US 20090069204A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2009/0069204 A1
(43) Pub. Date: Mar. 12, 2009

Kamimura et al.

(54) **LUBRICANT FOR OIL RETAINING BEARING**

(75) Inventors: **Hideto Kamimura**, Chiba (JP); **Shukichi Shimoda**, Chiba (JP); **Katsumi Hashimoto**, Chiba (JP)

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

(73) Assignee: **Idemitsu Kosan Co., Ltd.**, Chiyoda-ku (JP)

(21) Appl. No.: **11/913,182**

(22) PCT Filed: **Jul. 14, 2006**

(86) PCT No.: **PCT/JP2006/314040**

§ 371 (c)(1),
(2), (4) Date: **Oct. 31, 2007**

(30) **Foreign Application Priority Data**

Jul. 15, 2005 (JP) 2005-207278
Nov. 18, 2005 (JP) 2005-334169

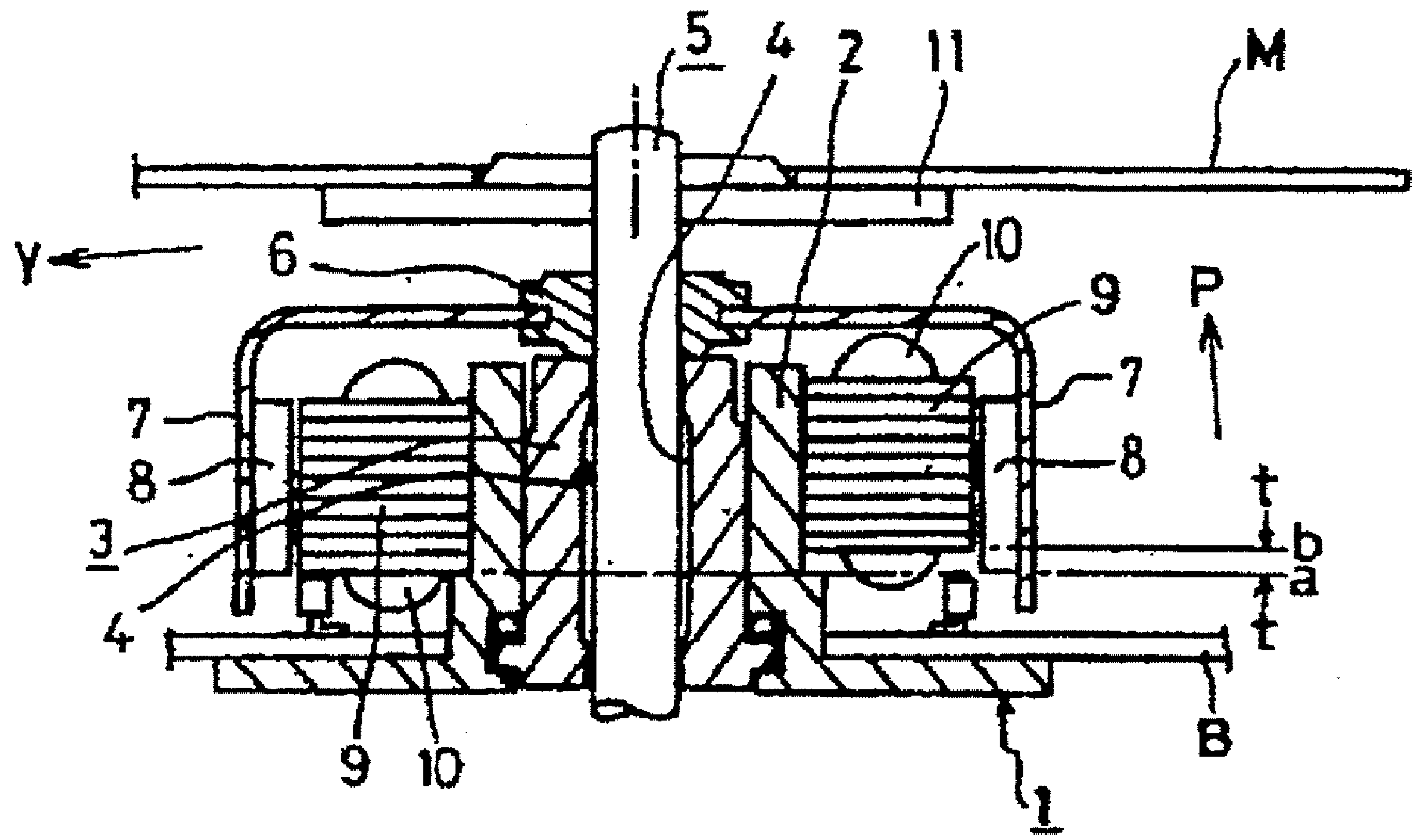
Publication Classification

(51) **Int. Cl.**
C10M 133/00 (2006.01)
C10M 169/04 (2006.01)

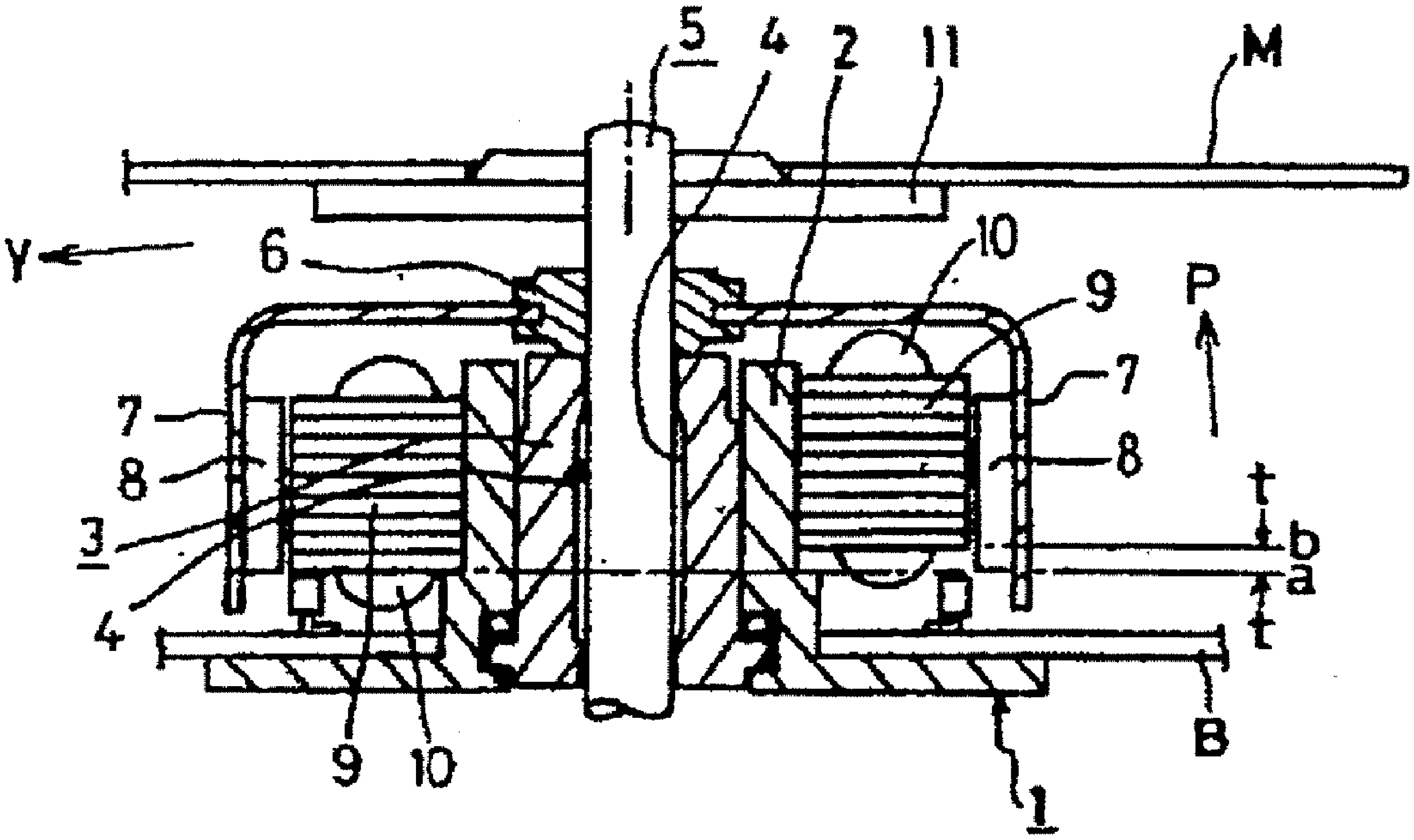
(52) **U.S. Cl.** **508/100**; 508/110; 508/545

(57) **ABSTRACT**

A lubricant for an oil retaining bearing containing 1 to 100% by mass of an ionic liquid. The lubricant has a low vapor pressure, low flammability, excellent heat resistance and ability to suppress the emanation of low volatile components and decomposed gases during use, or a lubricant for an oil retaining bearing which has antistatic property and is capable of grounding the static electricity generated by flow charging of the lubricant.



[FIG. 1]



LUBRICANT FOR OIL RETAINING BEARING

TECHNICAL FIELD

[0001] The present invention relates to a lubricant for an oil retaining bearing. More specifically, the present invention is directed to a lubricant for an oil retaining bearing which contains an ionic liquid in its base oil and which has a low vapor pressure, low flammability, excellent heat resistance and ability to suppress the emanation of low volatile components and decomposed gases during use, or a lubricant for an oil retaining bearing which contains an ionic liquid as an antistatic agent, which has antistatic property and which is capable of grounding the static electricity generated by flow charging of the lubricant.

BACKGROUND ART

[0002] In recent years, as bearings for spindle motors for driving, typically, magnetic disks and optical disks, there have been increasing cases in which sliding bearings, such as fluid bearings and sintered oil retaining bearings are used because of their silent operation and durability. With such a bearing, a shaft is separated by a lubricating oil film from an inside surface of the bearing. The bearing is characterized in that it can support a load applied to the shaft while reducing friction between the shaft and the bearing. Therefore, the performance of the bearing can be said to greatly depend upon the performance of the lubricating oil.

[0003] The lubricating oil for such sliding bearings is required to have suitable viscosity, durability, antistatic property, etc. Among them, the viscosity is important because the electric power loss of a spindle motor and the bearing rigidity depend upon the viscosity. In recent years, there is a tendency to choose a lubricant oil having a low viscosity which permits a reduced loss of electric power during high speed operation, because the rotation speed of spindle motors for recent information related equipments (particularly CD, DVD, HDD and laser printers (polygon mirrors)) increases year by year (to a range of 10,000 to 50,000 rpm). In general, with a decrease of the viscosity of a lubricating oil, the amount of vaporized oil increases. Thus, a thoughtless use of a low viscosity lubricating oil might cause a loss of the lubricating oil, resulting in a lubrication failure in the bearing, and in the worst case, damage of the bearing. In consideration of this point, various proposals have been made to use specific base oils for the lubricating oil of bearings that can satisfy both low viscosity and low volatility. For example, Patent Document 1 proposes the use of an ester compound, Patent Document 2 proposes the use of a monoester, Patent Document 3 proposes the use of a carbonic acid ester, Patent Document 4 and Patent Document 5 propose the conjoint use of poly(α-olefin) and an ester, Patent Document 6 proposes the conjoint use of a diester and a polyol ester, Patent Document 7 proposes the use of a neopentyl glycol ester, Patent Document 8 proposes the use of an aromatic ester or a diester, Patent Document 9 proposes the use of a monoester, and Patent Document 10 proposes the use of a specific diester of oxalic acid, malonic acid, succinic acid, etc.

