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(54) **CURABLE SILICONE COMPOSITION AND APPLICATIONS AND USES THEREOF**

(71) Applicant: **Momentive Performance Materials Inc.**, Waterford, NY (US)

(72) Inventors: **Pranabesh Dutta**, Bangalore (IN);
Anubhav Saxena, Bangalore (IN)

(73) Assignee: **Momentive Performance Materials Inc.**, Waterford, NY (US)

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(58) **Field of Classification Search**

CPC **C08G 77/50**
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Primary Examiner — Kuo Liang Peng
(74) *Attorney, Agent, or Firm* — Joseph Waters;
McDonald Hopkins LLC

(57) **ABSTRACT**

A curable composition comprising (A) an organopolysiloxane comprising a curable functional group; and (B) a silicone-free, organic material comprising a reactive functional group. The curable composition exhibits high refractive index and optical clarity. The curable composition can be used to prepare a cured material that exhibits high refractive index, optical clarity, crack resistance, and low moisture vapor permeability.

34 Claims, No Drawings

CURABLE SILICONE COMPOSITION AND APPLICATIONS AND USES THEREOF

FIELD OF INVENTION

The present invention relates to a curable silicone composition. In particular, the present invention relates to curable silicone composition comprising an organopolysiloxane and a silicone-free organic material. The curable silicone compositions may be used to form cured materials that may exhibit one or more of high refractive index, good moisture vapor permeability, high thermal resistance, crack resistance, and optical clarity. The curable composition may be used in a variety of applications including as a sealant, an encapsulant, a barrier coating layer, etc., and may find application in various environments including in electronic devices.

BACKGROUND

Many of the next generation flexible printed electronic displays such as organic light emitting diodes (OLEDs), organic photovoltaic displays (OPVs), organic thin film transistors (OTFTs), etc., are extremely sensitive to atmospheric moisture vapor and oxygen, which limits the lifetime of the display devices and their widespread commercialization.

The current encapsulation technology generally available in the field for moisture sensitive organic electronic devices is a glass lid with a getter material fixed to the substrate by epoxy glue. The getter materials, such as, e.g., calcium oxide or barium oxide, are incorporated into the package to react with any byproducts of the resin cure process or any residual water incorporated in the package or diffusing through the epoxy seal over time. Although the glass has been used prevalently as an encapsulant or barrier layer due to its low permeability to water vapor and oxygen transmission, the

main drawback with glass encapsulated technology is that the resultant devices become non-flexible and rigid, which cannot satisfy the applications demanding flexible devices.

Several attempts have been made to develop flexible barrier films. These include multilayer systems of alternating inorganic and organic layers (often more than 10 layers). Such systems are described in, for example, WO 00/36665 A1, WO01/81649 A1, WO 2004/089620 A2, WO 03/094256 A2, and WO2008/057045 A1. Although, the multilayer thin film technology provides good barrier properties and serves the purpose of encapsulation to the electronic devices, the complex nature and high cost of thin film preparation do not make them feasible in large area and large scale manufacturing processes. It is therefore desirable to provide substrates with improved barrier properties that can protect the display devices from the premature deterioration and extend their lifetimes.

SUMMARY

The following presents a summary of this disclosure to provide a basic understanding of some aspects. This sum-

mary is intended to neither identify key or critical elements nor define any limitations of embodiments or claims. Furthermore, this summary may provide a simplified overview of some aspects that may be described in greater detail in other portions of this disclosure.

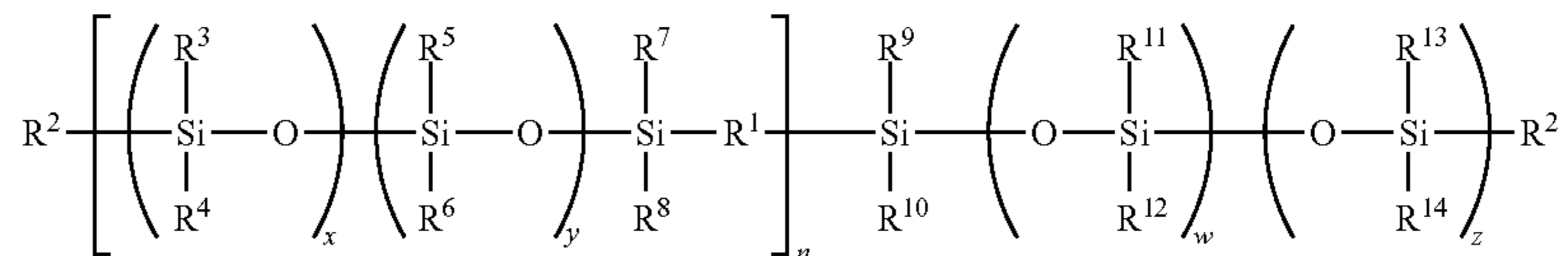
In accordance with various aspects and embodiments, the present technology provides a curable silicone composition comprising an organopolysiloxane and a silicone-free organic material. The organopolysiloxane comprises organofunctional groups in the main chain of the polysiloxane. Cured materials formed from compositions comprising such organopolysiloxanes have been found to exhibit relatively high refractive index, good optical clarity (e.g., low yellowing), flexibility, thermal resistivity, crack resistivity, and/or moisture permeability.

In various aspects, the present invention provides a curable composition suitable for thin film flexible encapsulation technology, which not only reduce the overall complexity but also provide high quality barrier films that are scalable and easy processable for making large area display devices.

The present invention provides, in aspects and embodiments thereof, a low moisture permeable siloxane composition, which can provide a cured material with high refractive index and/or improved barrier properties suitable for use in an organic electroluminescent display device and prolong their lifetime. In one aspect, this invention provides a curable composition of bicyclic modified silicone containing compounds wherein the bicyclic compound can be present in a terminal position, as a pendant group, and/or in the backbone of the silicone polymers. Methods of making the bicyclic modified silicone-containing compound, and methods of making cured materials from compositions are disclosed.

In one aspect, the present invention provides, a curable silicone composition comprising:

(A) an organopolysiloxane with a formula:



where R^1 is a divalent organic group chosen from a C1-C20 divalent hydrocarbon, a C4-C20 branched divalent hydrocarbon, or a C4-C30 cyclic-containing hydrocarbon group;

R^2 is a curable functional group independently chosen from a vinyl, a vinyl-containing group, an unsaturated hydrocarbon, an unsaturated cyclic hydrocarbon, an acrylate, a methacrylate, a hydroxy, an alkoxy, and an epoxy;

R^3 - R^{14} are independently chosen from hydrogen, a C1-C10 monovalent hydrocarbon group, a C6-C20 monovalent aromatic group, and a C4 to C30 monovalent saturated or unsaturated cycloalkyl group, siloxy group containing 1-20 silicon atoms;

x and z are independently 1-30;

y and w are independently 0-30; and

n is 1-30; and

(B) a silicone-free, organic material comprising a reactive functional group.

In one embodiment of the curable silicone composition, R^1 is chosen from a divalent group comprising a C4-C30

cyclic-containing hydrocarbon group chosen from a cyclobutyl group, cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, 1,1-diethenyl cyclohexane; 1,3-diethenyl cyclohexane; bicyclo[2.2.1]-2,5-dien-
 thenylheptane; 1,4-di-2,prope-1-nylcyclohexane; 1,3-di-
 isopropenylbenzene; a spiro[5.5]-3,8-diethenylundecane; a
 1,3-diethenyladamantane; a vinyl norbornene; 3,9-divinyl-
 2,4,8,10-tetraoxaspiro[5.5]undecane; pinane, bornane, nor-
 pinane, norbornane, spiro[2.2]pentane, spiro[2.3]hexane,
 spiro[2.4]heptane, spiro[2.5]octane, spiro[3.3]heptane, spiro
 [3.4]octane, spiro[3.5]nonane, spiro[4.4]nonane, spiro[4.5]
 decane, spiro[5.5]undecane, bicyclo[1.1.0]butane, bicyclo
 [2.1.0]pentane, bicyclo[2.2.0]hexane, bicyclo[3.1.0]hexane,
 bicyclo[3.2.0]heptane, bicyclo[3.3.0]octane, bicyclo[4.1.0]
 heptane, bicyclo[4.2.0]octane, bicyclo[4.3.0]nonane, bicy-
 clo[4.4.0]decane, bicyclo[1.1.1]pentane, bicyclo[2.1.1]
 hexane, bicyclo[2.2.1]heptane, bicyclo[2.2.2]octane,
 bicyclo[3.1.1]heptane, bicyclo[3.2.1]octane, bicyclo[3.2.2]
 nonane, bicyclo[3.3.1]nonane, bicyclo[3.3.2]decane, bicy-
 clo[3.3.3]undecane, an adamantyl, tricyclo[5.2.1.0^{2,6}]de-
 cane tricyclo[4.3.1.1^{2,5}]undecane rings.

In one embodiment of the curable silicone composition of
 any previous embodiment, R² is chosen from a C1-C20
 hydrocarbon radical comprising a vinyl functional group, a
 monovalent C4-C20 branched hydrocarbon radical compris-
 ing a vinyl functional group, or a monovalent C4 to C30
 cyclic hydrocarbon radical comprising a vinyl functional
 group.

In one embodiment of the curable silicone composition of
 any previous embodiment, R² is of the formula X—R¹⁶—
 where X is the curable functional group chosen from a vinyl
 group (CH₂=CH₂—), an unsaturated cyclic group, an
 unsaturated polycyclic group, and R¹⁶ is a bond or a mon-
 ovalent hydrocarbon. In one embodiment, X is chosen from
 cyclopentene, cyclohexene, cyclooctene, pinene, bornene,
 norpinene, norbornene, spiro[2.2]pentene, spiro[2.3]hexene,
 spiro[2.4]heptene, spiro[2.5]octene, spiro[3.3]heptene, spiro
 [3.4]octene, spiro[3.5]nonene, spiro[4.4]nonene, spiro[4.5]
 decene, spiro[5.5]undecene, bicyclo[1.1.0]butene, bicyclo
 [2.1.0]pentene, bicyclo[2.2.0]hexene, bicyclo[3.1.0]hexene,
 bicyclo[3.2.0]heptene, bicyclo[3.3.0]octene, bicyclo[4.1.0]
 heptene, bicyclo[4.2.0]octene, bicyclo [4.3.0]nonene, bicy-
 clo[4.4.0]decene, bicyclo[1.1.1]pentene, bicyclo[2.1.1]hex-
 ene, bicyclo[2.2.1]heptene, bicyclo[2.2.2]octene, bicyclo
 [3.1.1]heptene, bicyclo[3.2.1]octene, bicyclo[3.2.2]nonene,
 bicyclo[3.3.1]nonene, bicyclo[3.3.2]decene, bicyclo[3.3.3]
 undecene, an adamantene, tricyclo[5.2.1.0^{2,6}]decene, tricy-

clo[4.3.1.1^{2,5}]undecene rings, a limonene, a camphene, a
 limonene oxide, a vinyl cyclohexyl epoxide, a dicyclopent-
 tadiene, 5-ethylidene-2-norbornene, 2-vinyl adamantane,
 2-methylene admantane, dicyclopentadiene, or (-)-beta-
 chamigrene, 4-vinyl cyclohexyl.

In one embodiment of the curable silicone composition of
 any previous embodiment, the organic material (B) is chosen
 from a vinyl terminated polyisobutene. In one embodiment
 of the curable silicone composition of any previous embodi-
 ment, the polyisobutene has a number average molecular
 weigh of 200 to about 40,000. In one embodiment of the

curable silicone composition of any previous embodiment,
 the polyisobutene has a number average molecular weigh of
 900 to about 3,000.

In one embodiment of the curable silicone composition of
 any previous embodiment, the curable composition compris-
 es (C) a cross-linker selected from a compound compris-
 ing at least one —SiH group, at least one —SH group,
 or a combination of two or more thereof; (D) a reaction
 accelerating agent selected from a photoinitiator, a thermal
 initiator, a metal containing catalyst, or a combination of two
 or more thereof; (E) an inhibitor; and/or (F) one or more
 additives.

In one embodiment of the curable silicone composition of
 any previous embodiment, the cross-linker (C) is chosen
 from a silicone-containing compound comprising at least
 one —SiH group, at least one —SH group, or a combination
 of two or more thereof. In one embodiment, the silicone-
 containing compound is chosen from a cyclic silicone, a
 linear silicone, a branched silicone, or a combination of two
 or more thereof.

In one embodiment of the curable silicone composition of
 any previous embodiment, the reaction accelerating agent is
 selected from a metal-containing catalyst.

In one embodiment of the curable silicone composition of
 any previous embodiment, the inhibitor is selected from an
 ethylenic compound, an acetylenic compound, or a combi-
 nation thereof.

In one embodiment of the curable silicone composition of
 any previous embodiment, the additive is selected from an
 antioxidant, a thermal stabilizer, an adhesion promoter, a
 filler, or a combination of two or more thereof.

In one embodiment of the curable silicone composition of
 any previous embodiment, the composition has a refractive
 index of from 1.45 to 1.51.

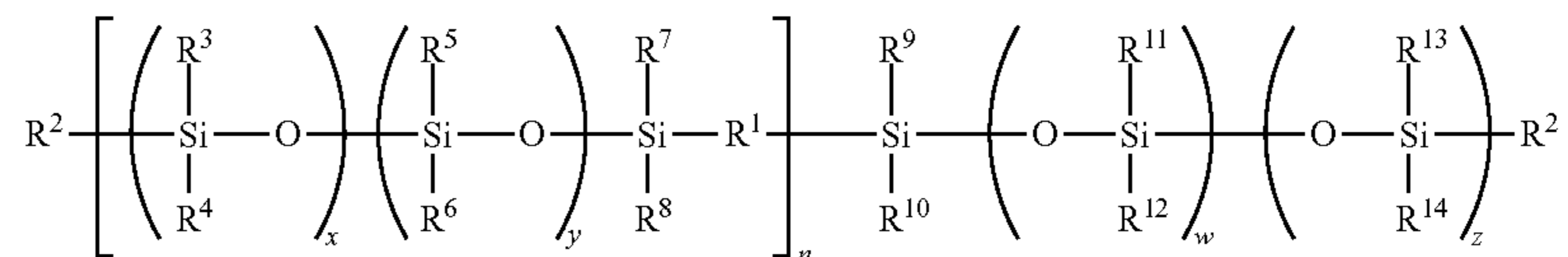
In one embodiment of the curable silicone composition of
 any previous embodiment, the composition has a transpar-
 ency of ≥95%; even greater than 98%.

In one embodiment of the curable silicone composition of
 any previous embodiment, the composition has a MVTR,
 WVTR, O permeability of 10⁻¹ to 10 g/m²-day.

In one aspect, the present invention provides a cured
 article formed from the curable composition of any previous
 embodiment.

In one aspect, the present invention provides a cured
 article formed from a curable silicone composition, said
 curable silicone composition comprising:

(A) an organopolysiloxane with a formula:



where R¹ is a divalent organic group chosen from a
 C1-C20 divalent hydrocarbon, a C4-C20 branched divalent
 hydrocarbon, or a C4-C30 cyclic-containing hydrocarbon
 group;

R² is a curable functional group independently chosen
 from a vinyl, a vinyl-containing group, an unsaturated
 hydrocarbon, an unsaturated cyclic hydrocarbon, an acry-
 late, a methacrylate, a hydroxy, an alkoxy, and an epoxy;

R³-R¹⁴ are independently chosen from hydrogen, a
 C1-C10 monovalent hydrocarbon group, a C6-C20 monova-

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lent aromatic group, and a C4 to C30 monovalent saturated or unsaturated cycloalkyl group;

x and z are independently 1-30;

y and w are independently 0-30; and

n is 1-30;

(B) a silicone-free, organic material comprising a reactive functional group. Optionally, the composition may comprise other components such as (C) a cross-linker selected from a compound comprising at least one —SiH group, at least one —SH group, or a combination of two or more thereof; (D) a reaction accelerating agent selected from a photoinitiator, a thermal initiator, a metal containing catalyst, or a combination of two or more thereof; (E) an inhibitor; and/or (F) one or more additives.

In one embodiment, R¹ is chosen from a divalent organic group comprising a C4-C30 cyclic-containing hydrocarbon group chosen from a cyclobutyl group, cyclopentyl group, a cyclohexyl group, a cycloheptyl group, cyclooctyl group, 1,1-diethenyl cyclohexane; 1,3-diethenyl cyclohexane; bicyclo[2.2.1]-2,5-dienthenylheptane; 1,4-di-2-propene-1-nyl-cyclohexane; 1,3-diisopropenylbenzene; spiro[5.5]-3,8-diethenylundecane; a 1,3-diethenyladamantane; a vinyl norbornene; 3,9-divinyl-2,4,8,10-tetraoxaspiro[5.5]undecane; pinane, bornane, norpinane, norbornane, spiro[2.2]pentane, spiro[2.3]hexane, spiro[2.4]heptane, spiro[2.5]octane, spiro[3.3]heptane, spiro[3.4]octane, spiro[3.5]nonane, spiro[4.4]nonane, spiro[4.5]decane, spiro[5.5]undecane, bicyclo[1.1.0]butane, bicyclo[2.1.0]pentane, bicyclo[2.2.0]hexane, bicyclo[3.1.0]hexane, bicyclo[3.2.0]heptane, bicyclo[3.3.0]octane, bicyclo[4.1.0]heptane, bicyclo[4.2.0]octane, bicyclo[4.3.0]nonane, bicyclo[4.4.0]decane, bicyclo[1.1.1]pentane, bicyclo[2.1.1]hexane, bicyclo[2.2.1]heptane, bicyclo[2.2.2]octane, bicyclo[3.1.1]heptane, bicyclo[3.2.1]octane, bicyclo[3.2.2]nonane, bicyclo[3.3.1]nonane, bicyclo[3.3.2]decane, bicyclo[3.3.3]undecane, an adamantyl, tricyclo[5.2.1.0^{2,6}]decane tricyclo[4.3.1.1^{2,5}]undecane rings.

