

DESCRIPTION

TITLE OF THE INVENTION: VISCOSITY LOWERING AGENT FOR
HIGH-REFRACTIVE INDEX POLYMERIZABLE COMPOUND AND
5 POLYMERIZABLE COMPOSITION COMPRISING SAME

TECHNICAL FIELD

[0001] The present invention relates to a viscosity lowering agent. Specifically,
10 the present invention relates to a viscosity lowering agent useful as a high-refractive
index diluent that can achieve a lower viscosity of a polymerizable optical material
having a high refractive index.

BACKGROUND ART

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[0002] Resin lenses are used in electronic devices such as mobile phones, digital
cameras, and vehicle-mounted cameras and required to have excellent optical properties
according to the purpose of each electronic device. The resin lenses are also required to
have high durability, for example, heat resistance and weather resistance, and
20 productivity that permits molding at high yields, according to the mode of use. For
example, thermoplastic transparent resins such as polycarbonate resins, cycloolefin
polymers, and methacrylic resins have been employed as materials for resin lenses that
satisfy these requirements.

For the production of resin lenses in recent years, a shift from the injection molding
25 of thermoplastic resins to molding at the wafer level by compression molding using
curable resins that are liquid at room temperature has been actively studied in order to
improve yields or production efficiency and furthermore, suppress optical axis
displacement at the time of lens lamination.

[0003] A plurality of lenses are used in high-resolution camera modules.

Among these lenses, one wavelength correction lens is required to be made of an optical material having high wavelength dispersing properties, i.e., a low Abbe number.

Such a material characterized by a low Abbe number is also required to
5 have high transparency in addition to a high refractive index. Improvement in these optical properties often increases the viscosity of the material and drastically deteriorates its handleability. This is generally because a component contributing to a high refractive index has a high electron density and therefore facilitates increasing the viscosity. The deteriorated handleability is an essential challenge to the development of
10 materials having a low Abbe number.

[0004] In response to these problems, for example, a curable composition for lens materials has been proposed which adopts a liquid (meth)acrylate having a relatively high refractive index as a diluent and attains a lower viscosity and improved handleability (Patent Document 1). Also, a curable composition has been proposed which introduces
15 an oxyalkylene group to a component contributing to a high refractive index and thereby achieves a lower viscosity without the use of a diluent (Patent Document 2).

Prior Art Documents

Patent Document

20 [0005] Patent Document 1: Japanese Patent Application Publication No. 2012-255914 (JP 2012-255914 A)

Patent Document 2: Japanese Patent Application Publication No. 2015-199952 (JP 2015-199952 A)

25 SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

[0006] However, the curable composition using the diluent mentioned above

(Patent Document 1) has Abbe number v_D of 25 or more which does not satisfy the requirements for a low Abbe number of, for example, 23 or less, though having refractive index n_D of around 1.61 at 589 nm after photocuring. The curable composition using no diluent (Patent Document 2) does not achieve refractive index n_D of 1.60 or more after photocuring and thus, does not sufficiently satisfy optical properties.

As mentioned above, a lower Abbe number and a lower viscosity are in a trade-off relationship. For example, there has not yet been any optical material that achieves a low viscosity of 10,000 mPa·s or less and also achieves excellent optical properties such as a high refractive index of 1.60 or more and a low Abbe number of 23 or less in a cured product.

Conventional diluents for achieving a lower viscosity generally have a low refractive index. On the other hand, further enhanced optical properties (high refractive index, low Abbe number, and high transparency) have been required for optical materials such as materials intended for lenses for high-resolution camera modules in recent years. Therefore, the addition of the conventional diluents (viscosity lowering agents) may rather incur a higher Abbe number of the optical materials.

The present invention has been made in light of these circumstances. An object of the present invention is to overcome the trade-off between a lower Abbe number and a lower viscosity and to provide a high-refractive index viscosity lowering agent that causes few losses of the refractive index when added, and a polymerizable composition comprising the same.

[0007] The present inventors have conducted diligent studies to attain the object and consequently completed the present invention by finding that, surprisingly, use of a low-Abbe number compound that is solid at normal temperature and normal pressure and has a viscosity of 10 mPa·s or less at 100°C as a viscosity lowering agent for a high-refractive index polymerizable compound can lower the viscosity of the system to 10,000 mPa·s or less or maintain the viscosity of the system at 10,000 mPa·s or less, and achieve excellent optical properties (low Abbe number and high refractive index) in a

cured product of the system.

[0008] Specifically, in the first aspect, the present invention relates to a method for using a compound as a viscosity lowering agent for a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product of the high-refractive index polymerizable compound,

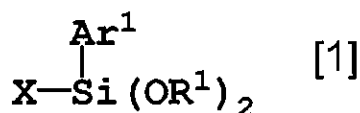
the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

In the second aspect, the present invention relates to the method according to the first aspect, wherein the viscosity lowering agent is a compound

having at least one aromatic group selected from the group consisting of a phenyl group or a phenylene group optionally substituted with a C₁₋₆ alkyl group, a monovalent or divalent condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), and a monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and

having at least one group having a polymerizable double bond, selected from the group consisting of vinyl group, an allyl group, a (meth)allyloxy group and a (meth)acryloyl group.

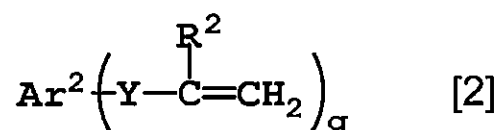
In the third aspect, the present invention relates to the method according to the second aspect, wherein the viscosity lowering agent is a compound of the following formula [1]:



(wherein X is a phenyl group having at least one substituent having a polymerizable

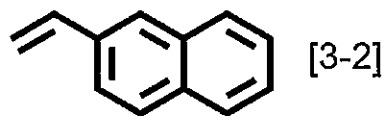
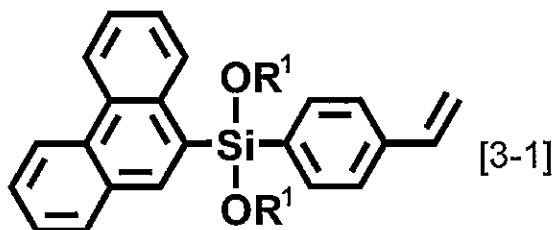
double bond, a naphthyl group having at least one substituent having a polymerizable double bond, a biphenyl group having at least one substituent having a polymerizable double bond, or a phenanthryl group having at least one substituent having a polymerizable double bond, Ar¹ is a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R¹ is methyl group, ethyl group, or isopropyl group).

In the fourth aspect, the present invention relates to the method according to the second aspect, wherein the viscosity lowering agent is a compound of the following formula [2]:



(wherein Ar² is a q-valent aromatic hydrocarbon residue, q is 1 or 2, Y is a single bond, -O-C(=O)- group, or -O- group, and R² is a hydrogen atom or methyl group).

In the fifth aspect, the present invention relates to the method according to the second aspect, wherein the viscosity lowering agent is a compound of the following formula [3-1] or formula [3-2]:



(wherein R¹ is methyl group, ethyl group, or isopropyl group).

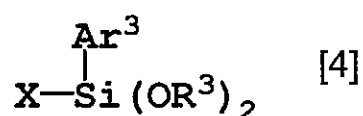
In the sixth aspect, the present invention relates to a viscosity lowering agent for a high-refractive index polymerizable compound having at least one

polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product thereof,

the viscosity lowering agent comprising a compound, the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

In the seventh aspect, the present invention relates to a polymerizable composition comprising 100 parts by mass of (a) a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product thereof, and 10 to 500 parts by mass of (b) a viscosity lowering agent comprising a compound, the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

In the eighth aspect, the present invention relates to the polymerizable composition according to the seventh aspect, wherein the high-refractive index polymerizable compound (a) comprises a reactive polysiloxane comprising at least one of a polycondensation product of alkoxy silicon compound A of formula [4], and a polycondensation product of the alkoxy silicon compound A of formula [4] with alkoxy silicon compound B of formula [5]:



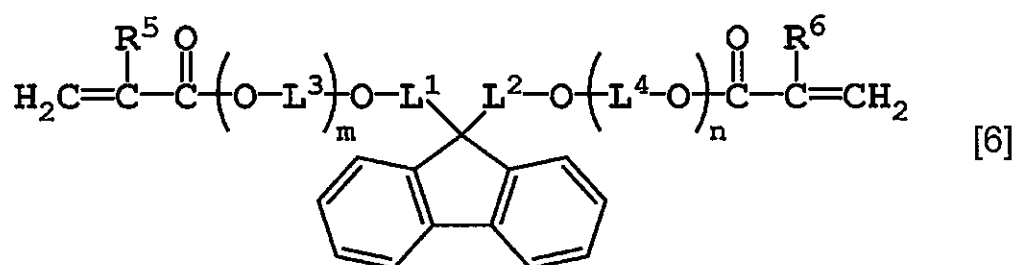
(wherein X is a phenyl group having at least one substituent having a polymerizable double bond, a naphthyl group having at least one substituent having a polymerizable double bond, a biphenyl group having at least one substituent having a polymerizable

double bond, or a phenanthryl group having at least one substituent having a polymerizable double bond, Ar³ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R³ is methyl group, ethyl group, or isopropyl group), and



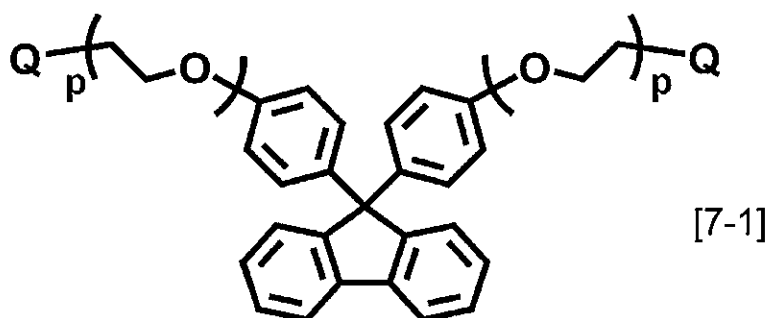
(wherein Ar⁴ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R⁴ is methyl group, ethyl group, or isopropyl group).

In the ninth aspect, the present invention relates to the polymerizable composition according to the seventh aspect, wherein the high-refractive index polymerizable compound (a) comprises a fluorene compound of formula [6]:

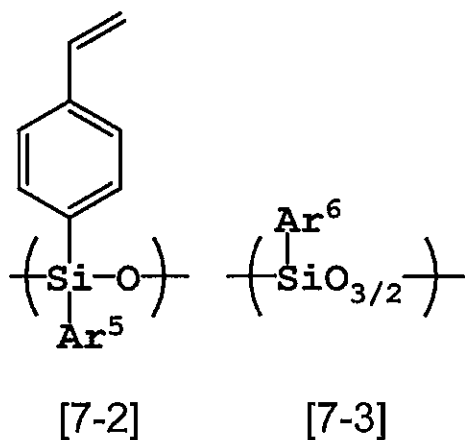


(wherein R⁵ and R⁶ are each independently a hydrogen atom or methyl group, L¹ and L² are each independently a phenylene group optionally having a substituent, or a naphthalenediyl group optionally having a substituent, L³ and L⁴ are each independently a C₁₋₆ alkylene group, and m and n are each independently 0 or a positive integer that satisfies 0 ≤ m + n ≤ 40).

In the tenth aspect, the present invention relates to the polymerizable composition according to the seventh aspect, wherein the high-refractive index polymerizable compound (a) is selected from the group consisting of a compound of the following formula [7-1], a compound having a structural unit of formula [7-2], and a compound having a structural unit of formula [7-2] and a structural unit of formula [7-3]:



(wherein two Q are the same groups and are each selected from the group consisting of vinyloxy group, an allyloxy group and a (meth)acryloyloxy group, and two p are the same integers of 0 to 3), and



(wherein Ar⁵ and Ar⁶ are each independently phenyl group, naphthyl group, or phenanthryl group).

In the eleventh aspect, the present invention relates to the polymerizable composition according to any one of the seventh to tenth aspects, further comprising (c) a polymerizable diluent being in a liquid state of matter at 23°C under 1013.25 hPa.

