

DESCRIPTION

Title of Invention:

PHOTOSENSITIVE RESIN COMPOSITION, CURED OBJECT,
AND SEMICONDUCTOR ELEMENT

Technical Field

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

Background Art

[0002] As semiconductor elements become more highly integrated, miniaturized, and micronized, insulating films that are used in surface protective layers, interlayer insulating layers, rewiring layers, and the like are required to have more excellent electrical characteristics, heat resistance, mechanical characteristics, and the like. As a material for forming an insulating film that has such characteristics in a combined manner, photosensitive resin compositions containing alkali-soluble resins have been developed (see, for example, Patent Literatures 1, 2, and 3). When these photosensitive resin compositions are each applied on a substrate and dried to form a resin film, and the resin film is exposed to light and developed, a patterned resin film (a resin film on which a pattern is formed) is obtained. Then, by heating and curing the above-described patterned resin film, a patterned cured film (a cured film on which a pattern is formed) can be formed, and the patterned cured film can be used as an insulating film.

Citation List

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

5 Technical Problem

[0004] A photosensitive resin composition for forming an insulating film such as a rewiring layer is required to increase the glass transition temperature (T_g) of the insulating film while sufficiently maintaining microprocessability and dielectric characteristics. However, when the ratio of bulky structures in the polymer is increased in order to increase the T_g, the photosensitive characteristics (cracks occurring in the patterned resin film after development) may deteriorate. Thus, it is an object of the present disclosure to provide a photosensitive resin composition that can form an insulating film having excellent photosensitive characteristics.

Solution to Problem

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

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

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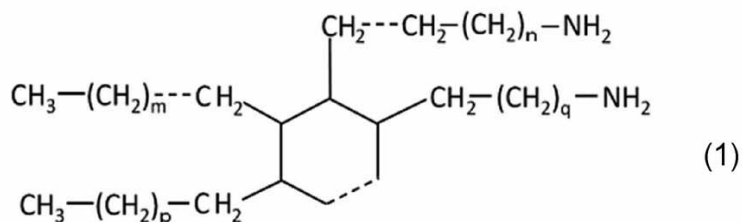
biphenyl skeleton.

[2] The photosensitive resin composition according to the above-described item [1], wherein the second amine contains 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.

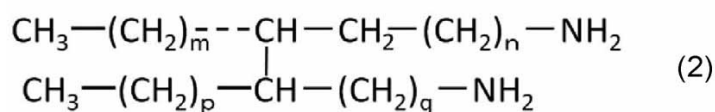
[3] The photosensitive resin composition according to the above-described item [1] or [2], wherein the tetracarboxylic acid dianhydride (a1) contains at least one of 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

[4] The photosensitive resin composition according to any one of the above-described items [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 Formulas (1) and (2), m, n, p, and q each represent an integer of 1 or greater 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; provided that when the bond indicated by a dashed line is a carbon-carbon double bond, Formulas (1) and (2) have a structure in which the number of hydrogen atoms bonded to each of the carbon atoms constituting the carbon-carbon double bond is one less than the number shown in Formula (1) or (2).

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

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

[7] The photosensitive resin composition according to any one of the above-described items [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 the above-described items [1] to [7], further containing a thermal polymerization initiator.

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

[10] A semiconductor element having a rewiring layer containing a cured product of the photosensitive resin composition according to any one of the above-described items [1] to [8].

Advantageous Effects of Invention

5 [0006] According to the present disclosure, a photosensitive resin composition that can form an insulating film having excellent photosensitive characteristics, a cured product of the photosensitive resin composition, and a semiconductor element having a rewiring layer containing the cured product can be provided.

Description of Embodiments

10 [0007] Hereinafter, a suitable embodiment of the present disclosure will be described in detail. However, the present invention is not limited to the following embodiments and can be carried out in various modified forms within the scope of the gist thereof.

