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dimethylsulfone (2 wt %)	633	587	92.7
Example C29	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfone (2 wt %)	632	582	92.1

TABLE 12-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example C30	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfone (2 wt %)	621	521	83.9
Example C31	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfone (2 wt %)	640	604	94.4
Example C32	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfone (2 wt %)	638	600	94.0
Example C33	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfite (2 wt %)	627	566	90.3
Example C34	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dimethylsulfite (0.2 wt %)	622	555	89.2
Example C35	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfite (2 wt %)	633	597	94.3
Example C36	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dimethylsulfite (2 wt %)	630	583	92.5

TABLE 13

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example C37	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfite (2 wt %)	628	577	91.9
Example C38	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfite (2 wt %)	620	517	83.4
Example C39	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfite (2 wt %)	639	608	95.1
Example C40	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethylsulfite (2 wt %)	636	600	94.3
Example C41	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Methyl methanesulfonate (2 wt %)	634	570	89.9
Example C42	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Methyl methanesulfonate (0.2 wt %)	628	558	88.9
Example C43	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Methyl methanesulfonate (2 wt %)	638	602	94.4
Example C44	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Methyl methanesulfonate (2 wt %)	634	590	93.1
Example C45	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Methyl methanesulfonate (2 wt %)	634	583	92.0

TABLE 14

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C46	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Methyl methanesulfonate (2 wt %)	619	521	84.2
Example C47	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Methyl methanesulfonate (2 wt %)	643	609	94.7
Example C48	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Methyl methanesulfonate (2 wt %)	641	604	94.2
Example C49	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethyl sulfate (2 wt %)	631	569	90.2
Example C50	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.8 wt %)	Dimethyl sulfate (0.2 wt %)	637	560	87.9
Example C51	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethyl sulfate (2 wt %)	636	601	94.5
Example C52	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Dimethyl sulfate (2 wt %)	634	591	93.2
Example C53	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethyl sulfate (2 wt %)	632	580	91.8
Example C54	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethyl sulfate (2 wt %)	621	523	84.2

TABLE 15

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C55	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethyl sulfate (2 wt %)	642	609	94.9
Example C56	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Dimethyl sulfate (2 wt %)	639	604	94.5
Example C57	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl sulfide (2 wt %)	625	565	90.4
Example C58	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl sulfide (2 wt %)	632	595	94.1
Example C59	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl sulfide (2 wt %)	637	601	94.3
Example C60	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl disulfide (2 wt %)	623	561	90.0
Example C61	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl disulfide (2 wt %)	630	593	94.1

TABLE 15-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C62	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl disulfide (2 wt %)	632	599	94.8
Example C63	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl sulfoxide (2 wt %)	626	560	89.5

TABLE 16

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C64	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl sulfoxide (2 wt %)	633	597	94.3
Example C65	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl sulfoxide (2 wt %)	639	603	94.4
Example C66	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl sulfone (2 wt %)	629	562	89.3
Example C67	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl sulfone (2 wt %)	632	595	94.1
Example C68	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl sulfone (2 wt %)	638	601	94.2
Example C69	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl sulfite (2 wt %)	624	562	90.1
Example C70	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl sulfite (2 wt %)	631	593	94.0
Example C71	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl sulfite (2 wt %)	635	599	94.3
Example C72	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Phenyl methanesulfonate (2 wt %)	632	568	89.9

TABLE 17

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C73	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Phenyl methanesulfonate (2 wt %)	635	599	94.3

TABLE 17-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C74	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Phenyl methanesulfonate (2 wt %)	640	605	94.5
Example C75	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	2,2,2-trifluoroethyl methanesulfonate (2 wt %)	634	572	90.2
Example C76	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	2,2,2-trifluoroethyl methanesulfonate (2 wt %)	637	601	94.3
Example C77	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	2,2,2-trifluoroethyl methanesulfonate (2 wt %)	642	604	94.1
Example C78	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Metyl 2,2,2-trifluoroethanesulfonate (2 wt %)	633	571	90.2
Example C79	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Metyl 2,2,2-trifluoroethanesulfonate (2 wt %)	636	600	94.3
Example C80	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Metyl 2,2,2-trifluoroethanesulfonate (2 wt %)	643	605	94.1

TABLE 18

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C81	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Diphenyl sulfate (2 wt %)	630	560	89.4
Example C82	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Diphenyl sulfate (2 wt %)	632	595	94.1
Example C83	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Diphenyl sulfate (2 wt %)	638	602	94.4
Example C84	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Bis (phenylthio)methane (2 wt %)	624	561	89.9
Example C85	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Bis (phenylthio)methane (2 wt %)	631	592	93.8
Example C86	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Bis (phenylthio)methane (2 wt %)	638	600	94.0
Example C87	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Busulfan (2 wt %)	634	571	90.1
Example C88	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Busulfan (2 wt %)	639	602	94.2
Example C89	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Busulfan (2 wt %)	643	608	94.6

TABLE 19

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example C90	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1,4-bis (2,2,2-trifluoroethane sulfonyloxy)buthane (2 wt %)	633	567	89.6
Example C91	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1,4-bis (2,2,2-trifluoroethane sulfonyloxy)buthane (2 wt %)	635	600	94.5
Example C92	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	1,4-bis (2,2,2-trifluoroethane sulfonyloxy)buthane (2 wt %)	642	607	94.5
Example C93	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1,2,4-tris (methane sufoniloxy)buthane	632	568	89.9
Example C94	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1,4-bis (2,2,2-trifluoroethane sulfonyloxy)buthane (2 wt %)	636	599	94.2
Example C95	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1,4-bis (2,2,2-trifluoroethane sulfonyloxy)buthane (2 wt %)	641	606	94.5

TABLE 20

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example C1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	615	494	80.3
Comparative Example C2	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	611	455	74.5
Comparative Example C3	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dibutyl sulfide (2 wt %)	594	328	55.2
Comparative Example C4	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dibutyl disulfide (2 wt %)	592	325	54.9
Comparative Example C5	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfoxide (2 wt %)	593	325	54.8
Comparative Example C6	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfone (2 wt %)	595	329	55.3
Comparative Example C7	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfite (2 wt %)	593	327	55.1
Comparative Example C8	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Methyl methanesulfonate (2 wt %)	598	331	55.4
Comparative Example C9	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethyl sulfate (2 wt %)	599	333	55.6

