

DESCRIPTION

Title of Invention: PHOTSENSITIVE RESIN COMPOSITION,
CURED PRODUCT, AND SEMICONDUCTOR ELEMENT

5 **Technical Field**

[0001] The present disclosure relates to a photosensitive resin composition, a cured product, and a semiconductor element.

Background Art

10 [0002] In accordance with high integration, miniaturization, and micronization of semiconductor elements, insulating films used for surface protective layers, interlayer insulating layers, redistribution layers, and the like of the semiconductor elements are required to have more excellent electrical characteristics, heat resistance, mechanical characteristics, and the like. As a material for forming an insulating film

15 having such characteristics, a photosensitive resin composition containing an alkali-soluble resin has been developed (see, for example, Patent Literatures 1, 2, and 3). These photosensitive resin compositions are applied onto a substrate and dried to form a resin film, and the resin film is exposed and developed to obtain a patterned resin film (a film on

20 which a pattern is formed). Then, a patterned cured film (cured film on which a pattern is formed) can be formed by thermally curing the patterned resin film, and the patterned cured film can be used as an insulating film.

Citation List

25 **Patent Literature**

[0003] [Patent Literature 1] JP 2008-309885 A

[Patent Literature 2] JP 2007-057595 A

[Patent Literature 3] WO 2010/073948 A1

Summary of Invention

Technical Problem

5 [0004] A photosensitive resin composition for forming an insulating film of a redistribution layer or the like is required to improve a glass transition temperature (T_g) and adhesion of the insulating film while sufficiently maintaining fine processability and dielectric characteristics. Therefore, an object of the present disclosure is to provide a
10 photosensitive resin composition capable of forming an insulating film having a high T_g and excellent adhesion.

Solution to Problem

[0005] An aspect of the present disclosure relates to the following photosensitive resin composition, a cured product of the photosensitive
15 resin composition, and a semiconductor element.

[1] A photosensitive resin composition comprising a maleimide compound; a crosslinking agent; and a photopolymerization initiator, wherein the maleimide compound is a reaction product of a tetracarboxylic acid dianhydride (a1), a diamine (a2), a triamine (a3),
20 and maleic anhydride (a4), the tetracarboxylic acid dianhydride (a1) includes a tetracarboxylic acid dianhydride having an aromatic ring, the diamine (a2) includes a dimer diamine and a second diamine other than the dimer diamine, and at least one of the second diamine and the triamine includes an amine having an aromatic ring.

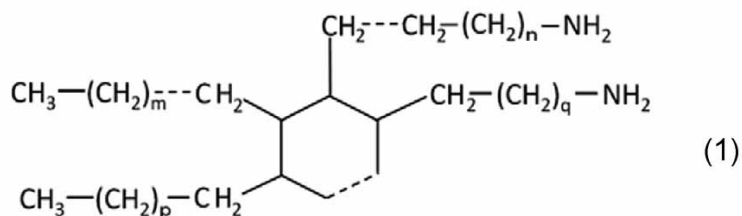
25 [2] The photosensitive resin composition according to [1], wherein the tetracarboxylic acid dianhydride having an aromatic ring

contains at least one of pyromellitic anhydride, 4,4'-oxydiphthalic anhydride, 3,4'-oxydiphthalic anhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 2,3',3,4'-biphenyltetracarboxylic acid dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

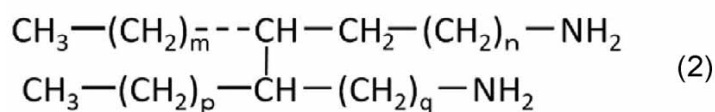
[3] The photosensitive resin composition according to [1] or [2], wherein the amine having an aromatic ring is a diamine having an aromatic ring, and the diamine having an aromatic ring includes at least one of 4,4'-diamino-2,2'-dimethylbiphenyl, 4,4'-diamino-2,2'-diethylbiphenyl, 4,4'-diamino-3,3'-dimethylbiphenyl, 4,4'-diamino-3,3'-diethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetramethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetraethylbiphenyl, 4,4'-diamino-2,2'-bis(trifluoromethyl)biphenyl, 4,4'-diamino-2,2'-dimethoxybiphenyl, and 4,4'-diamino-3,3'-dimethoxybiphenyl.

[4] The photosensitive resin composition according to any one of [1] to [3], wherein the dimer diamine contains at least one of a compound represented by the following general formula (1) and a compound represented by the following general formula (2):

[Chemical Formula 1]



[Chemical Formula 2]



wherein in formulae (1) and (2), m, n, p, and q each represent an integer of 1 or more selected such that m+n = 6 to 17 and p+q = 8 to 19, and a bond indicated by a dashed line means a carbon-carbon single bond or a carbon-carbon double bond. However, when the bond indicated by a dashed line is a carbon-carbon double bond, formulae (1) and (2) have a structure in which the number of hydrogen atoms bonded to each carbon atom constituting the carbon-carbon double bond is reduced by one from the number shown in formulae (1) and (2).

[5] The photosensitive resin composition according to any one of [1] to [4], wherein a weight average molecular weight of the maleimide compound is 3000 to 40000.

[6] The photosensitive resin composition according to any one of [1] to [5], in which the crosslinking agent includes a polymerizable crosslinking agent having a (meth)acryloyl group.

[7] The photosensitive resin composition according to any one of [1] to [6], wherein the crosslinking agent includes a polymerizable crosslinking agent having an allyl group or a vinyl group.

[8] The photosensitive resin composition according to any one of [1] to [7], further comprising a thermal polymerization initiator.

[9] A cured product of the photosensitive resin composition according to any one of [1] to [8].

[10] A semiconductor element having a redistribution layer comprising a cured product of the photosensitive resin composition according to any one of [1] to [8].

Advantageous Effects of Invention

[0006] According to the present disclosure, it is possible to provide a photosensitive resin composition capable of forming an insulating film having a high Tg and excellent adhesion, a cured product of the photosensitive resin composition, and a semiconductor element having a redistribution layer containing the cured product.

Description of Embodiments

[0007] Hereinafter, preferred embodiments of the present disclosure will be described in detail. However, the present invention is not limited to the following embodiments, and various modifications can be made within the scope of the gist of the present invention.

[0008] In the present specification, a numerical range indicated using “to” indicates a range including numerical values described before and after “to” as a minimum value and a maximum value, respectively. In the numerical range described in stages in the present specification, an upper limit value or a lower limit value of a numerical range of a certain stage can be arbitrarily combined with an upper limit value or a lower limit value of a numerical range of another stage. In the numerical range described in the present specification, the upper limit value or the lower limit value of the numerical range may be replaced with a value shown in Examples. “A or B” may include either A or B, or may include both A and B. The materials exemplified in the present specification can be used alone or in combination with two or more kinds thereof unless otherwise specified. When a plurality of materials corresponding to the respective components are present in the composition, a content of each component in the composition means the total amount of the plurality of

materials present in the composition unless otherwise specified.

[0009] In the present specification, the “layer” and the “film” include not only a structure having a shape formed on the entire surface but also a structure having a shape formed on a part thereof when observed as a plan view. The term “step” includes not only an independent step but also a step that cannot be clearly distinguished from other steps as long as the intended purpose of the step is achieved.

[0010] In the present specification, “(meth)acryloyl” means at least one of “acryloyl” and “methacryloyl” corresponding thereto, and the same applies to other similar expressions such as (meth)acrylic acid and (meth)acrylate. In the present specification, the “solid content” refers to a non-volatile content excluding a volatile substance (water, a solvent, or the like) contained in a photosensitive resin composition, and also includes a component in a liquid, syrupy, or waxy state at room temperature (around 25°C).

[0011] [Photosensitive Resin Composition]

The photosensitive resin composition according to the present embodiment contains, as essential components, a maleimide compound having a specific structure, a crosslinking agent, and a photopolymerization initiator. The above-described maleimide compound is a reaction product of a tetracarboxylic acid dianhydride (a1), a diamine (a2), a triamine (a3), and maleic anhydride (a4). The tetracarboxylic acid dianhydride (a1) includes a tetracarboxylic acid dianhydride having an aromatic ring, the diamine (a2) includes a dimer diamine and a second diamine other than the dimer diamine, and at least one of the second diamine and the triamine includes an amine having an

aromatic ring. The amine having an aromatic ring is a diamine having an aromatic ring or a triamine having an aromatic ring. The aromatic ring may have a lower alkyl (for example, methyl, ethyl, propyl, and the like) as a substituent.