15 [0008] In the present specification, a numerical value range indicated using the term “to” indicates a range including the numerical values described before and after the term “to” as the minimum value and the maximum value, respectively. With regard to a numerical value range described stepwise in the present specification, the upper limit value or
20 lower limit value of the numerical value range of a certain stage may be arbitrarily combined with the upper limit value or lower limit value of the numerical value range of another stage. With regard to a numerical value range described in the present specification, the upper limit value or lower limit value of the numerical value range may be replaced with
25 a value shown in the Examples. Regarding the phrase “A or B”, either A or B may be included, or both of them may be included. With regard

to the materials that will be described below as examples, unless particularly stated otherwise, one kind thereof can be used alone, or two or more kinds thereof can be used in combination. When there are a plurality of substances corresponding to each component in the composition, unless particularly stated otherwise, the content of each component in the composition means the total amount of the plurality of substances present in the composition.

[0009] In the present specification, the term “layer” and “film” include, when viewed in a plan view, a structure having a shape formed on the entire surface as well as a structure having a shape formed on a portion. 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, the term “(meth)acryloyl” means at least one of “acryloyl” and “methacryloyl” corresponding thereto, and the same also applies to other similar expressions such as (meth)acrylic acid and (meth)acrylate. In the present specification, the term “solid content” refers to a non-volatile content excluding volatile substances (water, solvent, and the like) included in the photosensitive resin composition and also includes components that are liquid, syrup-like, or wax-like at room temperature (near 25°C).

[0011] [Photosensitive resin composition]

A photosensitive resin composition according to the present embodiment contains a maleimide compound having a specific structure, a crosslinking agent, and a photopolymerization initiator as essential components. The maleimide compound is a reaction product of a

tetracarboxylic acid dianhydride (a1), an amine (a2), and maleic anhydride (a3), the amine (a2) includes a dimer diamine and a second amine other than a dimer diamine, and at least one of the tetracarboxylic acid dianhydride (a1) and the amine (a2) includes a compound having a biphenyl skeleton. The biphenyl skeleton may have a lower alkyl (for example, methyl, ethyl, or propyl) as a substituent.

[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 type photosensitive resin composition, and a cured product of the photosensitive resin composition can be suitably used as an insulating film for a rewiring layer. Hereinafter, each component used in the photosensitive resin composition of the present embodiment will be described in more detail.

[0013] (Maleimide compound)

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)”), an amine (a2) (hereinafter, also referred to as “component (a2)”), and maleic anhydride (a3) (hereinafter, also referred to as “component (a3)”). That is, the component (A) is a maleimide compound obtained by reacting the component (a1), component (a2), and component (a3). Here, the above-described component (a2) includes a dimer diamine and a second amine other than a dimer diamine. Furthermore, at least one of the above-described

component (a1) and the above-described component (a2) includes a compound having a biphenyl skeleton. The component (A) may have a plurality of maleimide groups in the molecule. The component (A) may be a bismaleimide compound. The component (A) can be used singly or in combination of two or more kinds thereof.

[0014] Examples of the compound having a biphenyl skeleton include tetracarboxylic acid dianhydrides such as 3,3',4,4'-biphenyltetracarboxylic acid dianhydride; and diamines 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. The compound having a biphenyl skeleton may be an amine having a biphenyl skeleton.

[0015] As the tetracarboxylic acid dianhydride of the component (a1), any compound known as a raw material of polyimide can be used. Examples of the component (a1) include pyromellitic anhydride, 4,4'-(hexafluoroisopropylidene)diphthalic anhydride, 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 4,4'-oxydiphthalic anhydride, 3,3',4,4'-diphenylsulfonetetracarboxylic acid dianhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 3,3',4,4'-benzophenonetetracarboxylic acid dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 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, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, 4,4'-(ethyne-1,2-diyl)diphthalic anhydride, 5-(2,5-dioxotetrahydrofuryl)-3-methyl-3-cyclohexene-1,2-dicarboxylic acid anhydride, dicyclohexyl-3,4,3',4'-tetracarboxylic acid dianhydride, 3,4'-oxydiphthalic anhydride, 3,4'-biphthalic anhydride, norbornane-2-spiro- α -cyclopentanone- α' -spiro-2"-norbornane-5,5'',6,6''-tetracarboxylic acid dianhydride, 5,5'-bis-2-norbornene-5,5',6,6'-tetracarboxylic acid-5,5',6,6'-dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