TABLE 21

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example C10	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	601	341	56.7
Comparative Example C11	Graphite	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	338	274	81.1
Comparative Example C12	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dibutyl sulfide (2 wt %)	326	268	82.2
Comparative Example C13	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dibutyl disulfide (2 wt %)	325	269	82.8
Comparative Example C14	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfoxide (2 wt %)	325	262	80.6
Comparative Example C15	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfone (2 wt %)	327	272	83.2
Comparative Example C16	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethylsulfite (2 wt %)	328	264	80.5
Comparative Example C17	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Methyl methanesulfonate (2 wt %)	332	275	82.8
Comparative Example C18	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	Dimethyl sulfate (2 wt %)	333	274	82.3

TABLE 22

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example C19	Graphite	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	342	301	88.0
Comparative Example C20	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl sulfide (2 wt %)	325	240	73.8
Comparative Example C21	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dibutyl disulfide (2 wt %)	323	235	72.8
Comparative Example C22	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfoxide (2 wt %)	323	238	73.7
Comparative Example C23	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfone (2 wt %)	330	242	73.3
Comparative Example C24	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethylsulfite (2 wt %)	325	237	72.9
Comparative Example C25	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Methyl methanesulfonate (2 wt %)	331	243	73.4
Comparative Example C26	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Dimethyl sulfate (2 wt %)	332	244	73.5
Comparative Example C27	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dibutyl sulfide (2 wt %)	321	222	69.2

TABLE 22-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example C28	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dibutyl disulfide (2 wt %)	319	218	68.3

TABLE 23

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (C) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example C29	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfoxide (2 wt %)	318	218	68.6
Comparative Example C30	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfone (2 wt %)	322	223	69.3
Comparative Example C31	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethylsulfite (2 wt %)	317	217	68.5
Comparative Example C32	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Methyl methanesulfonate (2 wt %)	327	220	67.3
Comparative Example C33	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Dimethyl sulfate (2 wt %)	329	224	68.1

[0757] The results shown in Tables 9 to 23 above indicate the following.

[0758] In Examples C1 to C95, where non-aqueous liquid electrolyte containing the specific compound (C) and the specific carbonate was used, the discharge capacity retention rate is improved remarkably in comparison with Comparative Example C10, where non-aqueous liquid electrolyte containing neither the specific compound (C) nor the specific carbonate was used.

[0759] In contrast, in Comparative Examples C3 to C9, where non-aqueous liquid electrolyte containing only the specific compound (C) was used, the discharge capacity retention rate is not improved in comparison with Comparative Example C10. The discharge capacity retention rates of Comparative Examples C1 and C2, where non-aqueous liquid electrolyte containing only the specific carbonate was used, are improved but still far inferior to those of Examples C1 to C95.

[0760] On the other hand, in Comparative Examples C11 to C33, only carbon material was used as negative-electrode active material. The non-aqueous liquid electrolyte of Comparative Example C11 contained no specific compound (C) or specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples C12 to C18 contained only the specific compound (C). The non-aqueous liquid electrolyte of Comparative Example C19 contained only the specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples C20 to C33 contained the specific compound (C) and the specific carbonate.

[0761] In Examples C1 to C95, where the negative-electrode active material was silicon alloy, the discharge capacity is high in comparison with Comparative Examples C20 to C33, where the negative-electrode active material consisted only of carbon material. When the negative-electrode active material was only carbon material, comparison among Comparative Examples C12 to C18, C19, and C20 to C33 indicates improvement in discharge capacity retention rate due to that the non-aqueous liquid electrolyte contained the specific carbonate, but the effect due to containing only the specific compound (C) or the synergistic effect due to containing both the specific compound (C) and the specific carbonate is not recognized.

Example•Comparative Example Group D: Examples D1 to D42 and Comparative Examples D1 to D17

[0762] Non-aqueous liquid electrolyte secondary batteries were assembled by the following procedure and their performances were evaluated. The results are shown in Tables 24 to 30.

[0763] [Preparation of Negative Electrode]

Preparation of Silicon Alloy Negative Electrode: Examples D1 to D42 and Comparative Examples D1 to D6

[0764] The silicon alloy negative electrode was prepared by the same method as described in the section <Preparation of

silicon alloy negative electrode> of the above-mentioned [Example•Comparative Example Group A].

Preparation of Graphite Negative Electrode: Comparative Examples D7 to D17

[0765] The graphite negative electrode was prepared by the same method as described in the section <Preparation of graphite negative electrode> of the above-mentioned [Example•Comparative Example Group A].

[0766] [Preparation of Positive Electrode]

[0767] The positive electrode was prepared by the same method as described in the section <Preparation of positive electrode> of the above-mentioned [Example Comparative Example Group A].

[0768] [Preparation of Non-Aqueous Liquid Electrolyte]

[0769] Compounds of [Specific carbonate], [Other compound] and [Specific compound (D)] described in each [Example] and [Comparative Example] of Tables 24 to 30 appearing later were mixed in a ratio specified in each column of the Tables. $LiPF_6$ was dissolved further as electrolyte salt at a concentration of 1 $mol \cdot dm^{-3}$ to prepare the non-aqueous liquid electrolyte (non-aqueous liquid electrolyte of Examples D1 to D42 and Comparative Examples D1 to D17).

[0770] [Preparation of Coin-Type Cell]

[0771] By using the above-mentioned positive electrode and negative electrode, and the non-aqueous liquid electrolytes prepared by the above-mentioned procedure (non-aqueous liquid electrolytes of Examples D1 to D42 and Comparative Examples D1 to D17), the coin-type cells (non-aqueous liquid electrolyte secondary batteries of Examples D1 to D42 and Comparative Examples D1 to D17) were prepared by the same procedure as described in [Preparation of coin-type cell] of the above-mentioned [Example•Comparative Example Group A]. As negative electrode, the above-mentioned silicon alloy negative electrode or graphite negative electrode was selected and used, according to the description of [Negative electrode] column in each [Example] and [Comparative Example] of Tables 24 to 30 appearing later.