In the twelfth aspect, the present invention relates to a cured product of the polymerizable composition according to any one of the seventh to eleventh aspects.

In the thirteenth aspect, the present invention relates to a material for a high-refractive index resin lens comprising the polymerizable composition according to
5 any one of the seventh to eleventh aspects.

In the fourteenth aspect, the present invention relates to the resin lens prepared from a polymerizable composition according to any one of the seventh to eleventh aspects.

In the fifteenth aspect, the present invention relates to a process for
10 producing a molded article, comprising: a step of introducing the polymerizable composition according to any one of the seventh to eleventh aspects into space between a support and a mold in contact with each other, or internal space of a separable mold; and a step of photopolymerizing the introduced composition by light exposure.

In the sixteenth aspect, the present invention relates to the production
15 process according to the fifteenth aspect, further comprising: a step of taking the obtained photopolymer out of the space filled therewith for mold release; and a step of heating the photopolymer before, during, or after the mold release.

In the seventeenth aspect, the present invention relates to the production process according to the fifteenth or sixteenth aspect, wherein the molded article is a lens
20 for a camera module.

Effects of the Invention

[0009] According to the present invention, a compound is used as a viscosity lowering agent for a high-refractive index polymerizable compound, the compound being
25 in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm). Use of this viscosity lowering agent can lower the viscosity of the system to 10,000

mPa·s or less or maintain the viscosity of the system at 10,000 mPa·s or less, and achieve excellent optical properties (low Abbe number and high refractive index) in a cured product of the system.

[0010] The polymerizable composition of the present invention achieves a lower viscosity by the addition of the viscosity lowering agent and is thus improved in terms of its handleability. In addition, a cured product thereof can achieve optical properties (low Abbe number and high refractive index) desirable for an optical device, for example, a lens for high-resolution camera modules.

Thus, the material for high-refractive index resin lenses of the present invention comprising the polymerizable composition can be suitably used as a lens for high-resolution camera modules.

[0011] The polymerizable composition of the present invention has a viscosity sufficiently handleable in a solvent-free form by the addition of the viscosity lowering agent. Therefore, the polymerizable composition of the present invention is moldable by the application of compression processing (imprint technology) using a mold such as a die and is also excellent in mold release properties from the mold after molding. Thus, a molded article can be suitably produced.

The production process of the present invention is excellent in the handleability of the polymerizable composition used and as such, can efficiently produce a molded article, particularly, a lens for camera modules.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] [FIG. 1] FIG. 1 is a diagram showing the ^1H NMR spectrum of dimethoxy(phenanthren-9-yl)(4-vinylphenyl)silane obtained in Production Example 1.

[FIG. 2] FIG. 2 is a diagram showing the ^1H NMR spectrum of trimethoxy(9-phenanthryl)silane obtained in Production Example 3.

MODES FOR CARRYING OUT THE INVENTION

[0013] The present invention relates to a method for using a compound as a viscosity lowering agent for a high-refractive index polymerizable compound mentioned later, the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number, i.e., v_D , of 23 or less at D-ray (589.3 nm). The present invention is also directed to the viscosity lowering agent.

10 Hereinafter, the present invention will be described in detail.

[0014] <<Viscosity lowering agent>>

The viscosity lowering agent of the present invention is not particularly limited as long as, as described above, the compound is in a solid state of matter at 23°C under 1013.25 hPa (i.e., atmospheric pressure) and has a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

[0015] Examples of the viscosity lowering agent include a compound having at least one aromatic group and at least one group having a polymerizable double bond. In this context, the term "polymerizable" refers to the property of causing polymerization reaction by cleavage or decomposition through the chemical reaction of a portion of a molecule by external stimulation such as heat or light.

Specific examples of the compound can include a compound having at least one aromatic group selected from the group consisting of a phenyl group or a phenylene group optionally substituted with a C₁₋₆ alkyl group, a monovalent or divalent condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), and a monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and having

at least one group having a polymerizable double bond selected from the group consisting of vinyl group, an allyl group, a (meth)allyloxy group and a (meth)acryloyl group.

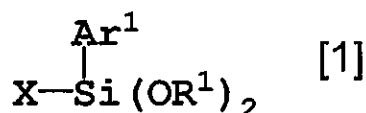
[0016] Examples of the monovalent or divalent condensed ring hydrocarbon group having two or more benzene ring structures as the aromatic group include monovalent or divalent groups derived from naphthalene, phenanthrene, anthracene, triphenylene, pyrene, chrysene, naphthacene, biphenylene, and fluorene.

Examples of the monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond include monovalent or divalent groups derived from biphenyl, terphenyl, quaterphenyl, binaphthalene, phenylnaphthalene, phenylfluorene, and diphenylfluorene.

Examples of the C₁₋₆ alkyl group optionally present as a substituent on the phenyl group or the phenylene group, the monovalent or divalent condensed ring hydrocarbon group, and the monovalent or divalent hydrocarbon ring assembly group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group, n-pentyl group, cyclopentyl group, n-hexyl group, and cyclohexyl group.

Among these aromatic groups, preferred examples of the group can include phenyl group, naphthyl group, and phenanthryl group, from the viewpoint of being capable of achieving solubility, effects on reduction in viscosity or maintenance of a lower viscosity, and excellent optical properties (high transparency, high refractive index, and low Abbe number) in a formulation.

[0017] Specific examples of the specific compound having at least one aromatic group and at least one group having a polymerizable double bond include a compound of the following formula [1]:



In formula [1] described above, X is a phenyl group having at least one

group having a polymerizable double bond, a naphthyl group having at least one group having a polymerizable double bond, a biphenyl group having at least one group having a polymerizable double bond, or a phenanthryl group having at least one group having a polymerizable double bond, Ar¹ is a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R¹ is methyl group, ethyl group, or isopropyl group.

[0018] Examples of the phenyl group having at least one group having a polymerizable double bond as X include 2-vinylphenyl group, 3-vinylphenyl group, 4-vinylphenyl group, 4-vinyloxyphenyl group, 4-allylphenyl group, 4-allyloxyphenyl group, and 4-isopropenylphenyl group.

[0019] Examples of the naphthyl group having at least one group having a polymerizable double bond as X include 4-vinylnaphthalen-1-yl group, 5-vinylnaphthalen-1-yl group, 6-vinylnaphthalen-2-yl group, 5-vinyloxynaphthalen-1-yl group, 5-allylnaphthalen-1-yl group, 4-allyloxynaphthalen-1-yl group, 5-allyloxynaphthalen-1-yl group, 8-allyloxynaphthalen-1-yl group, and 5-isopropenyl naphthalen-1-yl group.

[0020] Examples of the biphenyl group having at least one group having a polymerizable double bond as X include 4'-vinyl-[1,1'-biphenyl]-2-yl group, 4'-vinyl-[1,1'-biphenyl]-3-yl group, 4'-vinyl-[1,1'-biphenyl]-4-yl group, 4'-vinyloxy-[1,1'-biphenyl]-4-yl group, 4'-allyl-[1,1'-biphenyl]-4-yl group, 4'-allyloxy-[1,1'-biphenyl]-4-yl group, and 4'-isopropenyl-[1,1'-biphenyl]-4-yl group.

[0021] Examples of the phenanthryl group having at least one group having a polymerizable double bond as X include 3-vinylphenanthren-9-yl group, 7-vinylphenanthren-9-yl group, 10-vinylphenanthren-9-yl group, 7-vinylphenanthren-2-yl group, 6-vinylphenanthren-3-yl group, 10-vinylphenanthren-3-yl group, 3-vinyloxyphenanthren-9-yl group, 3-allylphenanthren-9-yl group,

3-allyloxyphenanthren-9-yl group, and 3-isopropenylphenanthren-9-yl group.

[0022] Among the above, the X is preferably a phenyl group having at least one group having a polymerizable double bond, more preferably vinylphenyl group.

[0023] Examples of the condensed ring hydrocarbon group having two or more
5 benzene ring structures as Ar¹ include monovalent groups derived from naphthalene, phenanthrene, anthracene, triphenylene, pyrene, chrysene, naphthacene, biphenylene, and fluorene.

Examples of the hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond include monovalent groups
10 derived from biphenyl, terphenyl, quaterphenyl, binaphthalene, phenylnaphthalene, phenylfluorene, and diphenylfluorene.

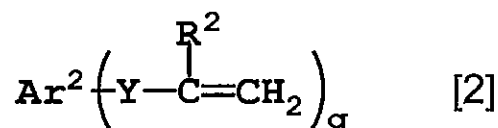
Examples of the C₁₋₆ alkyl group optionally present as a substituent on the condensed ring hydrocarbon group and the hydrocarbon ring assembly group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl
15 group, sec-butyl group, tert-butyl group, n-pentyl group, cyclopentyl group, n-hexyl group, and cyclohexyl group.

[0024] Among the above, the Ar¹ is preferably a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), more preferably phenanthryl group.

[0025] Specific examples of the compound of formula [1] include, but are not
20 limited to, dimethoxy(9-phenanthryl)(4-vinylphenyl)silane, diethoxy(9-phenanthryl)(4-vinylphenyl)silane, diisopropoxy(9-phenanthryl)(4-vinylphenyl)silane, dimethoxy(9-phenanthryl)(4-vinylnaphthalen-1-yl)silane, dimethoxy(9-phenanthryl)(4'-vinyl-[1,1'-biphenyl]-4-yl)silane,
25 dimethoxy(9-phenanthryl)(3-vinylphenanthren-9-yl)silane, dimethoxy(1-naphthyl)(4-vinylphenyl)silane, dimethoxy(2-naphthyl)(4-vinylphenyl)silane,

dimethoxy(2-phenanthryl)(4-vinylphenyl)silane,
 dimethoxy(3-phenanthryl)(4-vinylphenyl)silane,
 dimethoxy(9-phenanthryl)(4-vinylphenyl)silane, and
 [1,1'-biphenyl]-4-yl dimethoxy(4-vinylphenyl)silane.

- 5 [0026] Specific examples of the specific compound having at least one aromatic group and at least one group having a polymerizable double bond also include a compound of the following formula [2]:



- 10 In formula [2] described above, Ar^2 is a q-valent aromatic hydrocarbon residue, q is 1 or 2, Y is a single bond, -O-C(=O)- group, or -O- group, and R^2 is a hydrogen atom or methyl group.

- [0027] Examples of the q-valent aromatic hydrocarbon residue as Ar^2 include groups derived, by the removal of q hydrogen atom(s), from benzene, a condensed ring
 15 hydrocarbon having two or more benzene ring structures, or a hydrocarbon ring assembly in which two or more aromatic rings are directly bonded through a single bond. These groups are each optionally substituted with a C_{1-6} alkyl group.

- Specific examples thereof include a phenyl group or a phenylene group optionally substituted with a C_{1-6} alkyl group, a monovalent or divalent condensed ring
 20 hydrocarbon group having two or more benzene ring structures (optionally substituted with a C_{1-6} alkyl group), and a monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C_{1-6} alkyl group).

- [0028] Examples of the phenyl group optionally substituted with a C_{1-6} alkyl
 25 group as Ar^2 include phenyl group, o-tolyl group, m-tolyl group, p-tolyl group, 2,4,6-trimethylphenyl group, and 4-tert-butylphenyl group. Examples of the phenylene

group optionally substituted with a C₁₋₆ alkyl group include phenylene group, 2,4-methylphenylene group, 2,5-methylphenylene group, 2,4,5-trimethyl-1,3-phenylene group, and 2-tert-butyl-1,4-phenylene group.