5 [0012] The photosensitive resin composition according to the present embodiment may further contain a thermal polymerization initiator, a coupling agent, a rust inhibitor, a polymerization inhibitor, and the like, as necessary. The photosensitive resin composition according to the present embodiment is a negative photosensitive resin composition, and
10 a cured product of the photosensitive resin composition can be suitably used as an insulating film for a redistribution layer. Hereinafter, each component used in the photosensitive resin composition of the present embodiment will be described in more detail.

[0013] (Maleimide Compound)

15 The maleimide compound (hereinafter, also referred to as “component (A)”) according to the present embodiment can be obtained by reacting a tetracarboxylic acid dianhydride (a1) (hereinafter, also referred to as “component (a1)”), a diamine (a2) (hereinafter, also referred to as “component (a2)”), a triamine (a3) (hereinafter, also
20 referred to as “component (a3)”), and maleic anhydride (a4) (hereinafter, also referred to as “component (a4)”). That is, the component (A) is a maleimide compound obtained by reacting the component (a1), the component (a2), and the component (a3). The component (A) is a polyfunctional maleimide compound having two or more maleimide
25 groups, and may have a plurality of maleimide groups in the molecule. The component (A) can be used alone or in combination with two or

more kinds thereof.

[0014] The tetracarboxylic acid dianhydride of the component (a1) includes a tetracarboxylic acid dianhydride having an aromatic ring. Examples of the tetracarboxylic acid dianhydride having an aromatic ring include aromatic tetracarboxylic acid dianhydrides having no fluorene skeleton, such as pyromellitic anhydride, 4,4'-oxydiphthalic anhydride, 3,4'-oxydiphthalic anhydride, 4,4'-(hexafluoroisopropylidene)diphthalic anhydride, 3,3',4,4'-diphenylsulfonetetracarboxylic acid dianhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 2,3',3,4'-biphenyltetracarboxylic acid dianhydride, 3,3',4,4'-benzophenonetetracarboxylic acid dianhydride, and 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride; and tetracarboxylic acid dianhydrides having a fluorene skeleton, such as 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride, and 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione.

[0015] From the viewpoint of high Tg of the cured product, the component (a1) preferably contains at least one of pyromellitic anhydride, 4,4'-oxydiphthalic anhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 2,3',3,4'-biphenyltetracarboxylic acid dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride as the tetracarboxylic acid dianhydride having an aromatic ring.

[0016] From the viewpoint of solubility of the maleimide compound and high Tg of the cured product, it is preferable to use in combination a tetracarboxylic acid dianhydride having a fluorene skeleton and an aromatic tetracarboxylic acid dianhydride having no fluorene skeleton as the tetracarboxylic acid dianhydride having an aromatic ring. The component (a1) may include, for example, 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride and at least one of pyromellitic anhydride, 4,4'-oxydiphthalic anhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, and 2,3',3,4'-biphenyltetracarboxylic acid dianhydride.

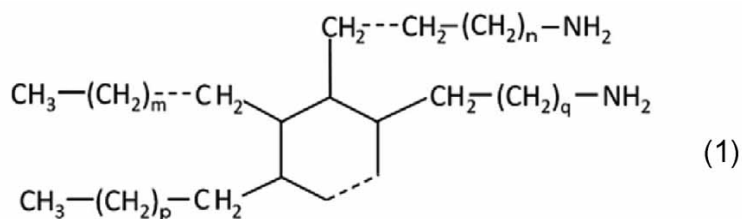
[0017] The component (a1) may further include a tetracarboxylic acid dianhydride having no aromatic ring. Examples of the tetracarboxylic acid dianhydride having no aromatic ring include 1,2,3,4-butanetetracarboxylic acid dianhydride, 1,2,3,4-cyclobutanetetracarboxylic acid dianhydride, 1,2,3,4-cyclopentanetetracarboxylic acid dianhydride, 1,2,3,4-tetramethyl-1,2,3,4-cyclobutanetetracarboxylic acid dianhydride, bicyclo[2.2.2]oct-7-ene-2,3,5,6-tetracarboxylic acid dianhydride, bis(1,3-dioxo-1,3-dihydroisobenzofuran-5-carboxylic acid) 1,4-phenylene, 4,4'-(ethyne-1,2-diyl)diphthalic anhydride, 5-(2,5-dioxotetrahydrofuryl)-3-methyl-3-cyclohexene-1,2-dicarboxylic anhydride, dicyclohexyl-3,4,3',4'-tetracarboxylic acid dianhydride, norbornane-2-spiro- α -cyclopentanone- α' -spiro-2"-norbornane-5,5",6,6"-tetracarboxylic acid dianhydride, and 5,5'-bis-2-norbornene-5,5',6,6'-tetracarboxylic acid-5,5',6,6'-dianhydride.

[0018] The component (a2) includes a dimer diamine (first diamine) and a second diamine (second amine) other than the dimer diamine.

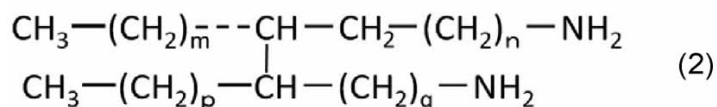
[0019] The dimer diamine is, for example, a compound derived from a dimer acid which is a dimer of an unsaturated fatty acid such as oleic acid, as described in JP H9-12712 A. By using a dimer diamine as the component (a2), the dielectric characteristics of the cured product can be lowered. In the present embodiment, a known dimer diamine can be used without particular limitation. The dimer diamine preferably includes at least one of a compound represented by the following general formula (1) and a compound represented by the following general formula (2), for example.

[0020]

[Chemical Formula 3]



[Chemical Formula 4]

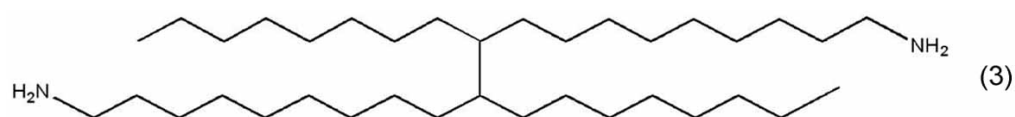


[0021] In formulae (1) and (2), m, n, p, and q each represent an integer of 1 or more selected such that $m+n = 6$ to 17 and $p+q = 8$ to 19, and a bond indicated by a dashed line means a carbon-carbon single bond or a carbon-carbon double bond. However, when the bond indicated by a dashed line is a carbon-carbon double bond, formulae (1) and (2) have a structure in which the number of hydrogen atoms bonded to each carbon

atom constituting the carbon-carbon double bond is reduced by one from the number shown in formulae (1) and (2).

[0022] The dimer diamine may be one represented by the above general formula (2) from the viewpoints of solubility in an organic solvent, heat resistance, heat-resistant adhesion, low viscosity, and the like, and may in particular be a compound represented by the following formula (3).

[Chemical Formula 5]



[0023] Examples of a commercially available product of the dimer diamine include PRIAMINE 1075 and PRIAMINE 1074 (both manufactured by Croda Japan K.K.) and the like. These can be used alone or in combination with two or more kinds thereof.

[0024] The second diamine is a diamine that does not correspond to the dimer diamine described above. The second diamine may include a diamine having an aromatic ring as an amine having an aromatic ring.

[0025] Examples of the diamine having an aromatic ring include diamines having a biphenyl skeleton, such as 4,4'-diamino-2,2'-dimethylbiphenyl, 4,4'-diamino-2,2'-diethylbiphenyl, 4,4'-diamino-3,3'-dimethylbiphenyl, 4,4'-diamino-3,3'-diethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetramethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetraethylbiphenyl, 4,4'-diamino-2,2'-bis(trifluoromethyl)biphenyl, 4,4'-diamino-2,2'-dimethoxybiphenyl, and 4,4'-diamino-3,3'-dimethoxybiphenyl; diamines having a fluorene skeleton, such as 2,7-diaminofluorene, 9,9-bis(4-aminophenyl)fluorene, 9,9-bis[3-fluoro-4-aminophenyl]fluorene, and 9,9-bis[4-(4-aminophenoxy)phenyl]fluorene; phenylenediamines

such as para-phenylenediamine, ortho-phenylenediamine, and meta-phenylenediamine; and bisaniline derivatives such as 4,4'-methylenedianiline, 4,4'-ethylenedianiline, 1,3-bis[2-(4-aminophenyl)-2-propyl]benzene, 2,2-bis[4-(4-aminophenoxy)phenyl]hexafluoropropane, 4,4'-(hexafluoroisopropylidene)dianiline, 1,1-bis(4-aminophenyl)cyclohexane, 4,4'-methylenebis(2,6-diethylaniline), 4,4'-methylenebis(2-ethyl-6-methylaniline), 2,2-bis[4-(4-aminophenoxy)phenyl]propane, bis[4-(4-aminophenoxy)phenyl]methane, bis[4-(4-aminophenoxy)phenyl]ether, bis[4-(4-aminophenoxy)phenyl]ketone, 1,3-bis(4-aminophenoxy)benzene, 1,4-bis(4-aminophenoxy)benzene, 4,4'-diaminodiphenyl ether, 3,3'-diaminodiphenyl ether, bis[4-(3-aminophenoxy)phenyl]sulfone, and bis[4-(4-aminophenoxy)phenyl]sulfone. These can be used alone or in combination with two or more kinds thereof.