[0772] [Evaluation of Coin-Type Cell (Discharge Capacity and Discharge Capacity Retention Rate)]

[0773] For the coin-type cells obtained by the above procedure (non-aqueous liquid electrolyte secondary batteries of Examples D1 to D42 and Comparative Examples D1 to D17), the discharge capacity and discharge capacity retention rate were evaluated by the same procedure as described in [Preparation of coin-type cell] [SIC]of the above-mentioned [Example•Comparative Example Group A].

[0774] Discharge capacities at the 1st and 10th cycles and discharge capacity retention rate (%) obtained for the coin-type cell of each Example and Comparative Example are shown in the column of [Evaluation of the cell] of Tables 24 to 30 below. Each value of the discharge capacities shown in Tables 24 to 30 indicates capacity per unit weight of negative-electrode active material ($mAh \cdot g^{-1}$) "wt %" indicates "weight %".

TABLE 24

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example D1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Ethyl diethylphosphinate (1 wt %)	630	570	90.5
Example D2	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.9 wt %)	Ethyl diethylphosphinate (0.1 wt %)	626	555	88.7
Example D3	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Ethyl diethylphosphinate (1 wt %)	638	601	94.2
Example D4	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (18 wt % + 61 wt %)	Ethyl diethylphosphinate (1 wt %)	632	586	92.7
Example D5	Silicon alloy	4,5-diFluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Ethyl diethylphosphinate (1 wt %)	631	579	91.8
Example D6	Silicon alloy	Vinylene carbonate(5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Ethyl diethylphosphinate (1 wt %)	619	520	84.0
Example D7	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Ethyl diethylphosphinate (1 wt %)	644	611	94.9
Example D8	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Ethyl diethylphosphinate (1 wt %)	640	603	94.2
Example D9	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Dimethyl methylphosphonate (1 wt %)	629	569	90.5

TABLE 25

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D10	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.9 wt %)	Dimethyl methylphosphonate (0.1 wt %)	624	553	88.6
Example D11	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Dimethyl methylphosphonate (1 wt %)	637	601	94.3
Example D12	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (18 wt % + 61 wt %)	Dimethyl methylphosphonate (1 wt %)	631	584	92.6
Example D13	Silicon alloy	4,5-diFluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Dimethyl methylphosphonate (1 wt %)	630	578	91.7
Example D14	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Dimethyl methylphosphonate (1 wt %)	620	522	84.2
Example D15	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Dimethyl methylphosphonate (1 wt %)	642	612	95.3
Example D16	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Dimethyl methylphosphonate (1 wt %)	640	603	94.2
Example D17	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Tributylphosphine oxide (1 wt %)	626	565	90.3
Example D18	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 59.9 wt %)	Tributylphosphine oxide (0.1 wt %)	620	550	88.7

TABLE 26

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D19	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethylene carbonate (60 wt %)	Tributylphosphine oxide (1 wt %)	634	597	94.2
Example D20	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (18 wt % + 61 wt %)	Tributylphosphine oxide (1 wt %)	630	582	92.4
Example D21	Silicon alloy	4,5-diFluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Tributylphosphine oxide (1 wt %)	628	576	91.7
Example D22	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Tributylphosphine oxide (1 wt %)	618	518	83.8
Example D23	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Tributylphosphine oxide (1 wt %)	640	610	95.3
Example D24	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Tributylphosphine oxide (1 wt %)	638	601	94.2
Example D25	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Methyl methylphenylphosphinate (1 wt %)	629	568	90.3

TABLE 26-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D26	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethylene carbonate (60 wt %)	Methyl methylphenylphosphinate (1 wt %)	635	600	94.5
Example D27	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethylene carbonate (59 wt %)	Methyl methylphenylphosphinate (1 wt %)	642	607	94.5

TABLE 27

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D28	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Dimethyl phenylphosphonate (1 wt %)	628	566	90.1
Example D29	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Dimethyl phenylphosphonate (1 wt %)	634	600	94.6
Example D30	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Dimethyl phenylphosphonate (1 wt %)	641	610	95.2
Example D31	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Triphenylphosphine oxide (1 wt %)	625	563	90.1
Example D32	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Triphenylphosphine oxide (1 wt %)	633	598	94.5
Example D33	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Triphenylphosphine oxide (1 wt %)	640	607	94.8
Example D34	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Etyl diethylphosphinate + Methyl ⓘethylphenylphosphinate (0.5 wt % + 0.5 wt %)	630	569	90.4
Example D35	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Etyl diethylphosphinate + Methyl ⓘethylphenylphosphinate (0.5 wt % + 0.5 wt %)	637	600	94.3

ⓘ indicates text missing or illegible when filed

TABLE 28

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D36	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Etyl diethylphosphinate + methylphenylphosphinate (0.5 wt % + 0.5 wt %)	641	609	95.0

TABLE 28-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Example D37	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Etyl diethylphosphinate + Dimethyl methylphosphonate (0.5 wt % + 0.5 wt %)	629	568	90.3
Example D38	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Etyl diethylphosphinate + Dimethyl methylphosphonate (0.5 wt % + 0.5 wt %)	638	602	94.4
Example D39	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Etyl diethylphosphinate + Dimethyl methylphosphonate (0.5 wt % + 0.5 wt %)	643	612	95.2
Example D40	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Etyl diethylphosphinate + tributylphosphine oxide (0.5 wt % + 0.5 wt %)	628	568	90.4
Example D41	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Etyl diethylphosphinate + tributylphosphine oxide (0.5 wt % + 0.5 wt %)	637	599	94.0
Example D42	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (59 wt %)	Etyl diethylphosphinate + tributylphosphine oxide (0.5 wt % + 0.5 wt %)	642	608	94.7