In one embodiment of the cured article of any previous embodiment, the R² functional group chosen from a C1-C20 hydrocarbon radical comprising a vinyl functional group, a monovalent C4-C20 branched hydrocarbon radical comprising a vinyl functional group, or a monovalent C4 to C30 cyclic hydrocarbon radical comprising a vinyl functional group.

In one embodiment of the cured article of any previous embodiment, the R² group is of the formula X—R¹⁶— where X is the curable functional group, and R¹⁶ is a bond or a monovalent hydrocarbon radical. In embodiments, R¹⁶ may be a C1-C20 alkylene group; a C1-C10 alkylene group; even a C1-C6 alkylene group, and X may be chosen from a vinyl group (CH₂=CH₂—), an unsaturated cyclic group, an unsaturated polycyclic group.

In one embodiment, X is chosen from cyclopentene, cyclohexene, cyclooctene, pinene, bornene, norpinene, norbornene, spiro[2.2]pentene, spiro[2.3]hexene, spiro[2.4]heptene, spiro[2.5]octene, spiro[3.3]heptene, spiro[3.4]octene, spiro[3.5]nonene, spiro[4.4]nonene, spiro[4.5]decene, spiro[5.5]undecene, bicyclo[1.1.0]butene, bicyclo[2.1.0]pentene, bicyclo[2.2.0]hexene, bicyclo[3.1.0]hexene, bicyclo[3.2.0]heptene, bicyclo[3.3.0]octene, bicyclo[4.1.0]heptene, bicyclo[4.2.0]octene, bicyclo[4.3.0]nonene, bicyclo[4.4.0]decene, bicyclo[1.1.1]pentene, bicyclo[2.1.1]hexene, bicyclo[2.2.1]heptene, bicyclo[2.2.2]octene, bicyclo[3.1.1]heptene, bicyclo[3.2.1]octene, bicyclo[3.2.2]nonene, bicyclo[3.3.1]nonene, bicyclo[3.3.2]decene, bicyclo[3.3.3]undecene, an adamantene, tricyclo[5.2.1.0^{2,6}]decene, tricyclo[4.3.1.1^{2,5}]undecene rings, a limonene, a camphene, a limonene oxide, a vinyl cyclohexyl epoxide, a dicyclopent-

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tadiene, 5-ethylidene-2-norbornene, 2-vinyl adamantane, 2-methylene adamantane, dicyclopentadiene, (–)-beta-chamigrene, 4-vinyl cyclohexyl,

In one embodiment of the cured article of any previous embodiment, the cross-linker (B) is chosen from a silicone-containing compound comprising at least one —SiH group, at least one —SH group, or a combination of two or more thereof.

In one embodiment, the silicone-containing compound is chosen from a cyclic silicone, a linear silicone, a branched silicone, or a combination of two or more thereof.

In one embodiment of the cured article of any previous embodiment, the reaction accelerating agent is selected from a metal containing catalyst.

In one embodiment of the cured article of any previous embodiment, the inhibitor is selected from a ethylenic compounds or a acetylenic compounds or a combination thereof.

In one embodiment of the cured article of any previous embodiment, the additive is selected from an antioxidant, a thermal stabilizer, an adhesion promoter, filler, or a combination thereof.

In one embodiment of the cured article of any previous embodiment, the article has a refractive index of from 1.45 to 1.51.

In one embodiment of the cured article of any previous embodiment, the article has a transparency of ≥95%; even greater than 98%.

In one embodiment of the cured article of any previous embodiment, the article has a MVTR, WVTR, O permeability of 10⁻¹ to 10 g/m²·day. In one embodiment, the cured article formed from the composition has a moisture vapor permeability of less than 3 g/m²·day.

In one embodiment of the cured article of any previous embodiment, the article is chosen from an LED encapsulant, an optical waveguide, an optical lens, an optical bonding material, an optical adhesive, an optical film or sheet, laminated film of sheet, in electronic component or in combination with semiconductor device.

In still another aspect, the present invention provides a personal care composition comprising the curable silicone composition of any of the previous embodiments. In one embodiment, the personal care composition is chosen from a cosmetic formulation, a sunscreen, a shampoo, a conditioner, a lotion, or a cream.

DETAILED DESCRIPTION

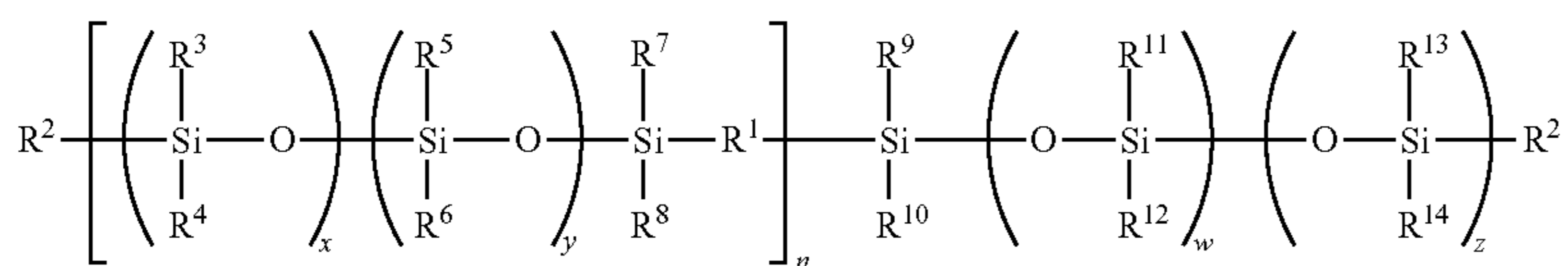
Reference will now be made to exemplary embodiments, examples of which are illustrated in the accompanying drawings. It is to be understood that other embodiments may be utilized and structural and functional changes may be made. Moreover, features of the various embodiments may be combined or altered. As such, the following description is presented by way of illustration only and should not limit in any way the various alternatives and modifications that may be made to the illustrated embodiments. In this disclosure, numerous specific details provide a thorough understanding of the subject disclosure. It should be understood that aspects of this disclosure may be practiced with other embodiments not necessarily including all aspects described herein, etc.

As used herein, the words “example” and “exemplary” mean an instance, or illustration. The words “example” or “exemplary” do not indicate a key or preferred aspect or embodiment. The word “or” is intended to be inclusive rather than exclusive, unless context suggests otherwise. As

an example, the phrase “A employs B or C,” includes any inclusive permutation (e.g., A employs B; A employs C; or A employs both B and C). As another matter, the articles “a” and “an” are generally intended to mean “one or more” unless context suggest otherwise.

The present technology provides a curable composition comprising: (A) an organopolysiloxane comprising a curable functional group; and (B) a silicone-free, organic material. The composition may also include other components such as, for example, (C) a cross-linker comprising a silyl hydride group or a thiol group; (D) a reaction accelerator; (E) an inhibitor; and/or (F) other additives.

The organopolysiloxane (A) comprises a siloxane polymer having organic functional groups between silicon atoms within a part of the main chain. The organopolysiloxane (A) comprises a compound of Formula (I):



where R^1 is a divalent organic group chosen from a C1-C20 hydrocarbon, a C4-C20 branched hydrocarbon, or a C4-C30 cyclic-containing hydrocarbon group;

R^2 is a curable functional group independently chosen from a vinyl, a vinyl-containing group, an unsaturated hydrocarbon, an unsaturated cyclic hydrocarbon, an acrylate, a methacrylate, a hydroxy, an alkoxy, and an epoxy;

R^3 - R^{14} are independently chosen from hydrogen, a C1-C10 monovalent hydrocarbon group, a C6-C20 monovalent aromatic group, and a C4 to C30 monovalent saturated or unsaturated cycloalkyl group, siloxy group containing 1-20 silicon atoms;

x and z are independently 1-30;

y and w are independently 0-30; and

n is 1-30.

R^1 may be chosen from a divalent C1-C20 hydrocarbon or a divalent C4-C20 branched divalent hydrocarbon group. The divalent hydrocarbon group is a group formed by removing two hydrogen atoms from an alkane (either two hydrogen atoms from the same carbon or one hydrogen atom from two different carbon atoms). Examples of suitable divalent hydrocarbon groups include, but are not limited to, methylene, ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene, nonylene, isopropylene, isobutylene, etc. In embodiments, R^1 is chosen from a C1-C6 linear or branched alkylene.

R^1 may also be chosen from a divalent cyclic hydrocarbon group. As used herein a “cyclic” or “cyclic-containing” hydrocarbon group refers to a group derived by removing two hydrogen atoms from an cyclic-containing alkane, where (i) both hydrogen atoms may be removed from the same ring carbon, (ii) one hydrogen atom is removed from one ring carbon, and the other hydrogen atom is removed from another ring carbon, (iii) one hydrogen is removed from a ring carbon, and one hydrogen is removed from a hydrocarbon group attached to the chain, (iv) both hydrogen atoms are removed from the same carbon of a hydrocarbon group connected to the cyclic group, or (v) one hydrogen is removed from a first hydrocarbon group connected to the cyclic group, and one hydrogen is removed from a second hydrocarbon group connected to the cyclic group.

The cyclic group in the cyclic-containing hydrocarbon may be a monocyclic hydrocarbon group or a polycyclic hydrocarbon group. Examples of suitable monocyclic hydrocarbon groups include a cycloalkyl group having 3 to 12 carbon atoms, such as, but not limited to, cyclobutyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, or a cyclooctyl group, or a cycloalkenyl group having 3 to 12 carbon atoms, such as a cyclohexenyl group. In embodiments, the monocyclic hydrocarbon group is a monocyclic hydrocarbon group having 3 to 7 carbon atoms. A cyclopentyl group and a cyclohexyl group are particularly suitable.

The polycyclic hydrocarbon groups include ring-assembly hydrocarbon groups and crosslinked-ring hydrocarbon groups. Examples of the ring-assembly hydrocarbon groups include a bicyclohexyl group, a perhydronaphthalene group,

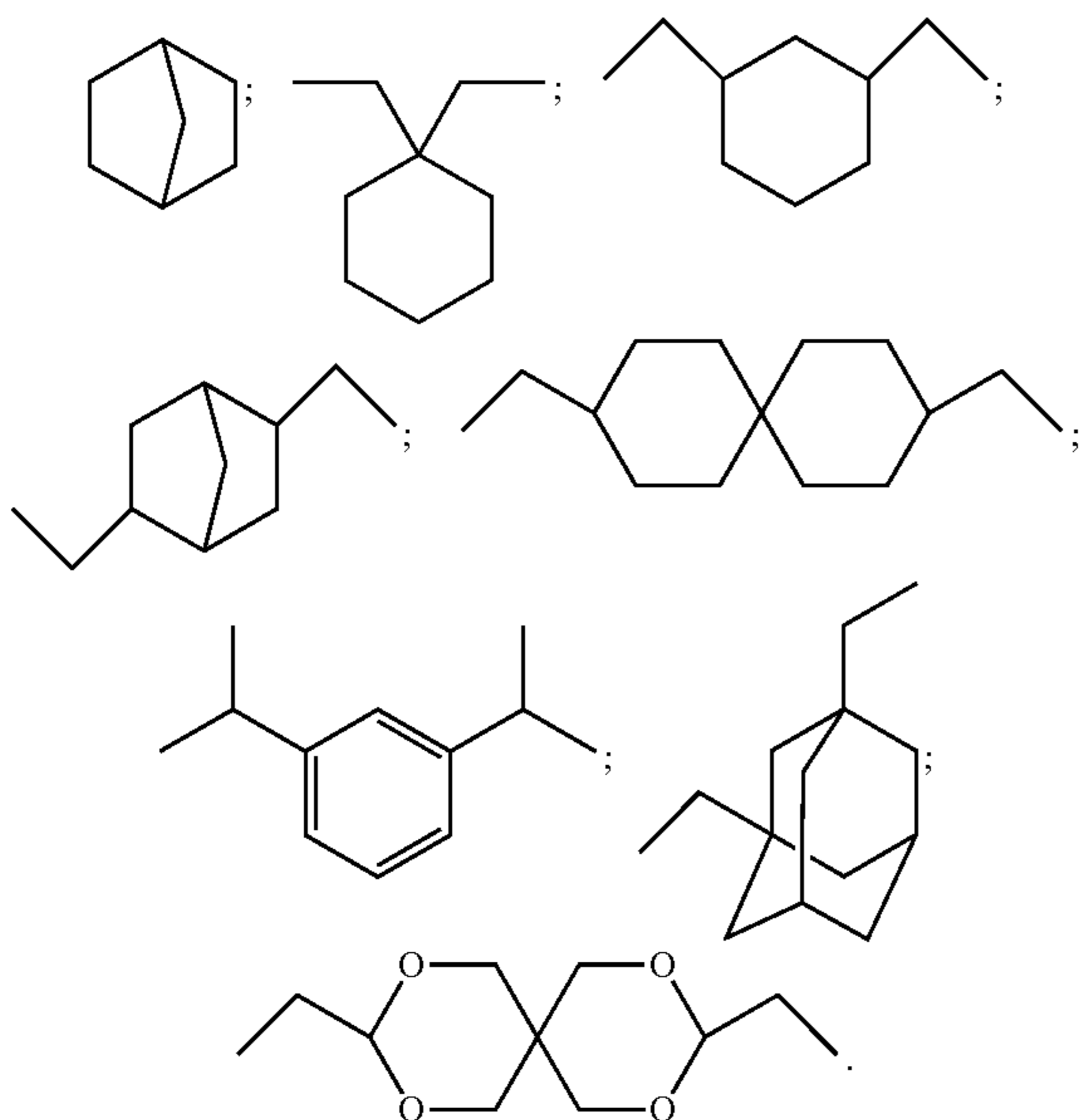
etc. Examples of crosslinked-ring hydrocarbon rings include, but are not limited to, for example, bicyclic hydrocarbon rings, tricyclic hydrocarbon rings, and tetracyclic hydrocarbon rings, such as tetracyclo[4.4.0.1^{2,5}.1^{7,10}]dodecane and perhydro-1,4-methano-5,8-methanonaphthalene rings. Further, the crosslinked-ring hydrocarbon rings include condensed-ring hydrocarbon rings, for example, condensed rings resulting from condensation of multiple 5- to 8-membered cycloalkane rings, such as perhydronaphthalene (decalin), perhydroanthracene, perhydrophenanthrene, perhydroacenaphthene, perhydrofluorene, perhydroindene and perhydrophenarene rings.

Examples of suitable polycyclic hydrocarbon groups of 4 to 30 which may be part of or provide the R^1 group include, but are not limited to, pinane, bornane, norpinane, norbornane, spiro[2.2]pentane, spiro[2.3]hexane, spiro[2.4]heptane, spiro[2.5]octane, spiro[3.3]heptane, spiro[3.4]octane, spiro[3.5]nonane, spiro[4.4]nonane, spiro[4.5]decane, spiro[5.5]undecane, bicyclo[1.1.0]butane, bicyclo[2.1.0]pentane, bicyclo[2.2.0]hexane, bicyclo[3.1.0]hexane, bicyclo[3.2.0]heptane, bicyclo[3.3.0]octane, bicyclo[4.1.0]heptane, bicyclo[4.2.0]octane, bicyclo[4.3.0]nonane, bicyclo[4.4.0]decane, bicyclo[1.1.1]pentane, bicyclo[2.1.1]hexane, bicyclo[2.2.1]heptane, bicyclo[2.2.2]octane, bicyclo[3.1.1]heptane, bicyclo[3.2.1]octane, bicyclo[3.2.2]nonane, bicyclo[3.3.1]nonane, bicyclo[3.3.2]decane, bicyclo[3.3.3]undecane, an adamantyl, tricyclo[5.2.1.0^{2,6}]decane tricyclo[4.3.1.1^{2,5}]undecane rings.

In embodiments, the cyclic-containing R^1 group may be represented by the formula: R^{15} -A- R^{15} , where R^{15} is a bond or a C1-C10 monovalent hydrocarbon radical, and A is a cyclic or polycyclic hydrocarbon group. The cyclic or polycyclic group A may be a cyclic or polycyclic group as described above. It will be appreciated that the R^{15} groups may be attached to the same ring carbon atom or to different carbon atoms on the ring.