[0016] From the viewpoint of low dielectric characteristics or high T_g, it is preferable that the component (a1) contains at least one selected from the group consisting of 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 4,4'-(hexafluoroisopropylidene)diphthalic anhydride, 5-(2,5-dioxotetrahydrofuryl)-3-methyl-3-cyclohexene-1,2-dicarboxylic acid dianhydride, dicyclohexyl-3,4,3',4'-tetracarboxylic acid dianhydride, bicyclo[2.2.2]octane-2,3,5,6-tetracarboxylic acid 2,3:5,6-dianhydride, 5,5'-bis-2-norbornene-5,5',6,6'-tetracarboxylic acid-5,5',6,6'-dianhydride, 3,4'-biphthalic anhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride; it is more preferable

that the component (a1) contains at least one selected from the group consisting of 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, 4,4'-(4,4'-isopropylidenediphenoxy)diphthalic anhydride, 4,4'-(hexafluoroisopropylidene)diphthalic anhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride; and it is more preferable that the component (a1) contains at least one of 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

[0017] The component (a2) contains a dimer diamine (first amine) and a second amine other than a dimer diamine.

[0018] The dimer diamine is a compound derived from dimer acid, which is a dimer of an unsaturated fatty acid such as oleic acid, as described in, for example, Japanese Unexamined Patent Publication No. H9-12712. By using a dimer diamine as the component (a2), the dielectric characteristics of the cured product can be lowered. In the present embodiment, any known dimer diamine can be used without particular limitation. It is preferable that the dimer diamine includes, for example, at least one of a compound represented by the following general Formula (1) and a compound represented by the following general Formula (2).

[0019] [Chemical Formula 3]

[0023] The second amine is an amine that does not fall under the category of the above-mentioned dimer diamine. The second amine may be a diamine or a triamine, or may be a diamine. By using an alicyclic diamine as the second amine, the dielectric constant can be further lowered. By using an aromatic diamine as the second amine, the elastic modulus and Tg of the cured product can be improved.

[0024] Examples of the second amine include 1,3-diaminopropane, norbornanediamine, 4,4'-methylenedianiline, 1,3-bis[2-(4-aminophenyl)-2-propyl]benzene, 4,4'-diamino-2,2'-bis(trifluoromethyl)biphenyl, 2,2-bis[4-(4-aminophenoxy)phenyl]hexafluoropropane, 9,9-bis(4-aminophenyl)fluorene, 9,9-bis[4-(4-aminophenoxy)phenyl]fluorene, 1,3-bis(aminomethyl)cyclohexane, 1,4-bis(aminomethyl)cyclohexane, bis(aminomethyl)norbornane, 4,4'-(hexafluoroisopropylidene)dianiline, 3(4),8(9)-bis(aminomethyl)tricyclo[5.2.1.0^{2,6}]decane, 1,3-cyclohexanediamine, 1,4-cyclohexanediamine, isophoronediamine, 4,4'-methylenebis(cyclohexylamine), 4,4'-methylenebis(2-methylcyclohexylamine), 1,1-bis(4-aminophenyl)cyclohexane, 2,7-diaminofluorene, 4,4'-ethylenedianiline, 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, 4,4'-bis(4-aminophenoxy)biphenyl, 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'-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'-dimethoxybiphenyl, 4,4'-diamino-3,3'-dimethoxybiphenyl, (4,4'-diamino)diphenyl ether, (3,3'-diamino)diphenyl ether, para-phenylenediamine, ortho-phenylenediamine, meta-phenylenediamine, bis[4-(3-aminophenoxy)phenyl]sulfone, and bis[4-(4-aminophenoxy)phenyl]sulfone.