TABLE 29

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle (mAh · g^{-1})	Capacity at 10th cycle (mAh · g^{-1})	Discharge capacity retention rate (%)
Comparative Example D1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	615	494	80.3
Comparative Example D2	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	611	455	74.5
Comparative Example D3	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Ethyl diethylphosphinate (1 wt %)	597	333	55.8
Comparative Example D4	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Dimethyl methylphosphonate (1 wt %)	595	330	55.5
Comparative Example D5	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Tributylphosphine oxide (1 wt %)	593	327	55.1
Comparative Example D6	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	601	341	56.7
Comparative Example D7	Graphite	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	338	274	81.1
Comparative Example D8	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Etyl diethylphosphinate (1 wt %)	334	277	82.9
Comparative Example D9	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Dimethyl methylphosphonate (1 wt %)	333	275	82.6

TABLE 30

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (D) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example D10	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 63 wt %)	Tributylphosphine oxide (1 wt %)	329	274	83.3
Comparative Example D11	Graphite	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	342	301	88.0
Comparative Example D12	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Etyl diethylphosphinate (1 wt %)	335	247	73.7
Comparative Example D13	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Dimethyl methylphosphonate (1 wt %)	331	240	72.5
Comparative Example D14	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Tributylphosphinate (1 wt %)	325	235	72.3
Comparative Example D15	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Etyl diethylphosphinate (1 wt %)	328	220	67.1
Comparative Example D16	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Dimethyl methylphosphonate (1 wt %)	326	217	66.6
Comparative Example D17	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (60 wt %)	Tributylphosphinate (1 wt %)	323	213	65.9

[0775] The results shown in Tables 24 to 30 above indicate the following.

[0776] In Examples D1 to D42, where non-aqueous liquid electrolyte containing the specific compound (D) and the specific carbonate was used, the discharge capacity retention rate is improved remarkably in comparison with Comparative Example D6, where non-aqueous liquid electrolyte containing neither the specific compound (D) nor the specific carbonate was used.

[0777] In contrast, in Comparative Examples D3 to D5, where non-aqueous liquid electrolyte containing only the specific compound (D) was used, the discharge capacity retention rate is not improved in comparison with Comparative Example D6. The capacity retentions of Comparative Examples D1 and D2, where non-aqueous liquid electrolyte containing only the specific carbonate was used, are improved but still far inferior to those of Examples D1 to D42.

[0778] On the other hand, in Comparative Examples D7 to D17, only carbon material was used as negative-electrode active material. The non-aqueous liquid electrolyte of Comparative Example D7 contained no specific compound (D) or specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples D8 to D10 contained only the specific compound (D). The non-aqueous liquid electrolyte of Comparative Example D11 contained only the specific carbonate. The non-aqueous liquid electrolytes of Comparative Examples D12 to D17 contained the specific compound (D) and the specific carbonate.

[0779] In Examples D1 to D42, where the negative-electrode active material was silicon alloy, the discharge capacity is high in comparison with Comparative Examples D7 to D17, where the negative-electrode active material consisted only of carbon material. When the negative-electrode active material was carbon material, comparison among Comparative Examples D7 to D17 indicates improvement in discharge capacity retention rate due to that the non-aqueous liquid electrolyte contained the specific carbonate, but the effect due to containing only the specific compound (D) or the synergistic effect due to containing both the specific compound (D) and the specific carbonate is not recognized.

Example•Comparative Example Group E: Examples E1 to E44 and Comparative Examples E1 to E9

[0780] Non-aqueous liquid electrolyte secondary batteries were assembled by the following procedure and their performances were evaluated. The results are shown in Tables 31 to 37.

[0781] [Preparation of Negative Electrode]

Preparation of Silicon Alloy Negative Electrode: Examples E1 to E44 and Comparative Examples E1 to E4

[0782] The silicon alloy negative electrode was prepared by the same method as described in the section <Preparation of silicon alloy negative electrode> of the above-mentioned [Example•Comparative Example Group A].

Preparation of Graphite Negative Electrode: Comparative Examples E5 to E9

[0783] The graphite negative electrode was prepared by the same method as described in the section <Preparation of graphite negative electrode> of the above-mentioned [Example• Comparative Example Group A].

[0784] [Preparation of Positive Electrode]

[0785] The positive electrode was prepared by the same method as described in the section <Preparation of positive electrode> of the above-mentioned [Example•Comparative Example Group A].

[0786] [Preparation of Non-Aqueous Liquid Electrolyte]

[0787] Compounds of [Specific carbonate], [Other compound] and [Specific compound (E)] described in each [Example] and [Comparative Example] of Tables 31 to 37 appearing later were mixed in a ratio specified in each column of the Tables. $LiPF_6$ was dissolved further as electrolyte salt at a concentration of 1 $mol \cdot dm^{-3}$ to prepare the non-aqueous liquid electrolyte (non-aqueous liquid electrolyte of Examples E1 to E44 and Comparative Examples E1 to E9).

[0788] [Preparation of Coin-Type Cell]

[0789] By using the above-mentioned positive electrode and negative electrode, and the non-aqueous liquid electrolyte prepared by the above-mentioned procedure (non-aqueous liquid electrolyte of Examples E1 to E44 and Comparative Examples E1 to E9), the coin-type cells (non-aqueous liquid electrolyte secondary batteries of Examples E1 to E44 and Comparative Examples E1 to E9) were prepared by the same procedure as described in [Preparation of coin-type cell] of the above-mentioned [Example•Comparative Example Group A]. As negative electrode, the above-mentioned silicon alloy negative electrode or graphite negative electrode was selected and used, according to the description of [Negative electrode] column in each [Example] and [Comparative Example] of Tables 31 to 37 appearing later.

[0790] [Evaluation of Coin-Type Cell (Discharge Capacity and Discharge Capacity Retention Rate)]

[0791] For the coin-type cells obtained by the above procedure (non-aqueous liquid electrolyte secondary batteries of Examples E1 to E44 and Comparative Examples E1 to E9), the discharge capacity and discharge capacity retention rate were evaluated by the same procedure as described in [Preparation of coin-type cell][SIC] of the above-mentioned [Example•Comparative Example Group A].

[0792] Discharge capacities at the 1st and 10th cycles and discharge capacity retention rate (%) obtained for the coin-type cell of each Examples and Comparative Examples are shown in the column of [Evaluation of the cell] of Tables 31 to 37 below. Each value of the discharge capacities shown in Tables 31 to 37 indicates capacity per unit weight of negative-electrode active material ($mAh \cdot g^{-1}$). "wt %" indicates "weight %".