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Examples of suitable groups for R¹ include but are not limited to:



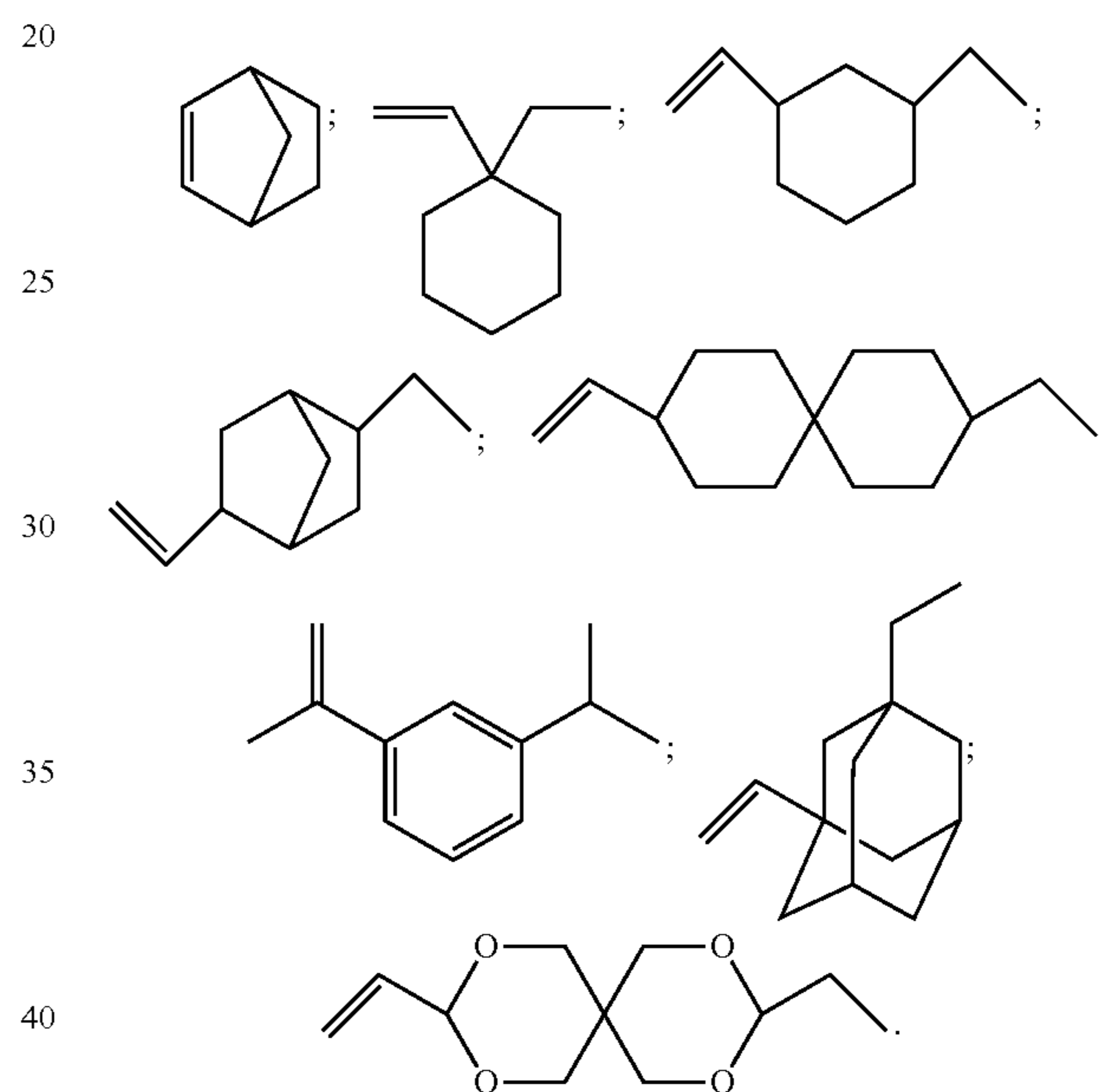
While the divalent organic groups or “alkylene” type groups for R¹ are described with respect to removal of a hydrogen, it will be appreciated by those of skill in the art of forming silicone-containing materials that the alkylene type groups for R¹ may be derived from and incorporated into the siloxane backbone by the reaction of a diene (conjugated or non-conjugated) compound comprising the desired R¹ group with an appropriate siloxane in the presence of a catalyst (e.g., Karstedt’s catalyst).

R² is a group comprising a curable functional group chosen from a vinyl, an acrylate, a methacrylate, a hydroxyl, an alkoxy, an alkenyloxy or an epoxy. R² may be chosen from a monovalent C1-C20 hydrocarbon radical comprising a curable functional group, a monovalent C4-C20 branched hydrocarbon radical comprising a curable functional group, or a monovalent C4 to C30 cyclic hydrocarbon radical comprising a curable functional group. The R² group may be represented, in embodiments, by the formula: X—R¹⁶— where X is the curable functional group, and R¹⁶ is a bond or a monovalent hydrocarbon radical. In embodiments, R¹⁶ may be a C1-C20 alkylene group; a C1-C10 alkylene group; even a C1-C6 alkylene group. X may be chosen from a vinyl group (CH₂=CH₂—), an unsaturated cyclic group, an unsaturated polycyclic group, etc. In embodiments, X is chosen from cyclohexene, cyclohexene, cyclooctene, pinene, bornene, norpinene, norbornene, spiro[2.2]pentene, spiro[2.3]hexene, spiro[2.4]heptene, spiro[2.5]octene, spiro[3.3]heptene, spiro[3.4]octene, spiro[3.5]nonene, spiro[4.4]

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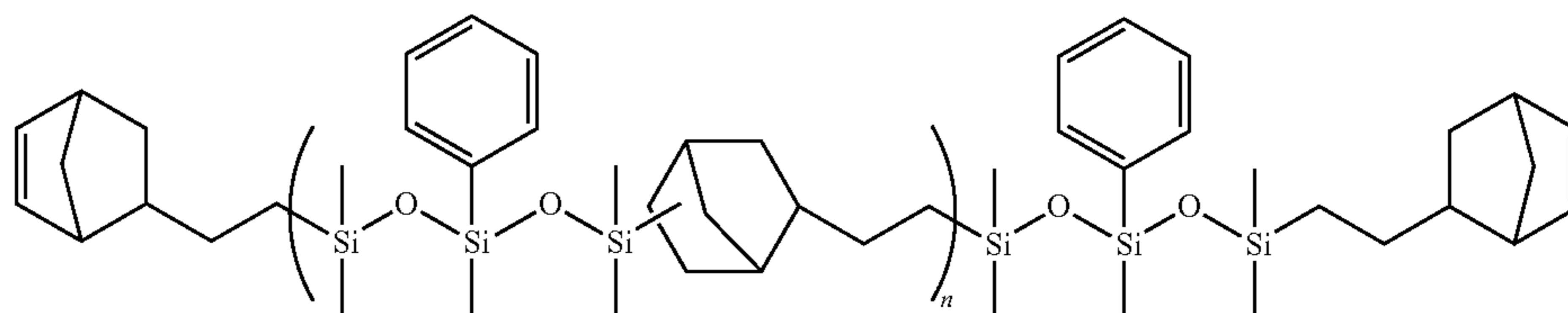
nonene, spiro[4.5]decene, spiro[5.5]undecene, bicyclo[1.1.0]butene, bicyclo[2.1.0]pentene, bicyclo[2.2.0]hexene, bicyclo[3.1.0]hexene, bicyclo[3.2.0]heptene, bicyclo[3.3.0]octene, bicyclo[4.1.0]heptene, bicyclo[4.2.0]octene, bicyclo[4.3.0]nonene, bicyclo[4.4.0]decene, bicyclo[1.1.1]pentene, bicyclo[2.1.1]hexene, bicyclo[2.2.1]heptene, bicyclo[2.2.2]octene, bicyclo[3.1.1]heptene, bicyclo[3.2.1]octene, bicyclo[3.2.2]nonene, bicyclo[3.3.1]nonene, bicyclo[3.3.2]decene, bicyclo[3.3.3]undecene, an adamantene, tricyclo[5.2.1.0^{2,6}]decene, tricyclo[4.3.1.1^{2,5}]undecene rings, a limonene, a camphene, a limonene oxide, a vinyl cyclohexyl epoxide, a dicyclopentadiene, 5-ethylidene-2-norbornene, 2-vinyl adamantane, 2-methylene adamantane, dicyclopentadiene, (-)-beta-chamigrene, 4-vinyl cyclohexyl, and the like.

Examples of suitable R² or X groups include, but are not limited to:



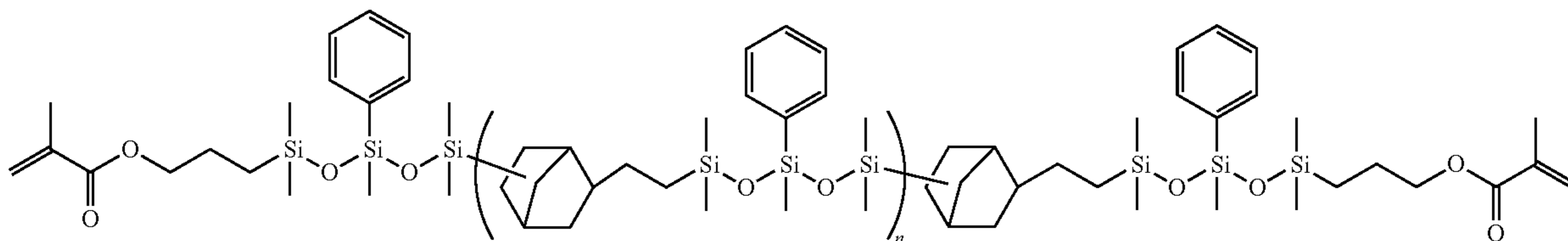
In embodiments, the polymer comprises an aromatic group attached to one of the silicon atoms, e.g., R³-R¹⁴. In embodiments, the R⁵ and R¹¹ groups in the polymer comprise an aromatic group. In embodiments, the aromatic group is a phenyl group. While not being bound to any particular theory, the presence of aryl groups may be desirable to limit the mobility of the silicon atoms.

In embodiments, the organopolysiloxane (A) comprises polycyclic groups and aromatic groups. The polycyclic groups may be in the siloxane chain (e.g., R¹) and at the terminal position (i.e., R²). In embodiments, the R⁵ and R¹¹ groups in the polymer comprise an aromatic group. In one embodiment, the organopolysiloxane (A) is a compound of the formula:



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In another embodiment, the organopolysiloxane (A) is a compound of the formula:



The silicone-free, organic material (B) is chosen from an organic monomer or oligomer with a reactive functional group. As used herein, the reactive functional group may also be referred to as a curable functional group. The reactive functional group may be chosen from, but is not limited to, an ethylenically unsaturated monomers (e.g., an allyl, a vinyl, etc.), ethylenically unsaturated aromatic compounds, ethylenically unsaturated acids, ethylenically unsaturated anhydrides an acrylate, a methacrylate, an acrylamide, or a combination of two or more thereof. Non-limiting examples of vinyl ether monomers include, e.g., methyl, ethyl, propyl, isobutyl, 2-ethylhexyl, cyclohexyl, 4-hydroxybutyl, decyl, dodecyl, octadecyl, 2-(diethylamino) ethyl, 2-(di-n-butylamino)ethyl and methyldiglycol vinyl ether, the corresponding allyl alkyl ethers, and combinations thereof. Non-limiting examples of ethylenically unsaturated acid and ethylenically unsaturated anhydride monomers include, e.g., acrylic acid, methacrylic acid, crotonic acid, itaconic acid, fumaric acid, and maleic acid, and anhydrides thereof, monovinyl adipate, and combinations thereof. Non-limiting examples of olefin monomers include, e.g., ethylene, propylene, butene, isobutylene, pentene, cyclopentene, hexane, cyclohexene, octane, 1-3 butadiene, chloroprene, cyclobutadiene, isoprene, and combinations thereof. Non-limiting examples of ethylenically unsaturated aromatic compounds include, e.g., styrene, alkyl styrenes, and chlorostyrene.

In one embodiment, the organic material (B) is chosen from a functionalized isobutylene compound. The polyisobutene may have a number-average molecular weight M_n of at least 200. In embodiments, the polyisobutene has a number-average molecular weight M_n in the range from 200 to 40,000, from 500 to 15,000, from 700 to 7,000, from 900 to 3,000, even from 900 to 1,100. As used herein, the term "polyisobutene" also includes oligomeric isobutenes such as dimeric, trimeric, tetrameric, pentameric, hexameric, and heptameric isobutene.

The reactivity of polyisobutenes increases as the concentration of the reactive functionality increases. In embodiments, the polyisobutene comprises at least 50 mol % of a reactive functional group; at least 60 mol % of a reactive functional group; even at least 80 mol % of a reactive functional group. In one embodiment, the polyisobutene comprises at least 50 mol % of terminal double bonds based on the total number of polyisobutene macromolecules; at least 60 mol % of terminal double bonds, and even at least 80 mol % of terminal double bonds based on the total number of polyisobutene macromolecules. The terminal double bonds may either be vinyl double bonds $[\text{CH}=\text{C}(\text{CH}_3)_2]$ (β -olefin) or vinylidene double bonds $[\text{CH}=\text{C}(\text{=CH}_2)-\text{CH}_3]$ (α -olefin). The substantially homopolymeric polyisobutene radicals may have uniform polymer backbones. In embodiments, the polyisobutene system is

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formed to an extent of at least 85% by weight, to an extent of at least 90% by weight, and even to an extent of at least

95% by weight from isobutene units of the repeat unit $[\text{CH}_2\text{C}(\text{CH}_3)_2-]$.

The polyisobutenes may, in embodiments, have a polydispersity index (PDI) of from 1.05 to 10, from 1.05 to 3.0, even from 1.05 to 2.0. Polydispersity refers to the ratio of the weight-average molecular weight M_w to the number-average molecular weight M_n ($\text{PDI} = M_w/M_n$).

The polyisobutenes suitable for use in the compositions include all polymers that are obtainable by cationic polymerization and comprise, in copolymerized form, at least 60% by weight of isobutene, at least 80% by weight, at least 90% by weight, and even at least 95% by weight of isobutene. In addition, the polyisobutenes may comprise, in copolymerized form, further butene isomers such as 1- or 2-butene, and also different olefinically unsaturated monomers which are copolymerizable with isobutene under cationic polymerization conditions.

Suitable isobutene feedstocks for the preparation of polyisobutenes include both isobutene itself and isobutenic C_4 hydrocarbon streams, e.g., C_4 raffinate, C_4 cuts from isobutene dehydrogenation, C_4 cuts from steamcrackers, FCC crackers (FCC: Fluid Catalyzed Cracking), provided that they have been substantially freed of 1,3-butadiene present therein. Particularly suitable C_4 hydrocarbon streams comprise generally less than 500 ppm, preferably less than 200 ppm of butadiene. When C_4 cuts are used as the starting material, the hydrocarbons other than isobutene assume the role of an inert solvent.

Useful monomers copolymerizable with isobutene include vinylaromatics such as styrene and α -methylstyrene, C_1 - C_4 -alkylstyrenes such as 2-, 3- and 4-methylstyrene, and also 4-tert-butylstyrene, isoolefins having from 5 to 10 carbon atoms such as 2-methylbutene-1, 2-methylpentene-1, 2-methylhexene-1, 2-ethylpentene-1, 2-ethylhexene-1 and 2-propylheptene-1.

Examples of polyisobutenes suitable in the compositions include, but are not limited to, the Glissopal® brands from BASF Aktiengesellschaft, e.g., Glissopal 550, Glissopal 1000, and Glissopal 2300, and also the Oppanol® brands from BASF Aktiengesellschaft, e.g., Oppanol B10, B12 and B15.

In another embodiment, the organic material (B) may be chosen from an acrylate monomer, an acrylate oligomer, or a combination thereof. As used herein, the acrylate monomer or acrylate oligomer refers to a monomer or oligomer, respectively, comprising one or more acryloyl groups, one or more methacryloyl groups, or one or more acryloyl groups and one or more methacryloyl groups. In one embodiment, the acrylate monomer or oligomer may be an epoxy acrylate, a urethane acrylate, an aminated acrylate, etc. It will be appreciated that the monomers and/or oligomers may contain one or more acryloyl or methacryloyl groups such that they may be mono acrylates, diacrylates, triacrylates, etc.

In one embodiment, the organic material (B) may include an acrylate monomer. Examples of suitable acrylate monomers include, but are not limited to, 2-butoxyethyl acrylate, 2-butoxyethyl methacrylate, 2-ethoxyethyl acrylate, 2-ethoxyethyl methacrylate, 2-ethyl-2-adamantyl acrylate, 2-ethyl-2-adamantyl methacrylate, 2-hydroxyethyl acrylate, 2-methyl-2-adamantyl acrylate, 2-methyl-2-adamantyl methacrylate, benzyl acrylate, cyclohexyl acrylate, di(ethyleneglycol)ethylether acrylate, di(ethyleneglycol)ethylether methacrylate, di(ethylene glycol)methylether methacrylate, dicyclofentanyl acrylate, epoxy acrylate, ethylene glycol methyl ether acrylate, ethylene glycol phenyl ether acrylate, hydroxypropyl acrylate, isobornyl acrylate, methyl adamantyl acrylate, neopentyl glycol benzoate acrylate, 2-hydroxymethyl methacrylate, adamantyl methacrylate, alkyl methacrylate, benzyl methacrylate, cyclohexyl methacrylate, dicyclopentanyl methacrylate, epoxy-cyclohexylmethyl methacrylate, ethylene glycol phenyl ether methacrylate, hydroxybutyl methacrylate, hydroxypropyl methacrylate, isobornyl methacrylate, glycidyl methacrylate, methyl adamantyl methacrylate, methyl methacrylate, methyl glycidyl methacrylate, isobutyl acrylate, tert-butyl acrylate, lauryl acrylate, alkyl acrylate, 2-hydroxy acrylate, trimethoxybutyl acrylate, ethyl carbitol acrylate, phenoxyethyl acrylate, 4-hydroxybutyl acrylate, 2-hydroxy-3-phenoxypropyl acrylate, 3-fluoroethyl acrylate, 4-fluoropropyl acrylate, and triethyl siloxyl ethyl acrylate, or a combination of two or more thereof.