[0004] Meanwhile, in the sliding bearings, a shaft is completely separated by a lubricating oil film from the bearing and is in non-contact therewith. Therefore, static electricity is apt to be generated by flow charging. Upon discharging, there is a fear that the important electronic parts (e.g., MR head of a hard disk drive) may become disordered. Therefore, it is necessary that the sliding bearing used in precision machines such as a magnetic disk apparatus should be grounded in order to remove the static electricity and to protect the electronic and magnetic parts. From this viewpoint, whilst the aforementioned conventional lubricating oils for bearings satisfy both low viscosity and low volatility, they still have a problem because they have a large volume resistivity and tend to generate static electricity.

[0005] To cope with the above problem, a lubricating oil compounded with conductive microparticles of a metal or a metal oxide is reported (see, for example, Patent Documents 11 and 12). However, a lubricating oil containing such microparticles may cause anomalous wear of the bearing, because the microparticles are present on the sliding surface at the time of starting or stopping the motor.

[0006] As a lubricating oil free of such metal particles, there a proposal to add an organic metal salt such as a sulfonic acid, a phenate, or a salicylate (see Patent Document 13). However, the antistatic agent of such an organic metal salt cannot exhibit satisfactory antistatic property unless it is used in a large amount. In addition, the antistatic agent has a problem because it is deteriorated during long-term use and converted into an oil-insoluble inorganic salt (sludge).

[0007] In the meanwhile, a series of ethylmethylimidazolium salts having different anions have been reported to have excellent heat stability and high ionic conductivity and to form a stable liquid even in the air atmosphere (see, for example, Non-Patent Document 1). Since then, organic ionic liquids composed of cations and anions have attracted an interest. Thus, studies are positively made on ionic liquids for various applications, such as electrolytic solutions for solar cells (see, for example, Patent Document 14), solvents for extraction and separation and reaction solvents, by utilizing their characteristics such as heat stability (low volatility and flame retardancy), high ionic density (high ionic conductivity) and low viscosity.

[0008] The ionic liquid, in which molecules are bound by strong ionic bonding rather than by intermolecular attractive forces as in a molecular liquid, is a liquid which is sparingly volatile, flame retarding and stable against heat and oxidation. Although the ionic liquid has a low viscosity, it has low volatility and excellent heat resistance. Therefore, it attracts much attention as a base oil for a lubricating oil that can satisfy possible future high requirements.

[0009] Further, since the ionic liquid is composed of a positively charged cation and a negatively charged anion, it has a specific electrical property such as capability of forming an electric double layer on an electrode surface. There is a possibility that such an electrical property of the ionic liquid might exert a certain influence upon the frictional characteristics thereof.

[0010] As an example of a lubricant using such an ionic fluid, a fluid bearing device is disclosed which includes a sleeve having a bearing hole, a shaft inserted into the bearing hole with a bearing gap being formed between the bearing hole and the shaft, a dynamic pressure generation groove provided in at least one of an inner periphery of the bearing hole or a surface of the shaft, and a lubricant filled in the bearing gap, wherein the lubricant contains an ionic liquid added as a conductivity imparting agent (see, for example, Patent Document 15). In this technique, however, the ionic liquid is added as a conductivity imparting agent to the lubricant for a fluid bearing. This technique does not use an ionic liquid in a lubricant for an oil retaining bearing.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. H11-315292

[Patent Document 2] Japanese Unexamined Patent Application Publication No. 2000-63860

[Patent Document 3] Japanese Unexamined Patent Application Publication No. 2001-107046

[Patent Document 4] Japanese Unexamined Patent Application Publication No. 2001-172656

[Patent Document 5] Japanese Unexamined Patent Application Publication No. 2001-240885

[Patent Document 6] Japanese Unexamined Patent Application Publication No. 2001-279284

[Patent Document 7] Japanese Unexamined Patent Application Publication No. 2001-316687

[Patent Document 8] Japanese Unexamined Patent Application Publication No. 2002-97482

[0011] [Patent Document 9] Japanese Unexamined Patent Application Publication No. 2002-146381 (paragraph [0007])

[Patent Document 10] Japanese Unexamined Patent Application Publication No. 2002

[0012] [Patent Document 11] Japanese Unexamined Patent Application Publication No. H10-30096
[Patent Document 12] Japanese Unexamined Patent Application Publication No. H11-315292 (paragraph [0023])

[Patent Document 13] Japanese Unexamined Patent Application Publication No. 2001-234187

[Patent Document 14] Japanese Unexamined Patent Application Publication No. 2003-31270

[0013] [Patent Document 15] Japanese Unexamined Patent Application Publication No. 2004-183868 [Non-Patent Document 1] "J. Chem. Soc. Chem. Commun.", p965 (1992)

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

[0014] Under the above circumstance, it is an object of the present invention to provide a lubricant for an oil retaining bearing which has a low vapor pressure, low flammability, excellent heat resistance and ability to suppress the emanation of low volatile components and decomposed gases during use, or a lubricant for an oil retaining bearing which has antistatic property and is capable of grounding the static electricity generated by flow charging of the lubricant.

Means for Solving the Problems

[0015] The present inventors have made an earnest study with a view toward developing a lubricant for an oil retaining bearing having the above-described desired properties and, as a result, have found that the objects can be fulfilled by a lubricant containing a specific proportion of an ionic liquid. The present invention has been completed on the basis of such a finding.

[0016] That is, the present invention provides:

(1) A lubricant for an oil retaining bearing including 1 to 100% by mass of an ionic liquid;

(2) A lubricant for an oil retaining bearing as recited in (1) above, including a base oil which contains 50 to 100% by mass of the ionic liquid;

(3) A lubricant for an oil retaining bearing as recited in (2) above, in which the ionic liquid contained in the base oil has a pour point of 0° C. or below;

(4) A lubricant for an oil retaining bearing as recited in (1) above, in which the ionic liquid is contained as an antistatic agent;

(5) A lubricant for an oil retaining bearing as recited in any one of (1) to (4) above, which has a volume resistivity at 25° C. of $1\times10^{10}\Omega\cdot$cm or less; retained bearing,

(6) A lubricant for an oil retaining bearing as recited in any one of (1) to (5) above, in which the ionic liquid is a compound represented by the following general formula (I):

$$(Z^{p+})_k\cdot(A^{q-})_m \qquad \text{(I)}$$

(where Z^{p+} represents a cation, A^{q-} represents an anion, p, q, k, m, p×k and q×m are each an integer of 1 to 3, with the proviso that p×k equals q×m and that, when k or m is 2 or more, Z or A may be the same or different, respectively);

(7) A lubricant for an oil retaining bearing as recited in (6) above, in which p, q, k and m in the general formula (I) are each 1;

(8) A lubricant for an oil retaining bearing as recited in any one of (1) to (5) above, in which the ionic liquid is of a zwitter ion type which the cation and the anion are bonded by a covalent bond;

(9) A lubricant for an oil retaining bearing as recited in any one of (6) to (8) above, in which the ionic liquid has a cation which a nitrogen atom is the ionic center;

(10) A lubricant for an oil retaining bearing as recited in any one of (1) to (9) above, which has a kinematic viscosity of 1 to 1,000 mm^2/s at a temperature of 40° C.;

(11) A lubricant for an oil retaining bearing as recited in any one of (1) to (10) above, which is retained in the bearing of a metal porous body, a plastic porous body or a ceramic porous body;

(12) An oil retaining bearing using a lubricant for an oil retaining bearing as recited in any one of (1) to (11) above; and

(13) A motor unit including an oil retaining bearing as recited in (12) above.

EFFECT OF THE INVENTION

[0017] According to the present invention, there can be provided a lubricant for an oil retaining bearing which contains an ionic liquid as its base oil and which has a low vapor pressure, low flammability, excellent heat resistance and ability to suppress the emanation of low volatile components and decomposed gases during use, or a lubricant for an oil retaining bearing which contains an ionic liquid as an antistatic agent, which has antistatic property and which is capable of grounding the static electricity generated by flow charging of the lubricant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** is an enlarged, cross-sectional view illustrating an example of a spindle motor to which the lubricant for an oil retaining bearing according to the present invention is applied.

EXPLANATION OF REFERENCE NUMERALS AND SYMBOLS

[0019] **1**: housing holder
[0020] **2**: cylindrical section
[0021] **3**: bearing
[0022] **4**: open center
[0023] **5**: motor shaft
[0024] **6**: retaining member
[0025] **7**: rotor
[0026] **8**: magnet

[0027] **9**: stacked core

[0028] **10**: coil

[0029] **11**: turn table

[0030] B: base

[0031] M: rotating medium

BEST MODE FOR CARRYING OUT THE INVENTION

[0032] The lubricant for an oil retaining bearing according to the present invention is characterized in that it contains 1 to 100% by mass of an ionic liquid.

[0033] In the present invention the ionic liquid may be of a type in which a cation and an anion are bonded by ionic bonding (hereinafter occasionally referred to as ionic liquid (I)) and of a type in which a cation and an anion are bonded by a covalent bond, namely of a zwitterionic type (hereinafter occasionally referred to as ionic liquid (II)).

[0034] As the ionic liquid (I), there may be used for example a compound represented by the following general formula (I):

$$(Z^{p+})_k \cdot (A^{q-})_m \qquad (1)$$

(where Z^{p+} represents a cation, A^{q-} represents an anion, p, q, k, m, p×k and q×m are each an integer of 1 to 3, with the proviso that p×k equals q×m and that, when k or m is 2 or more, Z or A may be the same or different, respectively).