TABLE 31

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Cyclohexylbenzene (2 wt %)	631	569	90.2
Example E2	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34.5 wt % + 59.5 wt %)	Cyclohexylbenzene (1 wt %)	627	557	88.8
Example E3	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Cyclohexylbenzene (2 wt %)	637	601	94.3
Example E4	Silicon alloy	Fluoroethylene carbonate (20 wt %)	Ethylene carbonate + Diethyl carbonate (17.5 wt % + 60.5 wt %)	Cyclohexylbenzene (2 wt %)	633	588	92.9
Example E5	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Cyclohexylbenzene (2 wt %)	620	522	84.2
Example E6	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Cyclohexylbenzene (2 wt %)	634	582	91.8
Example E7	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Cyclohexylbenzene (2 wt %)	641	607	94.7
Example E8	Silicon alloy	Fluoroethylene carbonate + Vinylethylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Cyclohexylbenzene (2 wt %)	640	604	94.4
Example E9	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Biphenyl (2 wt %)	629	563	89.5

TABLE 32

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E10	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Biphenyl (2 wt %)	631	565	89.5
Example E11	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Biphenyl (2 wt %)	634	595	93.8
Example E12	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Biphenyl (2 wt %)	639	601	94.1
Example E13	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-4-fluorobenzene (2 wt %)	633	573	92.3
Example E14	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-4-fluorobenzene (2 wt %)	638	589	90.5
Example E15	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1-cyclohexyl-4-fluorobenzene (2 wt %)	640	605	94.5
Example E16	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	1-cyclohexyl-4-fluorobenzene (2 wt %)	643	611	95.0
Example E17	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-2-fluorobenzene (2 wt %))	633	571	90.2

TABLE 33

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E18	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-2-fluorobenzene (2 wt %))	635	573	90.2
Example E19	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1-cyclohexyl-2-fluorobenzene (2 wt %)	638	600	94.1
Example E20	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	1-cyclohexyl-2-fluorobenzene (2 wt %)	641	607	94.7
Example E21	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Cyclohexyl fluorobenzene (a mixture in which 1,2-isomer:1,4-isomer = 3:7) (2 wt %)	634	574	90.5
Example E22	Silicon alloy	4,5-Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Cyclohexyl fluorobenzene (a mixture in which 1,2-isomer:1,4-isomer = 3:7) (2 wt %)	637	591	92.8

TABLE 33-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E23	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Cyclohexyl fluorobenzene (a mixture in which 1,2-isomer:1,4-isomer = 3:7) (2 wt %))	641	606	94.5
Example E24	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	Cyclohexyl fluorobenzene (a mixture in which 1,2-isomer:1,4-isomer = 3:7) (2 wt %)	644	912	95.0

TABLE 34

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E25	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-3-phenylbenzene (2 wt %)	626	556	88.8
Example E26	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1-cyclohexyl-3-phenylbenzene (2 wt %)	628	570	90.8
Example E27	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1-cyclohexyl-3-phenylbenzene (2 wt %)	630	580	92.1
Example E28	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	1-cyclohexyl-3-phenylbenzene (2 wt %)	633	587	92.7
Example E29	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1,3-diphenyl cyclohexane (2 wt %)	630	566	89.8
Example E30	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	1,3-diphenyl cyclohexane (2 wt %)	632	582	92.1
Example E31	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	1,3-diphenyl cyclohexane (2 wt %)	635	598	94.2
Example E32	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	1,3-diphenyl cyclohexane (2 wt %))	642	606	94.4
Example E33	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	partially-hydrogenated 1,3-diphenylbenzene (2 wt %)	627	564	90.0

TABLE 35

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E34	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	partially-hydrogenated 1,3-diphenylbenzene (2 wt %)	629	577	91.7
Example E35	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	partially-hydrogenated 1,3-diphenylbenzene (2 wt %)	630	594	94.3
Example E36	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	partially-hydrogenated 1,3-diphenylbenzene (2 wt %)	640	605	94.5
Example E37	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	(1,1-dimethylethyl)benzene (2 wt %)	626	551	88.0
Example E38	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	(1,1-dimethylethyl)benzene (2 wt %)	628	563	89.6
Example E39	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	(1,1-dimethylethyl)benzene (2 wt %)	630	574	91.1
Example E40	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	(1,1-dimethylethyl)benzene (2 wt %)	637	592	92.9
Example E41	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Fluorobenzene (2 wt %)	633	576	91.0
Example E42	Silicon alloy	4,5-difluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	Fluorobenzene (2 wt %)	635	587	92.4

TABLE 36

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh \cdot g^{-1}$)	Capacity at 10th cycle ($mAh \cdot g^{-1}$)	Discharge capacity retention rate (%)
Example E43	Silicon alloy	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	Fluorobenzene (2 wt %)	639	604	94.5
Example E44	Silicon alloy	Fluoroethylene carbonate + Vinylene carbonate (38 wt % + 2 wt %)	Diethyl carbonate (58 wt %)	partially-hydrogenated 1,3-diphenylbenzene (2 wt %)	640	605	94.5

TABLE 37

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle ($mAh * g^{-1}$)	Capacity at 10th cycle ($mAh * g^{-1}$)	Discharge capacity retention rate (%)
Comparative Example E1	Silicon alloy	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	615	494	80.3

TABLE 37-continued

		Non-aqueous liquid electrolyte			Evaluation of the cell		
	Negative electrode	Specific carbonate (Concentration)	Other compound (Concentration)	Specific compound (E) (Concentration)	Capacity at 1st cycle (mAh * g^{-1})	Capacity at 10th cycle (mAh * g^{-1})	Discharge capacity retention rate (%)
Comparative Example E2	Silicon alloy	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	611	455	74.5
Comparative Example E3	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	cyclohexyl benzene (2 wt %)	598	335	56.0
Comparative Example E4	Silicon alloy	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	601	341	56.7
Comparative Example E5	Graphite	none	Ethylene carbonate + Diethyl carbonate (37 wt % + 63 wt %)	none	338	274	81.1
Comparative Example E6	Graphite	none	Ethylene carbonate + Diethyl carbonate (36 wt % + 62 wt %)	cyclohexyl benzene (2 wt %)	335	278	83.0
Comparative Example E7	Graphite	Vinylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (35 wt % + 60 wt %)	none	342	301	88.0
Comparative Example E8	Graphite	Fluoroethylene carbonate (5 wt %)	Ethylene carbonate + Diethyl carbonate (34 wt % + 59 wt %)	cyclohexyl benzene (2 wt %)	335	250	74.6
Comparative Example E9	Graphite	Fluoroethylene carbonate (39 wt %)	Diethyl carbonate (59 wt %)	cyclohexyl benzene (2 wt %)	330	224	67.9

[0793] The results shown in Tables 31 to 37 above indicate the following.