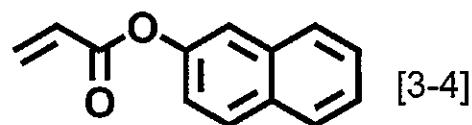
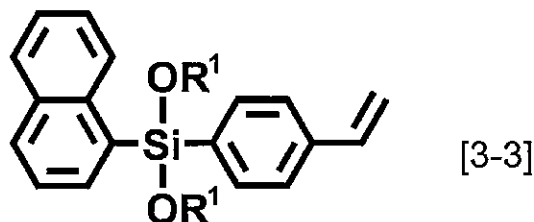
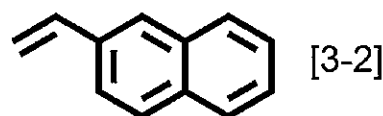
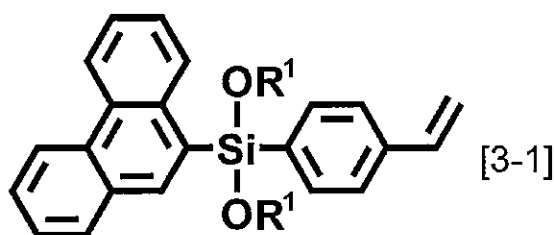
5 Examples of the monovalent or divalent condensed ring hydrocarbon group having two or more benzene ring structures as Ar² include monovalent or divalent groups derived from naphthalene, phenanthrene, anthracene, triphenylene, pyrene, chrysene, naphthacene, biphenylene, and fluorene.

10 Examples of the monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond include monovalent or divalent groups derived from biphenyl, terphenyl, quaterphenyl, binaphthalene, phenylnaphthalene, phenylfluorene, and diphenylfluorene.

15 Examples of the C₁₋₆ alkyl group optionally present as a substituent on the condensed ring hydrocarbon group and the hydrocarbon ring assembly group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group, n-pentyl group, cyclopentyl group, n-hexyl group, and cyclohexyl group.

[0029] Specific examples of the compound of formula [2] include 1-vinylnaphthalene, 2-vinylnaphthalene, 2-isopropenylnaphthalene, 2,7-bis(4-vinylphenyl)naphthalene, naphthalen-1-yl methyl (meth)acrylate, and 20 naphthalen-2-yl methyl (meth)acrylate.

[0030] Examples of the viscosity lowering agent according to the present invention can include compounds of formula [3-1] to formula [3-4] given below. Among these, compounds of formula [3-1] and formula [3-2] are preferred, and a compound of formula [3-1] is particularly preferred, from the viewpoint of achieving 25 effects on reduction in and maintenance of a viscosity, and excellent optical properties (low Abbe number).



In the formulas, R¹ is methyl group, ethyl group, or isopropyl group.

[0031] A commercially available product of a compound can be suitably used as
5 the viscosity lowering agent according to the present invention.

For example, an ester compound containing a (meth)acryloyl group, such as the compound of formula [3-4] can be produced by a conventional method and may be produced through the esterification reaction of an alcohol and a (meth)acrylic acid halide in the presence of triethylamine or pyridine.

10 [0032] The compounds of formula [3-1] and formula [3-3] (the compound of formula [1]) can be produced by a conventional method and may be produced, for example, through conventional Grignard reaction of reacting an alkoxy silane compound with a Grignard reagent to obtain an organoalkoxysilane compound, or through conventional coupling reaction of reacting an alkoxyhydrosilane compound with an aryl
15 halide by use of a transition metal catalyst to obtain an organoalkoxysilane compound.

Specifically, the polymerizable silane compound of formula [1] can be obtained by reacting a Grignard reagent having an Ar¹ group: Ar¹-Mg-Hal with a trialkoxysilane compound having an aromatic ring group having a polymerizable double bond: X-Si(OR¹)₃, or by reacting a Grignard reagent having an aromatic ring group
20 having a polymerizable double bond: X-Mg-Hal with a trialkoxysilane compound having Ar¹ group: Ar¹-Si(OR¹)₃ (the Ar¹, the X, and the R¹ are as defined in the formula [1], and

Hal is a halogen atom).

The Grignard reagent is obtained through the reaction of an aryl halide: $\text{Ar}^1\text{-Hal}$ or X-Hal with magnesium.

[0033] The production of the Grignard reagent and the reaction of the Grignard reagent with the alkoxysilane compound can be carried out in an organic solvent. In this context, examples of the organic solvent used can include inert organic solvents including: ether solvents such as diethyl ether, tetrahydrofuran, and tert-butyl methyl ether; and hydrocarbon solvents such as hexane, toluene, and xylene. These organic solvents may be used alone or as a mixture of two or more thereof.

The production temperature and the reaction temperature are preferably in the range of 0 to 200°C, particularly, 20 to 150°C.

If oxygen is present during the production of the Grignard reagent or in the reaction system of the Grignard reagent and the alkoxysilane compound, the Grignard reagent reacts with the oxygen in the production or reaction process, causing reduction in the yield of the polymerizable silane compound of interest. Therefore, these processes are preferably performed in an inert atmosphere such as a nitrogen or argon atmosphere.

[0034] The viscosity lowering agent can be used alone or in combination of two or more thereof.

[0035] <<High-refractive index polymerizable compound>>

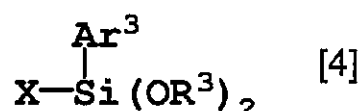
The viscosity lowering agent according to the present invention is used for a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index, i.e., n_D , of 1.60 or more at D-ray (589.3 nm) in a cured product thereof.

The high-refractive index polymerizable compound is not particularly limited as long as, as mentioned above, the compound has a polymerizable group and has a high refractive index of 1.60 or more in a cured product thereof. Examples thereof can include a specific reactive polysiloxane and a specific fluorene compound given below.

[0036] <Reactive polysiloxane>

The reactive polysiloxane comprises at least one of a polycondensation product of alkoxy silicon compound A of formula [4], and a polycondensation product of the alkoxy silicon compound A of formula [4] with alkoxy silicon compound B of formula [5].

5 [0037] [Alkoxy silicon compound A]



In formula [4] described above, X is a phenyl group having at least one substituent having a polymerizable double bond, a naphthyl group having at least one substituent having a polymerizable double bond, a biphenyl group having at least one substituent having a polymerizable double bond, or a phenanthryl group having at least one substituent having a polymerizable double bond, Ar³ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R³ is methyl group, ethyl group, or isopropyl group.

[0038] Specific examples of X in formula [4] described above include the groups listed as the group X in formula [1] in the compound of formula [1] and can particularly include the groups listed as preferred groups of the group X in formula [1].

Specific examples of Ar⁴ in formula [4] described above include the groups listed as the group Ar¹ in formula [1] and can particularly include the groups listed as preferred groups of the group Ar¹ in formula [4].

Specific examples of the compound of formula [4] include the compounds listed as specific examples of the compound of formula [1].

[0039] [Alkoxy silicon compound B]



In formula [5], Ar⁴ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R⁴ is methyl group, ethyl group, or isopropyl group.

[0040] Examples of the phenyl group optionally substituted with a C₁₋₆ alkyl group as Ar⁴ include phenyl group, o-tolyl group, m-tolyl group, p-tolyl group, 2,4,6-trimethylphenyl group, and 4-tert-butylphenyl group.

Examples of the condensed ring hydrocarbon group having two or more benzene ring structures as Ar⁴ include monovalent groups derived from naphthalene, phenanthrene, anthracene, triphenylene, pyrene, chrysene, naphthacene, biphenylene, and fluorene.

Examples of the hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond include monovalent groups derived from biphenyl, terphenyl, quaterphenyl, binaphthalene, phenylnaphthalene, phenylfluorene, and diphenylfluorene.

Examples of the C₁₋₆ alkyl group optionally present as a substituent on the condensed ring hydrocarbon group and the hydrocarbon ring assembly group include methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group, n-pentyl group, cyclopentyl group, n-hexyl group, and cyclohexyl group.

[0041] Among the above, the Ar⁴ is preferably a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), more preferably phenanthryl group.

[0042] Specific examples of the compound of formula [5] include, but are not limited to, trimethoxy(phenyl)silane, triethoxy(phenyl)silane, trimethoxy(p-tolyl)silane,

trimethoxy(1-naphthyl)silane, triethoxy(1-naphthyl)silane,
 triisopropoxy(1-naphthyl)silane, trimethoxy(2-naphthyl)silane,
 triethoxy(2-naphthyl)silane, triisopropoxy(2-naphthyl)silane,
 trimethoxy(2-phenanthryl)silane, trimethoxy(3-phenanthryl)silane,
 5 trimethoxy(9-phenanthryl)silane, triethoxy(9-phenanthryl)silane,
 triisopropoxy(9-phenanthryl)silane, [1,1'-biphenyl]-4-yltrimethoxysilane,
 [1,1'-biphenyl]-4-yltriethoxysilane, and [1,1'-biphenyl]-4-yltriisopropoxysilane.

[0043] When the alkoxy silicon compound constituting the reactive polysiloxane
 comprises the alkoxy silicon compound A of formula [4] as well as the alkoxy silicon
 10 compound B of formula [5], the molar mixing ratio required for the polycondensation
 reaction of these alkoxy silicon compounds is not particularly limited and is usually
 preferably in the range of 9 mol or less of the alkoxy silicon compound B with respect to
 one mol of the alkoxy silicon compound A, for the purpose of stabilizing the physical
 properties of a cured product, and more preferably in the range of 1.5 mol or less of the
 15 alkoxy silicon compound B. When the molar mixing ratio of the alkoxy silicon
 compound B to the number of moles of the alkoxy silicon compound A is 9 or less, a
 sufficient cross-linking density is obtained, and dimensional stability against heat is
 further improved. In addition, a cured product having a higher refractive index and a
 lower Abbe number can be obtained.

20 The alkoxy silicon compound A and the alkoxy silicon compound B
 mentioned above can be appropriately selected for use from the compounds according to
 the need. A plurality of compounds may be used in combination as the alkoxy silicon
 compound A or the alkoxy silicon compound B. In this case, the molar mixing ratio
 also falls within the range described above in terms of the ratio between the total molar
 25 quantity of the alkoxy silicon compounds A and the total molar quantity of the alkoxy
 silicon compounds B.

[0044] [Acidic or basic catalyst]

The polycondensation reaction of the alkoxy silicon compound A of

formula [4], or the polycondensation reaction of the alkoxy silicon compound comprising the alkoxy silicon compound A of formula [4] and the alkoxy silicon compound B of formula [5] is suitably carried out in the presence of an acidic or basic catalyst.

The catalyst for use in the polycondensation reaction is not particularly limited by its type as long as the catalyst is dissolved or uniformly dispersed in a solvent mentioned later. The catalyst can be appropriately selected and used according to the need.

Examples of the catalyst that can be used include: inorganic acids such as hydrochloric acid, nitric acid, and sulfuric acid, and organic acids such as acetic acid and oxalic acid, as acidic compounds; alkali metal hydroxides, alkaline earth metal hydroxides, ammonium hydroxide, quaternary ammonium salts, and amines as basic compounds; and NH_4F and NR_4F as fluorides. In this context, R is one or more groups selected from the group consisting of a hydrogen atom, a linear alkyl group having a carbon atom number of 1 to 12, a branched alkyl group having a carbon atom number of 3 to 12, and a cyclic alkyl group having a carbon atom number of 3 to 12.

These catalysts can be used alone or in combination of two or more thereof.

[0045] Examples of the acidic compound include hydrochloric acid, nitric acid, sulfuric acid, acetic acid, oxalic acid, and boric acid.

[0046] Examples of the basic compound include sodium hydroxide, potassium hydroxide, magnesium hydroxide, calcium hydroxide, strontium hydroxide, barium hydroxide, ammonium hydroxide, tetramethylammonium hydroxide, tetraethylammonium hydroxide, tetrabutylammonium hydroxide, and triethylamine.

[0047] Examples of the fluoride can include ammonium fluoride, tetramethylammonium fluoride, and tetrabutylammonium fluoride.

[0048] Among these catalysts, one or more selected from the group consisting of hydrochloric acid, acetic acid, potassium hydroxide, calcium hydroxide, barium hydroxide, and tetraethylammonium hydroxide are preferably used.

The amount of the catalyst used is 0.01 to 10% by mass, preferably 0.1 to 5% by mass, with respect to the total mass of the alkoxy silicon compounds. When the amount of the catalyst used is set to 0.01% by mass or more, the reaction proceeds more favorably. Use of the catalyst at 10% by mass or less suffices in consideration of cost efficiency.

[0049] [Polycondensation reaction]

A feature of the reactive polysiloxane (polycondensation product) is the structure of the alkoxy silicon compound A. The reactive group (polymerizable double bond) contained in the alkoxy silicon compound A is easily polymerized by a radical or a cation and exhibits high heat resistance after polymerization (after curing).