[0025] From the viewpoints of photosensitive characteristics and adhesion, it is preferable that the second amine contains 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.

[0026] In the component (a2), the molar ratio of the second amine with respect to the total amount of the diamines (number of moles of second amine/(number of moles of dimer diamine + number of moles of second amine)) may be 70 mol% or less or may be 50 mol% or less. When this ratio is 70 mol% or less, the dielectric characteristics of the cured product can be further lowered.

[0027] By using the dimer diamine as the amine, the dielectric characteristics of the cured product can be lowered. On the other hand, by using only the dimer diamine as the amine, the elastic modulus and Tg of the cured product are decreased. In contrast, by using the second

amine in combination with the dimer diamine, the elastic modulus and Tg of the cured product can be improved while maintaining the dielectric characteristics of the cured product.

5 [0028] The component (a2) may include a triamine. Examples of the triamine include tris(2-aminomethyl)amine, tris(2-aminoethyl)amine, tris(2-aminopropyl)amine, 2-(aminomethyl)-2-methyl-1,3-propanediamine, trimer triamine, 3,4,4'-triaminodiphenyl ether, 1,2,4-triaminobenzene, 1,3,5-triaminobenzene, 1,2,3-triaminobenzene, 1,3,5-triazine-2,4,6-triamine, 2,4,6-triaminopyrimidine, 1,3,5-tris(4-aminophenyl)benzene, and 1,3,5-tri(4-aminophenoxy)benzene. Among
10 these, from the viewpoint of the solubility of the synthesized component (A) in organic solvents, an aliphatic triamine is preferred, and furthermore, tris(2-aminomethyl)amine and tris(2-aminoethyl)amine, which have a small number of carbon atoms, are more preferred from
15 the viewpoint of obtaining a higher Tg.

[0029] At least one of the above-mentioned component (a1) and component (a2) includes a compound having a biphenyl skeleton. When at least one of the component (a1) and component (a2) constituting the maleimide compound includes a compound having a biphenyl skeleton,
20 a cured product obtained by using the maleimide compound has excellent photosensitive characteristics while a low dielectric constant and a low dielectric loss tangent are sufficiently maintained. From the viewpoint of obtaining a high Tg, it is preferable that the component (a2) includes a diamine having a biphenyl skeleton.

25 [0030] The component (A) can be produced by various known methods. For example, first, the component (a1) and the component (a2) are

subjected to a polyaddition reaction at a temperature of about 60°C to 120°C, and preferably 70°C to 90°C, usually for about 0.1 to 2 hours, and preferably 0.1 to 1.0 hours. Next, the obtained polyaddition product is further subjected to an imidation reaction, that is, a dehydration ring-closing reaction, at a temperature of about 80°C to 250°C, and preferably 100°C 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 (a3) are subjected to a maleimidation reaction, that is, a dehydration ring-closing reaction, at a temperature of about 60°C to 250°C, and preferably 80°C to 200°C, for about 0.5 to 30 hours, and preferably 0.5 to 10 hours, and thereby the intended component (A) is obtained.

[0031] In the imidation reaction or maleimidation reaction, various known reaction catalysts, dehydrating agents, and solvents can be used.

[0032] Examples of the reaction catalysts include aliphatic tertiary amines such as triethylamine; aromatic tertiary amines such as dimethylaniline; heterocyclic tertiary amines such as pyridine, picoline, and isoquinoline; and organic acids such as methanesulfonic acid and paratoluenesulfonic acid monohydrate. Examples of the dehydrating agents include aliphatic acid anhydrides such as acetic anhydride; and aromatic acid anhydrides such as benzoic anhydride.