In one embodiment, the organic material (B) comprises a multifunctional (meth)acrylate monomer. The multifunctional (meth)acrylate monomer can be saturated or unsaturated and can include aliphatic, alicyclic, aromatic, heterocyclic, and/or epoxy functionality. In some embodiments, saturated long-chain alkyl(meth)acrylates, cycloaliphatic (meth)acrylates, (meth)acrylate/epoxy monomers, or combinations thereof can be utilized as monomers. The multifunctional (meth)acrylate monomer can be unsubstituted or substituted with various groups such as hydroxy or alkoxy groups.

Exemplary long chain alkyl(meth)acrylates include, but are not limited to, octyl(meth)acrylate, stearyl(meth)acrylate, 1,9-nonanediol di(meth)acrylate, 1,10-decandiol di(meth)acrylate, and hydrogenated polybutadiene di(meth)acrylate resin. Exemplary cycloaliphatic(meth)acrylates include, but are not limited to, isobornyl(meth)acrylate, tetramethylpiperidiyl methacrylate, pentamethyl piperidiyl methacrylate, dicyclopentanyl(meth)acrylate, dicyclopentenyl(meth)acrylate, tricyclodecanediol di(meth)acrylate, tricyclodecanedimethanol di(meth)acrylate, and (meth)acrylated epoxies.

Examples of commercially available acrylate monomers include, for example, but are not limited to, the acrylate monomers under the trade names: EM21®, EM211®, EM221®, EM2230®, EM231®, EM235®, EM265®, EM70®, EM215®, EM218® or EM2108® produced by Eternal company.

In another embodiment, the organic material (B) may include an acrylate oligomer. Examples of suitable acrylate oligomers include, but are not limited to, those having a molecular weight from about 1,000 to 100,000. In embodiments, the acrylate oligomer may be chosen from polyester (meth)acrylates, urethane(meth)acrylates, alkoxyated (meth)acrylated oligomers, epoxy(meth)acrylates, aminated (meth)acrylates, (meth)acrylated (meth)acrylics, or a combination of two or more thereof.

Examples of suitable acrylate oligomers include, but are not limited to, acrylate, such as 2-hydroxy-3-phenoxypropyl

acrylate; methacrylate; urethane acrylate, such as aliphatic urethane acrylate, aliphatic urethane diacrylate, aliphatic urethane hexaacrylate, aromatic urethane hexaacrylate or acrylate terminated urethane; epoxy acrylate, such as bisphenol-A epoxy diacrylate or novolac epoxy acrylate; or a mixture of two or more thereof.

Examples of suitable commercially available acrylate oligomers include, for example, but are not limited to, the acrylate oligomers under the trade names: SR454®, SR494®, SR9020®, SR9021® or SR9041® produced by Sartomer company; 6101-100®, 611A-85®, 6112-100®, 6113®, 6114®, 6123®, 6131®, 6144-100®, 6145-100®, 6150-100®, 6160B-70®, 621A-80® or 621-100® produced by Eternal company; and Ebecryl 600®, Ebecryl 830®, Ebecryl 3605® or Ebecryl 6700® produced by UCB company.

Examples of suitable polyester (meth)acrylates include, but are not limited to, acrylated epoxidized soybean oil compounds like EBECRYL® 860 (Cytec), fatty acid containing polyester (meth)acrylates like EBECRYL® 870, EBECRYL® 657, EBECRYL® 450 (Cytec), and polyester (meth)acrylates like EBECRYL® 800, EBECRYL® 884, EBECRYL® 810 and EBECRYL® 830 (Cytec).

Examples of suitable epoxy(meth)acrylates include, but are not limited to, the di(meth)acrylate of diglycidyl ether of Bisphenol A (BADGED(M)A), and modifications thereof (see for instance EBECRYL® 3700 or EBECRYL® 600, EBECRYL® 3701, EBECRYL® 3703, EBECRYL® 3708 and EBECRYL® 3639 from Cytec). Examples of suitable urethane(meth)acrylates include, but are not limited to, EBECRYL® 284, EBECRYL® 264, EBECRYL® 210, EBECRYL® 230, EBECRYL® 1290 (Cytec). Examples of suitable aminated (meth)acrylates include, but are not limited to, EBECRYL® 80, EBECRYL® 81, EBECRYL® 83, EBECRYL® 7100, P115 and others. Examples of suitable (meth)acrylic (co)polymers that may be used include, but are not limited to, EBECRYL® 745 and/or EBECRYL® 1200. Examples of suitable inert polyesters include, but are not limited to, EBECRYL® 525 and optionally chlorinated variants thereof (such as EBECRYL® 436 and others).

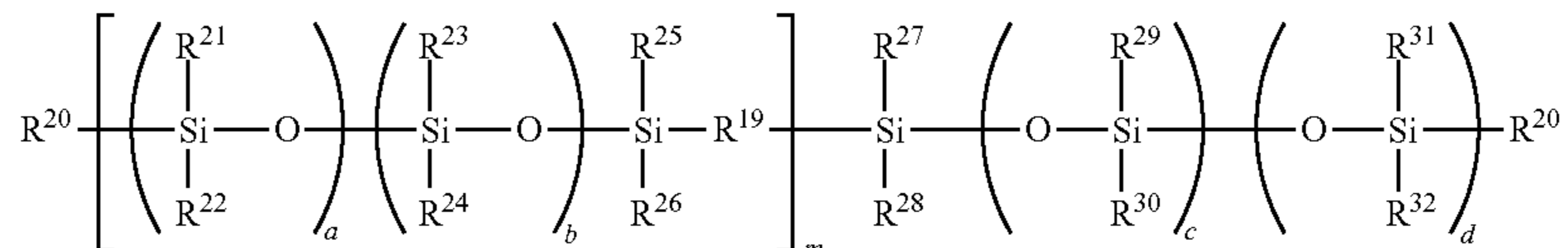
The cross-linker (C) comprises a functional group that is reactive with the curable functional group of the organopolysiloxane (a). In embodiments, the cross-linker (b) comprises a Si—H group, an S—H group, a vinyl group, a vinyl-containing group, an unsaturated hydrocarbon, an unsaturated cyclic hydrocarbon, an acrylate, a methacrylate, a hydroxy, an alkoxy, an epoxy, or a combination of two or more thereof. In embodiments, the cross-linker is chosen from a linear silicone, a branched silicone, or a cyclic silicone material comprising a Si—H or S—H group. It will be appreciated that combinations of different cross-linker compounds may be used as desired.

In embodiments, the cross-linker (C) is chosen from a silyl hydride. The silyl hydride is not particularly limited. In embodiments, the silyl hydride may be chosen from a compound of the formula $R^{17}_g SiH_{4-g} (R^{17}O)_g SiH_{4-3g} HSiR^{17}_g (OR^{17})_{3-g} R^{17}_3 Si(CH_2)_f (SiR^{17}_2 O)_k SiR^{17}_2 H$, $(R^{17}O)_3 Si(CH_2)_f (SiR^{17}_2 O)_k SiR^{17}_2 H$, $Q_u T_v T_p^H D_r^H M^H M_e$, $R^{17}_3 Si(CH_2)_h SiOSiR^{17}_2)_j OSiR^{17}_2 H$, or combinations of two or more thereof. Each occurrence of R^{17} is independently a C1-C18 alkyl, a C1-C18 substituted alkyl, wherein R^{17} optionally contains at least one heteroatom, each occurrence of g independently has a value from 0 to 3, f has a value of 1 to 8, k has a value of 0 to 3000, each of p , u , v , r and e independently has a value from 0 to 20, t and s are from 0 to 3000, provided that $p+s+r$ equals 1 to 1000 and the valences of the all the elements in the silyl hydride

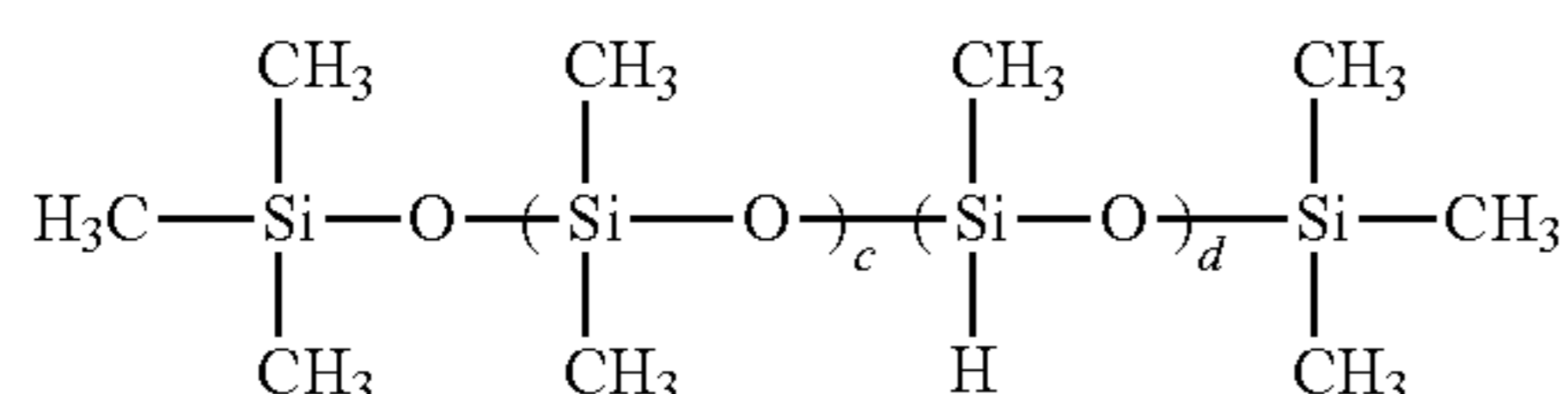
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are satisfied. As used herein, M represents a monofunctional group of formula $R^{18}_3SiO_{1/2}$, D represents a difunctional group of formula $R^{18}_2SiO_{2/2}$, T represents a trifunctional group of formula $R^{18}SiO_{3/2}$, Q represents a tetrafunctional group of formula $SiO_{4/2}$, an M^H represents $HR^{18}_2SiO_{1/2}$, T^H represents $HSiO_{3/2}$, and D^H represents $R^{18}HSiO_{2/2}$; each occurrence of R^{18} is independently C1-C18 alkyl, C1-C18 substituted alkyl, wherein R^{18} optionally contains at least one heteroatom; h is 1-8, and j is 0-10.

Some non-limiting examples of silyl hydrides include methylhydrogensiloxymethylsiloxane copolymers,

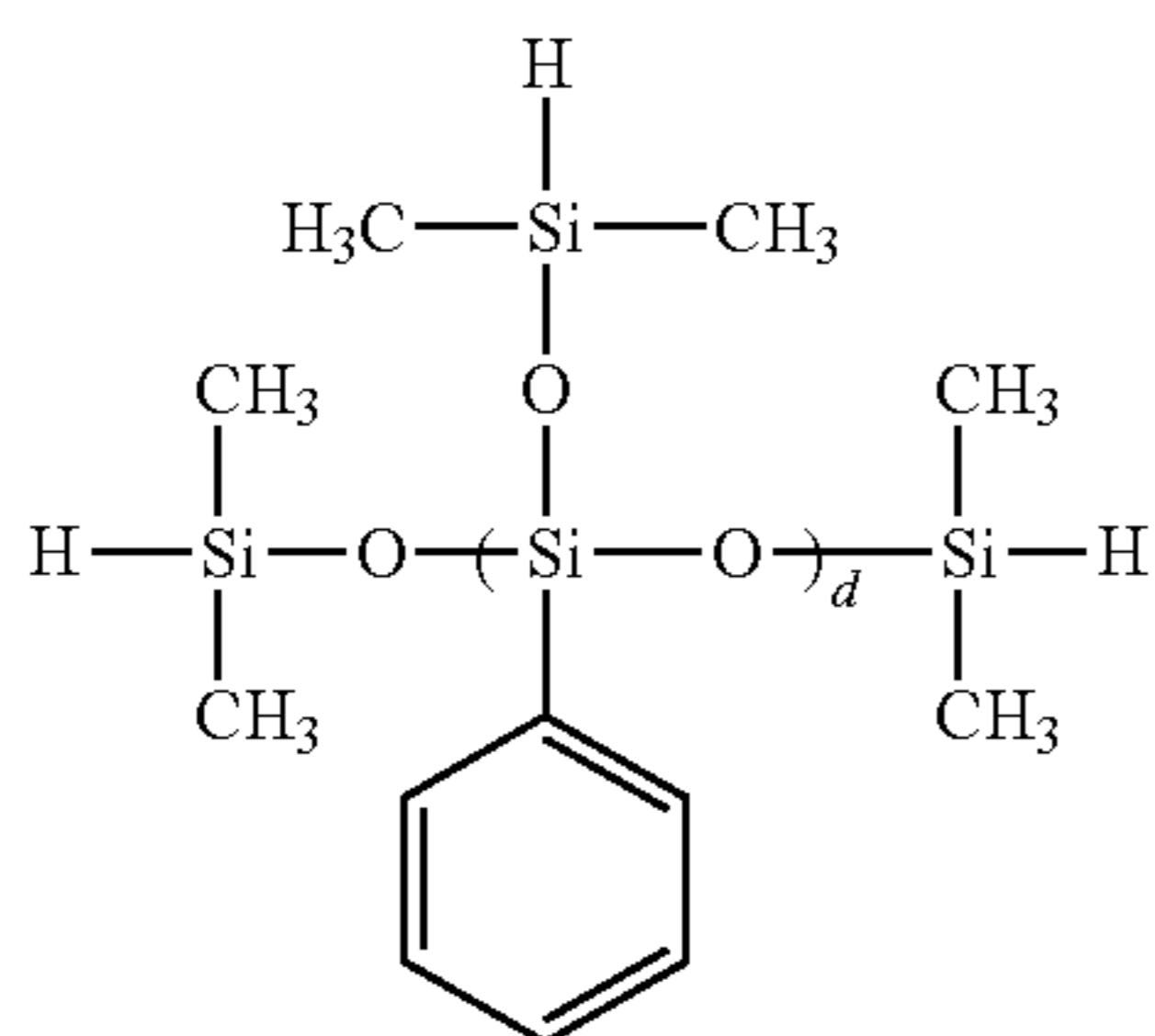


include those from Gelest such as, e.g., HMS 501 RPM-502, HMS-992, HMS-064, polyhydrosiloxane, and other hydride-containing copolymers or homopolymers of dimethyl siloxane or phenyl-containing siloxanes. Other suitable silyl hydrides include those present in SYLGARD 184 (a two-part silicone available from Dow Corning, Midland, Mich.) that was supplied free from the thermohydrosilation catalyst that the commercial version usually contains.



HMS-501-Methylhydrogensiloxymethylsiloxane copolymer

The following structure shows one example of an organo-hydrogenopolysiloxane (HDP-111-hydride terminated polyphenyl(dimethylhydrosiloxy)siloxane, available from Gelest Inc., Tullytown, Pa.) having phenyl functionality.



HDP-111-Hydride-terminated polyphenyl(dimethylhydrosiloxy)siloxane

Other examples of silyl hydride agents include a Q resin, which may also be referred to as HQ-type resins or hydride-modified silica Q resins. Examples of those compounds include, but are not limited to, those commercially available under the tradename MQH-9™ (Clariant LSM, Inc.), which is a hydride-modified silica Q resin characterized by a molecular weight of 900 g/mole and an activity of 9.5 equivalents/kg; HQM 105™ (Gelest, Inc.), which is a hydride modified silica Q resin characterized by a molecular weight of 500 g/mole and an activity of 8-9 equivalents/kg;

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and HQM 107™ (Gelest, Inc), which is a hydride-modified silica Q resin characterized by a molecular weight of 900 g/mole and an activity of 8-9 equivalents/kg.

Examples of suitable mercapto-functional siloxanes include, but are not limited to, products such as KF-2001 and KF-2004 by Shin-Etsu Chemical Co., Ltd., SMS-022, SMS-042 and SMS-992 by Gelest Inc.; PS848, PS849, PS849.5, PS850, PS850.5 and PS927 by United Chemical Corp.; and B 7610 available from Momentive Performance Materials Inc.

The cross-linker (C) may also be chosen from a compound of the formula:

where R^{19} is a divalent organic group chosen from a C1-C20 divalent hydrocarbon, a C4-C20 branched divalent hydrocarbon, or a C4-C30 cyclic-containing divalent hydrocarbon group;

R^{20} is a functional group chosen from hydrogen, an acrylate, a methacrylate, a thiol, or R^2 ;

R^{21} - R^{32} are independently chosen from hydrogen, a C1-C10 monovalent hydrocarbon group, a C⁶-C²⁰ monovalent aromatic group, and a C4 to C30 monovalent cycloalkyl group;

a and d are independently 1-30,

b and c are independently 0-30; and

m is 1-30.