The hydrolytic polycondensation reaction of the alkoxy silicon compound A, or the hydrolytic polycondensation reaction of the alkoxy silicon compound A with the alkoxy silicon compound B may be performed in the absence of a solvent. Alternatively, a solvent, such as tetrahydrofuran (THF), mentioned later which is inert to the alkoxy silicon compound used, may be used as a reaction solvent. Use of such a reaction solvent has the advantages that: the reaction system becomes easily homogeneous; and more stable polycondensation reaction is performed.

[0050] The synthesis reaction of the reactive polysiloxane may be performed in the absence of a solvent, as mentioned above. However, a solvent can be used for more homogeneous reaction without any problem. The solvent is not particularly limited as long as the solvent does not react with the alkoxy silicon compound to be used and dissolves a polycondensation product thereof.

Examples of such a reaction solvent include: ketones such as acetone and methyl ethyl ketone (MEK); aromatic hydrocarbons such as benzene, toluene, and xylene; ethers such as tetrahydrofuran (THF), 1,4-dioxane, diisopropyl ether, and cyclopentyl methyl ether (CPME); glycols such as ethylene glycol, propylene glycol, and hexylene glycol; glycol ethers such as ethyl cellosolve, butyl cellosolve, ethyl carbitol, butyl carbitol, diethyl cellosolve, and diethyl carbitol; and amides such as

N-methyl-2-pyrrolidone (NMP) and N,N-dimethylformamide (DMF). These solvents may be used alone or as a mixture of two or more thereof.

[0051] The reactive polysiloxane used in the present invention is obtained by performing the hydrolytic polycondensation of the alkoxy silicon compound A of formula [4], or the alkoxy silicon compound comprising the alkoxy silicon compound A of formula [4] and the alkoxy silicon compound B of formula [5], in the presence of the acidic or basic catalyst. The reaction temperature required for the hydrolytic polycondensation is 20 to 150°C, more preferably 30 to 120°C.

The reaction time is not particularly limited as long as the reaction time is equal to or longer than the time required for completing increase in the molecular weight of the polycondensation product and stabilizing a molecular weight distribution. More specifically, the reaction time is several hours to several days.

[0052] After the completion of polycondensation reaction, preferably, the obtained reactive polysiloxane is recovered by an arbitrary method such as filtration or solvent removal by distillation and appropriately subjected to purification treatment according to the need.

[0053] One example of the process for producing the reactive polysiloxane used in the present invention includes a process comprising polycondensing the alkoxy silicon compound A of formula [4], or the alkoxy silicon compound comprising the alkoxy silicon compound A of formula [4] and the alkoxy silicon compound B of formula [5], in the presence of a base, and removing the base using a cation-exchange resin.

The base and the amount of the base used can adopt one or more compounds selected from the group consisting of the basic compound and the fluoride mentioned above, and the amount of the compound(s) used. Preferably, one or more selected from the group consisting of potassium hydroxide, calcium hydroxide, barium hydroxide, and tetraethylammonium hydroxide can be used as the base.

The reaction conditions, etc. for use in the polycondensation reaction, or the reaction solvent, etc. can adopt those mentioned above.

After the completion of reaction, an ion-exchange resin having a sulfo group as an ion group is preferably used as the cation-exchange resin to remove the base.

[0054] For example, a styrenic (styrene-divinylbenzene copolymer) or acrylic resin having a matrix structure generally used can be used as the cation-exchange resin.

- 5 The cation-exchange resin may be any of a strongly acidic cation-exchange resin having a sulfo group as an ion group and a weakly acidic cation-exchange resin having a carboxy group as an ion group. Various forms such as granular, fibrous, and membrane forms can be used as the form of the cation-exchange resin. Commercially available products can be suitably used as these cation-exchange resins.

- 10 Among the above, a strongly acidic cation-exchange resin having a sulfo group as an ion group is preferably used.

- [0055] Examples of the commercially available strongly acidic cation-exchange resin include: Amberlite(R) 15, Amberlite(R) 200, Amberlite(R) 200C, Amberlite(R) 200CT, Amberlite(R) 252, Amberlite(R) 1200 H, Amberlite(R) IR120B, Amberlite(R) IR120 H, Amberlite(R) IR122 Na, Amberlite(R) IR124, Amberlite(R) IRC50, Amberlite(R) IRC86, Amberlite(R) IRN77, Amberlite(R) IRP-64, Amberlite(R) IRP-69, Amberlite(R) CG-50, Amberlite(R) CG-120, Amberjet(R) 1020, Amberjet(R) 1024, Amberjet(R) 1060, Amberjet(R) 1200, Amberjet(R) 1220, Amberlyst(R) 15, Amberlyst(R) 15DRY, Amberlyst(R) 15JWET, Amberlyst(R) 16, Amberlyst(R) 16WET, Amberlyst(R) 31WET, Amberlyst(R) 35WET, Amberlyst(R) 36, Dowex(R) 50Wx2, Dowex(R) 50Wx4, Dowex(R) 50Wx8, Dowex(R) DR-2030, Dowex(R) DR-G8, Dowex(R) HCR-W2, Dowex(R) 650C UPW, Dowex(R) G-26, Dowex(R) 88, Dowex(R) M-31, Dowex(R) N-406, Dowex(R) Monosphere(R) 650C, Dowex(R) Monosphere(R) 88, Dowex(R) Monosphere(R) M-31, Dowex(R) Monosphere(R) 99K/320, Dowex(R) Monosphere(R) 99K/350, Dowex(R) Monosphere(R) 99Ca/320, Dowex Marathon(R) MSC, and Dowex Marathon(R) C [all manufactured by The Dow Chemical Company]; Diaion(R) EXC04, Diaion(R) HPK25, Diaion(R) PK208, Diaion(R) PK212, Diaion(R) PK216, Diaion(R) PK220, Diaion(R) PK228L, Diaion(R) RCP160M, Diaion(R) SK1B,
- 15
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Diaion(R) SK1BS, Diaion(R) SK104, Diaion(R) SK110, Diaion(R) SK112, Diaion(R) SK116, Diaion(R) UBK510L, and Diaion(R) UBK555 [all manufactured by Mitsubishi Chemical Corp.]; and Lewatit(R) MonoPlus S100 and Lewatit(R) MonoPlus SP112 [both manufactured by Lanxess AG].

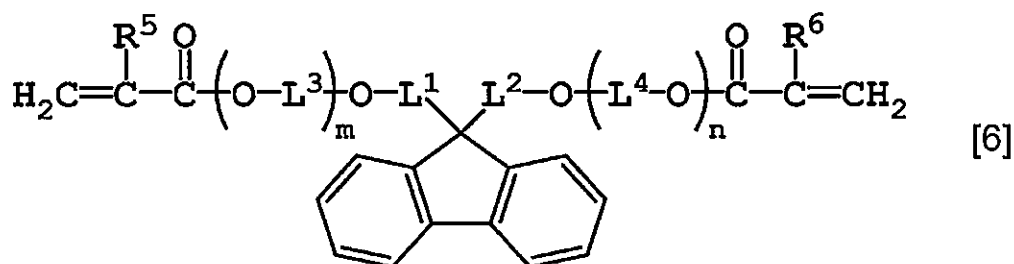
5 [0056] Examples of the commercially available weakly acidic cation-exchange resin include: Amberlite(R) CG-50, Amberlite(R) FPC3500, Amberlite(R) IRC50, Amberlite(R) IRC76, Amberlite(R) IRC86, Amberlite(R) IRP-64, and Dowex(R) MAC-3 [all manufactured by The Dow Chemical Company]; and Diaion(R) CWK30/S, Diaion(R) WK10, Diaion(R) WK11, Diaion(R) WK40, Diaion(R) WK100, and
10 Diaion(R) WT01S [all manufactured by Mitsubishi Chemical Corp.].

 [0057] The polycondensation compound obtained through the reaction as mentioned above has a weight-average molecular weight M_w of 500 to 100,000, preferably 500 to 30,000, and a degree of distribution: M_w (weight-average molecular weight)/ M_n (number-average molecular weight) of 1.0 to 10, measured on the basis of
15 polystyrene by GPC.

 The reactive polysiloxane is a compound having at least a siloxane unit of $[X(Ar^1)SiO]$, for example, a compound having a cross-linked structure having at least siloxane units of $[X(Ar^1)SiO]$ and $[Ar^2SiO_{3/2}]$.

 [0058] <Fluorene compound>

20 The fluorene compound is a compound of the following formula [6]:



 In formula [6] described above, R^5 and R^6 are each independently a hydrogen atom or methyl group, L^1 and L^2 are each independently a phenylene group

optionally having a substituent, or a naphthalenediyl group optionally having a substituent, L^3 and L^4 are each independently a C_{1-6} alkylene group, more preferably a C_{2-3} alkylene group, and m and n are each independently 0 or a positive integer that satisfies $0 \leq m + n \leq 40$.

5 [0059] Examples of the phenylene group optionally having a substituent as L^1 and L^2 include o-phenylene group, m-phenylene group, p-phenylene group, 2-methylbenzene-1,4-diyl group, 2-aminobenzene-1,4-diyl group, 2,4-dibromobenzene-1,3-diyl group, and 2,6-dibromobenzene-1,4-diyl group.

Examples of the naphthalenediyl group optionally having a substituent as
10 L^1 and L^2 include 1,2-naphthalenediyl group, 1,4-naphthalenediyl group, 1,5-naphthalenediyl group, 1,8-naphthalenediyl group, 2,3-naphthalenediyl group, and 2,6-naphthalenediyl group.

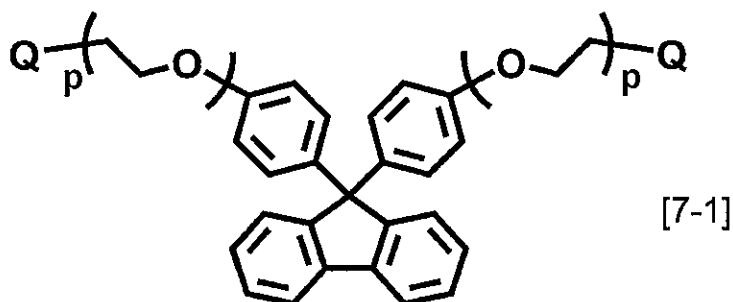
[0060] Examples of the C_{1-6} alkylene group as L^3 and L^4 include methylene group, ethylene group, trimethylene group, 1-methylethylene group, tetramethylene group,
15 1-methyltrimethylene group, 1,1-dimethylethylene group, pentamethylene group, 1-methyltetramethylene group, 2-methyltetramethylene group, 1,1-dimethyltrimethylene group, 1,2-dimethyltrimethylene group, 2,2-dimethyltrimethylene group, 1-ethyltrimethylene group, hexamethylene group, 1-methylpentamethylene group, 2-methylpentamethylene group, 3-methylpentamethylene group,
20 1,1-dimethyltetramethylene group, 1,2-dimethyltetramethylene group, 2,2-dimethyltetramethylene group, 1-ethyltetramethylene group, 1,1,2-trimethyltrimethylene group, 1,2,2-trimethyltrimethylene group, 1-ethyl-1-methyltrimethylene group, and 1-ethyl-2-methyltrimethylene group. Among these C_{1-6} alkylene groups, a group corresponding to a C_{2-3} alkylene group is more
25 preferred as L^3 and L^4 .

[0061] In the compound of formula [6], m and n each independently preferably satisfy $0 \leq m + n \leq 30$, more preferably $2 \leq m + n \leq 20$.