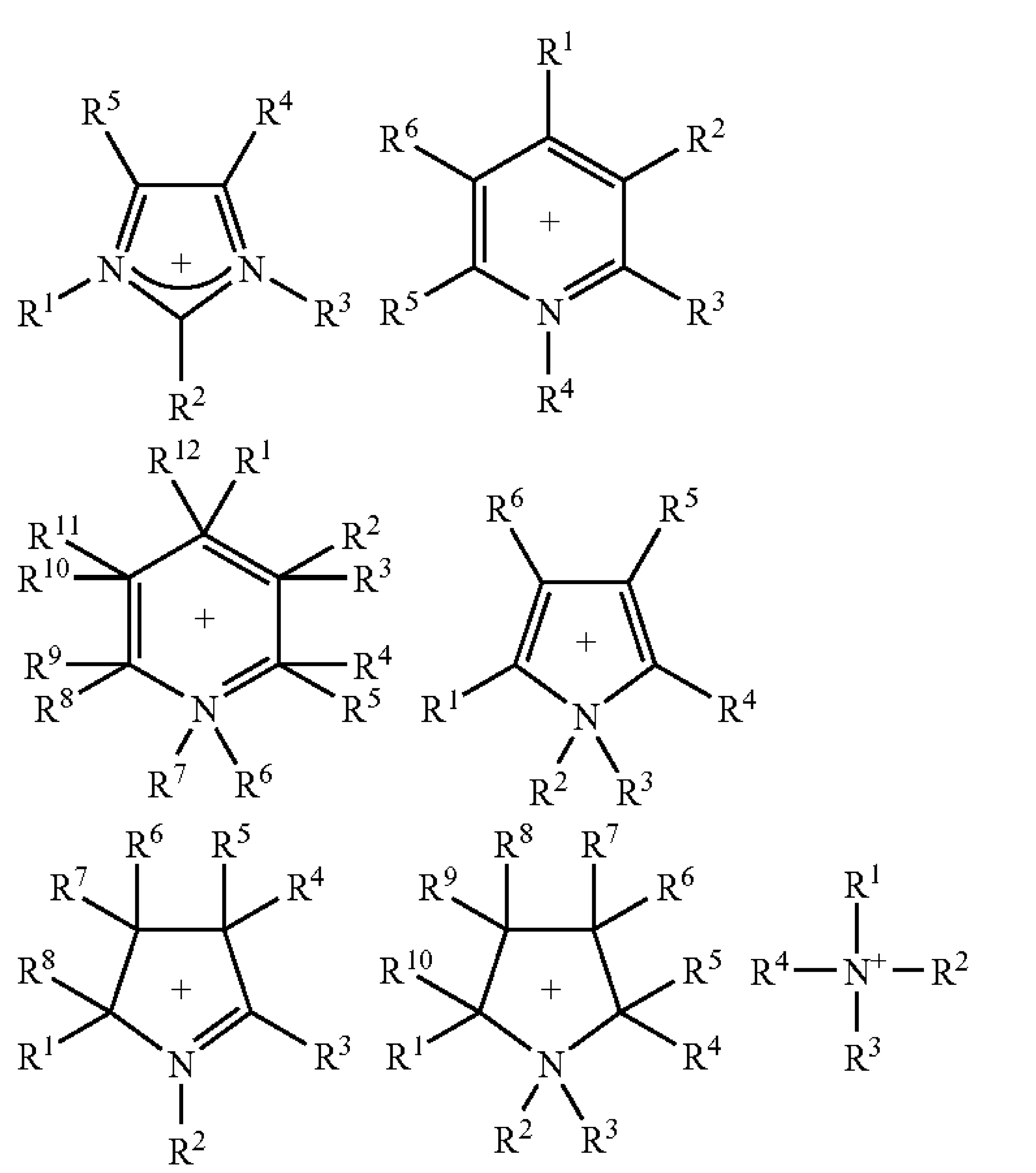
[0035] As the ionic liquid (I), a compound of the above general formula (I) in which p, k, q, and m are each 1, namely a compound of the following general formula (I-a):

$$Z^+.A^- \qquad \text{(I-a)}$$

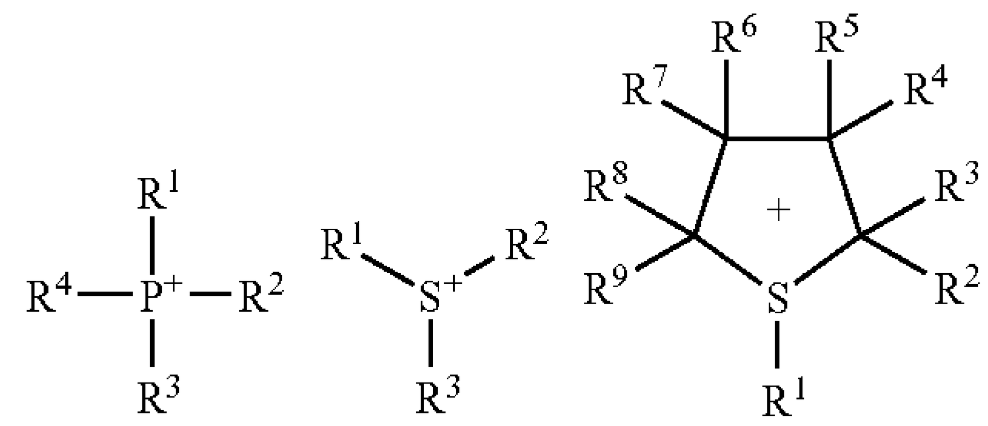
(where Z^+ represents a cation and A^- represents an anion), is preferred.

[0036] The aforementioned cation represented by Z^+ is not specifically limited and any cation may be properly selected from the known cations used in the conventional ionic liquid. For example, cations represented the following general formulas may be preferably used:

[Chemical Formula 1]



-continued



(where R^1 to R^{12}, which may be the same or different, each represent a group selected from a hydrogen atom, alkyl groups having 1 to 18 carbon atoms which may have an ether bond, and alkoxy groups having 1 to 18 carbon atoms.)

[0037] Examples of the alkyl group having 1 to 18 carbon atoms which may have an ether bond and which is represented by R^1 to R^{12} include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, various pentyl groups, various hexyl groups, various heptyl groups, various octyl groups and a 2-methoxyethyl group. Examples of the alkoxy group having 1 to 18 carbon atoms include a methoxy group, an ethoxy group, an n-propoxy group, an isopropoxy group, an n-butoxy group, an isobutoxy group, a sec-butoxy group, a tert-butoxy group, various pentoxy groups, various heptoxy groups and various octoxy groups.

[0038] In the present invention, cation groups having a nitrogen atom as the ionic center are preferred among the above-described cations.

[0039] On the other hand, the aforementioned anion represented by A^- is not specifically limited and any anion may be properly selected from the known anions used in the conventional ionic liquid. For example, anions represented by the following formulas:

$$BF_4^-, PF_6^-, C_nH_{(2n+1)}OSO_3^-, (C_nF_{(2n+1-x)}H_x)SO_3^-, (C_nF_{(2n+1-x)}H_x)COO^-, NO_3^-,$$

$$CH_3SO_3^-, (CN)_2N^-, HSO_3^-, C_6H_5SO_3^-, CH_3^-(C_6H_4)SO_3^-, I^-, I_3^-, F(HF)_n^-,$$

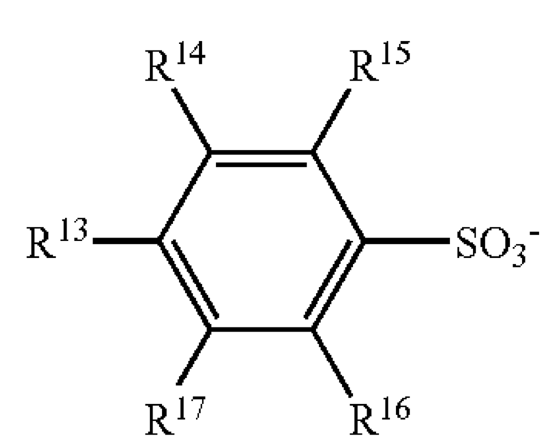
$$[C_nF_{(2n-1-x)}H_x]Y^1O_z)_3C^-, ([C_nF_{(2n+1-x)}H_x]Y^1O_z)_2N^-$$

(where Y^1 represents a carbon atom or a sulfur atom, provided that when there are plurality such Y^1 groups, they may be the same or different, and that the plural $(C_nF_{(2n+1-x)}H_x)Y^1O_2$ groups may be the same or different; n is an integer of 0 to 6; x is an integer of 0 to 13; and z is an integer of 1 to 3 when Y^1 is a carbon atom and 0 to 4 when Y^1 is a sulfur atom),

$$B(C_mY^2_{(2m+1)})_4^-, P(C_mY^2_{(2m+1)})_6^-$$

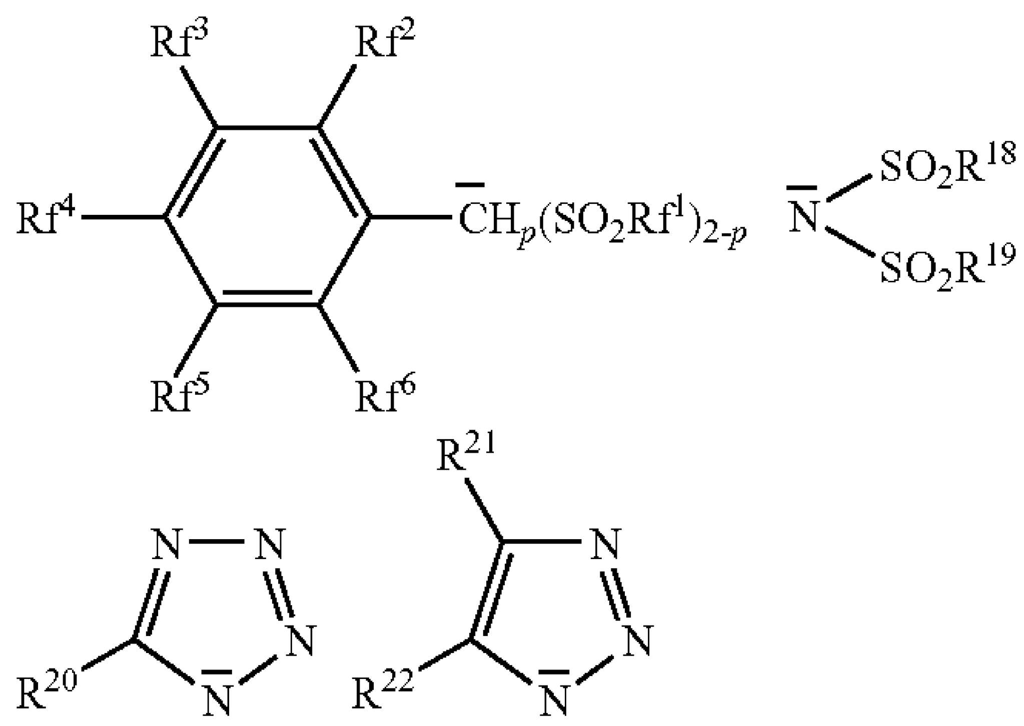
(where Y^2 is a hydrogen atom or a fluorine atom, provided that when there are plural such Y^2 groups, they may be the same or different; and m is an integer of 0 to 6), and anions of the following general formulas:

[Chemical Formula 2]



(where R^{13} to R^{17}, which may be the same or different, each represent a group selected from a hydrogen atom and $(C_nF_{(2n+1-x)}H_x)$; and n and x have the same meanings as above)

[Chemical Formula 3]

