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(54) **Title**: PATTERN FORMING METHOD, MULTI-LAYERED RESIST PATTERN, MULTI-LAYERED FILM FOR ORGANIC SOLVENT DEVELOPMENT, RESIST COMPOSITION, METHOD FOR MANUFACTURING ELECTRONIC DEVICE, AND ELECTRONIC DEVICE

(57) **Abstract**: A pattern forming method contains: (i) a step of forming a first film on a substrate by using a first resin composition (I), (ii) a step of forming a second film on the first film by using a second resin composition (II) different from the resin composition (I), (iii) a step of exposing a multi-layered film having the first film and the second film, and (iv) a step of developing the first film and the second film in the exposed multi-layered film by using an organic solvent-containing developer to form a negative pattern.

DESCRIPTION

Title of Invention

PATTERN FORMING METHOD, MULTI-LAYERED RESIST PATTERN, MULTI-LAYERED FILM FOR ORGANIC SOLVENT DEVELOPMENT, RESIST COMPOSITION, METHOD FOR MANUFACTURING ELECTRONIC DEVICE, AND ELECTRONIC DEVICE

Technical Field

The present invention relates to a pattern forming method suitably used for the process of producing a semiconductor such as IC or the production of a liquid crystal device or a circuit board such as thermal head and further for the lithography in other photo-fabrication processes, a multi-layered resist pattern, a multi-layered film for organic solvent development, a resist composition suitably used for the pattern forming method, a manufacturing method of an electronic device, and an electronic device. In particular, the present invention relates to a pattern forming method suitably used for exposure by an ArF or KrF exposure apparatus, a multi-layered resist pattern, a multi-layered film for organic solvent development, a manufacturing method of an electronic device, and an electronic device.

Background Art

Since the advent of a resist for KrF excimer laser (248 nm), an image forming method called chemical amplification is used as an image forming method for a resist so as to compensate for sensitivity reduction caused by light absorption. For example, the image forming method by positive chemical amplification is an image forming method of decomposing an acid generator in the exposed area upon exposure to excimer laser, electron beam, extreme-ultraviolet light or the like to produce an acid, converting an alkali-insoluble group into an alkali-soluble group by using the generated acid as a reaction catalyst in the baking after exposure (PEB: Post Exposure Bake), and removing the exposed area with an alkali developer.

As for the alkali developer used in the method above, various alkali developers have been proposed, but an aqueous alkali developer of 2.38 mass% TMAH (an aqueous tetramethylammonium hydroxide solution) is being used for general purposes.

Also, as an application of the above-described resist technology, a microfabrication

application such as application to ion implantation employed when implanting an ion (charge injection), which is one step of the logic device fabrication or the like, is expanding.

In the case of using a resist composition for the application to ion implantation, the resist composition is sometimes coated, exposed and developed on a substrate previously subjected to patterning (hereinafter, referred to as a stepped substrate), and microfabrication on a stepped substrate is required. In the application to ion implantation, the task encountered in the patterning of microfabrication involving development with the above-described alkali developer and difficult to solve is the problem of scum on the substrate, which is generated after development due to bad release property of the film formed of the resist composition.

To meet a need from such a microfabrication technology, not only the currently mainstream positive resist but also formation of a fine pattern by a negative image are being developed (see, for example, JP-A-2010-40849 (the term "JP-A" as used herein means an "unexamined published Japanese patent application"), JP-A-2008-292975, JP-A-2010-217884). Because, in the manufacture of a semiconductor device or the like, patterns having various profiles such as line, trench and hole need to be formed and some patterns are difficult to form by the current positive resist.

Summary of Invention

The present inventors have found that according to a negative pattern forming method by organic solvent development, for example, the problem of scum on the substrate in the patterning of microfabrication involving development with the above-described alkali developer can be solved.

However, the negative pattern forming method by organic solvent development faces a problem that pattern collapse readily occurs.

Considering the problem above, an object of the present invention is to provide a pattern forming method ensuring that pattern collapse hardly occurs in a negative pattern forming method by organic solvent development, a multi-layered resist pattern formed by the method, a multi-layered film for organic solvent development, which is suitably used for the pattern forming method, a resist composition suitably used for the pattern forming method, a manufacturing method of an electronic device, and an electronic device.

As a result of intensive studies to attain the above-described object, the present inventors have accomplished the present invention.

That is, the present invention has the following configurations.

[1] A pattern forming method comprising:

(i) a step of forming a first film on a substrate by using a first resin composition (I) containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin,

(ii) a step of forming a second film on the first film by using a second resin composition (II) different from the resin composition (I), in which the second resin composition (II) contains a resin having a group capable of decomposing by the action of an acid to produce a polar group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation,

(iii) a step of exposing a multi-layered film having the first film and the second film, and

(iv) a step of developing the first film and the second film in the exposed multi-layered film by using an organic solvent-containing developer to form a negative pattern.

[2] The pattern forming method as described in [1],

wherein the resin contained in the first resin composition (I) differs from the resin contained in the second resin composition (II).

[3] The pattern forming method as described in [1] or [2],

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin contained in the first resin composition (I), is 15 mol% or less based on all repeating units in the resin.

[4] The pattern forming method as described in any one of [1] to [3],

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin having a group capable of decomposing by the action of an acid to produce a polar group, which is contained in the second resin composition (II), is from 20 to 90 mol% based on all repeating units in the resin.

[5] The pattern forming method as described in any one of [1] to [4],

wherein the thickness of the first film is from 50 to 130 nm, the thickness of the second film is from 90 to 190 nm, and the exposure in the step (iii) is exposure to a KrF excimer laser.

[6] The pattern forming method as described in any one of [1] to [4],

wherein the thickness of the first film is from 20 to 80 nm, the thickness of the

second film is from 30 to 100 nm, and the exposure in the step (iii) is exposure to an ArF excimer laser.

[7] The pattern forming method as described in any one of [1] to [6],

wherein the first film is a developable bottom anti-reflective coating.

[8] The pattern forming method as described in any one of [1] to [7],

wherein the organic solvent-containing developer is a developer containing at least one kind of an organic solvent selected from the group consisting of a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent.

[9] A resin composition, which is the first resin composition (I) used for the pattern forming method as described in any one of [1], [2] and [4] to [8], wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin.

[10] A multi-layered resist pattern formed by the pattern forming method as described in any one of [1] to [8].

[11] A multi-layered film for organic solvent development, comprising:

a first film formed on a substrate by using a first resin composition (I) containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin, and

a second film formed on the first film by using a second resin composition (II) different from the resin composition (I), in which the second resin composition (II) contains a resin having a group capable of decomposing by the action of an acid to produce a polar group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation.

[12] A manufacturing method of an electronic device, comprising the pattern forming method a described in any one of [1] to [8].

[13] An electronic device manufactured by the manufacturing method of an electronic device as described in [12].

The present invention preferably further includes the following configurations.

[14] The pattern forming method as described in any one of [1] to [8], further comprising:

a heating step at least either before the exposure step (iii) or after the exposure step (iii) but before the development step (iv).

[15] The pattern forming method as described in any one of [1] to [8] and [14],

wherein the second resin composition (II) further contains a basic compound.

[16] The pattern forming method as described in [7],

wherein the first resin composition (I) contains an aromatic ring-containing repeating unit or an aromatic compound.

[17] The pattern forming method as described in any one of [1] to [8] and [14] to [16],

wherein both the first resin composition (I) and the second resin composition (II) are a chemical amplification resist composition for organic solvent development.

[18] The resin composition as described in [9],

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin contained in the first resin composition (I) is from 0 to 15 mol% based on all repeating units in the resin.

[19] The multi-layered film for organic solvent development as described in [11],

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin contained in the first resin composition (I) is from 0 to 15 mol% based on all repeating units in the resin.

[20] The multi-layered film for organic solvent development as described in [11] or [19],

wherein the thickness of the first film is from 50 to 130 nm and the thickness of the second film is from 90 to 190 nm.

[21] The multi-layered film for organic solvent development as described in [11] or [19],

wherein the thickness of the first film is from 20 to 80 nm and the thickness of the second film is from 30 to 100 nm.

According to the present invention, a pattern forming method ensuring that a pattern less prone to pattern collapse can be formed in a negative pattern forming method by organic solvent development, a multi-layered resist pattern formed by the method, a multi-layered film for organic solvent development, which is suitably used for the pattern forming method, a resist composition suitably used for the pattern forming method, a manufacturing method of an electronic device, and an electronic device can be provided.

Description of Embodiments

The mode for carrying out the present invention is described in detail below.

In the description of the present invention, when a group (atomic group) is denoted without specifying whether substituted or unsubstituted, the group encompasses both a group

having no substituent and a group having a substituent. For example, "an alkyl group" encompasses not only an alkyl group having no substituent (unsubstituted alkyl group) but also an alkyl group having a substituent (substituted alkyl group).

In the description of the present invention, the term "actinic ray" or "radiation" means, for example, a bright line spectrum of mercury lamp, a far ultraviolet ray typified by excimer laser, an extreme-ultraviolet ray (EUV light), an X-ray or an electron beam (EB). Also, in the present invention, the "light" means an actinic ray or radiation.

In the description of the present invention, unless otherwise indicated, the "exposure" encompasses not only exposure to a mercury lamp, a far ultraviolet ray typified by excimer laser, an extreme-ultraviolet ray, an X-ray, EUV light or the like but also lithography with a particle beam such as electron beam and ion beam.

The pattern forming method of the present invention comprises:

(i) a step of forming a first film on a substrate by using a first resin composition (I) containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin,

(ii) a step of forming a second film on the first film by using a second resin composition (II) different from the resin composition (I), in which the second resin composition (II) contains a resin containing a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation,

(iii) a step of exposing a multi-layered film having the first film and the second film, and

(iv) a step of developing the first film and the second film in the exposed multi-layered film by using an organic solvent-containing developer to form a negative pattern.

That is, in the present invention, the "negative pattern" has a pattern part formed by development of developing a first film and a pattern part formed by development of developing a second film.

The above-described problem that pattern collapse readily occurs in the negative pattern forming method by organic solvent development is considered to be attributable to the following phenomenon.

In order to produce a polar group for forming a negative pattern, a group capable of decomposing by the action of an acid (hereinafter, sometimes simply referred to as "acid-

decomposable group") in the resin contained in the resist film is decomposed by the action of an acid. This acid decomposition brings about shrinking of the resist film, and due to shrinking, a gap, a strain or the like is produced on the adhesive surface between the resist film and the substrate. The organic developer intrudes into the gap or the like, as a result, pattern collapse readily occurs.

With respect to such a problem, the reason why according to the pattern forming method of the present invention, pattern collapse is hardly caused in the negative pattern forming method by an organic solvent-containing developer is not clearly known but presumed as follows.

In the present invention, a first layer (lower layer) on the bottom side of a multi-layered resist film and a second film (upper layer) on the surface side of the multi-layered resist film are formed of different resin compositions, and the first layer (lower layer) is formed using a first resin composition (I) in which the content of a repeating unit having an acid-decomposable group is 20 mol% or less based on all repeating units in the resin, whereby the multi-layered resist film is prevented from shrinking and in turn, generation of a gap or the like on the adhesive surface with the substrate is suppressed, as a result, pattern collapse is estimated to hardly occur.

Here, when the content of the repeating unit having an acid-decomposable group in the resin contained in the first resin composition (I) forming the lower layer is as small as 20 mol% or less, it may be considered that the lower layer of the exposed area (pattern part) dissolves in the organic developer and a pattern cannot be formed.

However, the present inventors have found that in the present invention where a resin having an acid-decomposable group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation are incorporated into the second resin composition (II) forming the second film (upper layer) on the surface side of the multi-layered resist film, although the reason is unknown, surprisingly, a practically satisfactory pattern can be formed without causing a problem such that the lower layer of the exposed area (pattern part) is dissolved in the organic developer and a pattern is not formed. The present invention has been accomplished based on this finding.

The pattern forming method of the present invention may comprise a step of forming a third film by using a third resin composition (III) different from the second resin composition (II), after the step (ii) of forming a second film but before the exposure step (iii), and may further comprise a step of forming a fourth film by using a fourth resin composition

(IV) different from the third resin composition (III).

In the pattern forming method of the present invention, the developer is preferably a developer containing at least one kind of an organic solvent selected from the group consisting of a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent.

The pattern forming method of the present invention preferably further comprises a step of performing rinsing by using an organic solvent-containing rinsing solution.

The rinsing solution is preferably a rinsing solution containing at least one kind of an organic solvent selected from the group consisting of a hydrocarbon-based solvent, a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent.

The resin contained in the second resin composition (II) is a resin capable of increasing the polarity by the action of an acid to decrease the solubility for an organic solvent-containing developer, that is, a resin capable of increasing the polarity by the action of an acid to increase the solubility for an alkali developer, and the pattern forming method of the present invention may further comprise a step of performing development by using an alkali developer.

The present invention also relates to a multi-layered resist pattern.

According to the pattern forming method of the present invention, a multi-layered resist pattern having pattern parts formed by development of developing respective films (for example, a first film and a second film) is obtained.

The present invention also relates to a multi-layered film for organic solvent development.

The multi-layered film (multi-layered resist film) for organic solvent development of the present invention comprises:

a first film formed on a substrate by using a first resin composition (I) (hereinafter, sometimes simply referred to as "resin composition (I)") containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin, and

a second film formed on the first film by using a second resin composition (II) (hereinafter, sometimes simply referred to as "resin composition (II)") different from the resin composition (I), in which the second resin composition (II) contains a resin having a group capable of decomposing by the action of an acid to produce a polar group and a compound

capable of generating an acid upon irradiation with an actinic ray or radiation.

The term "for organic solvent development" as used herein means an application where the composition is subjected to at least a step of performing development by using an organic solvent-containing developer.

From the standpoint of enhancing the resolution, each of the first film and the second film in the pattern forming method of the present invention, the multi-layered resist pattern of the present invention, or the multi-layered film for organic solvent development of the present invention preferably has a thickness of 20 to 250 nm, more preferably a thickness of 30 to 200 nm. Such a film thickness can be obtained by setting the solid content concentration in each composition to an appropriate range, thereby imparting an appropriate viscosity and enhancing the coatability and film-forming property.

In the present invention, from the standpoint of allowing no dissolution of the first film (lower layer) in an organic developer and preventing pattern collapse, in the case of performing exposure to a KrF excimer laser, the first film and the second film preferably have a thickness of 50 to 130 nm and a thickness of 90 to 190 nm, respectively, and the first film nm and the second film more preferably have a thickness of 60 to 120 and a thickness of 100 to 180 nm, respectively.

In the case of performing exposure to an ArF excimer laser, the first film and the second film preferably have a thickness of 20 to 80 nm and a thickness of 30 to 100 nm, respectively, and the first film nm and the second film more preferably have a thickness of 30 to 70 nm and a thickness of 40 to 90 nm, respectively.

The resin compositions (I) and (II) for use in the present invention are described below.

The resin compositions (I) and (II) according to the present invention are used for negative development (development where the solubility for an organic solvent developer is decreased upon exposure, as a result, the exposed area remains as a pattern and the unexposed area is removed).

[1] Resin (A-1) Contained in Resin Composition (I) and Resin (A-2) Contained in Resin Composition (II)

The resin composition (I) for use in the present invention contains a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group (hereinafter, sometimes simply referred to as "acid-decomposable group") is 20 mol% or less based on all repeating units in the resin.

The resin in which the content of a repeating unit having an acid-decomposable group is 20 mol% or less based on all repeating units in the resin, which is contained in the resin composition (I), is hereinafter sometimes simply referred to as "resin (A-1)".

From the standpoint of preventing occurrence of pattern collapse by allowing for no shrinking of the resist film and reducing generation of a gap or the like on the adhesive surface to the substrate, the content of the repeating unit having an acid-decomposable group of the resin (A-1) contained in the resin composition (I) is preferably 15 mol% or less, more preferably 10 mol% or less, still more preferably 5 mol% or less, based on all repeating units in the resin, and the content is ideally 0 mol%, that is, it is particularly preferred not to contain a repeating unit having an acid-decomposable group.

The resin composition (I) for use in the present invention may contain components (for example, a solvent, a compound capable of generating an acid upon irradiation with an actinic ray or radiation, and a basic compound, which are described later) other than the resin (A-1), but the resin composition (I) is preferably composed of a resin (A-1) in which the content of the repeating unit having an acid-decomposable group is 20 mol% or less based on all repeating units in the resin, and a solvent. Those other components are described later.

In the present invention, the first resin composition (I) differs from the second resin composition (II). It is preferred that the resin (A-1) contained in the resin composition (I) is different from the resin (hereinafter, sometimes simply referred to as "resin (A-2)") contained in the resin composition (II).

The resin composition (II) for use in the present invention is a resin composition containing an acid-decomposable group-containing resin (A-2) (that is, a resin capable of producing a polar group by the action of an acid to increase the polarity and decrease the solubility for an organic solvent developer) and a compound capable of generating an acid upon irradiation with an actinic ray or radiation, and this is a so-called chemical amplification-type actinic ray-sensitive or radiation-sensitive resin composition. This actinic ray-sensitive or radiation-sensitive resin composition may contain components other than the acid-decomposable group-containing resin (hereinafter, sometimes simply referred to as "acid-decomposable resin") and the later-described compound capable of generating an acid upon irradiation with an actinic ray or radiation. These components are described later.

The resin (A-1) contained in the resin composition (I) or the resin (A-2) contained in the resin composition (II) includes, for example, a resin constructed by appropriately selecting respective repeating units described later, and examples thereof include:

a copolymer of a repeating unit described later in [Preferred Embodiment (1) of Acid-Decomposable Group-Containing Repeating Unit] and a repeating unit described later in [Repeating Unit Containing Aromatic Ring], and

a copolymer of a repeating unit (for example, the later-described repeating unit represented by formula (AAI)) described later in [Preferred Embodiment (2) of Repeating Unit Having Acid-Decomposable Group] and a repeating unit described later in [Other Repeating Units].

The resin (A-2) contained in the resin composition (II) for use in the present invention includes, for example, a resin having an acid-decomposable group in either one or both of the main chain and the side chain of the resin.

The resin (A-2) contained in the resin composition (II) for use in the present invention is typically, preferably a resin containing a repeating unit having an acid-decomposable group.

Incidentally, the resin (A-2) is also a resin capable of increasing the polarity by the action of an acid to increase the solubility for an alkali developer.

[Acid-Decomposable Group]

The acid-decomposable group preferably has a structure where a polar group is protected by a group capable of decomposing and leaving by the action of an acid.

The polar group is not particularly limited as long as it is a group capable of being sparingly solubilized or insolubilized in an organic solvent-containing developer, but examples thereof include a carboxyl group, an acidic group (a group capable of dissociating in an aqueous 2.38 mass% tetramethylammonium hydroxide solution which has been conventionally used as the developer for a resist) such as sulfonic acid group, and a hydroxyl group (e.g., alcoholic hydroxyl group, phenolic hydroxyl group).

The alcoholic hydroxyl group is a hydroxyl group bonded to a hydrocarbon group and indicates a hydroxyl group except for a hydroxyl group directly bonded on an aromatic ring (phenolic hydroxyl group), and an aliphatic alcohol as an acid group, which is substituted with an electron-withdrawing group such as fluorine atom at the α-position (for example, a fluorinated alcohol group (e.g., hexafluoroisopropanol)), is excluded. The alcoholic hydroxyl group is preferably a hydroxyl group having a pKa of 12 to 20.

The group preferred as the acid-decomposable group is a group where a hydrogen atom of the group above is substituted for by a group capable of leaving by the action of an acid.

Examples of the group capable of leaving by the action of an acid include -$C(R_{36})(R_{37})(R_{38})$, -$C(R_{36})(R_{37})(OR_{39})$ and -$C(R_{01})(R_{02})(OR_{39})$.

In the formulae, each of R_{36} to R_{39} independently represents an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group or an alkenyl group. R_{36} and R_{37} may combine with each other to form a ring.

Each of R_{01} and R_{02} independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group or an alkenyl group.

The alkyl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an alkyl group having a carbon number of 1 to 8, and examples thereof include a methyl group, an ethyl group, a propyl group, an n-butyl group, a sec-butyl group, a hexyl group and an octyl group.

The cycloalkyl group of R_{36} to R_{39}, R_{01} and R_{02} may be monocyclic or polycyclic. The monocyclic cycloalkyl group is preferably a cycloalkyl group having a carbon number of 3 to 8, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cyclooctyl group. The polycyclic cycloalkyl group is preferably a cycloalkyl group having a carbon number of 6 to 20, and examples thereof include an adamantyl group, a norbornyl group, an isoboronyl group, a camphanyl group, a dicyclopentyl group, an α-pinel group, a tricyclodecanyl group, a tetracyclododecyl group, and an androstanyl group. Incidentally, at least one carbon atom in the cycloalkyl group may be substituted with a heteroatom such as oxygen atom.

The aryl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an aryl group having a carbon number of 6 to 10, and examples thereof include a phenyl group, a naphthyl group, and an anthryl group.

The aralkyl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an aralkyl group having a carbon number of 7 to 12, and examples thereof include a benzyl group, a phenethyl group, and a naphthylmethyl group.

The alkenyl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an alkenyl group having a carbon number of 2 to 8, and examples thereof include a vinyl group, an allyl group, a butenyl group, and a cyclohexenyl group.

The ring formed by combining R_{36} and R_{37} is preferably a cycloalkyl group (monocyclic or polycyclic). The cycloalkyl group is preferably a monocyclic cycloalkyl group such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group, more preferably a monocyclic cycloalkyl group having a carbon number of 5 to 6, still more

preferably a monocyclic cycloalkyl group having a carbon number of 5.

[Preferred Embodiment (1) of Acid-Decomposable Group-Containing Repeating Unit]

The resin (A-1) contained in the resin composition (I) preferably contains no repeating unit having an acid-decomposable group as described above, but in the case where the resin (A-1) contains a repeating unit having an acid-decomposable group, and in the case where the resin (A-2) contained in the resin composition (II) contains a repeating unit having an acid-decomposable group, in one embodiment of the present invention, the resin contains an acid-decomposable group-containing repeating unit of preferred embodiment (1) described below.

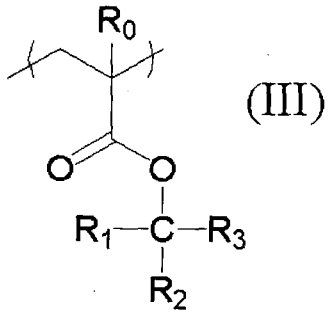
The acid-decomposable group-containing repeating unit of preferred embodiment (1) is not particularly limited in the exposure light source such as KrF excimer laser and ArF excimer laser but is preferably applied to KrF exposure.

Preferred embodiment (1) of the acid-decomposable group-containing repeating unit that is preferably applied to KrF exposure includes a repeating unit represented by the following formula (III), and a repeating unit represented by formula (VI) shown later.

Here, with respect to the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II), the resin embodiment that can be preferably applied to KrF exposure is preferably a resin containing a repeating unit having an aromatic ring. The repeating unit having an aromatic ring includes, for example, a repeating unit represented by formula (VI) shown later, an aromatic group-containing repeating unit described later, and a repeating unit represented by formula (IIB) shown later.

With respect to the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II), the resin embodiment that can be preferably applied to KrF exposure is preferably a resin composed of at least one repeating unit selected from the group consisting of a repeating unit represented by the following formula (III), a repeating unit represented by formula (VI) shown later, a repeating unit represented by formula (IIB) shown later and an aromatic group-containing repeating unit described later, and, if desired, at least one repeating unit selected from respective repeating units described later in [Other Repeating Units].

One of the acid-decomposable group-containing repeating units of preferred embodiment (1) which can be incorporated into the resin (A-1) contained in the resin composition (I) and into the resin (A-2) contained in the resin composition (II) is a repeating unit represented by the following formula (III):



(III)

In formula (III), R_0 represents a hydrogen atom or a linear or branched alkyl group.

Each of R_1 to R_3 independently represents a linear or branched alkyl group or a monocyclic or polycyclic cycloalkyl group.

Two members out of R_1 to R_3 may combine to form a monocyclic or polycyclic cycloalkyl group.

The linear or branched alkyl group of R_0 may have a substituent and is preferably a linear or branched alkyl group having a carbon number of 1 to 4, and examples thereof include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, and a tert-butyl group. Examples of the substituent include a hydroxyl group and a halogen atom (for example, fluorine atom).

R_0 is preferably a hydrogen atom, a methyl group, a trifluoromethyl group, or a hydroxymethyl group.

The alkyl group of R_1 to R_3 is preferably an alkyl group having a carbon number of 1 to 4, such as methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group and tert-butyl group.

The cycloalkyl group of R_1 to R_3 is preferably a monocyclic cycloalkyl group such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group.

The cycloalkyl group formed by combining two members out of R_1 to R_3 is preferably a monocyclic cycloalkyl group such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group, more preferably a monocyclic cycloalkyl group having a carbon number of 5 or 6.

One preferred embodiment is an embodiment where R_1 is a methyl group or an ethyl group and R_2 and R_3 are combined to form the above-described cycloalkyl group.

Each of the groups above may have a substituent, and examples of the substituent include a hydroxyl group, a halogen atom (such as fluorine atom), an alkyl group (having a

carbon number of 1 to 4), a cycloalkyl group (having a carbon number of 3 to 8), an alkoxy group (having a carbon number of 1 to 4), a carboxyl group, and an alkoxycarbonyl group (having a carbon number of 2 to 6). The carbon number is preferably 8 or less.

A particularly preferred embodiment of the repeating unit represented by formula (III) is an embodiment where each of R_1, R_2 and R_3 independently represents a linear or branched alkyl group.

In this embodiment, the linear or branched alkyl group of R_1, R_2 and R_3 is preferably an alkyl group having a carbon number of 1 to 4, and examples thereof include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, and a tert-butyl group.

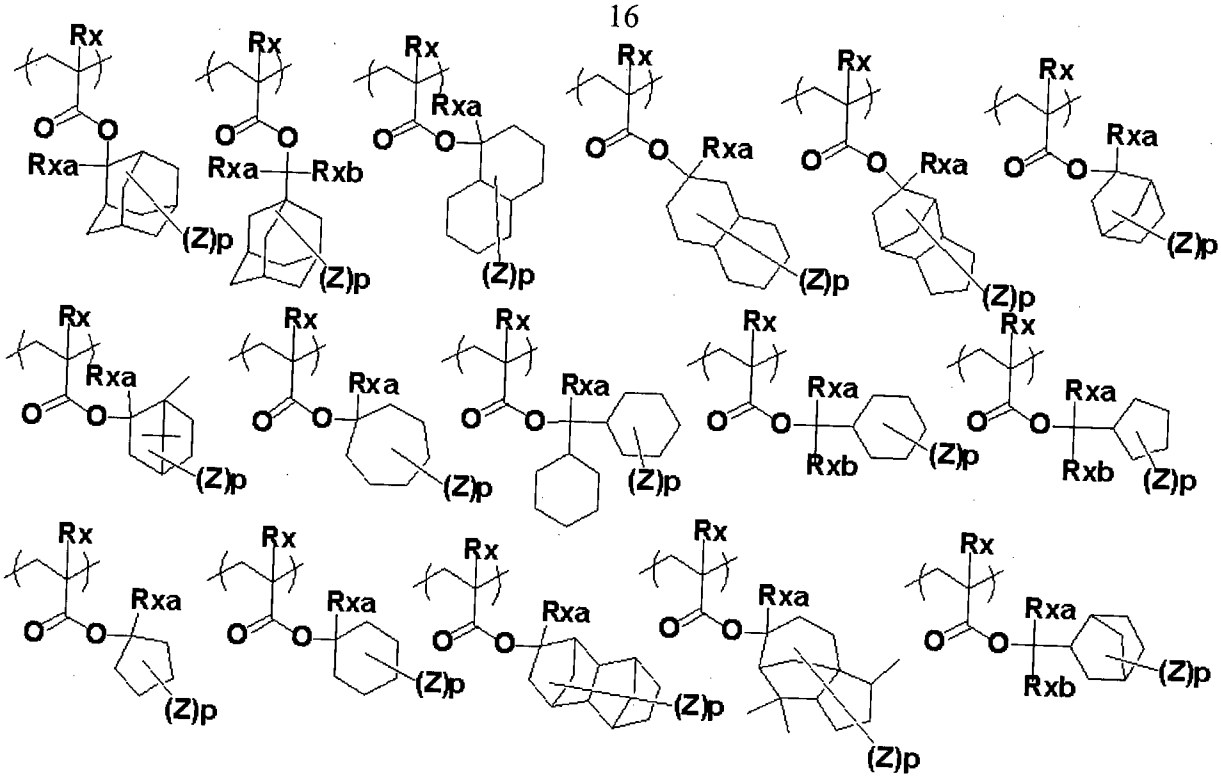
R_1 is preferably a methyl group, an ethyl group, an n-propyl group or an n-butyl group, more preferably a methyl group or an ethyl group, still more preferably a methyl group.

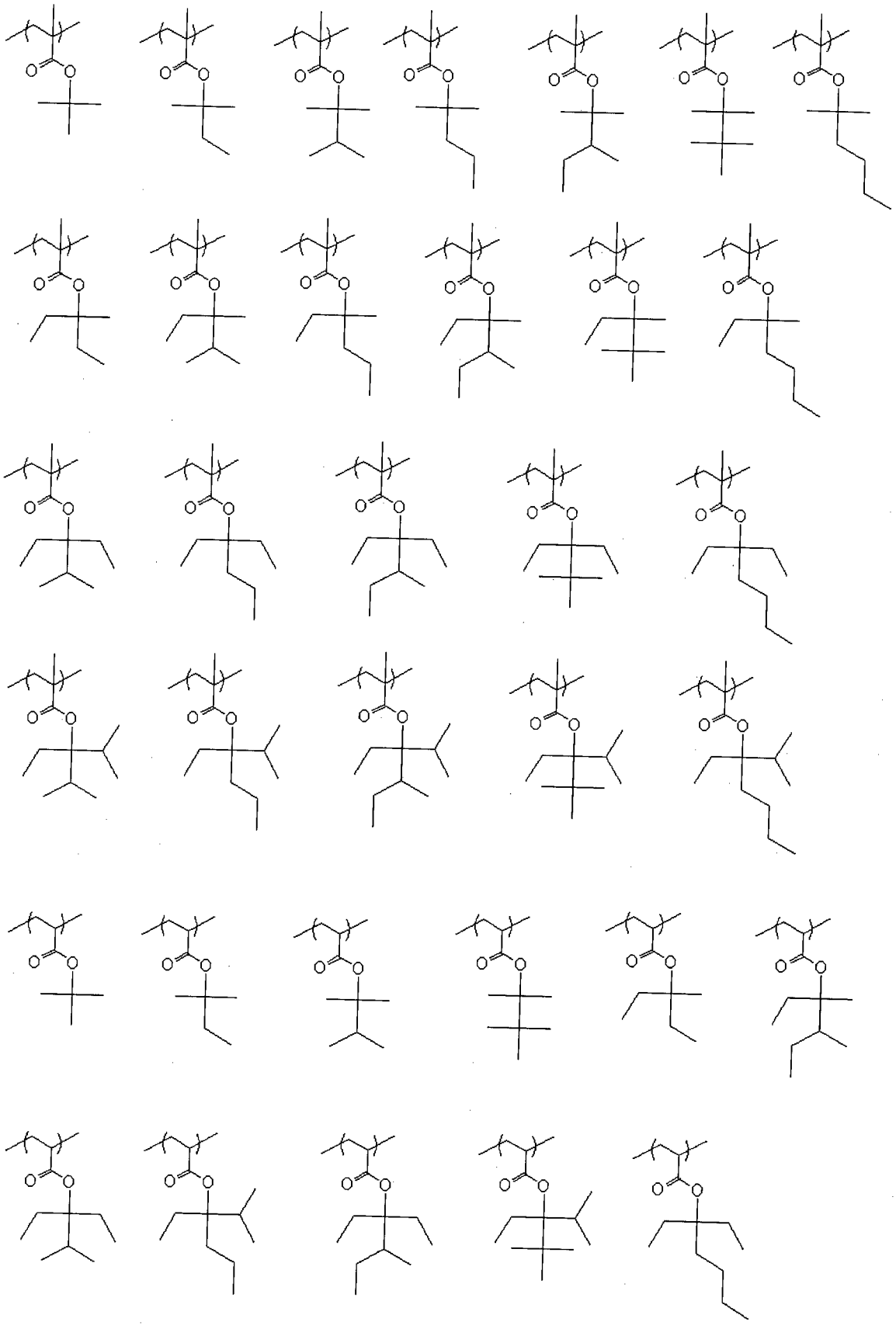
R_2 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group or an n-butyl group, more preferably a methyl group or an ethyl group, still more preferably a methyl group.

R_3 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group or a tert-butyl group, more preferably a methyl group, an ethyl group, an isopropyl group or an isobutyl group, still more preferably a methyl group, an ethyl group or an isopropyl group.

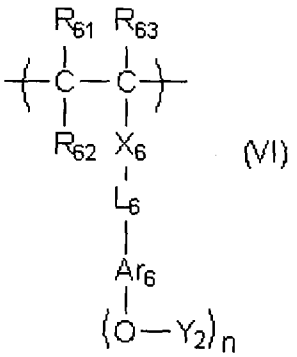
Specific examples of the acid-decomposable group-containing repeating unit of preferred embodiment (1) are illustrated below, but the present invention is not limited thereto.

In specific examples, Rx represents a hydrogen atom, CH_3, CF_3 or CH_2OH, and each of Rxa and Rxb represents an alkyl group having a carbon number of 1 to 4. Z represents a substituent, and when a plurality of Z's are present, each Z may be the same as or different from every other Z. p represents 0 or a positive integer. Specific examples and preferred examples of Z are the same as specific examples and preferred examples of the substituent which may be substituted on each of the groups such as R_1 to R_3.


Rx
Rxa
Rxb
(Z)p



One of the acid-decomposable group-containing repeating units of preferred embodiment (1) which can be incorporated into the resin (A-1) contained in the resin composition (I) and into the resin (A-2) contained in the resin composition (II) is a repeating unit represented by the following formula (VI):



(VI)

In formula (VI), each of R_{61}, R_{62} and R_{63} independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, a halogen atom, a cyano group, or an alkoxycarbonyl group. R_{62} may combine with Ar_6 to form a ring, and in this case, R_{62} represents a single bond or an alkylene group.

X_6 represents a single bond, -COO-, or -$CONR_{64}$-. R_{64} represents a hydrogen atom or an alkyl group.

L_6 represents a single bond or an alkylene group.

Ar_6 represents a (n+1)-valent aromatic ring group and in the case of combining with R_{62} to form a ring, represents a (n+2)-valent aromatic ring group.

Y_2 represents, when $n \geq 2$, each independently represents, a hydrogen atom or a group capable of leaving by the action of an acid. However, at least one Y_2 represents a group capable of leaving by the action of an acid.

n represents an integer of 1 to 4.

Formula (VI) is described in more detail.

The alkyl group of R_{61} to R_{63} in formula (VI) is preferably an alkyl group having a carbon number of 20 or less, such as methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, sec-butyl group, hexyl group, 2-ethylhexyl group, octyl group and dodecyl group, which may have a substituent, more preferably an alkyl group having a carbon number of 8 or less.

Preferred examples of the alkyl group contained in the alkoxycarbonyl group are the

same as those of the alkyl group in R_{61} to R_{63}.

The cycloalkyl group may be either monocyclic or polycyclic and is preferably a monocyclic cycloalkyl group having a carbon number of 3 to 8, such as cyclopropyl group, cyclopentyl group and cyclohexyl group, which may have a substituent.

The halogen atom includes a fluorine atom, a chlorine atom, a bromine atom and an iodine atom, with a fluorine atom being preferred.

In the case where R_{62} represents an alkylene group, the alkylene group is preferably an alkylene group having a carbon number of 1 to 8, such as methylene group, ethylene group, propylene group, butylene group, hexylene group and octylene group, which may have a substituent.

Examples of the alkyl group of R_{64} in -$CONR_{64}$- (wherein R_{64} represents a hydrogen atom or an alkyl group) represented by X_6 are the same as those of the alkyl group of R_{61} to R_{63}.

X_6 is preferably a single bond, -COO-, or -CONH-, more preferably a single bond or -COO-.

The alkylene group in L_6 is preferably an alkylene group having a carbon number of 1 to 8, such as methylene group, ethylene group, propylene group, butylene group, hexylene group and octylene group, which may have a substituent. The ring formed by combining R_{62} and L_6 is preferably a 5- or 6-membered ring.

Preferred examples of the divalent aromatic ring group when n in the (n+1)-valent aromatic ring group as Ar_6 is 1 include an arylene group having a carbon number of 6 to 18, such as phenylene group, tolylene group and naphthylene group, and a divalent aromatic ring group containing a heterocyclic ring such as thiophene, furan, pyrrole, benzothiophene, benzofuran, benzopyrrole, triazine, imidazole, benzimidazole, triazole, thiadiazole and thiazole.

Specific preferred examples of the (n+1)-valent aromatic ring group where n is an integer of 2 or more include groups formed by removing arbitrary (n-1) hydrogen atoms from the above-described specific examples of the divalent aromatic ring group.

The (n+1)-valent aromatic ring group as Ar_6 may further have a substituent.

Examples of the substituent which may be substituted on the above-described alkyl group, cycloalkyl group, alkoxycarbonyl group, alkylene group and (n+1)-valent aromatic ring group include an alkyl group, a cycloalkyl group, an aryl group, an amino group, an amido group, a ureido group, a urethane group, a hydroxyl group, a carboxyl group, a halogen atom,

an alkoxy group, a thioether group, an acyl group, an acyloxy group, an alkoxycarbonyl group, a cyano group, and a nitro group. The carbon number of the substituent is preferably 8 or less.

n is preferably 1 or 2, more preferably 1.

Each of n Y_2s independently represents a hydrogen atom or a group capable of leaving by the action of an acid, provided that at least one of n Y_2s represents a group capable of leaving by the action of an acid.

Examples of the group Y_2 capable of leaving by the action of an acid include -$C(R_{36})(R_{37})(R_{38})$, -$C(=O)$-O-$C(R_{36})(R_{37})(R_{38})$, -$C(R_{01})(R_{02})(OR_{39})$, -$C(R_{01})(R_{02})$-$C(=O)$-O-$C(R_{36})(R_{37})(R_{38})$ and -$CH(R_{36})(Ar)$.

In the formulae, each of R_{36} to R_{39} independently represents an alkyl group, a cycloalkyl group, a monovalent aromatic ring group, a group formed by combining an alkylene group and a monovalent aromatic ring group, or an alkenyl group. R_{36} and R_{37} may combine with each other to form a ring.

Each of R_{01} and R_{02} independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, a monovalent aromatic ring group, a group formed by combining an alkylene group and a monovalent aromatic ring group, or an alkenyl group.

Ar represents a monovalent aromatic ring group.

The alkyl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an alkyl group having a carbon number of 1 to 8, and examples thereof include a methyl group, an ethyl group, a propyl group, an n-butyl group, a sec-butyl group, a hexyl group, and an octyl group.

The cycloalkyl group of R_{36} to R_{39}, R_{01} and R_{02} may be monocyclic or polycyclic. The monocyclic cycloalkyl group is preferably a cycloalkyl group having a carbon number of 3 to 8, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cyclooctyl group. The polycyclic cycloalkyl group is preferably a cycloalkyl group having a carbon number of 6 to 20, and examples thereof include an adamantyl group, a norbornyl group, an isoboronyl group, a camphanyl group, a dicyclopentyl group, an α-pinel group, a tricyclodecanyl group, a tetracyclododecyl group, and an androstanyl group. Incidentally, a part of carbon atoms in the cycloalkyl group may be substituted with a heteroatom such as oxygen atom.

The monovalent aromatic ring group of R_{36} to R_{39}, R_{01}, R_{02} and Ar is preferably a monovalent aromatic ring group having a carbon number of 6 to 10, and examples thereof include an aryl group such as phenyl group, naphthyl group and anthranyl group, and a

divalent aromatic ring group containing a heterocyclic ring such as thiophene, furan, pyrrole, benzothiophene, benzofuran, benzopyrrole, triazine, imidazole, benzimidazole, triazole, thiadiazole and thiazole.

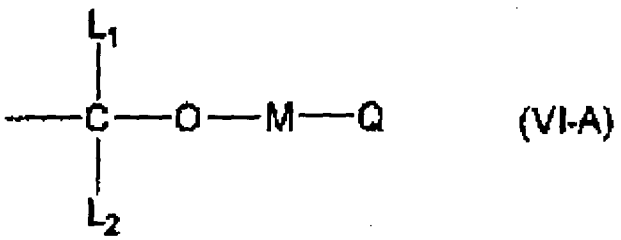
The group formed by combining an alkylene group and a monovalent aromatic ring group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an aralkyl group having a carbon number of 7 to 12, and examples thereof include a benzyl group, a phenethyl group, and a naphthylmethyl group.

The alkenyl group of R_{36} to R_{39}, R_{01} and R_{02} is preferably an alkenyl group having a carbon number of 2 to 8, and examples thereof include a vinyl group, an allyl group, a butenyl group, and a cyclohexenyl group.

The ring formed by combining R_{36} and R_{37} with each other may be either monocyclic or polycyclic. The monocyclic ring is preferably a cycloalkyl structure having a carbon number of 3 to 8, and examples thereof include a cyclopropane structure, a cyclobutane structure, a cyclopentane structure, a cyclohexane structure, a cycloheptane structure, and a cyclooctane structure. The polycyclic ring is preferably a cycloalkyl structure having a carbon number of 6 to 20, and examples thereof include an adamantane structure, a norbornane structure, a dicyclopentane structure, a tricyclodecane structure, and a tetracyclododecane structure. Incidentally, a part of carbon atoms in the cycloalkyl structure may be substituted with a heteroatom such as oxygen atom.

Each of the groups above as R_{36} to R_{39}, R_{01}, R_{02} and Ar may have a substituent, and examples of the substituent include an alkyl group, a cycloalkyl group, an aryl group, an amino group, an amido group, a ureido group, a urethane group, a hydroxyl group, a carboxyl group, a halogen atom, an alkoxy group, a thioether group, an acyl group, an acyloxy group, an alkoxycarbonyl group, a cyano group, and a nitro group. The carbon number of the substituent is preferably 8 or less.

The group Y_2 capable of leaving by the action of an acid is more preferably a structure represented by the following formula (VI-A):



(VI-A)

In the formula, each of L_1 and L_2 independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, a monovalent aromatic ring group, or a group formed by

combining an alkylene group and a monovalent aromatic ring group.

M represents a single bond or a divalent linking group.

Q represents an alkyl group, a cycloalkyl group which may contain a heteroatom, a monovalent aromatic ring group which may contain a heteroatom, an amino group, an ammonium group, a mercapto group, a cyano group, or an aldehyde group.

At least two members of Q, M and L_1 may combine to form a ring (preferably a 5- or 6-membered ring).

The alkyl group as L_1 and L_2 is, for example, an alkyl group having a carbon number of 1 to 8, and specific preferred examples thereof include a methyl group, an ethyl group, a propyl group, an n-butyl group, a sec-butyl group, a hexyl group, and an octyl group.

The cycloalkyl group as L_1 and L_2 is, for example, a cycloalkyl group having a carbon number of 3 to 15, and specific preferred examples thereof include a cyclopentyl group, a cyclohexyl group, a norbornyl group, and an adamantyl group.

The monovalent aromatic ring group as L_1 and L_2 is, for example, an aryl group having a carbon number of 6 to 15, and specific preferred examples thereof include a phenyl group, a tolyl group, a naphthyl group, and an anthryl group.

The group as L_1 and L_2 formed by combining an alkylene group and a monovalent aromatic ring group is, for example, an aralkyl group having a carbon number of 6 to 20, such as benzyl group and phenethyl group.

Examples of the divalent linking group as M include an alkylene group (e.g., methylene group, ethylene group, propylene group, butylenes group, hexylene group, octylene group), a cycloalkylene group (e.g., cyclopentylene group, cyclohexylene group, adamantylene group), an alkenylene group (e.g., ethenylene group, propenylene group, butenylene group), a divalent aromatic ring group (e.g., phenylene group, tolylene group, naphthylene group), -S-, -O-, -CO-, $-SO_2-$, $-N(R_0)-$, and a divalent linking group formed by combining a plurality of these members. R_0 is a hydrogen atom or an alkyl group (for example, an alkyl group having a carbon number of 1 to 8, and specifically, a methyl group, an ethyl group, a propyl group, an n-butyl group, a sec-butyl group, a hexyl group, an octyl group or the like).

Examples of the alkyl group as Q are the same as those of respective groups as L_1 and L_2.

Examples of the heteroatom-free aliphatic hydrocarbon ring group and heteroatom-free monovalent aromatic ring group in the cycloalkyl group as Q which may contain a

heteroatom and the monovalent aromatic ring group as Q which may contain a heteroatom include the above-described cycloalkyl group and monovalent aromatic ring group as L_1 and L_2, and the carbon number thereof is preferably from 3 to 15.

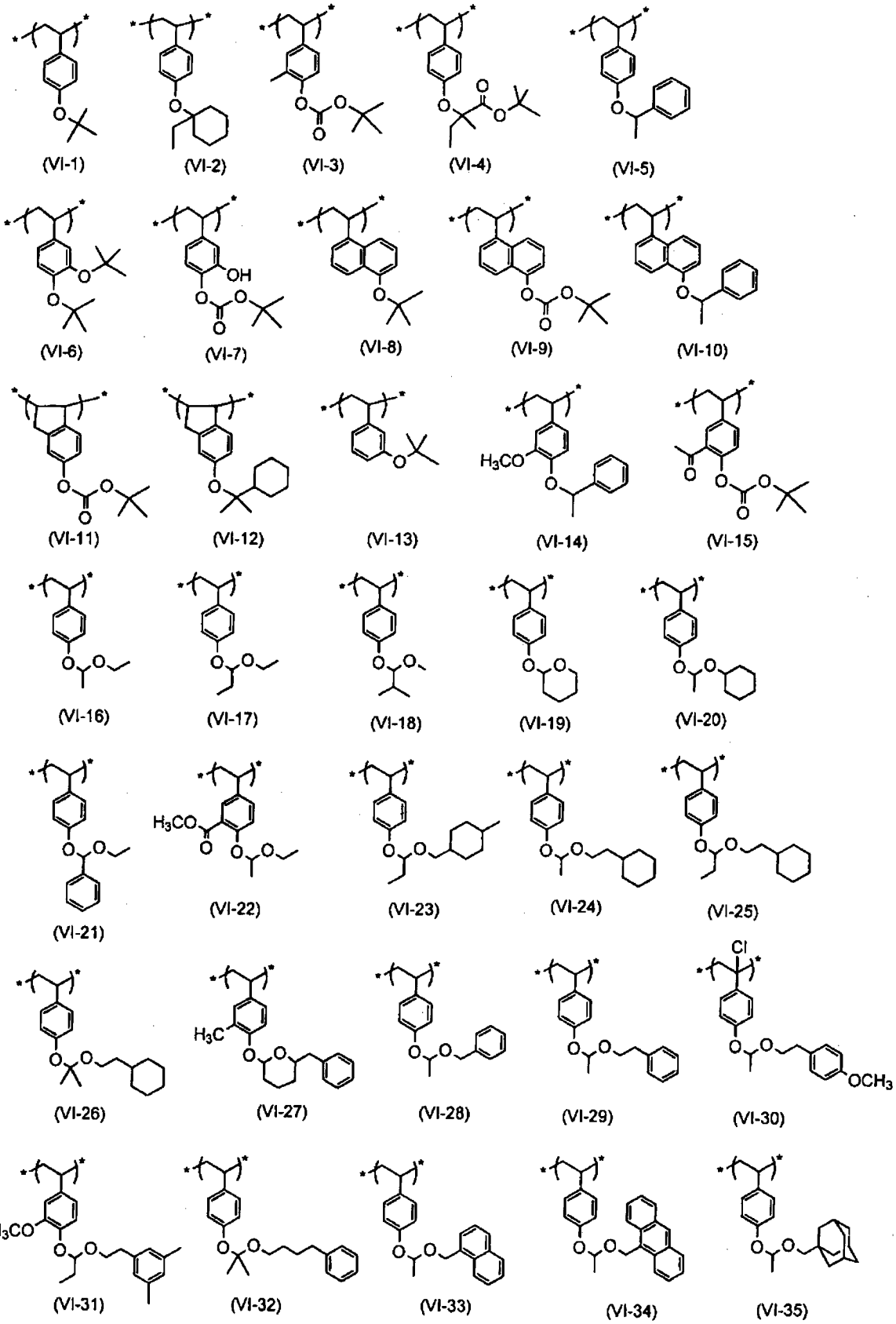
Examples of the heteroatom-containing cycloalkyl group and heteroatom-containing monovalent aromatic ring group include a group having a heterocyclic structure such as thiirane, cyclothiolane, thiophene, furan, pyrrole, benzothiophene, benzofuran, benzopyrrole, triazine, imidazole, benzimidazole, triazole, thiadiazole, thiazole and pyrrolidone, but the group is not limited thereto as long as it is a structure generally called a heterocyclic ring (a ring composed of carbon and a heteroatom or a ring composed of a heteroatom).

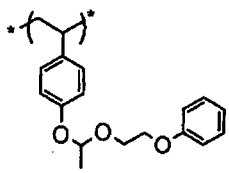
As for the ring which may be formed by combining at least two members out of Q, M and L_1, there is a case where at least two members out of Q, M and L_1 are combined to form, for example, a propylene group or a butylene group, thereby forming a 5- or 6-membered ring containing oxygen atom.

In formula (VI-A), each of the groups represented by L_1, L_2, M and Q may have a substituent, and examples of the substituent include those described above as the substituent which may be substituted on R_{36} to R_{39}, R_{01}, R_{02} and Ar. The carbon number of the substituent is preferably 8 or less.

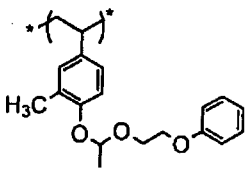
The group represented by -M-Q is preferably a group having a carbon number of 1 to 30, more preferably a group having a carbon number of 5 to 20.

Specific preferred examples of the repeating unit represented by formula (VI) are illustrated below, but the present invention is not limited thereto.