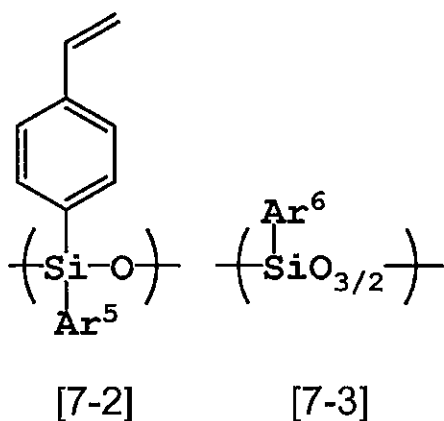
[0062] Specific examples of the compound of formula [6] include, but are not

limited to: 9,9-bis(4-(2-(meth)acryloyloxyethoxy)phenyl)-9H-fluorene; OGSOL(R) EA-0200, OGSOL(R) EA-0300, OGSOL(R) EA-F5003, OGSOL(R) EA-F5503, OGSOL(R) EA-F5510, OGSOL(R) EA-F5710, and OGSOL(R) GA-5000 [all manufactured by Osaka Gas Chemicals Co., Ltd.]; and NK Ester A-BPEF [manufactured by Shin-Nakamura Chemical Co., Ltd.] (in the present invention, the (meth)acryloyl group refers to both an acryloyl group and a methacryloyl group).

[0063] The compound preferred as the high-refractive index polymerizable compound is a compound of the following formula [7-1], a compound having a structural unit of formula [7-2], or a compound having a structural unit of formula [7-2] and a structural unit of formula [7-3]:



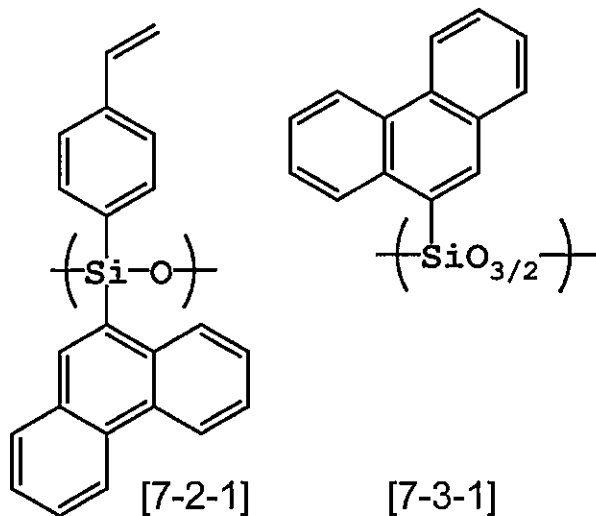
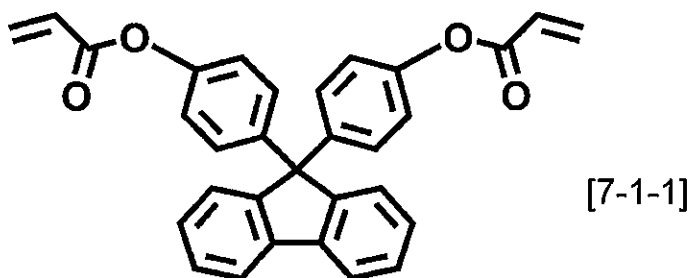
In formula [7-1], two Q are the same groups and are each selected from the group consisting of vinyloxy group, an allyloxy group and a (meth)acryloyloxy group, and two p are the same integers of 0 to 3.



In formulas [7-2] and [7-3], Ar⁵ and Ar⁶ are each independently phenyl

group, naphthyl group, or phenanthryl group.

[0064] The compound particularly preferred as the high-refractive index polymerizable compound is a compound of the following formula [7-1-1], a compound having a structural unit of formula [7-2-1], or a compound having a structural unit of formula [7-2-1] and a structural unit of formula [7-3-1]:



[0065] The high-refractive index polymerizable compound can be used alone or in combination of two or more thereof.

[0066] <<Polymerizable composition>>

The present invention is also directed to a polymerizable composition comprising 100 parts by mass of (a) the high-refractive index polymerizable compound described above and 10 to 500 parts by mass of (b) the viscosity lowering agent described above.

In the polymerizable composition, both the high-refractive index polymerizable compound (a) and the viscosity lowering agent (b) can each be used alone or in combination of two or more thereof.

The polymerizable composition may further comprise (c) a polymerizable
 5 diluent being in a liquid state of matter at 23°C under 1013.25 hPa, and (d) a polymerization initiator.

[0067] <(c) Polymerizable diluent>

The polymerizable diluent that may be used in the polymerizable composition of the present invention is a compound being in a liquid state of matter at
 10 23°C under 1013.25 hPa and is also called a liquid diluent. The polymerizable diluent can be used for the purpose of 1) adjusting the viscosity of the polymerizable composition and also 2) adjusting the cross-linking density of the polymerizable composition during curing. Use of the polymerizable diluent can further enhance effects on reduction in and maintenance of a viscosity by the viscosity lowering agent mentioned
 15 above.

[0068] Examples of the polymerizable diluent include 1,3-butanediol di(meth)acrylate, 1,4-butanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate, 2-methyl-1,8-octanediol di(meth)acrylate, 1,10-decanediol di(meth)acrylate,
 20 tricyclo[5.2.1.0^{2,6}]decanedimethanol di(meth)acrylate, trimethylolpropane tri(meth)acrylate, ditrimethylolpropane tetra(meth)acrylate, pentaerythritol tetra(meth)acrylate, dipentaerythritol hexa(meth)acrylate, 2-hydroxy-3-acryloyloxypropyl methacrylate, glycerin di(meth)acrylate, pentaerythritol tri(meth)acrylate, dipentaerythritol penta(meth)acrylate, bis((meth)acryloyloxyethyl)hydroxyethyl
 25 isocyanurate, benzyl (meth)acrylate, 2-phenoxyethyl (meth)acrylate, 2-phenoxybenzyl (meth)acrylate, 3-phenoxybenzyl (meth)acrylate, 4-phenoxybenzyl (meth)acrylate, 2-(2-biphenyloxy)ethyl (meth)acrylate, 2-(3-biphenyloxy)ethyl (meth)acrylate, 2-(4-biphenyloxy)ethyl (meth)acrylate, ethoxylated o-phenylphenol (meth)acrylate,

diethylene glycol monophenyl ether (meth)acrylate, polyethylene glycol monophenyl ether (meth)acrylate, 2-hydroxy-3-phenoxypropyl (meth)acrylate, neopentyl glycol benzoate (meth)acrylate, and divinylbenzene.

[0069] The polymerizable diluent is obtainable as a commercially available product. Specific Examples thereof include: NK Ester 701A, NK Ester A-DCP, NK Ester A-DON-N, NK Ester A-HD-N, NK Ester A-NOD-N, NK Ester DCP, NK Ester DOD-N, NK Ester HD-N, NK Ester NOD-N, NK Ester NPG, NK Ester A-TMM-3, NK Ester A-TMM-3L, NK Ester A-TMM-3LMN, NK Ester A-TMPT, NK Ester TMPT, NK Ester A-TMMT, NK Ester AD-TMP, NK Ester A-DPH, NK Ester A-9550, NK Ester A-9530, NK Ester ADP-51EH, NK Ester ATM-31EH, UA-7100, and A-LEN-10 [all manufactured by Shin-Nakamura Chemical Co., Ltd.]; and KAYARAD(R) T-1420, KAYARAD(R) D-330, KAYARAD(R) D-320, KAYARAD(R) D-310, KAYARAD(R) DPCA-20, KAYARAD(R) DPCA-30, KAYARAD(R) DPCA-60, KAYARAD(R) DPCA-120, KAYARAD(R) TMPTA, KAYARAD(R) PET-30, KAYARAD(R) DPHA, and KAYARAD(R) DPHA-2C [all manufactured by Nippon Kayaku Co., Ltd.].

[0070] In the case of using a polymerizable diluent, the polymerizable diluent may be used alone or as a mixture of two or more thereof. The amount of the polymerizable diluent added is 10 to 500 parts by mass with respect to 100 parts by mass of the component (a) and is preferably 0.1 to 40 parts by mass, more preferably 5 to 30 parts by mass, with respect to 100 parts by mass in total of the polymerizable composition. If the polymerizable diluent is added at more than 30 parts by mass, the refractive index may drop. In such a case, a high refractive index, which is the principal object of the present invention, may not be maintained.

[0071] <(d) Polymerization initiator>

The polymerizable composition of the present invention may further comprise a polymerization initiator. Any of a photopolymerization initiator and a thermal polymerization initiator can be used as the polymerization initiator.

[0072] Examples of the photopolymerization initiator include alkylphenones,

benzophenones, Michler's ketones, acylphosphine oxides, benzoyl benzoates, oxime esters, tetramethylthiuram monosulfides, and thioxanthenes.

Particularly, a photofragmentation-type photo radical polymerization initiator is preferred.

5 Examples of commercially available photo radical polymerization initiators can include: IRGACURE(R) 184, IRGACURE(R) 369, IRGACURE(R) 651, IRGACURE(R) 500, IRGACURE(R) 819, IRGACURE(R) 907, IRGACURE(R) 784, IRGACURE(R) 2959, IRGACURE(R) CGI1700, IRGACURE(R) CGI1750, IRGACURE(R) CGI1850, IRGACURE(R) CG24-61, IRGACURE(R) TPO, Darocur(R) 10 1116, and Darocur(R) 1173 [all manufactured by BASF Japan, Ltd.]; and ESACURE KIP150, ESACURE KIP65LT, ESACURE KIP100F, ESACURE KT37, ESACURE KT55, ESACURE KTO46, and ESACURE KIP75 [all manufactured by Lamberti S.p.A.].

[0073] Examples of the thermal polymerization initiator include azos and organic 15 peroxides.

Examples of commercially available azo thermal polymerization initiators can include V-30, V-40, V-59, V-60, V-65, and V-70 [all manufactured by Wako Pure Chemical Industries, Ltd.].

20 Examples of commercially available organic peroxide thermal polymerization initiators can include, but are not limited to: Perkadox(R) CH, Perkadox(R) BC-FF, Perkadox(R) 14, Perkadox(R) 16, Trigonox(R) 22, Trigonox(R) 23, Trigonox(R) 121, Kaya Ester(R) P, Kaya Ester(R) O, and Kaya Butyl(R) B [all manufactured by Kayaku Akzo Corp.]; and PERHEXA(R) HC, PERCUMYL(R) H, PEROCTA(R) O, PERHEXYL(R) O, PERHEXYL(R) Z, PERBUTYL(R) O, and 25 PERBUTYL(R) Z [all manufactured by NOF Corp.].

[0074] In the case of adding a polymerization initiator, the polymerization initiator may be used alone or as a mixture of two or more thereof. The amount of the polymerization initiator added is 0.1 to 20 parts by mass, more preferably 0.3 to 10 parts

by mass, with respect to 100 parts by mass in total of the polymerizable components, i.e., the component (a) and the component (b) (if desired, further the component (c)).

[0075] <Other additives>

The polymerizable composition of the present invention can further
 5 contain, for example, a chain transfer agent, an antioxidant, an ultraviolet absorber, a light stabilizer, a leveling agent, a rheology adjuster, an adhesion aid such as a silane coupling agent, a pigment, a dye, and an antifoaming agent, if necessary, without impairing the effect of the present invention.