R^{19} may be chosen from any group suitable as the R^1 group described above, and R^{21} - R^{32} may be chosen from any group suitable as R^3 - R^{14} described above. For the sake of brevity, however, the details of those groups are not repeated.

The composition includes a reaction accelerator (D) to effect curing of the organopolysiloxane (A), organic material (B), and the cross-linker (C). The reaction accelerator (D) may be, for example, a photoinitiator, a thermal initiator, a metal catalyst, or a combination of two or more thereof.

In embodiments, the reaction accelerator comprises a catalyst, e.g., a hydrosilation catalyst. Useful catalysts include those compounds or molecules that can catalyze the hydrosilation reaction between a reactive SiH-containing moiety or substituent and a carbon-carbon bond such as a carbon-carbon double bond. Also, in one or more embodiments, these catalysts may be soluble within the reaction medium. Types of catalysts include transition metal compounds including those compounds that include a Group VIII metal. Exemplary Group VIII metals include palladium, rhodium, germanium, and platinum. Exemplary catalyst compounds include chloroplatinic acid, elemental platinum, chloroplatinic acid hexahydrate, complexes of chloroplatinic acid with sym-divinyltetramethyldisiloxane, dichloro-bis(triphenylphosphine) platinum (II), cis-dichloro-bis(acetonitrile) platinum (II), dicarbonyldichloroplatinum (II), platinum chloride, and platinum oxide, zero valent platinum metal complexes such as Karstedt's catalyst, $[Cp^*Ru(MeCN)_3]PF_6$, $[PtCl_2(cyclooctadiene)]$, solid platinum supported on a carrier (such as alumina, silica or carbon black), platinum-vinylsiloxane complexes (e.g., $Pt_n(ViMe_2SiOSiMe_2Vi)_n$ and $Pt[(MeViSiO)_4]_m$), platinum-phosphine complexes (e.g., $Pt(PPh_3)_4$ and $Pt(PBU_3)_4$), and

platinum-phosphite complexes (e.g., Pt[P(Oph)₃]₄ and Pt[P(Obu)₃]₄), wherein Me represents methyl, Bu represents butyl, "Vi" represents vinyl and Ph represents phenyl, and n and m represent integers. Others include RhCl(PPh₃)₃, RhCl₃, Rh/Al₂O₃, RuCl₃, IrCl₃, FeCl₃, AlCl₃, PdCl₂·2H₂O, NiCl₂, TiCl₄, etc.

In embodiments, a photoinitiator may be employed as the reaction accelerator to promote curing of the siloxanes. The photoinitiator can be chosen as desired for a particular purpose or intended application. Examples of suitable photoinitiators include, but are not limited to, benzophenones, phosphine oxides, nitroso compounds, acryl halides, hydrazones, mercapto compounds, pyrillium compounds, triacrylimidazoles, benzimidazoles, chloroalkyl triazines, benzoin ethers, benzil ketals, thioxanthenes, camphorquinone, acyl phosphines, and acetophenone derivatives.

In one embodiment, the photoinitiator is chosen from an acylphosphine. The acyl phosphine can be a mono- or bis-acylphosphine. Examples of suitable acylphosphine oxides include those described in U.S. Pat. No. 6,803,392, which is incorporated herein by reference. Specific examples of suitable acylphosphine photoinitiators include, but are not limited to, diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide (DAROCUR® TPO), diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (ESACURE® TPO, LAMBERTI Chemical Specialties, Gallarate, Italy), diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (FIRSTCURE® HMPP available from Albemarle Corporation, Baton Rouge, La.), diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (LUCIRIN® TPO, available from BASF (Ludwigshafen, Germany), diphenyl(2,4,6-trimethylbenzoyl)phosphinate (LUCIRIN® TPO-L), phenyl bis(2,4,6-trimethyl benzoyl) phosphine oxide (IRGACURE® 819, available from Ciba Specialty Chemicals, Tarrytown, N.Y.), and bis(2,6-dimethoxybenzoyl)-2,4,4-trimethylpentylphosphine oxide (as IRGACURE® 1700, IRGACURE® 1800 and IRGACURE® 1850 in admixture with α -hydroxyketones from Ciba Spezialitätenchemie).

Examples of α -hydroxyketone photoinitiators can include 1-hydroxy-cyclohexylphenyl ketone (IRGACURE® 184), 2-hydroxy-2-methyl-1-phenyl-1-propanone (DAROCUR® 1173), and 2-hydroxy-1-[4-(2-hydroxyethoxy)phenyl]-2-methyl-1-propanone (IRGACURE® 2959), all available from Ciba Specialty Chemicals (Tarrytown, N.Y.).

Examples of α -aminoketones photoinitiators can include 2-benzyl-2-(dimethylamino)-1-[4-(4-morpholinyl)phenyl]-1-butanone (IRGACURE® 369), and 2-methyl-1-[4-(methylthio)phenyl]-2-(4-morpholinyl)-1-propanone (IRGACURE® 907), both available from Ciba Specialty Chemicals (Tarrytown, N.Y.).

The curable composition may optionally comprise a polymerization inhibitor (E). The polymerization inhibitor is not particularly limited and may be chosen as desired for a particular purpose or intended use. Inhibitors for component (E) of the platinum group metal catalysts are well known in the organosilicon art. Examples of suitable inhibitors include, but are not limited to, ethylenically unsaturated amides, aromatically unsaturated amides, acetylenic compounds, ethylenically unsaturated isocyanates, olefinic siloxanes, unsaturated hydrocarbon diesters, unsaturated hydrocarbon mono-esters of unsaturated acids, conjugated or isolated ene-yne, hydroperoxides, ketones, sulfoxides, amine, phosphines, phosphites, nitrites, diaziridines, etc. Particularly suitable inhibitors for the compositions are alkynyl alcohols and maleates. Examples of suitable polym-

erization inhibitors include, but are not limited to, diallyl maleate, hydroquinone, p-methoxyphenol, t-butylcatechol, phenothiazine, etc.

The amount of component (E) to be used in the compositions is not critical and can be any amount that will retard the above described platinum catalyzed hydrosilylation reaction at room temperature while not preventing said reaction at moderately elevated temperature, i.e. a temperature that is 25 to 125° C. above room temperature. No specific amount of inhibitor can be suggested to obtain a specified bath life at room temperature since the desired amount of any particular inhibitor to be used will depend upon the concentration and type of the platinum metal containing catalyst, the nature and amounts of components a and b. The range of component (E) can be 0 to about 10% weight, about 0.001 wt to 2% by weight, even about 0.12 to about 1 by weight. Here as elsewhere in the specification and claims, numerical values can be combined to form new and alternative ranges. In one embodiment, the compositions can be free of any inhibitor component (E).

The curable composition may also comprise other additives (F). Other additives may include, but are not limited to, an adhesion promoter, an antioxidant, a filler, pigments, dyes, filler treating agent, plasticizer, spacer, extender, biocide, stabilizer, flame retardant, surface modifier, anti-aging additive, rheological additive, corrosion inhibitor, surfactant or combination thereof.

Various organofunctional silane and siloxane adhesion promoters to inorganic substrates are useful in the composition. Suitable silanes include, but are not limited to, amino silanes, epoxy silanes, isocyanurate silanes, mercapto silanes, imido silanes, anhydride silanes, carboxylate functionalized siloxanes, etc. Combinations of various types of adhesions promoters may also be used. Such components typically hinder curing via metal catalyzed hydrosilylation. Suitable adhesion promoters include, but are not limited to various aminosilane materials such as Silquest® A-1120 silane, Silquest A-1110 silane, Silquest A-2120 silane, and Silquest A-1170 silane; epoxysilanes, such as Silquest A-187 silane; isocyanurate silanes such as Silquest A-597 silane; and mercaptosilanes such as Silquest A-189 silane, Silquest A-1891 silane, Silquest A-599 silane available from Momentive Performance Materials.

The curable compositions may also include an antioxidant compound. Examples of suitable classes of antioxidant compounds include, but are not limited to, hindered amines and/or hindered phenol compounds.

Examples of hindered amine antioxidant compounds include, but are not limited to Hindered amine series antioxidant (N,N',N'',N'''-tetrakis-(4,6-bis(butyl-(N-methyl)-2,2,6,6-tetramethylpiperidin-4-yl)amino)-triazine-2-yl)-4,7-diazadecan-1,10-diamine, a polycondensation product of dibutylamine-1,3,5-triazine-N,N'-bis-(2,2,6,6-tetramethyl-4-piperidyl)-1,6-hexamethylenediamine-N-(2,2,6,6-tetramethyl-4-piperidyl)butylamine, poly[{6-(1,1,3,3-tetramethylbutyl)amino-1,3,5-triazine-2,4-diyl}{(2,2,6,6-tetramethyl-4-piperidyl)imino}hexamethylene{(2,2,6,6-tetramethyl-4-piperidyl)imino}], a polymer of dimethyl succinate and 4-hydroxy-2,2,6,6-tetramethyl-1-piperidinethanol, [a reaction product of decanedioic acid bis(2,2,6,6-tetramethyl-1(octyloxy)-4-piperidyl) ester, 1,1-dimethylethylhydroperoxide and octane] (70%)-polypropylene (30%), bis(1,2,2,6,6-pentamethyl-4-piperidyl)[[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]methyl]butylmalonate, methyl 1,2,2,6,6-pentamethyl-4-piperidylsebacate, bis(2,2,6,6-tetramethyl-4-piperidyl)sebacate, bis(1,2,2,6,6-pentamethyl-4-piperidyl)sebacate, 1-[2-[3-(3,5-di-tert-butyl-4-hydroxyphenyl)

propionyloxy]ethyl]-4-[3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionyloxy]-2,2,6,6-tetramethylpiperidine, 4-benzoyloxy-2,2,6,6-tetramethylpiperidine, 8-acetyl-3-dodecyl-7,7,9,9-tetramethyl-1,3,8-triazaspiro[4.5]decan-2,4-dione, etc.)

In one embodiment, the antioxidant compound is a hindered phenolic compound. The hindered phenol can be chosen as desired for a particular purpose or intended application. Examples of suitable hindered phenols include, but are not limited to, monophenols such as 2,6-di-*t*-butyl-*p*-cresol, 2-*t*-butyl-4-methoxyphenol, 3-*t*-butyl-4-methoxyphenol, and 2,6-*t*-butyl-4-ethylphenol, bisphenols such as 2,2'-methylene-bis(4-methyl-6-*t*-butylphenol), 4,4'-thiobis(3-methyl-6-*t*-butylphenol), and 4,4'-butylidene-bis(3-methyl-6-*t*-butylphenol); and polymeric phenols such as 1,1,3-tris(2-methyl-4-hydroxy-5-*t*-butyl phenyl)butane, 1,3,5-trimethyl-2,4,6-tris(3,5-di-*t*-butyl-4-hydroxybenzyl)benzene, tetrakis[methylene-3-(3',5'-di-*t*-butyl-4'-hydroxyphenyl)propionate]methane, bis[3,3'-bis(4'-hydroxy-3-*t*-butylphenyl)butyric acid glycol ester, and tocopherol (vitamin E), pentaerythritol-tetrakis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate], thiodiethylene-bis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate], octadecyl-3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate), N,N'-hexane-1,6-diylbis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionamide), benzenepropanoic acid 3,5-bis(1,1-dimethylethyl)-4-hydroxy C7-C9 side chain alkyl ester, 2,4-dimethyl-6-(1-methylpentadecyl)phenol, diethyl[[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]methyl]phosphonate, 3,3',3'',5,5',5''-hexane-*tert*-butyl-4-*a,a',a''*-(mesitylene-2,4,6-*tolyl*)tri-*p*-cresol, calcium diethylbis[[[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]methyl]phosphonate], 4,6-bis(octylthiomethyl)-*o*-cresol, ethylenebis(oxyethylene)bis[3-(5-*tert*-butyl-4-hydroxy-*m*-*tolyl*)propionate], hexamethylenebis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate], 1,3,5-tris(3,5-di-*t*-butyl-4-hydroxybenzyl)-1,3,5-triazine-2,4,6-(1H,3H,5H)-trione, a reaction product of N-phenylbenzeneamine and 2,4,4-trimethylpentene, 2,6-di-*t*-butyl-4-(4,6-bis(octylthio)-1,3,5-triazine-2-ylamino)phenol etc.).

IRGANOX 1330 is a sterically hindered phenolic antioxidant ("3,3',3'',5,5',5''-hexa-*tert*-butyl-*a,a',a''*-(mesitylene-2,4,6-*triyl*)tri-*p*-cresol") commercially available from BASF. Irganox 1010 is a sterically hindered phenolic antioxidant ("Pentaerythritol Tetrakis(3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate)") commercially available from BASF, or 1,3,5-trimethyl-2,4,6-tris(3,5-di-*t*-butyl-4-hydroxybenzyl)benzene commercially available as ETHANOX™ 330 (Albemarle Corporation), pentaerythritol tetrakis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate] (Irganox 1010), tris(3,5-di-*t*-butyl-4-hydroxybenzyl) isocyanurate (Irganox 3114), tris(3,5-di-*t*-butyl-4-hydroxybenzyl) isocyanurate as Irganox 3114.

The curable composition may optionally comprise a photostabilizer. The photostabilizer is not particularly limited and may be chosen as desired for a particular application or intended use. Examples of suitable materials for the photostabilizer include, but are not limited to, 2,4-di-*t*-butyl-6-(5-chlorobenzotriazol-2-yl)phenol, 2-(2H-benzotriazol-2-yl)-4,6-di-*t*-butylphenol, 2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol, a reaction product of methyl 3-(3-(21-1-benzotriazol-2-yl)-5-*tert*-butyl-4-hydroxyphenyl)propionate/polyethylene glycol 300, 2-(2H-benzotriazol-2-yl)-6-(straight and branched dodecyl)-4-methylphenol, 2-(4,6-diphenyl-1,3,5-triazine-2-yl)-5-[(hexyl)oxy]phenol, octabenzene, 2,4-di-*t*-butylphenyl-3,5-di-*t*-butyl-4-hydroxybenzoate, tinuvin 622LD, Tinuvin 144,

CHIMASSORB 119FL, MARK LA-57, LA-62, LA-67, LA-63, SANDOL LS-765, LS-292, LS-2626, LS-1114, LS-744, etc.

The curable composition may comprise the organopolysiloxane (A) in an amount of from about 5 to about 98 mass %; from about 10 to about 90 mass %; or about 20 to about 80 mass %. The curable composition may comprise the organic material (B) in an amount of from about 2 to about 95 mass %; from about 10 to about 90 mass %; or about 20 to about 80 mass %. The cross-linker (C) may be present in an amount of from about 2 to about 25 mass %; from about 6 to about 20%; or about 6 to about 12 mass %. The reaction accelerator (C) may be present in an amount of from about 0.0001 to about 0.2 mass %; from about 0.0002 to about 0.05 mass %; or about 0.0005 to about 0.02 mass %. The inhibitor (D) may be present in an amount of from about 0.0001 to about 1 mass %; from about 0.0002 to about 0.6 mass %; or about 0.0005 to about 0.3 mass %. Adhesion promoters may be present in an amount of from about 0.1 to about 10 mass %; from about 0.3 to about 5 mass %; or about 0.5 to about 3 mass %.

The curable compositions have various properties that may make the compositions and cured materials formed therefrom useful in a variety of applications. For examples, the curable composition may have a refractive index of greater than about 1.40, 1.45, 1.5, 1.55, or 1.60. In embodiments, the curable composition has a refractive index of from about 1.40 to about 1.6, or from about 1.45 to about 1.55.

The curable composition may also exhibit excellent optical clarity. In embodiments, the curable composition has a transparency of about 95% or greater, about 96% or greater, about 97% or greater, about 98% or greater, even about 99% or greater at 400 nm to about 800 nm.

Additionally, the viscosity of the composition may be controlled or tuned over a wide range of viscosity as desired to allow for control in processing the composition as may be needed for an intended application. In embodiments, the viscosity of the curable composition may be from about 0.2 to about 43 Pa·S, from about 1 to about 35 Pa·S, from about 5 to about 25 Pa·S, even from about 10 to about 20 Pa·S.

Curing the curable organosilicon composition of the present invention yields a cured product that has a high degree of hardness and excellent transparency, crack resistance and heat resistance. There are no particular restrictions on the curing conditions, which vary depending on the quantity of the composition, but the curing temperature is preferably within a range from 60 to 180° C., and the curing time is typically within a range from 0.5 to 10 hours. In embodiments, curing can be achieved in 30 minutes at a temperature of about 100° C. Curing may also be accomplished by UV curing is performed in accordance with standard procedures for exposure to UV radiation.

The cured material formed from the curable composition may also exhibit desirable properties for a variety of applications. In embodiments, curable composition may have a refractive index of greater than about 1.40. In embodiments, the curable composition has a refractive index of from about 1.40 to about 1.60; about 1.42 to about 1.58; even 1.45 to about 1.50.

The cured material may also exhibit excellent optical clarity. In embodiments, a 1 mm thick sheet of the cured material has a transparency of about 95% or greater, about 96% or greater, about 97% or greater, about 98% or greater, even about 99% or greater at 400 nm to about 800 nm.