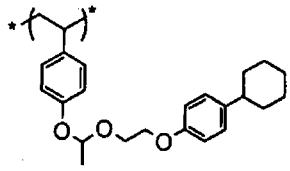

(VI-1)
(VI-2)
(VI-3)
(VI-4)
(VI-5)
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(VI-35)



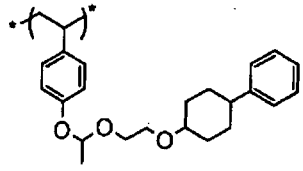
(VI-36)



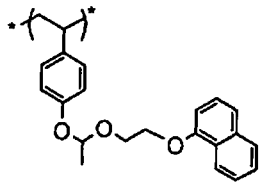
(VI-37)



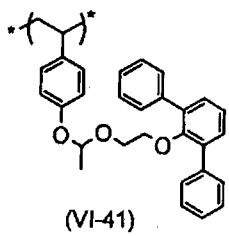
(VI-38)



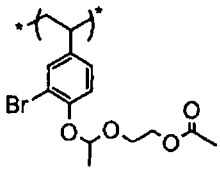
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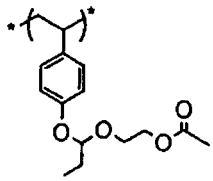
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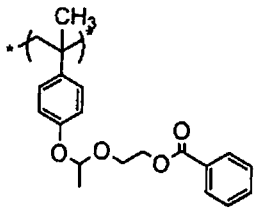
(VI-41)



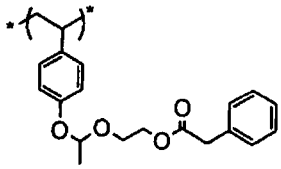
(VI-42)



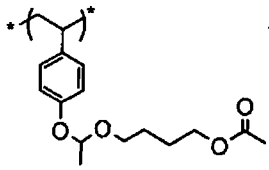
(VI-43)



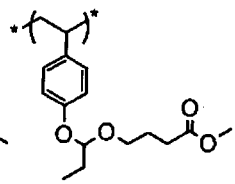
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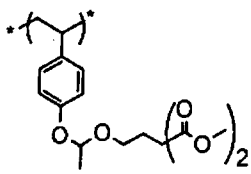
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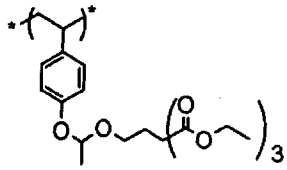
(VI-46)



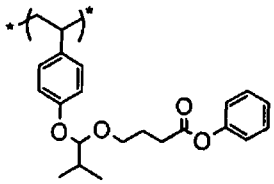
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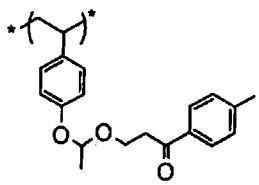
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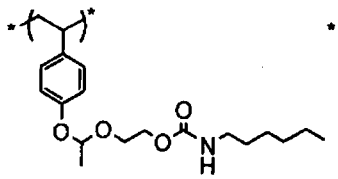
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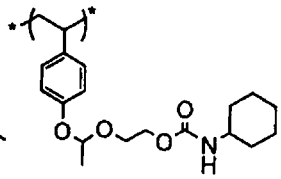
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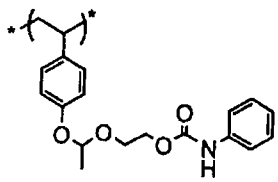
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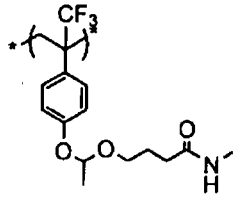
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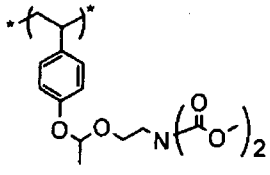
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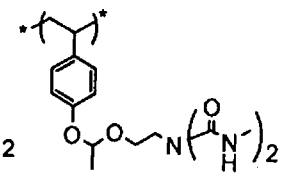
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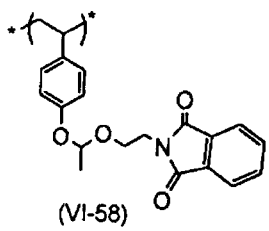
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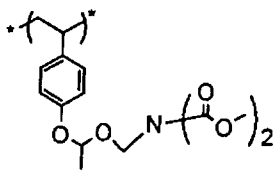
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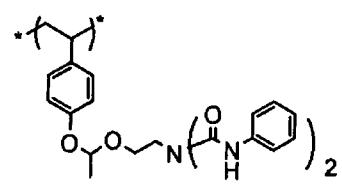
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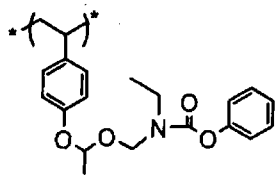
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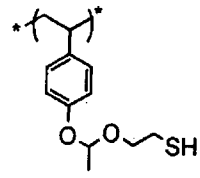
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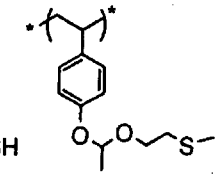
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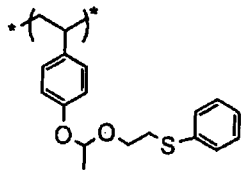
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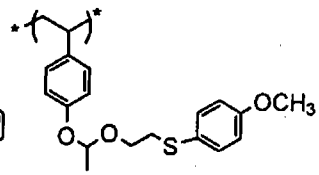
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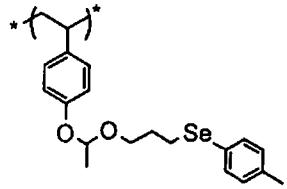
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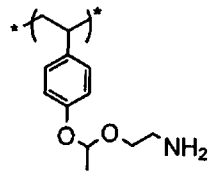
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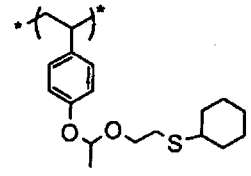
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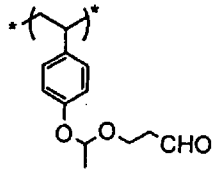
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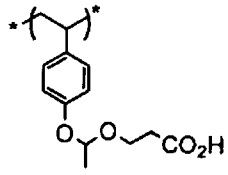
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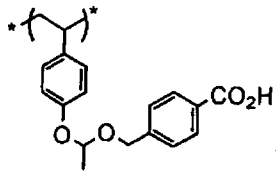
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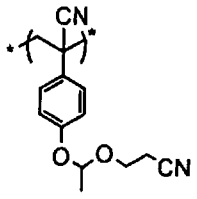
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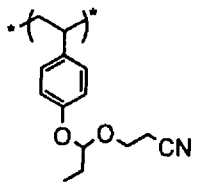
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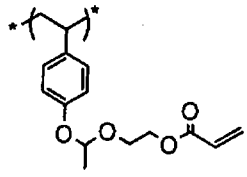
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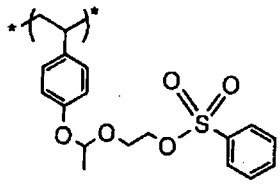
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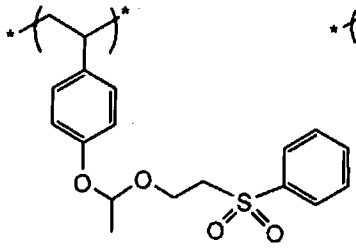
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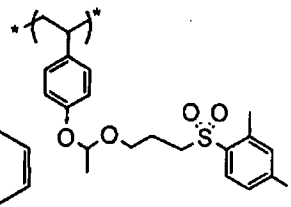
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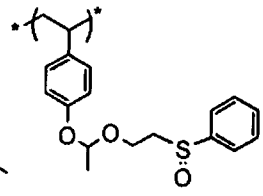
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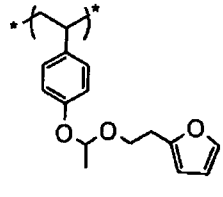
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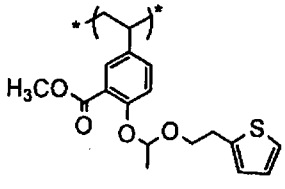
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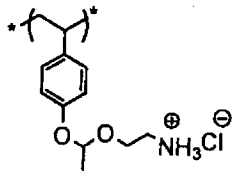
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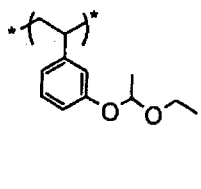
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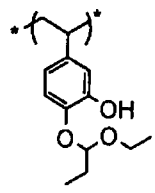
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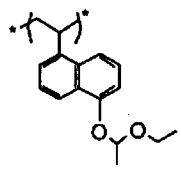
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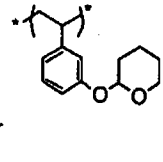
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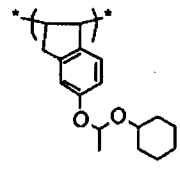
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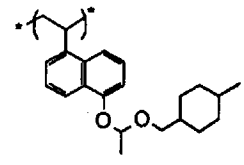
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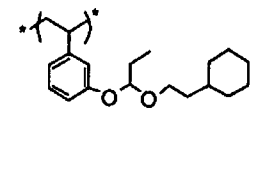
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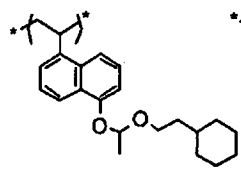
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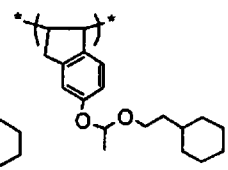
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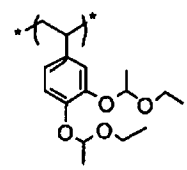
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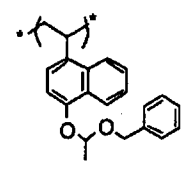
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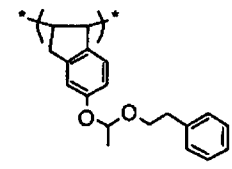
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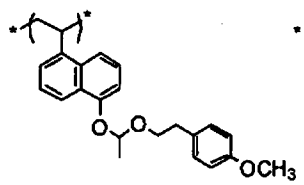
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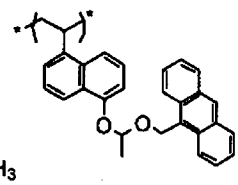
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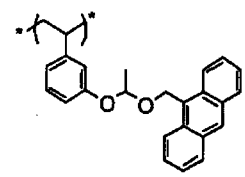
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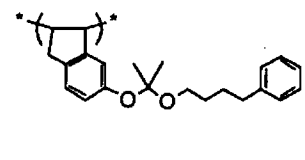
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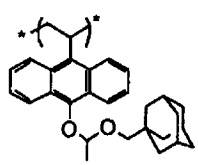
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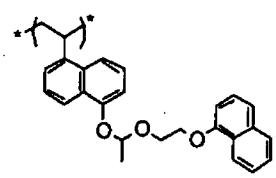
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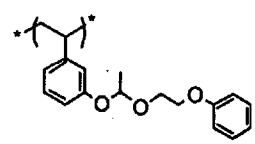
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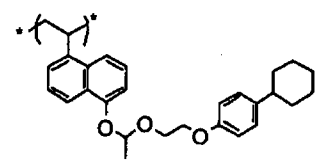
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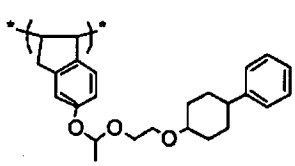
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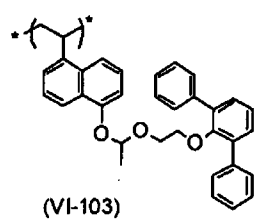
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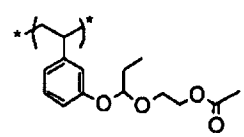
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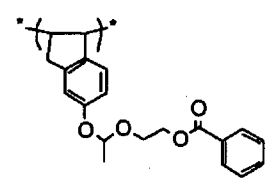
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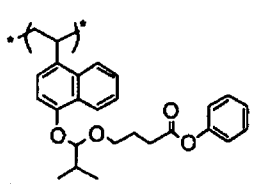
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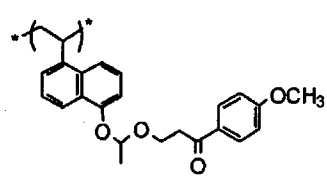
(VI-104)



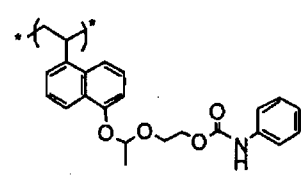
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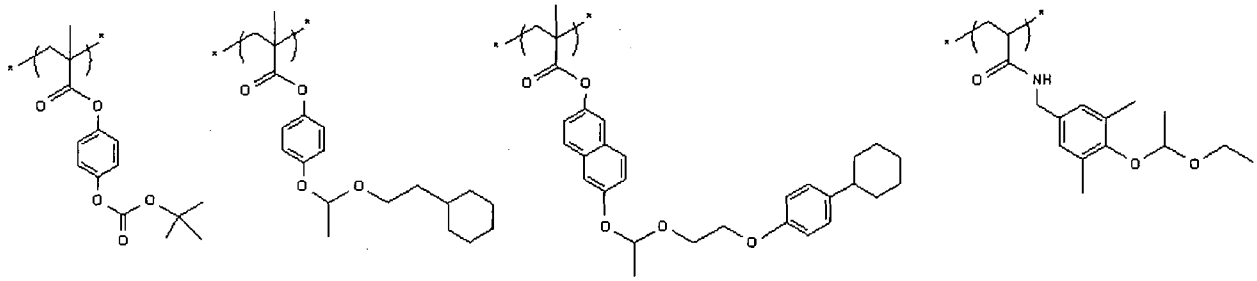
(VI-106)



(VI-107)



(VI-108)



(VI-113) (VI-114) (VI-115) (VI-116)

As for the acid-decomposable group-containing repeating unit of preferred embodiment (1) contained in the resin (A-1) or (A-2), one kind of a repeating unit may be used, or two or more kinds of repeating units may be used in combination.

Also in the resin embodiment that can be preferably applied to KrF exposure, the content of the acid-decomposable group-containing repeating unit (in the case of containing a plurality of kinds, as the total thereof) in the resin (A-1) is, similarly to the above, 20 mol% or less, preferably 15 mol% or less, more preferably 10 mol% or less, still more preferably 5 mol% or less, based on all repeating units in the resin, and the content is ideally 0 mol%, that is, it is particularly preferred not to contain a repeating unit having an acid-decomposable group.

Furthermore, in the resin embodiment that can be preferably applied to KrF exposure, from the standpoint of enhancing the dissolution contrast by sufficiently reducing the solubility of the exposed area for an organic developer and at the same time, maintaining adequate solubility of the unexposed area, the content of the acid-decomposable group-containing repeating unit (in the case of containing a plurality of kinds, as the total thereof) of preferred embodiment (1) (preferably the repeating unit represented by formula (III)) in the resin (A-2) is preferably from 20 to 90 mol%, more preferably from 25 to 85 mol%, still more preferably from 30 to 80 mol%, based on all repeating units in the resin (A-2).

In particular, from the standpoint of more reliably forming a practically satisfactory pattern not only in the second film (upper layer) formed of the resin (A-2) but also in the first film (lower layer) formed together with the upper layer, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-2) is preferably larger than the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-1). Specifically, in the case where the resin (A-1) contains a repeating unit having an acid-decomposable group, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units

in the resin (A-2) is preferably as large as 3 times or more, more preferably from 3 to 10 times, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-1).

[Preferred Embodiment (2) of Acid-Decomposable Group-Containing Repeating Unit]

The resin (A-1) contained in the resin composition (I) preferably contains no acid-decomposable group-containing repeating unit as described above, but in the case where the resin (A-1) contains a repeating unit having an acid-decomposable group, and in the case where the resin (A-2) contained in the resin composition (II) contains a repeating unit having an acid-decomposable group, in another embodiment of the present invention, the resin contains an acid-decomposable group-containing repeating unit of preferred embodiment (2) described below.

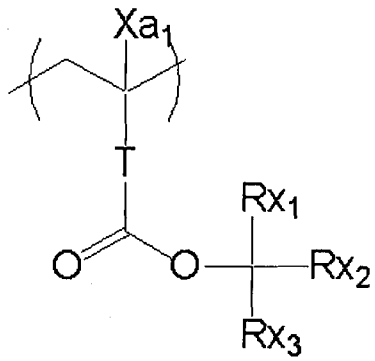
The acid-decomposable group-containing repeating unit of preferred embodiment (2) is not particularly limited in the exposure light source such as KrF excimer laser and ArF excimer laser but is preferably applied to ArF exposure.

Preferred embodiment (2) of the acid-decomposable group-containing repeating unit that can be preferably applied to ArF exposure includes a repeating unit represented by the following formula (AI) and a repeating unit represented by formula (AAI) shown later.

Here, with respect to the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II), the resin embodiment that can be preferably applied to ArF exposure is preferably a resin typically containing a (meth)acrylate-based repeating unit. With respect to the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II), in the resin embodiment that can be preferably applied to ArF exposure, the content of the (meth)acrylate-based repeating unit is usually 50 mol% or more, preferably 75 mol% or more, based on all repeating units in the resin. A resin where all repeating units are composed of a (meth)acrylate-based repeating unit is more preferred.

The resin embodiment that can be preferably applied to ArF exposure is more preferably a resin composed of at least one acid-decomposable group-containing repeating unit selected from the group consisting of a repeating unit represented by the following formula (AI) and a repeating unit represented by formula (AAI) shown later, and, if desired, at least one repeating unit selected from respective repeating units described later in [Other Repeating Units].

One of the acid-decomposable group-containing repeating units of preferred embodiment (2) which can be incorporated into the resin (A-1) contained in the resin composition (I) and into the resin (A-2) contained in the resin composition (II) is a repeating unit represented by the following formula (AI):



(AI)

In formula (AI), Xa_1 represents a hydrogen atom, a methyl group which may have a substituent, or a group represented by $-CH_2-R_9$. R_9 represents a hydroxyl group or a monovalent organic group. The monovalent organic group includes, for example, an alkyl group having a carbon number of 5 or less, and an acyl group having a carbon number of 5 or less, and is preferably an alkyl group having a carbon number of 3 or less, more preferably a methyl group. Xa_1 is preferably a hydrogen atom, a methyl group, a trifluoromethyl group, or a hydroxymethyl group.

T represents a single bond or a divalent linking group.

Each of Rx_1 to Rx_3 independently represents an alkyl group (linear or branched) or a cycloalkyl group (monocyclic or polycyclic).

Two members out of Rx_1 to Rx_3 may combine to form a cycloalkyl group (monocyclic or polycyclic).

Examples of the divalent linking group of T include an alkylene group, a -COO-Rt- group, and a -O-Rt- group. In the formulae, Rt represents an alkylene group or a cycloalkylene group.

T is preferably a single bond or a -COO-Rt- group, more preferably a single bond. Rt is preferably an alkylene group having a carbon number of 1 to 5, more preferably a $-CH_2-$ group, $-(CH_2)_2-$ group, or a $-(CH_2)_3-$ group.

The alkyl group of Rx_1 to Rx_3 is preferably an alkyl group having a carbon number of 1 to 4, such as methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group and tert-butyl group.

The cycloalkyl group of Rx_1 to Rx_3 is preferably a monocyclic cycloalkyl group

such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group.

The cycloalkyl group formed by combining two members out of Rx_1 to Rx_3 is preferably a monocyclic cycloalkyl group such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group, more preferably a monocyclic cycloalkyl group having a carbon number of 5 to 6.

An embodiment where Rx_1 is a methyl group or an ethyl group and Rx_2 and Rx_3 are combined to form the above-described cycloalkyl group is also preferred.

Above all, each of Rx_1 to Rx_3 is independently, preferably a linear or branched alkyl group and is preferably a linear or branched alkyl group having a carbon number of 1 to 4, and examples thereof include a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, and a tert-butyl group.

In the case where each of Rx_1 to Rx_3 is independently a linear or branched alkyl group, Rx_1 is preferably a methyl group, an ethyl group, an n-propyl group or an n-butyl group, more preferably a methyl group or an ethyl group, still more preferably a methyl group. Rx_2 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group or an n-butyl group, more preferably a methyl group or an ethyl group, still more preferably a methyl group. Rx_3 is preferably a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group or a tert-butyl group, more preferably a methyl group, an ethyl group, an isopropyl group or an isobutyl group, still more preferably a methyl group, an ethyl group or an isopropyl group.

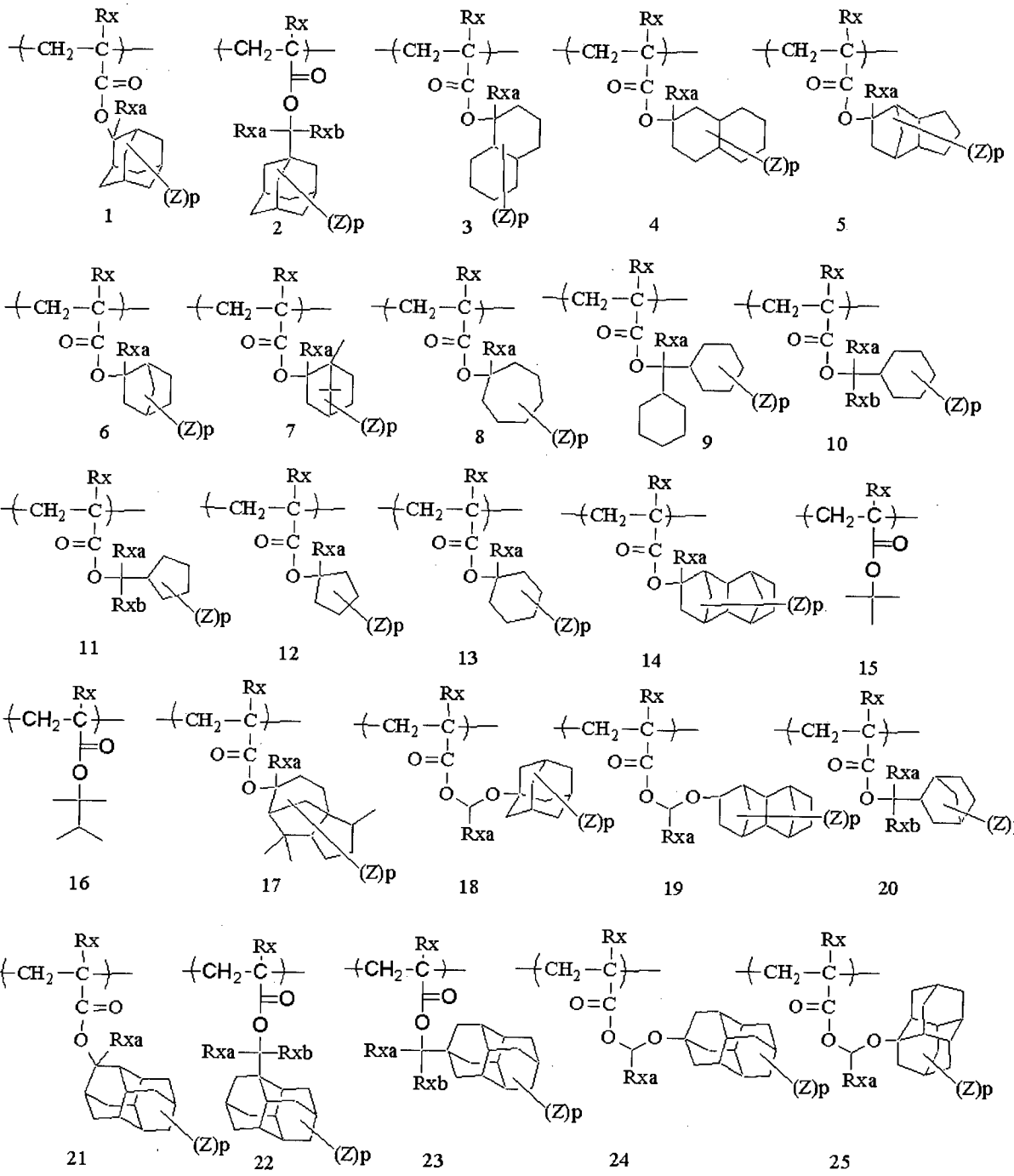
In the case where T is a single bond and at the same time, each of Rx_1 to Rx_3 is independently a linear or branched alkyl group (in this case, two members out of Rx_1 to Rx_3 do not combine to form a cycloalkyl group), the pattern forming method can ensure that the roughness performance, the uniformity of local pattern dimension and the exposure latitude are more excellent and the reduction in film thickness of the pattern part formed by exposure, so-called film loss, is more suppressed.

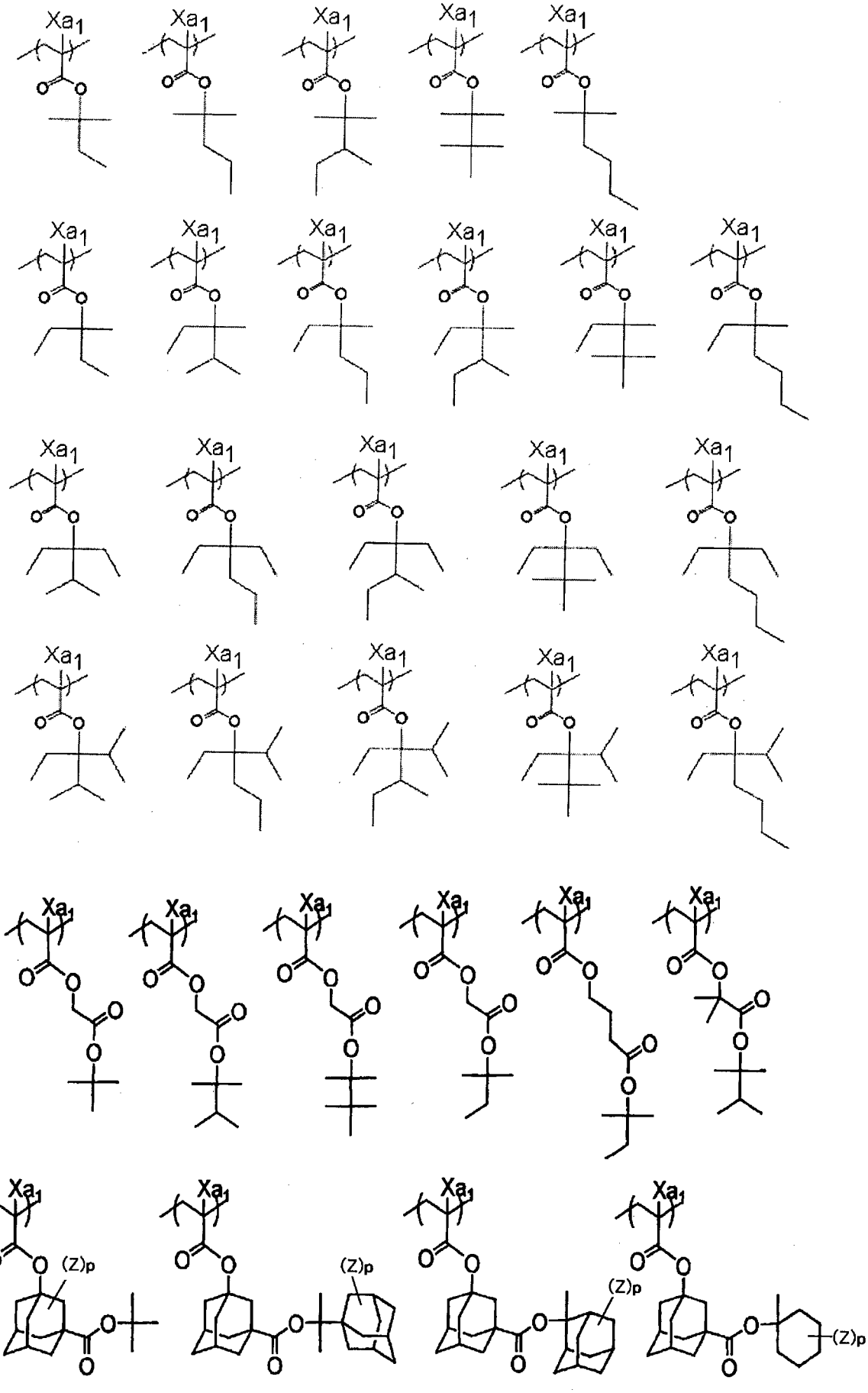
Each of the groups above may have a substituent, and examples of the substituent include an alkyl group (having a carbon number of 1 to 4), a halogen atom, a hydroxyl group, an alkoxy group (having a carbon number of 1 to 4), a carboxyl group, and an alkoxycarbonyl group (having a carbon number of 2 to 6). The carbon number is preferably 8 or less. Above all, from the standpoint of more enhancing the dissolution contrast for an organic

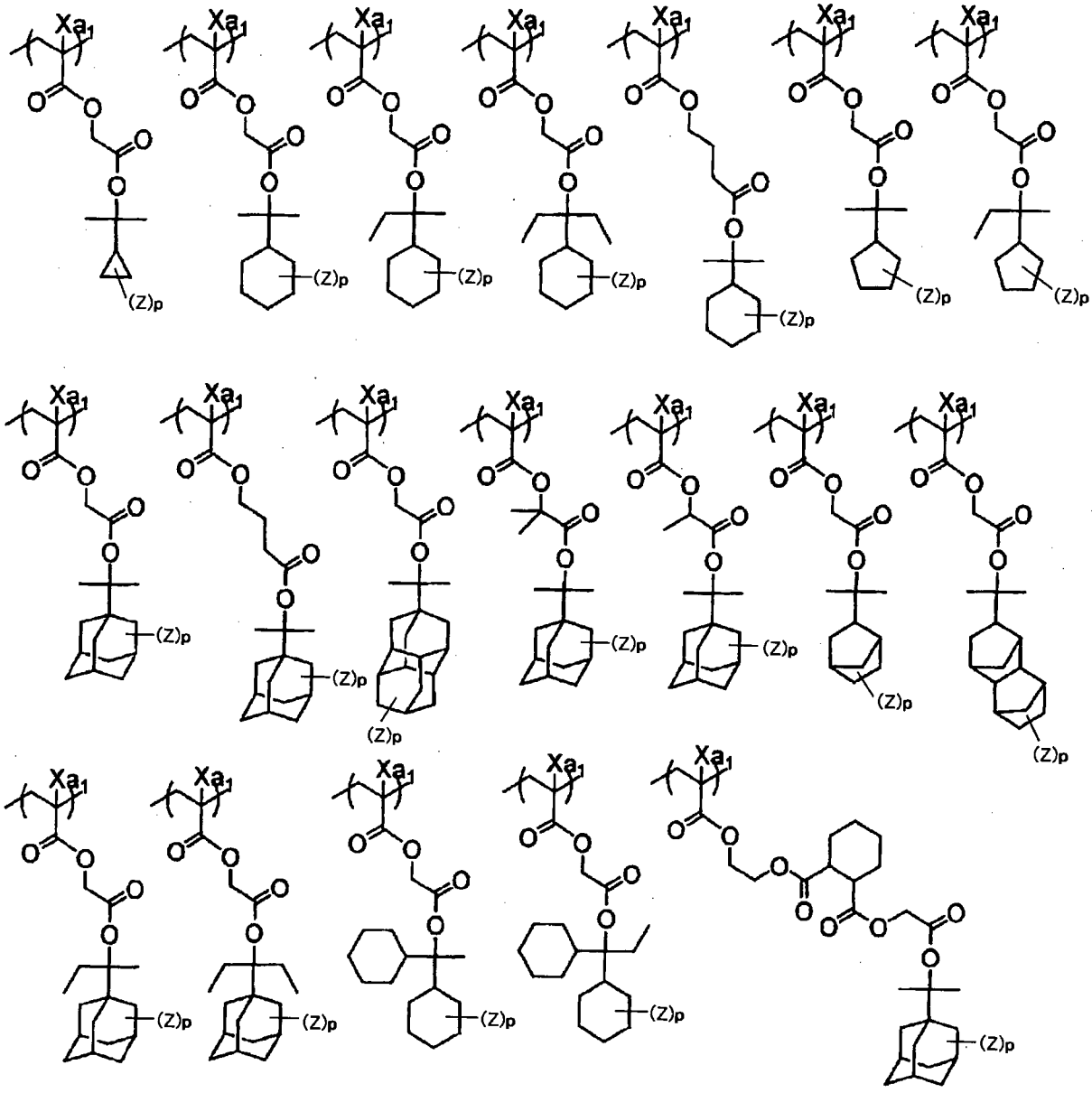
solvent-containing developer between before and after acid decomposition, the substituent is preferably a group free from a heteroatom such as oxygen atom, nitrogen atom and sulfur atom (for example, preferably not an alkyl group substituted with a hydroxyl group), more preferably a group composed of only a hydrogen atom and a carbon atom, still more preferably a linear or branched alkyl group or a cycloalkyl group.

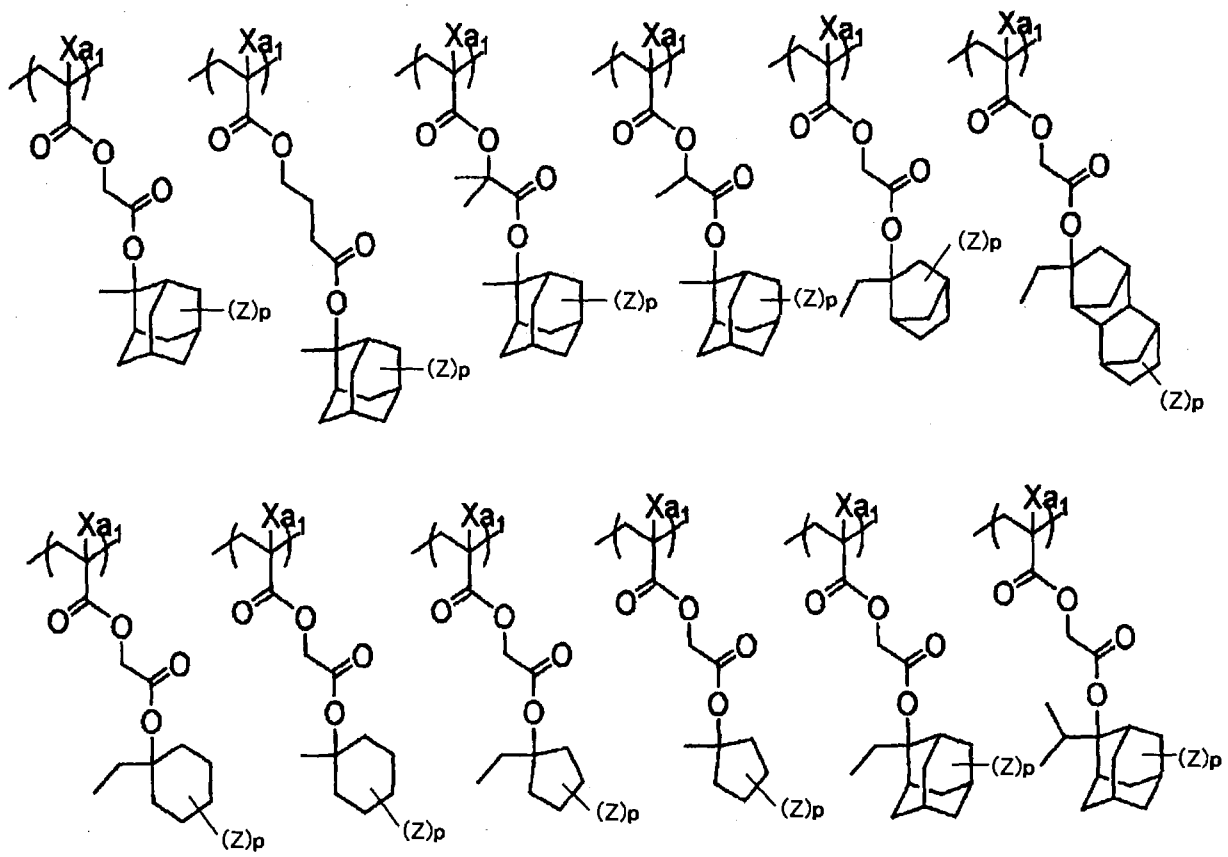
Specific examples of the acid-decomposable group-containing repeating unit of preferred embodiment (2) are illustrated below, but the present invention is not limited thereto.

In specific examples, each of Rx and Xa_1 represents a hydrogen atom, CH_3, CF_3 or CH_2OH, and each of Rxa and Rxb represents an alkyl group having a carbon number of 1 to 4. Z represents a substituent, and when a plurality of Z's are present, each Z may be the same as or different from every other Z. p represents 0 or a positive integer. Specific examples and preferred examples of Z are the same as specific examples and preferred examples of the substituent which may be substituted on each of the groups such as Rx_1 to Rx_3.

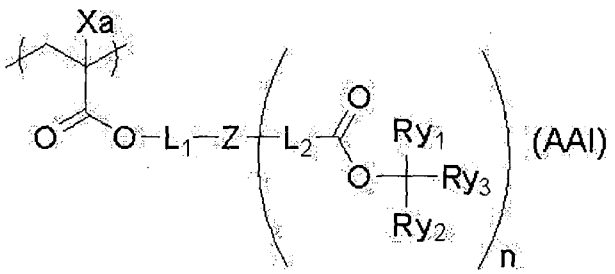

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Xa1
(Z)p





A repeating unit capable of decomposing by the action of an acid to produce a carboxyl group, represented by the following formula (AAI), is also one of the acid-decomposable group-containing repeating units of preferred embodiment (2). Thanks to this repeating, the pattern forming method can ensure that the roughness performance such as line width roughness, the uniformity of local pattern dimension and the exposure latitude are more excellent and the reduction in film thickness of the pattern part formed by development, so-called film loss, is more suppressed.



In the formula, Xa represents a hydrogen atom, an alkyl group, a cyano group or a halogen atom.

Each of Ry_1 to Ry_3 independently represents an alkyl group or a cycloalkyl group,

and two members out of Ry_1 to Ry_3 may combine to form a ring.

Z represents a (n+1)-valent linking group having a polycyclic hydrocarbon structure which may have a heteroatom as a ring member.

Each of L_1 and L_2 independently represents a single bond or a divalent linking group.

n represents an integer of 1 to 3.

When n is 2 or 3, each L_2, each Ry_1, each Ry_2 and each Ry_3 may be the same as or different from every other L_2, Ry_1, Ry_2 and Ry_3, respectively.

The alkyl group of Xa may have a substituent, and examples of the substituent include a hydroxyl group and a halogen atom (preferably, fluorine atom).

The alkyl group of Xa is preferably an alkyl group having a carbon number of 1 to 4, and examples thereof include a methyl group, an ethyl group, a propyl group, a hydroxymethyl group, and a trifluoromethyl group, with a methyl group being preferred.

Xa is preferably a hydrogen atom or a methyl group.

The alkyl group of Ry_1 to Ry_3 may be chain or branched and is preferably an alkyl group having a carbon number of 1 to 4, such as methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group and tert-butyl group.

The cycloalkyl group of Ry_1 to Ry_3 is preferably a monocyclic cycloalkyl group such as cyclopentyl group and cyclohexyl group, or a polycyclic cycloalkyl group such as norbornyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group.

The ring formed by combining two members out of Ry_1 to Ry_3 is preferably a monocyclic hydrocarbon ring such as cyclopentane ring and cyclohexane ring, or a polycyclic hydrocarbon ring such as norbornane ring, tetracyclodecane ring, tetracyclododecane ring and adamantane ring, more preferably a monocyclic hydrocarbon ring having a carbon number of 5 to 6.

Each of Ry_1 to Ry_3 is independently preferably an alkyl group, more preferably a chain or branched alkyl group having a carbon number of 1 to 4. Also, the total of the carbon numbers of the chain or branched alkyl groups as Ry_1 to Ry_3 is preferably 5 or less.

Each of Ry_1 to Ry_3 may further have a substituent, and examples of the substituent include an alkyl group (having a carbon number of 1 to 4), a cycloalkyl group (having a carbon number of 3 to 8), a halogen atom, an alkoxy group (having a carbon number of 1 to 4), a carboxyl group, and an alkoxycarbonyl group (having a carbon number of 2 to 6). The carbon number is preferably 8 or less. Above all, from the standpoint of more enhancing the dissolution contrast for an organic solvent-containing developer between before and after acid

decomposition, the substituent is preferably a group free from a heteroatom such as oxygen atom, nitrogen atom and sulfur atom (for example, preferably not an alkyl group substituted with a hydroxyl group), more preferably a group composed of only a hydrogen atom and a carbon atom, still more preferably a linear or branched alkyl group or a cycloalkyl group.

The linking group having a polycyclic hydrocarbon structure of Z includes a ring-assembly hydrocarbon ring group and a crosslinked cyclic hydrocarbon ring group, and these groups include a group obtained by removing arbitrary (n+1) hydrogen atoms from a ring-assembly hydrocarbon ring and a group obtained by removing arbitrary (n+1) hydrogen atoms from a crosslinked cyclic hydrocarbon ring, respectively.

Examples of the ring-assembly hydrocarbon ring group include a bicyclohexane ring group and a perhydronaphthalene ring group. Examples of the crosslinked cyclic hydrocarbon ring group include a bicyclic hydrocarbon ring group such as pinane ring group, bornane ring group, norpinane ring group, norbornane ring group and bicyclooctane ring group (e.g., bicyclo[2.2.2]octane ring group, bicyclo[3.2.1]octane ring group), a tricyclic hydrocarbon ring group such as homobledane ring group, adamantane ring group, tricyclo[5.2.1.$0^{2,6}$]decane ring group and tricyclo[4.3.1.$1^{2,5}$]undecane ring group, and a tetracyclic hydrocarbon ring group such as tetracyclo[4.4.0.$1^{2,5}$.$1^{7,10}$]dodecane ring group and perhydro-1,4-methano-5,8-methanonaphthalene ring group. The crosslinked cyclic hydrocarbon ring group also includes a condensed cyclic hydrocarbon ring group, for example, a condensed ring group obtained by fusing a plurality of 5- to 8-membered cycloalkane ring groups, such as perhydronaphthalene (decalin) ring group, perhydroanthracene ring group, perhydrophenathrene ring group, perhydroacenaphthene ring group, perhydrofluorene ring group, perhydroindene ring group and perhydrophenalene ring group.

Preferred examples of the crosslinked cyclic hydrocarbon ring group include a norbornane ring group, an adamantane ring group, a bicyclooctane ring group, and a tricycle[5,2,1,$0^{2,6}$]decane ring group. Of these crosslinked cyclic hydrocarbon ring groups, a norbornane ring group and an adamantane ring group are more preferred.

The linking group having a polycyclic hydrocarbon structure represented by Z may have a substituent. Examples of the substituent which may be substituted on Z include a substituent such as alkyl group, hydroxyl group, cyano group, keto group (=O), acyloxy group, -COR, -COOR, -CON$(R)_2$, -SO_2R, -SO_3R and -SO_2N$(R)_2$, wherein R represents a hydrogen atom, an alkyl group, a cycloalkyl group or an aryl group.

The alkyl group, alkylcarbonyl group, acyloxy group, -COR, -COOR, -CON$(R)_2$, -

SO_2R, $-SO_3R$ and $-SO_2N(R)_2$ as the substituent which Z may have may further have a substituent, and this substituent includes a halogen atom (preferably, fluorine atom).

In the linking group having a polycyclic hydrocarbon structure represented by Z, the carbon constituting the polycyclic ring (the carbon contributing to ring formation) may be carbonyl carbon. Also, as described above, the polycyclic ring may have, as a ring member, a heteroatom such as oxygen atom and sulfur atom.

Examples of the linking group represented by L_1 and L_2 include -COO-, -OCO-, -CONH-, -NHCO-, -CO-, -O-, -S-, -SO-, $-SO_2-$, an alkylene group (preferably having a carbon number of 1 to 6), a cycloalkylene group (preferably having a carbon number of 3 to 10), an alkenylene group (preferably having a carbon number of 2 to 6), and a linking group formed by combining a plurality of these members, and a linking group having a total carbon number of 12 or less is preferred.

L_1 is preferably a single bond, an alkylene group, -COO-, -OCO-, -CONH-, -NHCO-, -alkylene group-COO-, -alkylene group-OCO-, -alkylene group-CONH-, -alkylene group-NHCO-, -CO-, -O-, $-SO_2-$, or -alkylene group-O-, more preferably a single bond, an alkylene group, -alkylene group-COO-, or -alkylene group-O-.

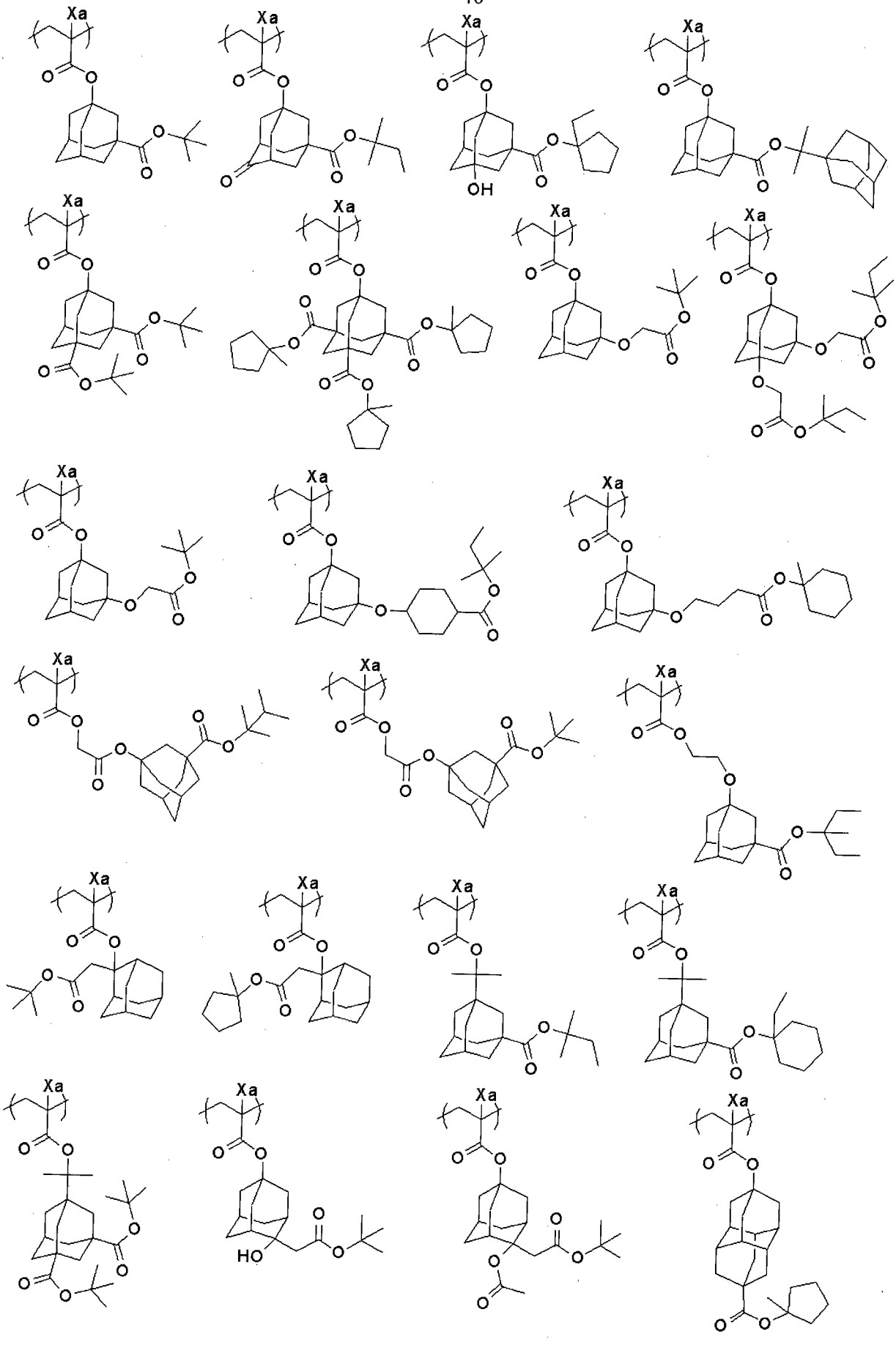
L_2 is preferably a single bond, an alkylene group, -COO-, -OCO-, -CONH-, -NHCO-, -COO-alkylene group-, -OCO-alkylene group-, -CONH-alkylene group-, -NHCO-alkylene group-, -CO-, -O-, $-SO_2-$, -O-alkylene group-, or -O-cycloalkylene group-, more preferably a single bond, an alkylene group, -COO-alkylene group-, -O-alkylene group-, or -O-cycloalkylene group-.

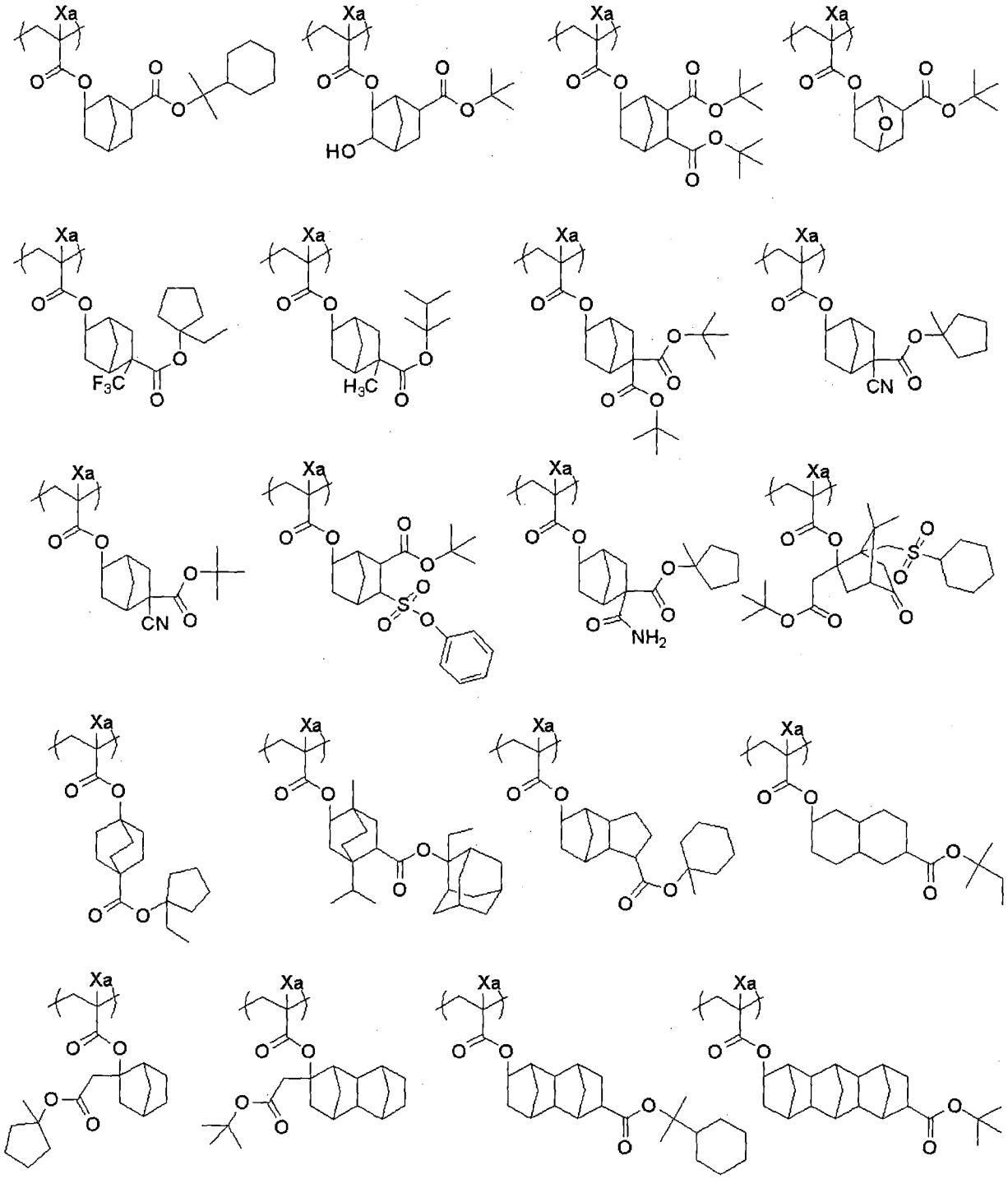
In the descriptions above, the bond "-" at the left end means to be bonded to the ester bond on the main chain side in L_1 and bonded to Z in L_2, and the bond "-" at the right end means to be bonded to Z in L_1 and bonded to the ester bond connected to the group represented by $(Ry_1)(Ry_2)(Ry_3)C-$ in L_2.

Incidentally, L_1 and L_2 may be bonded to the same atom constituting the polycyclic ring in Z.

n is preferably 1 or 2, more preferably 1.

Specific examples of the repeating unit represented by formula (AAI) are illustrated below, but the present invention is not limited thereto. In specific examples, Xa represents a hydrogen atom, an alkyl group, a cyano group or a halogen atom.





As for the acid-decomposable group-containing repeating unit of preferred embodiment (2) contained in the resin (A-1) or (A-2), one kind may be used, or two or more kinds may be used in combination.

In the present invention, the resin (A-2) as the resin embodiment that can be preferably applied to ArF exposure preferably contains the acid-decomposable group-containing repeating unit in which the molecular weight of the eliminated material produced

by the decomposition of the group capable of decomposing by the action of an acid to produce a polar group (acid-decomposable group) (in the case of producing a plurality of kinds of eliminated materials, the weighted average value of molecular weights by molar fraction (hereinafter, sometimes referred to as a "molar average value")) is 140 or less, in an amount (in the case of containing a plurality of kinds, as the total) of 50 mol% or more based on all repeating units in the resin. In the case of forming a negative image, the exposed area remains as a pattern and therefore, by letting the eliminated material have a small molecular weight, reduction in film thickness of the pattern part can be prevented.

In the present invention, the "eliminated material produced by the decomposition of an acid-decomposable group" indicates a material which corresponds to a group capable of decomposing and leaving by the action of an acid and is decomposed and eliminated by the action of an acid. For example, in the case of the later-described repeating unit (α) (in examples illustrated later, the upper leftmost repeating unit), the eliminated material indicates alkane ($H_2C=C(CH_3)_2$) produced by the decomposition of the tert-butyl moiety.

In the present invention, the molecular weight of the eliminated material produced by the decomposition of the acid-decomposable group (in the case of producing a plurality of kinds of eliminated materials, the molar average value) is preferably 100 or less from the standpoint of preventing reduction in film thickness of the pattern part.

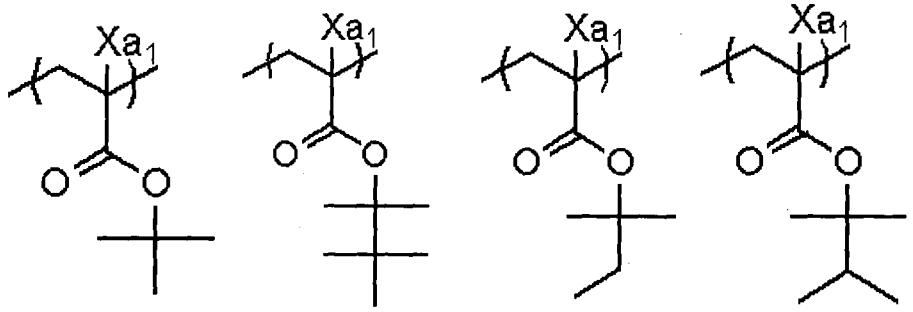
The lower limit of the molecular weight of the eliminated material produced by the decomposition of the acid-decomposable group (in the case of producing a plurality of kinds of eliminated materials, the average value thereof) is not particularly limited, but from the standpoint of letting the acid-decomposable group exert its function, the lower limit is preferably 45 or more, more preferably 55 or more.

In the present invention, in the light of more reliably maintaining the film thickness of the pattern part that is the exposed area, the resin (A-2) as the resin embodiment that can be preferably applied to ArF exposure more preferably contains the acid-decomposable group-containing repeating unit in which the molecular weight of the eliminated material produced by the decomposition of the acid-decomposable group is 140 or less, in an amount (in the case of containing a plurality of kinds, as the total) of 60 mol% or more, still more preferably 65 mol% or more, yet still more preferably 70 mol% or more, based on all repeating units in the resin. The upper limit is not particularly limited but is preferably 90 mol% or less, more preferably 85 mol% or less.

Specific examples of the acid-decomposable group-containing repeating unit of

preferred embodiment (2) in which the molecular weight of the eliminated material produced by the decomposition of the acid-decomposable group is 140 or less, are illustrated below, but the present invention is not limited thereto.

In specific examples, Xa_1 represents a hydrogen atom, CH_3, CF_3 or CH_2OH.



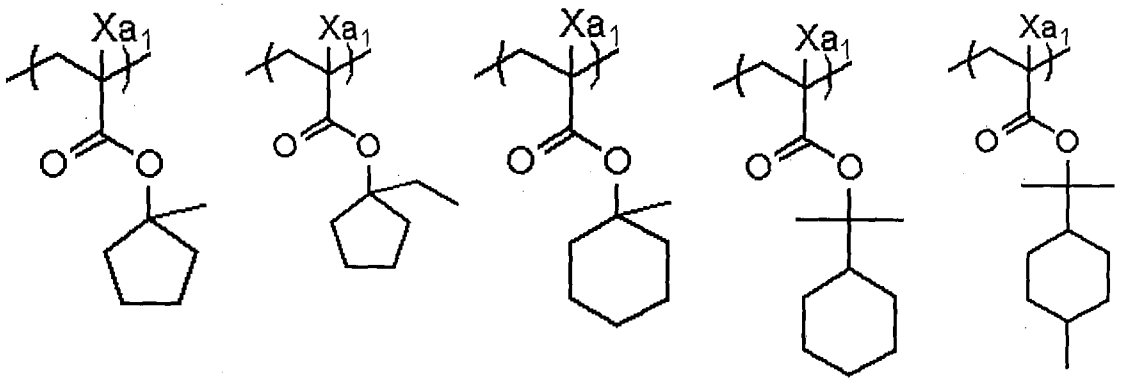
Repeating Unit (α)

Molecular weight of eliminated material: 56

Molecular weight of eliminated material: 98

Molecular weight of eliminated material: 70

Molecular weight of eliminated material: 84



Molecular weight of eliminated material: 82

Molecular weight of eliminated material: 96

Molecular weight of eliminated material: 96

Molecular weight of eliminated material: 124

Molecular weight of eliminated material: 138

Also in the resin embodiment that can be preferably applied to ArF exposure, the content of acid-decomposable group-containing the repeating unit (in the case of containing a plurality of kinds, as the total thereof) in the resin (A-1) is as described above.

Furthermore, in the resin embodiment that can be preferably applied to ArF exposure, the content as the total of the acid-decomposable group-containing repeating units of preferred embodiment (2) of the resin (A-2) forming the second film is preferably 20 mol% or more, more preferably 30 mol% or more, based on all repeating units in the resin (A-2).

In addition, in the resin embodiment that can be preferably applied to ArF exposure, the content as the total of the acid-decomposable group-containing repeating units of preferred embodiment (2) of the resin (A-2) forming the second film is preferably 90 mol% or less,

more preferably 85 mol% or less, based on all repeating units in the resin (A-2).

Also, from the standpoint of more reliably forming a practically satisfactory pattern not only in the second film (upper layer) formed of the resin (A-2) but also in the first film (lower layer) formed together with the upper layer, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-2) is preferably larger than the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-1). Specifically, in the case where the resin (A-1) contains a repeating unit having an acid-decomposable group, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-2) is preferably as large as 3 times or more, more preferably from 3 to 10 times, the content (mol%) of the acid-decomposable group-containing repeating unit based on all repeating units in the resin (A-1).

In the resin embodiment that can be preferably applied to ArF exposure, when the acid-decomposable group-containing repeating unit of preferred embodiment (2) of the resin (A-2) forming the second film is a repeating unit represented by formula (AI) and at the same time, particularly, each of Rx_1 to Rx_3 is independently a linear or branched alkyl group, the content of the repeating unit represented by formula (AI) is preferably 45 mol% or more, more preferably 50 mol% or more, still more preferably 55 mol% or more, based on all repeating units of the resin (A-2). The upper limit is, from the standpoint of forming a good pattern, preferably 90 mol% or less, more preferably 85 mol% or less. Within the ranges above, the pattern forming method can ensure that the roughness performance, the uniformity of local pattern dimension and the exposure latitude are more excellent and the reduction in film thickness of the pattern part formed by exposure, so-called film loss, is more suppressed.

[Repeating Unit Having Aromatic Ring]

As described above, the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II) are, as the resin embodiment that can be preferably applied to KrF exposure, preferably a resin containing a repeating unit having an aromatic ring.

In particular, as the resin embodiment that can be preferably applied to KrF exposure, the resin (A-1) contained in the resin composition (I) forming the first film (lower layer) is preferably a resin containing a repeating unit having an aromatic ring. When the resin (A-1) is a resin containing a repeating unit having an aromatic ring, the first film (lower

layer) can absorb the exposure light, so that the effect of standing wave due to reflection of exposure light from the substrate or the diffused reflection of exposure light due to the stepped portion of a stepped substrate can be unfailingly reduced. Also, in the present invention, the first film (lower layer) is developed together with the second film (upper layer) and therefore, the first layer (lower layer) can function as a Developable Bottom Anti-Reflective Coating (DBARC).

From the same standpoint, as the resin embodiment that can be preferably applied to ArF exposure, the resin (A-1) contained in the resin composition (I) forming the first film (lower layer) can be a resin containing a repeating unit having an aromatic ring.

The repeating unit having an aromatic ring includes, for example, a repeating unit represented by formula (VI), the below-described repeating unit having an aromatic group, and a repeating unit represented by formula (IIB) shown later.

Above all, from the standpoint of unfailingly achieving the function as the developable bottom anti-reflective coating, in the resin embodiment that can be preferably applied to KrF exposure, the resin (A-1) is preferably a resin containing a repeating unit having a polycyclic aromatic group.

Examples thereof include a repeating unit where Ar_6 in formula (VI) is a divalent polycyclic aromatic group, and a repeating unit where Ar_4 in formula (IIB) is a (n+1)-valent polycyclic aromatic group (in the case of combining with R_{42} to form a ring, a (n+2)-valent polycyclic aromatic group).

The polycyclic aromatic group includes a group formed by bonding a plurality of benzene rings through a single bond, such as biphenyl group, a polycyclic condensed aromatic group such as naphthalene ring group and anthracene ring group, a divalent aromatic ring group as Ar_6 in formula (VI), and, out of specific examples of the aromatic group in the repeating unit having an aromatic group, those corresponding to a polycyclic aromatic group.

The polycyclic aromatic group is preferably a polycyclic aromatic group having a carbon number of 10 to 20, more preferably a polycyclic aromatic group having a carbon number of 10 to 15.

(Repeating Unit Having Aromatic Group)

In the present invention, the aromatic ring-containing repeating unit that can be incorporated into the resin preferably applicable to KrF exposure includes a repeating unit having an aromatic group, and the repeating unit having an aromatic group may be a repeating

unit having a phenolic aromatic group or a repeating unit having a non-phenolic aromatic group. The repeating unit having an aromatic group preferably has no acid-decomposable group.