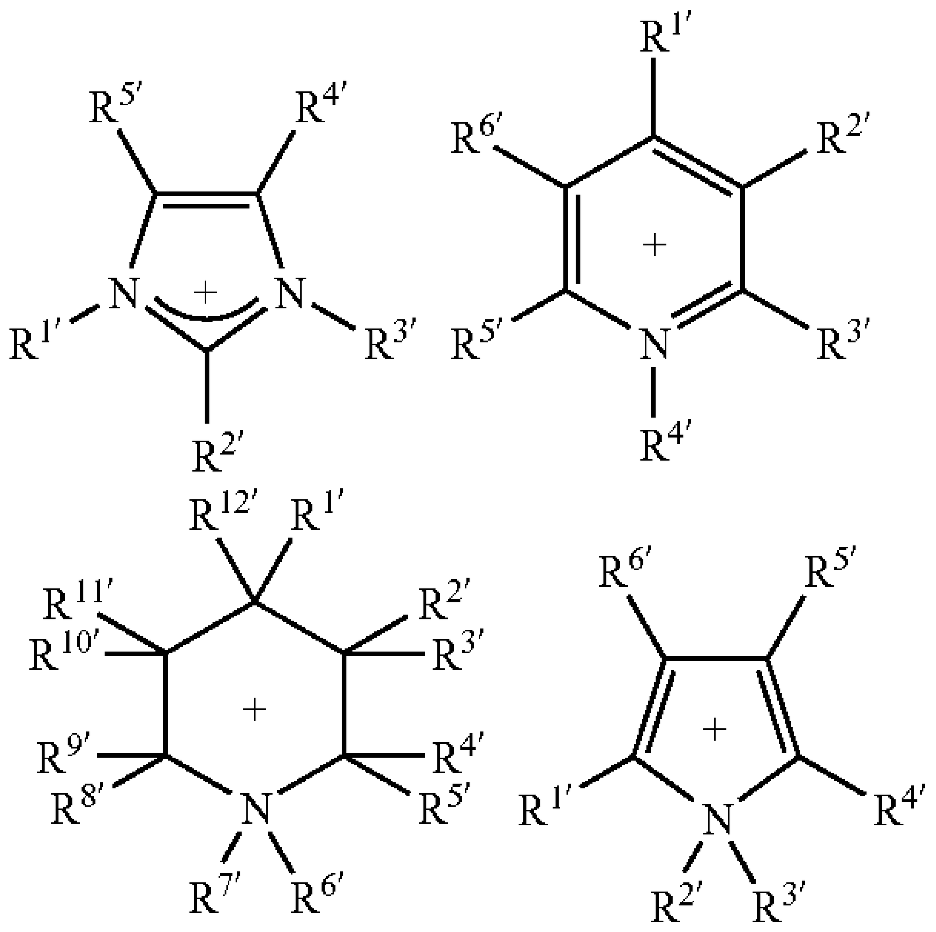


(where Rf^1 represents a perfluoroalkyl group, Rf^2 to Rf^6 each independently represent a fluorine atom, a perfluoroalkyl group or a perfluorobenzyl group, p is 0 or 1, R^{18} and R^{19} each independently represent a halogen atom or a halogenated alkyl group, R^{20} to R^{22} each independently represent a hydrogen atom, a hydroxyl group, a mercapto group, an amino group, a carboxyl group, a tetrazolyl group, a sulfonic acid group, an alkyl group having 1 to 10 carbon atoms, a cycloalkyl group having 3 to 10 carbon atoms, an aryl group having 6 to 10 carbon atoms or an aralkyl group having 7 to 10 carbon atoms, provided that each of the groups other than hydrogen atom can contain a substituent.) may be used.

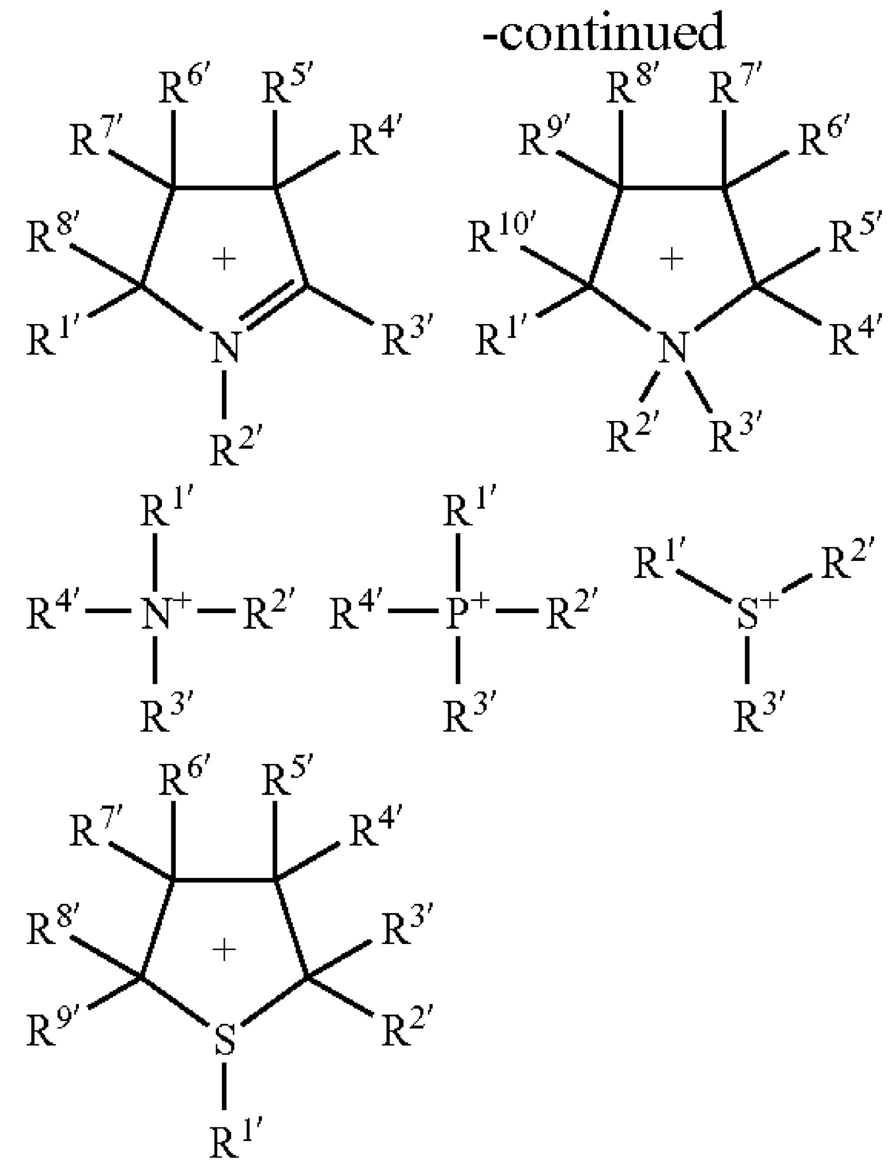
[0040] Among the above anions, preferred are A^-, PF_6^-, $C_nH_{(2n+1)}OSO_3^-$, $(C_nF_{(2n+1-x)}H_x)SO_3^-$, $(C_nF_{(2n+1-x)}H_x)COO^-$, NO_3^-, $CH_3SO_3^-$, $(CN)_2N^-$, HSO_3^-, $([C_nF_{(2n+1-x)}H_x]Y^1O_z)_2N^-$ (where Y^1 represents a carbon atom or a sulfur atom, provided that when there are plural such Y^1 groups, they may be the same or different; n is an integer of 0 to 6; x is an integer of 0 to 13; and z is an integer of 1 to 3 when Y^1 is a carbon atom and 0 to 4 when Y^1 is a sulfur atom) and the anions of the above general formulas are preferred. Particularly preferred are $C_nH_{(2n+1)}OSO_3^-$, $(C_nF_{(2n+1-x)}H_x)SO_3^-$, $(C_nF_{(2n+1-x)}H_x)COO^-$, NO_3^-, $CH_3SO_3^-$, $(CN)_2N^-$, HSO_3^- (where n is an integer of 1 to 6 and x is an integer of 0 to 13) and the anions of the above general formulas.

[0041] As the ionic liquid (II) (zwitterionic liquid), there may be used the following compounds of the general formulas:

[Chemical Formula 4]



-continued



(where R^1 to R^{12}, which may be the same or different, each represent a group selected from a hydrogen atom, alkyl groups having 1 to 18 carbon atoms which may have an ether bonding and alkoxyl groups having 1 to 18 carbon atoms, provided that at least one of $R^{1'}$ to $R^{12'}$ is $—(CH_2)_n—SO_3^-$ or $—(CH_2)_n—COO^-$ (where n is such an integer of 1 or more that the carbon number of the alkylene groups is 1 to 18).

[0042] It is preferred that, in the cation of the ionic liquid (II), a nitrogen atom be the ionic center.

[0043] In the present invention, the ionic liquids (I) and (II) may be incorporated into a lubricant as a base oil or as an additive. When used as the base oil, it is preferred that the ionic liquid be used in such an amount that the content of the ionic liquid in the base oil is 50 to 100% by mass, more preferably 70 to 100% by mass, still more preferably 90 to 100% by mass.

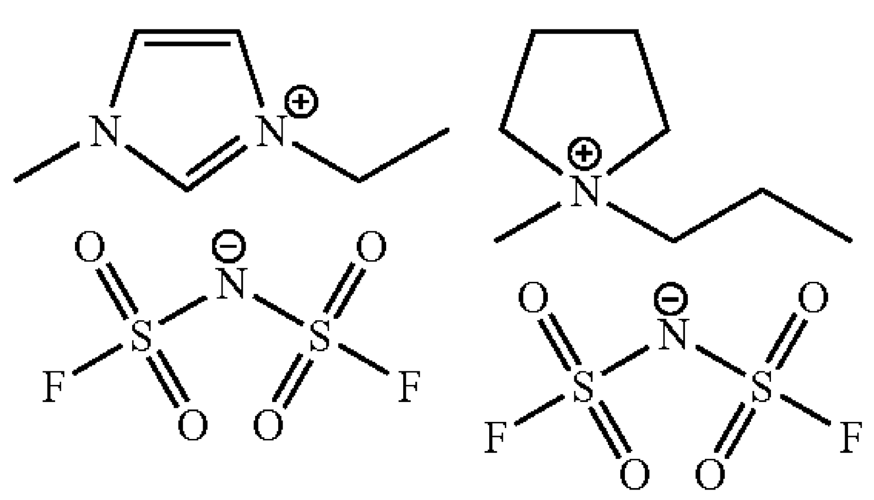
[0044] When the ionic liquid is used as the base oil, the pour point of the ionic liquid is preferably 0° C. or below, more preferably −2.5° C. or below. The ionic liquid having such a melting point is obtainable, for example, by adequately combining the cation Z^+ with the anion A^- in the general formula (I-a) in the case of the ionic liquid (I) or by using a mixture of at least two kinds of ionic liquids.