[0026] The diamine having an aromatic ring may contain at least one diamine having a biphenyl skeleton selected from 4,4'-diamino-2,2'-dimethylbiphenyl, 4,4'-diamino-2,2'-diethylbiphenyl, 4,4'-diamino-3,3'-dimethylbiphenyl, 4,4'-diamino-3,3'-diethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetramethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetraethylbiphenyl, 4,4'-diamino-2,2'-bis(trifluoromethyl)biphenyl, 4,4'-diamino-2,2'-dimethoxybiphenyl, and 4,4'-diamino-3,3'-dimethoxybiphenyl, from the viewpoint of further increasing the Tg of the cured product.

[0027] The content of the diamine having an aromatic ring may be 20 mol% or more, 25 mol% or more, 30 mol% or more, or 35 mol% or more

from the viewpoint of further increasing the Tg of the cured product, and may be 60 mol% or less, 55 mol% or less, 50 mol% or less, or 45 mol% or less from the viewpoint of further lowering the dielectric characteristics of the cured product, based on the total amount of the components (a2) and (a3).

[0028] The second diamine may include a diamine having no aromatic ring. Examples of the diamine having no aromatic ring include 1,3-diaminopropane, norbornanedi-amine, norbornenedi-amine, 1,3-bis(aminomethyl)cyclohexane, 1,4-bis(aminomethyl)cyclohexane, bis(aminomethyl)norbornane, 3(4),8(9)-bis(aminomethyl)tricyclo[5.2.1.0^{2,6}]decane, 1,3-cyclohexanedi-amine, 1,4-cyclohexanedi-amine, isophoronedi-amine, 4,4'-methylenebis(cyclohexylamine), 1,4-bisaminopropylpiperazine, and 4,4'-methylenebis(2-methylcyclohexylamine).

[0029] Examples of the triamine of the component (a3) include aliphatic triamines such as tris(2-aminomethyl)amine, tris(2-aminoethyl)amine, tris(2-aminopropyl)amine, 2-(aminomethyl)-2-methyl-1,3-propanedi-amine, and a trimer triamine; triamines having a heterocycle such as 1,3,5-triazine-2,4,6-tri-amine and 2,4,6-triaminopyrimidine; and triamines having an aromatic ring such as 3,4,4'-triaminodiphenyl ether, 1,2,4-triaminobenzene, 1,3,5-triaminobenzene, 1,2,3-triaminobenzene, 1,3,5-tris(4-aminophenyl)benzene, 1,3,5-tris(4-aminophenoxy)benzene, and tris(4-aminophenyl)methane. These can be used alone or in combination with two or more kinds thereof. Among these, from the viewpoint of solubility of the synthesized component (A) in an organic solvent, aliphatic triamines are preferable, and furthermore, tris(2-

aminomethyl)amine and tris(2-aminoethyl)amine, which have a small number of carbon atoms, are more preferable from the viewpoint of achieving a high Tg.

[0030] The content of the component (a3) may be 1 mol% or more, 4 mol% or more, 6 mol% or more, or 8 mol% or more from the viewpoint of HAZE (turbidity) of the maleimide compound and the elastic modulus and Tg of the cured product, and may be 30 mol% or less, 25 mol% or less, 20 mol% or less, or 15 mol% or less from the viewpoint of solubility and HAZE of the maleimide compound, based on the total amount of the components (a2) and (a3).

[0031] By using a dimer diamine as the diamine, a cured product having lower dielectric characteristics can be formed. On the other hand, when only a dimer diamine is used as the diamine, the Tg of the cured product decreases. In contrast, by using a dimer diamine, a second diamine, and a triamine, an insulating film having a high Tg and excellent adhesion can be formed while maintaining the dielectric characteristics of the cured product.

[0032] The component (A) can be produced by various known methods. For example, first, the component (a1), the component (a2), and the component (a3) are subjected to a polyaddition reaction at a temperature of about 60 to 120°C and preferably 70 to 90°C, for usually about 0.1 to 2 hours and preferably 0.1 to 1.0 hour. Next, the obtained polyaddition product is further subjected to an imidization reaction, that is, a dehydration ring-closing reaction, at a temperature of about 80 to 250°C and preferably 100 to 200°C for about 0.5 to 30 hours and preferably 0.5 to 10 hours. Subsequently, the product obtained by the dehydration ring-

closing reaction and the component (a4) are subjected to a maleimidation reaction, that is, a dehydration ring-closing reaction, at a temperature of about 60 to 250°C and preferably 80 to 200°C for about 0.5 to 30 hours and preferably 0.5 to 10 hours, thereby obtaining a target component (A).

5 [0033] In the imidization reaction or the maleimidation reaction, various known reaction catalysts, dehydrating agents, and solvents can be used.

[0034] Examples of the reaction catalyst include aliphatic tertiary amines such as triethylamine, aromatic tertiary amines such as dimethylaniline, heterocyclic tertiary amines such as pyridine, picoline,
10 and isoquinoline, and organic acids such as methanesulfonic acid and p-toluenesulfonic acid monohydrate. Examples of the dehydrating agent include aliphatic acid anhydrides such as acetic anhydride and aromatic acid anhydrides such as benzoic anhydride.

[0035] Examples of the solvent include aromatic hydrocarbon-based
15 solvents such as benzene, toluene, xylene, mesitylene, and pseudocumene; alcoholic solvents such as methanol, ethanol, isopropyl alcohol, butanol, pentanol, hexanol, propanediol, and phenol; ether-based solvents such as anisole; ketone-based solvents such as acetone, methyl isobutyl ketone, methyl ethyl ketone, pentanone, hexanone,
20 cyclopentanone, cyclohexanone, isophorone, and acetophenone; cellosolves such as methyl cellosolve and ethyl cellosolve; ester-based solvents such as methyl acetate, ethyl acetate, butyl acetate, methyl propionate, butyl formate, and γ -butyrolactone; glycol ether-based
25 solvents such as ethylene glycol mono-n-butyl ether, ethylene glycol mono-iso-butyl ether, ethylene glycol mono-tert-butyl ether, diethylene glycol mono-n-butyl ether, diethylene glycol mono-iso-butyl ether,

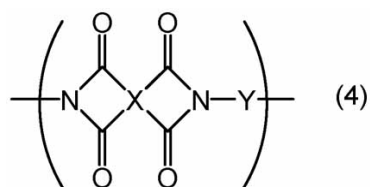
triethylene glycol mono-n-butyl ether, and tetraethylene glycol mono-n-butyl ether; and amide-based solvents such as N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, N-ethyl-2-pyrrolidone, 3-methoxy-N,N-dimethylpropanamide, and 3-butoxy-N,N-dimethylpropanamide. The solvents can be used alone or in combination with two or more kinds thereof.

[0036] The component (A) can be purified by various known methods, and the purity can be increased. For example, first, the component (A) dissolved in a solvent and pure water are placed in a separatory funnel. Next, the separatory funnel is shaken and allowed to stand. Subsequently, after an aqueous layer and an organic layer are separated, only the organic layer is recovered, such that the component (A) can be purified.

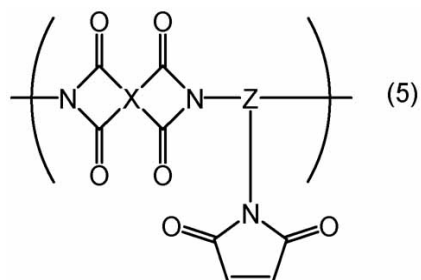
[0037] The component (A) produced by the above-described method may include one or more structural units represented by the following general formulae (4) to (6). The number of functional groups (number of maleimide groups) of the component (A) depends on the content of the triamine, but the component (A) is assumed to have 2 to 6 functional groups per molecule. The component (A) may be a mixture of a plurality of compounds having different structures or different numbers of functional groups. The component (A) may contain a compound having three or more functional groups per molecule that includes one or more structural units represented by the following general formulae (5) to (6).