[0794] In Examples E1 to E44, where non-aqueous liquid electrolyte containing the specific compound (E) and the specific carbonate was used, the discharge capacity retention rate after the cycle test is improved remarkably in comparison with Comparative Example E4, where non-aqueous liquid electrolyte containing neither the specific compound (E) nor the specific carbonate was used.

[0795] In Comparative Example E3, where non-aqueous liquid electrolyte containing only the specific compound (E) and no specific carbonate was used, the capacity retention rate is lowered in comparison with Comparative Example E4. The discharge capacity retention rates of Comparative Examples E1 and E2, where non-aqueous liquid electrolyte containing only the specific carbonate and no specific compound (E) was used, are improved but still far inferior to those of Examples E1 to E44.

[0796] On the other hand, in Comparative Examples E5 to E9, only carbon material was used as negative-electrode active material. The non-aqueous liquid electrolyte of Comparative Example E5 contained no specific compound (E) or specific carbonate. The non-aqueous liquid electrolyte of Comparative Example E6 contained only the specific compound (E) and no specific carbonate. It is evident from the comparison between the discharge capacity retention rates of Comparative Example E5 and Comparative Example E6 that the discharge capacity retention rate is improved due to containing the specific compound (E). The non-aqueous liquid electrolyte of Comparative Example E7 contained only the specific carbonate and no specific compound (E). It is evident from the comparison between the discharge capacity retention rates of Comparative Example E5 and Comparative Example E7 that the discharge capacity retention rate is improved due to containing the specific carbonate. On the other hand, it is evident from comparing the discharge capacity retention rates of Comparative Examples E8 and E9, where the non-aqueous liquid electrolyte contained the specific compound (E) and the specific carbonate, with that of Comparative Example E5, where neither the specific compound (E) nor the specific carbonate was contained, that the discharge capacity retention rate is lowered.

[0797] In Examples E1 to E44, where the negative-electrode active material was silicon alloy, the discharge capacity is high in comparison with Comparative Examples E5 to E9, where the negative-electrode active material consisted only of carbon material. And as described above, when the negative-electrode active material was carbon material, improvement in discharge capacity retention rate can be recognized when the non-aqueous liquid electrolyte contained either the specific carbonate or the specific compound (E). However, the discharge capacity retention rate was worse when containing both the specific compound (E) and the specific carbonate than when containing none of them or either of them.

[0798] On the other hand, when the negative-electrode active material was silicon alloy, the discharge capacity retention rate is worse in cells using liquid electrolyte containing only the specific compound (E) and no specific carbonate than in cells using liquid electrolyte containing neither the specific compound (E) nor the specific carbonate, but it is evident that the discharge capacity retention rate is improved in cells using liquid electrolyte containing both the specific carbonate and the specific compound (E).

INDUSTRIAL APPLICABILITY

[0799] The non-aqueous liquid electrolyte secondary battery of the present invention is excellent in long-term charge-

discharge cycle performance and, therefore, can be used as power source of notebook personal computers, pen-input personal computers, mobile personal computers, electronic book players, cellular phones, portable facsimiles, portable copiers, portable printers, headphone stereos, videotape cameras, liquid crystal display televisions, handy cleaners, portable CD players, mini disc players, transceivers, electronic databooks, electronic calculators, memory cards, portable tape recorders, radios, backup power sources, motors, lighting fixtures, toys, game machines, watches, stroboscopes, cameras, load leveling of power etc. and can also be used for electric bicycle, electric scooter, electric car etc.

[0800] The present invention has been explained in detail above with reference to specific embodiments. However, it is evident to those skilled in the art that various modifications can be added thereto without departing from the intention and the scope of the present invention.

[0801] The present application is based on Japanese Patent Application (Patent Application No. 2006-124041) filed on Apr. 27, 2006, Japanese Patent Application (Patent Application No. 2006-124042) filed on Apr. 27, 2006, Japanese Patent Application (Patent Application No. 2006-124043) filed on April 27, Japanese Patent Application (Patent Application No. 2006-124044) filed on Apr. 27, 2006 and Japanese Patent Application (Patent Application No. 2006-124045) filed on April 27, and their entireties are incorporated herewith by reference.

1. A non-aqueous liquid electrolyte to be used for a non-aqueous liquid electrolyte secondary battery comprising a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and the non-aqueous liquid electrolyte, the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom,

wherein said non-aqueous liquid electrolyte contains, at least, a carbonate having at least either an unsaturated bond or a halogen atom, and at least one kind selected from the group consisting of (A), (B), (C), (D) and (E) below,

(A) at least one lithium salt of $LiPF_6$ and $LiBF_4$ (hereinafter referred to as "first lithium salt") and at least one kind of lithium salt, which is different from said first lithium salt, represented by the formula (A-1) below (hereinafter referred to as "second lithium salt"),

[Chemical Formula 1]

$$Li_l(\alpha_m X^a{}_n) \quad \text{(A-1)}$$

in the formula (A-1),

l represents an integer of 1 or larger and 10 or smaller,

m represents an integer of 1 or larger and 100 or smaller,

and n represents an integer of 1 or larger and 200 or smaller,

α represents any atom selected from the group consisting of boron atom, carbon atom, nitrogen atom, oxygen atom and phosphorus atom; when m is 2 or larger, the two or more of α may be the same as or different from each other,

X^a represents a functional group having at least one kind of atom selected from 14 group to 17 group of the periodic table at its binding position to the α, when n is 2 or larger, the two or more of X^a may be the same or different from each other, in addition, two or more X^a may be connected to each other to form a ring structure,