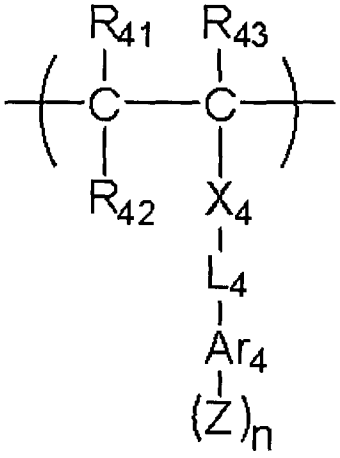
The "repeating unit having a non-phenolic aromatic group" indicates a repeating unit containing an aromatic group having no phenolic hydroxyl group, other than a repeating unit containing an aromatic group having a phenolic hydroxyl group and a repeating unit containing an aromatic group having a group derived from a phenolic hydroxyl group (for example, a group where a phenolic hydroxyl group is protected by a group capable of decomposing and leaving by the action of an acid). Such a repeating unit is sometimes preferred in terms of, for example, solubility in a solvent contained in the resin composition or compatibility with an organic solvent developer used in the development (an appropriate development rate is achieved).

The aromatic group in the repeating unit having an aromatic group may have a substituent and is preferably an aryl group having a carbon number of 6 to 20, and examples thereof include a phenyl group, a naphthyl group, a biphenyl group and an anthracenyl group.

Examples of the substituent include a linear or branched alkyl group having a carbon number of 1 to 4, a cycloalkyl group having a carbon number of 3 to 10, an aryl group having a carbon number of 6 to 10, a halogen atom such as fluorine atom, a cyano group, an amino group, a nitro group, and a carboxyl group. Of these substituents, the linear or branched alkyl group having a carbon number of 1 to 4, the cycloalkyl group having a carbon number of 3 to 10, and the aryl group having a carbon number of 6 to 10 may further have a substituent, and examples of the further substituent include a halogen atom such as fluorine atom.

Particularly, in the case of expecting the lower layer to have a function as a developable bottom anti-reflective coating, the aromatic group in the repeating unit having an aromatic group is preferably a naphthyl group, a biphenyl group or a phenyl group substituted with a carboxyl group.

As the repeating unit having an aromatic group, it is preferred to contain a repeating unit represented by the following formula (IIB):



(IIB)

In the formula, each of R_{41}, R_{42} and R_{43} independently represents a hydrogen atom, an alkyl group, a halogen atom, a cyano group, or an alkoxycarbonyl group. R_{42} and Ar_4 may combine to form a ring, and in this case, R_{42} represents a single bond or an alkylene group.

X_4 represents a single bond, -COO-, or -$CONR_{64}$-, and R_{64} represents a hydrogen atom or an alkyl group.

L_4 represents a single bond or an alkylene group.

Ar_4 represents a (n+1)-valent aromatic ring group and in the case of .combining with R_{42} to form a ring, represents a (n+2)-valent aromatic ring group.

Z represents a polar group.

n represents an integer of 0 to 4.

Specific examples of the alkyl group, cycloalkyl group, halogen atom and alkoxycarbonyl group of R_{41}, R_{42} and R_{43} in formula (IIB) and the substituent which these groups may have are the same as specific examples of respective groups in formula (VI).

Preferred examples of the monovalent aromatic group when n in the (n+1)-valent aromatic ring group as Ar_4 is 0 include an aryl group having a carbon number of 6 to 18, such as phenyl group, tolyl group, naphthyl group and anthracenyl group, and an aromatic ring group containing a heterocyclic ring such as thiophene, furan, pyrrole, benzothiophene, benzofuran, benzopyrrole, triazine, imidazole, benzimidazole, triazole, thiadiazole and thiazole.

Specific preferred examples of the (n+1)-valent aromatic ring group where n is an integer of 1 or more include groups formed by removing arbitrary n hydrogen atoms from the above-described specific examples of the monovalent aromatic ring group.

The (n+1)-valent aromatic ring group as Ar_4 may have a substituent different from the polar group as Z.

Examples of the substituent which the above-described alkyl group, cycloalkyl group, alkoxycarbonyl group, alkylene group and (n+1)-valent aromatic ring group may have include a halogen atom, an alkyl group, a cycloalkyl group, an alkoxy group such as methoxy group, ethoxy group, hydroxyethoxy group, propoxy group, hydroxypropoxy group and butoxy group, and an aryl group such as phenyl group.

Examples of the alkyl group of R_{64} in $-CONR_{64}-$ (R_{64} represents a hydrogen atom or an alkyl group) represented by X_4 are the same as those of the alkyl group of R_{61} to R_{63}.

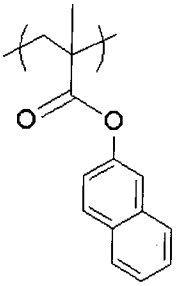
X_4 is preferably a single bond, -COO- or -CONH-, more preferably a single bond or -COO-.

The alkylene group in L_4 is preferably an alkylene group having a carbon number of 1 to 8, such as methylene group, ethylene group, propylene group, butylene group, hexylene group and octylene group, which may have a substituent.

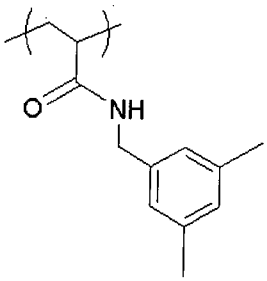
Ar_4 is preferably an arylene group having a carbon number of 6 to 18, which may have a substituent, more preferably a phenylene group, a naphthylene group, or a biphenylene group.

Examples of the polar group of Z are the same as those of the polar group described above in [Acid-Decomposable Group], with a carboxyl group being preferred.

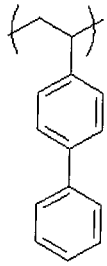
Specific examples of the repeating unit represented by formula (IIB) are illustrated below, but the present invention is not limited thereto. In the formulae, a represents an integer of 1 or 2.



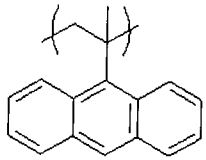
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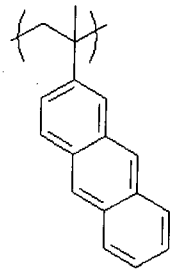
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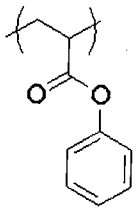
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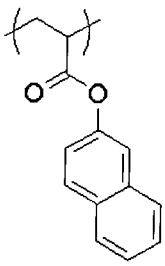
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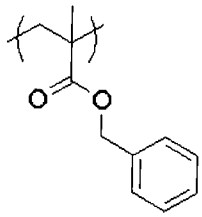
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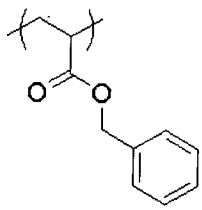
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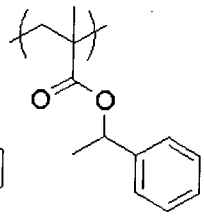
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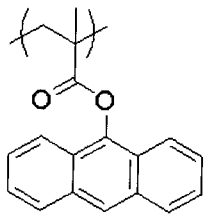
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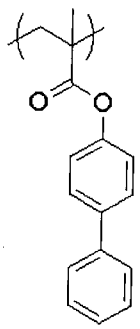
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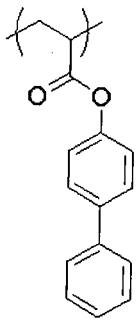
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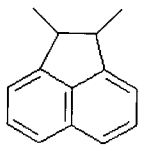
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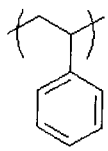
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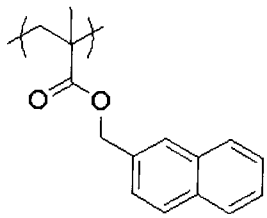
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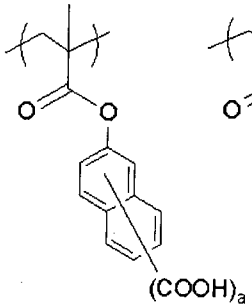
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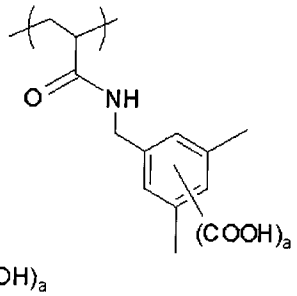
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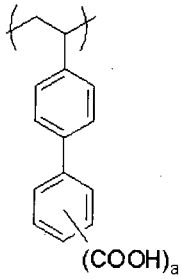
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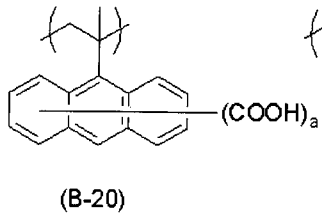
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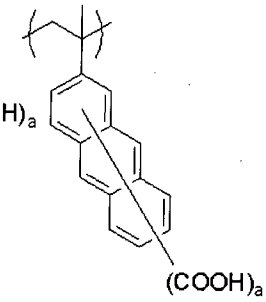
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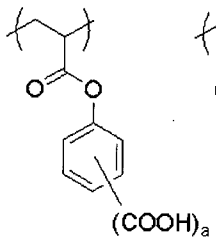
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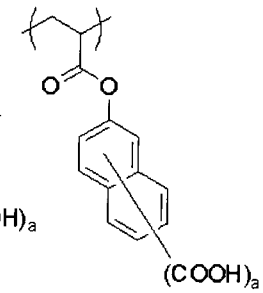
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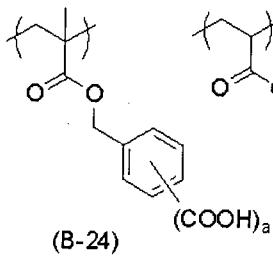
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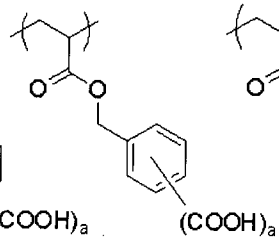
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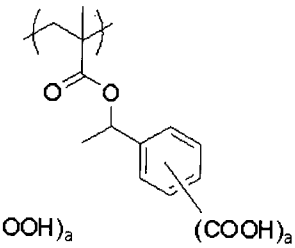
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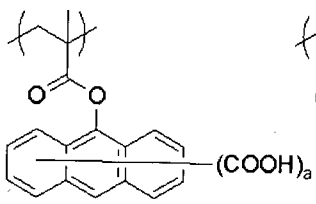
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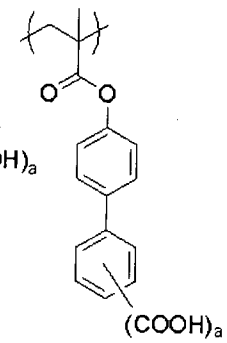
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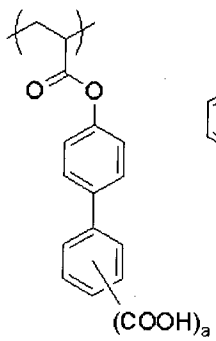
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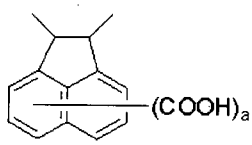
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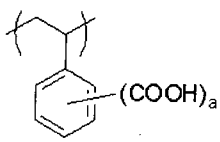
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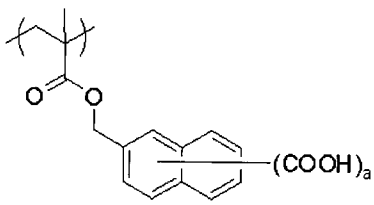
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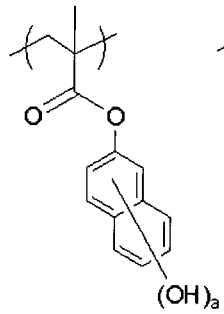
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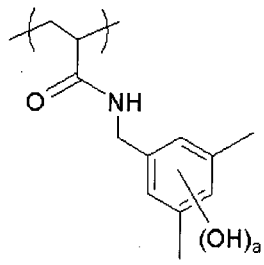
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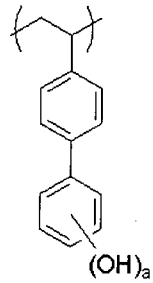
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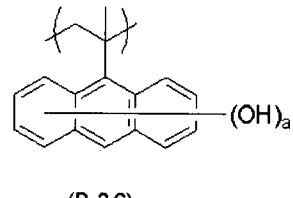
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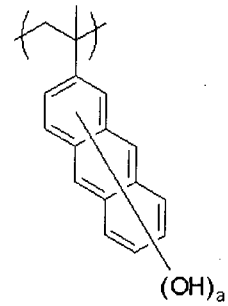
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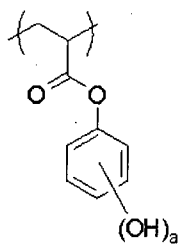
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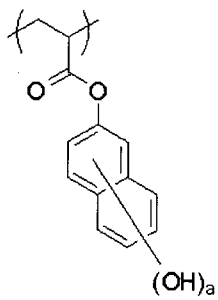
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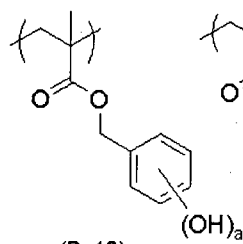
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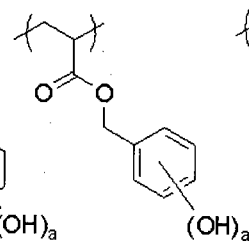
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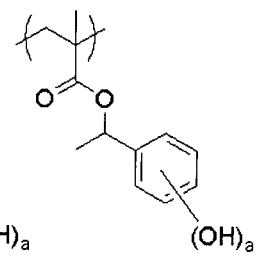
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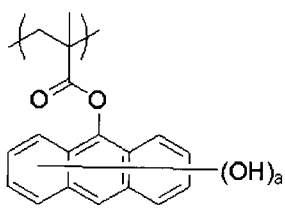
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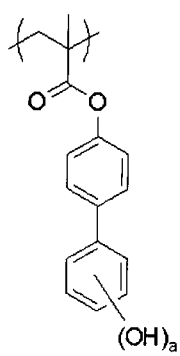
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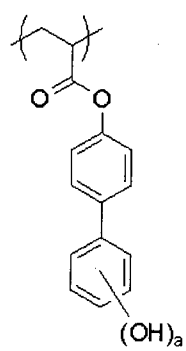
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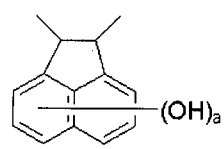
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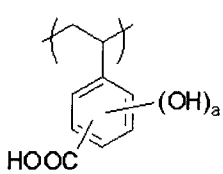
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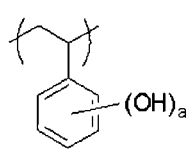
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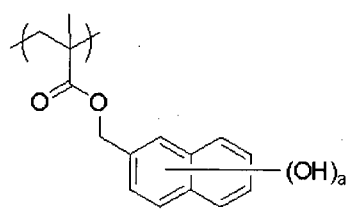
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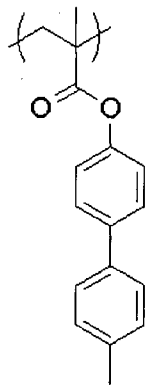
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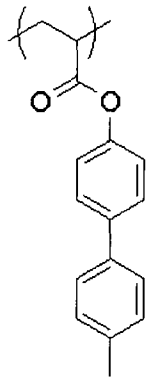
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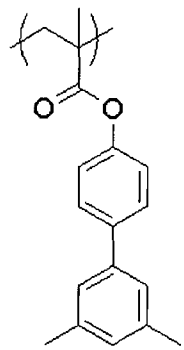
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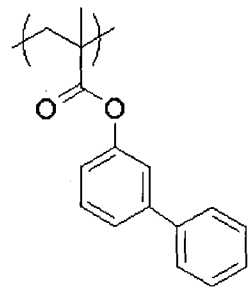
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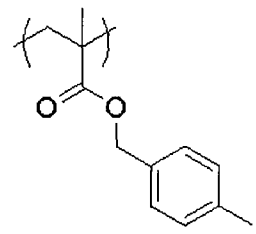
(B-51)



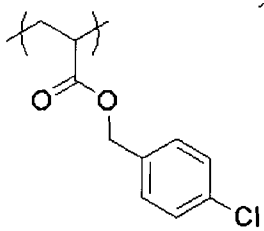
(B-52)



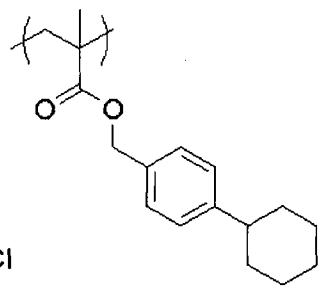
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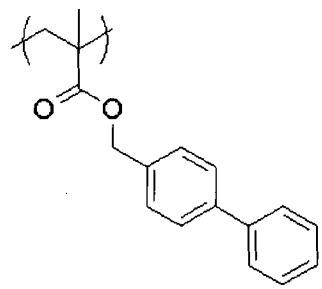
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(B-55)



(B-56)



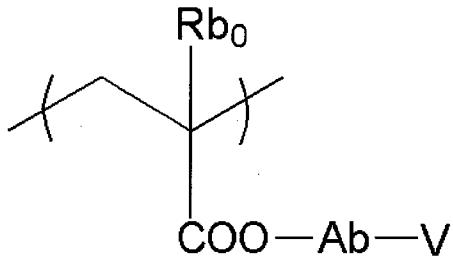
(B-57)

The resin (A-1) or (A-2) may contain two or more kinds of repeating units described above.

From the standpoint of absorbing the exposure light, enhancing the dissolution contrast by sufficiently reducing the solubility of the exposed area for an organic developer and at the same time, keeping the adequate solubility of the unexposed area, and imparting etching resistance, in the resin embodiment that can be preferably applied to KrF exposure, the content of the repeating unit above (in the case of containing a plurality of kinds, as the total thereof) is preferably from 5 to 60 mol%, more preferably from 10 to 50 mol%, still more preferably from 20 to 40 mol%, based on all repeating units in the resin (A-1) or (A-2).

[Other Repeating Units]

Each of the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II) may further contain a repeating unit having a lactone structure. The repeating unit having a lactone structure is preferably a repeating unit represented by the following formula (AII):



(AII)

In formula (AII), Rb_0 represents a hydrogen atom, a halogen atom, or an alkyl group (preferably having a carbon number of 1 to 4) which may have a substituent.

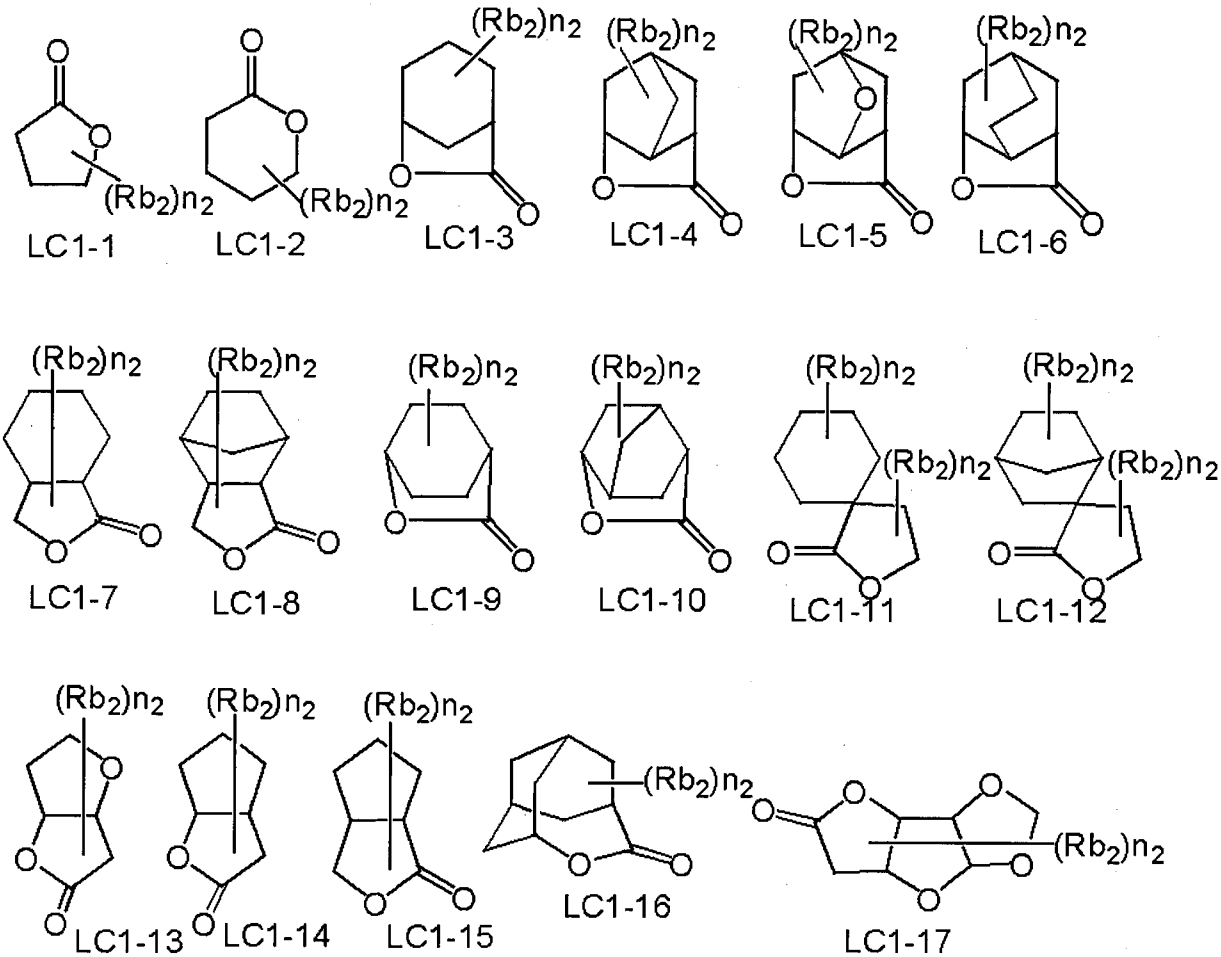
Preferred examples of the substituent which the alkyl group of Rb_0 may have include a hydroxyl group and a halogen atom. The halogen atom of Rb_0 includes a fluorine atom, a chlorine atom, a bromine atom and an iodine atom. Rb_0 is preferably a hydrogen atom, a methyl group, a hydroxymethyl group or a trifluoromethyl group, more preferably a hydrogen atom or a methyl group.

Ab represents a single bond, an alkylene group, a divalent linking group having a monocyclic or polycyclic cycloalkyl structure, an ether bond, an ester bond, a carbonyl group, or a divalent linking group formed by a combination thereof. Ab is preferably a single bond or a divalent linking group represented by $-Ab_1-CO_2-$.

Ab_1 is a linear or branched alkylene group or a monocyclic or polycyclic cycloalkylene group and is preferably a methylene group, an ethylene group, a cyclohexylene group, an adamantylene group or a norbornylene group.

V represents a group having a lactone structure.

As the group having a lactone structure, any group may be used as long as it has a lactone structure, but a 5- to 7-membered ring lactone structure is preferred, and a 5- to 7-membered ring lactone structure to which another ring structure is fused to form a bicyclo or spiro structure is preferred. It is more preferred to contain a repeating unit having a lactone structure represented by any one of the following formulae (LC1-1) to (LC1-17). The lactone structure may be bonded directly to the main chain. Preferred lactone structures are (LC1-1), (LC1-4), (LC1-5), (LC1-6), (LC1-8), (LC1-13) and (LC1-14).



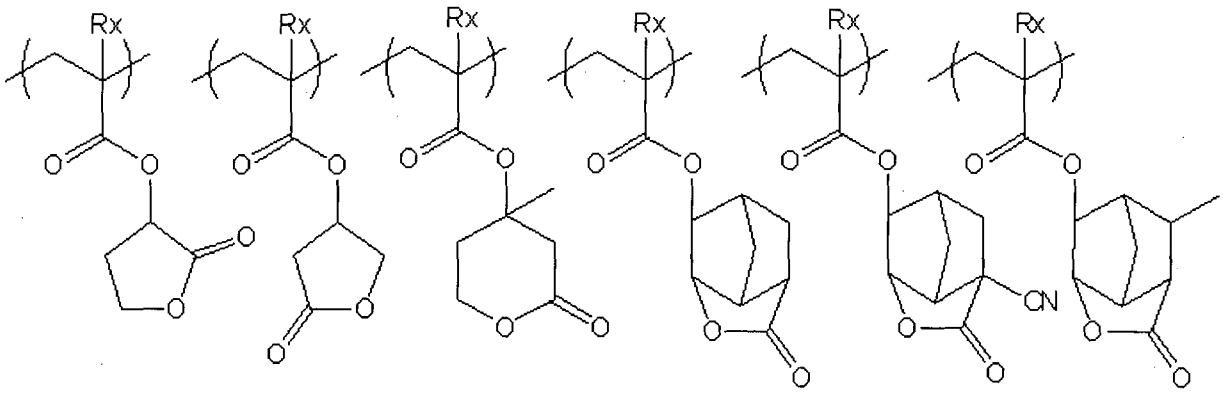
The lactone structure moiety may or may not have a substituent (Rb_2). Preferred examples of the substituent (Rb_2) include an alkyl group having a carbon number of 1 to 8, a monovalent cycloalkyl group having a carbon number of 4 to 7, an alkoxy group having a carbon number of 1 to 8, an alkoxycarbonyl group having a carbon number of 2 to 8, a carboxyl group, a halogen atom, a hydroxyl group, a cyano group, and an acid-decomposable group. Among these, an alkyl group having a carbon number of 1 to 4, a cyano group and an acid-decomposable group are more preferred. n_2 represents an integer of 0 to 4. When n_2 is 2 or more, each substituent (Rb_2) may be the same as or different from every other substituent (Rb_2) and also, the plurality of substituents (Rb_2) may combine with each other to form a ring.

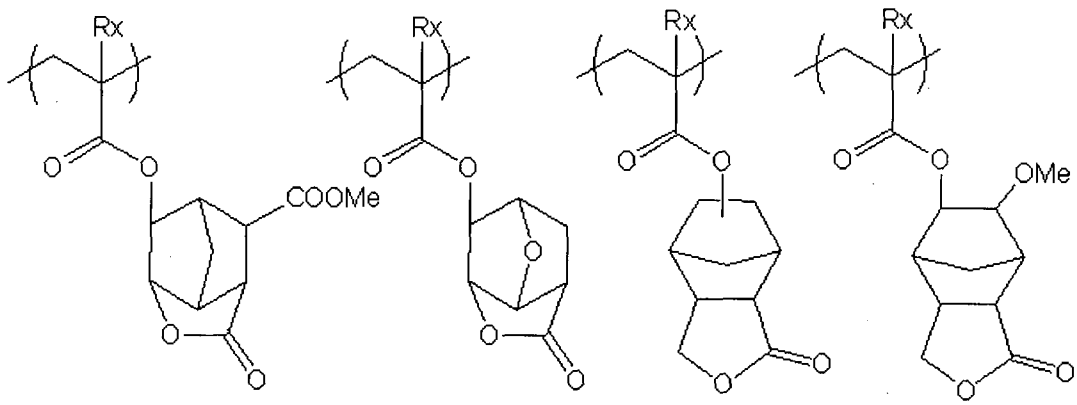
The repeating unit having a lactone group usually has an optical isomer, and any optical isomer may be used. One optical isomer may be used alone, or a mixture of a plurality of optical isomers may be used. In the case of mainly using one optical isomer, the optical purity (ee) thereof is preferably 90% or more, more preferably 95% or more.

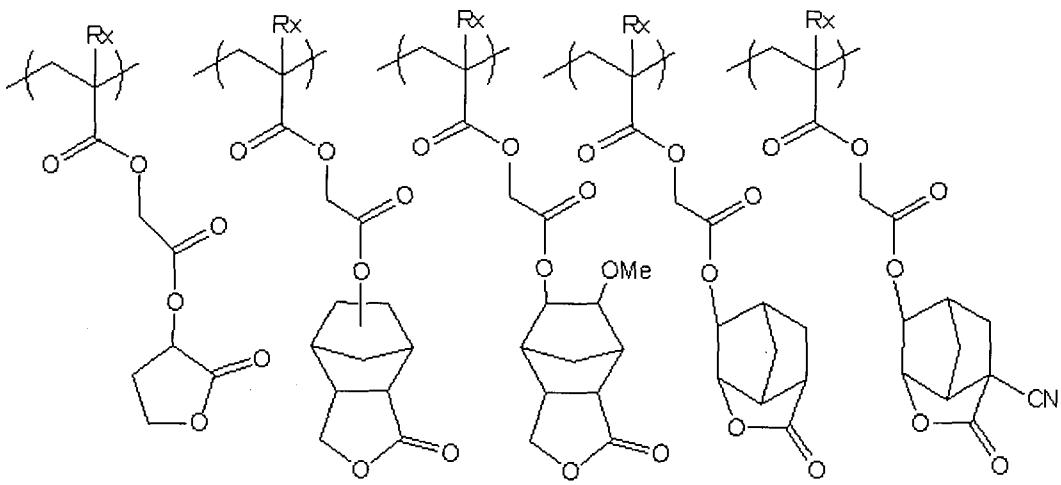
The resin (A-1) or (A-2) may or may not contain the repeating unit having a lactone structure, but in the case of containing the repeating unit having a lactone structure, the content

of the repeating unit in the resin (A-1) is preferably from 5 to 80 mol%, more preferably from 10 to 75 mol%, still more preferably from 15 to 70 mol%, based on all repeating units. The content of the repeating unit is preferably from 1 to 50 mol%, more preferably from 5 to 40 mol%, based on all repeating units in the resin (A-2). As for this repeating unit, one kind may be used, or two or more kinds may be used in combination. By virtue of using a specific lactone structure, the resolution of the pattern is enhanced, the pattern collapse is suppressed, and the rectangular profile is improved.

Specific examples of the repeating unit having a lactone structure in the resin (A-1) or (A-2) are illustrated below, but the present invention is not limited thereto. In the formulae, Rx represents H, CH_3, CH_2OH or CF_3.



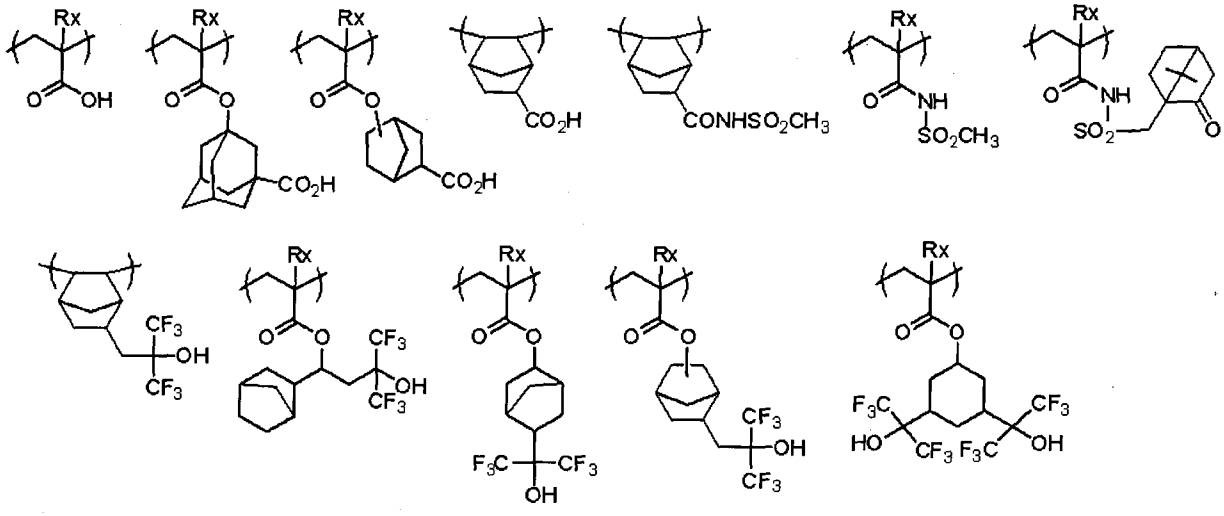




Each of the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II) may contain a repeating unit having an acid group. The acid group includes a carboxyl group, a sulfonamide group, a sulfonylimide group, a bissulfonylimide group, and an aliphatic alcohol substituted with an electron-withdrawing group at the α-position (for example, hexafluoroisopropanol group), and it is more preferred to contain a repeating unit having a carboxyl group. By virtue of containing a repeating unit having an acid group, the resolution increases, for example, in the usage of forming contact holes. As for the repeating unit having an acid group, a repeating unit where the acid group is directly bonded to the main chain of the resin, such as repeating unit by an acrylic acid or a methacrylic acid, a repeating unit where the acid group is bonded to the main chain of the resin through a linking group, and a repeating unit where the acid group is introduced into the terminal of the polymer chain by using an acid group-containing polymerization initiator or chain transfer agent at the polymerization, all are preferred. The linking group may have a monocyclic or polycyclic, cyclic hydrocarbon structure. A repeating unit by an acrylic acid or a methacrylic acid is more preferred.

Specific examples of the repeating unit having an acid group are illustrated below, but the present invention is not limited thereto.

In specific examples, Rx represents H, CH_3, CH_2OH or CF_3.

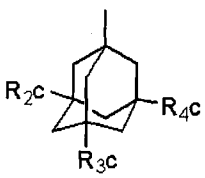


The resin (A-1) or (A-2) may or may not contain a repeating unit having an acid group, but in the case where the resin (A-1) or (A-2) contains a repeating unit having an acid group, the content of the repeating unit is preferably from 1 to 35 mol%, more preferably from 1 to 30 mol%, still more preferably from 3 to 25 mol%, based on all repeating units in the resin (A-1) or (A-2).

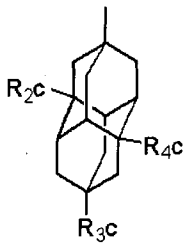
Each of the resin (A-1) contained in the resin composition (I) and the resin (A-2) contained in the resin composition (II) may further contain a repeating unit having a hydroxyl group or a cyano group, which is a repeating unit other than the above-described repeating units. Thanks to this repeating unit, adherence to substrate and affinity for developer can be enhanced. The repeating unit having a hydroxyl group or a cyano group is preferably a repeating unit having an alicyclic hydrocarbon structure substituted with a hydroxyl group or a cyano group and preferably has no acid-decomposable group. The alicyclic hydrocarbon structure in the alicyclic hydrocarbon structure substituted with a hydroxyl group or a cyano group is preferably an adamantyl group, a diamantyl group or a norbornane group, more preferably an adamantyl group. The alicyclic hydrocarbon structure is preferably substituted with a hydroxyl group, and it is more preferred to contain a repeating unit having an adamantyl group substituted with at least one hydroxyl group.

In particular, from the standpoint of controlling the diffusion of the acid generated, the resin (A-1) or (A-2) most preferably contains a repeating unit having a hydroxyadamantyl group or a dihydroxyadamantyl group.

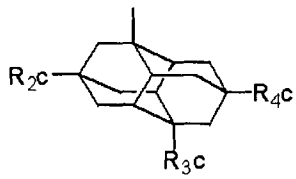
The alicyclic hydrocarbon structure substituted with a hydroxyl group or a cyano group is preferably a partial structure represented by the following formulae (VIIa) to (VIId), more preferably a partial structure represented by the following formula (VIIa):



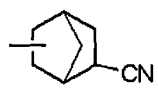
(VIIa)



(VIIb)



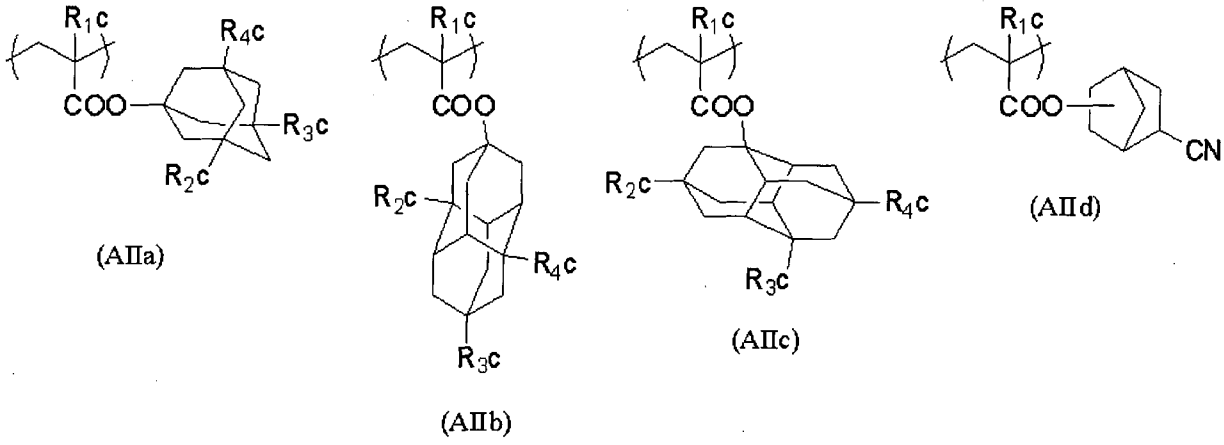
(VIIc)



(VIId)

In formulae (VIIa) to (VIIc), each of R_{2c} to R_{4c} independently represents a hydrogen atom, a hydroxyl group or a cyano group. However, at least one of R_{2c} to R_{4c} represents a hydroxyl group or a cyano group. A structure in which one or two members out of R_{2c} to R_{4c} are a hydroxyl group with the remaining being a hydrogen atom is preferred. In formula (VIIa), it is more preferred that two members out of R_{2c} to R_{4c} are a hydroxyl group and the remaining is a hydrogen atom.

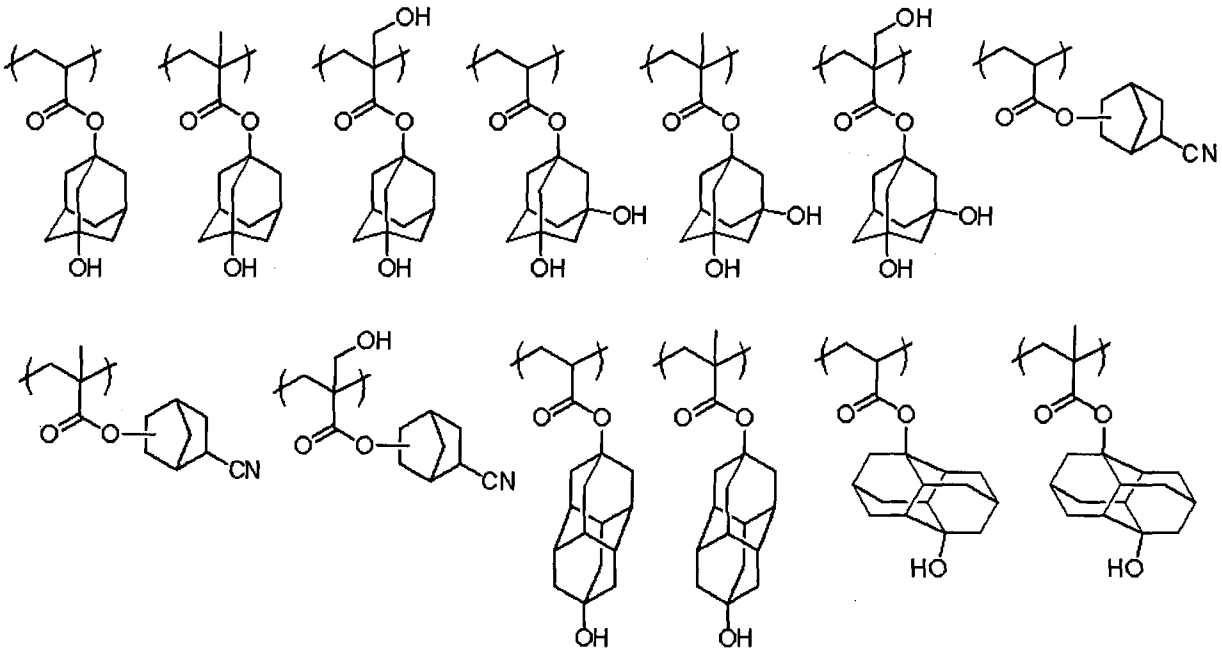
The repeating unit having a partial structure represented by formulae (VIIa) to (VIId) includes repeating units represented by the following formulae (AIIa) to (AIId):



In formulae (AIIa) to (AIId), R_1c represents a hydrogen atom, a methyl group, a trifluoromethyl group or a hydroxymethyl group.

R_2c to R_4c have the same meanings as R_2c to R_4c in formulae (VIIa) to (VIIc).

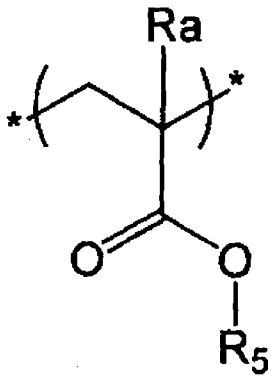
Specific examples of the repeating unit having a hydroxyl group or a cyano group are illustrated below, but the present invention is not limited thereto.



The resin (A-1) or (A-2) may or may not contain the repeating unit having a hydroxyl group or a cyano group, but in the case where the resin (A-1) or (A-2) contains the repeating unit having a hydroxyl group or a cyano group, the content of the repeating unit is preferably from 1 to 70 mol%, more preferably from 3 to 65 mol%, still more preferably from 5 to 60 mol%, based on all repeating units in the resin (A-1) or (A-2).

The resin (A-1) or (A-2) for use in the present invention may further contain a

repeating unit having an alicyclic hydrocarbon structure free from a polar group (for example, the above-described acid group, a hydroxyl group or a cyano group) and not exhibiting acid decomposability. Thanks to this repeating unit, the solubility of the resin at the development using an organic solvent-containing developer can be appropriately adjusted. Such a repeating unit includes a repeating unit represented by formula (IV):



(IV)

In formula (IV), R_5 represents a hydrocarbon group having at least one cyclic structure and having no polar group (such as hydroxyl group or cyano group).

Ra represents a hydrogen atom, an alkyl group, or a $-CH_2-O-Ra_2$ group, wherein Ra_2 represents a hydrogen atom, an alkyl group or an acyl group. Ra is preferably a hydrogen atom, a methyl group, a hydroxymethyl group or a trifluoromethyl group, more preferably a hydrogen atom or a methyl group.

The cyclic structure contained in R_5 includes a monocyclic hydrocarbon group and a polycyclic hydrocarbon group. Examples of the monocyclic hydrocarbon group include a cycloalkyl group having a carbon number of 3 to 12, such as cyclopentyl group, cyclohexyl group, cycloheptyl group and cyclooctyl group, and a cycloalkenyl group having a carbon number of 3 to 12, such as cyclohexenyl group. The monocyclic hydrocarbon group is preferably a monocyclic hydrocarbon group having a carbon number of 3 to 7, more preferably a cyclopentyl group or a cyclohexyl group.

The polycyclic hydrocarbon group includes a ring-assembly hydrocarbon group and a crosslinked cyclic hydrocarbon group. Examples of the ring-assembly hydrocarbon group include a bicyclohexyl group and a perhydronaphthalenyl group. Examples of the crosslinked cyclic hydrocarbon ring include a bicyclic hydrocarbon ring such as pinane ring, bornane ring, norpinane ring, norbornane ring and bicyclooctane ring (e.g., bicyclo[2.2.2]octane ring, bicyclo[3.2.1]octane ring), a tricyclic hydrocarbon ring such as homobledane ring, adamantane ring, tricyclo[5.2.1.$0^{2,6}$]decane ring and tricyclo[4.3.1.$1^{2,5}$]undecane ring, and a tetracyclic hydrocarbon ring such as

tetracyclo[4.4.0.$1^{2,5}$.$1^{7,10}$]dodecane ring and perhydro-1,4-methano-5,8-methanonaphthalene ring. The crosslinked cyclic hydrocarbon ring also includes a condensed cyclic hydrocarbon ring, for example, a condensed ring formed by fusing a plurality of 5- to 8-membered cycloalkane rings, such as perhydronaphthalene (decalin) ring, perhydroanthracene ring, perhydrophenathrene ring, perhydroacenaphthene ring, perhydrofluorene ring, perhydroindene ring and perhydrophenalene ring.

Preferred examples of the crosslinked cyclic hydrocarbon ring include a norbornyl group, an adamantyl group, a bicyclooctanyl group, and a tricycle[5,2,1,$0^{2,6}$]decanyl group. Of these crosslinked cyclic hydrocarbon rings, a norbornyl group and an adamantyl group are more preferred.

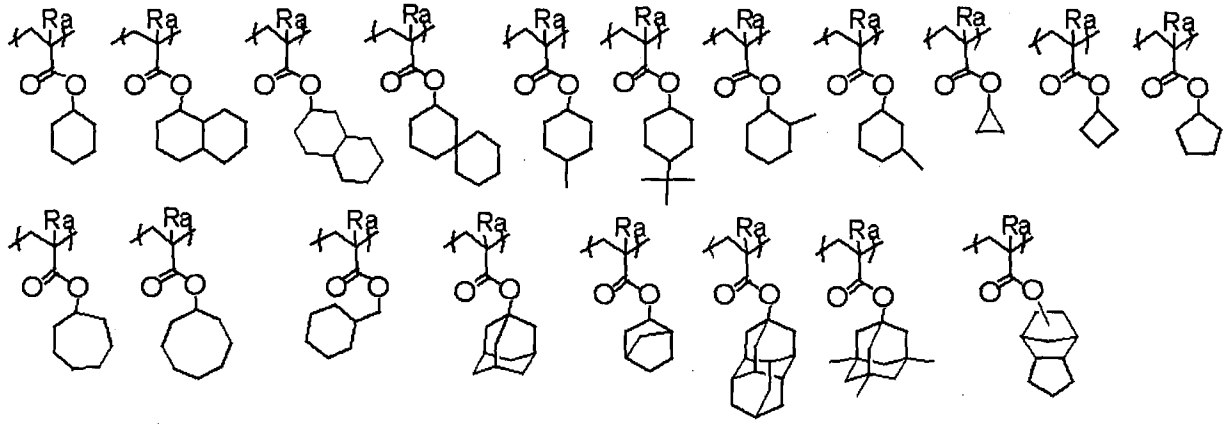
These alicyclic hydrocarbon groups may have a substituent, and preferred examples of the substituent include a halogen atom, an alkyl group, a hydroxyl group with a hydrogen atom being substituted for, and an amino group with a hydrogen atom being substituted for. The halogen atom is preferably bromine atom, chlorine atom or fluorine atom, and the alkyl group is preferably methyl group, ethyl group, butyl group or tert-butyl group. This alkyl group may further have a substituent, and the substituent which may be further substituted on the alkyl group includes a halogen atom, an alkyl group, a hydroxyl group with a hydrogen atom being substituted for, and an amino group with a hydrogen atom being substituted for.

Examples of the substituent for hydrogen atom include an alkyl group, a cycloalkyl group, an aralkyl group, a substituted methyl group, a substituted ethyl group, an alkoxycarbonyl group, and an aralkyloxycarbonyl group. The alkyl group is preferably an alkyl group having a carbon number of 1 to 4; the substituted methyl group is preferably a methoxymethyl group, a methoxythiomethyl group, a benzyloxymethyl group, a tert-butoxymethyl group, or a 2-methoxyethoxymethyl group; the substituted ethyl group is preferably a 1-ethoxyethyl group or a 1-methyl-1-methoxyethyl group; the acyl group is preferably an aliphatic acyl group having a carbon number of 1 to 6, such as formyl group, acetyl group, propionyl group, butyryl group, isobutyryl group, valeryl group and pivaloyl group; and the alkoxycarbonyl group includes, for example, an alkoxycarbonyl group having a carbon number of 1 to 4.

The resin (A-1) or (A-2) may or may not contain the repeating unit having a polar group-free alicyclic hydrocarbon structure and not exhibiting acid decomposability, but in the case where the resin (A-1) or (A-2) contains the repeating unit having a polar group-free alicyclic hydrocarbon structure and not exhibiting acid decomposability, the content of the

repeating unit in the resin (A-1) is preferably from 5 to 70 mol%, more preferably from 10 to 60 mol%, based on all repeating units in the resin (A-1). The content of the repeating unit in the resin (A-2) is preferably from 1 to 40 mol%, more preferably from 1 to 20 mol%, based on all repeating units in the resin (A-2).

Specific examples of the repeating unit having a polar group-free alicyclic hydrocarbon structure and not exhibiting acid decomposability are illustrated below, but the present invention is not limited thereto. In the formulae, Ra represents H, CH_3, CH_2OH or CF_3.



The resin (A-1) or (A-2) for use in the composition of the present invention may contain, in addition to the above-described repeating structural units, various repeating structural units for the purpose of controlling the dry etching resistance, aptitude for standard developer, adherence to substrate, resist profile and properties generally required of a resin composition, such as resolution, heat resistance and sensitivity.

Examples of such a repeating structural unit include, but are not limited to, repeating structural units corresponding to the monomers described below.

Thanks to such a repeating structural unit, the performance required of the resin for use in the composition of the present invention, particularly

(1) solubility for coating solvent,

(2) film-forming property (glass transition temperature),

(3) alkali developability,

(4) film loss (selection of hydrophilic, hydrophobic or alkali-soluble group),

(5) adherence of unexposed area to substrate,

(6) dry etching resistance,

and the like, can be subtly controlled.

Examples of the monomer include a compound having one addition-polymerizable

unsaturated bond selected from acrylic acid esters, methacrylic acid esters, acrylamides, methacrylamides, allyl compounds, vinyl ethers, vinyl esters, styrenes and crotonic acid esters.

Other monomers may be also copolymerized if the monomer is an addition-polymerizable unsaturated compound copolymerizable with the monomers corresponding to the above-described various repeating structural units.

In the resin (A-1) or (A-2) for use in the composition of the present invention, the molar ratio of respective repeating structural units contained is appropriately set to control the dry etching resistance of the composition, aptitude for standard developer, adherence to substrate, resist profile and performances generally required of a resist, such as resolution, heat resistance and sensitivity.

The form of the resin (A-1) or (A-2) for use in the present invention may be any of random type, block type, comb type and star type. The resin (A-1) or (A-2) can be synthesized, for example, by radical, cationic or anionic polymerization of unsaturated monomers corresponding to respective structures. It is also possible to obtain the target resin by polymerizing unsaturated monomers corresponding to precursors of respective structures and then performing a polymer reaction.

The resin (A-1) or (A-2) for use in the present invention can be synthesized by a conventional method (for example, radical polymerization). Examples of the general synthesis method include a batch polymerization method of dissolving monomer species and an initiator in a solvent and heating the solution, thereby effecting the polymerization, and a dropping polymerization method of adding dropwise a solution containing monomer species and an initiator to a heated solvent over 1 to 10 hours. A dropping polymerization method is preferred. Examples of the reaction solvent include tetrahydrofuran, 1,4-dioxane, ethers such as diisopropyl ether, ketones such as methyl ethyl ketone and methyl isobutyl ketone, an ester solvent such as ethyl acetate, an amide solvent such as dimethylformamide and dimethylacetamide, and the later-described solvent capable of dissolving the composition of the present invention, such as propylene glycol monomethyl ether acetate, propylene glycol monomethyl ether and cyclohexanone. The polymerization is more preferably performed using the same solvent as the solvent used in the resin composition for use in the present invention. By the use of the same solvent, production of particles during storage can be suppressed.

The polymerization reaction is preferably performed in an inert gas atmosphere such as nitrogen or argon. As for the polymerization initiator, the polymerization is started using a

commercially available radical initiator (such as azo-based initiator and peroxide). The radical initiator is preferably an azo-based initiator, and an azo-based initiator having an ester group, a cyano group or a carboxyl group is preferred. Preferred examples of the initiator include azobisisobutyronitrile, azobisdimethylvaleronitrile and dimethyl 2,2'-azobis(2-methylpropionate). The initiator is added additionally or in parts, if desired. After the completion of reaction, the reaction product is poured in a solvent, and the desired polymer is collected by a powder, solid or other recovery methods. The concentration at the reaction is from 5 to 50 mass%, preferably from 10 to 30 mass%, and the reaction temperature is usually from 10 to 150°C, preferably from 30 to 120°C, more preferably from 60 to 100°C. (In this specification, mass ratio is equal to weight ratio.)

After the completion of reaction, the reaction solution is allowed to cool to room temperature and purified. The purification may be performed by a normal method, for example, a liquid-liquid extraction method of applying water washing or combining it with an appropriate solvent to remove residual monomers or oligomer components; a purification method in a solution sate, such as ultrafiltration of extracting and removing only polymers having a molecular weight not more than a specific molecular weight; a reprecipitation method of adding dropwise the resin solution in a poor solvent to solidify the resin in the poor solvent and thereby remove residual monomers and the like; and a purification method in a solid state, such as washing of the resin slurry with a poor solvent after separation of the slurry by filtration. For example, the resin is precipitated as a solid by contacting the reaction solution with a solvent in which the resin is sparingly soluble or insoluble (poor solvent) and which is in a volumetric amount of 10 times or less, preferably from 10 to 5 times, the reaction solution.

The solvent used at the operation of precipitation or reprecipitation from the polymer solution (precipitation or reprecipitation solvent) may be sufficient if it is a poor solvent for the polymer, and the solvent which can be used may be appropriately selected from a hydrocarbon, a halogenated hydrocarbon, a nitro compound, an ether, a ketone, an ester, a carbonate, an alcohol, a carboxylic acid, water, a mixed solvent containing such a solvent, and the like, according to the kind of the polymer.

The amount of the precipitation or reprecipitation solvent used may be appropriately selected by taking into consideration the efficiency, yield and the like, but in general, the amount used is from 100 to 10,000 parts by mass, preferably from 200 to 2,000 parts by mass, more preferably from 300 to 1,000 parts by mass, per 100 parts by mass of the polymer solution.

The temperature at the precipitation or reprecipitation may be appropriately selected by taking into consideration the efficiency or operability but is usually on the order of 0 to 50°C, preferably in the vicinity of room temperature (for example, approximately from 20 to 35°C). The precipitation or reprecipitation operation may be performed using a commonly employed mixing vessel such as stirring tank by a known method such as batch system and continuous system.

The precipitated or reprecipitated polymer is usually subjected to commonly employed solid-liquid separation such as filtration and centrifugation, then dried and used. The filtration is performed using a solvent-resistant filter element preferably under pressure. The drying is performed under atmospheric pressure or reduced pressure (preferably under reduced pressure) at a temperature of approximately from 30 to 100°C, preferably at a temperature of approximately from 30 to 50°C.

Incidentally, after the resin is once precipitated and separated, the resin may be again dissolved in a solvent and then put into contact with a solvent in which the resin is sparingly soluble or insoluble. That is, there may be used a method comprising, after the completion of radical polymerization reaction, bringing the polymer into contact with a solvent in which the polymer is sparingly soluble or insoluble, to precipitate a resin (step a), separating the resin from the solution (step b), anew dissolving the resin in a solvent to prepare a resin solution A (step c), bringing the resin solution A into contact with a solvent in which the resin is sparingly soluble or insoluble and which is in a volumetric amount of less than 10 times (preferably 5 times or less) the resin solution A, to precipitate a solid resin (step d), and separating the precipitated resin (step e).

Also, for keeping the resin from aggregation or the like after preparation of the composition, as described, for example, in JP-A-2009-037108, a step of dissolving the synthesized resin in a solvent to make a solution, and heating the solution at approximately from 30 to 90°C for approximately from 30 minutes to 4 hours may be added.

The weight average molecular weight of the resin (A-1) or (A-2) for use in the composition of the present invention is preferably from 1,000 to 200,000, more preferably from 2,000 to 100,000, still more preferably from 3,000 to 70,000, yet still more preferably from 5,000 to 50,000, in terms of polystyrene by the GPC method. When the weight average molecular weight is from 1,000 to 200,000, reduction in the heat resistance and dry etching resistance can be inhibited and at the same time, the film-forming property can be prevented from deterioration due to impaired developability or increased viscosity.

The polydispersity (molecular weight distribution) is usually from 1.0 to 3.0, preferably from 1.0 to 2.6, more preferably from 1.2 to 2.4, still more preferably from 1.4 to 2.2. When the molecular weight distribution satisfies the range above, the resolution and resist profile are excellent, the side wall of the resist pattern is smooth, and the roughness is improved.

In the resin composition (I) for use in the present invention, the content of the resin (A-1) in the entire composition is preferably from 30 to 99 mass%, more preferably from 60 to 95 mass%, based on the entire solid content.

In the present invention, as for the resin (A-1) in the resin composition (I), one kind may be used or a plurality of kinds may be used in combination.

In the resin composition (II) for use in the present invention, the content of the resin (A-2) in the entire composition is preferably from 30 to 99 mass%, more preferably from 60 to 95 mass%, based on the entire solid content.

In the present invention, as for the resin (A-2) in the resin composition (II), one kind may be used or a plurality of kinds may be used in combination.

The resin composition (II) for use in the present invention may further contain, together with the resin (A-2), an acid-decomposable resin (a resin capable of increasing the polarity by the action of an acid to decrease the solubility for an organic solvent-containing developer) other than the resin (A-2). The acid-decomposable resin other than the resin (A-2) is an acid-decomposable resin composed of the same repeating units as the repeating units which may be contained in the resin (A-2), and preferred ranges of the repeating units and contents thereof in the resin are the same as those described for the resin (A-2).