[0038]

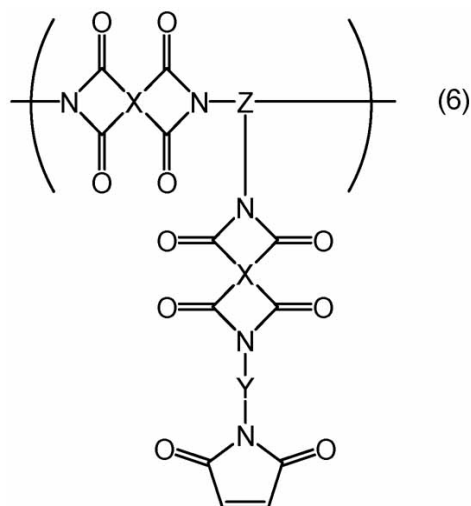
[Chemical Formula 6]



[Chemical Formula 7]



[Chemical Formula 8]



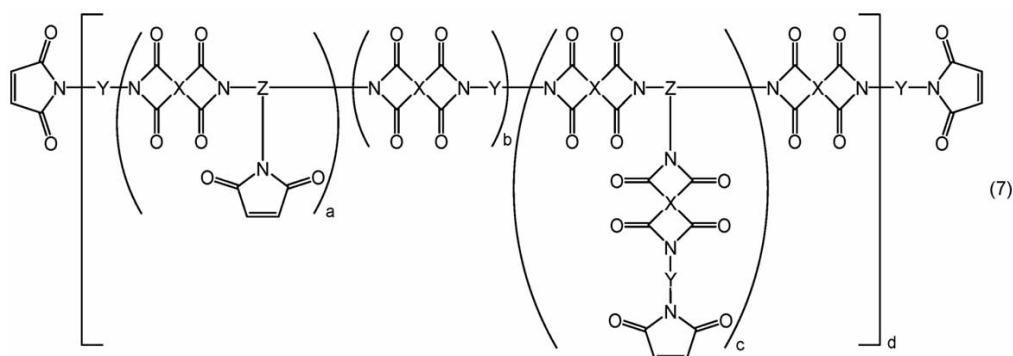
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[0039] In general formulae (4) to (6), X each independently represents a tetravalent organic group, Y each independently represents a divalent organic group, and Z each independently represents a trivalent organic group. X, Y, and Z may be organic groups having an aliphatic group, an alicyclic structure, or an aromatic ring, and these may contain a heteroatom. Y may be an organic group derived from a dimer diamine, and Z may be an organic group derived from a triamine (a3).

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[0040] An example of an assumed structure of the component (A) produced by the above-described method is shown in the following general formula (7).

[0041] [Chemical Formula 9]



[0042] X, Y, and Z in general formula (7) have the same meanings as X, Y, and Z in general formulae (4) to (6). In addition, a represents an integer of 0 to 20, b represents an integer of 0 to 30, c represents an integer of 0 to 20, and d represents an integer of 1 to 30. In general formula (7), the positions of the structural unit to which the symbol a is attached (the structural unit represented by the above general formula (5)), the structural unit to which the symbol b is attached (the structural unit represented by the above general formula (4)), and the structural unit to which the symbol c is attached (the structural unit represented by the above general formula (6)) may be interchanged with each other. The component (A) may contain a compound having three or more functional groups per molecule in which at least one of a and c is an integer of 1 or more.

[0043] The molecular weight of the component (A) can be controlled by the numbers of moles of the component (a1), the component (a2), and the component (a3), and the molecular weight can be made smaller as

the number of moles of the component (a1) is smaller than the total number of moles of the component (a2) and the component (a3). For the purpose of easily achieving the effect of the present disclosure, the number of moles of the component (a1) relative to 1 mole of the component (a2) and the component (a3), that is, [the number of moles of the component (a1)]/[the number of moles of the component (a2) + the number of moles of the component (a3)], is usually about 0.30 to 0.98, preferably 0.40 to 0.96, more preferably 0.50 to 0.94, and still more preferably in the range of 0.60 to 0.90.

[0044] The molecular weight of the component (A) is preferably 3000 to 40000 in terms of weight average molecular weight (Mw) from the viewpoint of solubility in a solvent and heat resistance, and may be 4000 to 30000, 5000 to 28000, 7000 to 27000, 10000 to 25000, 12000 to 22000, or 13000 to 20000. When the weight average molecular weight is 40000 or less, the solubility in an organic solvent tends to be good, and when the weight average molecular weight is 3000 or more, the effect of improving heat resistance tends to be sufficiently obtained. The Mw can be measured by gel permeation chromatography (GPC), and can be converted using a calibration curve of standard polystyrene.

[0045] (Crosslinking Agent)

The crosslinking agent (hereinafter, also referred to as “component (B)”) may be a polymerizable crosslinking agent. The polymerizable group may be a photopolymerizable group or a thermopolymerizable group. Examples of the polymerizable group include a (meth)acryloyl group, an allyl group, and a vinyl group. The component (B) may be a polyfunctional compound having two or more

polymerizable groups. In addition, the component (B) can be crosslinked, for example, not only with other crosslinking agents but also with the component (A) during exposure of the photosensitive layer. In addition, the component (B) can be crosslinked, for example, with other polymerizable crosslinking agents during heating of the resin film after pattern formation. The component (B) can be used alone or in combination with two or more kinds thereof.

[0046] The resin composition according to the present embodiment may contain a polymerizable crosslinking agent having a (meth)acryloyl group as a crosslinking agent from the viewpoint of dielectric characteristics. The polymerizable crosslinking agent having a (meth)acryloyl group can be crosslinked not only with other crosslinking agents but also with the component (A) during exposure of the photosensitive layer. The polymerizable crosslinking agent having a (meth)acryloyl group may be an acrylate compound or a methacrylate compound. The component (B) may include a methacrylate compound from the viewpoint of dielectric characteristics.

[0047] Examples of the polymerizable crosslinking agent having a (meth)acryloyl group include tricyclodecane dimethanol di(meth)acrylate, tris(2-(meth)acryloyloxyethyl)isocyanurate, dioxane glycol di(meth)acrylate, alkoxylated glycerin tri(meth)acrylate, trimethylolpropane tri(meth)acrylate, alkoxylated trimethylolpropane tri(meth)acrylate, pentaerythritol tri(meth)acrylate, pentaerythritol tetra(meth)acrylate, alkoxylated pentaerythritol tetra(meth)acrylate, 1,6-hexanediol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate, 1,10-decanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate,

ethoxylated bisphenol A di(meth)acrylate, propoxylated ethoxylated bisphenol A (meth)acrylate, dipentaerythritol poly(meth)acrylate, alkoxylated dipentaerythritol poly(meth)acrylate, ethoxylated isocyanuric acid tri(meth)acrylate, polyethylene glycol di(meth)acrylate, and polypropylene glycol di(meth)acrylate.

[0048] The polymerizable crosslinking agent having a (meth)acryloyl group may include at least one selected from the group consisting of tricyclodecane dimethanol di(meth)acrylate, tris(2-(meth)acryloyloxyethyl)isocyanurate, and dioxane glycol di(meth)acrylate from the viewpoint of heat resistance, dielectric characteristics, and fine processability, and may include tris(2-(meth)acryloyloxyethyl)isocyanurate from the viewpoint of heat resistance and dielectric characteristics.

[0049] The resin composition according to the present embodiment may contain a polymerizable crosslinking agent having an allyl group or a vinyl group as a crosslinking agent from the viewpoints of dielectric characteristics and heat resistance. The polymerizable crosslinking agent having an allyl group or a vinyl group can be crosslinked with other polymerizable crosslinking agents during heating of the resin film after pattern formation.

[0050] Examples of the polymerizable crosslinking agent having an allyl group include 1,3,4,6-tetraallyl glycoluril, triallyl isocyanurate, diallyl monoglycidyl isocyanurate, diallyl monomethyl isocyanurate, diallyl isocyanurate, triallyl trimellitate, and triallyl orthoformate.

[0051] Examples of the polymerizable crosslinking agent having a vinyl group include a polyvinylbenzyl compound and a polyvinylbenzyl ether

compound.