The cured material may also exhibit high thermal stability and crack resistance as evaluated and understood with

respect to various accepted test methods including, but not limited to, adhesion after water immersion, critical strain, abrasion, microindentation testing, etc.

The cured material may also exhibit good moisture vapor permeability. In embodiments, a 1 mm thick sheet of the cured material has a moisture vapor permeability of from about 0.1 to about 15 g/m²·day under the JISZ0208 test method. This may also be referred to as the Moisture Vapour Transmission Rate, Water Vapour Transmission Rate, Oxygen permeability (MVTR, WVTR, O permeability). The Moisture Vapour Transmission Rate, Water Vapour Transmission Rate, Oxygen permeability may be from about 0.1 to about 15 g/m²·day; about 0.5 to about 10 g/m²·day; about 1 to about 7.5 g/m²·day; about 2 to about 5 g/m²·day. In one embodiment the Moisture Vapour Transmission Rate, Water Vapour Transmission Rate, Oxygen permeability is from about 10 to about 15 g/m²·day. Here as elsewhere in the specification and claims, numerical values may be combined to form new and non-disclosed ranges.

The curable organosilicon composition of the present invention is useful as a curable silicone material, an encapsulating material for optical devices such as optical elements, an encapsulating material for other electronic devices such as semiconductor elements, and an electrically insulating coating material. Examples of optical devices include optical elements such as LEDs, semiconductor lasers, photodiodes, phototransistors, solar cells and CCDs; and optical components such as lenses, bonding materials, adhesives, films, sheets, etc. The cured material may be used as an encapsulant, e.g., an LED encapsulant. Examples of electronic devices include semiconductor elements such as diodes, transistors, ICs, CPUs and memory elements.

The curable silicone compositions can be included in a personal care composition such as, but not limited to, cosmetics, sunscreen, hair products such as shampoo or conditioner, lotions, creams, etc. Personal care compositions can include various ingredients such as a carrier, pigment, film formers, emulsifiers, vitamins, plasticizers, surfactants, antioxidants, waxes, oils, solvents, etc.

In one embodiment, a personal care product may optionally contain 0-90 parts by weight pigments. Pigments suitable for use herein are all inorganic and organic colors/pigments. These are usually aluminum, barium or calcium salts or lakes. Lakes are either a pigment that is extended or reduced with a solid diluent or an organic pigment that is prepared by the precipitation of a water-soluble dye on an adsorptive surface, which usually is aluminum hydrate. A lake also forms from precipitation of an insoluble salt from an acid or basic dye. Calcium and barium lakes are also used herein. Suitable lakes include, but are not limited to, Red 3 Aluminum Lake, Red 21 Aluminum Lake, Red 27 Aluminum Lake, Red 28 Aluminum Lake, Red 33 Aluminum Lake, Yellow 5 Aluminum Lake, Yellow 6 Aluminum Lake, Yellow 10 Aluminum Lake, Orange 5 Aluminum Lake and Blue 1 Aluminum Lake, Red 6 Barium Lake, Red 7 Calcium Lake. Other colors and pigments can also be included in the compositions, such as pearls, titanium oxides, Red 6, Red 21, Blue 1, Orange 5, and Green 5 dyes, chalk, talc, iron oxides and titanated micas.

A personal care composition may optionally contain 0-99 parts by weight organic film former known in the prior arts. The film-forming agent may be any which is cosmetically acceptable. Examples of useful film-forming agents include natural waxes, polymers such as polyethylene polymers, and copolymers of PVP, ethylene vinyl acetate, dimethicone gum, and resins, such as shellac, polyterpenes.

A personal care composition may optionally include 0-50 parts by weight either blocking or absorbing sunscreens agents. Blocking sunscreens agents are generally inorganic, such as various cesium oxides, chromium oxides, cobalt oxides, iron oxides, red petrolatum, silicone- and other treated titanium dioxides, titanium dioxide, zinc oxide, and/or zirconium oxide, BaTiO₃, CaTiO₃, SrTiO₃ and SiC. Absorbing sunscreens agents, which are usually organic species, are particularly useful. Such absorbing sunscreens agents include, but are not limited to, UV-A absorbers, which generally absorb radiation in the 320 to 400 nm region of the ultraviolet spectrum, for example anthranilates, benzophenones, and dibenzoyl methanes; and UV-B absorbers, which generally absorb radiation in the 280 to 320 nm region of the ultraviolet spectrum, for example, p-aminobenzoic acid derivatives, camphor derivatives, cinnamates, and salicylates. Specific examples of organic sunscreens agents include p-aminobenzoic acid, avobenzene cinoxate, dioxybenzone, homosalate, menthyl anthranilate, octocrylene, octyl methoxycinnamate, octyl salicylate, oxybenzone, padimate, phenylbenzimidazole sulfonic acids, sulisobenzone, trolamine salicylate, aminobenzoic acid, amyldimethyl p-aminobenzoic acid, diethanolamine p-methoxycinnamate, digalloyl trioleate, 2-ethylhexyl-2-cyano-3,3-diphenylacrylate, ethylhexylp-methoxycinnamate, 2-ethylhexyl salicylate, glyceryl aminobenzoate, homomenthyl salicylate, homosalate, 3-imidazol-4-ylacrylic acid and the ethyl ester thereof, methyl anthranilate, octyldimethyl PABA, 2-phenylbenzimidazole-5-sulfonic acid and salts, sulisobenzone, triethanolamine salicylate, N,N,N-trimethyl-4-(2-oxoborn-3-ylidene methyl)anilinium methyl sulfate, aminobenzoate, 4-isopropylbenzyl salicylate, 2-ethylhexyl 4-methoxycinnamate, methyl diisopropylcinnamate, isoamyl 4-methoxycinnamate, diethanolamine 4-methoxycinnamate, 3-(4'-trimethylammonium)-benzyliden-bornan-2-one methylsulfate, 2-hydroxy-4-methoxybenzophenone, 2-hydroxy-4-methoxybenzophenone-5-sulfonate, 2,4-dihydroxybenzophenone, 2,2',4,4'-tetrahydroxybenzophenone, 2,2'-dihydroxy-4,4'-dimethoxybenzophenone, 2-hydroxy-4-n-octoxybenzophenone, 2-hydroxy-4-methoxy-4'-methoxybenzophenone, ca-(2-oxoborn-3-ylidene)-tolyl-4-sulfonic acid and soluble salts thereof, 3-(4'-sulfo)benzyliden-bornan-2-one and soluble salts thereof, 3-(4'-methylbenzylidene)-d,l-camphor, 3-benzylidene-d,l-camphor, benzene 1,4-di(3-methylidene-10-camphosulfonic) acid and salts thereof, urocanic acid, 2,4,6-tris-(2'-ethylhexyl-1'-oxycarbonyl)-anilinol 1,3,5-triazine, 2-(p-(tert-butylamido)anilinol-4,6-bis-(p-(2'-ethylhexyl 1'-oxycarbonyl) anilinol 1,3,5-triazine, 2,4-bis{1,4-(2-ethylhexyloxy)-2-hydroxyl-phenyl}-6-(4-methoxyphenyl)-1,3,5-triazine, the polymer of N-(2 et 4)-(2-oxoborn-3-ylidene) methylbenzyl acrylamide, 1,4-bisbenzimidazolyl-phenylene-3,3',5,5'-tetrasulfonic acid and salts thereof, the benzalmalonate-substituted polyorganosiloxanes, the benzotriazole-substituted polyorganosiloxanes (Drometrizole Tri siloxane), solubilized 2,2'-methylene-bis-1,6-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl) phenol, 2-methyldibenzoylmethane, 4-methyldibenzoylmethane, 4-isopropylidibenzoylmethane, 4-tert-butylidibenzoylmethane, 2,4-dimethyldibenzoylmethane, 2,5-dimethyldibenzoylmethane, 4,4'-diisopropylidibenzoylmethane, 4,4'-dimethoxydibenzoylmethane, 4-tert-butyl-4'-methoxydibenzoylmethane, 2-methyl-5-isopropyl-4'-methoxydibenzoylmethane, 2-methyl-5-tert-butyl-4'-methoxydibenzoylmethane, 2,4-dimethyl-4'

methoxydibenzoylmethane, 2,6-dimethyl-4-tert-butyl-4'-methoxydibenzoylmethane, and combinations comprising at least one of the foregoing sunscreens agents.

A personal care composition can be specifically formulated for use as, but not limited to, a color cosmetic, sunscreen, hair conditioner, a moisturizer, etc. Suitable forms and formulations for such application are known to those of ordinary skill in the art. For example, when formulated for use as a sunscreen, the composition may be in the form of a lamellar emulsion, a microemulsion, or a nanoemulsion. In addition, the emulsions may be a fluid simple emulsion, a fluid multiple emulsion, a rigid simple emulsion, or a rigid multiple emulsion. The simple emulsion or multiple emulsion may comprise a continuous aqueous phase containing dispersed lipid vesicles or oil droplets, or a continuous fatty phase dispersed lipid vesicles or water droplets. In one embodiment, the sunscreen application is an emulsion having a continuous aqueous phase, and may be in the form of a stick, a lotion, a gel, a spray, and the like. Suitable emulsifiers for the formation of sunscreen emulsions include, for example ethoxylated surfactants known in the art such as Polysorbate-20, Laureth-7, Laureth-4, Sepigel® 305 available from SEPPIC, oils such as vegetable and mineral oil; animal and/or synthetic waxes such as beeswax, paraffin, rice bran wax, candelilla wax, carnauba wax and derivatives thereof; and hydrocarbon gels or bentone type gels, such as Gel SS71, Gel EA2786, Quaternium-18 Bentonite, 38 CE, Gel ISD V or Gel ISD; and organosilicone emulsifiers such as cetyl dimethicone copolyol-polyglyceryl-14-isostearate-hexylaurate (ABIL® WE 09) available from Goldschmidt Chemical Corporation, behenate dimethicone, cetyl dimethicone copolyol (ABIL® EM 90), (ABIL® EM 97), laurylmethicone copolyol (5200), cyclomethicone and dimethicone copolyol (DC 5225 C and DC 3225 C), cyclopentasiloxane and dimethicone copolyol (SF 1528).

A personal care composition may optionally contain vitamins or skin nourishing agents. Some suitable agents are ceramides, hyaluronic Acid, panthenol, peptides (copper hexapeptide-3), AHA's (lactic acid), retinols (retinyl palmitate)-Vit. A derivatives, vitamin C (1-ascorbic acid), BHA's (salicylic Acid), teas (Green Tea, White Tea, Red Tea), soy and other plant derivatives, isoflavones (Grape Seed Extract), argireline, acai berry.

Plasticizers may also be added to the formulation to improve the flexibility and cosmetic properties of the resulting formulation. Plasticizers are frequently used to avoid brittleness and cracking of film formers, and include, for example, lecithin, polysorbates, dimethicone copolyol, glycols, citrate esters, glycerin, and dimethicone. One skilled in the art may routinely vary the amount of plasticizer desired based on the properties desired and the application envisaged.

The composition of the present invention can be incorporated into a carrier, such as a volatile carrier which quickly volatilizes after application. The volatile carriers can be selected from volatile hydrocarbons, volatile silicones, and mixtures thereof.

Hydrocarbon oils useful in personal care products include those having boiling points in the range of 60-260° C., including hydrocarbon oils having from about C₈ to about

C₂₀ chain lengths, even C₈ to C₂₀ isoparaffins. Examples include isododecane, isohexadecane, isoeicosane, 2,2,4-trimethylpentane, 2,3-dimethylhexane, and mixtures of two or more thereof.

Suitable volatile silicone fluids include cyclomethicones having 3, 4 and 5 membered ring structures corresponding to the formula (R₂SiO)_x, where x is from about 3 to about 6.

What has been described above includes examples of the present specification. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the present specification, but one of ordinary skill in the art may recognize that many further combinations and permutations of the present specification are possible. Accordingly, the present specification is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the term "includes" is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim.

EXAMPLES

Aspects of this disclosure will now be described and may be further understood with respect to the following examples. The examples are intended to be illustrative only and are to be understood as not limiting the invention disclosed herein in any way as to materials, or process parameters, equipment or conditions.

Examples 1: Preparation of Component (A-1)

Component A-1 may be made according to the following procedures.

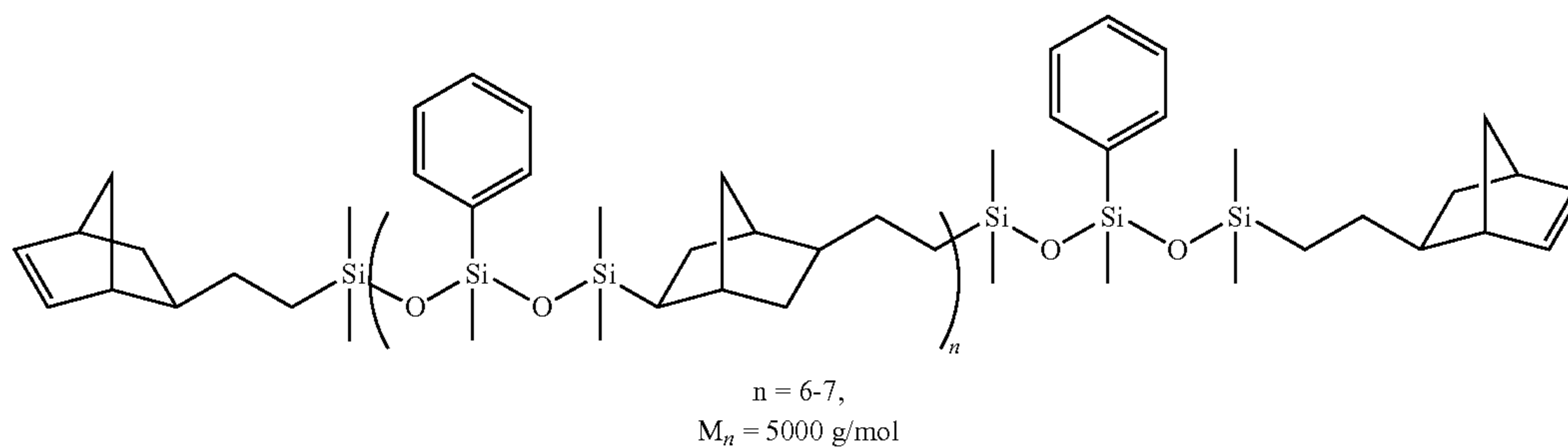
A norbornene end-capped phenylmethyl silicone norbornenylethyl block copolymer (A-1) having molecular weight 3 kD was synthesized according to the following scheme:

A 500 mL three neck round bottom flask fitted with a reflux condenser, dropping funnel and a mechanical stirrer under nitrogen environment was charged 100 mL of toluene and 5-vinylbicyclo[2.2.1]hept-2-ene (128.7 g, 1.07 mol). To this solution 0.289 g of Karstedt's catalyst (15 ppm of 2 wt % Pt) was added. The whole set-up was kept in an oil bath with the reaction temperature maintained at 50° C. 3-phenyl-1,1,3,3,5-pentamethyltrisiloxane (257.51 g, 0.95 mol) in a dropping funnel was added drop wise over a period of 1 h. The reaction temperature was subsequently increased to 80° C. and allowed to continue until all the hydride of gets consumed. After completion of the hydrosilylation polymerization, unreacted starting materials, volatile compounds and the solvent were stripped under reduced pressure. The final product was obtained as a yellow color liquid in quantitative yield and was decolorized with activated charcoal to yield the desired product as a colorless liquid in quantitative yield (Viscosity at 25° C.: 6810 mPa·s; GPC: M_n=3.06 kD; M_w=4.6 kD; PDI=1.5)

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A1



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A norbornene end-capped phenylmethyl silicone norbornenylethyl block copolymer (component A-2) having molecular weight of 140 kD was synthesized similar to the method described for A-1.