[0045] Specific examples of the ionic liquid (I) represented by the formula $Z^+.A^-$ and used as a base oil include 1-butyl-3-methylimidazolium tetrafluoroborate, 1-butyl-3-methylimidazolium hexafluoroborate, 1-hexyl-3-methylimidazolium hexafluorophosphate, 1-methyl-3-ethylimidazolium bis(fluorosulfonyl)imide, 1-methyl-1-propylpyrrolidinum bis(fluorosulfonyl)imide, 1-butyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide, alkylpyridinium tetrafluoroborate, alkylpyridinium hexafluorophosphate, alkylpyridinium bis(trifluoromethanesulfonyl)imide, alkylammonium tetrafluoroborate, alkylammonium hexafluorophosphate, alkylammonium bis(trifluoromethanesulfonyl)imide, N,N-diethyl-N-methyl(2-methoxyethyl)ammonium tetrafluoroborate, N,N-diethyl-N-methyl (2-methoxyethyl) ammonium hexafluorophosphate, and N,N-diethyl-N-methyl (2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl) imide. These ionic liquids may be used singly or in combination of two or more thereof.

[0046] Above all, alkylpyridinium hexafluorophosphate, alkylpyridinium bis(trifluoromethanesulfonyl)imide, alkylammonium hexafluorophosphate, alkylammonium bis(trifluoromethanesulfonyl)imide, N,N-diethyl-N-methyl(2-methoxyethyl)ammonium hexafluorophosphate and N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide are preferred.

[0047] Specific examples of the structure of bis(fluorosulfonyl)imides of the above-described ionic liquid (I) are given below.

[Chemical Formula 5]



[0048] When two or more ionic liquids are used as a mixture, it is preferred that each of the ionic liquids be present in an amount of at least 10% by mass based on the mixture. As the mixture of ionic liquids (I), there may be mentioned a mixture containing one Z^+ and two or more A^-, a mixture containing two or more Z^+ and one A^- and a mixture of two or more Z^+ and two or more A^-.

[0049] To be more specific, there may be mentioned a mixture of 1-butyl-3-methylimidazolium tetrafluoroborate and 1-butyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide, a mixture of an alkylpyridinium hexafluorophosphate and an alkylpyridinium bis(trifluoromethanesulfonyl)imide, a mixture of an alkylammonium bis(trifluoromethanesulfonyl)imide and 1-butyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide, a mixture of 1-butyl-3-methylimidazolium tetrafluoroborate and N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide, a mixture of 1-butyl-3-methylimidazolium hexafluorophosphate and N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide, a mixture of N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide and an alkylpyridinium tetrafluoroborate, and a mixture of N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide and an alkylpyridinium hexafluorophosphate.

[0050] Above all, a mixture of 1-butyl-3-methylimidazolium tetrafluoroborate and N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide, a mixture of 1-butyl-3-methylimidazolium hexafluorophosphate and N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide, a mixture of N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide and alkylpyridinium tetrafluoroborate, and a mixture of N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide and alkylpyridinium hexafluorophosphate are preferred.

[0051] When the ionic liquid (II) (zwitterionic liquid) is used as a base oil, an ionic liquid having a desired melting point is obtainable, for example, by adequately combining a cationic moiety of the ionic liquid (II) with an anionic moiety represented by $—(CH_2)_n—SO_3^-$ or $—(CH_2)_n—COO^-$ (where n is such an integer of one or more that the alkylene group has 1 to 18 carbon atoms), or by using a mixture of two or more kinds of ionic liquids (II) or a mixture of an ionic liquid (II) and an ionic liquid (I).

[0052] Specific examples of the ionic liquid (II) used as a base oil include 1-methyl-1,3-imidazolium N-butanesulfonate and N,N-diethyl-N-methylammonium N-butanesulfonate.

[0053] When the ionic liquid (i) or (II) is used as an additive for the lubricant, the additive may function as an antistatic agent. In this case the content of the ionic liquid (i) and/or ionic liquid (II) is suitably 1% by mass or more. While the upper limit is not specifically restricted, it is preferred that the lubricant have a volume resistivity of $1\times10^{10}\Omega\cdot$cm or less at 25° C. because suitable antistatic performance can be obtained so that generation of static electricity due to flow charging of the lubricant is suppressed and, therefore, trouble of electronic parts or magnetic parts (e.g. MR head of hard disk) can be prevented. The volume resistivity is more preferably $1\times10^{9}\Omega\cdot$cm or less.

[0054] Any ionic liquid (I) or (II) may be used as an additive as described above as long as it is soluble in a base oil. The melting point of the ionic liquid (I) or (II) is not specifically limited.

[0055] The ionic liquid used in the present invention preferably has an ion concentration (cation or anion concentration) of at least 1 mol/dm^3, more preferably at least 2 mol/dm^3, still more preferably at least 3 mol/dm^3. When the ion concentration is at least 1 mol/dm^3, the object of the above use can be fully accomplished.

[0056] In the lubricant for an oil retaining bearing according to the present invention, a base oil capable of being mixed with the ionic liquid or dissolving the ionic liquid may be used in addition to the ionic liquid. Such an additional base oil may be a polar base oil such as of a polyalkylene glycol type, a mono, di or polyether type, and a phosphate ester type.

[0057] In the present invention, various additives such as an antioxidant, an oiliness improver, a friction modifier, a rust preventing agent, a metal deactivator, an antifoaming agent and a viscosity index improver may be added to the lubricant for an oil retaining bearing as long as the effect of the present invention is not adversely affected.

[0058] (1) As the antioxidant, there may be mentioned an amine type antioxidant, a phenolic antioxidant and a sulfur-containing antioxidant.

[0059] Examples of the amine type antioxidant include a monoalkyldiphenylamine type antioxidant such as monooctyldiphenylamine and monononyldiphenylamine; a dialkyl diphenylamine type antioxidant such as 4,4'-dibutyldiphenylamine, 4,4'-dipentyldiphenylamine, 4,4'-dihexyldiphenylamine, 4,4'-diheptyldiphenylamine, 4,4'-dioctyldiphenylamine and 4,4'-dinonyldiphenylamine; a polyalkyldiphenylamine type antioxidant such as tetrabutyldiphenylamine, tetrahexyldiphenylamine, tetraoctyldiphenylamine and tetranonyldiphenylamine; and a naphthylamine type antioxidant such as α-naphthylamine, phenyl-α-naphthylamine, butylphenyl-α-naphthylamine, pentylphenyl-α-naphthylamine, hexylphenyl-α-naphthylamine, heptylphenyl-α-naphthylamine, octylphenyl-α-naphthylamine and nonylphenyl-α-naphthylamine. Above all, the dialkyl diphenylamine type antioxidants are particularly preferable.

[0060] Examples of the phenolic antioxidant include a monophenol type antioxidant such as 2,6-di-tert-butyl-4-methylphenol and 2,6-di-tert-butyl-4-ethylphenol; and a diphenol type antioxidant such as 4,4'-methylenebis(2,6-di-tert-butylphenol) and 2,2'-methylenebis(4-ethyl-6-tert-butylphenol).

[0061] Examples of the sulfur-containing antioxidant include phenothiazine, pentaerythritol-tetrakis(3-lauryl-thio-propionate), bis(3,5-tert-butyl-4-hydroxybenzyl)sulfide, thiodiethylenebis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)) propionate and 2,6-di-tert-butyl-4-(4,6-bis(octylthio)-1,3,5-triazine-2-methylamino)phenol.

[0062] The above antioxidants may be used alone or in combination of two or more thereof. The antioxidant may be generally used in an amount of 0.01 to 10% by mass, preferably 0.03 to 5% by mass, based on a total weight of the lubricant.

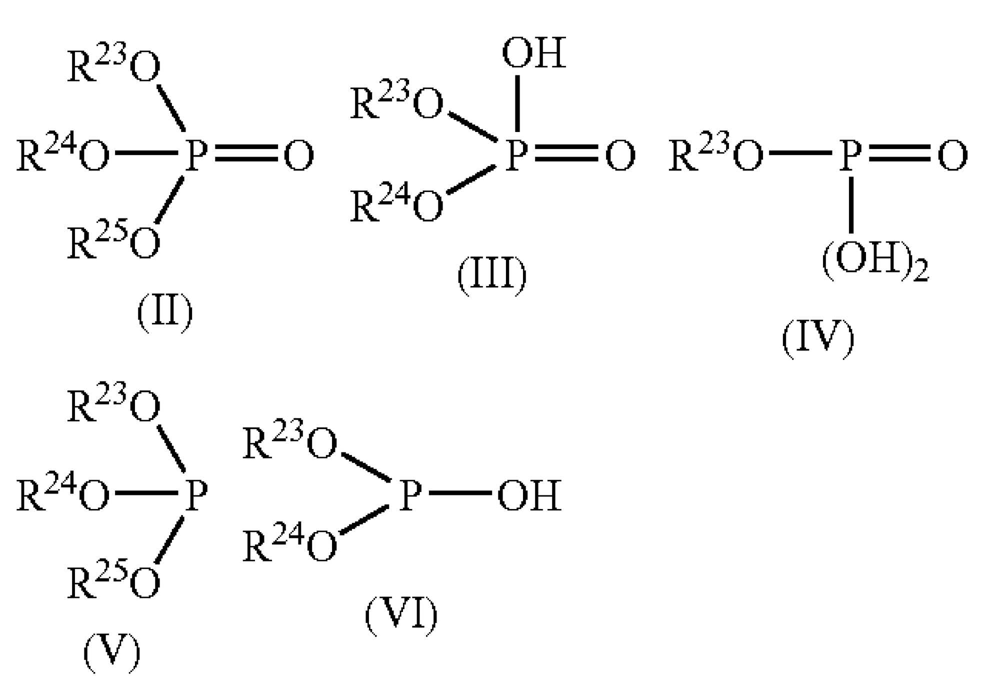
[0063] (2) Examples of the oiliness improver include aliphatic saturated or unsaturated monocarboxylic acids such as stearic acid and oleic acid; polymerized fatty acids such as dimer acid and hydrogenated dimer acid; hydroxyfatty acids such as ricinoleic acid and 12-hydroxystearic acid; aliphatic saturated or unsaturated monohydric alcohols such as lauryl alcohol and oleyl alcohol; aliphatic saturated or unsaturated monoamines such as stearylamine and oleylamine; aliphatic saturated or unsaturated monocarboxylamides such as lauramide and oleamide; and metal salts of the above-described fatty acids such as lithium stearate, aluminum stearate, aluminum oleate and lithium 12-hydroxystearate. The metals of the fatty acid metal salts include, for example, lithium, sodium, potassium, copper, silver, magnesium, calcium, zinc, aluminum and iron.

[0064] These oiliness improvers may be used singly or in combination of two or more thereof. The compounding amount of the oiliness improver is generally in the range of 0.01 to 10% by mass, preferably 0.1 to 5% by mass, based on the total weight of lubricant.