[0076] Examples of the chain transfer agent include thiol compounds including:

10 mercaptocarboxylic acid esters such as methyl mercaptoacetate, methyl 3-mercaptopropionate, 2-ethylhexyl 3-mercaptopropionate, 3-methoxybutyl 3-mercaptopropionate, n-octyl 3-mercaptopropionate, stearyl 3-mercaptopropionate, 1,4-bis(3-mercaptopropionyloxy)butane, 1,4-bis(3-mercaptobutyryloxy)butane, trimethylolethane tris(3-mercaptopropionate), trimethylolethane tris(3-mercaptobutyrate),
 15 trimethylolpropane tris(3-mercaptopropionate), trimethylolpropane tris(3-mercaptobutyrate), pentaerythritol tetrakis(3-mercaptopropionate), pentaerythritol tetrakis(3-mercaptobutyrate), dipentaerythritol hexakis(3-mercaptopropionate), dipentaerythritol hexakis(3-mercaptobutyrate), tris[2-(3-mercaptopropionyloxy)ethyl] isocyanurate, and tris[2-(3-mercaptobutyryloxy)ethyl] isocyanurate; alkylthiols such as
 20 ethanethiol, 2-methylpropane-2-thiol, n-dodecanethiol, 2,3,3,4,4,5-hexamethylhexane-2-thiol (tert-dodecanethiol), ethane-1,2-dithiol, propane-1,3-dithiol, and benzylthiol; aromatic thiols such as benzenethiol, 3-methylbenzenethiol, 4-methylbenzenethiol, naphthalene-2-thiol, pyridine-2-thiol, benzimidazole-2-thiol, and benzothiazole-2-thiol; mercapto alcohols such as
 25 2-mercaptoethanol and 4-mercapto-1-butanol; and silane-containing thiols such as 3-(trimethoxysilyl)propane-1-thiol and 3-(triethoxysilyl)propane-1-thiol, disulfide compounds including: alkyl disulfides such as diethyl disulfide, dipropyl disulfide, diisopropyl disulfide, dibutyl disulfide, di-tert-butyl disulfide, dipentyl disulfide,

diisopentyl disulfide, dihexyl disulfide, dicyclohexyl disulfide, didecyl disulfide, bis(2,3,3,4,4,5-hexamethylhexan-2-yl) disulfide (di-tert-dodecyl disulfide), bis(2,2-diethoxyethyl) disulfide, bis(2-hydroxyethyl) disulfide, and dibenzyl disulfide; aromatic disulfides such as diphenyl disulfide, di-p-tolyl disulfide, di(pyridin-2-yl)pyridyl disulfide, di(benzimidazol-2-yl) disulfide, and di(benzothiazol-2-yl) disulfide; and thiuram disulfides such as tetramethylthiuram disulfide, tetraethylthiuram disulfide, tetrabutylthiuram disulfide, and bis(pentamethylene)thiuram disulfide, and α -methylstyrene dimers.

[0077] In the case of adding a chain transfer agent, the chain transfer agent may be used alone or as a mixture of two or more thereof. The amount of the chain transfer agent added is 0.01 to 20 parts by mass, more preferably 0.1 to 10 parts by mass, with respect to 100 parts by mass in total of the polymerizable components, i.e., the component (a) and the component (b) (if desired, further the component (c)).

[0078] Examples of the antioxidant include phenol antioxidants, phosphoric acid antioxidants, and sulfide antioxidants. Among these antioxidants, a phenol antioxidant is preferred.

Examples of the phenol antioxidant include: IRGANOX(R) 245, IRGANOX(R) 1010, IRGANOX(R) 1035, IRGANOX(R) 1076, and IRGANOX(R) 1135 [all manufactured by BASF Japan, Ltd.]; SUMILIZER(R) GA-80, SUMILIZER(R) GP, SUMILIZER(R) MDP-S, SUMILIZER(R) BBM-S, and SUMILIZER(R) WX-R [all manufactured by Sumitomo Chemical Co., Ltd.]; and ADEKA STAB(R) AO-20, ADEKA STAB(R) AO-30, ADEKA STAB(R) AO-40, ADEKA STAB(R) AO-50, ADEKA STAB(R) AO-60, ADEKA STAB(R) AO-80, and ADEKA STAB(R) AO-330 [all manufactured by ADEKA Corp.].

[0079] In the case of adding an antioxidant, the antioxidant may be used alone or as a mixture of two or more thereof. The amount of the antioxidant added is 0.01 to 20 parts by mass, more preferably 0.1 to 10 parts by mass, with respect to 100 parts by mass in total of the polymerizable components, i.e., the component (a) and the component (b)

(if desired, further the component (c)).

[0080] <Process for preparing polymerizable composition>

The process for preparing the polymerizable composition of the present embodiment is not particularly limited. Examples of the preparation process include: a process comprising mixing the component (a) and the component (b), and, if necessary, the component (c) and the component (d) at a predetermined ratio, further adding thereto other additives, if desired, and mixing the mixture to prepare a homogeneous solution; a process comprising mixing a portion of, for example, the component (a) and the component (b), among these components to prepare a homogeneous solution, then adding thereto the remaining portion of the components, further adding thereto other additives, if desired, and mixing the mixture to prepare a homogeneous solution; and a process further using a conventional solvent in addition to these components.

[0081] In the case of using a solvent, the solid content ratio of this polymerizable composition is not particularly limited as long as each component is uniformly dissolved in the solvent. The solid content ratio is, for example, 1 to 50% by mass, 1 to 30% by mass, or 1 to 25% by mass. In this context, the solid content excludes the solvent component from all the components of the polymerizable composition.

[0082] The solution of the polymerizable composition is preferably used after being filtered through a filter or the like having a pore size of 0.1 to 5 μm .

20 [0083] <<Cured product>>

The polymerizable composition can be exposed to light (photocured) or heated (thermally cured) to obtain a cured product. The present invention is also directed to the cured product of the polymerizable compound.

Examples of the light beam for the light exposure include ultraviolet ray, electron beam, and X-ray. For example, sunlight, a chemical lamp, a low-pressure mercury lamp, a high-pressure mercury lamp, a metal halide lamp, a xenon lamp, or UV-LED can be used as a light source for use in ultraviolet irradiation. The cured product thus exposed to light may be post-baked in order to stabilize its physical

properties. The post-baking method is not particularly limited and is usually performed in the ranges of 50 to 260°C and 1 to 120 minutes using a hot plate, an oven, or the like.

The heating conditions for the thermal curing are not particularly limited and, usually, are appropriately selected from the ranges of 50 to 300°C and 1 to 120 minutes. Examples of the heating means include, but are not particularly limited to, hot plates and ovens.

[0084] The cured product obtained by curing the polymerizable composition of the present invention may have a refractive index as high as 1.620 or more, at a wavelength of 589.3 nm (D-ray) and further an Abbe number of 23 or less. Furthermore, the occurrence of cracks or coming off from a support due to heating is suppressed. Thus, the cured product can be expected to have dimensional stability and as such, can be suitably used as a material for high-refractive index resin lenses.

[0085] <<Molded article>>

From the polymerizable composition of the present invention, various molded articles can be easily produced concurrently with the formation of the cured product by use of a conventional molding method, for example, compression molding (imprint, etc.), casting, injection molding, or blow molding. The present invention is also directed to the molded article thus obtained.

Examples of the process for producing the molded article include a process comprising: a step of introducing the polymerizable composition of the present invention into space between a support and a mold in contact with each other, or internal space of a separable mold; a step of photopolymerizing the introduced composition by light exposure; a step of taking the obtained photopolymer out of the space filled therewith for mold release; and a step of heating the photopolymer before, during, or after the mold release.

The step of photopolymerization by light exposure can be carried out by the application of the conditions described in the preceding section <<Cured product>>.

The conditions for the heating step are not particularly limited and, usually,

are appropriately selected from the ranges of 50 to 260°C and 1 to 120 minutes.

Examples of the heating means include, but are not particularly limited to, hot plates and ovens.

5 The molded article produced by such a process can be suitably used as a module lens for cameras.

Examples

[0086] Hereinafter, the present invention will be described more specifically with reference to Examples. However, the present invention is not limited by Examples
10 given below.

In Examples, apparatuses and conditions used in the preparation of samples and the analysis of physical properties are as follows.

[0087] (1) Spin coater

Apparatus: Cee(R) 200X manufactured by Brewer Science, Inc.

15 (2) UV exposure

Apparatus: batch-type UV irradiation apparatus (high-pressure mercury lamp 2 kW × 1) manufactured by Eye Graphics Co., Ltd.

(3) ¹H NMR spectrum

Apparatus: AVANCE III HD manufactured by Bruker Corp.

20 Measurement frequency: 500 MHz

Solvent: CDCl₃

Internal standard: tetramethylsilane (δ = 0.00 ppm)

(4) Gel permeation chromatography (GPC)

Apparatus: Prominence(R) GPC system manufactured by Shimadzu Corp.

25 Column: Shodex(R) GPC KF-804L and GPC KF-803L manufactured by Showa Denko K.K.

Column temperature: 40°C

Solvent: tetrahydrofuran

Detector: RI

Calibration curve: standard polystyrene

(5) Abbe number v_D and Refractive index n_D

Apparatus A (for cured film measurement): multiple angle-of-incidence

5 spectroscopic ellipsometer VASE manufactured by J. A. Woollam Co., Inc.

Apparatus B (for molded article measurement): prism coupler model

2010/M manufactured by Metricon Corp.

Measurement temperature: room temperature (approximately 23°C)

(6) Melting point

10 Observation apparatus: polarizing microscope ECLIPSE(R) E600 POL
manufactured by Nikon Corp.

Heating apparatus: Stage automatic temperature control system for
microscopes, ThermoPlate(R) manufactured by TOKAI HIT Co., Ltd.

Heating rate: 0.5°C/sec

15 Measurement method: the temperature at which a portion of a sample
started to be melted in visual observation was used as a melting point.

(7) Viscosity

Apparatus: EMS-1000 manufactured by Kyoto Electronics Manufacturing
Co., Ltd.

20 (8) Transmittance

Apparatus: ultraviolet-visible and near-infrared spectrophotometer V-670
manufactured by JASCO Corp.

Reference: air

[0088] Abbreviations are as defined below.

25 NMA: naphthalen-2-yl methyl acrylate

VN: 2-vinylnaphthalene [manufactured by Nippon Steel & Sumitomo
Metal Corp.]

SPeDMS: dimethoxy(phenanthren-9-yl)(4-vinylphenyl)silane

BPOEA: 2-([1,1'-biphenyl]-2-yloxy)ethyl acrylate [NK Ester A-LEN-10 manufactured by Shin-Nakamura Chemical Co., Ltd.]

BnA: benzyl acrylate [Viscoat #160, BZA manufactured by Osaka Organic Chemical Industry Ltd.]

5 DVB: divinylbenzene [DVB-810 manufactured by Nippon Steel & Sumitomo Metal Corp.]

FDA: 9,9-bis(4-(2-acryloyloxyethoxy)phenyl)fluorene [NK Ester A-BPEF manufactured by Shin-Nakamura Chemical Co., Ltd.]

PheTMS: trimethoxy(9-phenanthryl)silane

10 STMS: trimethoxy(4-vinylphenyl)silane [Shin-Etsu Silicone(R) KBM-1403 manufactured by Shin-Etsu Chemical Co., Ltd.]

TMOS: tetramethoxysilane [manufactured by Tokyo Chemical Industry Co., Ltd.]

15 TEAH: aqueous solution containing 35% by mass of tetraethylammonium hydroxide [manufactured by Sigma Aldrich Co. LLC]

DDT: n-dodecanethiol [THIOKALCOL 20 manufactured by Kao Corp.]

I184: 1-hydroxy cyclohexyl phenyl ketone [IRGACURE(R) 184 manufactured by BASF Japan, Ltd.]

20 TPO: diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide [IRGACURE(R) TPO manufactured by BASF Japan, Ltd.]

PGMEA: propylene glycol monomethyl ether acetate

THF: tetrahydrofuran

[0089] [Production Example 1] Production of dimethoxy(phenanthren-9-yl)(4-vinylphenyl)silane (SPeDMS)

25 A 1 L reaction flask equipped with a condenser was charged with 15.7 g (0.65 mol) of magnesium turnings [manufactured by Kanto Chemical Co., Inc.], and the air in the flask was purged with nitrogen using a nitrogen balloon. A mixture of 151.2 g (0.58 mol) of 9-bromophenanthrene [manufactured by Tokyo Chemical Industry Co.,

Ltd.] and 518 g of THF was added dropwise thereto at room temperature (approximately 23°C) over 1 hour, and the mixture was further stirred for 1 hour to prepare a Grignard reagent.

A 2 L reaction flask was charged with 131.9 g (0.58 mol) of STMS and
5 259 g of THF, and the air in the flask was purged with nitrogen using a nitrogen balloon. The Grignard reagent was added dropwise thereto under reflux (approximately 66°C) over 30 minutes, and the mixture was further refluxed for 24 hours. From this reaction mixture, THF was distilled off under reduced pressure using an evaporator. Soluble matter was dissolved by the addition of 1,000 g of hexane to the obtained residue and
10 subsequent reflux for 1 hour. Then, insoluble matter was filtered off. To this insoluble matter, 750 g of hexane was added again, and soluble matter was dissolved in the same way as above. Then, insoluble matter was filtered off. The respective filtrates were mixed, and hexane was distilled off under reduced pressure using an evaporator to obtain a crude product. The crude product was recrystallized over 150 g of hexane to obtain
15 102.4 g (yield: 47%) of SPeDMS of interest.