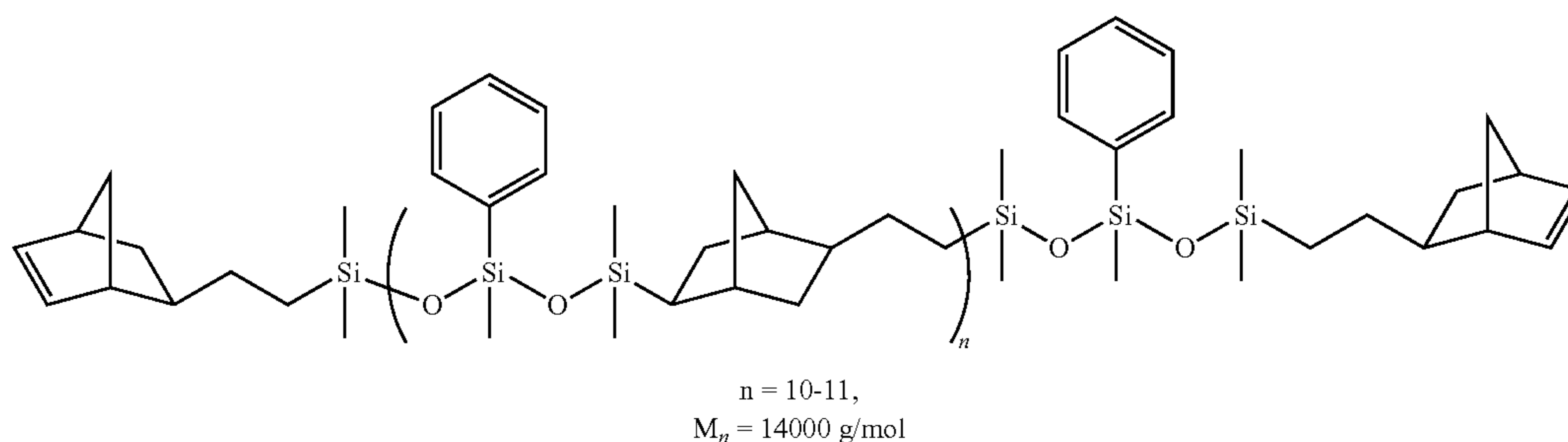
Briefly, in to a 500 mL three neck round bottom flask 150 mL of toluene and 5-vinylbicyclo[2.2.1]hept-2-ene (94 g, 0.78 mol). To this solution 0.225 g of Karstedt's catalyst (15 ppm of 2 wt % Pt) was added. 3-phenyl-1,1,3,3,5-pentamethyltrisiloxane (200 g, 0.74 mol) in a dropping funnel was added drop wise into the reaction mixture at 50° C. over a period of 1 h. The reaction temperature was subsequently increased to 80° C. and allowed to continue until all the hydride of gets consumed. After completion of the hydrosilylation polymerization, unreacted starting materials, volatile compounds and the solvent were stripped under reduced pressure. The final product was obtained as a yellow color liquid in quantitative yield and was decolorized with activated charcoal to yield the desired product as a colorless liquid in quantitative yield. (Viscosity at 25° C.: 14200 mPa·s; GPC: $M_n=5.2 \text{ kD}$; $M_w=7.8 \text{ kD}$; PDI=1.5)

Example 3-10: Curable Compositions

Examples 3

A curable silicone composition was prepared by mixing 43.85 parts by mass of A1, 41.5 parts by mass of polyisobutene (Olissopal 1000), 0.025 parts by mass of a platinum-vinylsiloxane complex as a curing catalyst, and 0.125 parts by mass of diallyl maleate as reaction inhibitor. Subsequently, to the resulting mixture was added 14.5 parts by mass of a polyphenyl-idemethylhydrosiloxy) siloxane cross linking agent. The composition was mixed thoroughly in a speed mixer until a homogeneous distribution of the components is achieved. This composition was then poured into a mold formed from glass plates to generate a thickness of 1 mm, and was then heated at 150° C. for 2 hours, to yield cured product.

A1

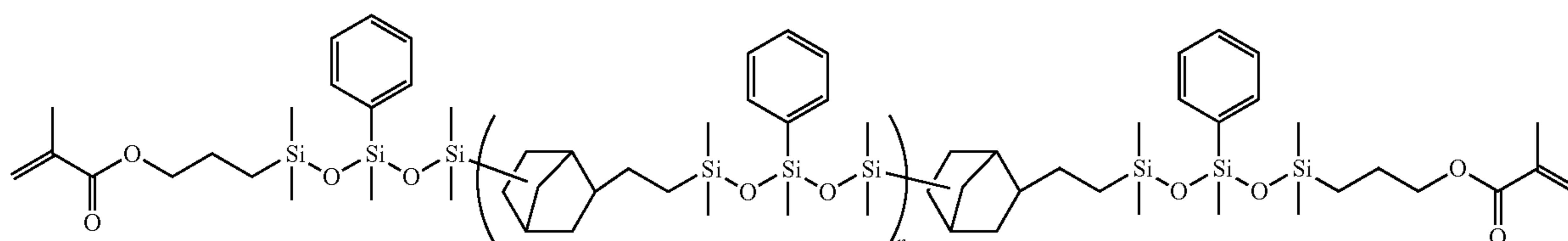


Example 2: Component (A-2)

A compound of the following formula is provided as component A-2.

Examples 4

A curable silicone composition was prepared by mixing 26.75 parts by mass of the siloxane component A1, 63.6



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parts by mass of polyisobutene (Olissopal 1000), 0.025 parts by mass of a platinum-vinylsiloxane complex catalyst and 0.125 parts by mass of diallyl maleate as reaction inhibitor. Subsequently, to the resulting mixture was added 9.5 parts by mass of a component a polyphenyl-idemethylhydrosiloxy) siloxane as cross linking agent. The entire composition was mixed thoroughly in a speed mixer until a homogeneous distribution of the components is achieved. This composition was then poured into a mold formed from glass plates to generate a thickness of 1 mm, and was then heated at 150° C. for 2 hours, thus yielding a cured product.

Example 5

A curable silicone composition was prepared by mixing 33.5 parts by mass of A1, 60 parts by mass of polyisobutene (Olissopal 1000), 0.025 parts by mass of a platinum-vinylsiloxane complex catalyst and 0.125 parts by mass of diallyl maleate as reaction inhibitor. Subsequently, to the resulting mixture was added 6.35 parts by mass of a component a polyphenyl-idemethylhydrosiloxy) siloxane as cross linking agent. The entire composition was mixed thoroughly in a speed mixer until a homogeneous distribution of the components is achieved. This composition was then poured into a mold formed from glass plates to generate a thickness of 1 mm, and was then heated at 150° C. for 2 hours, thus yielding a cured product.

Example 6

A curable silicone composition was prepared by mixing 25.9 parts by mass of A1, 60 parts by mass of polyisobutene (Olissopal 1000), 0.025 parts by mass of a platinum-vinylsiloxane complex catalyst and 0.125 parts by mass of diallyl maleate as reaction inhibitor. Subsequently, to the resulting mixture was added 10.35 parts by mass of a component a hydride modified MQ resin (MQH-9) as cross linking agent. The entire composition was mixed thoroughly in a speed mixer until a homogeneous distribution of the components is achieved. This composition was then poured into a mold formed from glass plates to generate a thickness of 1 mm, and was then heated at 150° C. for 2 hours, thus yielding a cured product.

Example 7

A curable silicone composition was prepared by mixing 29.9 parts by mass of the copolymer A-2, 59.9 parts by mass

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of a multi-acrylate (Ebecryl 745), 5 parts by mass of an isobornyl acrylate and 5 parts by mass of a 2-ethyl hexyl acrylate. Subsequently, to the resulting mixture was added 0.2 parts by mass of radiation curable initiator. The entire composition was mixed thoroughly in a speed mixer until a homogeneous distribution of the components is achieved. The composition was then poured into a mold and subjected to UV radiation (metal halide, 3000 mJ/cm²) to form cured product of thickness of 1 mm.

Example 8

A curable composition was prepared similar to the composition mentioned in example 7 with the addition of 59.9 parts by mass of the copolymer A-2, 29.9 parts by mass of a multi-acrylate (Ebecryl 745), 10 parts by mass of an isobornyl acrylate and 0.2 parts by mass of radiation curable initiator. A 1 mm cured sheet was obtained by curing the composition under UV radiation.

Example 9

A curable composition was prepared similar to the composition mentioned in example 7 with the addition of 49.9 parts by mass of the copolymer A-2, 9.9 parts by mass of a multi-acrylate (EM 221), 20 parts by mass of an isobornyl acrylate, 20 parts by mass of a 2-ethyl hexyl acrylate and 0.2 parts by mass of radiation curable initiator. A 1 mm cured sheet was obtained by curing the composition under UV radiation as described earlier in Example 8.

Example 10

A curable composition was prepared similar to the composition mentioned in example 4 with the addition of 39.9 parts by mass of the copolymer A-2, 49.9 parts by C1, 10 parts by mass of an isobornyl acrylate and 0.2 parts by mass of radiation curable initiator. A 1 mm cured sheet was obtained by curing the composition under UV radiation as described earlier in Example 8.

Performance Evaluation

Properties of the cured sheet obtained from the examples were evaluated (1 mm) by the following methods. The results have been summarized in Table 1.

TABLE 1

Materials	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10
A1(036)	43.85	26.75	33.5	25.9				
A2(Acrylate)					29.9	59.9	49.9	39.9
B1 (MQH-9)	14.5	9.5	6.35					
B3 (HDP-111)				10.35				
C1 (PIB-1000)	41.5	63.6						49.9
C2 (PIB-2300)			60	60				
D (DAM)	0.125	0.125	0.125	0.125				
E (Pt)	0.025	0.025	0.025	0.025				
(F1) (EB-745)						29.9		
Multiacrylate-1								
(F2) (EB-130)					59.9			
Multiacrylate-2								
(F3) (HDDA)							9.9	
Multiacrylate-3								
(F4) (IBOA)					5	10	20	10
Monoacrylate-1								
(F5) (EHA)					5		20	
Monoacrylate-2								
(G) PI					0.2	0.2	0.2	0.2

Viscosity of the curable composition was measured at 25°C. using HAAKE RheoStress 600.

To obtain information about the external appearance, the cured sheet of each example was inspected visually.

Transparency of the cured sheet was measured by spectrophotometer (Gretag Macbeth Color Eye 7000A spectrophotometer).

The water vapor permeability (WVTR) of the cured articles was evaluated using permeability cup tester from Yasuda Seiki Seisakusho, Ltd. by following method JIS Z 10 0208.

TABLE 2

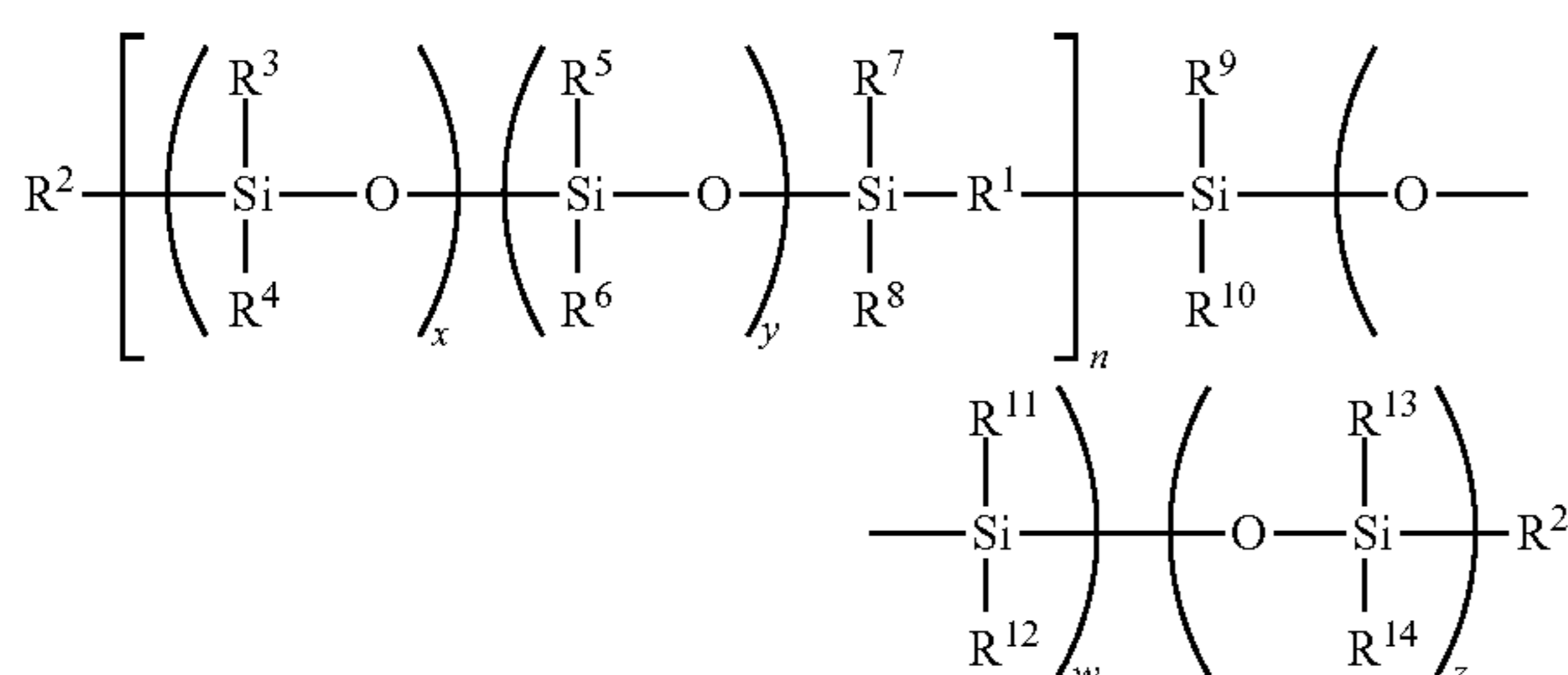
Properties	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10
Viscosity [Pas] (uncured)	3.44	6.57	31.2	45.3	0.2	4.3	1.27	12.9
Appearance	Transp.	Transp.	Transp.	Transp.	Transp.	Transp.	Transp.	Transp.
Mechanical Property	Flexible	Flexible	Flexible	Flexible	Semi-Flexible	Flexible	Flexible	Flexible
Transmittance (%) (cured)	>98%	>98%	>98%	>98%	>98%	>98%	>98%	>98%
WVTR (g/m ² · day) (cured@900 μm)	2.8	5.3	3.5	4.3	2.6	5.1	6.4	2.1

As shown in Table 2, the cured products obtained from the curable compositions exhibited excellent properties. The products were colorless and transparent and also exhibited a high degree of flexibility. Furthermore, the products also exhibited resistance to coloration on exposure to heat & light, indicating their applicability in optoelectronic application as encapsulant and barrier adhesives.

The foregoing description identifies various non-limiting embodiments of a heater assembly. Modifications may occur to those skilled in the art and to those who may make and use the invention. The disclosed embodiments are merely for illustrative purposes and not intended to limit the scope of the invention or the subject matter set forth in the claims.

What is claimed is:

1. A curable silicone composition comprising:
 - (A) an organopolysiloxane with a formula:



where R¹ is a divalent organic group chosen from a C1-C20 divalent hydrocarbon, a C4-C20 branched divalent hydrocarbon, or a C4-C30 cyclic-containing hydrocarbon group; R² is a curable functional group independently chosen from a vinyl, a vinyl-containing group, an unsaturated hydrocarbon, an unsaturated cyclic hydrocarbon, an acrylate, a methacrylate, a hydroxy, an alkoxy, and an epoxy;

R³-R¹⁴ are independently chosen from hydrogen, a C1-C10 monovalent hydrocarbon group, a C6-C20 monovalent aromatic group, and a C4 to C30 monovalent saturated or unsaturated cycloalkyl group, siloxy group containing 1-20 silicon atoms;

x and z are independently 1-30;
y and w are independently 0-30; and
n is 1-30; and

(B) a silicone-free organic material comprising a reactive functional group, wherein the silicone-free organic material (B) is chosen from an ethylenically unsaturated monomer, an ethylenically unsaturated aromatic compound, an ethylenically unsaturated acid, an ethylenically unsaturated anhydride, an acrylate, a methacrylate, an acrylamide, or a combination of two or more thereof.

2. The curable silicone composition of claim 1, wherein the silicone-free organic material (B) is chosen from an organic monomer comprising an olefinic functional group, an organic monomer comprising an acrylic functional group, an organic oligomer comprising an acrylic functional group, or a combination of two or more thereof.

3. The curable composition of claim 2, wherein the organic monomer comprising an olefinic functional group is chosen from a polyisobutene comprising an alkenyl functional group.

4. The curable composition of claim 3, wherein the polyisobutene is chosen from a vinyl terminated polyisobutene.

5. The curable composition of claim 1, wherein the organic monomer (B) is an organic monomer comprising an acrylic functional group chosen from a alkyl acrylate, an alkylene glycol acrylate, an epoxy acrylate, an alkoxy acrylate, an alkoxy alkyl acrylate, an aryl acrylate, a urethane acrylate, an aminated acrylate, or a combination of two or more thereof.

6. The curable composition of claim 5, wherein the organic monomer comprising an acrylic functional group is chosen from 2-butoxyethyl acrylate, 2-butoxyethyl methacrylate, 2-ethoxyethyl acrylate, 2-ethoxyethyl methacrylate, 2-ethyl-2-adamantyl acrylate, 2-ethyl-2-adamantyl methacrylate, 2-hydroxyethyl acrylate, 2-methyl-2-adamantyl acrylate, 2-methyl-2-adamantyl methacrylate, benzyl acrylate, cyclohexyl acrylate, di(ethyleneglycol)ethylether acrylate, di(ethyleneglycol)ethylether methacrylate, di(ethylene glycol)methylether methacrylate, dicyclofentanyl acrylate, epoxy acrylate, ethylene glycol methyl ether acrylate, ethylene glycol phenyl ether acrylate, hydroxypropyl acrylate, isobornyl acrylate, methyl adamantyl acrylate, neopentyl glycol benzoate acrylate, 2-hydroxymethyl methacrylate, adamantyl methacrylate, alkyl methacrylate, benzyl methacrylate, cyclohexyl methacrylate, dicyclopentanyl methacrylate, epoxycyclohexylmethyl methacrylate, ethylene glycol phenyl ether methacrylate, hydroxybutyl methacrylate, hydroxypropyl methacrylate, isobornyl methacrylate, glycidyl methacrylate, methyl adamantyl

methacrylate, methyl methacrylate, methyl glycidyl methacrylate, isobutyl acrylate, tert-butyl acrylate, lauryl acrylate, alkyl acrylate, 2-hydroxy acrylate, trimethoxybutyl acrylate, ethyl carbitol acrylate, phenoxyethyl acrylate, 4-hydroxybutyl acrylate, 2-hydroxy-3-phenoxypropyl acrylate, 3-fluoroethyl acrylate, 4-fluoropropyl acrylate, and triethyl siloxyl ethyl acrylate, or a combination of two or more thereof.