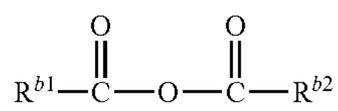
except such a compound that α is boron atom and X^a is represented by

$$(C_iH_{2(i-2)}O_4)(C_jH_{2(i-2)}O_4)$$

(in this context, i and j each represent, independently of each other, an integer of 2 or larger,)

(B) at least one kind of compound represented by the formula (B-1) below,

[Chemical Formula 2]



(B-1)

(in the formula (B-1), R^{b1} and R^{b2} represent, independently of each other, a hydrocarbon group, which may have a substituent, with carbon number of 15 or smaller, R^{b1} and R^{b2} may be connected to each other to form a ring structure,)

(C) at least one kind of chain compound having one or more sulfur-containing functional groups represented by the formula (C-1) below,

[Chemical Formula 3]

$$(O)_m[S(=O)_y]_x(O)_n \quad \text{(C-1)}$$

(in the formula (C-1),

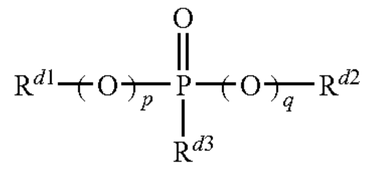
m and n represent, independently of each other, an integer of 0 or 1,

x represents an integer of 1 or 2, and

y represents an integer of 0 or larger and 2 or smaller,

(D) at least one kind of organic phosphorous compound represented by the formula (D-1) below,

[Chemical Formula 4]



(D-1)

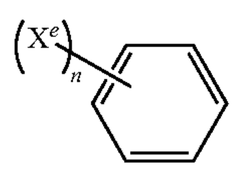
(in the formula (D-1),

p and q represent, independently of each other, an integer of 0 or 1, and

R^{d1}, R^{d2} and R^{d3} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller, any two of R^{d1}, R^{d2} and R^{d3} may be connected to each other to form a ring structure,)

(E) a least one kind of compound represented by the formula (E-1) below,

[Chemical Formula 5]



(E-1)

(in the formula (E-1),

X^e represents a halogen atom, alkyl group or aryl group hen X^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group,

n represents an integer of 1 or larger and 6 or smaller, when n is 2 or larger, the two or more of X^e may be the same or different from each other, in addition, two or more X^e may be connected to each other to form a ring structure or a cage structure.

2. A non-aqueous liquid electrolyte according to claim **1**, wherein

in the above formula (A-1),

α is boron atom or phosphorus atom, and

X^a is a substituent selected from the group consisting of fluorine atom, hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group and substituted sulfonyloxy group (in this context, when X^a is a hydrocarbon group, substituted carbonyloxy group, alkoxy group, substituted sulfinyloxy group or substituted sulfonyloxy group, a part or all of the hydrogen atoms may be substituted with a fluorine atom, in addition, when X^a exists plurally, they may be different from or the same as each other and may be connected to each other to form a ring structure).

3. A non-aqueous liquid electrolyte according to claim **1**, wherein

in the above formula (A-1),

α is carbon atom, nitrogen atom or oxygen atom, and

X^a is a group represented by $—SO_2R^{a0}$ (in this context, R^{a0} represents fluorine atom or a hydrocarbon group when R^{a0} is a hydrocarbon group, a part or all of the hydrogen atoms may be substituted with a fluorine atom, in addition, when the number of X^a is two or more, the two or more of R^{a0} may be the same or different from each other and further, the two or more of R^{a0} may be connected to each other to form a ring structure).

4. A non-aqueous liquid electrolyte according to claim **1**, wherein

in said non-aqueous liquid electrolyte, the concentration of said first lithium salt is 0.5 mol/liter or higher and 2.5 mol/liter or lower,

in said non-aqueous liquid electrolyte, the concentration of said second lithium salt is 0.001 mol/liter or higher and I mol/liter or lower, and

the molar ratio of said second lithium salt relative to the first lithium salt is 1 or smaller.

5. A non-aqueous liquid electrolyte according to claim **1**, wherein

said compound represented by the above formula (B-1) is a compound in which R^{b1} and R^{b2} are connected to each other directly to form a ring structure.

6. A non-aqueous liquid electrolyte according to claim **1**, wherein

in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (B-1) is 0.01 weight % or higher and 5 weight % or lower.

7. A non-aqueous liquid electrolyte according to claim **1**, wherein

said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is a compound represented by the formula (C-2) below,

[Chemical Formula 6]

$$R^{c1}\text{-}A^c\text{-}R^{c2} \qquad \text{(C-2)}$$

(In the formula (C-2),

A^c represents a sulfur-containing functional group represented by the above formula (C-1), and

R^{c1} and R^{c2} represent, independently of each other, a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller.)

8. A non-aqueous liquid electrolyte according to claim **1**, wherein

said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is a compound represented by the formula (C-3) below.

[Chemical Formula 7]

$$(R^{c3}\text{-}A^c)_z—R^{c4} \qquad \text{(C-3)}$$

(in the formula (C-3),

R^{c3} represents a hydrocarbon group, which may have a halogen atom, with carbon number of 1 or larger and 20 or smaller,

A^c represents a sulfur-containing functional group represented by the above formula (C-1),