[0065] (3) The friction modifier may be those generally used as an oiliness improver or an extreme pressure agent. Illustrative of particularly preferred friction reducing agents are phosphoric esters, amine salts of phosphoric esters and sulfur-containing extreme pressure agents.

[0066] Examples of the phosphoric esters include phosphoric esters, acid phosphoric esters, phosphorous acid esters and acid phosphorous acid esters which are represented by general formulas (II) to (VI) below.

[Chemical Formula 6]



[0067] In the above general formulas (II) to (VI), R^{23} to R^{25}, which may be the same or different, each represent an alkyl group, an alkenyl group, an alkylaryl group or an arylalkyl group having 4 to 30 carbon atoms.

[0068] The phosphoric acid ester may be, for example, a triaryl phosphate, a trialkyl phosphate, a trialkylaryl phosphate, a triarylalkyl phosphate or a trialkenyl phosphate. Specific examples of the phosphoric acid ester include triphenyl phosphate, tricresyl phosphate, benzyl diphenyl phosphate, ethyl diphenyl phosphate, tributyl phosphate, ethyl dibutyl phosphate, cresyl diphenyl phosphate, dicresyl phenyl phosphate, ethylphenyl diphenyl phosphate, diethylphenyl phenyl phosphate, propylphenyl diphenyl phosphate, dipropylphenyl phenyl phosphate, triethylphenyl phosphate, tripropylphenyl phosphate, butylphenyl diphenyl phosphate, dibutylphenyl phenyl phosphate, tributylphenyl phosphate, trihexyl phosphate, tri(2-ethylhexyl) phosphate, tridecyl phosphate, trilauryl phosphate, trimyristyl phosphate, tripalmityl phosphate, tristearyl phosphate and trioleyl phosphate.

[0069] Examples of the acid phosphoric ester include 2-ethylhexyl acid phosphate, ethyl acid phosphate, butyl acid phosphate, oleyl acid phosphate, tetracosyl acid phosphate, isodecyl acid phosphate, lauryl acid phosphate, tridecyl acid phosphate, stearyl acid phosphate and isostearyl acid phosphate.

[0070] Examples of the phosphorous acid ester include triethyl phosphite, tributyl phosphite, triphenyl phosphite, tricresyl phosphite, tri(nonylphenyl) phosphite, tri(2-ethylhexyl) phosphite, tridecyl phosphite, trilauryl phosphite, triisooctyl phosphite, diphenylisodecyl phosphite, tristearyl phosphite and trioleyl phosphite.

[0071] Examples of the acid phosphorous acid ester include dibutyl hydrogen phosphite, dilauryl hydrogen phosphite, dioleyl hydrogen phosphite, distearyl hydrogen phosphite and diphenyl hydrogen phosphite. Among the above phosphoric esters, tricresyl phosphate and triphenyl phosphate are particularly preferable.

[0072] Amines that form amine salts with the above acid phosphorus acid esters may be a monosubstituted amine, a disubstituted amine or a trisubstituted amine, which are represented by the following general formula (VII):

$$R^{26}{}_{p}NH_{3-p} \qquad \text{(VII)}$$

(where R^{26} represents an alkyl or alkenyl group having 3 to 30 carbon atoms, an aryl group having 6 to 30 carbon atoms, an arylalkyl group having 7 to 30 carbon atoms or a hydroxyalkyl group having 2 to 30 carbon atoms and p represents 1, 2 or 3 with the proviso that when there are a plurality of such R^{26} groups, they may be the same or different.)

[0073] The alkyl or alkenyl group having 3 to 30 carbon atoms represented by R^{26} in the above general formula (VII) may be straight chained, branched or cyclic.

[0074] Examples of the monosubstituted amine include butylamine, pentylamine, hexylamine, cyclohexylamine, octylamine, laurylamine, stearylamine, oleylamine and benzylamine. Examples of the disubstituted amine include dibutylamine, dipentylamine, dihexylamine, dicyclohexylamine, dioctylamine, dilaurylamine, distearylamine, dioleylamine, dibenzylamine, stearylmonoethanolamine, decylmonoethanolamine, hexylmonopropanolamine, benzylmonoethanolamine, phenylmonoethanolamine and tolylmonopropanolamine. Examples of the trisubstituted amine include tributylamine, tripentylamine, trihexylamine, tricyclohexylamine, trioctylamine, trilaurylamine, tristearylamine, trioleylamine, tribenzylamine, dioleylmonoethanolamine, dilaurylmonopropanolamine, dioctylmonoethanolamine, dihexylmonopropanolamine, dibutylmonopropanolamine, oleyldiethanolamine, stearyidipropanolamine, lauryldiethanolamine, octyidipropanolamine, butyliethanolamine, benzyldiethanolamine, phenyldiethanolamine, tolyidipropanolamine, xylyldiethanolamine, triethanolamine and tripropanolamine.

[0075] The sulfur-containing extreme pressure agent may be any compound as long as the compound has a sulfur atom in the molecule thereof and can be dissolved or uniformly dispersed in a lubricating base oil to exhibit extreme pressure performance and excellent friction characteristics. Examples of the sulfur-containing compound include sulfurized fats and oils, sulfurized fatty acid, sulfurized esters, olefin sulfides, dihydrocarbyl polysulfides, thiadiazole compounds, thiophosphoic esters (thiophosphites and thiophosphates), alkyl thiocarbamoyl compounds, thiocarbamate compounds, thioterpene compounds, and dialkyl thiodipropionate compounds. The sulfurized fats or oils may be produced by reaction of a fat or an oil (e.g., lard oil, whale oil, vegetable oil, or fish oil) with sulfur or a sulfur-containing compound. A content of the sulfur is not particularly limited, but 5 to 30% by mass is generally preferable. Concrete examples of the sulfurized fats and oils include a surfurized lard, a sulfurized rape seed oil, a sulfurized castor oil, a sulfurized soybean oil and a sulfurized rice bran oil. Concrete examples of the sulfurized fatty acid include sulfurized oleic acid. Concrete examples of the ester sulfide include sulfurized methyl oleate and sulfurized octyl ester of rice bran fatty acid.

[0076] As the olefin sulfide there may be mentioned a compound represented by the following general formula (VIII):

$$R^{27}—S_q—R^{28} \qquad (VIII)$$

(where R^{27} represents an alkenyl group having 2 to 15 carbon atoms, R^{28} represents an alkyl or alkenyl group having 2 to 15 carbons atoms and q is an integer of 1 to 8.)

[0077] These compounds may be produced by reaction between olefins having 2 to 15 carbon atoms or a dimer to tetramer thereof and a sulfidizing agent such as sulfur or sulfur chloride. Preferred olefins are propylene, isobutene and diisobutene.

[0078] The dihydrocarbyl polysulfide may be a compound represented by the following general formula (IX):

$$R^{29}S_r—R^{30} \qquad (IX)$$

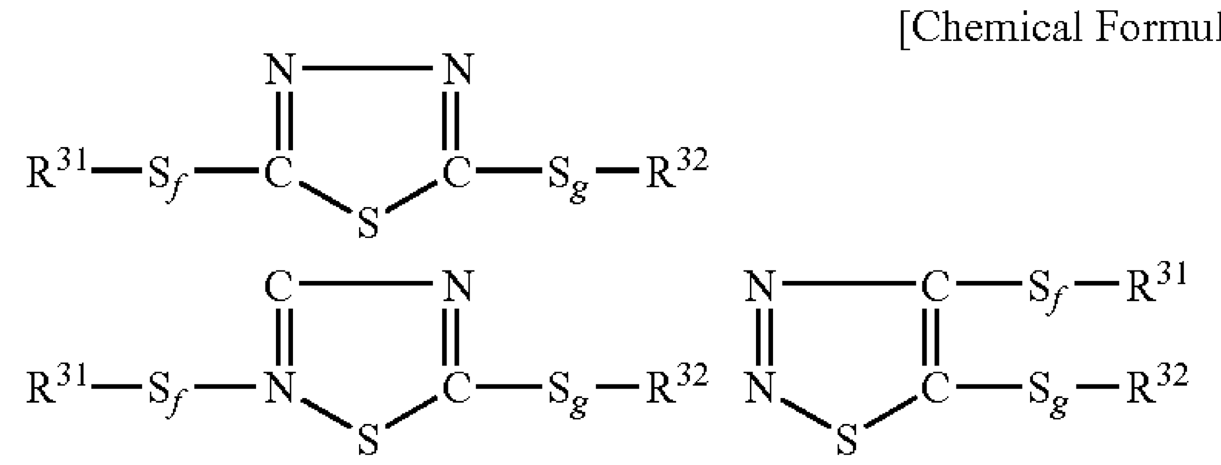
(where R^{29} and R^{30}, which may be the same or differen, each represents an alkyl or cyclic alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 7 to 20 carbon atoms, or an arylalkyl group having 7 to 20 carbon atoms and r is an integer of 1 to 8.) When each of R^{29} and R^{30} is an alkyl group, such a compound is called an alkyl sulfide.

[0079] Examples of R^{29} and R^{30} in the general formula (IX) include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, various pentyl groups, various hexyl groups, various heptyl group, various octyl group, various nonyl group, various decyl group, various dodecyl group, a cyclohexyl group, a cyclooctyl group, a phenyl group, a naphthyl group, a tolyl group, a xylyl group, a benzyl group and a phenethyl group.

[0080] Examples of the dihydrocarbyl polysulfide include dibenzyl polysulfide, various dinonyl polysulfides, various didodecyl polysulfides, various dibutyl polysulfides, various dioctyl polysulfides, diphenyl polysulfide and dicyclohexyl polysulfide.

[0081] As the thiadiazole compound, a 1,3,4-thiadiazole compound, a 1,2,4-thiadiazole compound or a 1,4,5-thiadiazole compound represented by the following general formulas (X) may be preferably used:

[Chemical Formula 7]



(X)

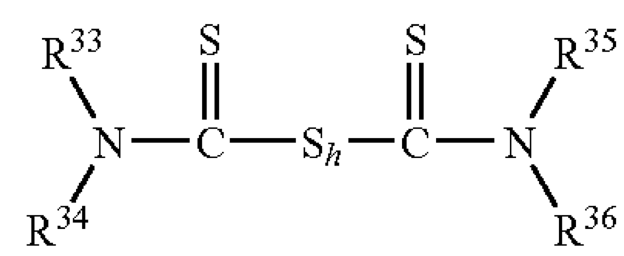
(where R^{31} and R^{32} each represent a hydrogen atom or a hydrocarbyl group having 1 to 20 carbon atoms. and f and g each represent an integer of 0 to 8.)