[0052] The polymerizable crosslinking agent having an allyl group or a vinyl group may include at least one selected from the group consisting of 1,3,4,6-tetraallyl glycoluril, triallyl isocyanurate, diallyl isocyanurate, and a polyvinylbenzyl ether compound from the viewpoint of dielectric characteristics and fine processability, and may include triallyl isocyanurate from the viewpoint of dielectric characteristics.

[0053] From the viewpoint of further improving the balance between low dielectric characteristics and fine processability, a content of the component (B) is preferably less than 50 parts by mass, and may be 1 to 45 parts by mass, 5 to 40 parts by mass, 8 to 30 parts by mass, or 10 to 20 parts by mass, when the total amount of the component (A) and the component (B) is 100 parts by mass.

[0054] (Photopolymerization Initiator)

The photopolymerization initiator (hereinafter, also referred to as “component (C)”) is not particularly limited as long as it is a compound that initiates polymerization by radiation with an active ray (ultraviolet ray or the like), and examples thereof include an alkylphenone-based photopolymerization initiator, an acylphosphine oxide-based photopolymerization initiator, an intramolecular hydrogen abstraction type photopolymerization initiator, and an oxime ester-based photopolymerization initiator.

[0055] The alkylphenone-based photopolymerization initiator can be purchased as, for example, Omnirad 651, Omnirad 184, Omnirad 1173, Omnirad 2959, Omnirad 127, Omnirad 907, Omnirad 369, or Omnirad 379EG manufactured by IGM Resins B.V., or the like. The

acylphosphine oxide-based photopolymerization initiator can be purchased as, for example, Omnirad 819 or Omnirad TPO H manufactured by IGM Resins B.V., or the like. The intramolecular hydrogen abstraction type photopolymerization initiator can be purchased as, for example, Omnirad MBF or Omnirad 754 manufactured by IGM Resins B.V., or the like. The oxime ester-based photopolymerization initiator can be purchased as, for example, Irgacure OXE01 or Irgacure OXE02 manufactured by BASF Japan Ltd., or the like. In order to promote the photoreaction, a titanocene-based photopolymerization initiator (for example, Irgacure 784, manufactured by BASF Japan Ltd.) may be used in combination.

[0056] The content of the component (C) may be 0.1 to 10.0 parts by mass, 0.5 to 8.0 parts by mass, 0.8 to 6.0 parts by mass, or 1.0 to 5.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B) in terms of easily obtaining excellent fine processability.

[0057] (Thermal Polymerization Initiator)

The photosensitive resin composition according to the present embodiment may further contain a thermal polymerization initiator as the component (D) from the viewpoint of promoting a polymerization reaction of a thermopolymerizable group. As the component (D), a compound that is decomposed by heating during curing to generate radicals and promotes the polymerization reaction of the component (A) and the component (B) is preferable. Examples of the component (D) include an organic peroxide.

[0058] Examples of the organic peroxide include methyl ethyl ketone

peroxide, methylcyclohexanone peroxide, methyl acetoacetate peroxide,
 acetylacetone peroxide, 1,1-bis(t-butylperoxy)-3,3,5-
 trimethylcyclohexane, 1,1-bis(t-hexylperoxy)cyclohexane, 1,1-bis(t-
 hexylperoxy)-3,3,5-trimethylcyclohexane, 1,1-bis(t-
 5 butylperoxy)cyclohexane, 2,2-bis(4,4-di-t-
 butylperoxycyclohexyl)propane, 1,1-bis(t-butylperoxy)cyclododecane,
 n-butyl 4,4-bis(t-butylperoxy)valerate, 2,2-bis(t-butylperoxy)butane,
 1,1-bis(t-butylperoxy)-2-methylcyclohexane, t-butyl hydroperoxide, p-
 menthane hydroperoxide, 1,1,3,3-tetramethylbutyl hydroperoxide, t-
 10 hexyl hydroperoxide, dicumyl peroxide, 2,5-dimethyl-2,5-bis(t-
 butylperoxy)hexane, α,α' -bis(t-butylperoxy)diisopropylbenzene, t-
 butylcumyl peroxide, di-t-butyl peroxide, 2,5-dimethyl-2,5-bis(t-
 butylperoxy)hexyne-3, isobutyryl peroxide, 3,5,5-trimethylhexanoyl
 peroxide, octanoyl peroxide, lauroyl peroxide, cinnamic acid peroxide,
 15 m-toluoyl peroxide, benzoyl peroxide, diisopropyl peroxydicarbonate,
 bis(4-t-butylcyclohexyl) peroxydicarbonate, di-3-methoxybutyl
 peroxydicarbonate, di-2-ethylhexyl peroxydicarbonate, di-sec-butyl
 peroxydicarbonate, di(3-methyl-3-methoxybutyl) peroxydicarbonate,
 di(4-t-butylcyclohexyl) peroxydicarbonate, α,α' -
 20 bis(neodecanoylperoxy)diisopropylbenzene, cumyl
 peroxyneodecanoate, 1,1,3,3-tetramethylbutyl peroxyneodecanoate, 1-
 cyclohexyl-1-methylethyl peroxyneodecanoate, t-hexyl
 peroxyneodecanoate, t-butyl peroxyneodecanoate, t-hexyl
 peroxypivalate, t-butyl peroxypivalate, 2,5-dimethyl-2,5-bis(2-
 25 ethylhexanoylperoxy)hexane, 1,1,3,3-tetramethylbutylperoxy-2-
 ethylhexanoate, 1-cyclohexyl-1-methylethylperoxy-2-ethylhexanoate, t-

hexylperoxy-2-ethylhexanoate, t-butylperoxy-2-ethylhexanoate, t-butylperoxyisobutyrate, t-butylperoxymaleic acid, t-butylperoxylaurate, t-butylperoxy-3,5,5-trimethylhexanoate, t-butylperoxyisopropyl monocarbonate, t-butylperoxy-2-ethylhexyl monocarbonate, 2,5-dimethyl-2,5-bis(benzoylperoxy)hexane, t-butylperoxyacetate, t-hexylperoxybenzoate, t-butylperoxy-m-toluoyl benzoate, t-butylperoxybenzoate, bis(t-butylperoxy)isophthalate, t-butylperoxyallyl monocarbonate, and 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone.

[0059] The content of the component (D) is not particularly limited, and may be 0.1 to 10.0 parts by mass, 0.3 to 8.0 parts by mass, 0.5 to 5.0 parts by mass, 0.7 to 3.0 parts by mass, or 0.7 to 2.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B).

[0060] (Coupling Agent)

The photosensitive resin composition according to the present embodiment may further contain a coupling agent from the viewpoint of improving the adhesion of the cured product of the photosensitive resin composition. The coupling agent may be a silane coupling agent. The silane coupling agent may have, for example, a group such as a vinyl group, an epoxy group, a styryl group, an acryloyl group, a methacryloyl group, an amino group, a ureido group, an isocyanate group, an isocyanurate group, or a mercapto group.

[0061] Examples of the silane coupling agent having a vinyl group include KBM-1003 and KBE-1003 (trade name, manufactured by Shin-Etsu Chemical Co., Ltd., the same applies hereinafter). Examples of the

silane coupling agent having an epoxy group include KBM-303, 402, and 403, KBE-402 and 403, X-12-981S, and X-12-984S. Examples of the silane coupling agent having a styryl group include KBM-1403. Examples of the silane coupling agent having a methacryloyl group include KBM-502 and 503 and KBE-502 and 503. Examples of the silane coupling agent having an acryloyl group include KBM-5103, X-12-1048, and X-12-1050. Examples of the silane coupling agent having an amino group include KBM-602, 603, 903, 573, and 575, KBE-903 and 9103P, and X-12-972F. Examples of the silane coupling agent having a ureido group include KBE-585. Examples of the silane coupling agent having an isocyanate group include KBE-9007 and X-12-1159L. Examples of the silane coupling agent having an isocyanurate group include KBM-9659. Examples of the silane coupling agent having a mercapto group include KBM-802 and 803, X-12-1154, and X-12-1156. The silane coupling agent may be a silane coupling agent having a methacryloyl group. The silane coupling agents can be used alone or in combination with two or more kinds thereof.

[0062] The content of the silane coupling agent may be 0.01 to 10.0 parts by mass, 0.1 to 8.0 parts by mass, 0.3 to 6.0 parts by mass, 0.5 to 5.0 parts by mass, or 1.0 to 3.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B).