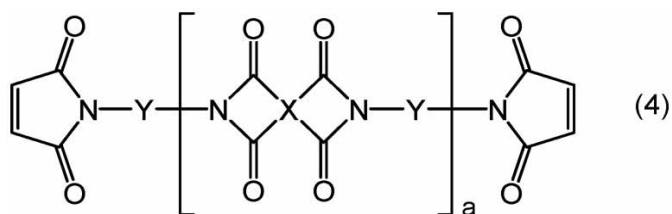
[0033] Examples of the organic solvents include aromatic hydrocarbon-based solvents such as benzene, toluene, xylene, mesitylene, and pseudocumene; alcohol-based solvents such as methanol, ethanol, isopropyl alcohol, butanol, pentanol, hexanol, propanediol, and phenol; ketone-based solvents such as acetone, methyl isobutyl ketone, methyl

ethyl ketone, pentanone, hexanone, 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 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 organic solvents can be used singly or in combination of two or more kinds thereof.

[0034] 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 left to stand still. Subsequently, after an aqueous layer and an organic layer are separated, the component (A) can be purified by collecting only the organic layer.

[0035] The assumed structure of the component (A) produced by the above-described method is represented by the following general Formula (4). The general Formula (4) is an assumption that the second amine is a diamine.

[Chemical Formula 6]



[0036] In the general Formula (4), X's each independently represents a tetravalent organic group; Y's each independently represent a divalent organic group; and a represents an integer of 1 or greater. However, at least one of a plurality of Y's present in the formula represents a divalent organic group derived from the above-mentioned dimer diamine, while at least one of a plurality of Y's present in the formula represents a divalent organic group derived from the above-mentioned second amine. Furthermore, X and Y may be each an aliphatic group or an organic group having an alicyclic structure or an aromatic ring, and those may contain a heteroatom. However, at least one of X and Y represents a tetravalent organic group having a biphenyl skeleton.

[0037] The molecular weight of the component (A) can be controlled by the number of moles of the component (a1) and the component (a2), and as the number of moles of the component (a1) is smaller than the number of moles of the component (a2), the molecular weight can be made smaller. For the purpose of easily achieving the effects of the present disclosure, usually, the number of moles of the component (a1) with respect to 1 mole of the component (a2), that is, [number of moles of component (a1)]/[number of moles of component (a2)], is in the range of about 0.30 to 0.98, preferably 0.40 to 0.96, more preferably 0.50 to 0.94, and even more preferably 0.60 to 0.90.

[0038] From the viewpoints of solubility in organic solvents and heat resistance, the molecular weight of the component (A) as the weight

average molecular weight (Mw) is preferably 3000 to 40000, and may be 4000 to 30000, 5000 to 28000, 7000 to 27000, 7500 to 25000, 8000 to 23000, or 8500 to 20000. When the weight average molecular weight is 40000 or less, the solubility in organic solvents is improved, and when the weight average molecular weight is 3000 or more, a sufficient effect of improving heat resistance tends to be obtained. The Mw can be measured by gel permeation chromatography (GPC) and calculated using a calibration curve of polystyrene standards.

[0039] (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 may be a thermally polymerizable group. Examples of the polymerizable group include a (meth)acryloyl group, an allyl group, and a vinyl group. The compound (B) may be a polyfunctional compound having two or more polymerizable groups. Furthermore, the component (B) can be crosslinked not only to other crosslinking agent molecules but also to the component (A) when the photosensitive layer is exposed to light. Furthermore, the component (B) can be crosslinked to, for example, other polymerizable crosslinking agent molecules when the resin film after pattern formation is heated. The component (B) can be used singly or in combination of two or more kinds thereof.

[0040] From the viewpoint of dielectric characteristics, the resin composition according to the present embodiment may contain a polymerizable crosslinking agent having a (meth)acryloyl group as the crosslinking agent. The polymerizable crosslinking agent having a

(meth)acryloyl group can be crosslinked not only to other crosslinking agent molecules but also to the component (A) when the photosensitive layer is exposed to light. The polymerizable crosslinking agent having a (meth)acryloyl group may be an acrylate compound or a methacrylate compound. From the viewpoint of dielectric characteristics, the component (B) may include a methacrylate compound.