In the case of containing an acid-decomposable resin other than the resin (A-2), the content of the acid-decomposable resin in the composition (II) according to the present invention may be sufficient if the total of the contents of the resin (A-2) and the acid-decomposable resin other than the resin (A-2) falls in the range above. The mass ratio between the resin (A-2) and the acid-decomposable resin other than the resin (A-2) may be appropriately adjusted as long as the effects of the present invention are successfully provided, but the ratio [resin (A-2)/acid-decomposable resin other than resin (A-2)] is preferably from 99.9/0.1 to 10/90, more preferably from 99.9/0.1 to 60/40.

From the standpoint of offering high resolution and rectangular profile of the resist pattern and imparting etching resistance at dry etching, the resin composition (II) for use in the present invention preferably contains only the resin (A-2) as the acid-decomposable resin.

[2] (B) Compound capable of generating an acid upon irradiation with an actinic ray or radiation

The second resin composition (II) for forming the second film in the present invention contains (B) a compound capable of generating an acid upon irradiation with an actinic ray or radiation (hereinafter, sometimes referred to as "acid generator").

The second resin composition (II) for use in the present invention preferably further contains the later-described basic compound.

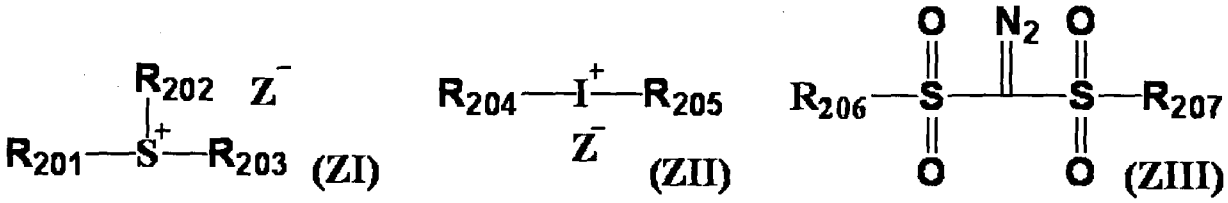
The first resin composition (I) for use in the present invention may or may not contain an acid generator. Because light attenuates as the light runs on in the resist film and the light reaching the bottom side of the resist film (for example, the vicinity of the bottom of a stepped substrate in microfabrication such as application to ion implantation using a stepped substrate) becomes weak, it is considered that the amount of the acid generated decays on the bottom side (lower layer side) of the second film (upper layer). Accordingly, from the standpoint of assisting in the acid generation performance of the second film (upper layer) from the first film side (lower layer side), it is also one embodiment of the present invention that the first resin composition (I) contains an acid generator. In the case of incorporating an acid generator into the first resin composition (I), the later-described basic compound may be incorporated together so that the diffusivity of the generated acid and the rectangularity can be controlled.

The (B) compound capable of generating an acid upon irradiation with an actinic ray or radiation is preferably a compound capable of generating an organic acid upon irradiation with an actinic ray or radiation.

The acid generator which can be used may be appropriately selected from a photo-initiator for cationic photopolymerization, a photo-initiator for radical photopolymerization, a photo-decoloring agent for dyes, a photo-discoloring agent, a known compound capable of generating an acid upon irradiation with an actinic ray or radiation, which is used for microresist or the like, and a mixture thereof.

Examples thereof include a diazonium salt, a phosphonium salt, a sulfonium salt, an iodonium salt, imidosulfonate, oxime sulfonate, diazodisulfone, disulfone and o-nitrobenzyl sulfonate.

Out of the acid generators, preferred compounds include compounds represented by the following formulae (ZI), (ZII) and (ZIII):



In formula (ZI), each of R_{201}, R_{202} and R_{203} independently represents an organic group.

The carbon number of the organic group as R_{201}, R_{202} and R_{203} is generally from 1 to 30, preferably from 1 to 20.

Two members out of R_{201} to R_{203} may combine to form a ring structure, and the ring may contain an oxygen atom, a sulfur atom, an ester bond, an amide bond or a carbonyl group. Examples of the group formed by combining two members out of R_{201} to R_{203} include an alkylene group (e.g., butylene group, pentylene group).

Z^- represents a non-nucleophilic anion.

Examples of the non-nucleophilic anion as Z^- include a sulfonate anion, a carboxylate anion, a sulfonylimide anion, a bis(alkylsulfonyl)imide anion and a tris(alkylsulfonyl)methyl anion.

The non-nucleophilic anion is an anion having an extremely low ability of causing a nucleophilic reaction and this anion can suppress the decomposition with aging due to intramolecular nucleophilic reaction. Thanks to this anion, the aging stability of the resist composition is improved.

Examples of the sulfonate anion include an aliphatic sulfonate anion, an aromatic sulfonate anion, and a camphorsulfonate anion.

Examples of the carboxylate anion include an aliphatic carboxylate anion, an aromatic carboxylate anion, and an aralkylcarboxylate anion.

The aliphatic moiety in the aliphatic sulfonate anion and aliphatic carboxylate may be an alkyl group or a cycloalkyl group but is preferably an alkyl group having a carbon number of 1 to 30 or a cycloalkyl group having a carbon number of 3 to 30, and examples thereof include a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a pentyl group, a neopentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a nonadecyl group, an eicosyl group, a cyclopropyl group, a cyclopentyl group, a cyclohexyl group, an adamantyl group, a norbornyl group and a

bornyl group.

The aromatic group in the aromatic sulfonate anion and aromatic carboxylate anion is preferably an aryl group having a carbon number of 6 to 14, and examples thereof include a phenyl group, a tolyl group and a naphthyl group.

The alkyl group, cycloalkyl group and aryl group in the aliphatic sulfonate anion and aromatic sulfonate anion may have a substituent. Examples of the substituent on the alkyl group, cycloalkyl group and aryl group in the aliphatic sulfonate anion and aromatic sulfonate anion include a nitro group, a halogen atom (e.g., fluorine atom, chlorine atom, bromine atom, iodine atom), a carboxyl group, a hydroxyl group, an amino group, a cyano group, an alkoxy group (preferably having a carbon number of 1 to 15), a cycloalkyl group (preferably having a carbon number of 3 to 15), an aryl group (preferably having a carbon number of 6 to 14), an alkoxycarbonyl group (preferably having a carbon number of 2 to 7), an acyl group (preferably having a carbon number of 2 to 12), an alkoxycarbonyloxy group (preferably having a carbon number of 2 to 7), an alkylthio group (preferably having a carbon number of 1 to 15), an alkylsulfonyl group (preferably having a carbon number of 1 to 15), an alkyliminosulfonyl group (preferably having a carbon number of 1 to 15), an aryloxysulfonyl group (preferably having a carbon number of 6 to 20), an alkylaryloxysulfonyl group (preferably having a carbon number of 7 to 20), a cycloalkylaryloxysulfonyl group (preferably having a carbon number of 10 to 20), an alkyloxyalkyloxy group (preferably having a carbon number of 5 to 20), and a cycloalkylalkyloxyalkyloxy group (preferably having a carbon number of 8 to 20). The aryl group and ring structure in each group may further have, as the substituent, an alkyl group (preferably having a carbon number of 1 to 15) or a cycloalkyl group (preferably having a carbon number of 3 to 15).

The aralkyl group in the aralkylcarboxylate anion is preferably an aralkyl group having a carbon number of 7 to 12, and examples thereof include a benzyl group, a phenethyl group, a naphthylmethyl group, a naphthylethyl group and a naphthylbutyl group.

The alkyl group, cycloalkyl group, aryl group and aralkyl group in the aliphatic carboxylate anion, aromatic carboxylate anion and aralkylcarboxylate anion may have a substituent. Examples of the substituent include the same halogen atom, alkyl group, cycloalkyl group, alkoxy group and alkylthio group as those in the aromatic sulfonate anion.

Examples of the sulfonylimide anion include saccharin anion.

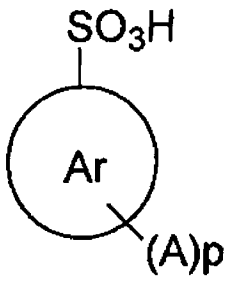
The alkyl group in the bis(alkylsulfonyl)imide anion and tris(alkylsulfonyl)methide anion is preferably an alkyl group having a carbon number of 1 to 5, and examples thereof

include a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a pentyl group and a neopentyl group. Examples of the substituent on such an alkyl group include a halogen atom, a halogen atom-substituted alkyl group, an alkoxy group, an alkylthio group, an alkyloxysulfonyl group, an aryloxysulfonyl group, and a cycloalkylaryloxysulfonyl group, with a fluorine atom-substituted alkyl group being preferred.

Other examples of the non-nucleophilic anion include fluorinated phosphorus (e.g., PF_6^-), fluorinated boron (e.g., BF_4^-), and fluorinated antimony (e.g., SbF_6^-).

The non-nucleophilic anion of Z^- is preferably an aliphatic sulfonate anion substituted with a fluorine atom at least at the α-position of sulfonic acid, an aromatic sulfonate anion substituted with a fluorine atom or a fluorine atom-containing group, a bis(alkylsulfonyl)imide anion in which the alkyl group is substituted with a fluorine atom, or a tris(alkylsulfonyl)methide anion in which the alkyl group is substituted with a fluorine atom. The non-nucleophilic anion is more preferably a perfluoroaliphatic sulfonate anion having a carbon number of 4 to 8 or a benzenesulfonate anion having a fluorine atom, still more preferably nonafluorobutanesulfonate anion, perfluorooctanesulfonate anion, pentafluorobenzenesulfonate anion or 3,5-bis(trifluoromethyl)benzenesulfonate anion.

The acid generator may be a compound capable of generating a sulfonic acid represented by the following formula (BI). In the case where the acid generator is, for example, a compound represented by formula (ZI) or (ZII), the aromatic sulfonate anion may be an anion capable of producing an arylsulfonic acid represented by the following formula (BI):



(BI)

In formula (BI), Ar represents an aromatic ring and may further have a substituent in addition to the sulfonic acid group and the A group.

p represents an integer of 0 or more.

A represents a group containing a hydrocarbon group.

When p is 2 or more, each A group may be the same as or different from every other A group.

Formula (BI) is described in detail below.

The aromatic ring represented by Ar is preferably an aromatic ring having a carbon number of 6 to 30, more preferably a benzene ring, a naphthalene ring or an anthracene ring, still more preferably a benzene ring.

Examples of the substituent which may be substituted on the aromatic ring in addition to the sulfonic acid group and the A group include a halogen atom (e.g., fluorine atom, chlorine atom, bromine atom, iodine atom), a hydroxyl group, a cyano group, a nitro group and a carboxyl group. In the case of having two or more substituents, at least two substituents may combine with each other to form a ring.

Examples of the group having a hydrocarbon group, represented by A, include an alkoxy group, an aryloxy group, an alkylthioxy group, an arylthioxy group, an alkoxycarbonyl group, an acetoxy group, a linear alkyl group, a branched alkyl group, an alkenyl group, an alkynyl group, an aryl group, and an acyl group.

The hydrocarbon group in the group containing a hydrocarbon group, represented by A, includes an acyclic hydrocarbon group and a cyclic aliphatic group. The carbon number of the hydrocarbon group is preferably 3 or more.

As for the A group, the carbon atom adjacent to Ar is preferably a tertiary or quaternary carbon atom.

Examples of the acyclic hydrocarbon group in the A group include an isopropyl group, a tert-butyl group, a tert-pentyl group, a neopentyl group, an s-butyl group, an isobutyl group, an isohexyl group, a 3,3-dimethylpentyl group, and a 2-ethylhexyl group. The upper limit of the carbon number of the acyclic hydrocarbon group is preferably 12 or less, more preferably 10 or less.

Examples of the cyclic aliphatic group in the A group include a cycloalkyl group, an adamantyl group, a norbornyl group, a bornyl group, a camphenyl group, a decahydronaphthyl group, a tricyclodecanyl group, a tetracyclodecanyl group, a camphoroyl group, a dicyclohexyl group, and a pinenyl group, each of which may have a substituent. The upper limit of the carbon number of the cyclic aliphatic group is preferably 15 or less, more preferably 12 or less.

In the case where the acyclic hydrocarbon group or cyclic aliphatic group has a substituent, examples of the substituent include a halogen atom, an alkoxy group, an aryloxy group, an alkylthioxy group, an arylthioxy group, an alkoxycarbonyl group, an acetoxy group,

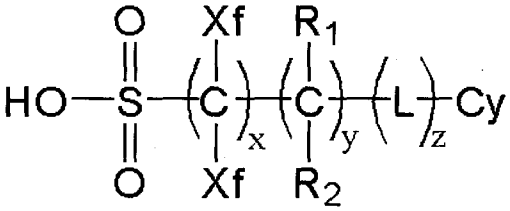
a linear alkyl group, a branched alkyl group, a cycloalkyl group, an alkenyl group, an alkynyl group, an aryl group, a hydroxy group, a carboxy group, a sulfonic acid group, a carbonyl group, and a cyano group.

p represents an integer of 0 or more, and the upper limit thereof is not particularly limited as long as it is a chemically possible number. From the standpoint of suppressing diffusion of the acid, p is usually from 0 to 5, preferably from 1 to 4, more preferably 2 or 3, and most preferably 3.

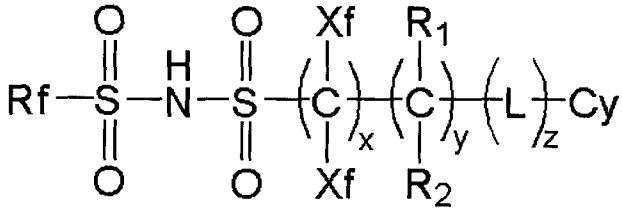
In view of suppressing diffusion of the acid, the A group is preferably substituted on at least one o-position, more preferably on two o-positions, with respect to the sulfonic acid group.

The acid generator is preferably a compound capable of generating an acid represented by the following formula (III) or (IV) upon irradiation with an actinic ray or radiation. The compound capable of generating an acid represented by the following formula (III) or (IV) has a cyclic organic group, so that the resolution and roughness performance can be more improved.

The non-nucleophilic anion described above can be an anion capable of generating an organic acid represented by the following formula (III) or (IV):



(III)



(IV)

In the formulae, each Xf independently represents a fluorine atom or an alkyl group substituted with at least one fluorine atom.

Each of R_1 and R_2 independently represents a hydrogen atom, a fluorine atom or an alkyl group.

Each L independently represents a divalent linking group.

Cy represents a cyclic organic group.

Rf represents a fluorine atom-containing group.

x represents an integer of 1 to 20.

y represents an integer of 0 to 10.

z represents an integer of 0 to 10.

Xf represents a fluorine atom or an alkyl group substituted with at least one fluorine atom. The carbon number of the alkyl group is preferably from 1 to 10, more preferably from 1 to 4. Also, the alkyl group substituted with at least one fluorine atom is preferably a perfluoroalkyl group.

Xf is preferably a fluorine atom or a perfluoroalkyl group having a carbon number of 1 to 4. Specifically, Xf is preferably a fluorine atom, CF_3, C_2F_5, C_3F_7, C_4F_9, C_5F_{11}, C_6F_{13}, C_7F_{15}, C_8F_{17}, CH_2CF_3, $CH_2CH_2CF_3$, $CH_2C_2F_5$, $CH_2CH_2C_2F_5$, $CH_2C_3F_7$, $CH_2CH_2C_3F_7$, $CH_2C_4F_9$ or $CH_2CH_2C_4F_9$, more preferably a fluorine atom or CF_3, and it is still more preferred that both Xf are a fluorine atom.

Each of R_1 and R_2 independently represents a hydrogen atom, a fluorine atom or an alkyl group. The alkyl group may have a substituent (preferably fluorine atom) and is preferably an alkyl group having a carbon number of 1 to 4, more preferably a perfluoroalkyl group having a carbon number of 1 to 4. Specific examples of the alkyl group having a substituent of R_1 and R_2 include CF_3, C_2F_5, C_3F_7, C_4F_9, C_5F_{11}, C_6F_{13}, C_7F_{15}, C_8F_{17}, CH_2CF_3, $CH_2CH_2CF_3$, $CH_2C_2F_5$, $CH_2CH_2C_2F_5$, $CH_2C_3F_7$, $CH_2CH_2C_3F_7$, $CH_2C_4F_9$ and $CH_2CH_2C_4F_9$, with CF_3 being preferred.

L represents a divalent linking group. Examples of the divalent linking group include -COO-, -OCO-, -CONH-, -NHCO-, -CO-, -O-, -S-, -SO-, $-SO_2-$, an alkylene group (preferably having a carbon number of 1 to 6), a cycloalkylene group (preferably having a carbon number of 3 to 10), an alkenylene group (preferably having a carbon number of 2 to 6), and a divalent linking group formed by combining a plurality of these members. Among these, -COO-, -OCO-, -CONH-, -NHCO-, -CO-, -O-, $-SO_2-$, -COO-alkylene group-, -OCO-alkylene group-, -CONH-alkylene group- and -NHCO-alkylene group- are preferred, and -COO-, -OCO-, -CONH-, $-SO_2-$, -COO-alkylene group- and -OCO-alkylene group- are more preferred,

Cy represents a cyclic organic group. Examples of the cyclic organic group include an alicyclic group, an aryl group and a heterocyclic group

The alicyclic group may be monocyclic or polycyclic. The monocyclic alicyclic group includes, for example, a monocyclic cycloalkyl group such as cyclopentyl group, cylohexyl group and cyclooctyl group. The polycyclic alicyclic group includes, for example, a polycyclic cycloalkyl group such as norbornyl group, tricyclodecanyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group. Above all, an alicyclic group having a bulky structure with a carbon number of 7 or more, such as norbornyl

group, tricyclodecanyl group, tetracyclodecanyl group, tetracyclododecanyl group and adamantyl group, is preferred from the standpoint of controlling in-film diffusion in the PEB (post-exposure baking) step and improving MEEF (Mask Error Enhancement Factor).

The aryl group may be monocyclic or polycyclic. Examples of the aryl group include a phenyl group, a naphthyl group, a phenanthryl group and an anthryl group. Among these, a naphthyl group having relatively low light absorbance at 193 nm is preferred.

The heterocyclic group may be monocyclic or polycyclic, but a polycyclic heterocyclic group can more suppress the diffusion of an acid. The heterocyclic group may have aromaticity or may not have aromaticity. Examples of the heterocyclic ring having aromaticity include a furan ring, a thiophene ring, a benzofuran ring, a benzothiophene ring, a dibenzofuran ring, a dibenzothiophene ring, and a pyridine ring. Examples of the heterocyclic ring not having aromaticity include a tetrahydropyran ring, a lactone ring and a decahydroisoquinoline ring. The heterocyclic ring in the heterocyclic group is preferably a furan ring, a thiophene ring, a pyridine ring or a decahydroisoquinoline ring. Examples of the lactone ring include lactone structures exemplified in the resin (A-1) or (A-2) above.

The above-described cyclic organic group may have a substituent, and examples of the substituent include an alkyl group (may be linear or branched, preferably having a carbon number of 1 to 12), a cycloalkyl group (may be monocyclic, polycyclic or spirocyclic, preferably having a carbon number of 3 to 20), an aryl group (preferably having a carbon number of 6 to 14), a hydroxyl group, an alkoxy group, an ester group, an amide group, a urethane group, a ureido group, a thioether group, a sulfonamido group and a sulfonic acid ester group. Incidentally, the carbon constituting the cyclic organic group (the carbon contributing to ring formation) may be carbonyl carbon.

x is preferably from 1 to 8, more preferably from 1 to 4, still more preferably 1. y is preferably from 0 to 4, more preferably 0. z is preferably from 0 to 8, more preferably from 0 to 4.

The fluorine atom-containing group represented by Rf includes, for example, an alkyl group having at least one fluorine atom, a cycloalkyl group having at least one fluorine atom, and an aryl group having at least one fluorine atom

These alkyl group, cycloalkyl group and aryl group may be substituted with a fluorine atom or may be substituted with another fluorine atom-containing substituent. In the case where Rf is a cycloalkyl group having at least one fluorine atom or an aryl group having at least one fluorine atom, the another fluorine-containing substituent includes, for example, an

alkyl group substituted with at least one fluorine atom.

Also, the alkyl group, cycloalkyl group and aryl group may be further substituted with a fluorine atom-free substituent. Examples of this substituent include those not containing a fluorine atom out of the substituents described above for Cy.

Examples of the alkyl group having at least one fluorine atom represented by Rf are the same as those described above as the alkyl group substituted with at least one fluorine atom represented by Xf. Examples of the cycloalkyl group having at least one fluorine atom represented by Rf include a perfluorocyclopentyl group and a perfluorocyclohexyl group. Examples of the aryl group having at least one fluorine atom represented by Rf include a perfluorophenyl group.

The organic group represented by R_{201}, R_{202} and R_{203} includes, for example, corresponding groups in the later-described compounds (ZI-1), (ZI-2), (ZI-3) and (ZI-4).

The compound may be a compound having a plurality of structures represented by formula (ZI). For example, the compound may be a compound having a structure where at least one of R_{201} to R_{203} in a compound represented by formula (ZI) is bonded to at least one of R_{201} to R_{203} in another compound represented by formula (ZI) through a single bond or a linking group.

Compounds (ZI-1), (ZI-2), (ZI-3) and (ZI-4) described below are more preferred as the component (ZI).

The compound (ZI-1) is an arylsulfonium compound where at least one of R_{201} to R_{203} in formula (ZI) is an aryl group, that is, a compound having an arylsulfonium as the cation.

In the arylsulfonium compound, all of R_{201} to R_{203} may be an aryl group, or a part of R_{201} to R_{203} may be an aryl group, with the remaining being an alkyl group or a cycloalkyl group.

Examples of the arylsulfonium compound include a triarylsulfonium compound, a diarylalkylsulfonium compound, an aryldialkylsulfonium compound, a diarylcycloalkylsulfonium compound, and an aryldicycloalkylsulfonium compound.

The aryl group in the arylsulfonium compound is preferably a phenyl group or a naphthyl group, more preferably a phenyl group. The aryl group may be an aryl group having a heterocyclic structure containing an oxygen atom, a nitrogen atom, a sulfur atom or the like. Examples of the heterocyclic structure include a pyrrole residue, a furan residue, a thiophene residue, an indole residue, a benzofuran residue and a benzothiophene residue. In

the case where the arylsulfonium compound has two or more aryl groups, these two or more aryl groups may be the same or different.

The alkyl or cycloalkyl group which is contained, if desired, in the arylsulfonium compound is preferably a linear or branched alkyl group having a carbon number of 1 to 15 or a cycloalkyl group having a carbon number of 3 to 15, and examples thereof include a methyl group, an ethyl group, a propyl group, an n-butyl group, a sec-butyl group, a tert-butyl group, a cyclopropyl group, a cyclobutyl group, and a cyclohexyl group.

The aryl group, alkyl group and cycloalkyl group of R_{201} to R_{203} may have, as the substituent, an alkyl group (for example, having a carbon number of 1 to 15), a cycloalkyl group (for example, having a carbon number of 3 to 15), an aryl group (for example, having a carbon number of 6 to 14), an alkoxy group (for example, having a carbon number of 1 to 15), a halogen atom, a hydroxyl group or a phenylthio group. The substituent is preferably a linear or branched alkyl group having a carbon number of 1 to 12, a cycloalkyl group having a carbon number of 3 to 12, or a linear, branched or cyclic alkoxy group having a carbon number of 1 to 12, more preferably an alkyl group having a carbon number of 1 to 4, or an alkoxy group having a carbon number of 1 to 4. The substituent may be substituted on any one of three members R_{201} to R_{203} or may be substituted on all of these three members. In the case where R_{201} to R_{203} are an aryl group, the substituent is preferably substituted on the p-position of the aryl group.

The compound (ZI-2) is described below.

The compound (ZI-2) is a compound where each of R_{201} to R_{203} in formula (ZI) independently represents an aromatic ring-free organic group. The aromatic ring as used herein encompasses an aromatic ring containing a heteroatom.

The aromatic ring-free organic group as R_{201} to R_{203} has a carbon number of generally from 1 to 30, preferably from 1 to 20.

Each of R_{201} to R_{203} is independently, preferably an alkyl group, a cycloalkyl group, an allyl group or a vinyl group, more preferably a linear or branched 2-oxoalkyl group, a 2-oxocycloalkyl group or an alkoxycarbonylmethyl group, still more preferably a linear or branched 2-oxoalkyl group.

The alkyl group and cycloalkyl group of R_{201} to R_{203} are preferably a linear or branched alkyl group having a carbon number of 1 to 10 (e.g., methyl, ethyl, propyl, butyl, pentyl) and a cycloalkyl group having a carbon number of 3 to 10 (e.g., cyclopentyl, cyclohexyl, norbornyl). The alkyl group is more preferably a 2-oxoalkyl group or an

alkoxycarbonylmethyl group. The cycloalkyl group is more preferably a 2-oxocycloalkyl group.

The 2-oxoalkyl group may be either linear or branched and is preferably a group having >C=O at the 2-position of the above-described alkyl group.

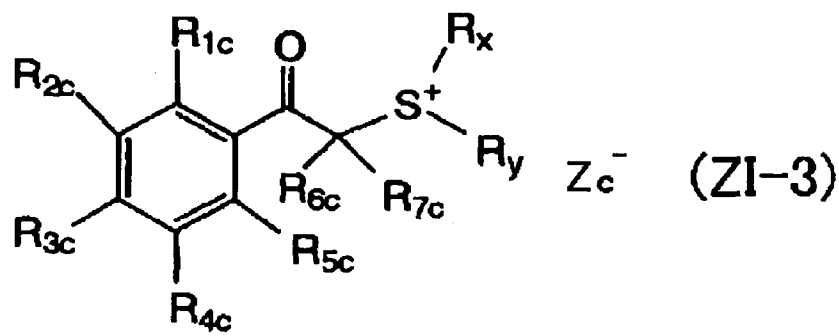
The 2-oxocycloalkyl group is preferably a group having >C=O at the 2-position of the above-described cycloalkyl group.

The alkoxy group in the alkoxycarbonylmethyl group is preferably an alkoxy group having a carbon number of 1 to 5 (e.g., methoxy group, ethoxy group, propoxy group, butoxy group, pentoxy group).

R_{201} to R_{203} may be further substituted with a halogen atom, an alkoxy group (for example, having a carbon number of 1 to 5), a hydroxyl group, a cyano group or a nitro group.

The compound (ZI-3) is described below.

The compound (ZI-3) is a compound represented by the following formula (ZI-3), and this is a compound having a phenacylsulfonium salt structure.



In formula (ZI-3), each of R_{1c} to R_{5c} independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, an aryl group, an alkoxy group, an aryloxy group, an alkoxycarbonyl group, an alkylcarbonyloxy group, a cycloalkylcarbonyloxy group, a halogen atom, a hydroxyl group, a nitro group, an alkylthio group, or an arylthio group.

Each of R_{6c} and R_{7c} independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, a halogen atom, a cyano group, or an aryl group.

Each of R_x and R_y independently represents an alkyl group, a cycloalkyl group, a 2-oxoalkyl group, a 2-oxocycloalkyl group, an alkoxycarbonylalkyl group, an allyl group, or a vinyl group.

Any two or more members out of R_{1c} to R_{5c}, a pair of R_{5c} and R_{6c}, a pair of R_{6c} and R_{7c}, a pair of R_{5c} and R_x, or a pair of R_x and R_y may combine together to form a ring structure. This ring structure may contain an oxygen atom, a sulfur atom, a ketone group, an ester bond

or an amide bond.

The ring structure above includes an aromatic or non-aromatic hydrocarbon ring, an aromatic or non-aromatic heterocyclic ring, and a polycyclic condensed ring formed by combining two or more of these rings. The ring structure includes a 3- to 10-membered ring and is preferably a 4- to 8-membered ring, more preferably a 5- or 6-membered ring.

Examples of the group formed by combining any two or more members of R_{1c} to R_{5c}, a pair of R_{6c} and R_{7c}, or a pair of R_x and R_y include a butylene group and a pentylene group.

The group formed by combining a pair of R_{5c} and R_{6c} or a pair of R_{5c} and R_x is preferably a single bond or an alkylene group, and examples of the alkylene group include a methylene group and an ethylene group.

Zc^- represents a non-nucleophilic anion, and examples thereof are the same as those of the non-nucleophilic anion of Z^- in formula (ZI).

The alkyl group as R_{1c} to R_{7c} may be either linear or branched and is, for example, an alkyl group having a carbon number of 1 to 20, preferably a linear or branched alkyl group having a carbon number of 1 to 12 (such as methyl group, ethyl group, linear or branched propyl group, linear or branched butyl group, or linear or branched pentyl group). The cycloalkyl group includes, for example, a cycloalkyl group having a carbon number of 3 to 10 (e.g., cyclopentyl group, cyclohexyl group).

The aryl group as R_{1c} to R_{5c} is preferably an aryl group having a carbon number of 5 to 15, and examples thereof include a phenyl group and a naphthyl group.

The alkoxy group as R_{1c} to R_{5c} may be linear, branched or cyclic and is, for example, an alkoxy group having a carbon number of 1 to 10, preferably a linear or branched alkoxy group having a carbon number of 1 to 5 (such as methoxy group, ethoxy group, linear or branched propoxy group, linear or branched butoxy group, or linear or branched pentoxy group), or a cyclic alkoxy group having a carbon number of 3 to 10 (such as cyclopentyloxy group or cyclohexyloxy group).

Specific examples of the alkoxy group in the alkoxycarbonyl group as R_{1c} to R_{5c} are the same as specific examples of the alkoxy group of R_{1c} to R_{5c}.

Specific examples of the alkyl group in the alkylcarbonyloxy group and alkylthio group as R_{1c} to R_{5c} are the same as specific examples of the alkyl group of R_{1c} to R_{5c}.

Specific examples of the cycloalkyl group in the cycloalkylcarbonyloxy group as R_{1c} to R_{5c} are the same as specific examples of the cycloalkyl group of R_{1c} to R_{5c}.

Specific examples of the aryl group in the aryloxy group and arylthio group as R_{1c} to

R_{5c} are the same as specific examples of the aryl group of R_{1c} to R_{5c}.

A compound where any one of R_{1c} to R_{5c} is a linear or branched alkyl group, a cycloalkyl group, or a linear, branched or cyclic alkoxy group is preferred, and a compound where the sum of carbon numbers of R_{1c} to R_{5c} is from 2 to 15 is more preferred. Thanks to such a compound, the solvent solubility is more enhanced and production of particles during storage can be suppressed.

The ring structure which may be formed by combining any two or more members of R_{1c} to R_{5c} with each other is preferably a 5- or 6-membered ring, more preferably a 6-membered ring (such as phenyl ring).

The ring structure which may be formed by combining R_{5c} and R_{6c} with each other includes a 4- or higher-membered ring (preferably a 5- or 6-membered ring) formed together with the carbonyl carbon atom and carbon atom in formula (I) by combining R_{5c} and R_{6c} with each other to constitute a single bond or an alkylene group (such as methylene group or ethylene group).

The aryl group as R_{6c} and R_{7c} is preferably an aryl group having a carbon number of 5 to 15, and examples thereof include a phenyl group and a naphthyl group.

An embodiment where both of R_{6c} and R_{7c} are an alkyl group is preferred, an embodiment where each of R_{6c} and R_{7c} is a linear or branched alkyl group having a carbon number of 1 to 4 is more preferred, and an embodiment where both are a methyl group is still more preferred.

In the case where R_{6c} and R_{7c} are combined to form a ring, the group formed by combining R_{6c} and R_{7c} is preferably an alkylene group having a carbon number of 2 to 10, and examples thereof include an ethylene group, a propylene group, a butylene group, a pentylene group and a hexylene group. Also, the ring formed by combining R_{6c} and R_{7c} may contain a heteroatom such as oxygen atom in the ring.

Examples of the alkyl group and cycloalkyl group as R_x and R_y are the same as those of the alkyl group and cycloalkyl group in R_{1c} to R_{7c}.

Examples of the 2-oxoalkyl group and 2-oxocycloalkyl group as R_x and R_y include a group having >C=O at the 2-position of the alkyl group or cycloalkyl group as R_{1c} to R_{7c}.

Examples of the alkoxy group in the alkoxycarbonylalkyl group as R_x and R_y are the same as those of the alkoxy group in R_{1c} to R_{5c}. The alkyl group is, for example, an alkyl group having a carbon number of 1 to 12, preferably a linear alkyl group having a carbon number of 1 to 5 (such as methyl group or ethyl group).

The allyl group as R_x and R_y is not particularly limited but is preferably an unsubstituted allyl group or an allyl group substituted with a monocyclic or polycyclic cycloalkyl group (preferably a cycloalkyl group having a carbon number of 3 to 10).

The vinyl group as R_x and R_y is not particularly limited but is preferably an unsubstituted vinyl group or a vinyl group substituted with a monocyclic or polycyclic cycloalkyl group (preferably a cycloalkyl group having a carbon number of 3 to 10).

The ring structure which may be formed by combining R_{5c} and R_x with each other includes a 5- or higher-membered ring (preferably a 5-membered ring) formed together with the sulfur atom and carbonyl carbon atom in formula (I) by combining R_{5c} and R_x with each other to constitute a single bond or an alkylene group (such as methylene group or ethylene group).

The ring structure which may be formed by combining R_x and R_y with each other includes a 5- or 6-membered ring, preferably a 5-membered ring (that is, tetrahydrothiophene ring), formed by divalent R_x and R_y (for example., a methylene group, an ethylene group or a propylene group) together with the sulfur atom in formula (ZI-3).

Each of R_x and R_y is preferably an alkyl or cycloalkyl group having a carbon number of 4 or more, more preferably 6 or more, still more preferably 8 or more.

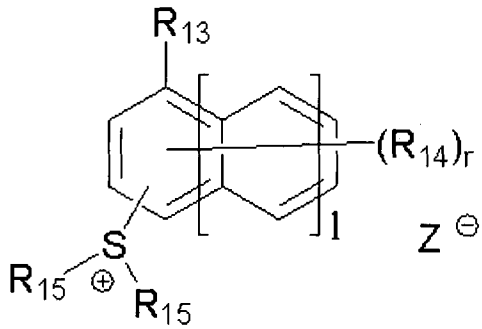
Each of R_{1c} to R_{7c}, R_x and R_y may further have a substituent, and examples of such a substituent include a halogen atom (e.g., fluorine atom), a hydroxyl group, a carboxyl group, a cyano group, a nitro group, an alkyl group, a cycloalkyl group, an aryl group, an alkoxy group, an aryloxy group, an acyl group, an arylcarbonyl group, an alkoxyalkyl group, an aryloxyalkyl group, an alkoxycarbonyl group, an aryloxycarbonyl group, an alkoxycarbonyloxy group, and an aryloxycarbonyloxy group.

In formula (ZI-3), it is more preferred that each of R_{1c}, R_{2c}, R_{4c} and R_{5c} independently represents a hydrogen atom and R_{3c} represents a group except for a hydrogen atom, that is, represents an alkyl group, a cycloalkyl group, an aryl group, an alkoxy group, an aryloxy group, an alkoxycarbonyl group, an alkylcarbonyloxy group, a cycloalkylcarbonyloxy group, a halogen atom, a hydroxyl group, a nitro group, an alkylthio group or an arylthio group.

Examples of the cation in the compound (ZI-2) or (ZI-3) for use in the present invention include cations described in paragraphs [0130] to [0134] of JP-A-2010-256842 and paragraphs [0136] to [0140] of JP-A-2011-76056.

The compound (ZI-4) is described below.

The compound (ZI-4) is represented by the following formula (ZI-4):



(ZI-4)

In formula (ZI-4), R_{13} represents a hydrogen atom, a fluorine atom, a hydroxyl group, an alkyl group, a cycloalkyl group, an alkoxy group, an alkoxycarbonyl group, or a group having a cycloalkyl group. These groups may have a substituent.

R_{14} represents, when a plurality of R_{14}s are present, each independently represents, a hydroxyl group, an alkyl group, a cycloalkyl group, an alkoxy group, an alkoxycarbonyl group, an alkylcarbonyl group, an alkylsulfonyl group, a cycloalkylsulfonyl group, or a group having a cycloalkyl group. These groups may have a substituent.

Each R_{15} independently represents an alkyl group, a cycloalkyl group, or a naphthyl group. Two R_{15}s may combine with each other to form a ring. These groups may have a substituent.

l represents an integer of 0 to 2.

r represents an integer of 0 to 8.

Z^- represents a non-nucleophilic anion, and examples thereof are the same as those of the nucleophilic anion of Z^- in formula (ZI).

In formula (ZI-4), the alkyl group of R_{13}, R_{14} and R_{15} is a linear or branched alkyl group preferably having a carbon number of 1 to 10, and preferred examples thereof include a methyl group, an ethyl group, an n-butyl group and a tert-butyl group.

The cycloalkyl group of R_{13}, R_{14} and R_{15} includes a monocyclic or polycyclic cycloalkyl group (preferably a cycloalkyl group having a carbon number of 3 to 20) and is preferably cyclopropyl, cyclopentyl, cyclohexyl, cycloheptyl, or cyclooctyl, among others.

The alkoxy group of R_{13} and R_{14} is a linear or branched alkoxy group preferably having a carbon number of 1 to 10, and preferred examples thereof include a methoxy group, an ethoxy group, an n-propoxy group and an n-butoxy group.

The alkoxycarbonyl group of R_{13} and R_{14} is a linear or branched alkoxycarbonyl group preferably having a carbon number of 2 to 11, and preferred examples thereof include a methoxycarbonyl group, an ethoxycarbonyl group and an n-butoxycarbonyl group.

The group having a cycloalkyl group of R_{13} and R_{14} includes a monocyclic or polycyclic cycloalkyl group (preferably a cycloalkyl group having a carbon number of 3 to 20), and examples thereof include a monocyclic or polycyclic cycloalkyloxy group and an alkoxy group having a monocyclic or polycyclic cycloalkyl group. These groups may further have a substituent.

The monocyclic or polycyclic cycloalkyloxy group of R_{13} and R_{14} preferably has a total carbon number of 7 or more, more preferably a total carbon number of 7 to 15, and it is preferred to have a monocyclic cycloalkyl group. The monocyclic cycloalkyloxy group having a total carbon number of 7 or more indicates a monocyclic cycloalkyloxy group where a cycloalkyloxy group such as cyclopropyloxy group, cyclobutyloxy group, cyclopentyloxy group, cyclohexyloxy group, cycloheptyloxy group, cyclooctyloxy group and cyclododecanyloxy group arbitrarily has a substituent such as alkyl group (e.g., methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, octyl group, dodecyl group, 2-ethylhexyl group, isopropyl group, sec-butyl group, tert-butyl group, isoamyl group), hydroxyl group, halogen atom (e.g., fluorine, chlorine, bromine, iodine), nitro group, cyano group, amido group, sulfonamido group, alkoxy group (e.g., methoxy group, ethoxy group, hydroxyethoxy group, propoxy group, hydroxypropoxy group, butoxy group), alkoxycarbonyl group (e.g., methoxycarbonyl group, ethoxycarbonyl group), acyl group (e.g., formyl group, acetyl group, benzoyl group), acyloxy group (e.g., acetoxy group, butyryloxy group) and carboxy group and where the total carbon number inclusive of the carbon number of an arbitrary substituent on the cycloalkyl group is 7 or more.

Examples of the polycyclic cycloalkyloxy group having a total carbon number of 7 or more include a norbornyloxy group, a tricyclodecanyloxy group, a tetracyclodecanyloxy group, and an adamantyloxy group.

The alkoxy group having a monocyclic or polycyclic cycloalkyl group of R_{13} and R_{14} preferably has a total carbon number of 7 or more, more preferably a total carbon number of 7 to 15, and is preferably an alkoxy group having a monocyclic cycloalkyl group. The alkoxy group having a total carbon number of 7 or more and having a monocyclic cycloalkyl group indicates an alkoxy group where the above-described monocyclic cycloalkyl group which may have a substituent is substituted on an alkoxy group such as methoxy, ethoxy, propoxy, butoxy, pentyloxy, hexyloxy, heptoxy, octyloxy, dodecyloxy, 2-ethylhexyloxy, isopropoxy, sec-butoxy, tert-butoxy and isoamyloxy and where the total carbon number inclusive of the carbon number of the substituent is 7 or more. Examples thereof include a

cyclohexylmethoxy group, a cyclopentylethoxy group, and a cyclohexylethoxy group, with a cyclohexylmethoxy group being preferred.

Examples of the alkoxy group having a total carbon number of 7 or more and having a polycyclic cycloalkyl group include a norbornylmethoxy group, a norbornylethoxy group, a tricyclodecanylmethoxy group, a tricyclodecanylethoxy group, a tetracyclodecanylmethoxy group, a tetracyclodecanylethoxy group, an adamantylmethoxy group, and an adamantylethoxy group, with a norbornylmethoxy group and a norbornylethoxy group being preferred.

Specific examples of the alkyl group in the alkylcarbonyl group of R_{14} are the same as those of the alkyl group of R_{13} to R_{15}.

The alkylsulfonyl or cycloalkylsulfonyl group of R_{14} is a linear, branched or cyclic alkylsulfonyl group preferably having a carbon number of 1 to 10, and preferred examples thereof include a methanesulfonyl group, an ethanesulfonyl group, an n-propanesulfonyl group, an n-butanesulfonyl group, a cyclopentanesulfonyl group, and a cyclohexanesulfonyl group.

Examples of the substituent which each of the groups above may have include a halogen atom (e.g., fluorine atom), a hydroxyl group, a carboxyl group, a cyano group, a nitro group, an alkoxy group, an alkoxyalkyl group, an alkoxycarbonyl group, and an alkoxycarbonyloxy group.

Examples of the alkoxy group include a linear, branched or cyclic alkoxy group having a carbon number of 1 to 20, such as methoxy group, ethoxy group, n-propoxy group, i-propoxy group, n-butoxy group, 2-methylpropoxy group, 1-methylpropoxy group, tert-butoxy group, cyclopentyloxy group and cyclohexyloxy group.

Examples of the alkoxyalkyl group include a linear, branched or cyclic alkoxyalkyl group having a carbon number of 2 to 21, such as methoxymethyl group, ethoxymethyl group, 1-methoxyethyl group, 2-methoxyethyl group, 1-ethoxyethyl group and 2-ethoxyethyl group.

Examples of the alkoxycarbonyl group include a linear, branched or cyclic alkoxycarbonyl group having a carbon number of 2 to 21, such as methoxycarbonyl group, ethoxycarbonyl group, n-propoxycarbonyl group, i-propoxycarbonyl group, n-butoxycarbonyl group, 2-methylpropoxycarbonyl group, 1-methylpropoxycarbonyl group, tert-butoxycarbonyl group, cyclopentyloxycarbonyl group and cyclohexyloxycarbonyl group.

Examples of the alkoxycarbonyloxy group include a linear, branched or cyclic alkoxycarbonyloxy group having a carbon number of 2 to 21, such as methoxycarbonyloxy group, ethoxycarbonyloxy group, n-propoxycarbonyloxy group, i-propoxycarbonyloxy group,

n-butoxycarbonyloxy group, tert-butoxycarbonyloxy group, cyclopentyloxycarbonyloxy group and cyclohexyloxycarbonyloxy group.

The ring structure which may be formed by combining two R_{15}s with each other includes a 5- or 6-membered ring, preferably a 5-membered ring (that is, tetrahydrothiophene ring), formed by two R_{15}s together with the sulfur atom in formula (ZI-4) and may be fused with an aryl group or a cycloalkyl group. The divalent R_{15} may have a substituent, and examples of the substituent include a hydroxyl group, a carboxyl group, a cyano group, a nitro group, an alkyl group, a cycloalkyl group, an alkoxy group, an alkoxyalkyl group, an alkoxycarbonyl group, and an alkoxycarbonyloxy group. As for the substituent on the ring structure, a plurality of substituents may be present, and they may combine with each other to form a ring (for example, an aromatic or non-aromatic hydrocarbon ring, an aromatic or non-aromatic heterocyclic ring, or a polycyclic condensed ring formed by combining two or more of these rings).

In formula (ZI-4), R_{15} is preferably, for example, a methyl group, an ethyl group, a naphthyl group, or a divalent group capable of forming a tetrahydrothiophene ring structure together with the sulfur atom when two R_{15}s are combined.

The substituent which may be substituted on R_{13} and R_{14} is preferably a hydroxyl group, an alkoxy group, an alkoxycarbonyl group, or a halogen atom (particularly fluorine atom).

l is preferably 0 or 1, more preferably 1.

r is preferably from 0 to 2.

Examples of the cation in the compound represented by formula (ZI-4) for use in the present invention include cations described in paragraphs [0121], [0123] and [0124] of JP-A-2010-256842 and paragraphs [0127], [0129] and [0130] of JP-A-2011-76056.

Formulae (ZII) and (ZIII) are described below.

In formulae (ZII) and (ZIII), each of R_{204} to R_{207} independently represents an aryl group, an alkyl group or a cycloalkyl group.

The aryl group of R_{204} to R_{207} is preferably a phenyl group or a naphthyl group, more preferably a phenyl group. The aryl group of R_{204} to R_{207} may be an aryl group having a heterocyclic structure containing an oxygen atom, a nitrogen atom, a sulfur atom or the like. Examples of the framework of the aryl group having a heterocyclic structure include pyrrole, furan, thiophene, indole, benzofuran, and benzothiophene.

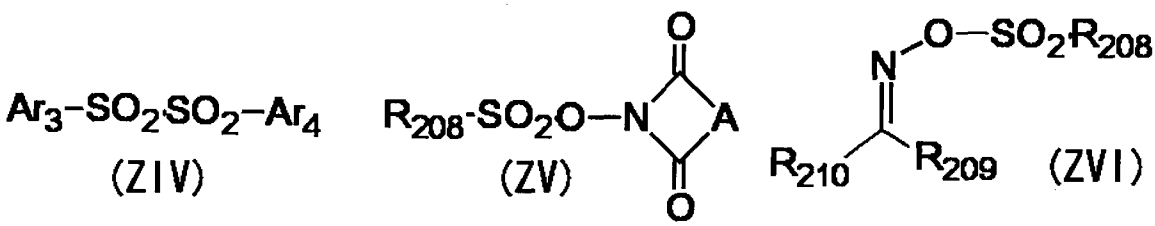
The alkyl group and cycloalkyl group in R_{204} to R_{207} are preferably a linear or

branched alkyl group having a carbon number of 1 to 10 (e.g., methyl group, ethyl group, propyl group, butyl group, pentyl group) and a cycloalkyl group having a carbon number of 3 to 10 (e.g., cyclopentyl group, cyclohexyl group, norbornyl group).

The aryl group, alkyl group and cycloalkyl group of R_{204} to R_{207} may have a substituent. Examples of the substituent which the aryl group, alkyl group and cycloalkyl group of R_{204} to R_{207} may have include an alkyl group (for example, having a carbon number of 1 to 15), a cycloalkyl group (for example, having a carbon number of 3 to 15), an aryl group (for example, having a carbon number of 6 to 15), an alkoxy group (for example, having a carbon number of 1 to 15), a halogen atom, a hydroxyl group, and a phenylthio group.

Z^- represents a non-nucleophilic anion, and examples thereof are the same as those of the non-nucleophilic anion of Z^- in formula (ZI).

Other examples of the acid generator include compounds represented by the following formulae (ZIV), (ZV) and (ZVI):



In formulae (ZIV) to (ZVI), each of Ar_3 and Ar_4 independently represents an aryl group.

Each of R_{208}, R_{209} and R_{210} independently represents an alkyl group, a cycloalkyl group, or an aryl group.

A represents an alkylene group, an alkenylene group, or an arylene group.

Specific examples of the aryl group of Ar_3, Ar_4, R_{208}, R_{209} and R_{210} are the same as specific examples of the aryl group of R_{201}, R_{202} and R_{203} in formula (ZI-1).

Specific examples of the alkyl group and cycloalkyl group of R_{208}, R_{209} and R_{210} are the same as specific examples of the alkyl group and cycloalkyl group of R_{201}, R_{202} and R_{203} in formula (ZI-2).

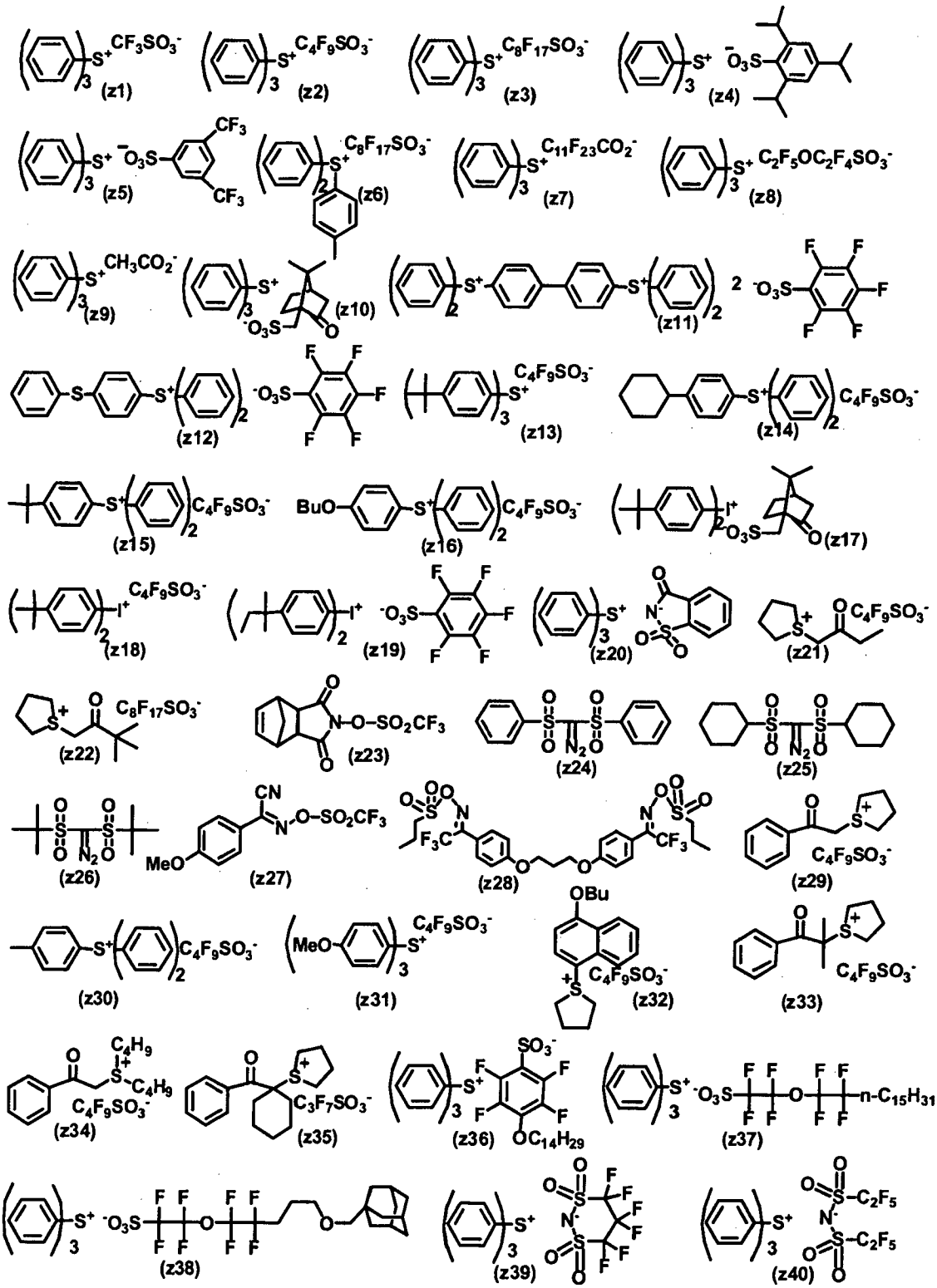
The alkylene group of A includes an alkylene group having a carbon number of 1 to 12 (e.g., methylene group, ethylene group, propylene group, isopropylene group, butylenes group, isobutylene group); the alkenylene group of A includes an alkenylene group having a carbon number of 2 to 12 (e.g., ethenylene group, propenylene group, butenylene group); and the arylene group of A includes an arylene group having a carbon number of 6 to 10 (e.g.,

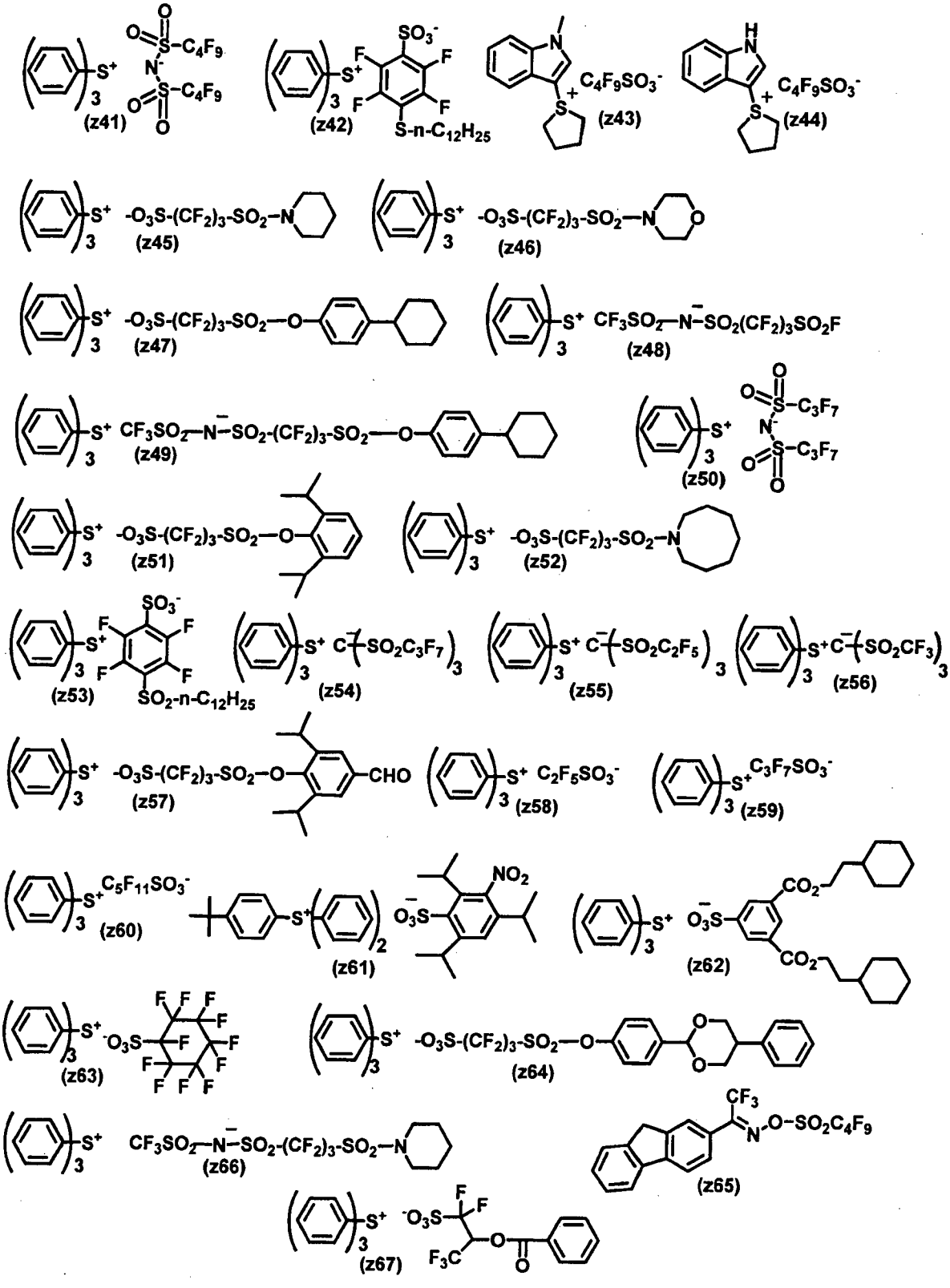
phenylene group, tolylene group, naphthylene group).

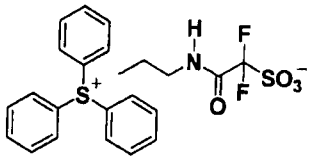
Among the acid generators, more preferred are the compounds represented by formulae (ZI) to (ZIII).

Also, the acid generator is preferably a compound that generates an acid having one sulfonic acid group or imide group, more preferably a compound that generates a monovalent perfluoroalkanesulfonic acid, a compound that generates an aromatic sulfonic acid substituted with a monovalent fluorine atom or a fluorine atom-containing group, or a compound that generates an imide acid substituted with a monovalent fluorine atom or a fluorine atom-containing group, still more preferably a sulfonium salt of fluoro-substituted alkanesulfonic acid, fluorine-substituted benzenesulfonic acid, fluorine-substituted imide acid or fluorine-substituted methide acid. Among others, the acid generator which can be used is preferably a compound that generates a fluoro-substituted alkanesulfonic acid, a fluoro-substituted benzenesulfonic acid or a fluoro-substituted imide acid, where pKa of the acid generated is -1 or less, and in this case, the sensitivity is enhanced.