[0063] (Rust Inhibitor)

The photosensitive resin composition according to the present embodiment may further contain a rust inhibitor from the viewpoint of suppressing corrosion of the copper wiring or preventing discoloration. Examples of the rust inhibitor include a triazole derivative such as

benzotriazole and a tetrazole derivative. The rust inhibitors may be used alone or in combination with two or more kinds thereof.

[0064] The content of the rust inhibitor may be 0.01 to 10.0 parts by mass, 0.1 to 5.0 parts by mass, 0.3 to 4.0 parts by mass, 0.5 to 3.0 parts by mass, or 1.0 to 3.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B).

[0065] (Polymerization Inhibitor)

The photosensitive resin composition according to the present embodiment may further contain a polymerization inhibitor from the viewpoint of storage stability.

[0066] Examples of the polymerization inhibitor include 4-tert-butylcatechol, 4-hydroxy-2,2,6,6-tetramethylpiperidine-1-oxy radical, p-methoxyphenol, diphenyl-p-benzoquinone, benzoquinone, hydroquinone, pyrogallol, phenothiazine, resorcinol, ortho-dinitrobenzene, para-dinitrobenzene, meta-dinitrobenzene, phenanthraquinone, N-phenyl-2-naphthylamine, cupferron, 2,5-toluquinone, tannic acid, para-benzylaminophenol, tris(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)isocyanuric acid, and nitrosamines. The polymerization inhibitors may be used alone or in combination with two or more kinds thereof.

[0067] The content of the polymerization inhibitor may be 0.01 to 10.0 parts by mass, 0.05 to 5.0 parts by mass, 0.10 to 2.0 parts by mass, or 0.10 to 1.0 part by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B).

[0068] (Sensitizer)

The photosensitive resin composition may further contain a

sensitizer from the viewpoint of achieving both maintenance of a residual film ratio in a wide range of exposure amount and excellent resolution.

[0069] Examples of the sensitizer include Michler's ketone, benzoin, 2-methylbenzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzoin butyl ether, 2-t-butylanthraquinone, 1,2-benzo-9,10-anthraquinone, anthraquinone, methylantraquinone, 4,4'-bis(diethylamino)benzophenone, acetophenone, benzophenone, thioxanthone, 1,5-acenaphthene, 2,2-dimethoxy-2-phenylacetophenone, 1-hydroxycyclohexyl phenyl ketone, 2-methyl-[4-(methylthio)phenyl]-2-morpholino-1-propanone, diacetyl benzyl, benzyl dimethyl ketal, benzyl diethyl ketal, diphenyl disulfide, anthracene, phenanthrenequinone, riboflavin tetrabutyrates, acridine orange, erythrosine, phenanthrenequinone, 2-isopropylthioxanthone, 2,6-bis(p-diethylaminobenzylidene)-4-methyl-4-azacyclohexanone, 6-bis(p-dimethylaminobenzylidene)-cyclopentanone, 2,6-bis(p-diethylaminobenzylidene)-4-phenylcyclohexanone, aminostyryl ketone, a 3-ketocoumarin compound, a biscoumarin compound, N-phenylglycine, N-phenyldiethanolamine, and 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone. The sensitizers may be used alone or in combination with two or more kinds thereof.

[0070] When the photosensitive resin composition contains a sensitizer, the content thereof is preferably 0.1 to 2.0 parts by mass, and more preferably 0.2 to 1.5 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and the component (B).

[0071] (Solvent)

When the photosensitive resin composition according to the present embodiment contains a solvent for dissolving and dispersing each component, the photosensitive resin composition can be easily applied onto a substrate to form a coating film having a uniform thickness. The solvents may be used alone or in combination with two or more kinds thereof.

[0072] Examples of the solvent include ketone-based solvents such as methyl ethyl ketone, cyclohexanone, and cyclopentanone; aromatic hydrocarbon-based solvents such as toluene, xylene, tetramethylbenzene, mesitylene, and pseudocumene; glycol ether-based solvents such as methyl cellosolve, butyl cellosolve, methyl carbitol, butyl carbitol, propylene glycol monomethyl ether, dipropylene glycol monoethyl ether, dipropylene glycol dimethyl ether, dipropylene glycol diethyl ether, and triethylene glycol monoethyl ether; ester-based solvents such as ethyl acetate, butyl acetate, butyl cellosolve acetate, carbitol acetate, and γ -butyrolactone; and amide-based solvents such as N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, N-ethyl-2-pyrrolidone, 3-methoxy-N,N-dimethylpropanamide, and 3-butoxy-N,N-dimethylpropanamide.

[0073] A blending amount of the solvent is not particularly limited, and may be an amount in which a solid content in the photosensitive resin composition is 5 to 60 mass%, 10 to 50 mass%, or 15 to 40 mass%.

[0074] The preparation means, conditions, and the like of the photosensitive resin composition are not particularly limited. For example, a method in which the respective main components are sufficiently uniformly stirred and mixed in predetermined blending

amounts by a mixer or the like, and then kneaded by using a mixing roll, an extruding machine, a kneader, a roll, an extruder, or the like can be mentioned. The kneading method is not particularly limited.

5 [0075] The relative dielectric constant of the cured product of the photosensitive resin composition according to the present embodiment at 10 GHz may be 2.80 or less, 2.75 or less, or 2.70 or less. The dielectric loss tangent of the cured product of the photosensitive resin composition at 10 GHz may be 0.0060 or less, 0.0050 or less, 0.0045 or less, or 0.0040 or less. The relative dielectric constant and the dielectric loss tangent
10 can be measured by the method described in Examples using a cured film of the photosensitive resin composition.

[0076] The photosensitive resin composition according to the present embodiment can form a fine pattern. The photosensitive resin composition according to the present embodiment can form an insulating
15 film exhibiting low dielectric characteristics and excellent insulation reliability. A semiconductor element including an interlayer insulating layer formed using a cured product of the above-described photosensitive resin composition, and an electronic device including the semiconductor element can be produced. The semiconductor element
20 includes a redistribution layer containing the cured product of the photosensitive resin composition according to the present embodiment, such that high frequency characteristics can be improved. The semiconductor element may be, for example, a memory, a package, or the like having a multilayer wiring structure, a redistribution structure,
25 or the like. Examples of the electronic device include a mobile phone, a smartphone, a tablet terminal, a personal computer, and a hard disk

suspension. By including a patterned cured film formed of the photosensitive resin composition of the present embodiment, it is possible to provide a semiconductor element and an electronic device having excellent reliability.

5 [Examples]

[0077] Hereinafter, the present disclosure will be specifically described by way of Examples and Comparative Examples, but the present disclosure is not limited thereto. In each example, parts and % are based on mass unless otherwise specified.

10 [0078] [Synthesis of Maleimide Compound]

The following components (a1) to (a4), an acid catalyst, and a solvent were prepared in order to synthesize a maleimide compound.

(Component (a1))

15 BPAF: 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride
(manufactured by JFE Chemical Corporation, trade name "BPAF")

PMDA: pyromellitic anhydride (manufactured by Daicel Corporation)

ODPA: 4,4'-oxydiphthalic anhydride (manufactured by Manac Incorporated, trade name "ODPA")

20 s-BPDA: 3,3',4,4'-biphenyltetracarboxylic acid dianhydride
(manufactured by JFE Chemical Corporation, trade name "BPDA")

a-BPDA: 2,3',3,4'-biphenyltetracarboxylic acid dianhydride
(manufactured by JFE Chemical Corporation, trade name "a-BPDA")

(Component (a2))