The ¹H NMR spectrum of the obtained compound is shown in FIG. 1.

[0090] [Production Example 2] Production of naphthalen-2-yl methyl acrylate (NMA)

A 200 mL reaction flask was charged with 25.0 g (0.158 mol) of
20 2-naphthalenemethanol [manufactured by Tokyo Chemical Industry Co., Ltd.] and 158 g of THF, and the air in the flask was purged with nitrogen using a nitrogen balloon. Then, the mixture was cooled to 0°C. To this flask, 17.58 g (0.174 mol) of triethylamine [manufactured by Tokyo Chemical Industry Co., Ltd.] and 15.73 g (0.174 mol) of acryloyl chloride [manufactured by Tokyo Chemical Industry Co., Ltd.] were added, and
25 the mixture was stirred at room temperature (approximately 23°C) for 1 hour. To this reaction mixture, 158 g of water was added, and a product was extracted with 158 g of ethyl acetate. From the organic layer, the solvent was distilled off under reduced pressure using an evaporator to obtain a crude product. The crude product was purified

by silica gel chromatography (hexane/ethyl acetate = 9/1 (mass ratio)) to obtain 21.5 g (yield: 64%) of naphthalen-2-yl methyl acrylate of interest.

The obtained compound was confirmed to have the structure of interest from the ^1H NMR spectrum.

5 [0091] [Production Example 3] Production of trimethoxy(9-phenanthryl)silane (PheTMS)

A 500 mL reaction flask equipped with a condenser was charged with 10.4 g (0.43 mol) of magnesium turnings [manufactured by Kanto Chemical Co., Inc.], and the air in the flask was purged with nitrogen using a nitrogen balloon. A mixture of 100.3 g
10 (0.39 mol) of 9-bromophenanthrene [manufactured by Tokyo Chemical Industry Co., Ltd.] and 346 g of THF was added dropwise thereto at room temperature (approximately 23°C) over 1 hour, and the mixture was further stirred for 30 minutes to prepare a Grignard reagent.

A 1 L reaction flask was charged with 178.0 g (1.17 mol) of TMOS and
15 346 g of THF, and the air in the flask was purged with nitrogen using a nitrogen balloon. The Grignard reagent was added dropwise thereto at room temperature (approximately 23°C) over 30 minutes, and the mixture was further stirred for 2 hours. From this reaction mixture, THF was distilled off under reduced pressure using an evaporator. Soluble matter was dissolved by the addition of 1,000 g of hexane to the obtained residue.
20 Then, insoluble matter was filtered off. To this insoluble matter, 500 g of hexane was added again, and insoluble matter was filtered off in the same way as above. The respective filtrates were mixed, and hexane was distilled off under reduced pressure using an evaporator to obtain a crude product. The crude product was distilled under reduced pressure (1 mmHg, 120 to 150°C) and then recrystallized over 389 g of methanol to
25 obtain 74.6 g (yield: 64%) of PheTMS of interest.

The ^1H NMR spectrum of the obtained compound is shown in FIG. 2.

[0092] [Production Example 4] Production of high-refractive index polymerizable compound 1 (PSPeDMS)

A 50 mL reaction flask equipped with a condenser was charged with 1.36 g (3.23 mmol) of TEAH and 12 g of THF, and the air in the flask was purged with nitrogen using a nitrogen balloon. A mixture of 29.9 g (80.7 mmol) of SPeDMS produced according to Production Example 1 and 24 g of THF was added dropwise thereto at room temperature (approximately 23°C) over 10 minutes, and the mixture was stirred at 40°C for 16 hours. This mixture was cooled to room temperature (approximately 23°C). Subsequently, to this reaction mixture, 6.0 g of a cation-exchange resin [Amberlyst(R) 15JWET manufactured by The Dow Chemical Company] washed in advance with THF, and 1.2 g of a filter aid [KC Flock W-100GK manufactured by Nippon Paper Industries Co., Ltd.] were added, and the reaction was terminated by stirring for 1 hour. Then, the cation-exchange resin and the filter aid were filtered through a membrane filter having a pore size of 0.5 μm and further washed off with 30 g of ethyl acetate. This filtrate and the washes were combined and added to 897 g of methanol to precipitate a polymer. This precipitate was filtered and dried to obtain 18.9 g of high-refractive index polymerizable compound 1 (hereinafter, also abbreviated to PSPeDMS) of interest.

The obtained compound had a weight-average molecular weight M_w of 610 and a degree of distribution: M_w (weight-average molecular weight)/ M_n (number-average molecular weight) of 1.2 measured on the basis of polystyrene by GPC.

[0093] [Production Example 5] Production of high-refractive index polymerizable compound 2 (XPe55)

A 50 mL reaction flask equipped with a condenser was charged with 0.90 g (2.14 mmol) of TEAH, 0.86 g (47.7 mmol) of ion-exchange water, and 7 g of THF, and the air in the flask was purged with nitrogen using a nitrogen balloon. A mixture of 9.9 g (26.8 mmol) of SPeDMS produced according to Production Example 1, 8.0 g (26.8 mmol) of PheTMS produced according to Production Example 3, and 14 g of THF was added dropwise thereto at room temperature (approximately 23°C) over 10 minutes, and the mixture was stirred at 40°C for 16 hours. This mixture was cooled to room

temperature (approximately 23°C). Subsequently, to this reaction mixture, 3.6 g of a cation-exchange resin [Amberlyst(R) 15JWET manufactured by The Dow Chemical Company] washed in advance with THF, and 0.72 g of a filter aid [KC Flock W-100GK manufactured by Nippon Paper Industries Co., Ltd.] were added, and the reaction was
5 terminated by stirring for 1 hour. Then, the cation-exchange resin and the filter aid were filtered through a membrane filter having a pore size of 0.5 μm and further washed off with 18 g of ethyl acetate. This filtrate and the washes were combined and added to 538 g of methanol to precipitate a polymer. This precipitate was filtered and dried to obtain
10 14.8 g of high-refractive index polymerizable compound 2 (hereinafter, also abbreviated to XPe55) of interest.

The obtained compound had a weight-average molecular weight M_w of 1,000 and a degree of distribution: M_w/M_n of 1.0 measured on the basis of polystyrene by GPC.

[0094] The state of matter and the viscosity at 23°C and 100°C under atmospheric
15 pressure were measured as to SPeDMS and NMA produced according to Production Examples 1 and 2, and as to VN and BPOEA. The results are shown in Table 1.

[0095] 100 parts by mass of SPeDMS, NMA, VN, or BPOEA described above, 1 part by mass of I184, and 233 parts by mass of PGMEA were mixed. This solution was filtered through a PTFE syringe filter having a pore size of 0.2 μm to obtain varnish
20 having a solid concentration of 30% by mass.

A silicon wafer was spin-coated (1,500 rpm $\times$ 30 sec) with each varnish, which was then dried by heating on a hot plate of 80°C for 1 minute. This coating was exposed to UV at 20 mW/cm² for 250 seconds in a nitrogen atmosphere and further heated on a hot plate of 150°C for 20 minutes to prepare a cured film having a film
25 thickness of 1.0 μm . The Abbe number v_D at a wavelength of 589 nm (D-ray) of the obtained cured film was measured. The results are also shown in Table 1.

[0096] [Table 1]

	Melting point[°C]	23°C		100°C		Abbe number v_D
		State	Viscosity [mPa·s]	State	Viscosity [mPa·s]	
SPeDMS	78	Solid	-	Liquid	0.6	20.0
NMA	28	Solid	-	Liquid	0.5	20.6
VN	65	Solid	-	Liquid	0.9	19.9
BPOEA	<23	Liquid	150	Liquid	0.4	26.5

[0097] [Example 1] Preparation of polymerizable composition 1

Two parts by mass of the viscosity lowering agent VN as the component (b), 6 parts by mass of the high-refractive index polymerizable compound FDA as the component (a), and 2 parts by mass of the polymerizable diluent BnA as the component (c) were mixed and stirred at 40°C for 2 hours. To this mixture, 0.1 parts by mass of I184 and 0.07 parts by mass of TPO as polymerization initiators were added as the component (d), and the mixture was stirred at 40°C for 1 hour. Further, 0.3 parts by mass of DDT as a chain transfer agent (reaction accelerator) were added thereto, and the mixture was stirred at room temperature (approximately 23°C) for 2 hours to obtain polymerizable composition 1 as homogeneous transparent varnish.

[0098] [Examples 2 to 9 and Comparative Examples 1 to 7] Preparation of polymerizable compositions 2 to 16

Polymerizable compositions 2 to 16 were each prepared by the same operation as in Example 1 except that each formation was changed as described in Table 2. In Table 2, the term "parts" refers to "parts by mass".

[0099] [Table 2]

Example/ Comparative Example	Polymerizable composition	(b) Viscosity lowering agent		(a) High-refractive index polymerizable compound		(c) Polymerizable diluent		I184 [parts]	TPO [parts]	DDT [parts]
			[parts]		[parts]		[parts]			
Example 1	Polymerizable composition 1	VN	2	FDA	6	BnA	2	0.1	0.07	0.3
Example 2	Polymerizable composition 2	NMA	2	FDA	6	BnA	2	0.1	0.07	0.3
Example 3	Polymerizable composition 3	SPeDMS	2	FDA	6	BnA	2	0.1	0.07	0.3
Example 4	Polymerizable composition 4	SPeDMS	2	FDA	6	DVB	2	0.1	0.07	0.3
Example 5	Polymerizable composition 5	SPeDMS	2	PSPeDMS	6	DVB	2	0.1	0.07	0.3
Example 6	Polymerizable composition 6	SPeDMS	4	PSPeDMS	4	DVB	2	0.1	0.07	0.3
Example 7	Polymerizable composition 7	SPeDMS	2	PSPeDMS	5	DVB	2	0.1	0.07	0.3
				FDA	1					
Example 8	Polymerizable composition 8	SPeDMS	1.5	PSPeDMS	5	DVB	2	0.1	0.07	0.3
				FDA	1.35	BnA	0.25			
Example 9	Polymerizable composition 9	SPeDMS	1.8	XPe55	5.5	DVB	2.7	0.1	0.07	0.3
Comparative Example 1	Polymerizable composition 10	none	-	FDA	7.5	BnA	2.5	0.1	0.07	0.3
Comparative Example 2	Polymerizable composition 11	none	-	FDA	7.5	DVB	2.5	0.1	0.07	0.3
Comparative Example 3	Polymerizable composition 12	none	-	PSPeDMS	7.5	DVB	2.5	0.1	0.07	0.3
Comparative Example 4	Polymerizable composition 13	none	-	XPe55	6.67	DVB	3.33	0.1	0.07	0.3
Comparative Example 5	Polymerizable composition 14	BPOEA	2	PSPeDMS	6	DVB	2	0.1	0.07	0.3
Comparative Example 6	Polymerizable composition 15	BPOEA	2	PSPeDMS	5	DVB	2	0.1	0.07	0.3
				FDA	1					
Comparative Example 7	Polymerizable composition 16	BPOEA	1.8	XPe55	5.5	DVB	2.7	0.1	0.07	0.3

[0100] The viscosity of each polymerizable composition at 25°C is shown in

Table 3.

[0101] [Preparation and optical property evaluation of cured product]

Each polymerizable composition was sandwiched, together with a 1 mm thick silicone rubber spacer, between two mold release-treated glass plates. The polymerizable composition thus sandwiched was exposed to UV at 20 mW/cm^2 for 250 seconds. The cured product was peeled from the glass plates and then heated on a hot plate of 150°C for 20 minutes to prepare a molded article having a diameter of 30 mm and a thickness of 1 mm.

The Abbe number ν_D and the refractive index n_D at a wavelength of 589 nm (D-ray), and the average transmittance at a wavelength of 400 to 800 nm, of the obtained molded article were measured. The results are also shown in Table 3.