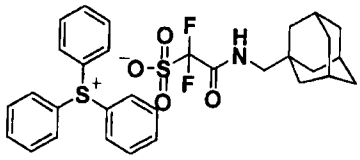
Among the acid generators, particularly preferred examples are illustrated below.


(z1)
(z2)
(z3)
(z4)
(z5)
(z6)
(z7)
(z8)
(z9)
(z10)
(z11)
(z12)
(z13)
(z14)
(z15)
(z16)
(z17)
(z18)
(z19)
(z20)
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(z25)
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(z27)
(z28)
(z29)
(z30)
(z31)
(z32)
(z33)
(z34)
(z35)
(z36)
(z37)
(z38)
(z39)
(z40)

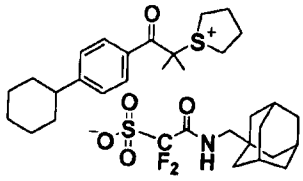

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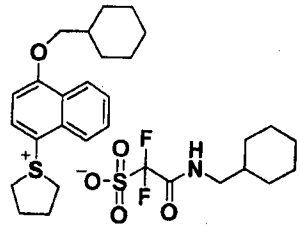
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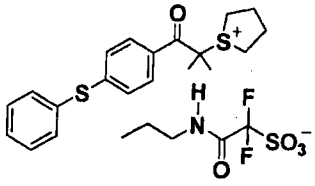
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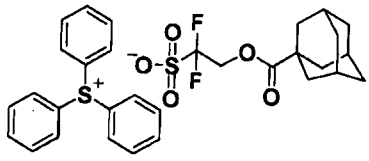
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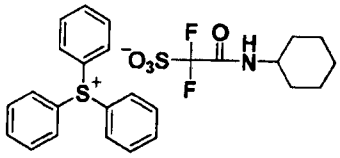
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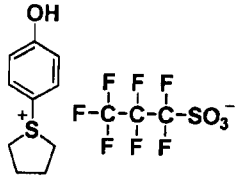
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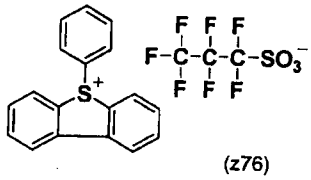
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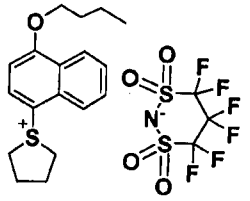
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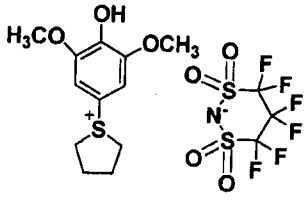
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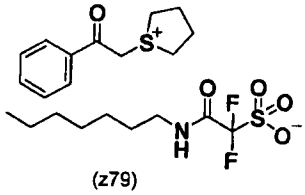
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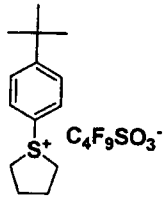
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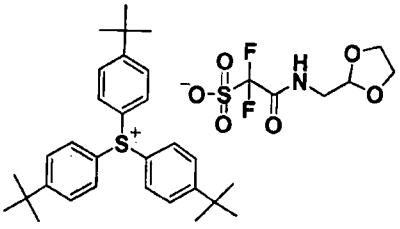
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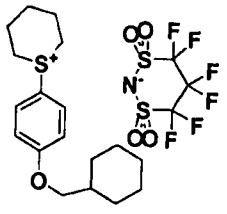
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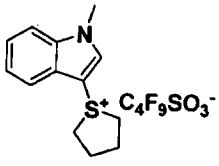
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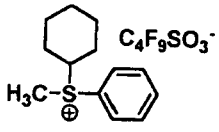
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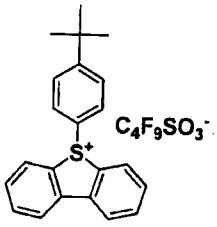
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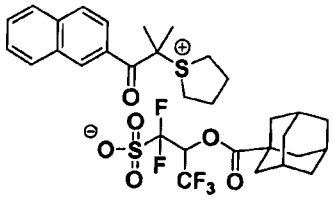
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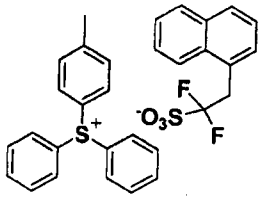
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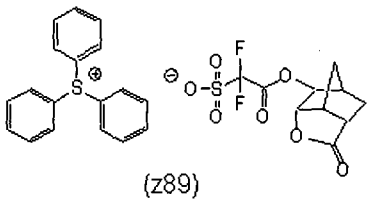
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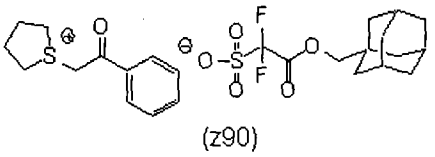
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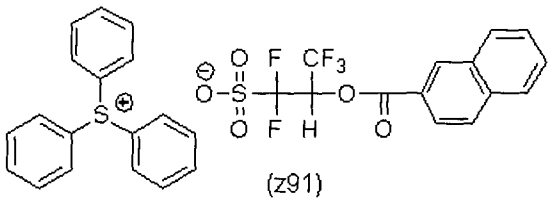
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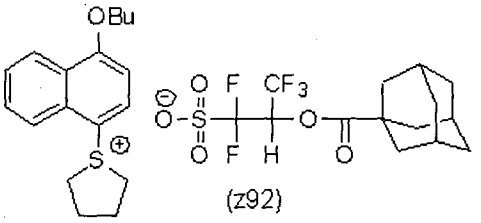
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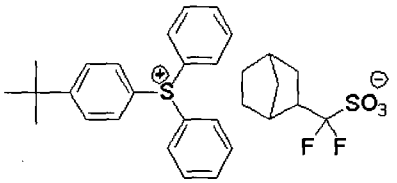
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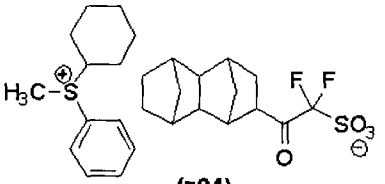
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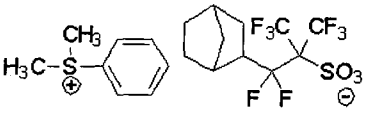
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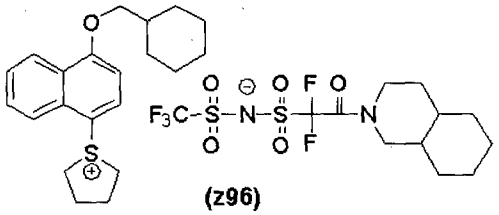
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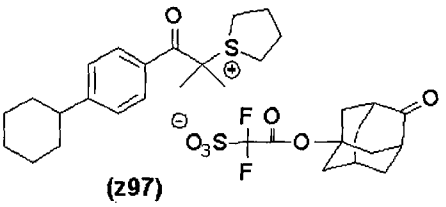
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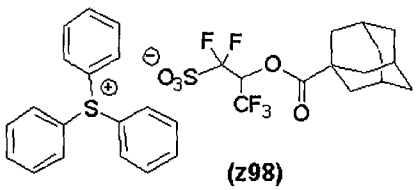
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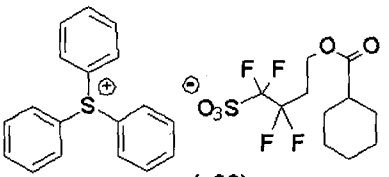
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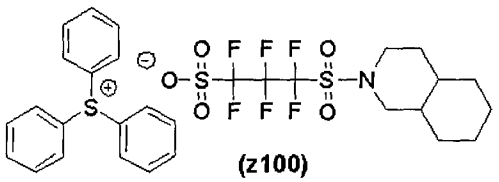
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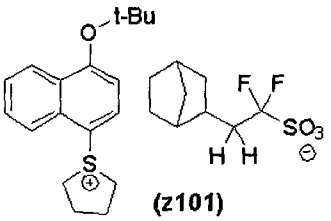
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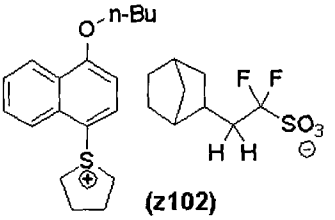
(z99)



(z100)



(z101)



(z102)

The acid generator can be synthesized by a known method, for example, can be synthesized in accordance with the method described in JP-A-2007-161707.

As for the acid generator, one kind may be used alone, or two or more kinds may be used in combination.

The content of the compound capable of generating an acid upon irradiation with an actinic ray or radiation, in the composition (I) or (II), is preferably from 0.1 to 30 mass%, more preferably from 0.5 to 25 mass%, still more preferably from 3 to 20 mass%, yet still more preferably from 3 to 15 mass%, based on the entire solid content of the resin composition (I) or (II).

Also, in the case where the acid generator is represented by formula (ZI-3) or (ZI-4), the content thereof is preferably from 5 to 35 mass%, more preferably from 8 to 30 mass%, still more preferably from 9 to 30 mass%, yet still more preferably from 9 to 25 mass%, based on the entire solid content of the composition (I) or (II).

[3] (C) Solvent

Examples of the solvent which can be used in the preparation of the resin composition (I) or (II) for use in the present invention include an organic solvent such as alkylene glycol monoalkyl ether carboxylate, alkylene glycol monoalkyl ether, alkyl lactate, alkyl alkoxypropionate, cyclic lactone (preferably having a carbon number of 4 to 10), monoketone compound (preferably having a carbon number of 4 to 10) which may contain a ring, alkylene carbonate, alkyl alkoxyacetate and alkyl pyruvate.

Specific examples of these solvents include those described in paragraphs [0441] to [0455] of U.S. Patent Application Publication No. 2008/0187860.

In the present invention, a mixed solvent prepared by mixing a solvent containing a hydroxyl group in the structure and a solvent not containing a hydroxyl group may be used as the organic solvent.

The solvent containing a hydroxyl group and the solvent not containing a hydroxyl group may be appropriately selected from the compounds exemplified above, but the solvent containing a hydroxyl group is preferably an alkylene glycol monoalkyl ether, an alkyl lactate or the like, more preferably propylene glycol monomethyl ether (PGME, another name: 1-methoxy-2-propanol) or ethyl lactate. The solvent not containing a hydroxyl group is preferably an alkylene glycol monoalkyl ether acetate, an alkyl alkoxypropionate, a monoketone compound which may contain a ring, a cyclic lactone, an alkyl acetate or the like, more preferably propylene glycol monomethyl ether acetate (PGMEA, another name: 1-methoxy-2-acetoxypropane), ethyl ethoxypropionate, 2-heptanone, γ-butyrolactone, cyclohexanone or butyl acetate, and most preferably propylene glycol monomethyl ether acetate, ethyl ethoxypropionate or 2-heptanone.

The mixing ratio (by mass) between the solvent containing a hydroxyl group and the solvent not containing a hydroxyl group is from 1/99 to 99/1, preferably from 10/90 to 90/10, more preferably from 20/80 to 60/40. A mixed solvent in which the solvent not containing a hydroxyl group accounts for 50 mass% or more is particularly preferred in view of coating uniformity.

The solvent preferably contains propylene glycol monomethyl ether acetate and is preferably a solvent containing propylene glycol monomethyl ether acetate alone or a mixed solvent of two or more kinds of solvents containing propylene glycol monomethyl ether acetate.

In the present invention, from the standpoint of preventing occurrence of intermixing at the interface between the first film and the second film, in one preferred embodiment, the solvent incorporated into the second resin composition (II) for forming the second film is an alcohol not having an oxygen atom except for a hydroxyl group, an ester having a carbon number of 7 or more, or an ether not having an oxygen atom except for an ether bond.

Each of these specific solvents has appropriate polarity and therefore, while respective solid contents in the second resin composition (II) are dissolved, the first film after film formation is not dissolved, so that occurrence of intermixing can be prevented.

It is particularly preferred that the solvent contained in the second resin composition (II) for forming the second film is an alcohol not having an oxygen atom except for a hydroxyl group, an ester having a carbon number of 7 or more, or an ether not having an oxygen atom except for an ether bond and at the same time, the resin contained in the first resin composition (I) for forming the first film is a resin composed of a (meth)acrylate-based repeating unit (preferably a resin where all repeating units are composed of a (meth)acrylate-based repeating unit).

The alcohol not having an oxygen atom except for a hydroxyl group is preferably a monohydric alcohol not having an oxygen atom except for a hydroxyl group. The carbon number of the alcohol not having an oxygen atom except for a hydroxyl group is preferably from 1 to 20, more preferably from 3 to 15, still more preferably from 4 to 12, yet still more preferably from 5 to 10. Specific examples of the alcohol include 4-methyl-2-pentanol.

The ester having a carbon number of 7 or more is preferably an ester having a carbon number of 7 or more and not having an oxygen atom other than one ester bond. The carbon number of the ester having a carbon number of 7 or more is preferably from 7 to 20,

more preferably from 7 to 15, still more preferably from 7 to 12, yet still more preferably from 7 to 10. Specific examples of the ester include isobutyl isobutyrate.

Examples of the ether not having an oxygen atom other than an ether bond include a dialkyl ether and an alkylaryl ether. The carbon number of the ether not having an oxygen atom other than an ether bond is preferably from 3 to 20, more preferably from 4 to 15, still more preferably from 5 to 12.

Specific examples of the ether include diisoamyl ether.

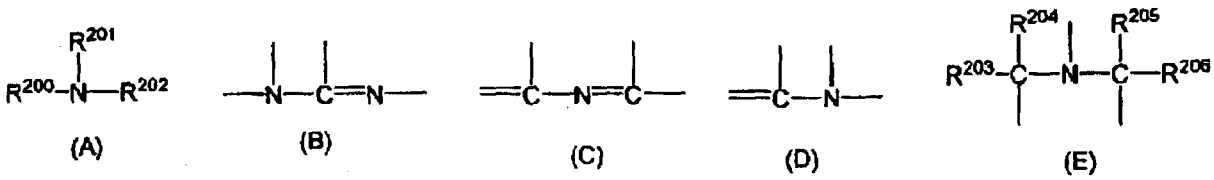
Such a solvent preferably accounts for 30 mass% or more, more preferably 50 mass% or more, still more preferably 80 mass% or more, based on all solvents contained in the second resin composition (II).

[4] (D) Basic compound

In the present invention, from the standpoint of controlling the diffusion of the acid generated, the second resin composition (II) preferably contains (D) a basic compound.

Also, for example, in the case where the first resin composition (I) contains the above-described acid generator, the first resin composition (I) may or may not contain the basic compound (D).

The basic compound is preferably a compound having a structure represented by the following formulae (A) to (E):



In formulae (A) and (E), each of R^{200}, R^{201} and R^{202}, which may be the same or different, represents a hydrogen atom, an alkyl group (preferably having a carbon number of 1 to 20), a cycloalkyl group (preferably having a carbon number of 3 to 20) or an aryl group (having a carbon number of 6 to 20), and R^{201} and R^{202} may combine together to form a ring. Each of R^{203}, R^{204}, R^{205} and R^{206}, which may be the same or different, represents an alkyl group having a carbon number of 1 to 20.

As for the alkyl group, the alkyl group having a substituent is preferably an aminoalkyl group having a carbon number of 1 to 20, a hydroxyalkyl group having a carbon number of 1 to 20, or a cyanoalkyl group having a carbon number of 1 to 20.

The alkyl group in formulae (A) and (E) is more preferably unsubstituted.

Preferred examples of the compound include guanidine, aminopyrrolidine, pyrazole, pyrazoline, piperazine, aminomorpholine, aminoalkylmorpholine, and piperidine. More preferred examples of the compound include a compound having an imidazole structure, a diazabicyclo structure, an onium hydroxide structure, an onium carboxylate structure, a trialkylamine structure, an aniline structure or a pyridine structure; an alkylamine derivative having a hydroxyl group and/or an ether bond; and an aniline derivative having a hydroxyl group and/or an ether bond.

Examples of the compound having an imidazole structure include imidazole, 2,4,5-triphenylimidazole, and benzimidazole. Examples of the compound having a diazabicyclo structure include 1,4-diazabicyclo[2,2,2]octane, 1,5-diazabicyclo[4,3,0]non-5-ene, and 1,8-diazabicyclo[5,4,0]undec-7-ene. Examples of the compound having an onium hydroxide structure include a triarylsulfonium hydroxide, a phenacylsulfonium hydroxide, and a sulfonium hydroxide having a 2-oxoalkyl group, specifically, triphenylsulfonium hydroxide, tris(tert-butylphenyl)sulfonium hydroxide, bis(tert-butylphenyl)iodonium hydroxide, phenacylthiophenium hydroxide and 2-oxopropylthiophenium hydroxide. The compound having an onium carboxylate structure is a compound where the anion moiety of the compound having an onium hydroxide structure becomes a carboxylate, and examples thereof include an acetate, an adamantane-1-carboxylate, and a perfluoroalkyl carboxylate. Examples of the compound having a trialkylamine structure include tri(n-butyl)amine and tri(n-octyl)amine. Examples of the compound having an aniline structure include 2,6-diisopropylaniline, N,N-dimethylaniline, N,N-dibutylaniline, and N,N-dihexylaniline. Examples of the alkylamine derivative having a hydroxyl group and/or an ether bond include ethanolamine, diethanolamine, triethanolamine, and tris(methoxyethoxyethyl)amine. Examples of the aniline derivative having a hydroxyl group and/or an ether bond include N,N-bis(hydroxyethyl)aniline.

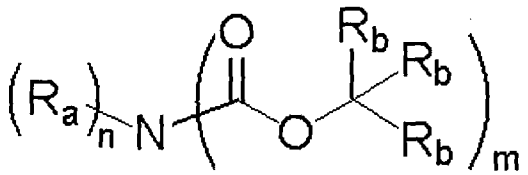
Other preferred basic compounds include a phenoxy group-containing amine compound, a phenoxy group-containing ammonium salt compound, a sulfonic acid ester group-containing amine compound, and a sulfonic acid ester group-containing ammonium salt compound.

In the phenoxy group-containing amine compound, phenoxy group-containing ammonium salt compound, sulfonic acid ester group-containing amine compound and sulfonic acid ester group-containing ammonium salt compound, at least one alkyl group is preferably

bonded to the nitrogen atom and also, the alkyl chain preferably contains an oxygen atom to form an oxyalkylene group. The number of oxyalkylene groups in the molecule is 1 or more, preferably from 3 to 9, more preferably from 4 to 6. Among oxyalkylene groups, those having a structure of $-CH_2CH_2O-$, $-CH(CH_3)CH_2O-$ or $-CH_2CH_2CH_2O-$ are preferred.

Specific examples of the phenoxy group-containing amine compound, phenoxy group-containing ammonium salt compound, sulfonic acid ester group-containing amine compound and sulfonic acid ester group-containing ammonium salt compound include, but are not limited to, Compounds (C1-1) to (C3-3) illustrated in paragraph [0066] of U.S. Patent Application Publication No. 2007/0224539.

A nitrogen-containing organic compound having a group capable of leaving by the action of an acid may be also used as a kind of the basic compound. Examples of this compound include a compound represented by the following formula (F). Incidentally, the compound represented by the following formula (F) exhibits an effective basicity in the system as a result of elimination of the group capable of leaving by the action of an acid.



(F)

In formula (F), each Ra independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, an aryl group, or an aralkyl group. Also, when n=2, two Ra's may be the same or different, and two Ra's may combine with each other to form a divalent heterocyclic hydrocarbon group (preferably having a carbon number of 20 or less) or a derivative thereof.

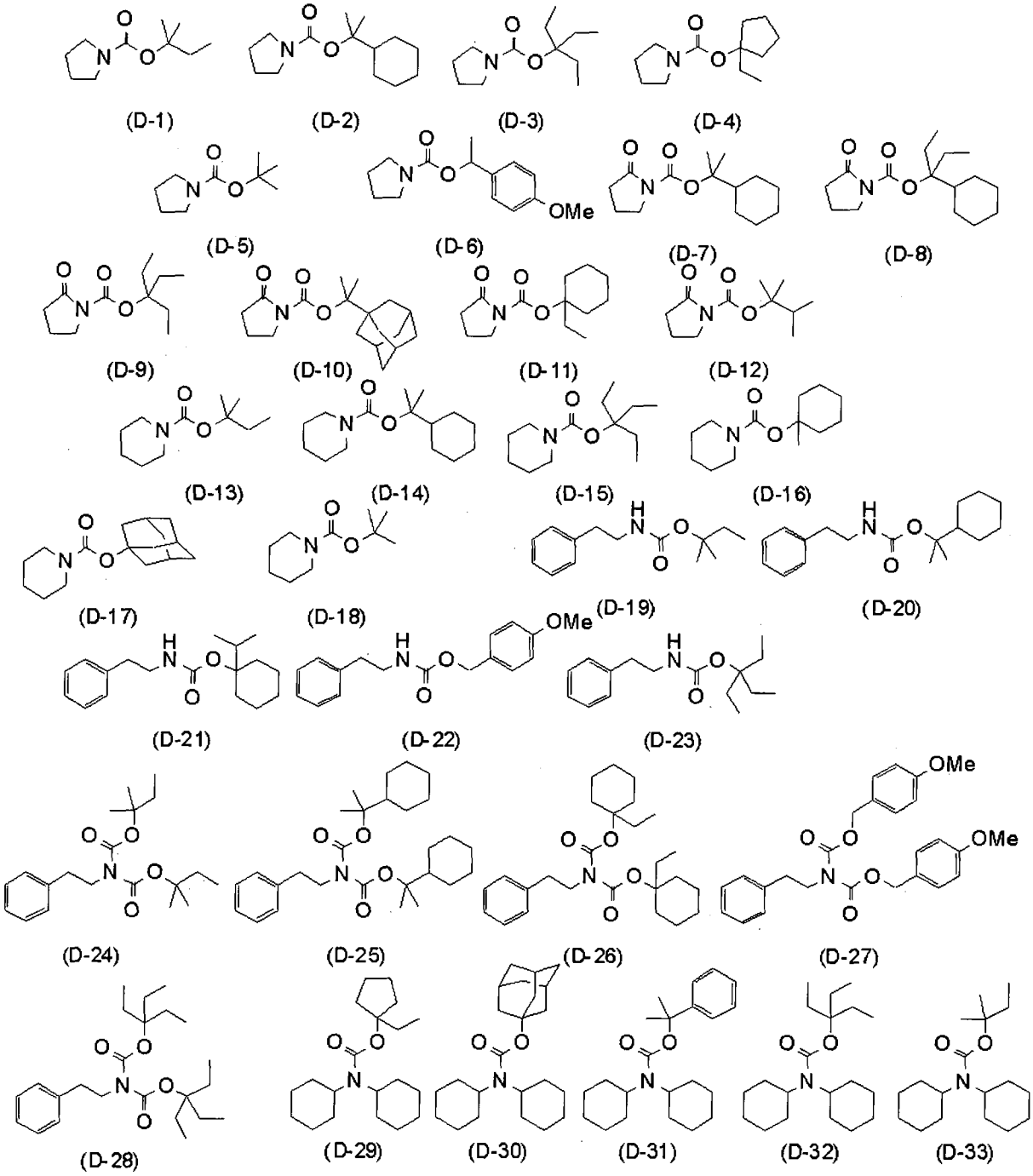
Each Rb independently represents a hydrogen atom, an alkyl group, a cycloalkyl group, an aryl group, or an aralkyl group, provided that in -C(Rb)(Rb)(Rb), when one or more Rb's are a hydrogen atom, at least one of remaining Rb's is a cyclopropyl group or a 1-alkoxyalkyl group.

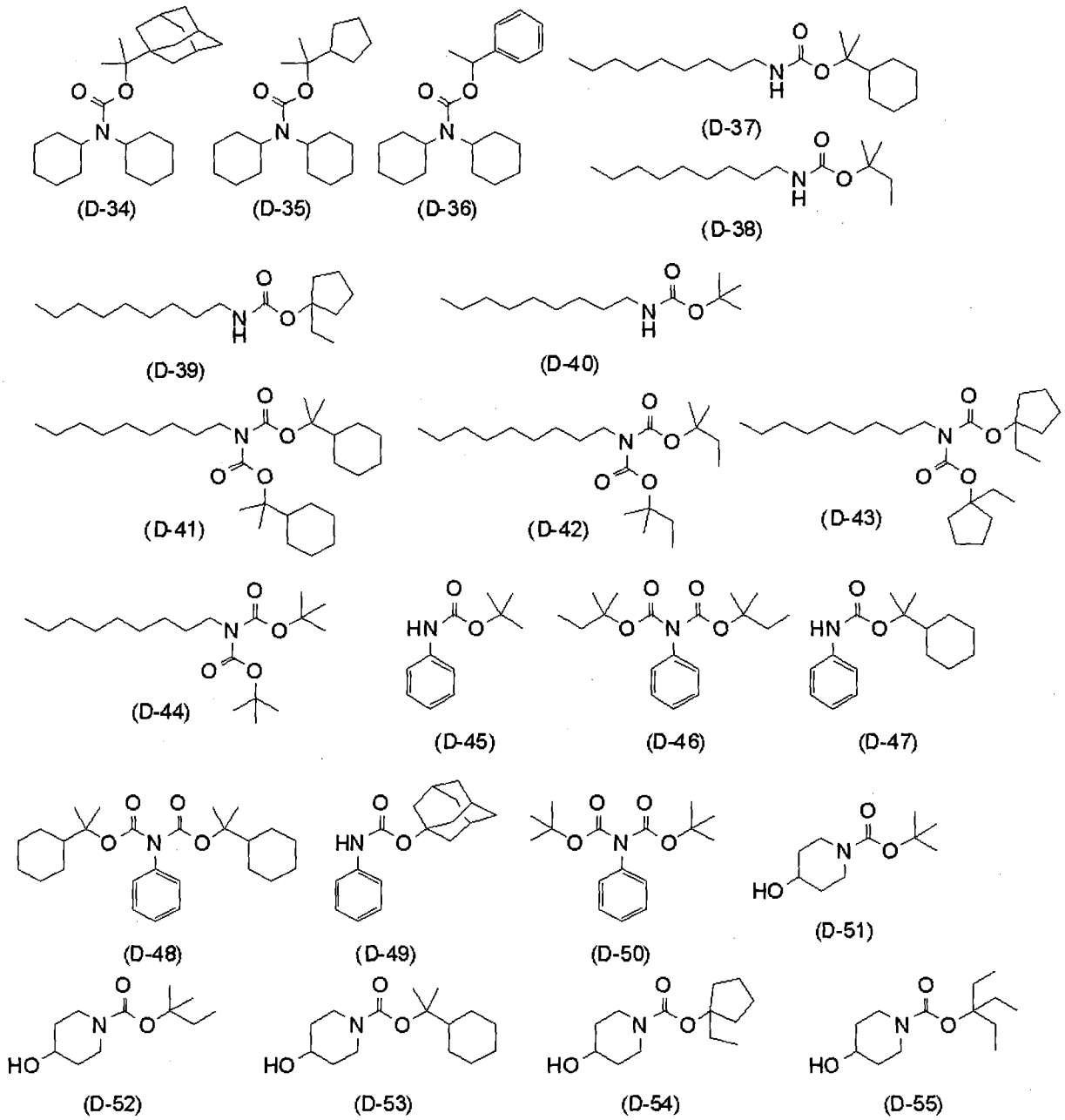
At least two Rb's may combine to form an alicyclic hydrocarbon group, an aromatic hydrocarbon group, a heterocyclic hydrocarbon group, or a derivative thereof.

n represents an integer of 0 to 2, m represents an integer of 1 to 3, and n+m=3.

In formula (F), each of the alkyl group, cycloalkyl group, aryl group and aralkyl group represented by Ra and Rb may be substituted with a functional group such as hydroxyl group, cyano group, amino group, pyrrolidino group, piperidino group, morpholino group and oxo group, an alkoxy group, or a halogen atom.

Specific examples of the compound represented by formula (F) are illustrated below, but the present invention is not limited thereto.





The compound represented by formula (F) can be synthesized based on, for example, JP-A-2009-199021.

The molecular weight of the basic compound (D) is preferably from 250 to 2,000, more preferably from 400 to 1,000. In view of, for example, more reduction in the pattern collapse or rectangularity of the pattern, the molecular weight of the basic compound is preferably 400 or more, more preferably 500 or more, still more preferably 600 or more.

One of these basic compounds (D) is used alone, or two or more thereof are used in combination.

In the present invention, the amount of the basic compound used is preferably from

0.001 to 20 mass%, more preferably from 0.01 to 10 mass%, based on the solid content of the resin composition (I) or (II).

The ratio between the acid generator and the basic compound used is preferably acid generator/basic compound (molar ratio) = from 2.5 to 300. That is, the molar ratio is preferably 2.5 or more in view of sensitivity and resolution and preferably 300 or less from the standpoint of suppressing the reduction in resolution due to thickening of the resist pattern with aging after exposure until heat treatment. The acid generator/basic compound (molar ratio) is more preferably from 5.0 to 200, still more preferably from 7.0 to 150.

Also, the composition preferably contains a basic compound or ammonium salt compound whose basicity decreases upon irradiation with an actinic ray or radiation (hereinafter, sometimes referred to as a "compound (D')"), as a kind of basic compound.

The compound (D') is preferably (D-1) a compound having a basic functional group or an ammonium group and a group capable of generating an acidic functional group upon irradiation with an actinic ray or radiation. That is, the compound (D') is preferably a basic compound having a basic functional group and a group capable of generating an acidic functional group upon irradiation with an actinic ray or radiation, or an ammonium salt compound having an ammonium group and a group capable of generating an acidic functional group upon irradiation with an actinic ray or radiation.

The compound which is generated due to decomposition of the compound (D') or (D-1) upon irradiation with an actinic ray or radiation and decreased in the basicity includes compounds represented by the following formulae (PA-I), (PA-II) and (PA-III), and from the standpoint that excellent effects can be attained in a high level in terms of all of LWR, uniformity of local pattern dimension and DOF, compounds represented by formulae (PA-II) and (PA-III) are preferred.

The compound represented by formula (PA-I) is described below.

$Q\text{-}A_1\text{-}(X)_n\text{-}B\text{-}R$ (PA-I)

In formula (PA-I), A_1 represents a single bond or a divalent linking group.

Q represents $-SO_3H$ or $-CO_2H$. Q corresponds to an acidic functional group that is generated upon irradiation with an actinic ray or radiation.

X represents $-SO_2-$ or -CO-.

n represents 0 or 1.

B represents a single bond, an oxygen atom or -N(Rx)-.

Rx represents a hydrogen atom or a monovalent organic group.

R represents a monovalent organic group having a basic functional group, or a monovalent organic group having an ammonium group.

The divalent linking group of A_1 is preferably a divalent linking group having a carbon number of 2 to 12, and examples thereof include an alkylene group and a phenylene group. An alkylene group having at least one fluorine atom is more preferred, and the carbon number thereof is preferably from 2 to 6, more preferably from 2 to 4. The alkylene chain may contain a linking group such as oxygen atom and sulfur atom. The alkylene group is preferably an alkylene group where from 30 to 100% by number of hydrogen atoms are substituted for by a fluorine atom, more preferably an alkylene group where the carbon atom bonded to the Q moiety has a fluorine atom, still more preferably a perfluoroalkylene group, yet still more preferably perfluoroethylene group, perfluoropropylene group or perfluorobutylene group.

The monovalent organic group in Rx is preferably a monovalent organic group having a carbon number of 4 to 30, and examples thereof include an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group and an alkenyl group.

The alkyl group in Rx may have a substituent and is preferably a linear or branched alkyl group having a carbon number of 1 to 20, and the alkyl chain may contain an oxygen atom, a sulfur atom or a nitrogen atom.

Incidentally, the alkyl group having a substituent particularly includes a group where a cycloalkyl group is substituted on a linear or branched alkyl group (for example, an adamantylmethyl group, an adamantylethyl group, a cycohexylethyl group and a camphor residue).

The cycloalkyl group in Rx may have a substituent and is preferably a cycloalkyl group having a carbon number of 3 to 20, and the cycloalkyl group may contain an oxygen atom in the ring.

The aryl group in Rx may have a substituent and is preferably an aryl group having a carbon number of 6 to 14.

The aralkyl group in Rx may have a substituent and is preferably an aralkyl group having a carbon number of 7 to 20.

The alkenyl group in Rx may have a substituent and includes, for example, a group having a double bond at an arbitrary position of the alkyl group described as Rx.

Preferred examples of the partial structure of the basic functional group include a crown ether structure, a primary to tertiary amine structure, and a nitrogen-containing heterocyclic structure (e.g., pyridine, imidazole, pyrazine).

Preferred examples of the partial structure of the ammonium group include a primary to tertiary ammonium structure, a pyridinium structure, an imidazolinium structure and a pyrazinium structure.

The basic functional group is preferably a functional group having a nitrogen atom, more preferably a structure having a primary to tertiary amino group, or a nitrogen-containing heterocyclic structure. In these structures, from the standpoint of enhancing the basicity, it is preferred that all atoms adjacent to nitrogen atom contained in the structure are a carbon atom or a hydrogen atom. Also, in view of enhancing the basicity, an electron-withdrawing functional group (such as carbonyl group, sulfonyl group, cyano group and halogen atom) is preferably not bonded directly to the nitrogen atom.

The monovalent organic group in the monovalent organic group (group R) containing such a structure is preferably an organic group having a carbon number of 4 to 30, and examples thereof include an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group and an alkenyl group. Each of these groups may have a substituent.

The alkyl group, cycloalkyl group, aryl group, aralkyl group and alkenyl group in the basic functional group- or ammonium group-containing alkyl, cycloalkyl, aryl, aralkyl and alkenyl groups of R are the same as the alkyl group, cycloalkyl group, aryl group, aralkyl group and alkenyl group described for Rx.

Examples of the substituent which each of the groups above may have include a halogen atom, a hydroxyl group, a nitro group, a cyano group, a carboxy group, a carbonyl group, a cycloalkyl group (preferably having a carbon number of 3 to 10), an aryl group (preferably having a carbon number of 6 to 14), an alkoxy group (preferably having a carbon number of 1 to 10), an acyl group (preferably having a carbon number of 2 to 20), an acyloxy group (preferably having a carbon number of 2 to 10), an alkoxycarbonyl group (preferably having a carbon number of 2 to 20), and an aminoacyl group (preferably having a carbon number of 2 to 20). The cyclic structure in the aryl group, cycloalkyl group and the like may further have an alkyl group (preferably having a carbon number of 1 to 20) as the substituent. The aminoacyl group may further have one or two alkyl groups (preferably having a carbon number of 1 to 20) as the substituent.

In the case where B is -N(Rx)-, R and Rx preferably combine together to form a ring.

By virtue of forming a ring structure, the stability is enhanced and in turn, the composition using this compound is improved in the storage stability. The number of carbons constituting the ring is preferably from 4 to 20, and the ring may be monocyclic or polycyclic and may contain an oxygen atom, a sulfur atom or a nitrogen atom.

Examples of the monocyclic structure include a 4- to 8-membered ring containing a nitrogen atom. Examples of the polycyclic structure include a structure composed of a combination of two monocyclic structures or three or more monocyclic structures. The monocyclic structure and polycyclic structure may have a substituent, and preferred examples of the substituent include a halogen atom, a hydroxyl group, a cyano group, a carboxy group, a carbonyl group, a cycloalkyl group (preferably having a carbon number of 3 to 10), an aryl group (preferably having a carbon number of 6 to 14), an alkoxy group (preferably having a carbon number of 1 to 10), an acyl group (preferably having a carbon number of 2 to 15), an acyloxy group (preferably having a carbon number of 2 to 15), an alkoxycarbonyl group (preferably having a carbon number of 2 to 15), and an aminoacyl group (preferably having a carbon number of 2 to 20). The cyclic structure in the aryl group, cycloalkyl group and the like may further have an alkyl group (preferably having a carbon number of 1 to 15) as the substituent. The aminoacyl group may have one or two alkyl groups (preferably having a carbon number of 1 to 15) as the substituent.

Out of the compounds represented by formula (PA-I), a compound where the Q moiety is a sulfonic acid can be synthesized using a general sulfonamidation reaction. For example, this compound can be obtained by a method of selectively reacting one sulfonyl halide moiety of a bis-sulfonyl halide compound with an amine compound to form a sulfonamide bond and then hydrolyzing the other sulfonyl halide moiety, or a method of ring-opening a cyclic sulfonic anhydride through reaction with an amine compound.

The compound represented by formula (PA-II) is described below.

Q_1-X_1-NH-X_2-Q_2 (PA-II)

In formula (PA-II), each of Q_1 and Q_2 independently represents a monovalent organic group, provided that either one of Q_1 and Q_2 has a basic functional group. It is also possible that Q_1 and Q_2 combine together to form a ring and the ring formed has a basic functional group.

Each of X_1 and X_2 independently represents -CO- or -SO_2-.

Here, -NH- corresponds to the acidic functional group generated upon irradiation with an actinic ray or radiation.

The monovalent organic group as Q_1 and Q_2 in formula (PA-II) is preferably a monovalent organic group having a carbon number of 1 to 40, and examples thereof include an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group, and an alkenyl group.

The alkyl group in Q_1 and Q_2 may have a substituent and is preferably a linear or branched alkyl group having a carbon number of 1 to 30, and the alkyl chain may contain an oxygen atom, a sulfur atom or a nitrogen atom.

The cycloalkyl group in Q_1 and Q_2 may have a substituent and is preferably a cycloalkyl group having a carbon number of 3 to 20, and the cycloalkyl group may contain an oxygen atom or a nitrogen atom in the ring.

The aryl group in Q_1 and Q_2 may have a substituent and is preferably an aryl group having a carbon number of 6 to 14.

The aralkyl group in Q_1 and Q_2 may have a substituent and is preferably an aralkyl group having a carbon number of 7 to 20.

The alkenyl group in Q_1 and Q_2 may have a substituent and includes a group having a double bond at an arbitrary position of the alkyl group above.

Examples of the substituent which each of these groups may have include a halogen atom, a hydroxyl group, a nitro group, a cyano group, a carboxy group, a carbonyl group, a cycloalkyl group (preferably having a carbon number of 3 to 10), an aryl group (preferably having a carbon number of 6 to 14), an alkoxy group (preferably having a carbon number of 1 to 10), an acyl group (preferably having a carbon number of 2 to 20), an acyloxy group (preferably having a carbon number of 2 to 10), an alkoxycarbonyl group (preferably having a carbon number of 2 to 20), and an aminoacyl group (preferably having a carbon number of 2 to 10). The cyclic structure in the aryl group, cycloalkyl group and the like may further have an alkyl group (preferably having a carbon number of 1 to 10) as the substituent. The aminoacyl group may further have an alkyl group (preferably having a carbon number of 1 to 10) as the substituent. The alkyl group having a substituent includes, for example, a perfluoroalkyl group such as perfluoromethyl group, perfluoroethyl group, perfluoropropyl group and perfluorobutyl group.

Preferred partial structures of the basic functional group contained in at least either Q_1 or Q_2 are the same as those of the basic functional group contained in R of formula (PA-I).

The structure where Q_1 and Q_2 combine together to form a ring and the ring formed

has a basic functional group includes, for example, a structure where the organic groups of Q_1 and Q_2 are bonded further through an alkylene group, an oxy group, an imino group or the like.

In formula (PA-II), at least either one of X_1 and X_2 is preferably $-SO_2-$.

The compound represented by formula (PA-III) is described below.

$$Q_1\text{-}X_1\text{-}NH\text{-}X_2\text{-}A_2\text{-}(X_3)_m\text{-}B\text{-}Q_3 \qquad \text{(PA-III)}$$

In formula (PA-III), each of Q_1 and Q_3 independently represents a monovalent organic group, provided that either one of Q_1 and Q_3 has a basic functional group. It is also possible that Q_1 and Q_3 combine together to form a ring and the ring formed has a basic functional group.

Each of X_1, X_2 and X_3 independently represents -CO- or $-SO_2-$.

A_2 represents a divalent linking group.

B represents a single bond, an oxygen atom or -N(Qx)-.

Qx represents a hydrogen atom or a monovalent organic group.

In the case where B is -N(Qx)-, Q_3 and Qx may combine to form a ring.

m represents 0 or 1.

Here, -NH- corresponds to the acidic functional group generated upon irradiation with an actinic ray or radiation.

Q_1 has the same meaning as Q_1 in formula (PA-II).

Examples of the organic group of Q_3 are the same as those of the organic group of Q_1 and Q_2 in formula (PA-II).

The structure where Q_1 and Q_3 combine to form a ring and the ring formed has a basic functional group includes, for example, a structure where the organic groups of Q_1 and Q_3 are bonded further through an alkylene group, an oxy group, an imino group or the like.

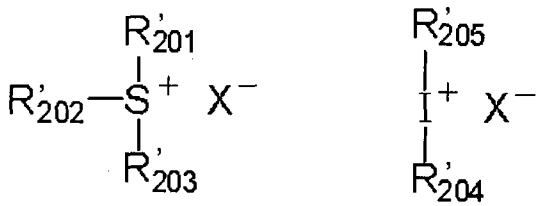
The divalent linking group in A_2 is preferably a divalent linking group having a carbon number of 1 to 8 and containing a fluorine atom, and examples thereof include a fluorine atom-containing alkylene group having a carbon number of 1 to 8, and a fluorine atom-containing phenylene group. A fluorine atom-containing alkylene group is more preferred, and the carbon number thereof is preferably from 2 to 6, more preferably from 2 to 4. The alkylene chain may contain a linking group such as oxygen atom and sulfur atom. The alkylene group is preferably an alkylene group where from 30 to 100% by number of hydrogen atoms are substituted for by a fluorine atom, more preferably a perfluoroalkylene

group, still more preferably a perfluoroalkylene group having a carbon number of 2 to 4.

The monovalent organic group in Qx is preferably an organic group having a carbon number of 4 to 30, and examples thereof include an alkyl group, a cycloalkyl group, an aryl group, an aralkyl group and an alkenyl group. Examples of the alkyl group, cycloalkyl group, aryl group, aralkyl group and alkenyl group are the same as those for Rx in formula (PA-I).

In formula (PA-III), each of X_1, X_2 and X_3 is preferably $-SO_2-$.

The compound (D') is preferably a sulfonium salt compound of the compound represented by formula (PA-I), (PA-II) or (PA-III), or an iodonium salt compound of the compound represented by formula (PA-I), (PA-II) or (PA-III), more preferably a compound represented by the following formula (PA1) or (PA2):



(PA1) (PA2)

In formula (PA1), each of R'_{201}, R'_{202} and R'_{203} independently represents an organic group, and specific examples thereof are the same as those for R_{201}, R_{202} and R_{203} of formula ZI in the component (B).

X^- represents a sulfonate or carboxylate anion resulting from elimination of a hydrogen atom in the $-SO_3H$ moiety or -COOH moiety of the compound represented by formula (PA-I), or an anion resulting from elimination of a hydrogen atom in the -NH- moiety of the compound represented by formula (PA-II) or (PA-III).

In formula (PA2), each of R'_{204} and R'_{205} independently represents an aryl group, an alkyl group or a cycloalkyl group, and specific examples thereof are the same as those for R_{204} and R_{205} of formula ZII in the component (B).

X^- represents a sulfonate or carboxylate anion resulting from elimination of a hydrogen atom in the $-SO_3H$ moiety or -COOH moiety of the compound represented by formula (PA-I), or an anion resulting from elimination of a hydrogen atom in the -NH- moiety of the compound represented by formula (PA-II) or (PA-III).

The compound (D') decomposes upon irradiation with an actinic ray or radiation to generate, for example, a compound represented by formula (PA-I), (PA-II) or (PA-III).

The compound represented by formula (PA-I) is a compound having a sulfonic or

carboxylic acid group together with a basic functional group or an ammonium group and thereby being reduced in or deprived of the basicity or changed from basic to acidic as compared with the compound (D').

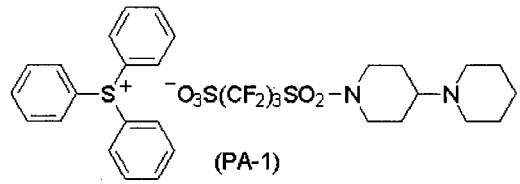
The compound represented by formula (PA-II) or (PA-III) is a compound having an organic sulfonylimino or organic carbonylimino group together with a basic functional group and thereby being reduced in or deprived of the basicity or changed from basic to acidic as compared with the compound (D').

In the present invention, the expression "reduced in the basicity upon irradiation with an actinic ray or radiation" means that the acceptor property for a proton (an acid generated upon irradiation with an actinic ray or radiation) of the compound (D') is decreased by the irradiation with an actinic ray or radiation. The expression "the acceptor property is decreased" means that when an equilibrium reaction of producing a noncovalent bond complex as a proton adduct from a basic functional group-containing compound and a proton takes place or when an equilibrium reaction of exchanging the counter cation of an ammonium group-containing compound with a proton takes place, the equilibrium constant in the chemical equilibrium decreases.

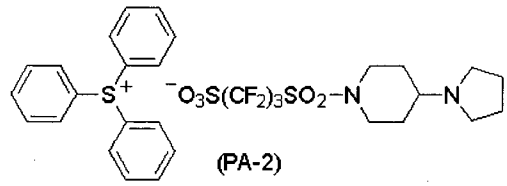
In this way, the compound (D') whose basicity decreases upon irradiation with an actinic ray or radiation is contained in the resist film, so that in the unexposed area, the acceptor property of the compound (D') can be sufficiently brought out and an unintended reaction between an acid diffused from the exposed area or the like and the resin (A-1) or (A-2) can be inhibited, whereas in the exposed area, the acceptor property of the compound (D') can decrease and the intended reaction of an acid with the resin (A-1) or (A-2) can occur unfailingly. Such an operation mechanism is considered to contribute to obtaining a pattern excellent in terms of line width variation (LWR), uniformity of local pattern dimension, focus latitude (DOF) and pattern profile.

Incidentally, the basicity can be confirmed by measuring the pH, or a calculated value can be computed using a commercially available software.

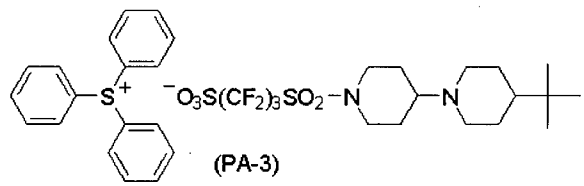
Specific examples of the compound (D') capable of generating a compound represented by formula (PA-I) upon irradiation with an actinic ray or radiation are illustrated below, but the present invention is not limited thereto.



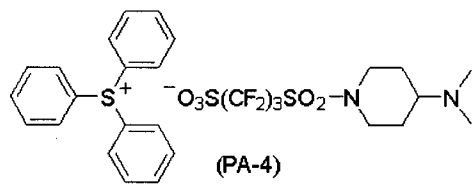
(PA-1)



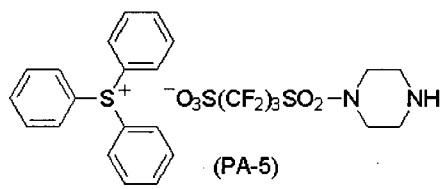
(PA-2)



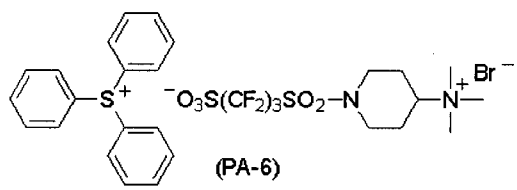
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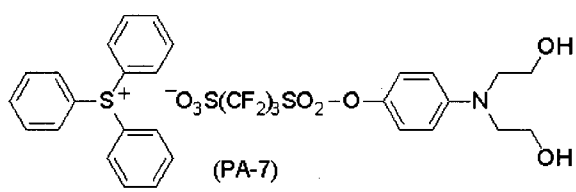
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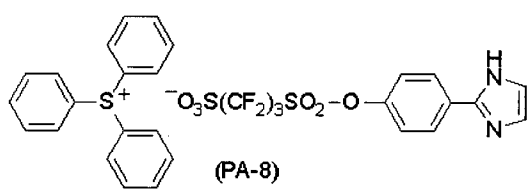
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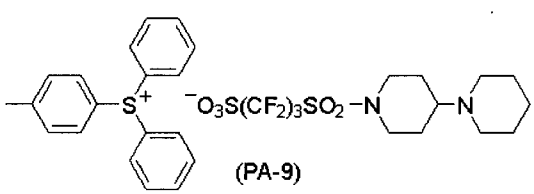
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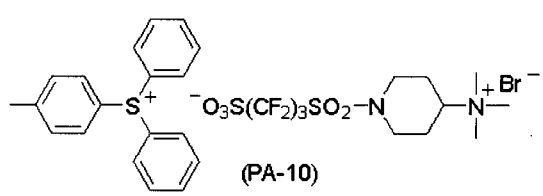
(PA-7)



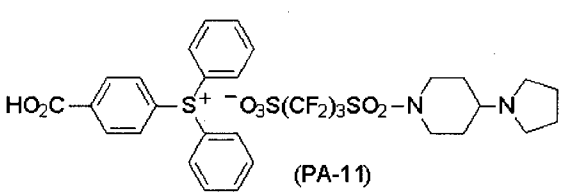
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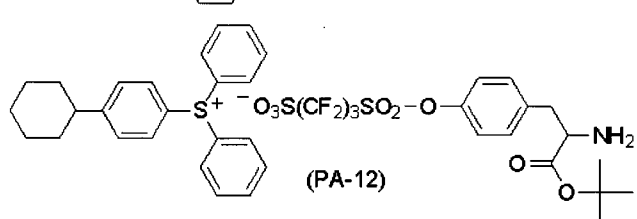
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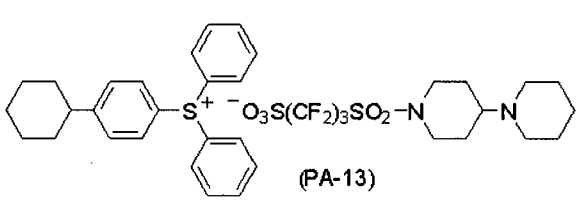
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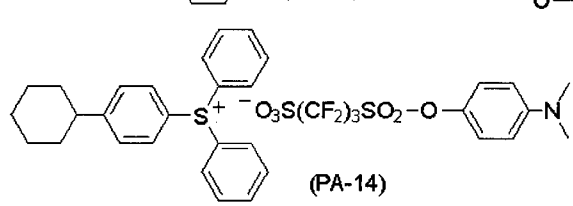
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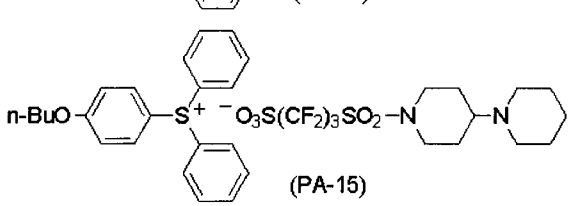
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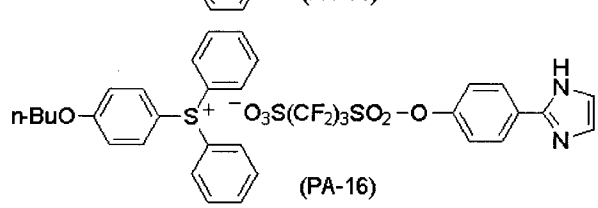
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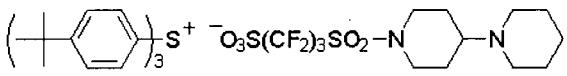
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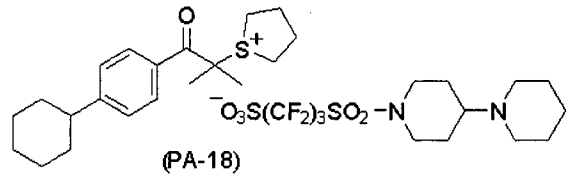
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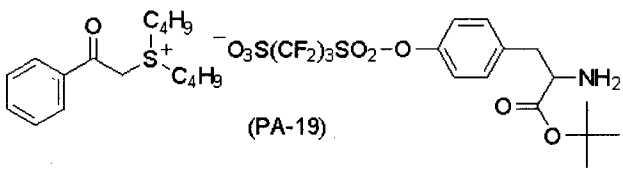
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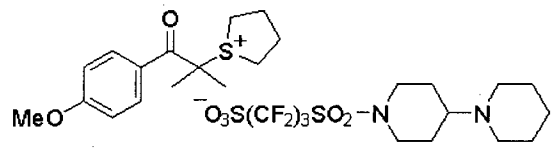
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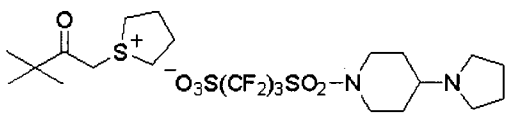
(PA-18)



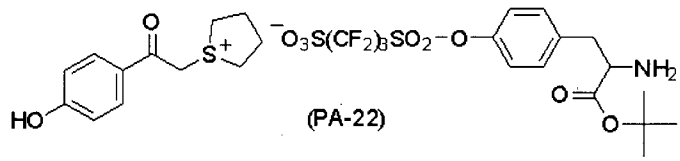
(PA-19)



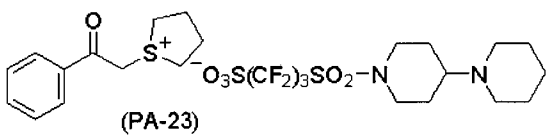
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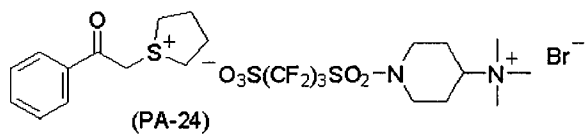
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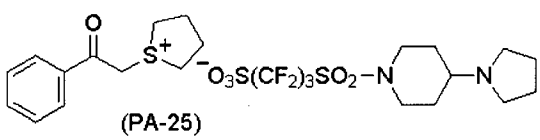
(PA-22)