25 DDA: dimer diamine (manufactured by Croda Japan K.K., trade name "PRIAMINE 1075")

mTBHG: 4,4'-diamino-2,2'-dimethylbiphenyl (manufactured by

- Wakayama Seika Kogyo Co., Ltd., trade name “m-TB-HG”)
 NBDA: norbornanedi-amine (manufactured by Mitsui Fine Chemicals, Inc.)
 (Component (a3))
- 5 TAEA: tris(2-aminoethyl)amine (manufactured by Tokyo Chemical Industry Co., Ltd.)
 (Component (a4))
 Maleic anhydride (manufactured by FUSO CHEMICAL CO., LTD.)
 (Acid catalyst)
- 10 Methanesulfonic acid aqueous solution (manufactured by BASF, trade name “Lutropur MSA”)
 (Solvent)
 Pseudocumene (manufactured by Toyo Gosei Co., Ltd., aromatic high-boiling solvent)
- 15 SOLMIX A-11 (manufactured by Japan Alcohol Trading Co., Ltd., alcoholic solvent)
 γ -Butyrolactone (manufactured by FUJIFILM Wako Pure Chemical Corporation)
 Toluene (manufactured by Yamaichi Chemical Industries Co., Ltd.)
- 20 N-Methyl-2-pyrrolidone (manufactured by FUJIFILM Wako Pure Chemical Corporation)
 [0079] (Synthesis Example 1)
- 25 Into a 0.3 L flask vessel equipped with a condenser, a nitrogen introducing tube, a thermocouple, and a stirrer, 18.48 parts by mass of 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride (BPAF), 8.8 parts by mass of pyromellitic anhydride (PMDA), 123.49 parts by mass of

pseudocumene, 33.45 parts by mass of SOLMIX A-11, and 29.94 parts by mass of γ -butyrolactone were introduced. After the introduction, the temperature was raised to 80°C, the mixture was kept warm for 0.5 hours, 25.98 parts by mass of a dimer diamine (DDA) was added dropwise, then 1.05 parts by mass of tris(2-aminoethyl)amine (TAEA) was added dropwise, and then 10.28 parts by mass of 4,4'-diamino-2,2'-dimethylbiphenyl (mTBHG) was added. After the addition, 2.69 parts by mass of a methanesulfonic acid aqueous solution was added, and the temperature was raised to 160°C. After raising the temperature, 40.00 parts by mass of toluene was added, and a dehydration ring-closing reaction was performed at 160°C for 3 hours to remove water and alcohol in the reaction solution, thereby obtaining an intermediate polyimide. Subsequently, the polyimide was cooled to 130°C, 7.93 parts by mass of maleic anhydride was added, the temperature was raised to 160°C, a dehydration ring-closing reaction was performed at 160°C for 4 hours, and water in the reaction solution was removed, thereby obtaining a maleimide compound.

[0080] The maleimide compound was placed in a separatory funnel, 500 parts by mass of pure water was added thereto, and the separatory funnel was shaken and allowed to stand. After the standing, an aqueous layer and an organic layer were separated, and then only the organic layer was recovered. The recovered organic layer was introduced into a 1 L glass vessel equipped with a condenser, a nitrogen introducing tube, a thermocouple, a stirrer, and a vacuum pump, the temperature was raised to 88 to 93°C, and then, water was removed. Thereafter, the temperature was raised to 100°C, and the solvent was partially removed for 0.5 hours

in a state where the pressure was reduced from the atmospheric pressure by 0.1 MPa, thereby obtaining a solution of a maleimide compound (A-1) as a component (A).

[0081] (Synthesis Examples 2 to 8)

5 Solutions of maleimide compounds (A-2) to (A-8) were obtained in the same manner as that of Synthesis Example 1, except that the blending amounts of the respective components were changed as shown in Table 1.

[0082] (Synthesis Example 9)

10 A solution of a maleimide compound (A-9) was obtained in the same manner as that of Synthesis Example 1, except that γ -butyrolactone was changed to N-methyl-2-pyrrolidone (NMP) and the blending amounts of the respective components were changed as shown in Table 1.

15 [0083] (Non-Volatile Content)

0.75 g $\pm$ 0.25 g of the solution of the maleimide compound was weighed on a metal petri dish with a precision balance, and then dried at 150°C for 0.5 hours with a hot air dryer, and the non-volatile content (NV) was calculated using the following equation.

20
$$NV \text{ (mass\%)} = \{(W3 - W1)/W2\} \times 100$$

W1: mass (g) of empty metal petri dish

W2: mass (g) of solution of maleimide compound before drying

W3: mass (g) of metal petri dish + maleimide compound after drying

25 [0084] (Solubility)

The solubility of the maleimide compound was evaluated by

placing the solution of the maleimide compound in a 20 mL screw tube and visually checking for the presence or absence of precipitates or turbidity. The solubility was evaluated as “A” when neither precipitates nor turbidity were observed in the solution of the maleimide compound, as “B” when no precipitates but turbidity was observed in the solution of the maleimide compound, and as “C” when precipitates were observed in the solution of the maleimide compound.

[0085] (Weight Average Molecular Weight)

The weight average molecular weight (Mw) of the maleimide compounds of Synthesis Examples 1 to 5, 7, and 8 was measured by GPC (gel permeation chromatography). 50 μ L of a sample obtained by dissolving the maleimide compound in tetrahydrofuran (THF) so as to have a concentration of 3 mass% was injected into columns (GL-R420 $\times$ 1, GL-R430 $\times$ 1, and GL-R440 $\times$ 1 (all manufactured by Hitachi High-Tech Fielding Corporation)) heated to 30°C, and the measurement was performed under the condition of a flow rate of 1.6 mL/min using THF as an eluent. As a detector, L-3350 RI detector (manufactured by Hitachi, Ltd.) was used, and the Mw was converted from the elution time by a molecular weight/elution time curve created using standard polystyrene (manufactured by Tosoh Corporation).

[0086] [Table 1]

Synthesis Example		1	2	3	4	5	6	7	8	9
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9
(a1)	PMDA	8.8	-	-	-	-	-	8.8	-	-
	s-BPDA	-	11.31	7.36	10.56	-	-	-	12.13	-
	a-BPDA	-	-	-	-	11.31	-	-	-	-
	BPAF	18.48	17.62	22.93	16.46	17.63	-	18.48	18.92	117.79
	ODPA	-	-	-	-	-	25.6	-	-	-
(a2)	DDA	25.98	24.76	24.19	24.78	24.77	29.53	27.57	41.33	104.70
	mTBHG	10.28	9.8	9.55	9.81	9.8	11.67	10.85	7.02	-
	NBDA	-	-	-	-	-	-	-	-	20.02
(a3)	TAEA	1.05	1.00	0.98	1.00	1.00	-	0.52	-	-
(a4)	Maleic anhydride	7.93	7.54	7.36	9.07	7.56	8.09	7.93	8.10	23.90
Acid catalyst	Methanesulfonic acid aqueous solution	2.69	2.57	2.51	2.56	2.58	1.48	2.70	1.49	4.40
Solvent	Pseudocumene	123.49	123.05	124.17	119.93	123.40	126.75	125.9	115.08	250.10
	SOLMIX A-11	33.45	37.69	32.58	32.16	33.90	28.32	33.6	28.71	107.40
	γ -Butyrolactone	29.94	29.74	33.21	30.58	29.73	30.14	33.25	30.07	-
	NMP	-	-	-	-	-	-	-	-	50.00
	Toluene	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	60.00
N.V. (mass%)		39.2	33.5	36.5	36.7	38.7	-	44.4	55.4	57.0
Mw		16800	19000	17700	13300	16400	-	12000	11200	9700
Solubility		A	A	A	A	A	C	A	B	A

[0087] The following compounds were prepared as component (B).

A-9300: tris(2-acryloyloxyethyl)isocyanurate (trade name, manufactured by SHIN-NAKAMURA CHEMICAL CO., LTD.)

TAIC: triallyl isocyanurate (trade name, manufactured by Shinryo Corporation)

A-DOG: dioxane glycol diacrylate (trade name, manufactured by SHIN-NAKAMURA CHEMICAL CO., LTD.)

[0088] The following compounds were prepared as the component (C),

the coupling agent, the polymerization inhibitor, the rust inhibitor, and the solvent.

Component (C): oxime ester-based photopolymerization initiator (manufactured by BASF Japan Ltd., trade name “Irgacure OXE01” and “Irgacure OXE02”)

Coupling agent: 3-methacryloxypropyltrimethoxysilane (manufactured by Shin-Etsu Chemical Co., Ltd., trade name “KBM-503”)

Polymerization inhibitor: 4-hydroxy-2,2,6,6-tetramethylpiperidine-1-oxy radical (TEMPOL) (manufactured by Tokyo Chemical Industry Co., Ltd.)

Rust inhibitor: 1,2,3-benzotriazole (manufactured by Johoku Chemical CO., LTD., trade name “BT-120”)

Solvent: mesitylene (manufactured by Toyo Gosei Co., Ltd.)

[0089] [Photosensitive Resin Composition]

For the maleimide compounds of Synthesis Examples 1 to 5 and 7 to 9, the respective components in the blending amounts (parts by mass, solid content) shown in Table 2 or Table 3 were mixed, and the mixture was stirred at 25°C for 30 minutes or longer and then filtered through a filter with a mesh size of 0.5 μm , thereby preparing photosensitive resin compositions of Examples and Comparative Examples.