7. The curable silicone composition of claim 1, wherein R^1 is chosen from a divalent group comprising a C4-C30 cyclic-containing hydrocarbon group chosen from a cyclobutyl group, cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, a divalent group derived from 1,1-diethenyl cyclohexane; 1,3-diethenyl cyclohexane; bicyclo[2.2.1]-2,5-dienthenylheptane; 1,4-di-2-prope-1-nylcyclohexane; a spiro[5.5]-3,8-diethenylundecane; a 1,3-diethenyladamantane; a vinyl norbornene; 3,9-divinyl-2,4,8,10-tetraoxaspiro[5.5]undecane; or pinane, bornane, norpinane, norbornane, spiro[2.2]pentane, spiro[2.3]hexane, spiro[2.4]heptane, spiro[2.5]octane, spiro[3.3]heptane, spiro[3.4]octane, spiro[3.5]nonane, spiro[4.4]nonane, spiro[4.5]decane, spiro[5.5]undecane, bicyclo[1.1.0]butane, bicyclo[2.1.0]pentane, bicyclo[2.2.0]hexane, bicyclo[3.1.0]hexane, bicyclo[3.2.0]heptane, bicyclo[3.3.0]octane, bicyclo[4.1.0]heptane, bicyclo[4.2.0]octane, bicyclo[4.3.0]nonane, bicyclo[4.4.0]decane, bicyclo[1.1.1]pentane, bicyclo[2.1.1]hexane, bicyclo[2.2.1]heptane, bicyclo[2.2.2]octane, bicyclo[3.1.1]heptane, bicyclo[3.2.1]octane, bicyclo[3.2.2]nonane, bicyclo[3.3.1]nonane, bicyclo[3.3.2]decane, bicyclo[3.3.3]undecane, an adamantyl, tricyclo[5.2.1.0^{2,6}]decane tricyclo[4.3.1.1^{2,5}]undecane rings.

8. The curable silicone composition of claim 1, wherein R^2 is chosen from a C1-C20 hydrocarbon radical comprising a vinyl functional group, a monovalent C4-C20 branched hydrocarbon radical comprising a vinyl functional group, or a monovalent C4 to C30 cyclic hydrocarbon radical comprising a vinyl functional group.

9. The curable silicone composition of claim 1, wherein R^2 is of the formula $X-R^{16}$ where X is the curable functional group chosen from a vinyl group ($CH_2=CH_2-$), an unsaturated cyclic group, an unsaturated polycyclic group, and R^{16} is a bond or a C1-C20 monovalent hydrocarbon radical.

10. The curable silicone composition of claim 9, wherein X is chosen from cyclopentene, cyclohexene, cyclooctene, pinene, bornene, norpinene, norbornene, spiro[2.2]pentene, spiro[2.3]hexene, spiro[2.4]heptene, spiro[2.5]octene, spiro[3.3]heptene, spiro[3.4]octene, spiro[3.5]nonene, spiro[4.4]nonene, spiro[4.5]decene, spiro[5.5]undecene, bicyclo[1.1.0]butene, bicyclo[2.1.0]pentene, bicyclo[2.2.0]hexene, bicyclo[3.1.0]hexene, bicyclo[3.2.0]heptene, bicyclo[3.3.0]octene, bicyclo[4.1.0]heptene, bicyclo[4.2.0]octene, bicyclo[4.3.0]nonene, bicyclo[4.4.0]decene, bicyclo[1.1.1]pentene, bicyclo[2.1.1]hexene, bicyclo[2.2.1]heptene, bicyclo[2.2.2]octene, bicyclo[3.1.1]heptene, bicyclo[3.2.1]octene, bicyclo[3.2.2]nonene, bicyclo[3.3.1]nonene, bicyclo[3.3.2]decene, bicyclo[3.3.3]undecene, an adamantene, tricyclo[5.2.1.0^{2,6}]decene, tricyclo[4.3.1.1^{2,5}]undecene rings, a limonene, a camphene, a limonene oxide, a vinyl cyclohexyl epoxide, a dicyclopentadiene, 5-ethylidene-2-norbornene, 2-vinyl adamantane, 2-methylene admantane, dicyclopentadiene, or (-)-beta-chamigrene, 4-vinyl cyclohexyl.

11. The curable silicone composition of claim 1 further comprising (C) a cross-linker; (D) a reaction accelerating agent; (E) an inhibitor; and/or (F) one or more additives.

12. The curable silicone composition of claim 11 comprising the cross-linker (C), wherein the cross-linker is

chosen from a silicone-containing compound comprising at least one $-SiH$ group, at least one $-SH$ group, a vinyl group, a vinyl-containing group, an unsaturated hydrocarbon, an unsaturated cyclic hydrocarbon, an acrylate, a methacrylate, a hydroxy, an alkoxy, an epoxy, or a combination of two or more thereof.

13. The curable silicone composition of claim 11, wherein the reaction accelerating agent is selected from a photoinitiator, a thermal initiator, a metal-containing catalyst, or a combination of two or more thereof.

14. The curable silicone composition of claim 11, wherein the inhibitor is selected from an ethylenically unsaturated amide, an aromatically unsaturated amide, an acetylenic compound, an ethylenically unsaturated isocyanate, an olefinic siloxane, an unsaturated hydrocarbon diester, an unsaturated hydrocarbon mono-ester of an unsaturated acid, a conjugated or isolated ene-yne, a hydroperoxide, a ketone, a sulfoxide, an amine, a phosphine, a phosphite, a nitrite, a diaziridine, or a combination of two or more thereof.

15. The curable silicone composition of claim 11, wherein the additive is selected from an antioxidant, a thermal stabilizer, an adhesion promoter, a filler, a pigment, a dye, a filler treating agent, a plasticizer, a spacer, an extender, a biocide, a stabilizer, a flame retardant, a surface modifier, an anti-aging additive, a rheological additive, a corrosion inhibitor, a surfactant or a combination of two or more thereof.

16. The composition of claim 15, wherein the adhesion promoter is chosen from an amino silane, an epoxy silane, an isocyanurate silane, a mercapto silane, an imido silane, an anhydride silane, a carboxylate functionalized siloxane, or a combination of two or more thereof.

17. The curable silicone composition of claim 1, wherein the composition has a refractive index of from 1.40 to 1.60.

18. The curable silicone composition of claim 1, wherein the composition has a transparency of $\geq 95\%$.

19. The curable silicone composition of claim 1, wherein the composition has a MVTR of about 0.1 to about 15 $g/m^2 \cdot day$, and an O permeability of 10^{-1} to 10 $g/m^2 \cdot day$.

20. A cured article formed from curing the composition of claim 1.

21. The cured article of claim 20, wherein the article has a refractive index of from 1.40 to 1.60; a transparency of $\geq 95\%$; a MVTR of about 0.1 to about 15 $g/m^2 \cdot day$, and an O permeability of 10^{-1} to 10 $g/m^2 \cdot day$, or a combination of two or more thereof.

22. The cured article of claim 20, wherein the article is chosen from an encapsulant, an optical waveguide, a lens, a bonding material, an adhesive, an film or sheet, laminated film of sheet, a coating, a pressure sensitive adhesive, or a wound care patch.

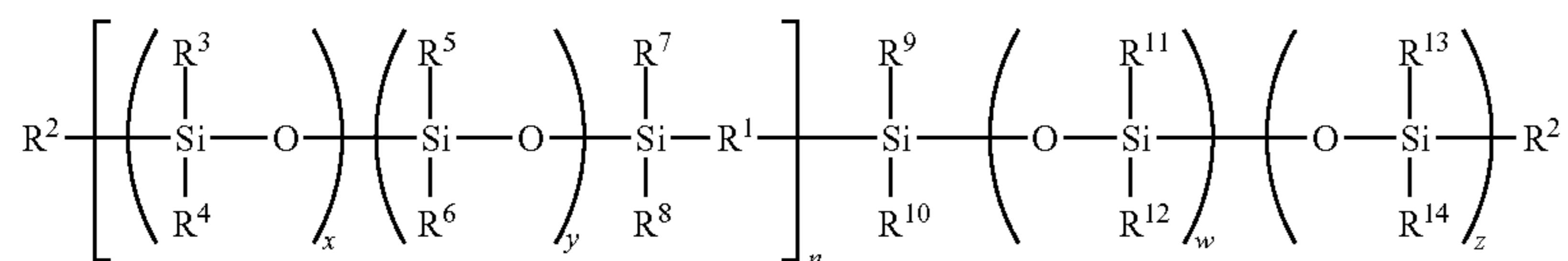
23. The cured article of claim 20, wherein the article is chosen from an LED encapsulant, an optical waveguide, an optical lens, an optical bonding material, an optical adhesive, an optical film or sheet, laminated film of sheet, in electronic component or in combination with semiconductor device.

24. A personal care composition comprising the curable silicone composition of claim 1.

25. The personal care composition of claim 24, wherein the personal care composition is chosen from a cosmetic formulation, a sunscreen, a shampoo, a conditioner, a lotion, or a cream.

26. A method of forming a cured article comprising subjecting the composition of claim 1 to heat and/or UV radiation conditions to effect curing of the composition.

27. A compound of the formula:



where R^2 is of the formula $X-R^{16}$ — where X is bicyclo [2.2.1]heptane or R^2 comprises a methacrylate group, and R^{16} is a bond or a C1-C20 monovalent hydrocarbon radical;

wherein $R^3, R^4, R^6, R^7, R^8, R^9, R^{10}, R^{12}, R^{13}$, and R^{14} are methyl; R^5 and R^{11} are phenyl; R^1 comprises a bicyclo [2.2.1]heptane group;

x and z are independently 1-30;

y and w are independently 0-30, $y+w \geq 1$; and

n is 1-30.

28. The compound of claim 27, wherein R^1 is chosen from a divalent group comprising a C4-C30 cyclic-containing hydrocarbon group chosen from a cyclobutyl group, cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, a divalent group derived from 1,1-diethenyl cyclohexane; 1,3-diethenyl cyclohexane; bicyclo[2.2.1]-2,5-dienthenylheptane; 1,4-di-2-prope-1-nylcyclohexane; a spiro[5.5]-3,8-diethenylundecane; a 1,3-diethenyladamantane; a vinyl norbornene; 3,9-divinyl-2,4,8,10-tetraoxaspiro [5.5]undecane; or pinane, bornane, norpinane, norbornane, spiro[2.2]pentane, spiro[2.3]hexane, spiro[2.4]heptane, spiro[2.5]octane, spiro[3.3]heptane, spiro[3.4]octane, spiro [3.5]nonane, spiro[4.4]nonane, spiro[4.5]decane, spiro[5.5] undecane, bicyclo[1.1.0]butane, bicyclo[2.1.0]pentane, bicyclo[2.2.0]hexane, bicyclo[3.1.0]hexane, bicyclo[3.2.0] heptane, bicyclo[3.3.0]octane, bicyclo[4.1.0]heptane, bicyclo[4.2.0]octane, bicyclo[4.3.0]nonane, bicyclo[4.4.0]decane, bicyclo[1.1.1]pentane, bicyclo[2.1.1]hexane, bicyclo [2.2.1]heptane, bicyclo[2.2.2]octane, bicyclo[3.1.1]heptane, bicyclo[3.2.1]octane, bicyclo[3.2.2]nonane, bicyclo[3.3.1] nonane, bicyclo[3.3.2]decane, bicyclo[3.3.3]undecane, an adamantyl, tricyclo[5.2.1.0^{2,6}]decane tricyclo[4.3.1.1^{2,5}]undecane rings.

29. The compound of claim 27, wherein R^2 is chosen from a C1-C20 hydrocarbon radical comprising a vinyl functional

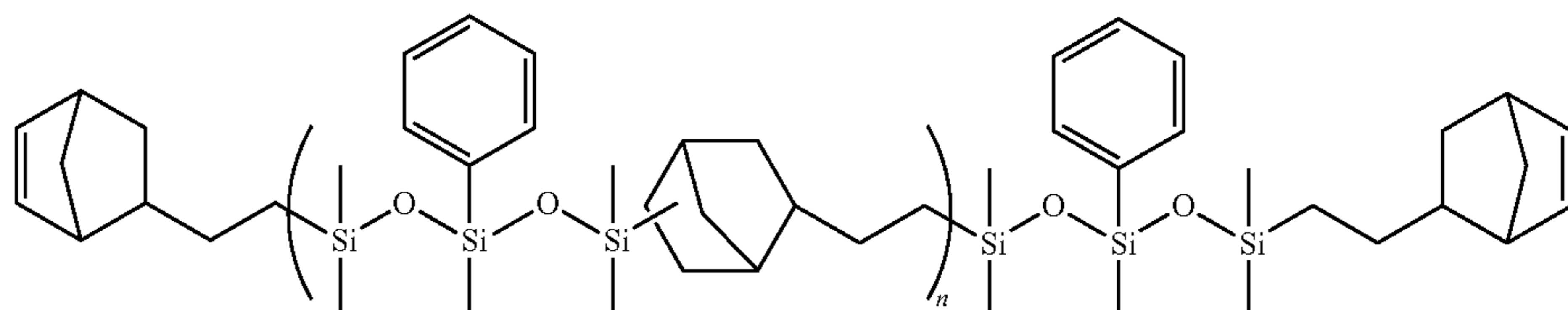
group, a monovalent C4-C20 branched hydrocarbon radical comprising a vinyl functional group, or a monovalent C4 to C30 cyclic hydrocarbon radical comprising a vinyl functional group.

30. The compound of claim 27, wherein R^2 is of the formula $X-R^{16}$ — where X is the curable functional group chosen from a vinyl group ($\text{CH}_2=\text{CH}_2-$), an unsaturated cyclic group, an unsaturated polycyclic group, and R^{16} is a bond or a monovalent hydrocarbon.

31. The compound of claim 30, wherein X is chosen from cyclopentene, cyclohexene, cyclooctene, pinene, bornene, norpinene, norbornene, spiro[2.2]pentene, spiro[2.3]hexene, spiro[2.4]heptene, spiro[2.5]octene, spiro[3.3]heptene, spiro [3.4]octene, spiro[3.5]nonene, spiro[4.4]nonene, spiro[4.5] decene, spiro[5.5]undecene, bicyclo[1.1.0]butene, bicyclo [2.1.0]pentene, bicyclo[2.2.0]hexene, bicyclo[3.1.0]hexene, bicyclo[3.2.0]heptene, bicyclo[3.3.0]octene, bicyclo[4.1.0] heptene, bicyclo[4.2.0]octene, bicyclo[4.3.0]nonene, bicyclo[4.4.0]decene, bicyclo[1.1.1]pentene, bicyclo[2.1.1]hexene, bicyclo[2.2.1]heptene, bicyclo[2.2.2]octene, bicyclo [3.1.1]heptene, bicyclo[3.2.1]octene, bicyclo[3.2.2]nonene, bicyclo[3.3.1]nonene, bicyclo[3.3.2]decene, bicyclo[3.3.3] undecene, an adamantene, tricyclo[5.2.1.0^{2,6}]decene, tricyclo[4.3.1.1^{2,5}]undecene rings, a limonene, a camphene, a limonene oxide, a vinyl cyclohexyl epoxide, a dicyclopentadiene, 5-ethylidene-2-norbornene, 2-vinyl adamantane, 2-methylene admantane, dicyclopentadiene, or (-)-beta-chamigrene, 4-vinyl cyclohexyl.

32. The compound of claim 27, wherein $R^3, R^4, R^6, R^7, R^8, R^9, R^{10}, R^{12}, R^{13}$, and R^{14} are methyl; R^5 and R^{11} are phenyl; R^1 is comprises a bicyclo[2.2.1]heptane group, and R^2 comprises a methacrylate group.

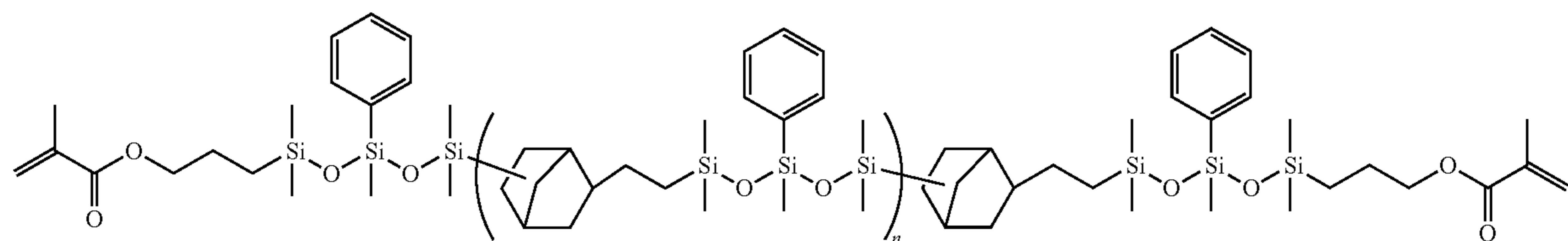
33. The compound of claim 27, wherein the compound is of the formula:



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34. The compound of claim 27, wherein the compound is of the formula:



* * * * *