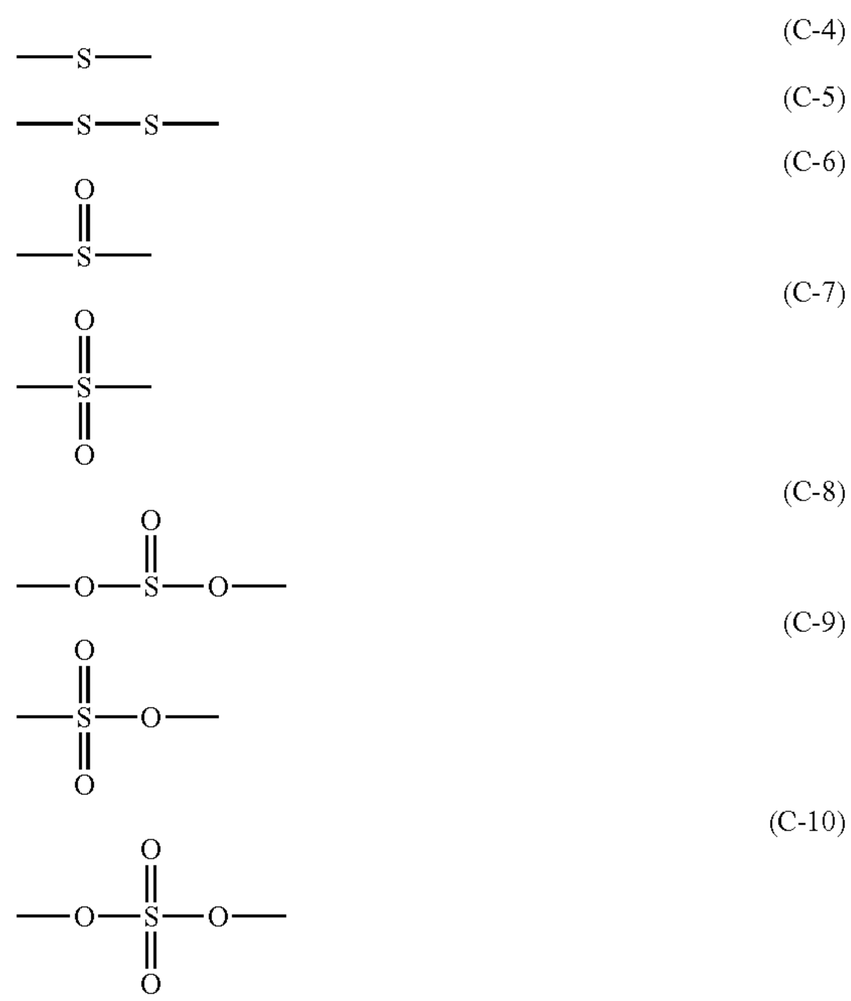
z represents an integer of 2 or larger and 4 or smaller, and

R^{c4} represents a hydrocarbon group, which may have a halogen atom, with z number of connection parts and with carbon number of 1 or larger and 20 or smaller; in this context, the z number of R^{c3} and A^c may be the same or different from each other, respectively.)

9. A non-aqueous liquid electrolyte according to claim **1**, wherein

said sulfur-containing functional group represented by the above formula (C-1) is any one of functional groups represented by the formulae (C-4) to (C-10) below,

[Chemical Formula 8]



10. A non-aqueous liquid electrolyte according to claim **1**, wherein

in said non-aqueous liquid electrolyte, the concentration of said chain compound having said sulfur-containing functional group represented by the above formula (C-1) is 0.01 weight % or higher and 10 weight % or lower.

11. A non-aqueous liquid electrolyte according to claim **1**, wherein

in the above formula (D-1), p+q is equal to 1 or 2.

12. A non-aqueous liquid electrolyte according to claim **1**, wherein

in the above formula (D-1), p+q is equal to 0.

13. A non-aqueous liquid electrolyte according to claim **1**, wherein

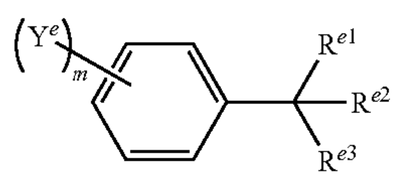
in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (D-1) is 0.01 weight % or higher and 10 weight % or lower.

14. A non-aqueous liquid electrolyte according to claim **1**, wherein

said compound represented by the above formula (E-1) is the compound represented by the formula (E-2) below;

[Chemical Formula 9]

(E-2)



(In the formula (E-2),

R^{e1}, R^{e2} and R^{e3} represent, independently of each other, hydrogen atom, or an alkyl group that may be substituted with a halogen atom; in addition, two or three of R^{e1}, R^{e2} and R^{e3} may be connected to each other to form a ring structure or cage structure; however, none of or one of R^{e1}, R^{e2} and R^{e3} is hydrogen atom.

Y^e represents a halogen atom, alkyl group or aryl group, when Y^e is an alkyl group or aryl group, it may be further substituted with a halogen atom, alkyl group or aryl group;

m represents an integer of 0 or larger and 5 or smaller; when m is 2 or larger, the two or more of Y^e may be the same or different from each other; in addition, two or more Y^e may be connected to each other to form a ring structure or cage structure.)

15. A non-aqueous liquid electrolyte according to claim **1**, wherein

in the above formula (E-1), at least one of X^e is halogen atom, or an aryl group that may be substituted with a halogen atom.

16. A non-aqueous liquid electrolyte according to claim **1**, wherein

in said non-aqueous liquid electrolyte, the concentration of said compound represented by the above formula (E-1) is 0.01 weight % or higher and 10 weight % or lower.

17. A non-aqueous liquid electrolyte according to claim **1**, wherein

in said non-aqueous liquid electrolyte, the concentration of said carbonate having at least either an unsaturated bond or a halogen atom is 0.01 weight % or higher, and 70 weight % or lower.

18. A non-aqueous liquid electrolyte according to claim **1**, wherein

wherein said carbonate having at least either an unsaturated bond or a halogen atom is one or more kinds of carbonates selected from the group consisting of vinylene carbonate, vinylethylene carbonate, fluoroethylene carbonate, difluoroethylene carbonate and derivatives of these carbonates.

19. A non-aqueous liquid electrolyte according to claim **1**, further containing ethylene carbonate and/or propylene carbonate.

20. A non-aqueous liquid electrolyte according to claim **1**, further containing at least one carbonate selected from the group consisting of dimethyl carbonate, ethylmethyl carbonate, diethyl carbonate, methyl-n-propyl carbonate, ethyl-n-propyl carbonate and di-n-propyl carbonate.

21. A non-aqueous liquid electrolyte secondary battery comprising a negative electrode and a positive electrode, capable of intercalating and deintercalating lithium ions, and a non-aqueous liquid electrolyte,

the negative electrode containing a negative-electrode active material having at least one kind of atom selected from the group consisting of Si atom, Sn atom and Pb atom, wherein

said non-aqueous liquid electrolyte is a non-aqueous liquid electrolyte according to claim **1**.

* * * * *