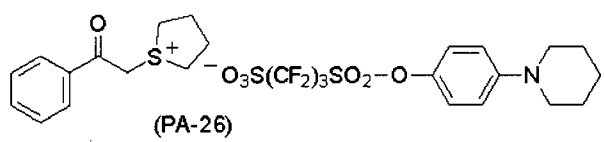
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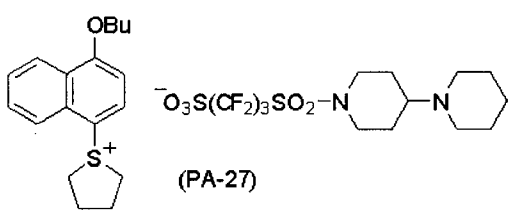
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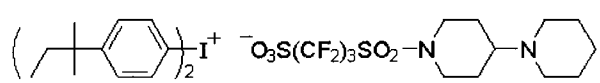
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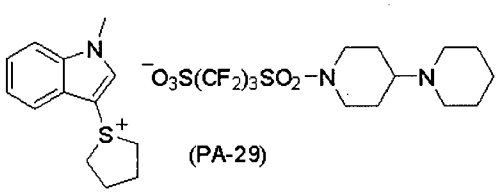
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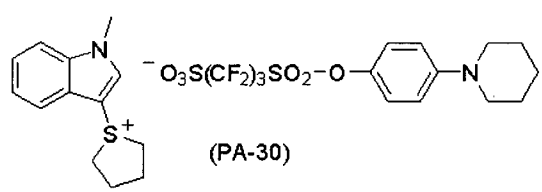
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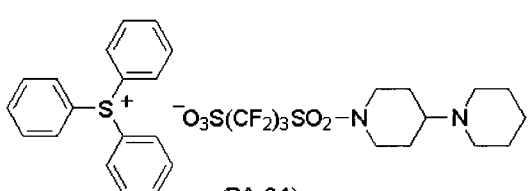
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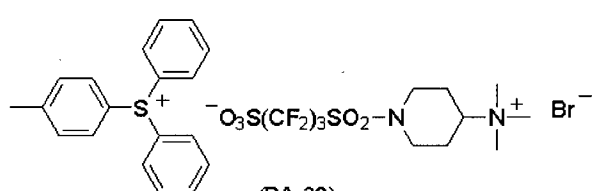
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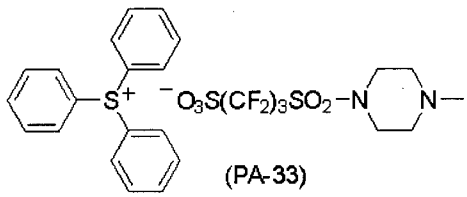
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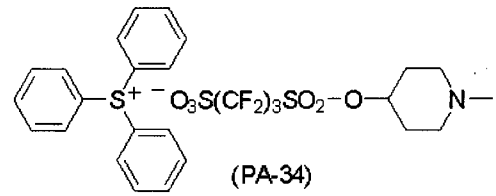
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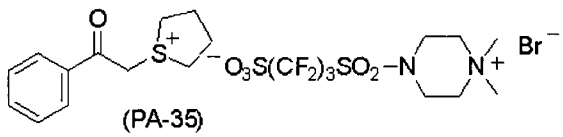
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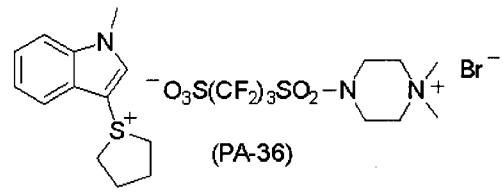
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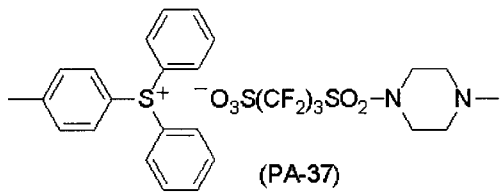
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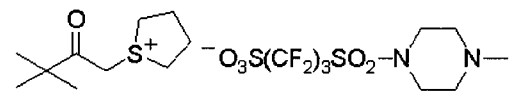
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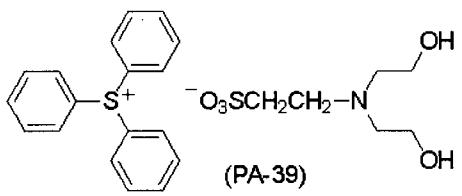
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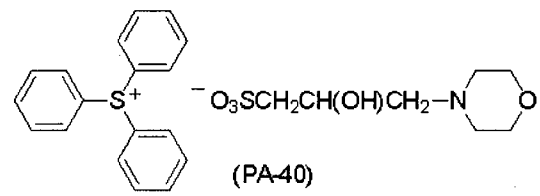
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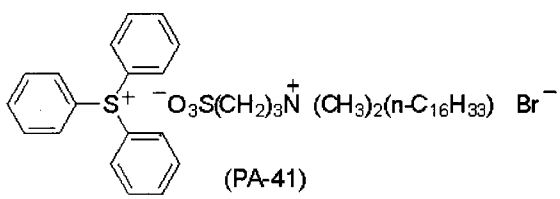
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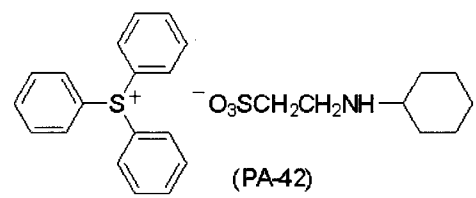
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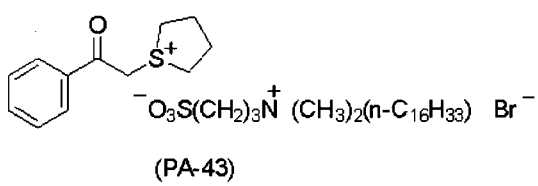
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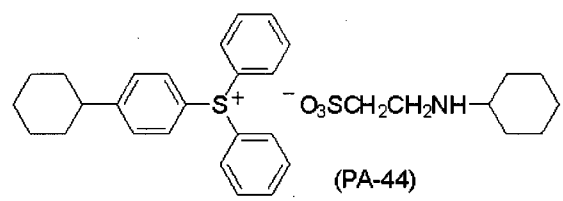
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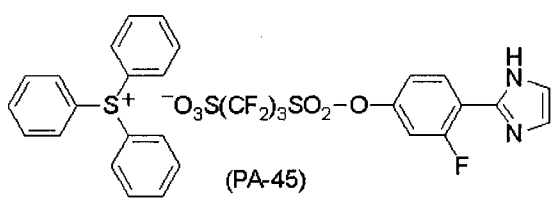
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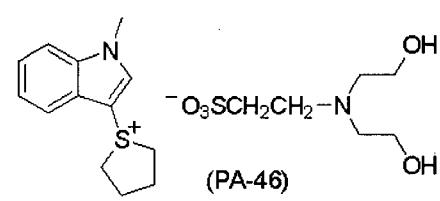
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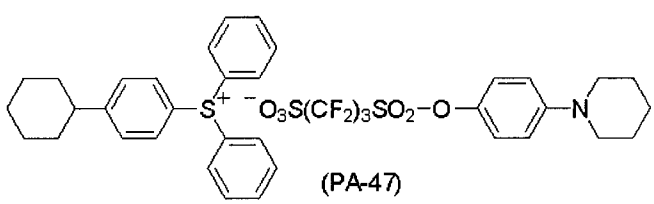
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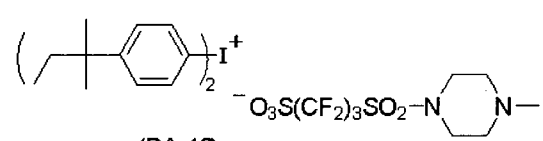
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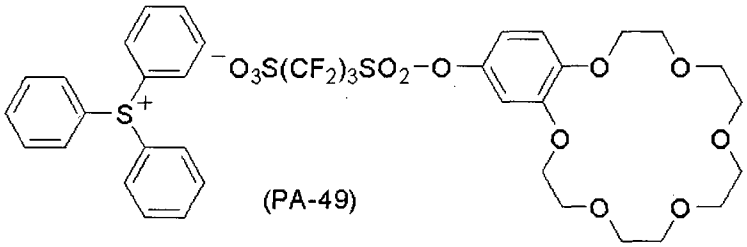
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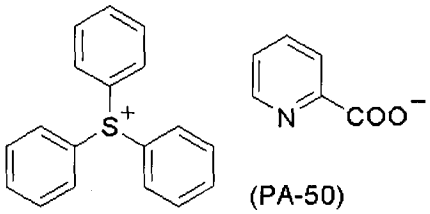
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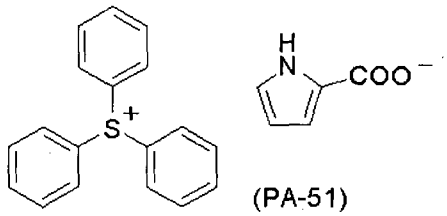
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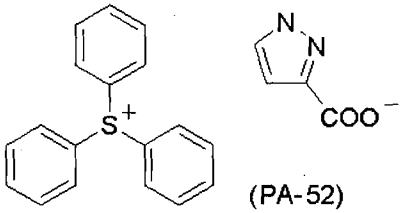
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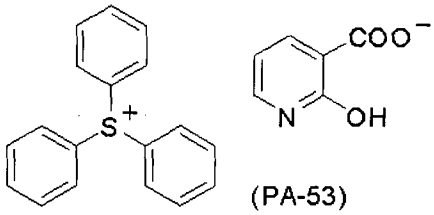
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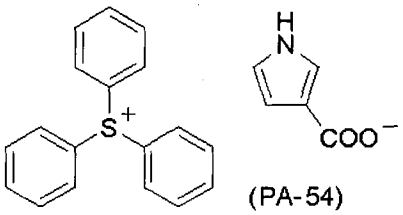
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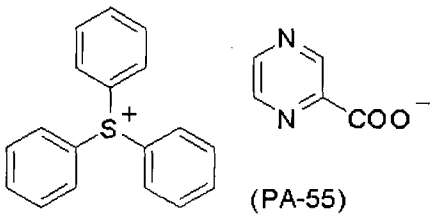
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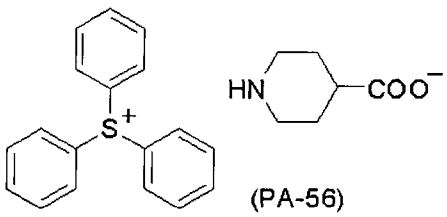
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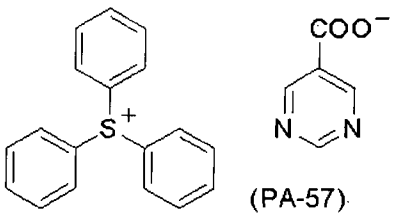
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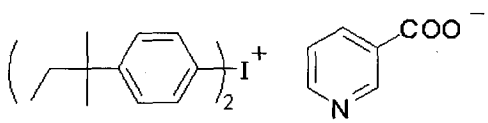
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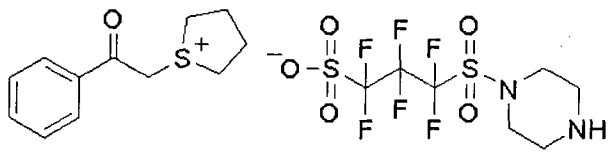
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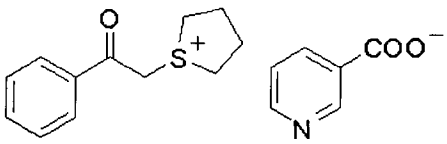
(PA-57)



(PA-58)



(PA-59)

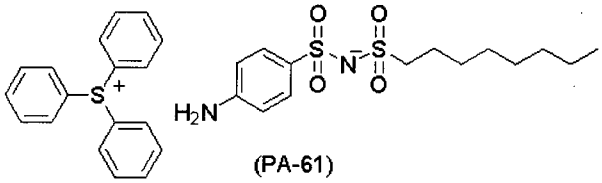


(PA-60)

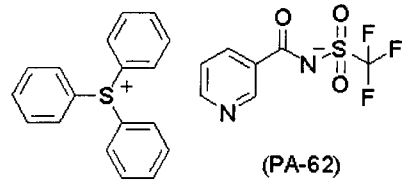
These compounds can be easily synthesized from a compound represented by

formula (PA-I) or a lithium, sodium or potassium salt thereof and a hydroxide, bromide, chloride or the like of iodonium or sulfonium, by utilizing the salt exchange method described in JP-T-11-501909 (the term "JP-T" as used herein means a "published Japanese translation of a PCT patent application") or JP-A-2003-246786. The synthesis may be also performed in accordance with the synthesis method described in JP-A-7-333851.

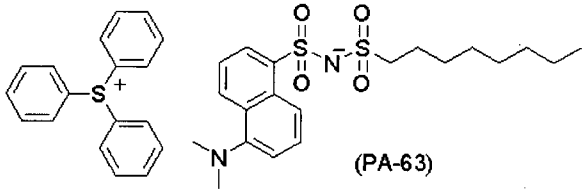
Specific examples of the compound (D') capable of generating a compound represented by formula (PA-II) or (PA-III) upon irradiation with an actinic ray or radiation are illustrated below, but the present invention is not limited thereto.



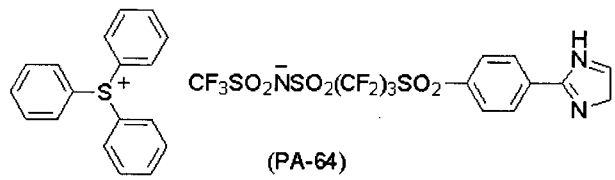
(PA-61)



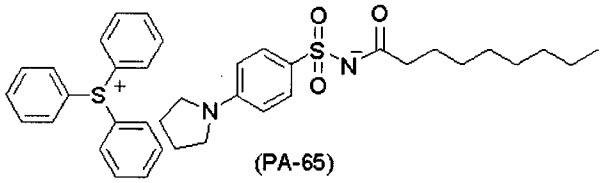
(PA-62)



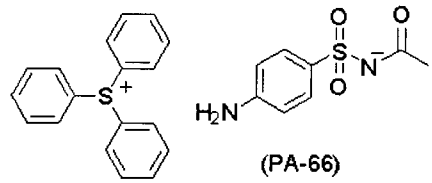
(PA-63)



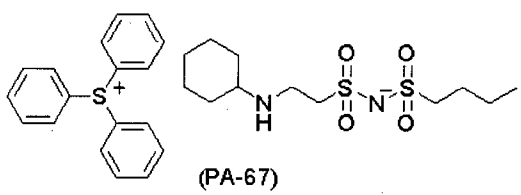
(PA-64)



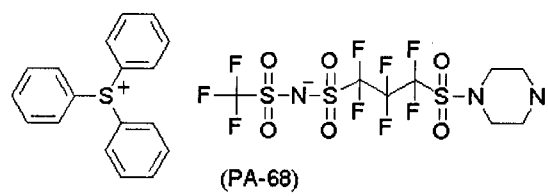
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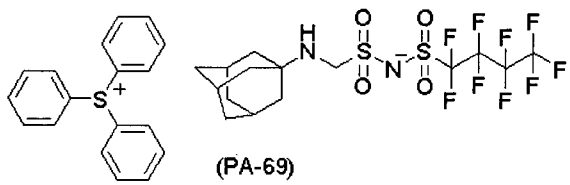
(PA-66)



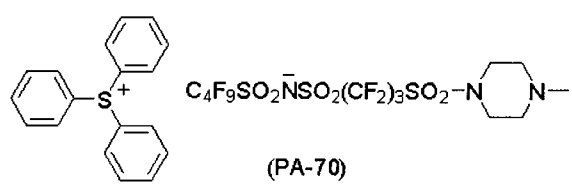
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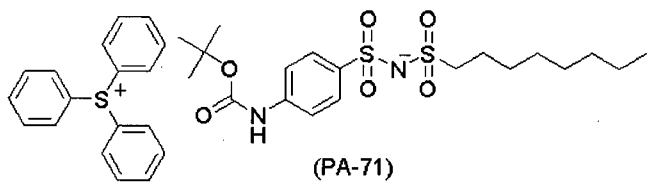
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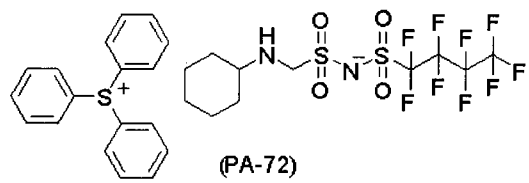
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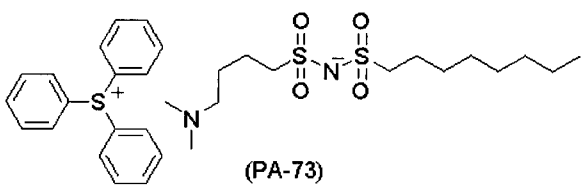
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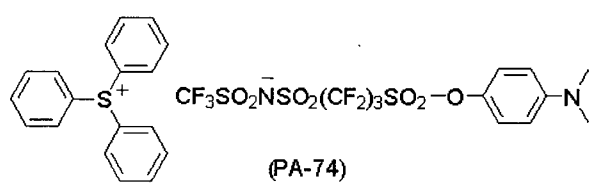
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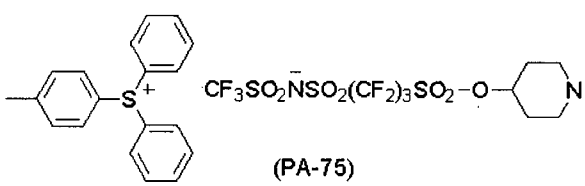
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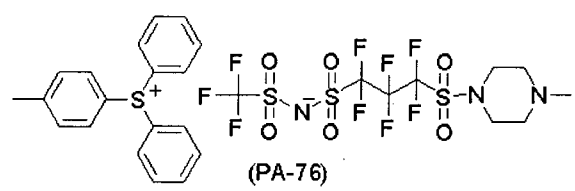
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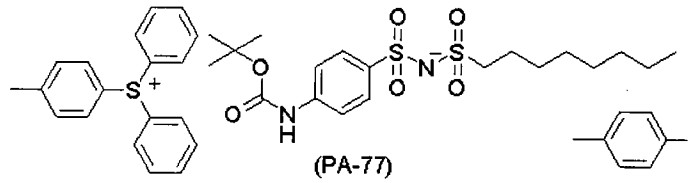
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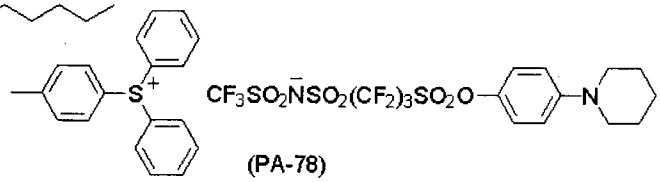
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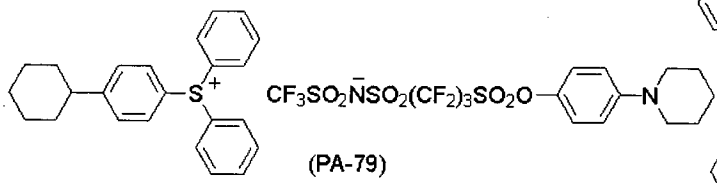
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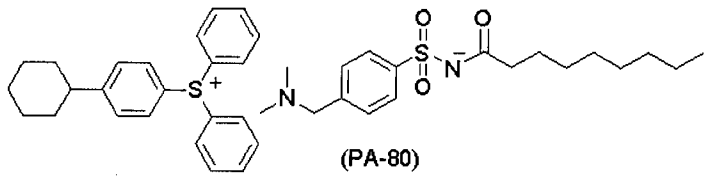
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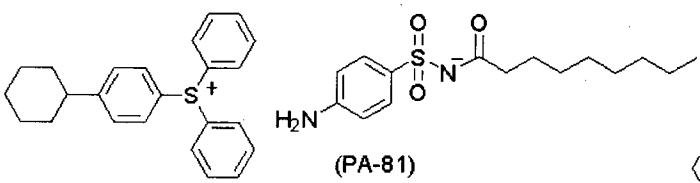
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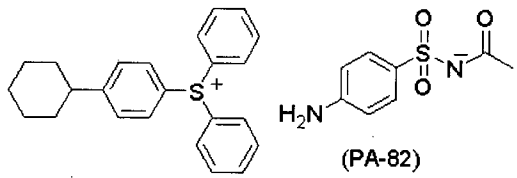
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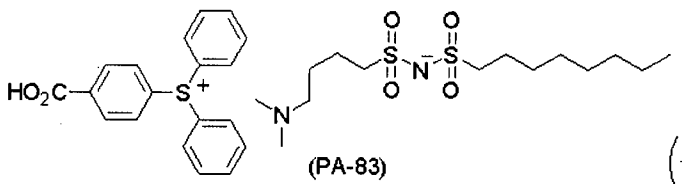
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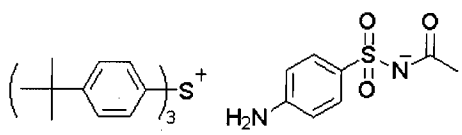
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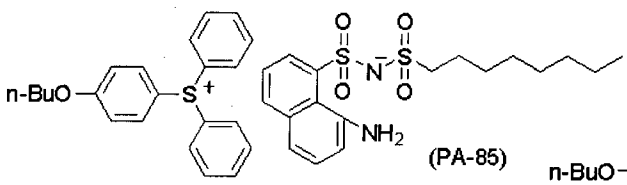
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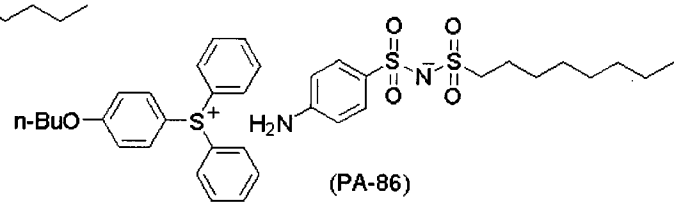
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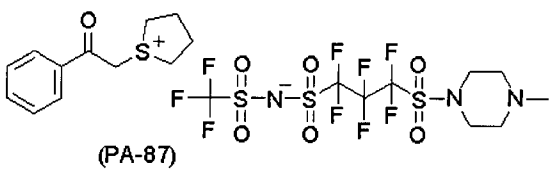
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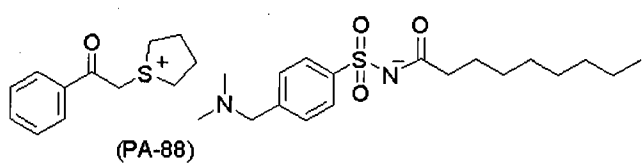
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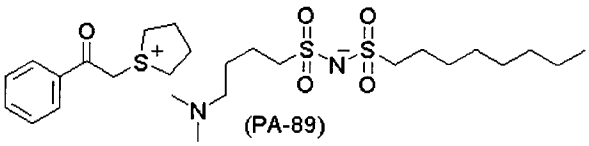
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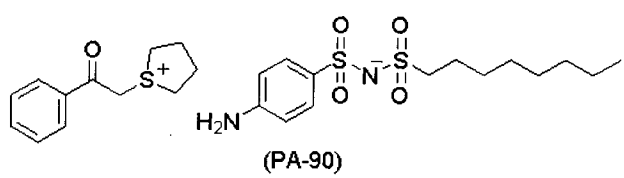
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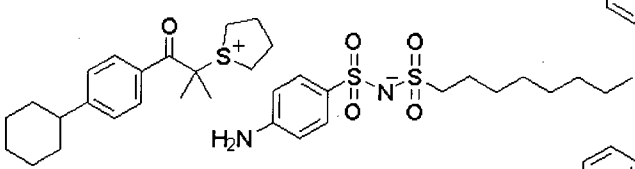
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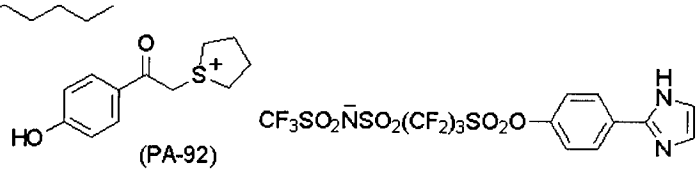
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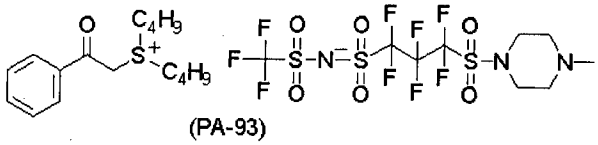
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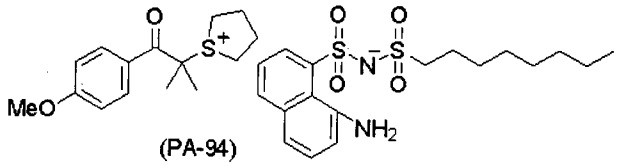
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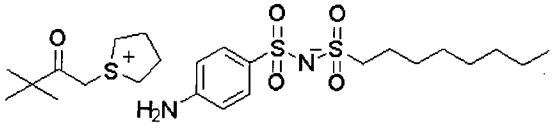
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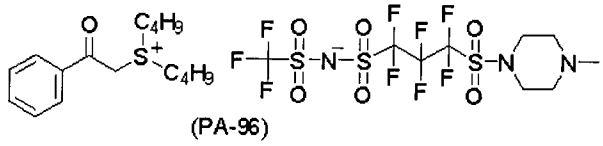
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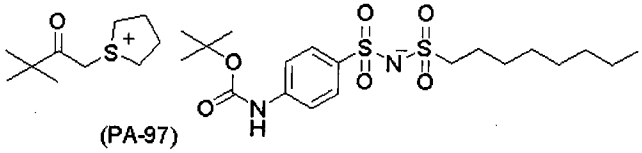
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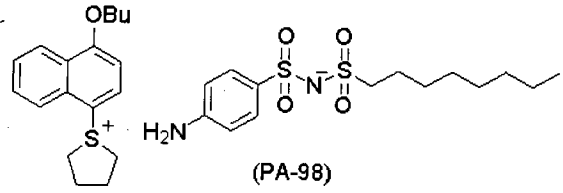
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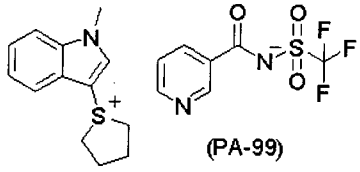
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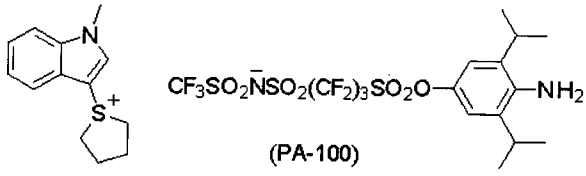
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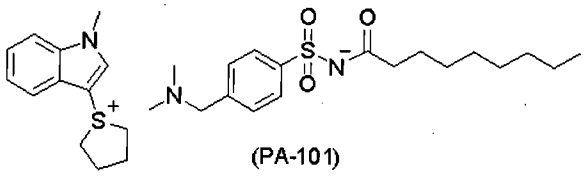
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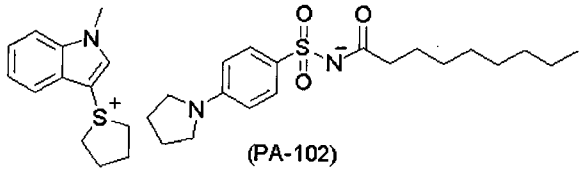
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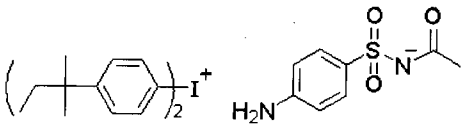
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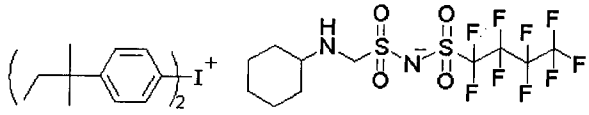
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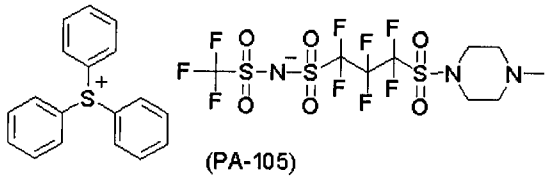
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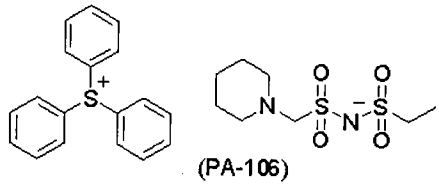
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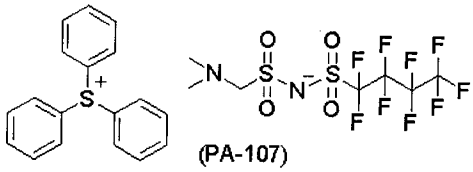
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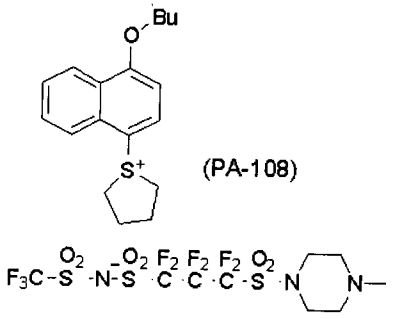
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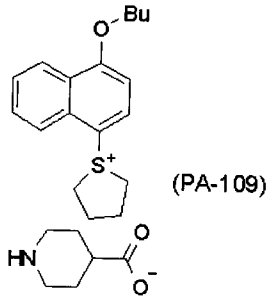
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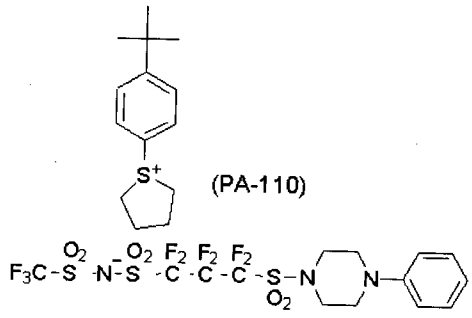
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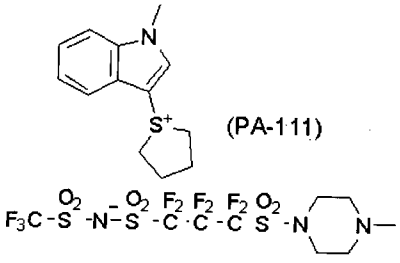
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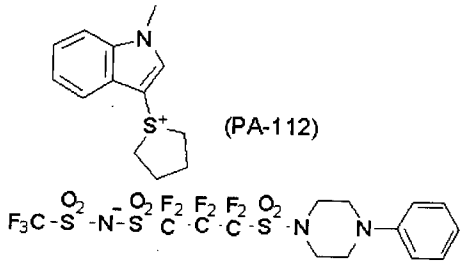
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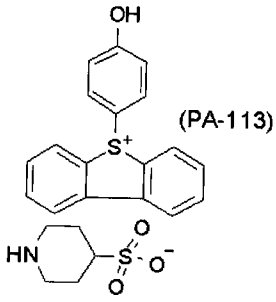
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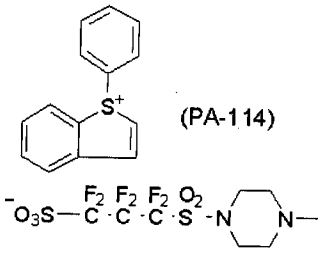
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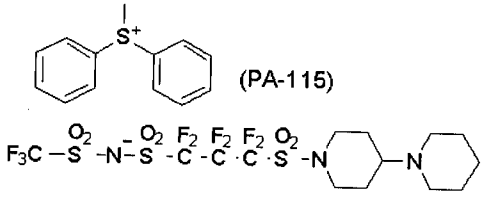
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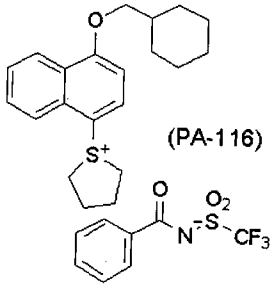
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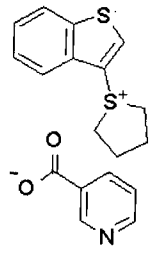
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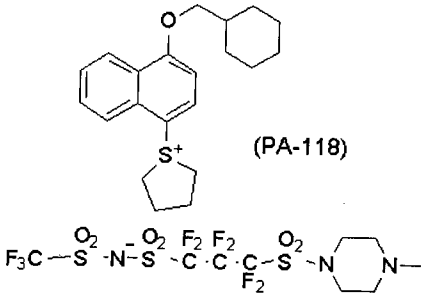
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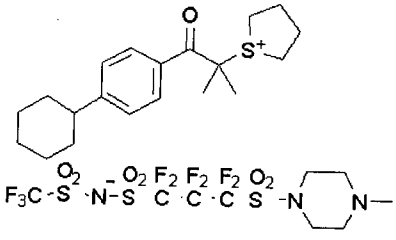
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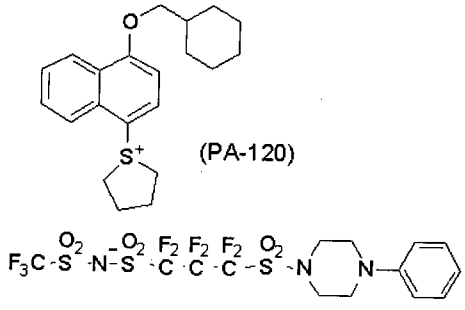
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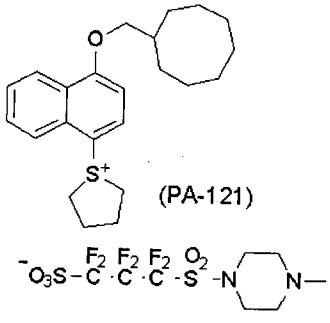
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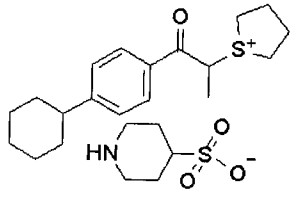
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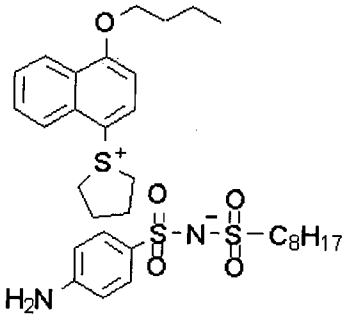
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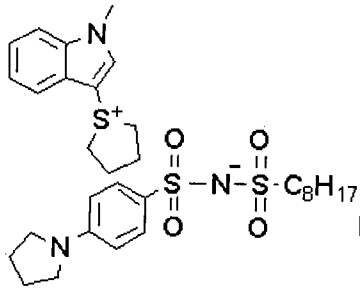
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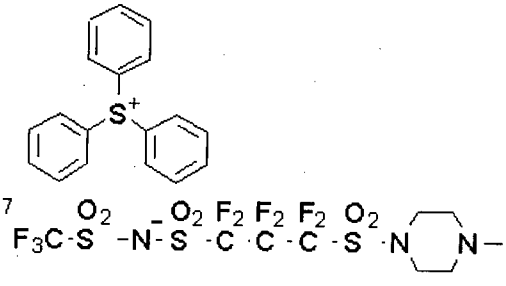
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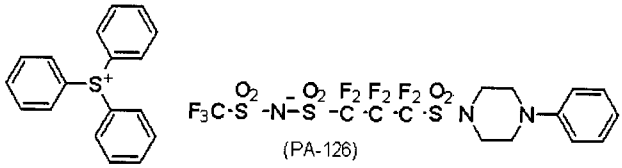
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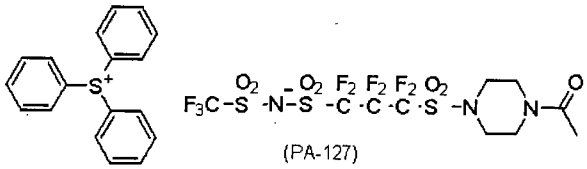
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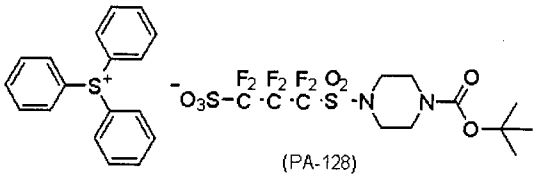
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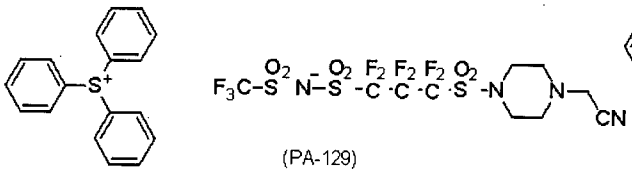
(PA-126)



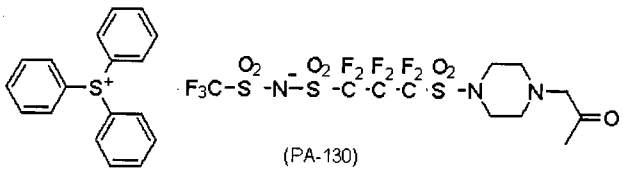
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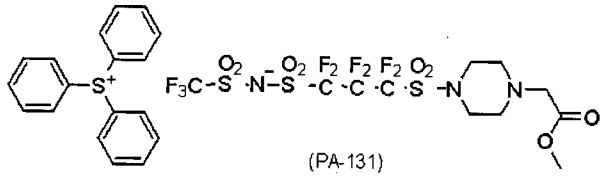
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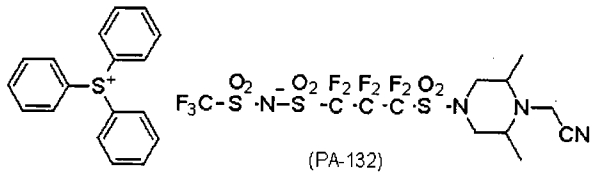
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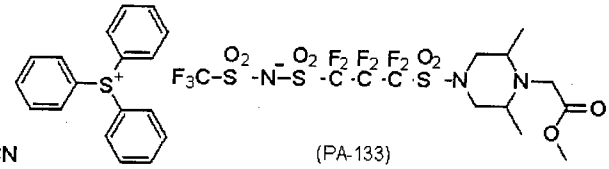
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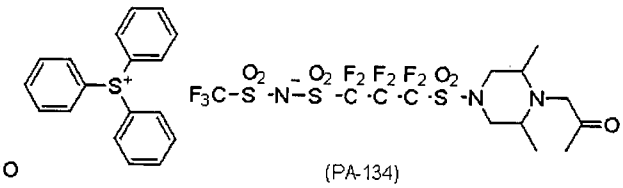
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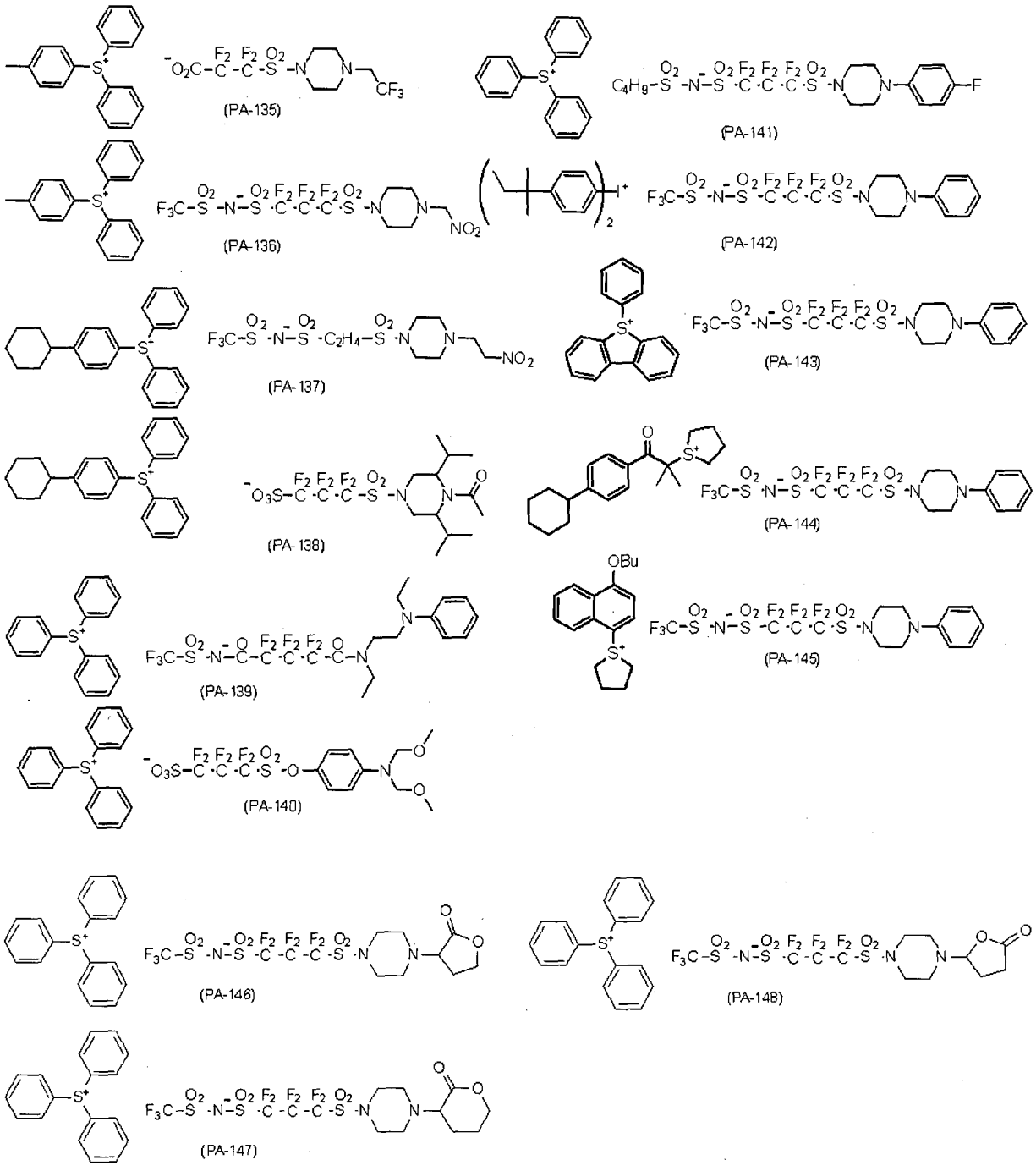
(PA-132)



(PA-133)



(PA-134)



These compounds can be easily synthesized using a general sulfonic acid esterification reaction or sulfonamidation reaction. For example, the compound may be obtained by a method of selectively reacting one sulfonyl halide moiety of a bis-sulfonyl halide compound with an amine, alcohol or the like containing a partial structure represented by formula (PA-II) or (PA-III) to form a sulfonamide bond or a sulfonic acid ester bond and then hydrolyzing the other sulfonyl halide moiety, or a method of ring-opening a cyclic sulfonic anhydride by an amine or alcohol containing a partial structure represented by

formula (PA-II). The amine or alcohol containing a partial structure represented by formula (PA-II) or (PA-III) can be synthesized by reacting an amine or an alcohol with an anhydride (e.g., $(R'O_2C)_2O$, $(R'SO_2)_2O$) or an acid chloride compound (e.g., $R'O_2CCl$, $R'SO_2Cl$) (R' is, for example, a methyl group, an n-octyl group, or a trifluoromethyl group) under basic conditions.

In particular, the synthesis of the compound (D') may be performed in accordance with synthesis examples and the like in JP-A-2006-330098 and JP-A-2011-100105.

The molecular weight of the compound (D') is preferably from 500 to 1,000.

The content of the compound (D') for use in the present invention is preferably from 0.1 to 20 mass%, more preferably from 0.1 to 10 mass%, based on the solid content of the composition (I) or (II).

[5] Aromatic Compound

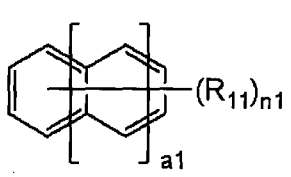
In the pattern forming method of the present invention, from the standpoint of absorbing the exposure light with no fail and unfailingly reducing the effect of standing wave due to reflection of exposure light from the substrate or the diffused reflection of exposure light due to the stepped portion of a stepped substrate, the first resin composition (I) may further contain an aromatic compound. The aromatic compound in the case where the first resin composition (I) further contains an aromatic compound is described below.

The aromatic compound is a compound different from the resin (A-1) and may be a resin or a low molecular compound but is preferably a low molecular compound.

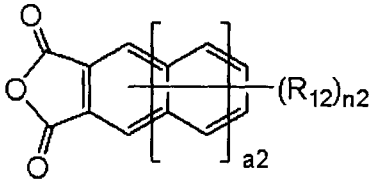
In the case where the aromatic compound is a resin, the resin is preferably a resin containing a repeating unit having an aromatic ring, and the description on the repeating unit having an aromatic ring is the same as that in the resin (A-1). Also, in the case where the aromatic compound is a resin, the resin does not have an acid-decomposable group.

In the case where the aromatic compound is a low molecular compound, the molecular weight of the aromatic compound is preferably 2,000 or less, more preferably 1,500 or less, still more preferably 900 or less. The low molecular compound as used in the present invention is not a so-called polymer or oligomer obtained by cleaving the unsaturated bond of a compound having an unsaturated bond (so-called polymerizable monomer) with use of an initiator and allowing chain-reaction growth of the bond, but a compound having a given molecular weight (a compound having substantially no molecular weight distribution). The molecular weight is usually 100 or more.

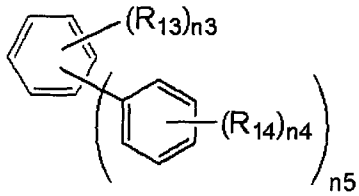
The aromatic compound is not particularly limited as long as it has an aromatic ring, but is preferably a compound represented by the following formulae (A1) to (A3):



(A1)



(A2)



(A3)

In formulae (A1), (A2) and (A3), each of R_{11}, R_{12}, R_{13} and R_{14} independently represents a hydroxyl group, an alkyl group, an alkoxy group, an alkoxycarbonyl group, an alkylcarbonyl group, or a lactonyloxycarbonyl group.

a1 represents an integer of 0 to 2.

a2 represents an integer of 0 to 2.

n1 represents an integer of 0 to 10.

n2 represents an integer of 0 to 8.

n3 represents an integer represented by (6-n5).

n4 represents an integer of 0 to 5.

n5 represents an integer of 1 to 6.

In the case where n1 is an integer of 2 or more, each R_{11} may be the same as or different from every other R_{11}, and R_{11}s may combine with each other to form a ring.

In the case where n2 is an integer of 2 or more, each R_{12} may be the same as or different from every other R_{12}, and R_{12}s may combine with each other to form a ring.

In the case where n3 is an integer of 2 or more, each R_{13} may be the same as or different from every other R_{13}, and R_{13}s may combine with each other to form a ring.

In the case where n4 or n5 is an integer of 2 or more, each R_{14} may be the same as or different from every other R_{14}, and R_{14}s may combine with each other to form a ring.

The alkyl group of R_{11}, R_{12}, R_{13} and R_{14} is a linear or branched alkyl group preferably having a carbon number of 1 to 10, and preferred examples thereof include a methyl group, an ethyl group, an n-butyl group and a tert-butyl group.

The alkoxy group of R_{11}, R_{12}, R_{13} and R_{14} is a linear or branched alkoxy group preferably having a carbon number of 1 to 10, and preferred examples thereof include a methoxy group, an ethoxy group, an n-propoxy group and an n-butoxy group.

The alkoxycarbonyl group of R_{11}, R_{12}, R_{13} and R_{14} is a linear or branched

alkoxycarbonyl group preferably having a carbon number of 2 to 11, and preferred examples thereof include a methoxycarbonyl group, an ethoxycarbonyl group and an n-butoxycarbonyl group.

Specific examples of the alkyl group in the alkylcarbonyl group of R_{11}, R_{12}, R_{13} and R_{14} are the same as those of the alkyl group described above of R_{11}, R_{12}, R_{13} and R_{14}.

The lactonyl group in the lactonyloxycarbonyl group of R_{11}, R_{12}, R_{13} and R_{14} is preferably a 5- to 7-membered ring lactonyl group, more preferably a 5- or 6-membered ring lactonyl group.

Each of the ring formed by combining a plurality of R_{11}s with one another, the ring formed by combining a plurality of R_{12}s with one another, the ring formed by combining a plurality of R_{13}s with one another, and the ring formed by combining a plurality of R_{14}s with one another is preferably a 5- or 6-membered ring.

Each of the groups as R_{11}, R_{12}, R_{13} and R_{14}, the ring formed by combining a plurality of R_{11}s with one another, the ring formed by combining a plurality of R_{12}s with one another, the ring formed by combining a plurality of R_{13}s with one another, and the ring formed by combining a plurality of R_{14}s with one another may further have a substituent, and examples of the substituent include a halogen atom (e.g., fluorine), a hydroxyl group, a carboxyl group, a cyano group, a nitro group, an alkoxy group, an alkoxyalkyl group, an alkoxycarbonyl group, and an alkoxycarbonyloxy group.

The alkoxy group includes, for example, a linear, branched or cyclic alkoxy group having a carbon number of 1 to 20, such as methoxy group, ethoxy group, n-propoxy group, i-propoxy group, n-butoxy group, 2-methylpropoxy group, 1-methylpropoxy group, tert-butoxy group, cyclopentyloxy group and cyclohexyloxy group.

The alkoxyalkyl group includes, for example, a linear, branched or cyclic alkoxyalkyl group having a carbon number of 2 to 21, such as methoxymethyl group, ethoxymethyl group, 1-methoxyethyl group, 2-methoxyethyl group, 1-ethoxyethyl group and 2-ethoxyethyl group.

The alkoxycarbonyl group includes, for example, a linear, branched or cyclic alkoxycarbonyl group having a carbon number of 2 to 21, such as methoxycarbonyl group, ethoxycarbonyl group, n-propoxycarbonyl group, i-propoxycarbonyl group, n-butoxycarbonyl group, 2-methylpropoxycarbonyl group, 1-methylpropoxycarbonyl group, tert-butoxycarbonyl group, cyclopentyloxycarbonyl group and cyclohexyloxycarbonyl group.

The alkoxycarbonyloxy group includes, for example, a linear, branched or cyclic

alkoxycarbonyloxy group having a carbon number of 2 to 21, such as methoxycarbonyloxy group, ethoxycarbonyloxy group, n-propoxycarbonyloxy group, i-propoxycarbonyloxy group, n-butoxycarbonyloxy group, tert-butoxycarbonyloxy group, cyclopentyloxycarbonyloxy group and cyclohexyloxycarbonyloxy group.

n1 is preferably an integer of 0 to 5, more preferably an integer of 0 to 3, still more preferably 0 or 1.

n2 is preferably an integer of 0 to 5, more preferably an integer of 0 to 3, still more preferably 0 or 1.

n3 is preferably an integer of 0 to 3, more preferably 0 or 1.

n4 is preferably an integer of 0 to 3, more preferably 0 or 1.

n5 is preferably an integer of 1 to 3, more preferably 1 or 2.

In particular, when the exposure is exposure using a KrF excimer laser, the aromatic compound is preferably a polycyclic aromatic compound. The polycyclic aromatic compound can absorb the exposure light with no fail and therefore, the effect of standing wave due to reflection of exposure light from the substrate or the diffused reflection of exposure light due to the stepped portion of a stepped substrate can be unfailingly reduced, so that a pattern excellent in the cross-sectional profile can be obtained.

The polycyclic aromatic ring structure in the polycyclic aromatic compound includes a structure formed by connecting a plurality of benzene rings through a single bond, such as biphenyl ring, and a polycyclic condensed aromatic structure such as naphthalene ring and anthracene ring.

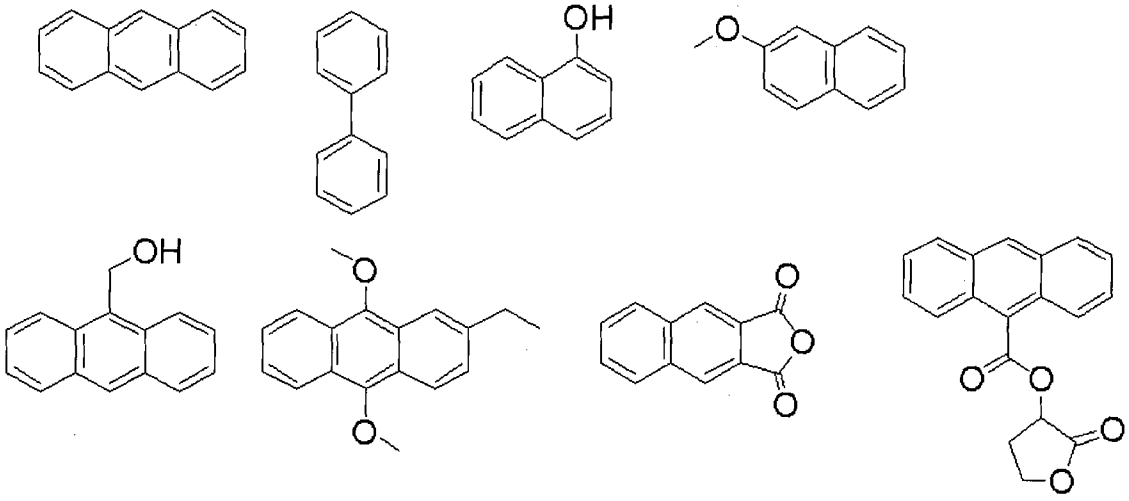
Accordingly, in the case where the exposure is exposure using a KrF excimer laser, a1 in formula (A1) or (A2) is preferably 1 or 2 and a2 is preferably 1 or 2.

In the case where the first resin composition (I) further contains an aromatic compound, the content of the aromatic compound is preferably from 0.1 to 0.4 mass%, more preferably from 0.15 to 0.3 mass%, based on the entire solid content of the first resin composition (I).

The aromatic compound may be a commercially available product or may be synthesized by a conventional method.

Specific examples of the aromatic compound are illustrated below, but the present invention is not limited thereto.

120



[6] (E) Hydrophobic resin

The resin composition (I) or (II) (above all, the resin composition (II)) for use in the present invention may contain a hydrophobic resin having at least either a fluorine atom or a silicon atom particularly when the composition is applied to immersion exposure (hereinafter, sometimes referred to as "hydrophobic resin (E)" or simply as "resin (E)"). The hydrophobic resin (E) is unevenly distributed to the film surface layer and when the immersion medium is water, the static/dynamic contact angle of the resist film surface for water as well as the followability of immersion liquid can be enhanced.

The hydrophobic resin (E) is preferably designed to be unevenly distributed to the interface as described above but unlike a surfactant, need not have necessarily a hydrophilic group in the molecule and may not contribute to uniform mixing of polar/nonpolar substances.

The hydrophobic resin (E) typically contains a fluorine atom and/or a silicon atom. The fluorine atom and/or silicon atom in the hydrophobic resin (E) may be contained in the main chain of the resin or may be contained in the side chain.

In the case where the hydrophobic resin (E) contains a fluorine atom, the resin preferably contains, as the fluorine atom-containing partial structure, a fluorine atom-containing alkyl group, a fluorine atom-containing cycloalkyl group or a fluorine atom-containing aryl group.

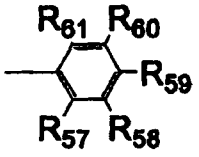
The fluorine atom-containing alkyl group (preferably having a carbon number of 1 to 10, more preferably a carbon number of 1 to 4) is a linear or branched alkyl group with at least one hydrogen atom being substituted for by a fluorine atom and may further have a substituent other than fluorine atom.

The fluorine atom-containing cycloalkyl group is a monocyclic or polycyclic

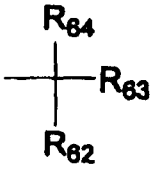
cycloalkyl group with at least one hydrogen atom being substituted for by a fluorine atom and may further have a substituent other than fluorine atom.

The fluorine atom-containing aryl group is an aryl group such as phenyl group or naphthyl group with at least one hydrogen atom being substituted for by a fluorine atom and may further have a substituent other than fluorine atom.

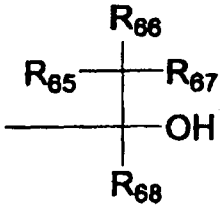
Preferred fluorine atom-containing alkyl group, fluorine atom-containing cycloalkyl group and fluorine atom-containing aryl group include groups represented by the following formulae (F2) to (F4), but the present invention is not limited thereto.



(F2)



(F3)



(F4)

In formulae (F2) to (F4), each of R_{57} to R_{68} independently represents a hydrogen atom, a fluorine atom, or an alkyl group (linear or branched), provided that at least one of R_{57} to R_{61}, at least one of R_{62} to R_{64}, and at least one of R_{65} to R_{68} each independently represents a fluorine atom or an alkyl group (preferably having a carbon number of 1 to 4) with at least one hydrogen atom being substituted for by a fluorine atom.

It is preferred that all of R_{57} to R_{61} and R_{65} to R_{67} are a fluorine atom. Each of R_{62}, R_{63} and R_{68} is preferably an alkyl group (preferably having a carbon number of 1 to 4) with at least one hydrogen atom being substituted for by a fluorine atom, more preferably a perfluoroalkyl group having a carbon number of 1 to 4. R_{62} and R_{63} may combine with each other to form a ring.

Specific examples of the group represented by formula (F2) include p-fluorophenyl group, pentafluorophenyl group, and 3,5-di(trifluoromethyl)phenyl group.

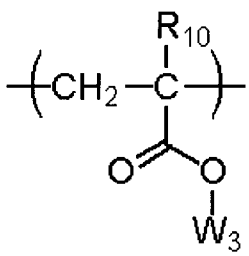
Specific examples of the group represented by formula (F3) include a trifluoromethyl group, a pentafluoropropyl group, a pentafluoroethyl group, a heptafluorobutyl group, a hexafluoroisopropyl group, a heptafluoroisopropyl group, a hexafluoro(2-methyl)isopropyl group, a nonafluorobutyl group, an octafluoroisobutyl group, a nonafluorohexyl group, a nonafluoro-tert-butyl group, a perfluoroisopentyl group, a perfluorooctyl group, a perfluoro(trimethyl)hexyl group, a 2,2,3,3-tetrafluorocyclobutyl group,

and a perfluorocyclohexyl group. A hexafluoroisopropyl group, a heptafluoroisopropyl group, a hexafluoro(2-methyl)isopropyl group, an octafluoroisobutyl group, a nonafluoro-tert-butyl group and a perfluoroisopentyl group are preferred, and a hexafluoroisopropyl group and a heptafluoroisopropyl group are more preferred.

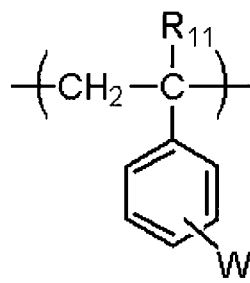
Specific examples of the group represented by formula (F4) include $-C(CF_3)_2OH$, $-C(C_2F_5)_2OH$, $-C(CF_3)(CH_3)OH$ and $-CH(CF_3)OH$, with $-C(CF_3)_2OH$ being preferred.

The fluorine atom-containing partial structure may be bonded directly to the main chain or may be bonded to the main chain through a group selected from the group consisting of an alkylene group, a phenylene group, an ether bond, a thioether bond, a carbonyl group, an ester bond, an amide bond, a urethane bond and a ureylene bond, or a group formed by combining two or more of these groups and bonds.

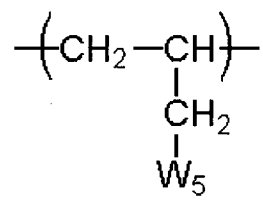
Suitable repeating units having a fluorine atom include the followings.