[0102] [Table 3]

Example	Polymerizable composition	Viscosity [mPa·s]	Abbe number ν_D	Refractive index n_D	Transmittance [%]
Example 1	Polymerizable composition 1	384	25.5	1.62	86.8
Example 2	Polymerizable composition 2	229	28.3	1.62	86.9
Example 3	Polymerizable composition 3	1,570	25.3	1.62	87.5
Example 4	Polymerizable composition 4	971	24.5	1.63	89.0
Example 5	Polymerizable composition 5	4,220	20.4	1.66	87.1
Example 6	Polymerizable composition 6	367	22.4	1.64	86.8
Example 7	Polymerizable composition 7	2,990	20.3	1.66	87.1
Example 8	Polymerizable composition 8	2,700	21.8	1.65	87.5
Example 9	Polymerizable composition 9	3,340	20.4	1.65	87.6
Comparative Example 1	Polymerizable composition 10	2,520	27.1	1.61	83.6
Comparative Example 2	Polymerizable composition 11	1,410	26.0	1.62	88.7
Comparative Example 3	Polymerizable composition 12	10,900	20.9	1.67	87.2
Comparative Example 4	Polymerizable composition 13	1,960	21.8	1.64	84.7
Comparative Example 5	Polymerizable composition 14	2,200	22.1	1.66	87.9
Comparative Example 6	Polymerizable composition 15	2,560	22.1	1.65	87.6
Comparative Example 7	Polymerizable composition 16	2,750	26.9	1.62	86.6

[0103] As shown in Tables 2 and 3, the results were obtained, indicating that the addition of the low viscosity agent of the present invention achieves a lower viscosity and a lower Abbe number ν_D and can also improve the refractive index n_D and the transmittance to equivalent or higher values, as compared with the case of adding no viscosity lowering agent (see Examples 1 and 3 vs. Comparative Example 1, Example 4

vs. Comparative Example 2, and Example 5 vs. Comparative Example 3). In Example 2, the addition of the low viscosity agent achieved a lower viscosity, a high refractive index and high transmittance, whereas a rise in Abbe number was seen due to a decreased ratio of the high-refractive index polymerizable compound to the polymerizable composition.

5 The conventional liquid diluent BPOEA was able to reduce a viscosity or to maintain a viscosity at 10,000 mPa·s or less, as in the viscosity lowering agent of the present invention, but elevated an Abbe number (see Example 5 vs. Comparative Example 5, Example 7 vs. Comparative Example 6, and Example 9 vs. Comparative Example 7). The results indicate that the addition of BPOEA rather elevated an Abbe
10 number, as compared with the case of adding no viscosity lowering agent (see Comparative Example 3 vs. 5 and Comparative Example 4 vs. 7).

[0104] [Optical properties of high-refractive index polymerizable compound (a)]

100 parts by mass of FDA, PSPeDMS, XPe55 or BPOEA described above, 1 part by mass of I184, and 233 parts by mass of PGMEA were mixed. This solution
15 was filtered through a PTFE syringe filter having a pore size of 0.2 μm to obtain varnish having a solid concentration of 30% by mass.

A silicon wafer was spin-coated (1,500 rpm $\times$ 30 sec) with each varnish, which was then dried by heating on a hot plate of 80°C for 1 minute. This coating was exposed to UV at 20 mW/cm² for 250 seconds in a nitrogen atmosphere and further
20 heated on a hot plate of 150°C for 20 minutes to prepare a cured film having a film thickness of 1.0 μm . The refractive index and the Abbe number v_D at a wavelength of 589 nm (D-ray) of the obtained cured film were measured. The results are shown in Table 4.

[0105] [Table 4]

	Refractive index	Abbe number ν_D
FDA	1.62	25.4
PSPeDMS	1.74	17.8
XPe55	1.75	17.4
BPOEA	1.61	26.5

CLAIMS

1. A method for using a compound as a viscosity lowering agent for a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product of the high-refractive index polymerizable compound,

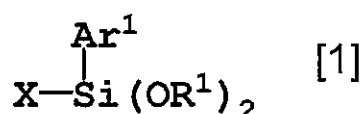
the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

2. The method according to claim 1, wherein the viscosity lowering agent is a compound

having at least one aromatic group selected from the group consisting of a phenyl group or a phenylene group optionally substituted with a C₁₋₆ alkyl group, a monovalent or divalent condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), and a monovalent or divalent hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and

having at least one group having a polymerizable double bond, selected from the group consisting of vinyl group, an allyl group, a (meth)allyloxy group and a (meth)acryloyl group.

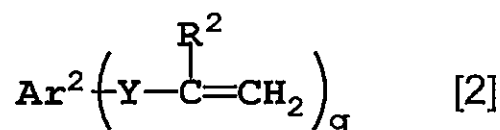
3. The method according to claim 2, wherein the viscosity lowering agent is a compound of the following formula [1]:



(wherein X is a phenyl group having at least one substituent having a polymerizable double bond, a naphthyl group having at least one substituent having a polymerizable double bond, a biphenyl group having at least one substituent having a polymerizable double bond, or a phenanthryl group having at least one substituent having a polymerizable double bond, Ar¹ is a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R¹ is methyl group, ethyl group, or isopropyl group).

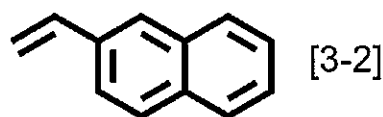
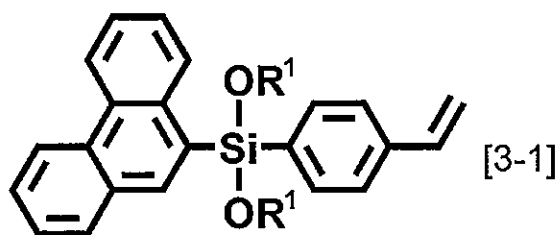
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4. The method according to claim 2, wherein the viscosity lowering agent is a compound of the following formula [2]:



15 (wherein Ar² is a q-valent aromatic hydrocarbon residue, q is 1 or 2, Y is a single bond, -O-C(=O)- group, or -O- group, and R² is a hydrogen atom or methyl group).

5. The method according to claim 2, wherein the viscosity lowering agent is a compound of the following formula [3-1] or formula [3-2]:



20

(wherein R¹ is methyl group, ethyl group, or isopropyl group).

6. A viscosity lowering agent for a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product thereof,

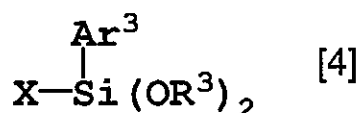
the viscosity lowering agent comprising a compound, the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

7. A polymerizable composition comprising

100 parts by mass of (a) a high-refractive index polymerizable compound having at least one polymerizable double bond and exhibiting a refractive index of 1.60 or more at D-ray (589.3 nm) in a cured product thereof, and

10 to 500 parts by mass of (b) a viscosity lowering agent comprising a compound, the compound being in a solid state of matter at 23°C under 1013.25 hPa and having a melting point of lower than 100°C, wherein a viscosity of the compound at 100°C is 10 mPa·s or less, and a cured product of the compound has an Abbe number of 23 or less at D-ray (589.3 nm).

8. The polymerizable composition according to claim 7, wherein the high-refractive index polymerizable compound (a) comprises a reactive polysiloxane comprising at least one of a polycondensation product of alkoxy silicon compound A of formula [4], and a polycondensation product of the alkoxy silicon compound A of formula [4] with alkoxy silicon compound B of formula [5]:



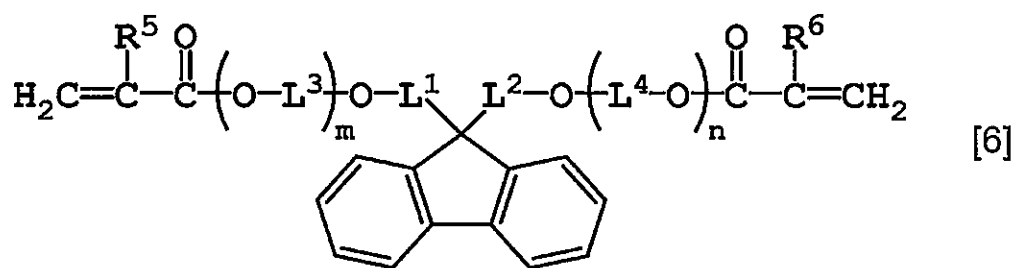
(wherein X is a phenyl group having at least one substituent having a polymerizable double bond, a naphthyl group having at least one substituent having a polymerizable

double bond, a biphenyl group having at least one substituent having a polymerizable double bond, or a phenanthryl group having at least one substituent having a polymerizable double bond, Ar³ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R³ is methyl group, ethyl group, or isopropyl group), and



(wherein Ar⁴ is a phenyl group optionally substituted with a C₁₋₆ alkyl group, a condensed ring hydrocarbon group having two or more benzene ring structures (optionally substituted with a C₁₋₆ alkyl group), or a hydrocarbon ring assembly group in which two or more aromatic rings are directly bonded through a single bond (optionally substituted with a C₁₋₆ alkyl group), and R⁴ is methyl group, ethyl group, or isopropyl group).

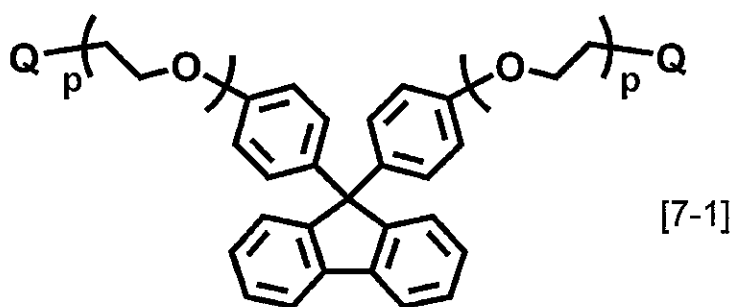
9. The polymerizable composition according to claim 7, wherein the high-refractive index polymerizable compound (a) comprises a fluorene compound of formula [6]:



(wherein R⁵ and R⁶ are each independently a hydrogen atom or methyl group, L¹ and L² are each independently a phenylene group optionally having a substituent, or a naphthalenediyl group optionally having a substituent, L³ and L⁴ are each independently

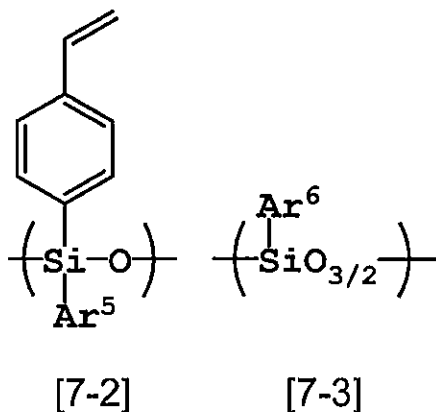
a C₁₋₆ alkylene group, and m and n are each independently 0 or a positive integer that satisfies $0 \leq m + n \leq 40$).

10. The polymerizable composition according to claim 7, wherein the
 5 high-refractive index polymerizable compound (a) is selected from the group consisting of a compound of the following formula [7-1], a compound having a structural unit of formula [7-2], and a compound having a structural unit of formula [7-2] and a structural unit of formula [7-3]:



10

(wherein two Q are the same groups and are each selected from the group consisting of vinyloxy group, an allyloxy group and a (meth)acryloyloxy group, and two p are the same integers of 0 to 3), and



15

(wherein Ar⁵ and Ar⁶ are each independently phenyl group, naphthyl group, or phenanthryl group).

11. The polymerizable composition according to any one of claims 7 to 10, further comprising (c) a polymerizable diluent being in a liquid state of matter at 23°C under 1013.25 hPa.

5 12. A cured product of the polymerizable composition according to any one of claims 7 to 11.

13. A material for a high-refractive index resin lens comprising the polymerizable composition according to any one of claims 7 to 11.

10

14. A resin lens prepared from the polymerizable composition according to any one of claims 7 to 11.

15. A process for producing a molded article, comprising the steps of:

15 introducing the polymerizable composition according to any one of claims 7 to 11 into space between a support and a mold in contact with each other, or internal space of a separable mold; and
 photopolymerizing the introduced composition by light exposure.

20 16. The production process according to claim 15, further comprising the steps of:
 taking the obtained photopolymer out of the space filled therewith for mold release; and
 heating the photopolymer before, during, or after the mold release.

25 17. The production process according to claim 15 or 16, wherein the molded article is a lens for a camera module.