[0082] Examples of the thiadiazole compound include 2,5-bis(n-hexyldithio)-1,3,4-thiadiazole, 2,5-bis(n-octyldithio)-1,3,4-thiadiazole, 2,5-bis(n-nonyidithio)-1,3,4-thiadiazole, 2,5-bis-(1,1,3,3-tetramethylbutyldithio)-1,3,4-thiadiazole, 3,5-bis(n-hexyldithio)-1,2,4-thiadiazole, 3,6-bis(n-octyldithio)-1,2,4-thiadiazole, 3,5-bis(n-nonyidithio)-1,2,4-thiadiazole, 3,5-bis-(1,1,3,3-tetramethylbutyldithio)-1,2,4-thiadiazole, 4,5-bis(n-octyldithio)-1,2,3-thiadiazole, 4,5-bis (n-nonyldithio)-1,2,3-thiadiazole and 4,5-bis-(1,1,3,3-tetramethylbutyldithio)-1,2,3-thiadiazole.

[0083] Examples of the thiophosphorus acid ester include alkyl trithiophosphites, aryl or alkylaryl thiophosphates and zinc dilauryldithiophosphate. Among them, lauryl trithiophosphite and triphenyl thiophosphate are particularly preferable.

[0084] As the alkylthiocarbamoyl compound, a compound represented by the following general formula (XI) may be used:

[Chemical Formula 8]



(XI)

(where R^{33} to R^{36} each represent an alkyl group having 1 to 20 carbon atoms and h is an integer of 1 to 8.)

[0085] Examples of the alkylthiocarbamoyl compound include bis(dimethylthiocarbamoyl) monosulfide, bis(dibutylthiocarbamoyl) monosulfide, bis(dimethylthiocarbamoyl) disulfide, bis(dibutylthiocarbamoyl) disulfide, bis(diamylthiocarbamoyl) disulfide and bis(dioctylthiocarbamoyl) disulfide.

[0086] Examples of the thiocarbamate compound include a zinc dialkyl dithiocarbamate. The thioterpene compound may be, for example, a reaction product of a phosphorus pentasulfide and pinene. Examples of the dialkyl thiodipropionate compound include dilauryl thiodipropionate and distearyl thiodipropionate. Among the above sulfur-containing extreme pressure agents, the thiadiazole compounds and benzyl sulfide are particularly preferable for reasons of good extreme pressure performance, friction characteristics and stability against thermal oxidation.

[0087] The friction modifiers may be used singly or in combination of two or more thereof. The compounding amount of the friction modifier is generally 0.01 to 10% by mass, preferably 0.05 to 5% by mass, based on the total amount of the lubricant.

[0088] (4) Examples of the rust preventing agent include alkyl and alkenyl succinate derivatives such as dodecenyl succinate half esters, otcadecenyl succinic anhydride, and dodecenylsuccinamide; polyhydric alcohol partial esters such as sorbitan monooleate, glycerin monoolate and pentaerythritol monooleate; amines such as rosin amines, N-oleylsarcosine and alkylamines; and dialkyl phosphite amine salts. These rust preventing agents may be used alone or in combination of two or more thereof.

[0089] The compounding amount of the rust preventing agent is preferably 0.01 to 5% by mass, particularly preferably 0.05 to 2% by mass, based on the total amount of the lubricant.

[0090] (5) As the metal deactivator, there may be used, for example, benzotriazole compounds, thiadiazole compounds and gallic acid ester compounds. The compounding amount of the metal deactivator is preferably in the range of 0.01 to 0.4% by mass, more preferably from 0.01 to 0.2% by mass, based on the total amount of the lubricant.

[0091] (6) As the antifoaming agent, a liquid silicone is suited. Methylsilicone, fluorosilicone and polyacrylate may be used.

[0092] The compounding amount of the antifoaming agent is preferably in the range of 0.0005 to 0.01% by mass based on the total amount of the lubricant.

[0093] (7) Examples of the viscosity index improver include olefin copolymers, polyalkyl methacrylates, polyalkylstyrenes, polubutenes, ethylene-propylene copolymers, styrene-diene copolymers and styrene-maleic anhydride ester copolymers.

[0094] The compounding amount of the viscosity index improver is preferably 0.1 to 15% by mass, particularly preferably 0.5 to 7% by mass based on the total amount of the lubricant.

[0095] The lubricant for an oil retaining bearing according to the present invention preferably has a kinematic viscosity at 40° C. of 1 to 1,000 mm^2/s. When the kinematic viscosity is within the above range, an evaporation loss and a power loss due to viscosity resistance can be suppressed. The kinematic viscosity is more preferably 5 to 300 mm^2/s.

[0096] The pour point is preferably −10° C. or lower, more preferably −20° C. or lower, still more preferably −30° C. or lower, for reasons of reduced viscosity resistance at low temperatures.

[0097] The viscosity index is preferably at least 80, more preferably at least 100, still more preferably at least 120, for reasons of suppressing temperature dependency of the viscosity.

[0098] The 5% mass reduction temperature is preferably 350° C. or higher, more preferably 380° C. or higher. The flash point is preferably 200° C. or higher, more preferably 250° C. or higher, particularly preferably 300° C. or higher.

[0099] The acid value is preferably 1 mgKOH/g or less, more preferably 0.5 mgKOH/g or less, still preferably 0.3 mgKOH/g or less, from the viewpoint of preventing corrosion of metal parts to which the lubricant of the present invention is applied.

[0100] The lubricant for an oil retaining bearing according to the present invention is used for retaining bearings made of a metallic porous body, a plastic porous body, a ceramic porous body, etc. and is particularly suited for a sintered, oil retaining bearing obtained by compacting and sintering metal powder.

[0101] Operation accuracy of spindle motors used in information equipments (particularly CD and DVD) has been increased year by year. Bearings conventionally used in spindle motors for such information equipments include rolling bearings, fluid dynamic bearings and sintered, oil retaining bearings. From these bearings a particular bearing best suited for the intended use is selected in consideration of the performance and cost.

[0102] Sintered, oil retaining bearings, which have remarkably excellent production efficiency and can be produced on a large scale, have a merit that it can be put into the marketplace at a lower price as compared with rolling bearings or hydrodynamic bearings.

[0103] However, for use in an HDD spindle motor which is a high precision and high quality recording instrument requiring much higher rotation accuracy and higher credibility, the sintered, oil retaining bearings have a problem because there is a certain clearance relative to the rotational axis and, hence, a rotational variation is apt to occur.

[0104] To solve this problem, a specific mechanism has been developed in which a prescribed-directional lateral pressure is applied to a sintered, oil retaining bearing so as to reduce the deflection of the rotational axis of the motor while retaining inherent characteristics of the sintered, oil retaining bearing (Japanese Unexamined Patent Application Publication No. 2001-295844). The lubricant of the present invention is suitably used in such a mechanism.

[0105] The above-described mechanism will be next described with reference to the accompanying drawing. FIG. **1** is an enlarged, cross-sectional view illustrating an example of a spindle motor. The reference numeral **1** designates a housing holder, **3** designates a bearing and **5** designates a motor shaft. The housing holder **1** is mounted on a base B and has a cylindrical section **2**. The cylindrical section **2** has an outer periphery provided with stacked cores **9** each having a coil **10** wound therearound.

[0106] The bearing **3** is produced by compacting and molding metal powder such as copper powder into a shape capable of being accommodated in the housing holder **1**, followed by sintering and impregnation with a lubricant for an oil retaining bearing according to the present invention. The bearing **3** is provided with an open center **4** at a middle portion of its shaft hole and, therefore, is of a so-called open center and center free type. The motor shaft **5** is supported at opposite end portions in the longitudinal direction of the bearing **3**.

[0107] The motor shaft **5** is made of a metal rod having such an outer diameter that the shaft is capable of being received in the bearing **3**. Integrally mounted, through a retaining member **6**, to a portion near an edge of the motor shaft **5** on an output side of the motor is a rotor **7** covering the laminate cores **9** and the coils **10** and provided with a magnet **8** on its inside periphery at a position facing each of the laminate cores **9**. A hub configured to secure a rotation medium M of HDD is also integrally attached to an edge portion of the motor shaft **5**.

[0108] Means is provided to apply a lateral pressure in a specific direction to the motor shaft **5** received in the oil retaining bearing **3** formed of compacted and sintered metal powder so that one of the stacked cores **9** which are fixed at symmetrical positions relative to the motor shaft **5** is displaced by a distance t-t from the position indicated by the line “a” to the position indicated by the line “b”. As a consequence of the inclination of the stacked cores **9**, it is possible to always urge the rotor **7** rotating at a high speed in the direction indicated by the arrow P. Therefore, a side pressure is always applied to the motor shaft **5** in a specific direction (in the direction of the arrow Y).

[0109] By applying a side pressure in the specific direction to the motor shaft, the deflection of the shaft relative to the oil retaining bearing formed by compacting and sintering metal powder.

[0110] The lubricant for an oil retaining bearing according to the present invention can contain at least 50% by mass of the ionic liquid as a base oil. In such a case, the lubricant has a low vapor pressure and has low flammability. Further, it has excellent heat resistance and can suppress the emanation of low volatile components and decomposed gases during use.

[0111] The lubricant can also contain the ionic liquid as an additive such as an antistatic agent. In such a case, it is possible to ground the static electricity generated by flow charging of the lubricant. It is without saying that such a function can be also obtained when the ionic fluid is used in the base oil.

[0112] The lubricant for an oil retaining bearing of the present invention can be utilized for various domestic motors and car motors.

[0113] Examples of the domestic motors for which the lubricant for an oil retaining bearing of the present invention can be utilized include floppy disk drive motors, CD drive motors, MO drive motors, DVD drive motors, hard disk drive motors, fan motors for coolers and blowers, polygon mirror drive motors, vibrating motors for mobile phones, stepping motors for optical lenses, etc.

[0114] Examples of the car motors for which the lubricant for an oil retaining bearing can be utilized include light retractable motors, water pump motors, wiper motors, head lamp cleaner motors, door lock actuator motors, antenna motors, power wind motors, power seat motors, mirror motors, telescopic motors, tilt steering motors, sun roof motors, electric curtain motors, radiator cooling fan motors, blower motors, air conditioner cooling fan motors, servo motors, automatic air conditioner internal air sensor motors, fuel leakage detecting sensor motors, air cleaner motors, car height adjuster motors, antilock brake motors, idle revolution controller motors, 4WD differential lock motors, odometer stepping motors, automatic drive motors, fuel stop motors, etc.

[0115] The lubricant for an oil retaining bearing is insoluble in a non-polar solvent such as gasoline, light oil or kerosene and, therefore, is suited for use in a motor bearing installed in a fuel tank, particularly in a motor for a sensor for detecting leakage of a fuel.

[0116] The present invention will be next described in more detail by way of examples but is not limited to these examples in any way. Various properties of lubricants were measured by the following methods.

(1) Kinematic Viscosity

[0117] Kinematic viscosity was measured in accordance with “test method of kinematic viscosity for petroleum products” as specified in JIS K2283.

(2) Viscosity Index

[0118] Viscosity index was measured in accordance with “test method of kinematic viscosity for petroleum products” as specified in JIS K2283.