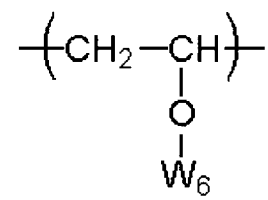
(C-Ia)



(C-Ib)



(C-Ic)

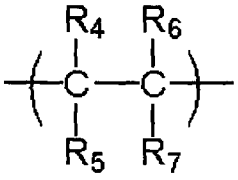


(C-Id)

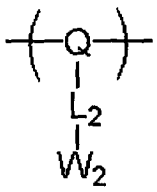
In the formulae, each of R_{10} and R_{11} independently represents a hydrogen atom, a fluorine atom, or an alkyl group. The alkyl group is preferably a linear or branched alkyl group having a carbon number of 1 to 4 and may have a substituent, and the alkyl group having a substituent includes, in particular, a fluorinated alkyl group.

Each of W_3 to W_6 independently represents an organic group having at least one or more fluorine atoms, and the organic group specifically includes the atomic groups of (F2) to (F4).

In addition, the hydrophobic resin (E) may contain a unit shown below as the repeating unit having a fluorine atom.



(C-II)



(C-III)

In the formulae, each of R_4 to R_7 independently represents a hydrogen atom, a fluorine atom, or an alkyl group. The alkyl group is preferably a linear or branched alkyl group having a carbon number of 1 to 4 and may have a substituent, and the alkyl group having a substituent includes, in particular, a fluorinated alkyl group.

However, at least one of R_4 to R_7 represents a fluorine atom. R_4 and R_5, or R_6 and R_7 may form a ring.

W_2 represents an organic group having at least one fluorine atom, and the organic group specifically includes the atomic groups of (F2) to (F4).

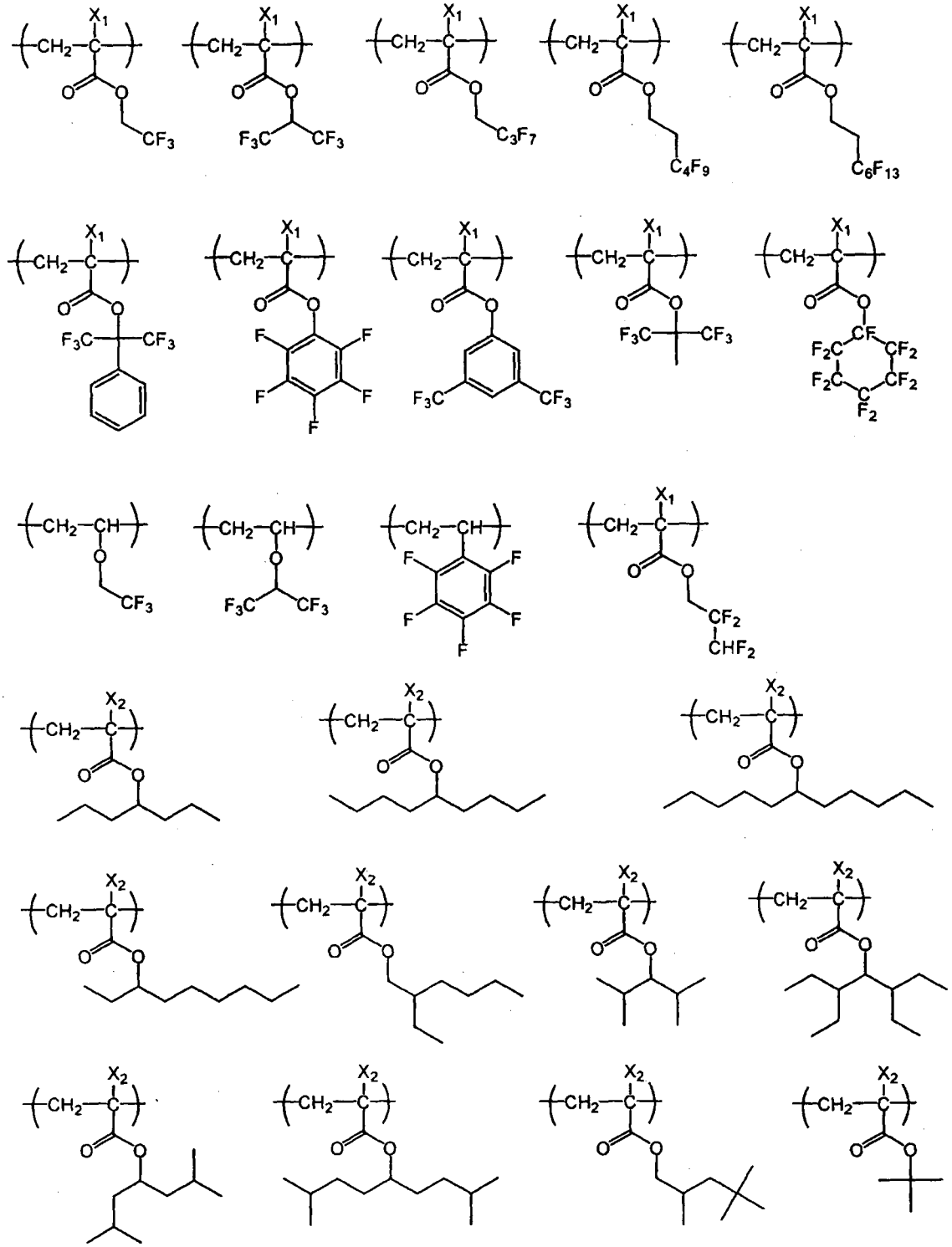
L_2 represents a single bond or a divalent linking group. The divalent linking group is a substituted or unsubstituted arylene group, a substituted or unsubstituted alkylene group, a substituted or unsubstituted cycloalkylene group, -O-, $-SO_2-$, -CO-, -N(R)- (wherein R represents a hydrogen atom or an alkyl group), $-NHSO_2-$, or a divalent linking group formed by combining a plurality of these groups.

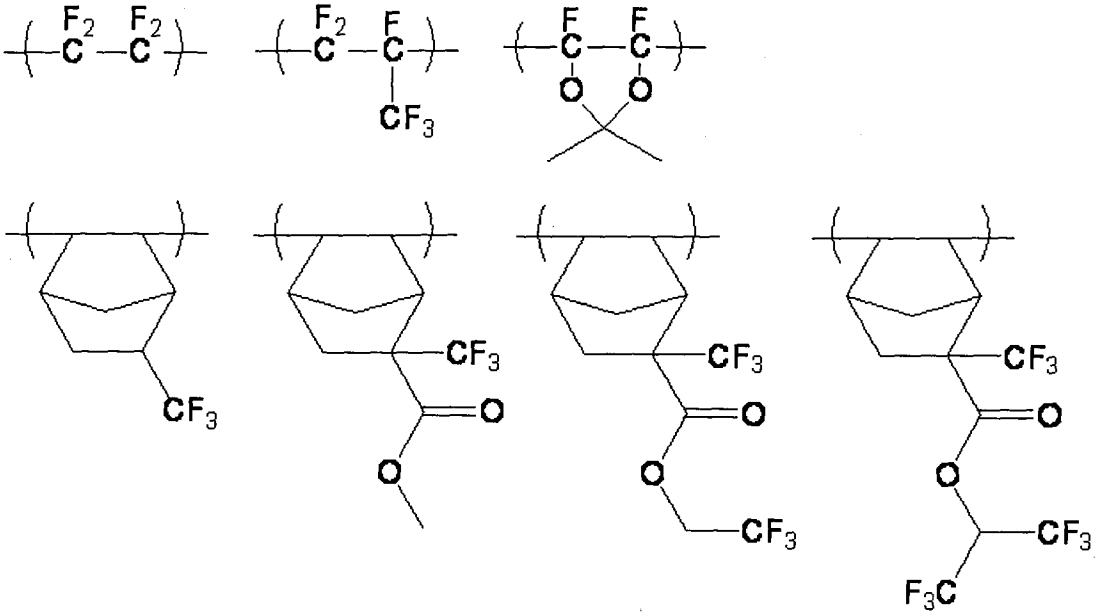
Q represents an alicyclic structure. The alicyclic structure may have a substituent and may be monocyclic or polycyclic, and in the case of a polycyclic structure, the structure may be a crosslinked structure. The monocyclic structure is preferably a cycloalkyl group having a carbon number of 3 to 8, and examples thereof include a cyclopentyl group, a cyclohexyl group, a cyclobutyl group, and a cyclooctyl group. Examples of the polycyclic structure include a group having a bicyclo, tricyclo or tetracyclo structure with a carbon number of 5 or more. A cycloalkyl group having a carbon number of 6 to 20 is preferred, and examples thereof include an adamantyl group, a norbornyl group, a dicyclopentyl group, a tricyclodecanyl group, and a tetracyclododecyl group. A part of carbon atoms in the cycloalkyl group may be substituted with a heteroatom such as oxygen atom. Above all, Q is preferably, for example, a norbornyl group, a tricyclodecanyl group, or a tetracyclododecyl group.

Specific examples of the repeating unit having a fluorine atom are illustrated below,

but the present invention is not limited thereto.

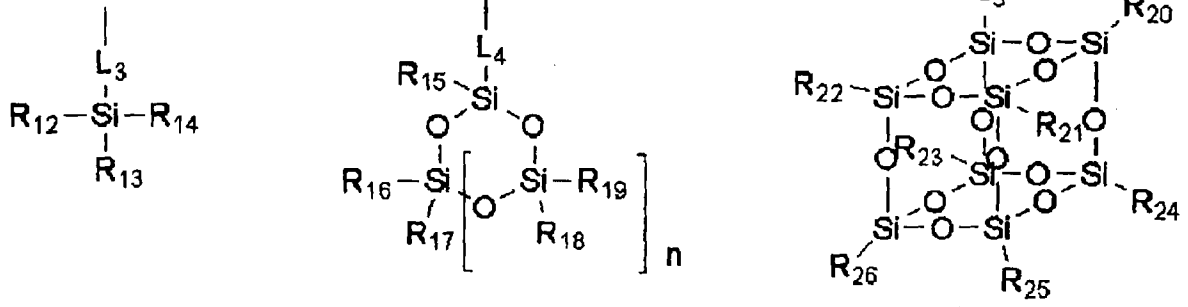
In specific examples, X_1 represents a hydrogen atom, $-CH_3$, -F or $-CF_3$. X_2 represents -F or $-CF_3$.





The hydrophobic resin (E) may contain a silicon atom. The resin preferably has, as the silicon atom-containing partial structure, an alkylsilyl structure (preferably a trialkylsilyl group) or a cyclic siloxane structure.

Specific examples of the alkylsilyl structure and cyclic siloxane structure include groups represented by the following formulae (CS-1) to (CS-3):



(CS-1) (CS-2) (CS-3)

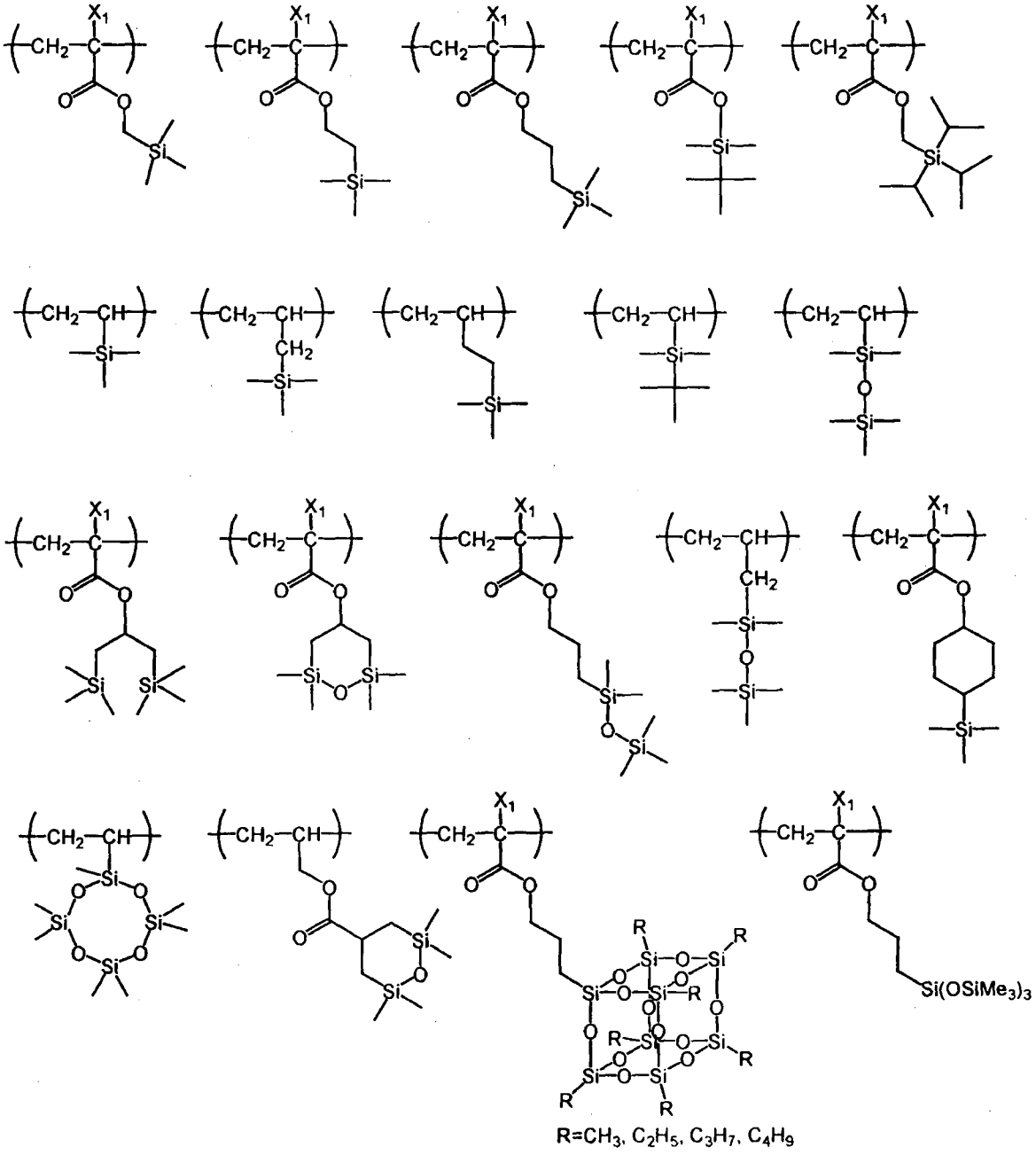
In formulae (CS-1) to (CS-3), each of R_{12} to R_{26} independently represents a linear or branched alkyl group (preferably having a carbon number of 1 to 20) or a cycloalkyl group (preferably having a carbon number of 3 to 20).

Each of L_3 to L_5 represents a single bond or a divalent linking group. The divalent linking group is a sole member or a combination of two or more members (preferably having a total carbon number of 12 or less), selected from the group consisting of an alkylene group, a

phenylene group, an ether bond, a thioether bond, a carbonyl group, an ester bond, an amide bond, a urethane bond and a urea bond.

n represents an integer of 1 to 5. n is preferably an integer of 2 to 4.

Specific examples of the repeating unit having a group represented by formulae (CS-1) to (CS-3) are illustrated below, but the present invention is not limited thereto. In specific examples, X_1 represents a hydrogen atom, $-CH_3$, -F or $-CF_3$.



Furthermore, the hydrophobic resin (E) may contain at least one group selected from the group consisting of the following (x) to (z):

(x) an acid group,

(y) a lactone structure-containing group, an acid anhydride group, or an acid imide group, and

(z) a group capable of decomposing by the action of an acid.

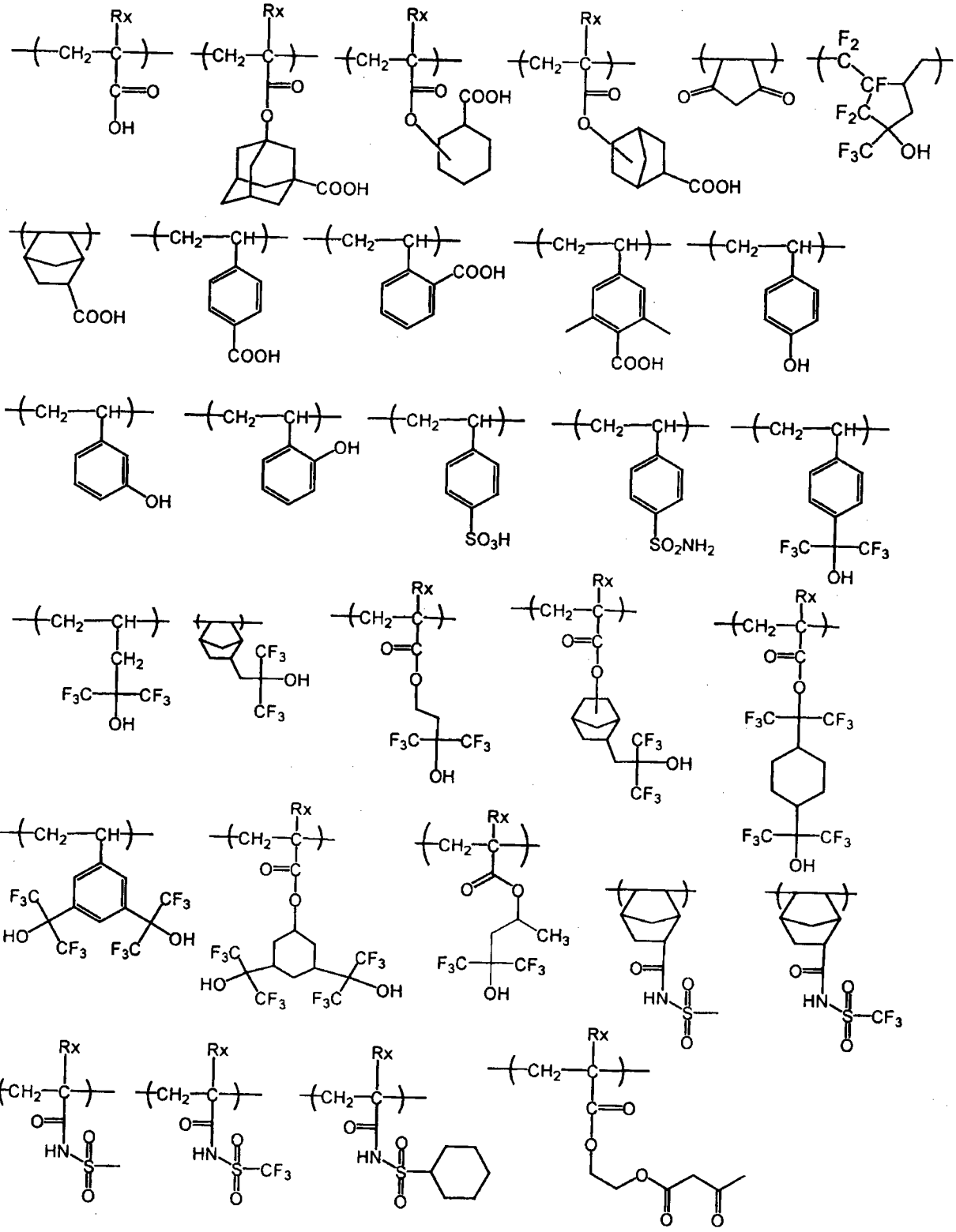
Examples of the acid group (x) include a phenolic hydroxyl group, a carboxylic acid group, a fluorinated alcohol group, a sulfonic acid group, a sulfonamide group, a sulfonylimide group, an (alkylsulfonyl)(alkylcarbonyl)methylene group, an (alkylsulfonyl)(alkylcarbonyl)imide group, a bis(alkylcarbonyl)methylene group, a bis(alkylcarbonyl)imide group, a bis(alkylsulfonyl)methylene group, a bis(alkylsulfonyl)imide group, a tris(alkylcarbonyl)methylene group, and a tris(alkylsulfonyl)methylene group.

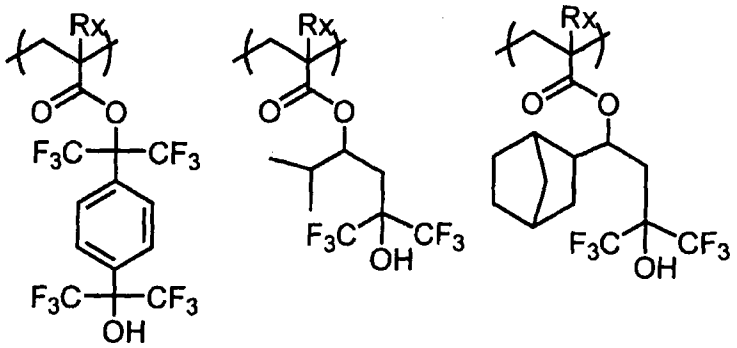
Preferred acid groups are a fluorinated alcohol group (preferably hexafluoroisopropanol), a sulfonimide group and a bis(alkylcarbonyl)methylene group.

The repeating unit having (x) an acid group includes, for example, a repeating unit where the acid group is directly bonded to the main chain of the resin, such as repeating unit by an acrylic acid or a methacrylic acid, and a repeating unit where the acid group is bonded to the main chain of the resin through a linking group, and the acid group may be also introduced into the terminal of the polymer chain by using an acid group-containing polymerization initiator or chain transfer agent at the polymerization. All of these cases are preferred. The repeating unit having (x) an acid group may have at least either a fluorine atom or a silicon atom.

The content of the repeating unit having (x) an acid group is preferably from 1 to 50 mol%, more preferably from 3 to 35 mol%, still more preferably from 5 to 20 mol%, based on all repeating units in the hydrophobic resin (E).

Specific examples of the repeating unit having (x) an acid group are illustrated below, but the present invention is not limited thereto. In the formulae, Rx represents a hydrogen atom, CH_3, CF_3 or CH_2OH.





As for the (y) lactone structure-containing group, acid anhydride group or acid imide group, a lactone structure-containing group is preferred.

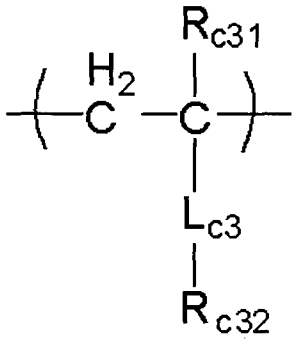
The repeating unit containing such a group is, for example, a repeating unit where the group is directly bonded to the main chain of the resin, such as repeating unit by an acrylic acid ester or a methacrylic acid ester. This repeating unit may be a repeating unit where the group is bonded to the main chain of the resin through a linking group. Alternatively, in this repeating unit, the group may be introduced into the terminal of the resin by using a polymerization initiator or chain transfer agent containing the group at the polymerization.

Examples of the repeating unit having a lactone structure-containing group are the same as those of the repeating unit having a lactone structure described above in the paragraph of the resin (A-1) or (A-2).

The content of the repeating unit having a lactone structure-containing group, an acid anhydride group or an acid imide group is preferably from 1 to 100 mol%, more preferably from 3 to 98 mol%, still more preferably from 5 to 95 mol%, based on all repeating units in the hydrophobic resin

Examples of the repeating unit having (z) a group capable of decomposing by the action of an acid, contained in the hydrophobic resin (E), are the same as those of the repeating unit having an acid-decomposable group described for the resin (A-1) or (A-2). The repeating unit having (z) a group capable of decomposing by the action of an acid may contain at least either a fluorine atom or a silicon atom. In the hydrophobic resin (E), the content of the repeating unit having (z) a group capable of decomposing by the action of an acid is preferably from 1 to 80 mol%, more preferably from 10 to 80 mol%, still more preferably from 20 to 60 mol%, based on all repeating units in the resin (E).

The hydrophobic resin (E) may further contain a repeating unit represented by the following formula (III):



(III)

In formula (III), R_{c31} represents a hydrogen atom, an alkyl group (which may be substituted with a fluorine atom or the like), a cyano group, or a $-CH_2-O-R_{ac2}$ group, wherein R_{ac2} represents a hydrogen atom, an alkyl group, or an acyl group. R_{c31} is preferably a hydrogen atom, a methyl group, a hydroxymethyl group or a trifluoromethyl group, more preferably a hydrogen atom or a methyl group.

R_{c32} represents a group having an alkyl group, a cycloalkyl group, an alkenyl group, a cycloalkenyl group or an aryl group. These groups may be substituted with a fluorine atom or a silicon atom-containing group.

L_{c3} represents a single bond or a divalent linking group.

In formula (III), the alkyl group of R_{c32} is preferably a linear or branched alkyl group having a carbon number of 3 to 20.

The cycloalkyl group is preferably a cycloalkyl group having a carbon number of 3 to 20.

The alkenyl group is preferably an alkenyl group having a carbon number of 3 to 20.

The cycloalkenyl group is preferably a cycloalkenyl group having a carbon number of 3 to 20.

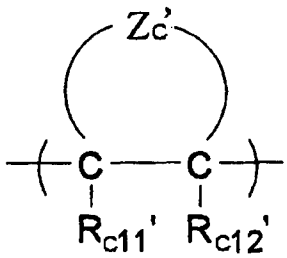
The aryl group is preferably an aryl group having a carbon number of 6 to 20, more preferably a phenyl group or a naphthyl group, and these groups may have a substituent.

R_{c32} is preferably an unsubstituted alkyl group or a fluorine atom-substituted alkyl group.

The divalent linking group of L_{c3} is preferably an alkylene group (preferably having a carbon number of 1 to 5), an ether bond, a phenylene group, or an ester bond (a group represented by -COO-).

The content of the repeating unit represented by formula (III) is preferably from 1 to 100 mol%, more preferably from 10 to 90 mol%, still more preferably from 30 to 70 mol%, based on all repeating units in the hydrophobic resin.

It is also preferred that the hydrophobic resin (E) further contains a repeating unit represented by the following formula (CII-AB):



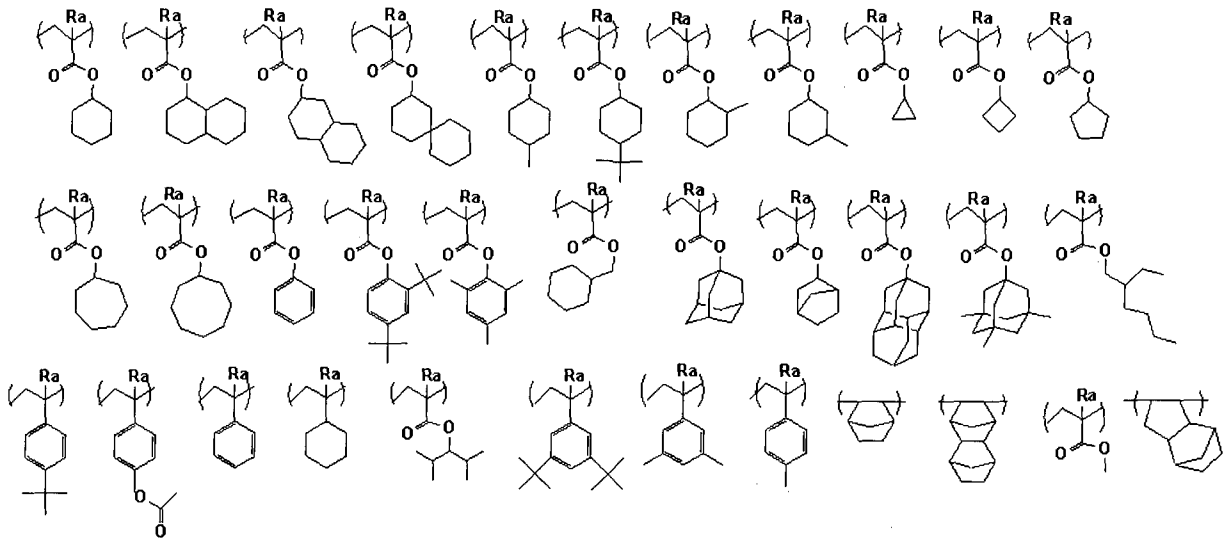
(CII-AB)

In formula (CII-AB), each of R_{c11}' and R_{c12}' independently represents a hydrogen atom, a cyano group, a halogen atom, or an alkyl group.

Z_c' represents an atomic group for forming an alicyclic structure containing two carbon atoms (C-C) to which Z_c' is bonded.

The content of the repeating unit represented by formula (CII-AB) is preferably from 1 to 100 mol%, more preferably from 10 to 90 mol%, still more preferably from 30 to 70 mol%, based on all repeating units in the hydrophobic resin.

Specific examples of the repeating units represented by formulae (III) and (CII-AB) are illustrated below, but the present invention is not limited thereto. In the formulae, Ra represents H, CH_3, CH_2OH, CF_3 or CN.



In the case where the hydrophobic resin (E) contains a fluorine atom, the fluorine atom content is preferably from 5 to 80 mass%, more preferably from 10 to 80 mass%, based on the weight average molecular weight of the hydrophobic resin (E). Also, the fluorine

atom-containing repeating unit preferably accounts for 10 to 100 mol%, more preferably from 30 to 100 mol%, based on all repeating units contained in the hydrophobic resin (E).

In the case where the hydrophobic resin (E) contains a silicon atom, the silicon atom content is preferably from 2 to 50 mass%, more preferably from 2 to 30 mass%, based on the weight average molecular weight of the hydrophobic resin (E). Also, the silicon atom-containing repeating unit preferably accounts for 10 to 100 mol%, more preferably from 20 to 100 mol%, based on all repeating units contained in the hydrophobic resin (E).

The weight average molecular weight of the hydrophobic resin (E) is preferably from 1,000 to 100,000, more preferably from 1,000 to 50,000, still more preferably from 2,000 to 15,000, in terms of standard polystyrene.

As for the hydrophobic resin (E), one kind may be used, or a plurality of kinds may be used in combination.

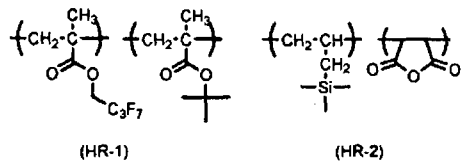
In the case where the resin composition (I) or (II) contains (E) a hydrophobic resin, the content of the hydrophobic resin (E) in each composition is preferably from 0.01 to 20 mass%, more preferably from 0.05 to 10 mass%, still more preferably from 0.1 to 8 mass%, yet still more preferably from 0.1 to 5 mass%, based on the entire solid content in the composition of the present invention.

In the hydrophobic resin (E), similarly to the resin (A-1) or (A-2), it is of course preferred that the content of impurities such as metal is small, but the content of residual monomers or oligomer components is also preferably from 0.01 to 5 mass%, more preferably from 0.01 to 3 mass%, still more preferably from 0.05 to 1 mass%. Thanks to the content in this range, a resin composition free from in-liquid extraneous substances and change with aging of sensitivity and the like can be obtained. Furthermore, in view of resolution, resist profile, side wall of resist pattern, roughness and the like, the molecular weight distribution (Mw/Mn, sometimes referred to as "polydispersity") is preferably from 1 to 5, more preferably from 1 to 3, still more preferably from 1 to 2.

As the hydrophobic resin (E), various commercially products may be used, or the resin may be synthesized by a conventional method (for example, radical polymerization). Examples of the general synthesis method include a batch polymerization method of dissolving monomer species and an initiator in a solvent and heating the solution, thereby effecting the polymerization, and a dropping polymerization method of adding dropwise a solution containing monomer species and an initiator to a heated solvent over 1 to 10 hours. A dropping polymerization method is preferred.

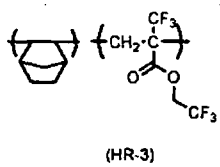
The reaction solvent, the polymerization initiator, the reaction conditions (e.g., temperature, concentration) and the purification method after reaction are the same as those described for the resin (A-1) or (A-2), but in the synthesis of the hydrophobic resin (E), the concentration at the reaction is preferably from 30 to 50 mass%.

Specific examples of the hydrophobic resin (E) are illustrated below. Also, the molar ratio of repeating units (corresponding to repeating units starting from the left), weight average molecular weight and polydispersity of each resin are shown in the Tables later.

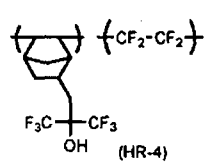


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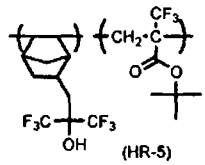
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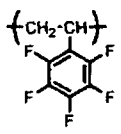
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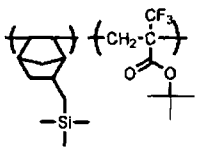
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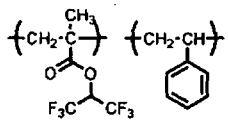
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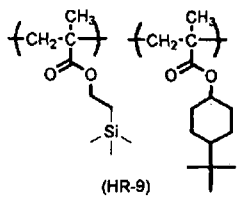
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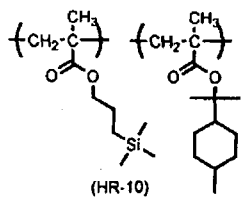
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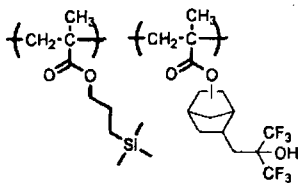
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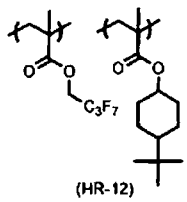
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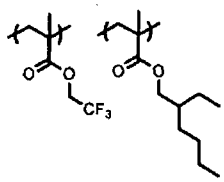
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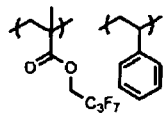
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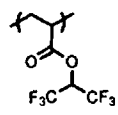
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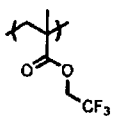
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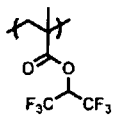
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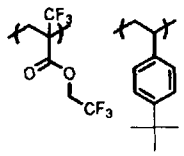
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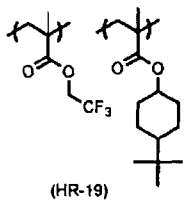
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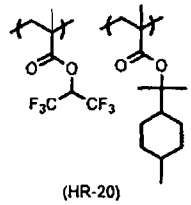
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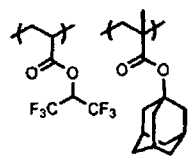
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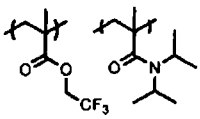
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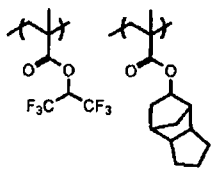
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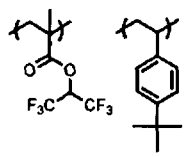
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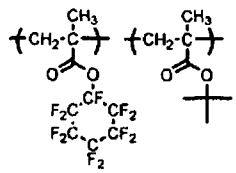
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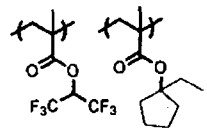
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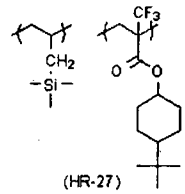
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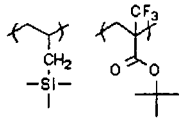
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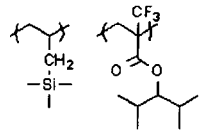
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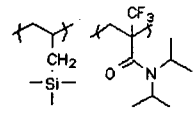
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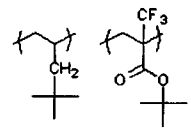
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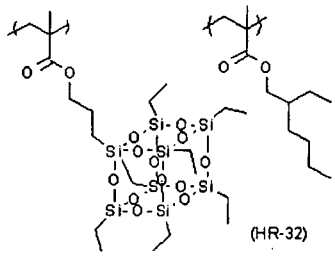
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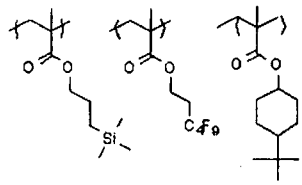
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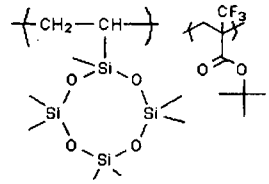
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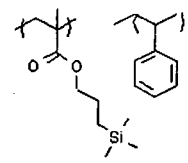
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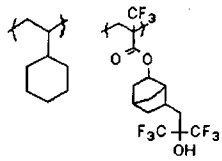
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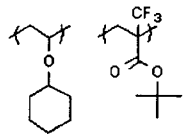
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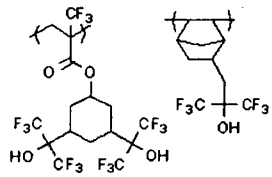
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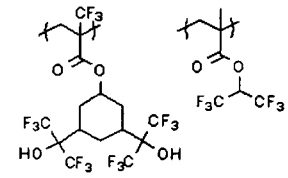
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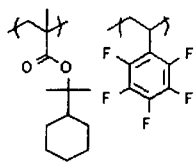
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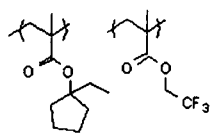
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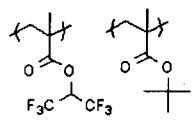
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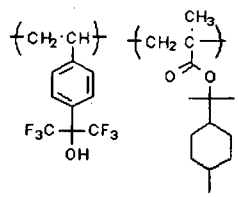
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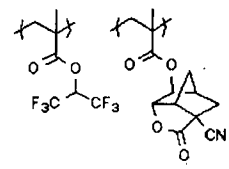
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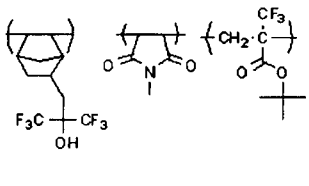
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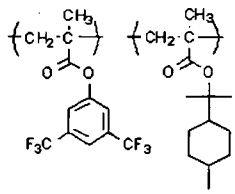
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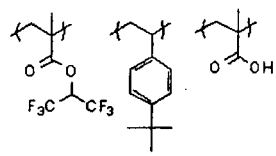
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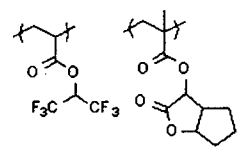
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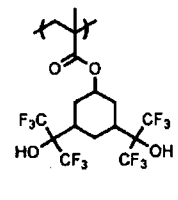
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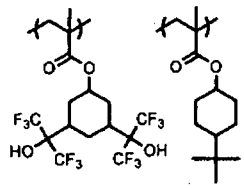
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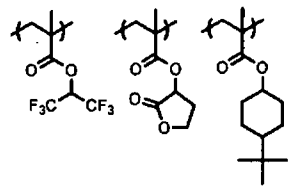
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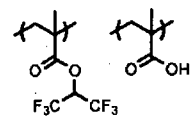
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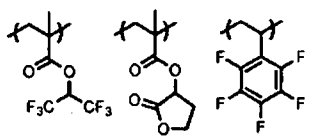
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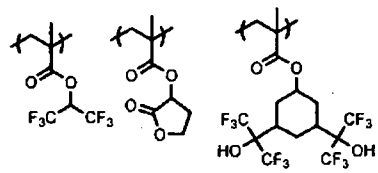
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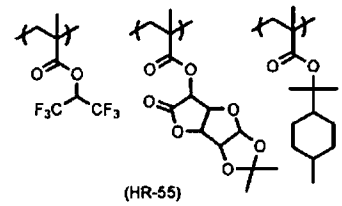
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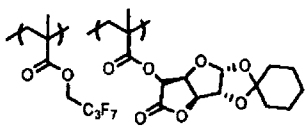
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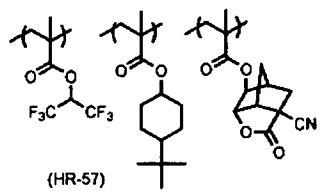
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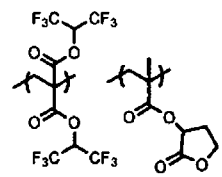
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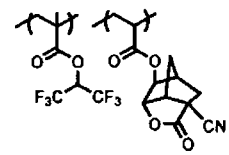
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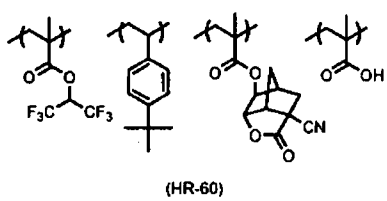
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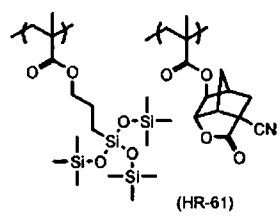
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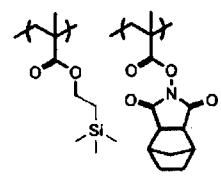
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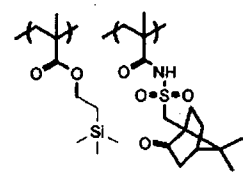
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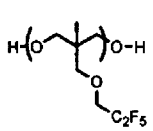
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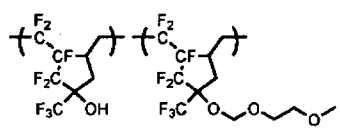
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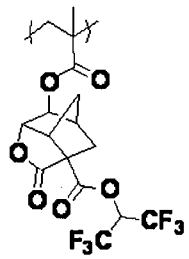
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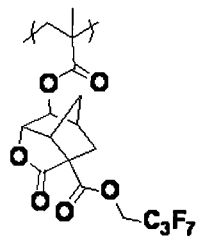
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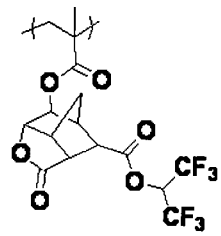
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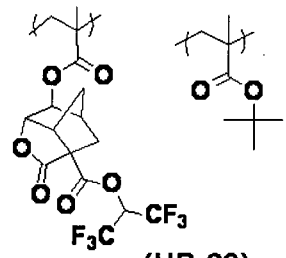
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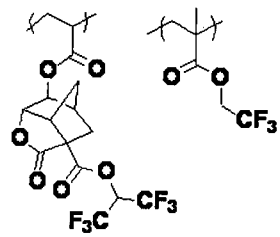
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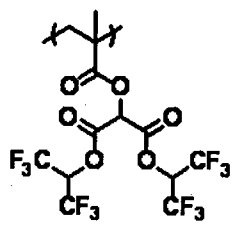
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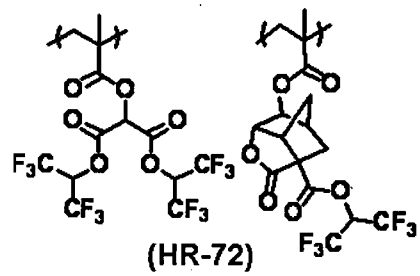
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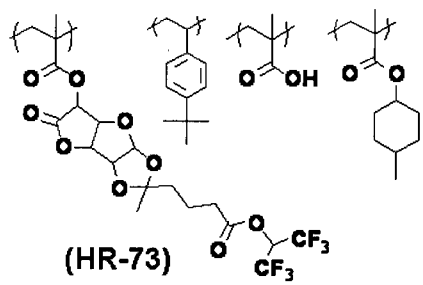
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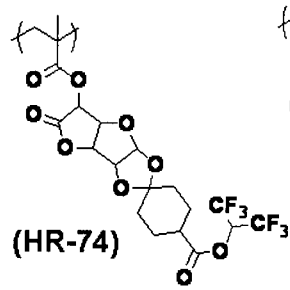
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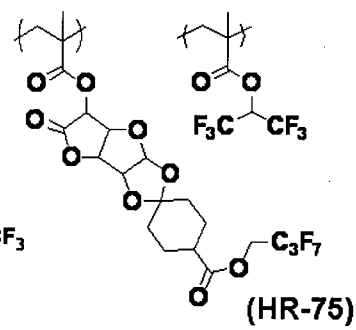
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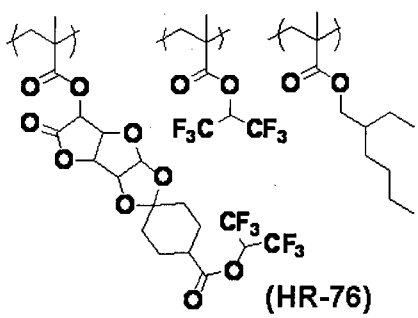
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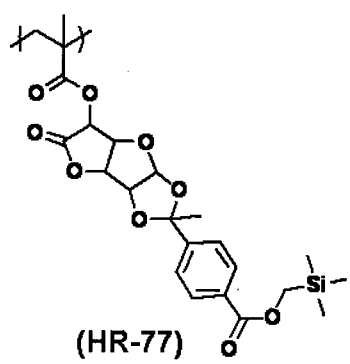
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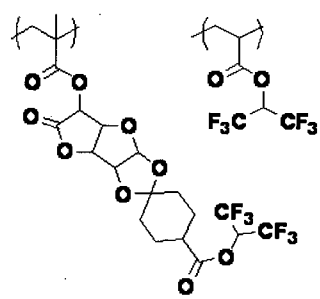
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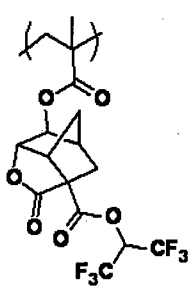
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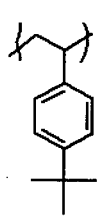


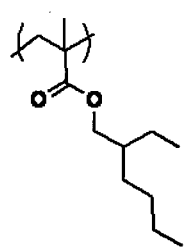
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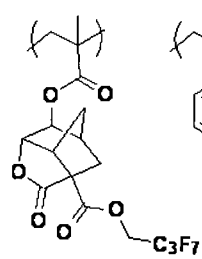
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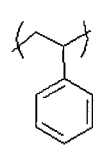


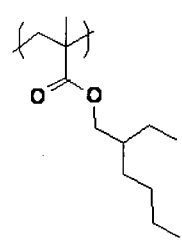




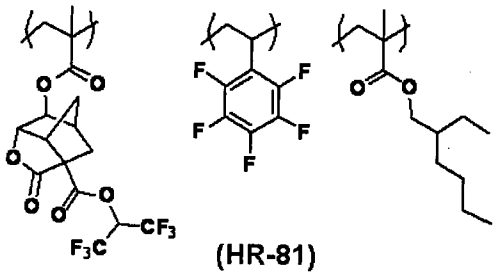
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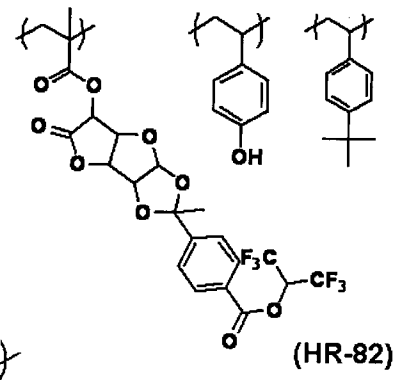




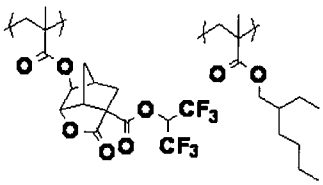
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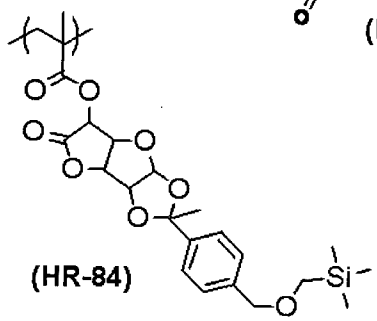
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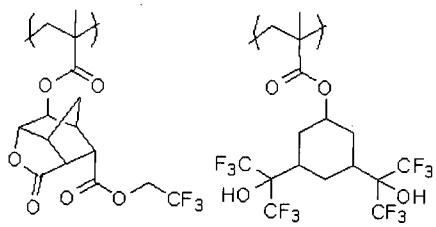
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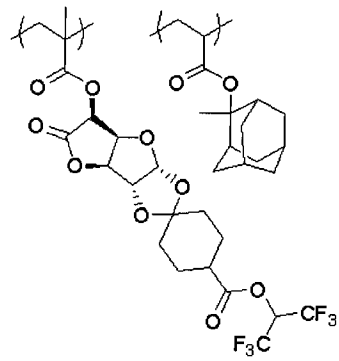
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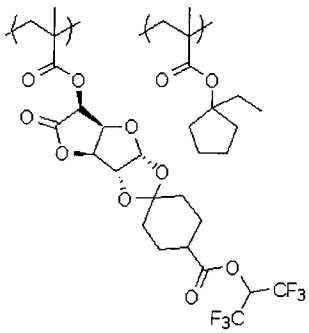
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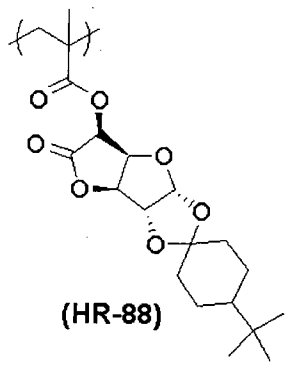
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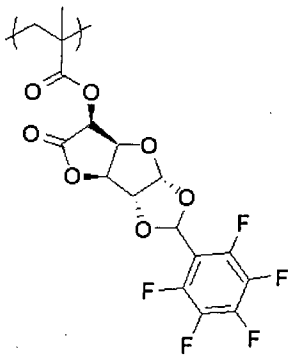
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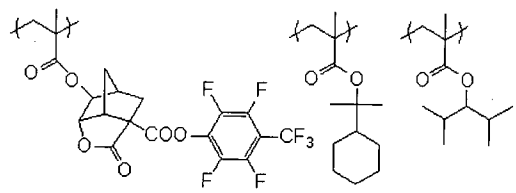
(HR-87)



(HR-88)



(HR-89)



(HR-90)

Table 1

Resin	Composition	Mw	Mw/Mn
HR-1	50/50	4900	1.4
HR-2	50/50	5100	1.6
HR-3	50/50	4800	1.5
HR-4	50/50	5300	1.6
HR-5	50/50	4500	1.4
HR-6	100	5500	1.6
HR-7	50/50	5800	1.9
HR-8	50/50	4200	1.3
HR-9	50/50	5500	1.8
HR-10	40/60	7500	1.6
HR-11	70/30	6600	1.8
HR-12	40/60	3900	1.3
HR-13	50/50	9500	1.8
HR-14	50/50	5300	1.6
HR-15	100	6200	1.2
HR-16	100	5600	1.6
HR-17	100	4400	1.3
HR-18	50/50	4300	1.3
HR-19	50/50	6500	1.6
HR-20	30/70	6500	1.5
HR-21	50/50	6000	1.6
HR-22	50/50	3000	1.2
HR-23	50/50	5000	1.5
HR-24	50/50	4500	1.4
HR-25	30/70	5000	1.4
HR-26	50/50	5500	1.6
HR-27	50/50	3500	1.3
HR-28	50/50	6200	1.4
HR-29	50/50	6500	1.6
HR-30	50/50	6500	1.6
HR-31	50/50	4500	1.4
HR-32	30/70	5000	1.6
HR-33	30/30/40	6500	1.8
HR-34	50/50	4000	1.3
HR-35	50/50	6500	1.7

Resin	Composition	Mw	Mw/Mn
HR-36	50/50	6000	1.5
HR-37	50/50	5000	1.6
HR-38	50/50	4000	1.4
HR-39	20/80	6000	1.4
HR-40	50/50	7000	1.4
HR-41	50/50	6500	1.6
HR-42	50/50	5200	1.6
HR-43	50/50	6000	1.4
HR-44	70/30	5500	1.6
HR-45	50/20/30	4200	1.4
HR-46	30/70	7500	1.6
HR-47	40/58/2	4300	1.4
HR-48	50/50	6800	1.6
HR-49	100	6500	1.5
HR-50	50/50	6600	1.6
HR-51	30/20/50	6800	1.7
HR-52	95/5	5900	1.6
HR-53	40/30/30	4500	1.3
HR-54	50/30/20	6500	1.8
HR-55	30/40/30	7000	1.5
HR-56	60/40	5500	1.7
HR-57	40/40/20	4000	1.3
HR-58	60/40	3800	1.4
HR-59	80/20	7400	1.6
HR-60	40/40/15/5	4800	1.5
HR-61	60/40	5600	1.5
HR-62	50/50	5900	2.1
HR-63	80/20	7000	1.7
HR-64	100	5500	1.8
HR-65	50/50	9500	1.9

Table 2

Resin	Composition	Mw	Mw/Mn
HR-66	100	6000	1.5
HR-67	100	6000	1.4
HR-68	100	9000	1.5
HR-69	60/40	8000	1.3
HR-70	80/20	5000	1.4
HR-71	100	9500	1.5
HR-72	40/60	8000	1.4
HR-73	55/30/5/10	8000	1.3
HR-74	100	13000	1.4
HR-75	70/30	8000	1.3
HR-76	50/40/10	9500	1.5
HR-77	100	9000	1.6
HR-78	80/20	3500	1.4
HR-79	90/8/2	13000	1.5
HR-80	85/10/5	5000	1.5

Resin	Composition	Mw	Mw/Mn
HR-81	80/18/2	6000	1.5
HR-82	50/20/30	5000	1.3
HR-83	90/10	8000	1.4
HR-84	100	9000	1.6
HR-85	80/20	15000	1.6
HR-86	70/30	4000	1.42
HR-87	60/40	8000	1.32
HR-88	100	3800	1.29
HR-89	100	6300	1.35
HR-90	50/40/10	8500	1.51

[7] (F) Surfactant

The resin composition (I) or (II) for use in the present invention may or may not further contain a surfactant, but in the case of containing a surfactant, it is preferred to contain any one of fluorine-containing and/or silicon-containing surfactants (a fluorine-containing surfactant, a silicon-containing surfactant and a surfactant containing both a fluorine atom and a silicon atom), or two or more thereof.

By containing a surfactant, the resin composition (I) or (II) for use in the present invention can give a resist pattern improved in the sensitivity, resolution and adherence and reduced in the development defect when using an exposure light source with a wavelength of 250 nm or less, particularly 220 nm or less.

Examples of the fluorine-containing and/or silicon-containing surfactants include surfactants described in paragraph [0276] of U.S. Patent Application Publication No. 2008/0248425, such as EFtop EF301 and EF303 (produced by Shin-Akita Kasei K.K.); Florad FC430, 431 and 4430 (produced by Sumitomo 3M Inc.); Megaface F171, F173, F176, F189, F113, F110, F177, F120 and R08 (produced by Dainippon Ink & Chemicals, Inc.); Surflon S-382, SC101, 102, 103, 104, 105 and 106 and KH-20 (produced by Asahi Glass Co., Ltd.); Troysol S-366 (produced by Troy Chemical); GF-300 and GF-150 (produced by Toagosei Chemical Industry Co., Ltd.); Surflon S-393 (produced by Seimi Chemical Co., Ltd.); EFtop

EF121, EF122A, EF122B, RF122C, EF125M, EF135M, EF351, EF352, EF801, EF802 and EF601 (produced by JEMCO Inc.); PF636, PF656, PF6320 and PF6520 (produced by OMNOVA); and FTX-204G, 208G, 218G, 230G, 204D, 208D, 212D, 218D and 222D (produced by NEOS Co., Ltd.). In addition, polysiloxane polymer KP-341 (produced by Shin-Etsu Chemical Co., Ltd.) may be also used as the silicon-containing surfactant.

Other than those known surfactants, a surfactant using a polymer having a fluoro-aliphatic group derived from a fluoro-aliphatic compound which is produced by a telomerization process (also called a telomer process) or an oligomerization process (also called an oligomer process), may be used. The fluoro-aliphatic compound can be synthesized by the method described in JP-A-2002-90991.

Examples of the surfactant coming under the surfactant above include Megaface F178, F-470, F-473, F-475, F-476 and F-472 (produced by Dainippon Ink & Chemicals, Inc.); a copolymer of a C_6F_{13} group-containing acrylate (or methacrylate) with a (poly(oxyalkylene)) acrylate (or methacrylate); and a copolymer of a C_3F_7 group-containing acrylate (or methacrylate) with a (poly(oxyethylene)) acrylate (or methacrylate) and a (poly(oxypropylene)) acrylate (or methacrylate).

In the present invention, surfactants other than the fluorine-containing and/or silicon-containing surfactants, described in paragraph [0280] of U.S. Patent Application Publication No. 2008/0248425, may be also used.

One of these surfactants may be used alone, or some of them may be used in combination.

The resin composition (I) or (II) for use in the present invention may or may not contain a surfactant, but in the case where the resin composition (I) or (II) contains a surfactant, the amount of the surfactant used is preferably from 0.0001 to 2 mass%, more preferably from 0.0005 to 1 mass%, based on the entire amount of the resin composition (I) or (II) (excluding the solvent).

[8] (G) Other additives

The resin composition (I) or (II) for use in the present invention may or may not contain an onium carboxylate. Examples of the onium carboxylate include those described in paragraphs [0605] to [0606] of U.S. Patent Application Publication No. 2008/0187860.

Such an onium carboxylate can be synthesized by reacting a sulfonium hydroxide, iodonium hydroxide or ammonium hydroxide and a carboxylic acid with silver oxide in an

appropriate solvent.

In the case where the resin composition (I) or (II) contains an onium carboxylate, the content thereof is generally from 0.1 to 20 mass%, preferably from 0.5 to 10 mass%, more preferably from 1 to 7 mass%, based on the entire solid content of the composition (I) or (II).