[0090] (Tg)

The photosensitive resin composition was spin-coated onto a silicon wafer with a Cu sputtered film, and dried by heating at 90°C for 5 minutes to form a resin film having a thickness of 14 μm . Next, the resin film was subjected to pattern exposure using a mask aligner-

exposure machine (manufactured by MIKASA CO., LTD., trade name “MA-20”) under the condition of an exposure amount of 1000 mJ/cm² so as to form a resin film having a width of 10 mm, and then heated at 100°C for 1 minute. The exposed resin film was developed at 25°C for 30 seconds using a developer (a mixed solution of cyclopentanone and propylene glycol monomethyl ether acetate), washed with propylene glycol monomethyl ether acetate, and cured at 200°C for 2 hours under a nitrogen atmosphere. The silicon wafer on which the patterned cured film was formed was immersed in an ammonium persulfate aqueous solution, and the cured film was peeled off from the silicon wafer. The cured film was washed with pure water to obtain a strip-shaped resin film having a width of 10 mm. The resin film was cut to a length of 50 mm, and the T_g was measured using a dynamic viscoelasticity measuring apparatus (manufactured by TA Instruments Japan Inc., trade name “RSA G2”) under the conditions of a chuck distance of 20 mm and a measurement temperature range of -50 to 350°C.

[0091] (Adhesion)

The photosensitive resin composition was spin-coated onto a silicon wafer with a Cu sputtered film, and dried by heating at 90°C for 5 minutes to form a resin film. Next, the entire surface was exposed at an exposure amount of 1000 mJ/cm² using a mask aligner-exposure machine (MA-20), and then heated at 100°C for 1 minute. The silicon wafer on which the resin film was formed was heated at 200°C for 2 hours under a nitrogen atmosphere to form a cured film having a thickness of 5 μm on the silicon wafer. Using a cross-cut guide (manufactured by Kotec Ltd., trade name “CCJ-1”) and a cutter (NT

cutter eA-300), 11 slits were made in the cured film at 1 mm intervals in both the vertical and horizontal directions to form 100 grid squares. A cellophane tape (manufactured by Nichiban Co., Ltd., trade name “CT1535”) was firmly pressed onto the grid area, the tape was then peeled off, and the number of grid squares that remained without peeling was evaluated. The same evaluation was performed three times, and the average values of the evaluation results are shown in Tables 2 and 3.

[0092] (Photosensitive Characteristics)

The photosensitive resin composition of Example 1 was spin-coated onto a silicon wafer, and dried by heating at 90°C for 5 minutes to form a resin film having a thickness of 7 μm . Next, the resin film was subjected to pattern exposure using a mask aligner-exposure machine (MA-20) under the condition of an exposure amount of 1000 mJ/cm^2 , and then heated at 100°C for 1 minute. The silicon wafer on which the exposed resin film was formed was developed at 25°C for 15 seconds using a developer (a mixed solution of cyclopentanone and propylene glycol monomethyl ether acetate), and then washed with propylene glycol monomethyl ether acetate. The resin film after development was confirmed with a metallurgical microscope, and it was found that no cracks were generated and the photosensitive characteristics were excellent.

[0093] [Table 2]

Example		1	2	3	4	5	6	7	8
Component (A)	A-1	85	-	-	-	-	-	-	-
	A-2	-	85	-	-	-	-	-	-
	A-3	-	-	85	-	-	-	-	-
	A-4	-	-	-	85	-	-	-	-
	A-5	-	-	-	-	85	-	-	-
	A-7	-	-	-	-	-	70	70	70
Component (B)	A-9300	5	5	5	5	5	-	5	-
	TAIC	10	10	10	10	10	30	25	25
	A-DOG	-	-	-	-	-	-	-	5
Component (C)	OXE01	3	3	3	3	3	7	7	7
	OXE02	2	2	2	2	2	2	2	2
Coupling agent		1.7	1.7	1.7	1.7	1.7	5.1	5.1	5.1
Polymerization inhibitor		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Rust inhibitor		1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Solvent		218	218	218	218	218	230	230	230
Tg (°C)		182	178	185	185	177	166	166	164
Adhesion		100	100	100	100	100	100	100	100

[0094] [Table 3]

Comparative Example		1	2
Component (A)	A-8	85.0	-
	A-9	-	85.0
Component (B)	A-9300	5.0	5.0
	TAIC	10.0	10.0
Component (C)	OXE01	3.0	3.0
	OXE02	2.0	2.0
Coupling agent		1.7	1.7
Polymerization inhibitor		0.27	0.27
Rust inhibitor		1.7	1.7
Solvent		218	218
Tg (°C)		116	142
Adhesion		20	100

CLAIMS

[Claim 1] A photosensitive resin composition comprising a maleimide compound; a crosslinking agent; and a photopolymerization initiator,

5 wherein the maleimide compound is a reaction product of a tetracarboxylic acid dianhydride (a1), a diamine (a2), a triamine (a3), and maleic anhydride (a4),

the tetracarboxylic acid dianhydride (a1) includes a tetracarboxylic acid dianhydride having an aromatic ring,

10 the diamine (a2) includes a dimer diamine and a second diamine other than the dimer diamine, and

at least one of the second diamine and the triamine includes an amine having an aromatic ring.

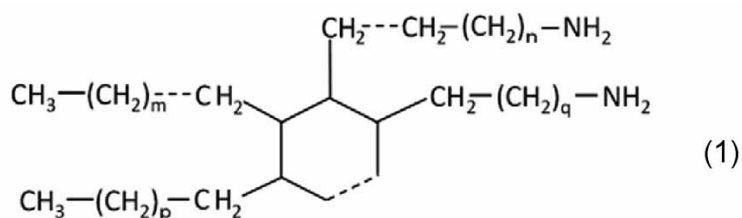
[Claim 2] The photosensitive resin composition according to claim 15 1, wherein the tetracarboxylic acid dianhydride having an aromatic ring contains at least one of pyromellitic anhydride, 4,4'-oxydiphthalic anhydride, 3,4'-oxydiphthalic anhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 2,3',3,4'-biphenyltetracarboxylic acid dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

[Claim 3] The photosensitive resin composition according to claim 25 1, wherein the amine having an aromatic ring is a diamine having an aromatic ring, and the diamine having an aromatic ring includes at least one of 4,4'-diamino-2,2'-dimethylbiphenyl, 4,4'-diamino-2,2'-diethylbiphenyl, 4,4'-diamino-3,3'-dimethylbiphenyl, 4,4'-diamino-3,3'-

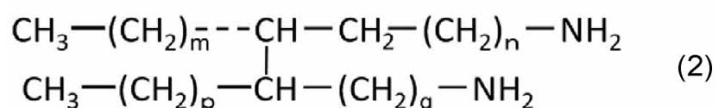
diethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetramethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetraethylbiphenyl, 4,4'-diamino-2,2'-bis(trifluoromethyl)biphenyl, 4,4'-diamino-2,2'-dimethoxybiphenyl, and 4,4'-diamino-3,3'-dimethoxybiphenyl.

5 [Claim 4] The photosensitive resin composition according to claim 1, wherein the dimer diamine contains at least one of a compound represented by the following general formula (1) and a compound represented by the following general formula (2):

[Chemical Formula 1]



[Chemical Formula 2]



wherein in formulae (1) and (2), m, n, p, and q each represent an integer of 1 or more selected such that m+n = 6 to 17 and p+q = 8 to 19, and a bond indicated by a dashed line means a carbon-carbon single bond or a carbon-carbon double bond. However, when the bond indicated by a dashed line is a carbon-carbon double bond, formulae (1) and (2) have a structure in which the number of hydrogen atoms bonded to each carbon atom constituting the carbon-carbon double bond is reduced by one from the number shown in formulae (1) and (2).

[Claim 5] The photosensitive resin composition according to claim 1, wherein a weight average molecular weight of the maleimide

compound is 3000 to 40000.

[Claim 6] The photosensitive resin composition according to claim 1, wherein the crosslinking agent includes a polymerizable crosslinking agent having a (meth)acryloyl group.

5 [Claim 7] The photosensitive resin composition according to claim 1, wherein the crosslinking agent includes a polymerizable crosslinking agent having an allyl group or a vinyl group.

[Claim 8] The photosensitive resin composition according to claim 1, further comprising a thermal polymerization initiator.

10 [Claim 9] A cured product of the photosensitive resin composition according to any one of claims 1 to 8.

[Claim 10] A semiconductor element having a redistribution layer comprising a cured product of the photosensitive resin composition according to any one of claims 1 to 8.

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