(3) Pour Point

[0119] Pour point was measured in accordance with JIS K2269.

(4) Total Acid Number

[0120] Total acid number was measured by potentiometry in accordance with “test method of neutralization number for lubricants” as specified in JIS K2501.

(5) Flash Point

[0121] Flash point was determined by the C.O.C method in accordance with JIS K2265.

(6) 5% Mass Reduction Temperature

[0122] The temperature at which the initial mass of a sample was reduced by 5%/min was determined using a differential thermal analyzer at a heating rate of 10° C. It can be said that the higher the 5% mass reduction temperature, the greater are the resistance to vaporization and the resistance to heat.

(7) Volume Resistivity

[0123] Volume resistivity was measured in accordance with JIS C2102.

(8) Load Resistance Test

[0124] In accordance with ASTM D 2783, test was performed at a revolution speed of 1,800 rpm at room temperature. A load wear index (LWI) was determined from the last non-seizure load (LNL) and the welding load (WL). The greater the load wear index, the better is the load resistance.

(9) Wear Resistance Test

[0125] In accordance with ASTM D 2783, test was performed under a load of 196 N, at a revolution speed of 1,200 rpm and an oil temperature of 75° C. for a testing time of 60 minutes. An average wear scar diameter was calculated by averaging wear scar diameters of three 0.5 inch balls.

EXAMPLES 1 TO 6 AND COMPARATIVE EXAMPLE 1

[0126] Lubricants having compositions shown in Table 1 were prepared and tested for various properties. The results are shown in Table 1.

TABLE 1

			Examples						Comparative
			1	2	3	4	5	6	Ex. 1
Lubricant (mass %)	Base oil	Ionic liquid 1	100	—	—	—	—	—	—
		Ionic liquid 2	—	100	99	99	—	—	—
		Ionic liquid 3	—	—	—	—	96.9	—	—
		Ionic liquid 4	—	—	—	—	—	100	—
		Polyol ester	—	—	—	—	—	—	100
	Additive	TCP	—	—	1	—	1	—	—
		DBDS	—	—	—	1	—	—	—
		n-Octylamine	—	—	—	—	2	—	—
		Benzotriazole	—	—	—	—	0.1	—	—
Evaluation	40° C. Kinematic viscosity (mm^2/s)		22.41	27.10	27.14	27.10	13.23	26.69	19.50
	Viscosity index		160	114	114	114	189	155	132
	Pour point (° C.)		−20.0	−30.0	−30.0	−30.0	−22.5	−50>	−45.0
	Total acid number (mgKOH/g)		0.29	0.30	0.32	0.30	0.01	0.01	0.05
	Flash point (C.O.C)		300<	300<	300<	300<	300<	300<	236
	5% Mass reduction temperature (° C.)		411.3	363.8	362.5	361.1	393	387	269.3
	Load resistance test (LWI)		1512	1526	1519	1533	1575	1575	139
	Wear resistance test (mm)		0.43	0.52	0.4	0.37	0.38	0.53	0.57
	Compatibility with gasoline		insoluble	insoluble	insoluble	insoluble	insoluble	insoluble	soluble
	Compatibility with light oil		insoluble	insoluble	insoluble	insoluble	insoluble	insoluble	soluble
	Compatibility with kerosene		insoluble	insoluble	insoluble	insoluble	insoluble	insoluble	soluble

Remarks:

[0127] Ionic liquid 1: Butylpyridinium bis(trifluoromethanesulfonyl)imide

[0128] Ionic liquid 2: N,N-diethyl-N-methyl(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide

[0129] Polyol ester: Ester of trimethylolpropane with fatty acids having 8 and 10 carbon atoms

[0130] Ionic liquid 3: 1-Ethyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide

[0131] Ionic liquid 4: 1-Hexyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide

[0132] TCP: Tricresyl phosphate

[0133] DBDS: Dibenzyldisulfide

[0134] It is seen from Table 1 that the lubricants of Examples 1 to 5 have a flash point higher than 300° C. notwithstanding the fact that it is low in viscosity. Further, the 5% mass reduction temperature is higher than 360° C., which shows that the lubricants have low volatility and excellent heat resistance. Moreover, the inventive lubricants have excellent load resistance and wear resistance.

[0135] In contrast, the lubricant of Comparative Example 1 has a flash point of 236° C. which is lower than those of Examples 1 to 5. Further, the 5% mass reduction temperature is 269.3° C. which is much lower than those of Examples 1 to 5.

EXAMPLES 7 TO 14

[0136] Lubricants having compositions shown in Tables 2-1 and 2-2 were prepared and tested for various properties. The results are shown in Tables 2-1 and 2-2.

TABLE 2-1

			Examples				
			7	1	8	9	10
Lubricant (mass %)	Base oil	Ionic liquid 5	100	—	90	80	60
		Ionic liquid 1		100	10	20	40
Evaluation	40° C. Kinematic viscosity (mm^2/s)		85.29	22.41	65.39	45.73	44.46
	Viscosity index		123	160	—	162	130
	Pour point (° C.)		−7.5	−20.0	−27.5	−37.5	−35.0
	Total acid number (mgKOH/g)		0.06	0.29	0.08	0.11	0.15
	Flash point (C.O.C)		300<	300<	300<	300<	300<
	5% Mass reduction temperature (° C.)		372.0	411.3	373.2	380.2	397.6
	Load resistance test (LWI)		1522	1512	1511	1523	1517
	Wear resistance test (mm)		0.5	0.43	0.45	0.46	0.42

TABLE 2-2

			Examples			
			11	12	13	14
Lubricant (mass %)	Base oil	Ionic liquid 5	50	40	20	10
		Ionic liquid 1	50	60	80	90
Evaluation	40° C. Kinematic viscosity (mm^2/s)		38.65	35.31	35.73	24.63
	Viscosity index		143	160	185	162
	Pour point (° C.)		−45.0	−37.5	−40.0	−27.5
	Total acid number (mgKOH/g)		0.18	0.20	0.24	0.27
	Flash point (C.O.C)		300<	300<	300<	300<
	5% Mass reduction temperature (° C.)		401.4	406.1	407.0	408.9
	Load resistance test (LWI)		1523	1531	1527	1533
	Wear resistance test (mm)		0.44	0.43	0.42	0.44

Remarks:

[0137] Ionic liquid 5: N,N-diethyl-N-methyl(2-methoxyethyl)ammonium tetrafluoroborate

[0138] Ionic liquid 1: the same as given in the remarks of Table 1

[0139] The results shown in Tables 2-1 and 2-2 indicate that the use of two kinds of ionic liquids in combination can improve the viscosity index and pour point.

EXAMPLES 15 TO 17 AND COMPARATIVE EXAMPLE 2

[0140] Lubricants having compositions shown in Table 3 were prepared and tested for various properties. The results are shown in Table 3.

TABLE 3

			Examples			Comparative Example
			15	16	17	2
Lubricant (mass %)	Base oil	Ether-based base oil	95	90	80	100
	Additive	Ionic liquid 2	5	10	20	—
Evaluation	40° C. Kinematic viscosity (mm^2/s)		8.588	8.856	9.471	8.340
	Viscosity index		129	131	134	129
	Pour point (° C.)		−45	−45	−42.5	−45
	Total acid number (mgKOH/g)		0.02	0.04	0.06	0.01
	Flash point (C.O.C)		212	223	241	210
	5% Mass reduction temperature (° C.)		208	215	228	208
	Load resistance test (LWI)		230	254	294	46
	Wear resistance test (mm)		0.58	0.56	0.55	0.78
	Volume resistivity ($\times 10^{10}$ Ω · cm)		0.9	0.7	0.2	8

Remarks:

[0141] Ether-based base oil: 2-octyldodecyl decyl ether

Ionic liquid 2: the same as given in the remarks of Table 1

[0142] The results shown in Table 3 indicate that the incorporation of the ionic liquid as an additive can reduce the volume resistivity of the lubricant and can impart antistatic property thereto.

[0143] The lubricant for an oil retaining bearing according to the present invention which contains an ionic liquid as a base oil, has a low vapor pressure and has low flammability and, further, has excellent heat resistance and can suppress the emanation of low volatile components and decomposed gases during use.

[0144] When the lubricant contains an ionic liquid as an additive, it is possible to ground the static electricity generated by flow charging of the lubricant.

[0145] The lubricant for an oil retaining bearing according to the present invention is used for retaining bearings made of a metallic porous body, a plastic porous body, a ceramic porous body, etc. and is particularly suited for a sintered, oil retaining bearing for spindle motors used in information equipments.

[0146] Further, the lubricant for an oil retaining bearing is insoluble in a non-polar solvent such as gasoline, light oil or kerosene and, therefore, is suited for use in a motor bearing installed in a fuel tank, particularly in a motor for a sensor for detecting leakage of a fuel.

1. A lubricant for an oil retaining bearing comprising 1 to 100% by mass of an ionic liquid.

2. A lubricant for an oil retaining bearing as defined in claim **1**, comprising a base oil which contains 50 to 100% by mass of the ionic liquid.

3. A lubricant for an oil retaining bearing as defined in claim **2**, wherein the ionic liquid contained in the base oil has a pour point of 0° C. or below.

4. A lubricant for an oil retaining bearing as defined in claim **1**, wherein the ionic liquid is contained as an antistatic agent.

5. A lubricant for an oil retaining bearing as defined in any one of claims **1** to **4**, which has a volume resistivity at 25° C. of 1×10^{10}Ω·cm or less.

6. A lubricant for an oil retaining bearing as defined in any one of claims **1** to **5**, wherein the ionic liquid is a compound represented by the following general formula (I):

$$(Z^{p+})_k\cdot(A^{q-})_m \quad \text{(I)}$$

(where Z^{p+} represents a cation, A^{q-} represents an anion, p, q, k, m, p×k and q×m are each an integer of 1 to 3, with the proviso that p×k equals q×m and that, when k or m is 2 or more, Z or A may be the same or different, respectively.)

7. A lubricant for an oil retaining bearing as defined in claim **6**, wherein p, q, k and m in the general formula (I) are each 1.

8. A lubricant for an oil retaining bearing as defined in any one of claims **1** to **5**, wherein the ionic liquid is of a zwitter ion type in which the cation and the anion are bonded by a covalent bond.

9. A lubricant for an oil retaining bearing as defined in any one of claims **6** to **8**, wherein the ionic liquid has a cation in which a nitrogen atom is the ionic center.

10. A lubricant for an oil retaining bearing as defined in any one of claims **1** to **9**, which has a kinematic viscosity of 1 to 1,000 mm^2/s at a temperature of 40° C.

11. A lubricant for an oil retaining bearing as defined in any one of claims **1** to **10**, which is retained in the bearing of a metal porous body, a plastic porous body or a ceramic porous body.

12. An oil retaining bearing using a lubricant for an oil retaining bearing as defined in any one of claims **1** to **11**.

13. A motor unit comprising an oil retaining bearing as defined in claim **12**.

* * * * *