The resin composition (I) or (II) for use in the present invention may further contain, for example, a dye, a plasticizer, a photosensitizer, a light absorber, an alkali-soluble resin, a dissolution inhibitor, and a compound for accelerating dissolution in a developer (for example, a phenol compound having a molecular weight of 1,000 or less, or a carboxyl group-containing alicyclic or aliphatic compound), if desired.

The phenol compound having a molecular weight of 1,000 or less can be easily synthesized by one skilled in the art by referring to the method described, for example, in JP-A-4-122938, JP-A-2-28531, U.S. Patent 4,916,210 or European Patent 219294.

Specific examples of the carboxyl group-containing alicyclic or aliphatic compound include, but are not limited to, a carboxylic acid derivative having a steroid structure, such as cholic acid, deoxycholic acid and lithocholic acid, an adamantanecarboxylic acid derivative, an adamantanedicarboxylic acid, a cyclohexanecarboxylic acid, and a cyclohexanedicarboxylic acid.

The solid content concentration in each of the resin compositions (I) and (II) for use in the present invention is usually from 1.0 to 15 mass%, preferably from 1.5 to 13 mass%, more preferably from 2.0 to 12 mass%. By setting the solid content concentration to the range above, the resist solution can be uniformly coated on a substrate and furthermore, a resist pattern having high resolution and a rectangular profile and being excellent in the etching resistance can be formed. The reason therefor is not clearly known, but it is considered that thanks to a solid content concentration of 10 mass% or less, preferably 5.7 mass% or less, aggregation of materials, particularly, a photoacid generator, in the resist solution is suppressed, as a result, a uniform resist film can be formed.

The solid content concentration is a weight percentage of the weight of resist components excluding the solvent, based on the total weight of the resin composition.

Each of the resin compositions (I) and (II) for use in the present invention is used by dissolving the components above in a predetermined organic solvent, preferably in the above-described mixed solvent, filtering the solution through a filter, and coating it on a predetermined support (substrate). The filter used for filtration is preferably a polytetrafluoroethylene-, polyethylene- or nylon-made filter having a pore size of 0.1 μm or

less, more preferably 0.05 μm or less, still more preferably 0.03 μm or less. In the filtration through a filter, as described, for example, in JP-A-2002-62667, circulating filtration may be performed, or the filtration may be performed by connecting a plurality of kinds of filters in series or in parallel. Also, the composition may be filtered a plurality of times. Furthermore, a deaeration treatment or the like may be applied to the composition before and after filtration through a filter.

[9] Pattern forming method

The pattern forming method (negative pattern forming method) of the present invention is as described above.

In the pattern forming method of the present invention, the exposure step (iii) may be performed a plurality of times.

The exposure in the step (iii) may be immersion exposure.

In the pattern forming method of the present invention, the step of forming a film on a substrate by using each of the resin compositions (I) and (II), the step of exposing the multi-layered film, and the development step can be performed by generally known methods.

In the pattern forming method of the present invention, the heating step may be performed a plurality of times.

In the present invention, it is preferred to further contain a heating step at least either before the exposure step (iii) or after the exposure step (iii) but before the development step (iv).

It is more preferred to contain a pre-baking step (PB) after the film formation step (i) of the first film but before the film formation step (ii) of the second film.

It is also preferred to contain a pre-baking step (PB) after the film formation of the second film but before the exposure step (iii).

Furthermore, it is also preferred to contain a post-exposure baking step (PEB) after the exposure step (iii) but before the development step (iv).

As for the heating temperature, both PB and PEB are preferably performed at 70 to 150°C, more preferably at 80 to 140°C.

The heating time is preferably from 30 to 300 seconds, more preferably from 30 to 180 seconds, still more preferably from 30 to 90 seconds.

The heating can be performed using a device attached to an ordinary exposure/developing machine or may be performed using a hot plate or the like.

Thanks to baking, the reaction in the exposed area is accelerated, and the sensitivity and pattern profile are improved.

The light source wavelength of the exposure apparatus for use in the present invention is not limited, and the light source includes, for example, near infrared light, visible light, ultraviolet light, far ultraviolet light, extreme-ultraviolet light, X-ray and electron beam but is preferably far ultraviolet light at a wavelength of 250 nm or less, more preferably 220 nm or less, still more preferably from 1 to 200 nm. Specific examples thereof include a KrF excimer laser (248 nm), an ArF excimer laser (193 nm), an F_2 excimer laser (157 nm), an X-ray, an EUV (13 nm) and an electron beam. A KrF excimer laser, an ArF excimer laser, an EUV and an electron beam are preferred, and a KrF excimer laser and an ArF excimer laser are more preferred.

In the present invention, the substrate on which the film is formed is not particularly limited, and an inorganic substrate such as silicon, SiN, SiO_2 and SiN, a coating-type inorganic substrate such as SOG, or a substrate generally used in the process of producing a semiconductor such as IC or producing a liquid crystal device or a circuit board such as thermal head or in the lithography of other photo-fabrication processes can be used. If desired, an organic bottom anti-reflective coating may be formed between the film and the substrate.

For example, in microfabrication such as application to ion plantation, the pattern forming method of the present invention may use a stepped substrate as the substrate.

The stepped substrate is a substrate where at least one stepped shape is formed on a substrate.

As described above, in such microfabrication as using a stepped substrate, a negative pattern forming method by organic solvent development is suitable, but on the other hand, pattern collapse readily occurs. However, according to the pattern forming method, occurrence of pattern collapse is suppressed and a rectangular pattern is obtained.

The thickness of the multi-layered film formed on the stepped substrate means the height from the bottom on the stepped substrate to the top of the multi-layered film formed.

The height from the bottom of the stepped substrate to the top of the stepped shape is preferably smaller than the thickness of the multi-layered film and is, for example, less than 200 nm.

For example, in the case of microfabrication such as application to ion implantation, a substrate obtained by patterning fins or gates on a flat substrate can be used as the stepped

substrate. The thickness of the multi-layered film formed by coating the resin compositions (I) and (II) on such a stepped substrate having patterned thereon fins or gates means not a height from the top of the fin or gate to the top of the multi-layered film formed but, as described above, a height from the bottom on the stepped substrate to the top of the multi-layered film formed.

As for the size (e.g., width, length, height), interval, structure, configuration and the like of fins and gates, those described, for example, in "Saisentan FinFET Process/Shuseki-ka Gijutsu (Advanced FinFET Process/Integration Technology)" of Journal of IEICE, Vol. 91, No. 1, pp. 25-29 (2008), and "Fin-Type Double-Gate Metal-Oxide-Semiconductor Field-Effect Transistors Fabricated by Orientation-Dependent Etching and Electron Beam Lithography" of Jpn. J. Appl. Phys., Vol. 42 (2003), pp. 4142-4146, Part 1, No. 6B, June 2003, may be appropriately applied.

In the pattern forming method of the present invention, as for the developer in the step of performing development by using an organic solvent-containing developer (hereinafter, sometimes referred to as an "organic developer"), a polar solvent such as ketone-based solvent, ester-based solvent, alcohol-based solvent, amide-based solvent and ether-based solvent, or a hydrocarbon-based solvent can be used.

Examples of the ketone-based solvent include 1-octanone, 2-octanone, 1-nonanone, 2-nonanone, acetone, 2-heptanone (methyl amyl ketone), 4-heptanone, 1-hexanone, 2-hexanone, diisobutyl ketone, cyclohexanone, methylcyclohexanone, phenylacetone, methyl ethyl ketone, methyl isobutyl ketone, acetyl acetone, acetonyl acetone, ionone, diacetonyl alcohol, acetyl carbinol, acetophenone, methyl naphthyl ketone, isophorone, and propylene carbonate.

Examples of the ester-based solvent include methyl acetate, butyl acetate, ethyl acetate, isopropyl acetate, pentyl acetate, isopentyl acetate, amyl acetate, propylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether acetate, ethyl-3-ethoxypropionate, 3-methoxybutyl acetate, 3-methyl-3-methoxybutyl acetate, methyl formate, ethyl formate, butyl formate, propyl formate, ethyl lactate, butyl lactate, and propyl lactate.

Examples of the alcohol-based solvent include an alcohol such as methyl alcohol, ethyl alcohol, n-propyl alcohol, isopropyl alcohol, n-butyl alcohol, sec-butyl alcohol, tert-butyl alcohol, isobutyl alcohol, n-hexyl alcohol, n-heptyl alcohol, n-octyl alcohol and n-decanol; a glycol-based solvent such as ethylene glycol, diethylene glycol and triethylene glycol; and a

glycol ether-based solvent such as ethylene glycol monomethyl ether, propylene glycol monomethyl ether, ethylene glycol monoethyl ether, propylene glycol monoethyl ether, diethylene glycol monomethyl ether, triethylene glycol monoethyl ether and methoxymethyl butanol.

Examples of the ether-based solvent include, in addition to the glycol ether-based solvents above, dioxane and tetrahydrofuran.

Examples of the amide-based solvent which can be used include N-methyl-2-pyrrolidone, N,N-dimethylacetamide, N,N-dimethylformamide, hexamethylphosphoric triamide and 1,3-dimethyl-2-imidazolidinone.

Examples of the hydrocarbon-based solvent include an aromatic hydrocarbon-based solvent such as toluene and xylene, and an aliphatic hydrocarbon-based solvent such as pentane, hexane, octane and decane.

A plurality of these solvents may be mixed, or the solvent may be used by mixing it with a solvent other than those described above or with water. However, in order to sufficiently bring out the effects of the present invention, the water content ratio in the entire developer is preferably less than 10 mass%, and it is more preferred to contain substantially no water.

That is, the amount of the organic solvent used in the organic developer is preferably from 90 to 100 mass%, more preferably from 95 to 100 mass%, based on the entire amount of the developer.

In particular, the organic developer is preferably a developer containing at least one kind of an organic solvent selected from the group consisting of a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent.

The vapor pressure at 20°C of the organic developer is preferably 5 kPa or less, more preferably 3 kPa or less, still more preferably 2 kPa or less. By setting the vapor pressure of the organic developer to 5 kPa or less, evaporation of the developer on a substrate or in a development cup is suppressed and the temperature uniformity in the wafer plane is enhanced, as a result, the dimensional uniformity in the wafer plane is improved.

Specific examples of the solvent having a vapor pressure of 5 kPa or less include a ketone-based solvent such as 1-octanone, 2-octanone, 1-nonanone, 2-nonanone, 2-heptanone (methyl amyl ketone), 4-heptanone, 2-hexanone, diisobutyl ketone, cyclohexanone, methylcyclohexanone, phenylacetone and methyl isobutyl ketone; an ester-based solvent such

as butyl acetate, pentyl acetate, isopentyl acetate, amyl acetate, propylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether acetate, ethyl-3-ethoxypropionate, 3-methoxybutyl acetate, 3-methyl-3-methoxybutyl acetate, butyl formate, propyl formate, ethyl lactate, butyl lactate and propyl lactate; an alcohol-based solvent such as n-propyl alcohol, isopropyl alcohol, n-butyl alcohol, sec-butyl alcohol, tert-butyl alcohol, isobutyl alcohol, n-hexyl alcohol, n-heptyl alcohol, n-octyl alcohol and n-decanol; a glycol-based solvent such as ethylene glycol, diethylene glycol and triethylene glycol; a glycol ether-based solvent such as ethylene glycol monomethyl ether, propylene glycol monomethyl ether, ethylene glycol monoethyl ether, propylene glycol monoethyl ether, diethylene glycol monomethyl ether, triethylene glycol monoethyl ether and methoxymethylbutanol; an ether-based solvent such as tetrahydrofuran; an amide-based solvent such as N-methyl-2-pyrrolidone, N,N-dimethylacetamide and N,N-dimethylformamide; an aromatic hydrocarbon-based solvent such as toluene and xylene; and an aliphatic hydrocarbon-based solvent such as octane and decane.

Specific examples of the solvent having a vapor pressure of 2 kPa or less that is a particularly preferred range include a ketone-based solvent such as 1-octanone, 2-octanone, 1-nonanone, 2-nonanone, 4-heptanone, 2-hexanone, diisobutyl ketone, cyclohexanone, methylcyclohexanone and phenylacetone; an ester-based solvent such as butyl acetate, amyl acetate, propylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, diethylene glycol monobutyl ether acetate, diethylene glycol monoethyl ether acetate, ethyl-3-ethoxypropionate, 3-methoxybutyl acetate, 3-methyl-3-methoxybutyl acetate, ethyl lactate, butyl lactate and propyl lactate; an alcohol-based solvent such as n-butyl alcohol, sec-butyl alcohol, tert-butyl alcohol, isobutyl alcohol, n-hexyl alcohol, n-heptyl alcohol, n-octyl alcohol and n-decanol; a glycol-based solvent such as ethylene glycol, diethylene glycol and triethylene glycol; a glycol ether-based solvent such as ethylene glycol monomethyl ether, propylene glycol monomethyl ether, ethylene glycol monoethyl ether, propylene glycol monoethyl ether, diethylene glycol monomethyl ether, triethylene glycol monoethyl ether and methoxymethylbutanol; an amide-based solvent such as N-methyl-2-pyrrolidone, N,N-dimethylacetamide and N,N-dimethylformamide; an aromatic hydrocarbon-based solvent such as xylene; and an aliphatic hydrocarbon-based solvent such as octane and decane.

In the organic developer, an appropriate amount of a surfactant may be added, if desired.

The surfactant is not particularly limited but, for example, ionic or nonionic

fluorine-containing and/or silicon-containing surfactants can be used. Examples of such fluorine-containing and/or silicon-containing surfactants include surfactants described in JP-A-62-36663, JP-A-61-226746, JP-A-61-226745, JP-A-62-170950, JP-A-63-34540, JP-A-7-230165, JP-A-8-62834, JP-A-9-54432, JP-A-9-5988 and U.S. Patents 5,405,720, 5,360,692, 5,529,881, 5,296,330, 5,436,098, 5,576,143, 5,294,511 and 5,824,451. A nonionic surfactant is preferred. The nonionic surfactant is not particularly limited, but use of a fluorine-containing surfactant or a silicon-containing surfactant is more preferred.

The amount of the surfactant used is usually from 0.001 to 5 mass%, preferably from 0.005 to 2 mass%, more preferably from 0.01 to 0.5 mass%, based on the entire amount of the developer.

As regards the developing method, for example, a method of dipping the substrate in a bath filled with the developer for a fixed time (dipping method), a method of raising the developer on the substrate surface by the effect of a surface tension and keeping it still for a fixed time, thereby performing development (puddle method), a method of spraying the developer on the substrate surface (spraying method), and a method of continuously ejecting the developer on the substrate spinning at a constant speed while scanning the developer ejecting nozzle at a constant rate (dynamic dispense method) may be applied.

In the case where the above-described various developing methods include a step of ejecting the developer toward the resist film from a development nozzle of a developing apparatus, the ejection pressure of the developer ejected (the flow velocity per unit area of the developer ejected) is preferably 2 mL/sec/mm^2 or less, more preferably 1.5 mL/sec/mm^2 or less, still more preferably 1 mL/sec/mm^2 or less. The flow velocity has no particular lower limit but in view of throughput, is preferably 0.2 mL/sec/mm^2 or more.

By setting the ejection pressure of the ejected developer to the range above, pattern defects attributable to the resist scum after development can be greatly reduced.

Details of this mechanism are not clearly known, but it is considered that thanks to the ejection pressure in the above-described range, the pressure imposed on the resist film by the developer becomes small and the resist film•resist pattern is kept from inadvertent chipping or collapse.

Here, the ejection pressure (mL/sec/mm^2) of the developer is a value at the outlet of a development nozzle in a developing apparatus.

Examples of the method for adjusting the ejection pressure of the developer include a method of adjusting the ejection pressure by a pump or the like, and a method of supplying

the developer from a pressurized tank and adjusting the pressure to change the ejection pressure.

After the step of performing development by using an organic solvent-containing developer, a step of stopping the development by replacing the solvent with another solvent may be practiced.

It is preferred to provide a step of rinsing the film with a rinsing solution after the step of performing development by using an organic solvent-containing developer.

The rinsing solution used in the rinsing step after the step of performing development by using an organic solvent-containing developer is not particularly limited as long as it does not dissolve the resist pattern, and a solution containing a general organic solvent may be used. As for the rinsing solution, a rinsing solution containing at least one kind of an organic solvent selected from the group consisting of a hydrocarbon-based solvent, a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent is preferably used.

Specific examples of the hydrocarbon-based solvent, ketone-based solvent, ester-based solvent, alcohol-based solvent, amide-based solvent and ether-based solvent are the same as those described above for the organic solvent-containing developer.

After the step of performing development by using an organic solvent-containing developer, more preferably, a step of rinsing the film by using a rinsing solution containing at least one kind of an organic solvent selected from the group consisting of a ketone-based solvent, an ester-based solvent, an alcohol-based solvent and an amide-based solvent is preformed; still more preferably, a step of rinsing the film by using a rinsing solution containing an alcohol-based solvent or an ester-based solvent is performed; yet still more preferably, a step of rinsing the film by using a rinsing solution containing a monohydric alcohol is performed; and most preferably, a step of rinsing the film by using a rinsing solution containing a monohydric alcohol having a carbon number of 5 or more is performed.

The monohydric alcohol used in the rinsing step includes a linear, branched or cyclic monohydric alcohol, and specific examples of the monohydric alcohol which can be used include 1-butanol, 2-butanol, 3-methyl-1-butanol, tert-butyl alcohol, 1-pentanol, 2-pentanol, 1-hexanol, 4-methyl-2-pentanol, 1-heptanol, 1-octanol, 2-hexanol, cyclopentanol, 2-heptanol, 2-octanol, 3-hexanol, 3-heptanol, 3-octanol and 4-octanol. As for the particularly preferred monohydric alcohol having a carbon number of 5 or more, 1-hexanol, 2-hexanol, 4-methyl-2-pentanol, 1-pentanol, 3-methyl-1-butanol and the like can be used.

A plurality of these components may be mixed, or the solvent may be used by mixing it with an organic solvent other than those described above.

The water content ratio in the rinsing solution is preferably 10 mass% or less, more preferably 5 mass% or less, still more preferably 3 mass% or less. By setting the water content ratio to 10 mass% or less, good development characteristics can be obtained.

The vapor pressure at 20°C of the rinsing solution used after the step of performing development by using an organic solvent-containing developer is preferably from 0.05 to 5 kPa, more preferably from 0.1 to 5 kPa, and most preferably from 0.12 to 3 kPa. By setting the vapor pressure of the rinsing solution to the range from 0.05 to 5 kPa, the temperature uniformity in the wafer plane is enhanced and moreover, swelling due to permeation of the rinsing solution is suppressed, as a result, the dimensional uniformity in the wafer plane is improved.

The rinsing solution may be also used after adding thereto an appropriate amount of a surfactant.

In the rinsing step, the wafer after development using an organic solvent-containing developer is rinsed using the above-described organic solvent-containing rinsing solution. The method for rinsing treatment is not particularly limited, but examples of the method which can be applied include a method of continuously ejecting the rinsing solution on the substrate spinning at a constant speed (spin coating method), a method of dipping the substrate in a bath filled with the rinsing solution for a fixed time (dipping method), and a method of spraying the rinsing solution on the substrate surface (spraying method). Above all, it is preferred to perform the rinsing treatment by the spin coating method and after the rinsing, remove the rinsing solution from the substrate surface by spinning the substrate at a rotational speed of 2,000 to 4,000 rpm. It is also preferred to include a heating step (Post Bake) after the rinsing step. The developer and rinsing solution remaining between patterns as well as in the inside of the pattern are removed by the baking. The heating step after the rinsing step is performed at usually from 40 to 160°C, preferably from 70 to 95°C, for usually from 10 seconds to 3 minutes, preferably from 30 to 90 seconds.

In the case where the pattern forming method of the present invention further includes a step of developing the film by using an alkali developer, examples of the alkali developer which can be used include an alkaline aqueous solution of inorganic alkalis such as sodium hydroxide, potassium hydroxide, sodium carbonate, sodium silicate, sodium metasilicate and aqueous ammonia, primary amines such as ethylamine and n-propylamine,

secondary amines such as diethylamine and di-n-butylamine, tertiary amines such as triethylamine and methyldiethylamine, alcohol amines such as dimethylethanolamine and triethanolamine, quaternary ammonium salts such as tetramethylammonium hydroxide and tetraethylammonium hydroxide, or cyclic amines such as pyrrole and piperidine.

The alkaline aqueous solution above may be also used after adding thereto alcohols and a surfactant each in an appropriate amount.

The alkali concentration of the alkali developer is usually from 0.1 to 20 mass%.

The pH of the alkali developer is usually from 10.0 to 15.0.

In particular, an aqueous 2.38 mass% tetramethylammonium hydroxide solution is preferred.

As the rinsing solution in the rinsing treatment performed after the alkali development, pure water is used, and the pure water may be also used after adding thereto an appropriate amount of a surfactant.

After the development treatment or rinsing treatment, a treatment of removing the developer or rinsing solution adhering on the pattern by a supercritical fluid may be performed.

The present invention also relates to a method for manufacturing an electronic device, comprising the pattern forming method of the present invention, and an electronic device manufactured by this manufacturing method.

The electronic device of the present invention is suitably mounted on electric electronic equipment (such as home electronic device, OA•media-related device, optical device and communication device).

Examples

The present invention is described in greater detail below by referring to Examples, but the present invention should not be construed as being limited to these Examples.

Synthesis Example 1: Synthesis of Resin (pol-1)

In a nitrogen stream, 61.2 parts by mass of cyclohexanone was charged into a three-neck flask and heated at 80°C. Subsequently, a mixed solution containing a monomer (15.0 parts by mass) corresponding to unit-1 shown below, a monomer (3.54 parts by mass) corresponding to unit-5 shown below, a monomer (12.3 parts by mass) corresponding to unit-28 shown below, 1.38 parts by mass of dimethyl 2,2'-azobisisobutyrate [V-601, produced by Wako Pure Chemical Industries, Ltd.], and cyclohexanone (113.6 parts by mass) was added

dropwise to the flask over 4 hours. After the completion of dropwise addition, the reaction was further allowed to proceed at 80°C for 2 hours. The reaction solution was left standing to cool, reprecipitated in a large amount of heptane/ethyl acetate (8/2 by mass) and filtered, and the obtained solid was vacuum-dried to obtain 27.4 parts by mass of Resin (pol-1). The weight average molecular weight of Resin (pol-1) obtained was 12,000, the polydispersity (Mw/Mn) was 1.6, and the compositional ratio as measured by ^{13}C-NMR was 45/10/45.

Resins (pol-2) to (pol-27) were synthesized by the same operation as in Synthesis Example 1.

With respect to Resins (pol-1) to (pol-27), the repeating unit (unit), the compositional ratio (molar ratio), the weight average molecular weight (Mw) and the polydispersity are shown in Tables 3 and 4 below. The numerals in the compositional ratio correspond to repeating units starting from the left.

Table 3

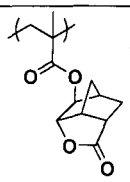
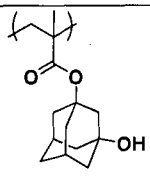
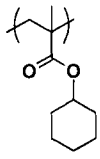
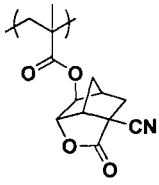
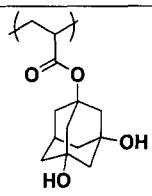
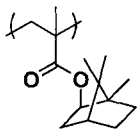
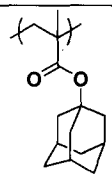
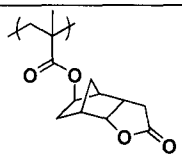
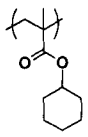
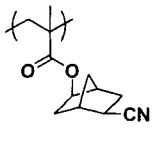
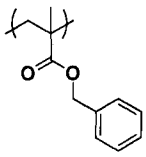
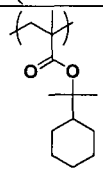
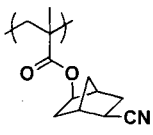
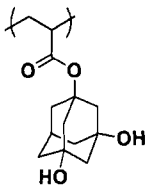
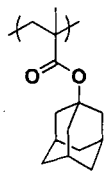
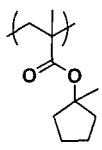
	Unit 1	Unit 2	Unit 3	Unit 4	Compositional Ratio (molar ratio)	Mw	Polydispersity
pol-1	 unit-1	 unit-5	 unit-28	-	45/10/45	12000	1.6
pol-2	 unit-2	 unit-6	 unit-9	 unit-10	30/10/50/10	7000	1.6
pol-3	 unit-3	 unit-28	biphenyl methacrylate (unit-29)	-	40/40/20	10000	1.6
pol-4	 unit-4	 unit-7	 unit-20	-	60/30/10	8000	1.6
pol-5	 unit-4	 unit-6	 unit-10	 unit-21	40/20/35/5	16000	1.8

Table 3 (Continued)

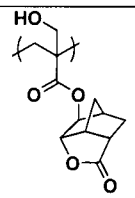
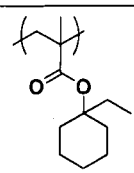
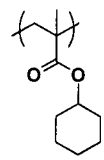
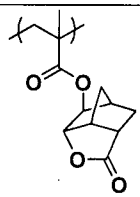
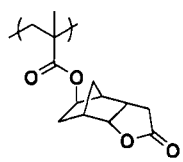
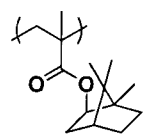
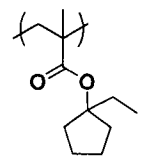
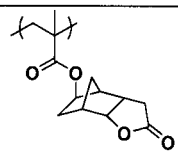
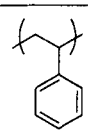
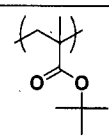
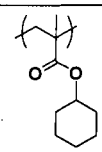
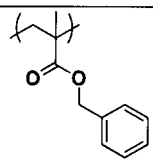
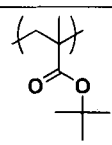
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pol-6	 unit-11	 unit-23	 unit-28	-	25/15/60	20000	1.9
pol-7	 unit-1	 unit-3	 unit-9	 unit-22	30/20/30/20	14000	1.6
pol-8	 unit-3	 unit-12	 unit-18	 unit-28	40/30/18/12	10000	1.6
pol-9	 unit-7	 unit-18	-	-	45/55	12000	1.6

Table 3 (continued)

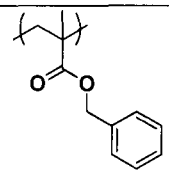
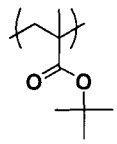
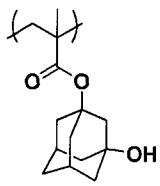
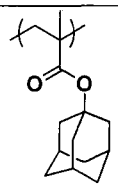
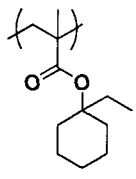
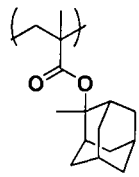
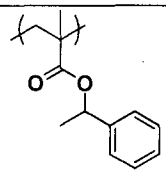
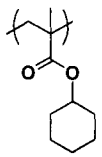
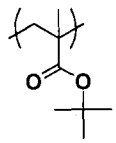
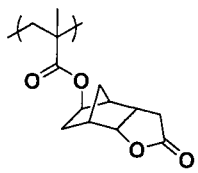
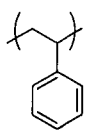
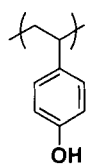
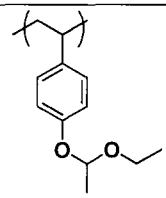
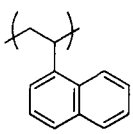
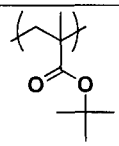
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pol-11	 unit-5	 unit-10	 unit-23	 unit-26	20/10/45/25	16000	1.8
pol-12	 unit-8	 unit-28	 unit-18	-	30/20/50	12000	1.6
pol-13	 unit-3	 unit-12	 unit-14	 unit-27	10/20/40/30	14000	1.7
pol-14	 unit-13	 unit-18	-	-	40/60	15000	1.8

Table 3 (continued)

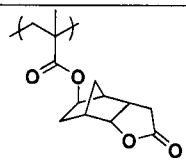
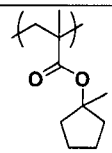
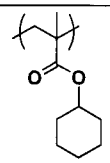
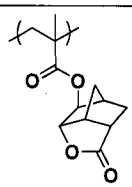
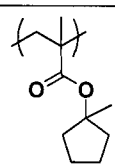
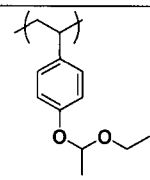
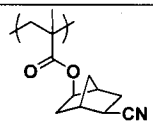
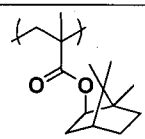
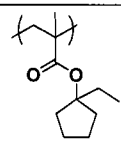
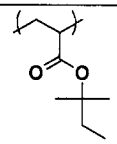
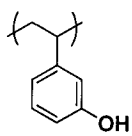
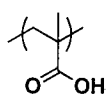
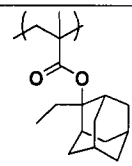
	Unit 1	Unit 2	Unit 3	Unit 4	Compositional Ratio (molar ratio)	Mw	Polydispersity
pol-15	 unit-3	 unit-21	 unit-28	-	50/25/25	7000	1.6
pol-16	 unit-1	 unit-17	 unit-21	 unit-27	30/30/20/20	9000	1.6
pol-17	 unit-4	 unit-9	 unit-22	 unit-19	40/10/20/30	15000	1.8
pol-18	 unit-15	 unit-16	 unit-25	-	30/10/60	22000	1.9

Table 4

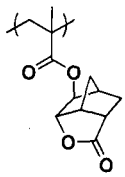
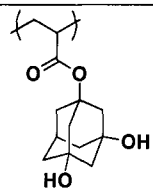
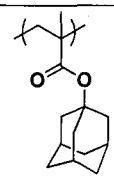
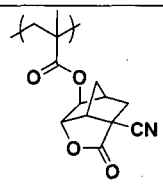
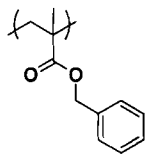
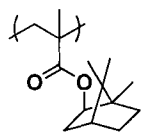
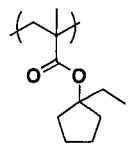
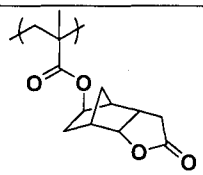
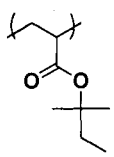
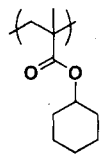
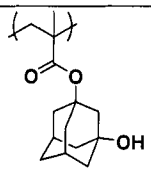
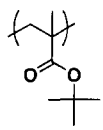
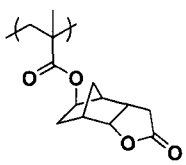
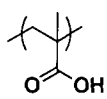
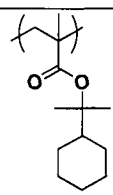
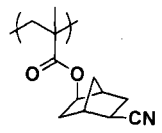
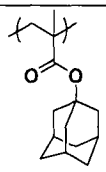
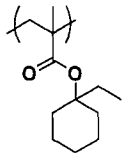
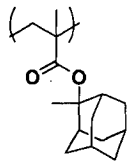
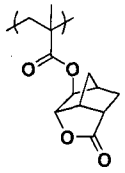
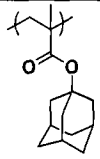
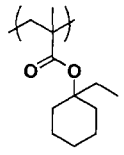
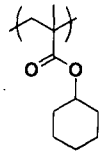
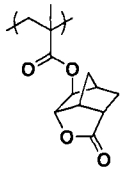
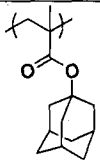
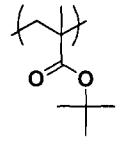
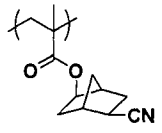
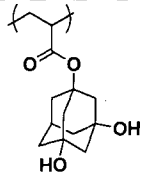
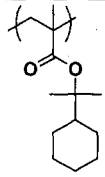
	Unit 1	Unit 2	Unit 3	Unit 4	Compositional Ratio (molar ratio)	Mw	Polydispersity
pol-19	 unit-1	 unit-6	 unit-10	-	50/10/40	10000	1.6
pol-20	 unit-2	 unit-7	 unit-9	 unit-22	30/30/30/10	7000	1.6
pol-21	 unit-3	 unit-19	 unit-28	-	40/15/45	15000	1.7
pol-22	 unit-5	 unit-18	-	-	30/70	23000	1.9
pol-23	 unit-3	 unit-16	 unit-20	-	10/25/65	14000	1.7

Table 4 (Continued)

	Unit 1	Unit 2	Unit 3	Unit 4	Compositional Ratio (molar ratio)	Mw	Polydispersity
pol-24	 unit-4	 unit-10	 unit-23	 unit-26	20/20/35/25	9000	1.6
pol-25	 unit-1	 unit-10	 unit-23	 unit-28	20/20/35/25	9000	1.6
pol-26	 unit-1	 unit-10	 unit-18	-	30/20/50	15000	1.7
pol-27	 unit-4	 unit-6	 unit-20	-	35/5/60	10000	1.6

[Preparation of Resin Composition]

The components shown in Tables 5 and 6 below were dissolved in a solvent to prepare a resist solution, and this solution was filtered through a polyethylene filter having a pore size of 0.03 μm to prepare a resin composition (resist composition). The solid content concentration of each resin composition was appropriately adjusted in a range of 2.0 to 7.0 mass% so that the composition can be coated to the thickness shown in Tables 7 and 8 below.

Table 5

Resin Composition	Resin–A (mass%)*	Resin-B (mass%)	Acid Generator-A (mass%)	Acid Generator-B (mass%)	Basic Compound-A (mass%)	Basic Compound-B (mass%)	Additive (mass%)	Solvent (mass ratio)
R-1	pol-1 (100)	–	–	–	–	–	–	SL-1/SL-5 (70/30)
R-2	pol-2 (99.70)	–	–	–	–	–	W-1 (0.30)	SL-1/SL-3 (80/20)
R-3	pol-3 (79.54)	pol-1 (19.89)	–	–	N-2 (0.27)	–	W-2 (0.30)	SL-1 (100)
R-4	pol-4 (99.70)	–	–	–	–	–	W-6 (0.30)	SL-1/SL-4 (90/10)
R-5	pol-5 (50.00)	pol-6 (50.00)	–	–	–	–	–	SL-1/SL-6 (95/5)
R-6	pol-6 (99.70)	–	–	–	–	–	W-5 (0.30)	SL-2/SL-7 (98/2)
R-7	pol-7 (94.02)	–	PAG-1 (5.8)	–	N-4 (0.18)	–	–	SL-1/SL-5 (70/30)
R-8	pol-8 (99.60)	–	–	–	–	–	W-6 (0.40)	SL-1/SL-5 (70/30)
R-9	pol-1 (27.75)	pol-7 (64.75)	PAG-3 (7.2)	–	–	–	W-6 (0.30)	SL-1 (100)
R-10	pol-9 (91.67)	–	PAG-1 (4.2)	PAG-6 (3.5)	N-1 (0.33)	–	W-6 (0.30)	SL-8 (100)
R-11	pol-10 (84.93)	–	PAG-2 (5.0)	PAG-7 (9.5)	N-2 (0.27)	–	W-6 (0.30)	SL-8/SL-9 (90/10)
R-12	pol-11 (37.65)	pol-13 (56.47)	PAG-6 (5.3)	–	N-3 (0.28)	–	W-6 (0.30)	SL-9 (100)
R-13	pol-12 (90.60)	–	PAG-8 (8.2)	–	N-4 (0.20)	N-5 (1.0)	–	SL-8/SL-1 (90/10)
R-14	pol-13 (90.42)	–	PAG-1 (2.5)	PAG-8 (6.5)	N-3 (0.28)	–	W-4 (0.30)	SL-8/SL-5 (90/10)
R-15	pol-14 (93.71)	–	PAG-1 (5.8)	–	N-2 (0.19)	–	W-3 (0.30)	SL-10 (100)
R-16	pol-15 (97.80)	–	–	–	N-5 (2.2)	–	–	SL-8 (100)
R-17	pol-16 (99.70)	–	–	–	–	–	W-6 (0.30)	SL-8/SL-1 (90/10)
R-18	pol-17 (94.38)	–	PAG-2 (5.0)	–	N-1 (0.32)	–	W-6 (0.30)	SL-1/SL-5 (70/30)
R-19	pol-18 (87.80)	–	PAG-5 (3.3)	PAG-4 (8.2)	N-2 (0.40)	–	W-6 (0.30)	SL-1/SL-5 (70/30)

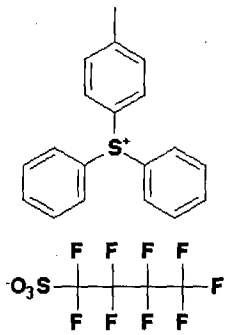
*In the Table, (mass%) is a value based on the entire solid content of the composition; hereinafter the same.

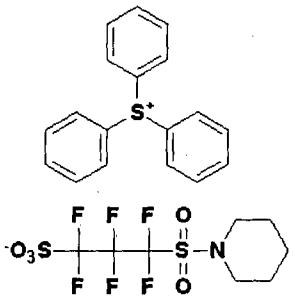
Table 6

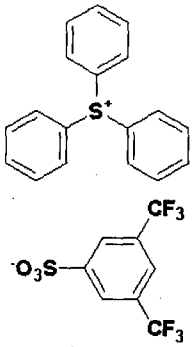
Resin Composition	Resin–A (mass%)	Resin-B (mass%)	Acid Generator-A (mass%)	Acid Generator-B (mass%)	Basic Compound-A (mass%)	Basic Compound-B (mass%)	Additive (mass%)	Solvent (mass ratio)
R-20	pol-19 (100)	–	–	–	–	–	–	SL-1/SL-5 (80/20)
R-21	pol-20 (99.70)	–	–	–	–	–	W-1 (0.30)	SL-1/SL-3 (80/20)
R-22	pol-21 (99.55)	–	–	–	N-1 (0.15)	–	W-6 (0.30)	SL-1/SL-4 (90/10)
R-23	pol-19 (36.59)	pol-21 (54.89)	PAG-1 (8.2)	–	N-3 (0.32)	–	–	SL-1/SL-6 (95/5)
R-24	pol-22 (87.35)	–	PAG-2 (9.1)	–	N-1 (0.05)	N-5 (3.5)	–	SL-1/SL-5 (50/50)
R-25	pol-23 (89.32)	–	PAG-6 (5.2)	PAG-7 (5.2)	N-4 (0.28)	–	–	SL-8 (100)
R-26	pol-24 (88.50)	–	PAG-8 (6.3)	–	N-5 (5.2)	–	–	SL-8/SL-9 (90/10)
R-27	pol-23 (17.14)	pol-24 (68.54)	PAG-2 (5.5)	PAG-4 (8.2)	N-2 (0.32)	–	W-4 (0.30)	SL-8/SL-5 (90/10)
R-28	pol-25 (99.08)	–	–	–	N-2 (0.62)	–	W-3 (0.30)	SL-10 (100)
R-29	pol-26 (99.70)	–	–	–	–	–	W-6 (0.30)	SL-8/SL-1 (90/10)
R-30	pol-27 (89.18)	–	PAG-6 (10.5)	–	N-3 (0.32)	–	–	SL-1/SL-5 (70/30)

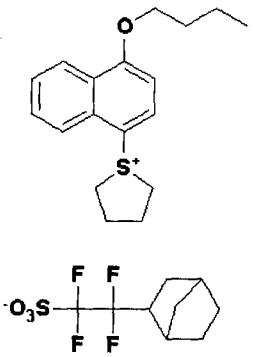
Components and abbreviations in Tables 5 and 6 are as follows.

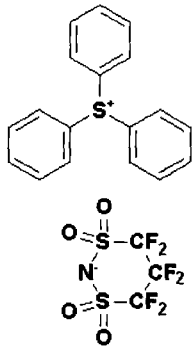
[Acid Generator]

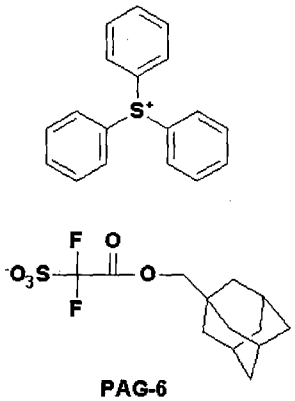

PAG-1

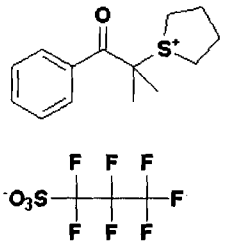

PAG-2

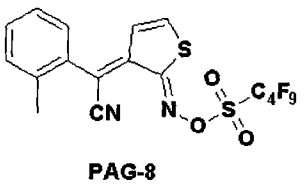

PAG-3


PAG-4

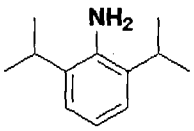

PAG-5

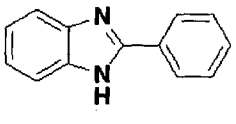

PAG-6

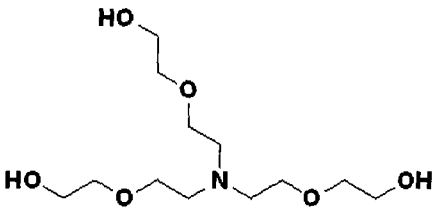

PAG-7

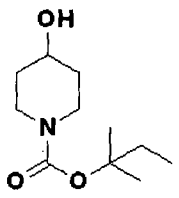

PAG-8

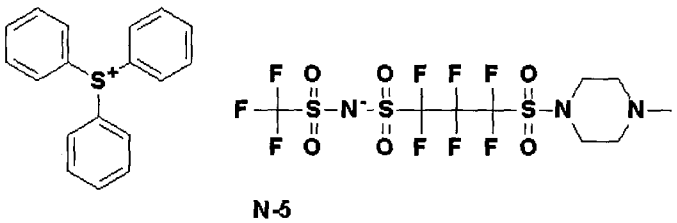
[Basic Compound]


N-1


N-2


N-3


N-4


N-5

[Additive (Surfactant)]

W-1: Megaface F176 (produced by Dainippon Ink and Chemicals, Inc.; fluorine-containing)

W-2: Megaface R08 (produced by Dainippon Ink and Chemicals, Inc.; fluorine- and silicon-containing)

W-3: Polysiloxane Polymer KP-341 (produced by Shin-Etsu Chemical Co., Ltd.; silicon-containing)

W-4: Troysol S-366 (produced by Troy Chemical)

W-5: KH-20 (produced by Asahi Glass Co., Ltd.)

W-6: PolyFox PF-6320 (produced by OMNOVA Solutions Inc., fluorine-containing)

[Solvent]

SL-1: Propylene glycol monomethyl ether acetate (PGMEA)

SL-2: Propylene glycol monomethyl ether propionate

SL-3: Ethyl lactate

SL-4: Propylene glycol monomethyl ether (PGME)

SL-5: Cyclohexanone

SL-6: γ-Butyrolactone

SL-7: Propylene carbonate

SL-8: 4-Methyl-2-pentanol

SL-9: Isobutyl isobutyrate

SL-10: Diisoamyl ether

The prepared resin composition was evaluated by the following methods.

[KrF Exposure Examples] (Examples 1 to 15, Reference Examples 1 and 2, and Comparative Examples 1 and 2)

An HMDS (hexamethyldisilazane) treatment (at 110°C for 35 seconds) was applied to a silicon wafer, and the first resin composition (resist composition) shown in Table 7 below was coated thereon and baked (Pre-Bake; PB) under the conditions shown in Table 7 below to form a first-layer (lower-layer) resist film having the thickness shown in Table 7 below. Subsequently, the second resist composition was coated on the obtained first-layer resist film, and the film was baked under the conditions shown in Table 7 to form a second-layer (upper-layer) resist film having the thickness shown in Table 7 below. In this way, a wafer on which two resist film layers are stacked was obtained.

The obtained wafer was patternwise exposed through a halftone mask having a line-and-space pattern with a light-shielding part width of 150 nm and an opening part width of 150 nm by using a KrF excimer laser scanner (PAS5500/850, manufactured by ASML) (NA:

0.80). Thereafter, the wafer was baked (Post-Exposure Bake; PEB) under the conditions shown in Table 7 below, developed by puddling the organic developer shown in Tale 7 below for 30 seconds, rinsed by puddling the rinsing solution shown in Table 7 below (when the rinsing solution is not shown in the Table below, the rinsing was not performed), and then rotated at a rotational speed of 4,000 rpm for 30 seconds to obtain a line-and-space (1:1) pattern having a pitch of 300 nm and a line width of 150 nm.

[ArF Exposure Examples] (Examples 16 to 22, Reference Examples 3 and 4, and Comparative Example 3)

An organic bottom anti-reflective coating, ARC29A (produced by Nissan Chemical Industries, Ltd.), was coated on a silicon wafer and baked at 205°C for 60 seconds to form a bottom anti-reflective coating having a thickness of 86 nm, and the first resist composition shown in Table 8 below was coated thereon and baked (Pre-Bake: PB) under the conditions shown in Table 8 below to form a first-layer (lower-layer) resist film having the thickness shown in Table 8 below. Subsequently, the second resist composition was coated on the obtained first-layer resist film and baked under the conditions shown in Table 8 below to form a second-layer (upper-layer) resist film having the thickness shown in Table 8 below. In this way, a wafer on which two resist film layers are stacked was obtained.

The obtained wafer was patternwise exposed through a halftone mask having a line-and-space pattern with a light-shielding part width of 75 nm and an opening part width of 75 nm by using an ArF excimer laser scanner (PAS5500/1100, manufactured by ASML) (NA: 0.75). Thereafter, the wafer was baked (Post-Exposure Bake; PEB) under the conditions shown in Table 8 below, developed by puddling the organic developer shown in Tale 8 below for 30 seconds, rinsed by puddling the rinsing solution shown in Table 8 below (when the rinsing solution is not shown in the Table below, the rinsing was not performed), and then rotated at a rotational speed of 4,000 rpm for 30 seconds to obtain a line-and-space (1:1) pattern having a pitch of 150 nm and a line width of 75 nm.

[Pattern Collapse Evaluation Method]

With respect to the obtained line-and-space pattern, the line width when the exposure dose was changed was observed using a scanning electron microscope (SEM, S-9380II manufactured by Hitachi Ltd.), and the minimum line width below which pattern collapse occurs was measured as the dimension before collapse. A smaller value indicates

higher resistance to pattern collapse.

The results of KrF Exposure Examples and the results of ArF Exposure Examples are shown in Tables 7 and 8, respectively. In the Tables below, for example, "100°C/60 sec" means that heating is performed at 100°C for 60 seconds. Abbreviations of developers and rinsing solutions in the Tables below stand for the followings.

[Developer/Rinsing Solution]

D-1: Butyl acetate

D-2: Pentyl acetate

D-3: 2-Heptanone

D-4: 4-Methyl-2-pentanol

D-5: Decane

D-6: Octane

D-7: 1-Hexanol

Table 7

	First Layer (lower layer)			Second Layer (upper layer)						
	Resin Composition	PB	Film Thickness /nm	Resin Composition	PB	Film Thickness /nm	PEB	Developer	Rinsing Solution	Dimension Before Collapse /nm
Example 1	R-1	100°C/60 sec	100	R-11	120°C/60 sec	100	100°C/60 sec	D-1	–	72
Example 2	R-2	100°C/60 sec	100	R-12	100°C/60 sec	140	115°C/50 sec	D-2	–	76
Example 3	R-3	100°C/50 sec	80	R-13	100°C/50 sec	130	100°C/50 sec	D-1	D-7	77
Example 4	R-4	90°C/60 sec	60	R-14	90°C/60 sec	180	90°C/60 sec	D-1	D-6	80
Example 5	R-5	80°C/60 sec	60	R-15	80°C/60 sec	130	125°C/60 sec	D-3	–	80
Example 6	R-6	100°C/40 sec	80	R-11	100°C/40 sec	130	100°C/40 sec	D-2	–	81
Example 7	R-7	105°C/60 sec	80	R-12	130°C/60 sec	140	100°C/60 sec	D-1	D-4	85
Example 8	R-8	100°C/60 sec	100	R-13	100°C/60 sec	100	100°C/40 sec	D-1	D-5	84
Example 9	R-9	120°C/60 sec	60	R-14	120°C/60 sec	100	130°C/60 sec	D-1	–	81
Example 10	R-2	90°C/60 sec	100	R-15	90°C/50 sec	100	90°C/60 sec	D-1	–	70
Example 11	R-3	95°C/60 sec	120	R-11	105°C/60 sec	100	100°C/60 sec	D-2	–	79
Example 12	R-4	100°C/80 sec	100	R-12	100°C/80 sec	130	100°C/80 sec	D-3	–	80
Example 13	R-1	100°C/60 sec	120	R-13	100°C/60 sec	100	100°C/60 sec	D-2	–	77
Example 14	R-8	95°C/60 sec	80	R-14	90°C/60 sec	100	90°C/60 sec	D-2	–	83
Example 15	R-1	100°C/60 sec	100	R-15	100°C/60 sec	130	100°C/80 sec	D-3	D-4	76
Reference Example 1	R-16	95°C/60 sec	80	R-10	80°C/60 sec	130	105°C/60 sec	D-1	D-4	95
Reference Example 2	R-19	100°C/60 sec	100	R-11	100°C/40 sec	130	90°C/60 sec	D-3	–	100
Comparative Example 1	R-18	100°C/60 sec	240	–	–	–	105°C/60 sec	D-1	D-4	115
Comparative Example 2	R-19	110°C/60 sec	200	–	–	–	90°C/60 sec	D-3	–	120

As apparent from Table 7 showing the results of KrF Exposure Examples, in Reference Examples 1 and 2 where two resist film layers are stacked but the content of the acid-decomposable-containing repeating unit in the resin in the resin composition for the first layer (lower layer) exceeds 20 mol%, the dimension before collapse is slightly large, revealing that pattern collapse is somewhat liable to occur.

Also, in Comparative Examples 1 and 2 where a single-layer resist film is formed and a pattern is formed therein, the dimension before collapse is large, revealing that pattern collapse is liable to occur.

On the other hand, in Examples 1 to 15 where two resist film layers are stacked and the content of the acid-decomposable group-containing repeating unit in the resin in the resin composition for the first layer (lower layer) is 20 mol% or less, the dimension before collapse is small, revealing that pattern collapse hardly occurs.

Table 8

	First Layer (lower layer)			Second Layer (upper layer)						
	Resin Composition	PB	Film Thickness /nm	Resin Composition	PB	Film Thickness /nm	PEB	Developer	Rinsing Solution	Dimension Before Collapse /nm
Example 16	R-20	100°C/60 sec	30	R-24	120°C/60 sec	70	105°C/60 sec	D-1	–	34
Example 17	R-21	100°C/60 sec	40	R-25	130°C/60 sec	40	115°C/50 sec	D-2	–	42
Example 18	R-22	90°C/60 sec	60	R-26	90°C/60 sec	40	90°C/60 sec	D-1	D-6	38
Example 19	R-23	100°C/60 sec	70	R-27	100°C/60 sec	50	100°C/60 sec	D-2	–	40
Example 20	R-20	105°C/60 sec	30	R-24	100°C/60 sec	90	80°C/60 sec	D-1	–	40
Example 21	R-22	80°C/60 sec	30	R-25	80°C/60 sec	80	125°C/60 sec	D-3	–	45
Example 22	R-23	100°C/60 sec	50	R-26	90°C/60 sec	40	100°C/60 sec	D-3	–	39
Reference Example 3	R-28	100°C/60 sec	50	R-27	130°C/60 sec	50	100°C/80 sec	D-3	D-4	52
Reference Example 4	R-29	100°C/60 sec	20	R-24	100°C/60 sec	90	80°C/60 sec	D-1	D-4	50
Comparative Example 3	R-30	100°C/60 sec	100	–	–.	–	100°C/60 sec	D-1	D-4	68

As apparent from Table 8 showing the results of ArF Exposure Examples, in Reference Examples 3 and 4 where two resist film layers are stacked but the content of the acid-decomposable-containing repeating unit in the resin in the resin composition for the first layer (lower layer) exceeds 20 mol%, the dimension before collapse is slightly large, revealing that pattern collapse is somewhat liable to occur.

Also, in Comparative Example 3 where a single-layer resist film is formed and a pattern is formed therein, the dimension before collapse is large, revealing that pattern collapse is liable to occur.

On the other hand, in Examples 16 to 22 where two resist film layers are stacked and the content of the acid-decomposable group-containing repeating unit in the resin in the resin composition for the first layer (lower layer) is 20 mol% or less, the dimension before collapse is small, revealing that pattern collapse hardly occurs.

Incidentally, it is confirmed that the first layer (lower layer) in Example 17 can function also as a developable bottom anti-reflective coating.

Industrial Applicability

According to the present invention, a pattern forming method ensuring that a pattern less prone to pattern collapse can be formed in a negative pattern forming method by organic solvent development, a multi-layered resist pattern formed by the method, a multi-layered film for organic solvent development, which is suitably used for the pattern forming method, a resist composition suitably used for the pattern forming method, a manufacturing method of an electronic device, and an electronic device can be provided.

This application is based on a Japanese patent application filed on October 27, 2011 (Japanese Patent Application No. 2011-236455), and the contents thereof are incorporated herein by reference.

Claims

1. A pattern forming method comprising:

(i) a step of forming a first film on a substrate by using a first resin composition (I) containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin,

(ii) a step of forming a second film on the first film by using a second resin composition (II) different from the resin composition (I), in which the second resin composition (II) contains a resin having a group capable of decomposing by the action of an acid to produce a polar group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation,

(iii) a step of exposing a multi-layered film having the first film and the second film, and

(iv) a step of developing the first film and the second film in the exposed multi-layered film by using an organic solvent-containing developer to form a negative pattern.

2. The pattern forming method according to claim 1,

wherein the resin contained in the first resin composition (I) differs from the resin contained in the second resin composition (II).

3. The pattern forming method according to claim 1 or 2,

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin contained in the first resin composition (I), is 15 mol% or less based on all repeating units in the resin.

4. The pattern forming method according to any one of claims 1 to 3,

wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group, in the resin having a group capable of decomposing by the action of an acid to produce a polar group, which is contained in the second resin composition (II), is from 20 to 90 mol% based on all repeating units in the resin.

5. The pattern forming method according to any one of claims 1 to 4,

wherein the thickness of the first film is from 50 to 130 nm, the thickness of the second film is from 90 to 190 nm, and the exposure in the step (iii) is exposure to a KrF excimer laser.

6. The pattern forming method according to any one of claims 1 to 4,

wherein the thickness of the first film is from 20 to 80 nm, the thickness of the second film is from 30 to 100 nm, and the exposure in the step (iii) is exposure to an ArF excimer laser.

7. The pattern forming method according to any one of claims 1 to 6,

wherein the first film is a developable bottom anti-reflective coating.

8. The pattern forming method according to any one of claims 1 to 7,

wherein the organic solvent-containing developer is a developer containing at least one kind of an organic solvent selected from the group consisting of a ketone-based solvent, an ester-based solvent, an alcohol-based solvent, an amide-based solvent and an ether-based solvent.

9. A resin composition, which is the first resin composition (I) used for the pattern forming method claimed in any one of claims 1, 2 and 4 to 8, wherein the content of the repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin.

10. A multi-layered resist pattern formed by the pattern forming method according to any one of claims 1 to 8.

11. A multi-layered film for organic solvent development, comprising:

a first film formed on a substrate by using a first resin composition (I) containing a resin in which the content of a repeating unit having a group capable of decomposing by the action of an acid to produce a polar group is 20 mol% or less based on all repeating units in the resin, and

a second film formed on the first film by using a second resin composition (II)

different from the resin composition (I), in which the second resin composition (II) contains a resin having a group capable of decomposing by the action of an acid to produce a polar group and a compound capable of generating an acid upon irradiation with an actinic ray or radiation.

12. A manufacturing method of an electronic device, comprising the pattern forming method according to any one of claims 1 to 8.

13. An electronic device manufactured by the manufacturing method of an electronic device according to claim 12.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/077663

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. G03F7/038(2006.01)i, G03F7/039(2006.01)i, G03F7/11(2006.01)i, G03F7/32(2006.01)i, H01L21/027(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. G03F7/038, G03F7/039, G03F7/11, G03F7/32, H01L21/027

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2012
Registered utility model specifications of Japan 1996-2012
Published registered utility model applications of Japan 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2010-122535 A (JSR CORP,JP) 2010.06.03, 【0002】 (no family)	13 1-12
X A	JP 2011-197587 A (FUJI FILM CO LTD,JP) 2011.10.06, 【0001】 (no family)	13 1-12
X A	WO 2008/153109 A1 (FUJITSU CO LTD,JP) 2008.12.18, 【0001】 & EP 2157479 A1 & KR 2010017759 A & US 2010/167201 A1 & JP 4551970 B2 & KR 989565 B1 & US 7851140 B2 & US 2011/045413 A1	13 1-12

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
16.11.2012	27.11.2012

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