[0041] Examples of the polymerizable crosslinking agent having a (meth)acryloyl group include di(meth)acrylate compounds having two (meth)acryloyl groups, such as tricyclodecane dimethanol di(meth)acrylate, dioxane glycol di(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 di(meth)acrylate, polyethylene glycol di(meth)acrylate, and polypropylene glycol di(meth)acrylate; and (meth)acrylate compounds having three or more (meth)acryloyl groups, such as tris(2-(meth)acryloyloxyethyl) isocyanurate, ethoxylated isocyanuric acid tri(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, dipentaerythritol poly(meth)acrylate, and alkoxylated dipentaerythritol poly(meth)acrylate.

[0042] From the viewpoints of heat resistance, dielectric characteristics, and microprocessability, 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, or may include tris(2-(meth)acryloyloxyethyl) isocyanurate from the viewpoints of heat resistance and dielectric characteristics.

[0043] From the viewpoints of photosensitive characteristics and dielectric characteristics, the polymerizable crosslinking agent having a (meth)acryloyl group may include a di(meth)acrylate compound. From the viewpoints of photosensitive characteristics and dielectric characteristics, the di(meth)acrylate compound may be 1,6-hexanediol di(meth)acrylate, 1,9-nonanediol di(meth)acrylate, or 1,10-decanediol di(meth)acrylate. From the viewpoints of photosensitive characteristics and dielectric characteristics, the polymerizable crosslinking agent having a (meth)acryloyl group may include dioxane glycol di(meth)acrylate or may include dioxane glycol dimethacrylate.

[0044] The resin composition according to the present embodiment may contain a polymerizable crosslinking agent having an allyl group or a vinyl group as the 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 to other polymerizable crosslinking agent molecules when the resin film after pattern formation is heated.

[0045] 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.

[0046] Examples of the polymerizable crosslinking agent having a vinyl group include a polyvinylbenzyl compound and a polyvinylbenzyl ether compound.

5 [0047] From the viewpoints of dielectric characteristics and microprocessability, 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, or may include triallyl isocyanurate from the viewpoint of dielectric
10 characteristics.

[0048] From the viewpoint of further improving the balance between low dielectric characteristics and microprocessability, the 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, 6 to 35 parts by mass, 8 to 30
15 parts by mass, 9 to 25 parts by mass, or 10 to 20 parts by mass, when the total amount of the component (A) and component (B) is 100 parts by mass.

[0049] (Photopolymerization initiator)

20 The photopolymerization initiator (hereinafter, also referred to as “component (C)”) is not particularly limited as long as it is a compound that initiates polymerization when irradiated with actinic light rays (ultraviolet rays or the like), and examples thereof include an alkylphenone-based photopolymerization initiator, an acylphosphine oxide-based photopolymerization initiator, an intramolecular hydrogen-
25 withdrawing type photopolymerization initiator, and an oxime ester-based photopolymerization initiator.

[0050] 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, and Omnirad 379EG manufactured by IGM Resins B.V. The acylphosphine oxide-based photopolymerization initiator can be purchased as, for example, Omnirad 819 and Omnirad TPO H manufactured by IGM Resins B.V. The intramolecular hydrogen-withdrawing type photopolymerization initiator can be purchased as, for example, Omnirad MBF and Omnirad 754 manufactured by IGM Resins B.V. The oxime ester-based photopolymerization initiator can be purchased as, for example, Irgacure OXE01 and Irgacure OXE02 manufactured by BASF Japan, Ltd. In order to accelerate a photoreaction, a titanocene-based photopolymerization initiator (for example, Irgacure 784 manufactured by BASF Japan, Ltd.) may be used in combination.

[0051] From the viewpoint that excellent microprocessability is likely to be obtained, the content of the component (C) may be 0.1 to 10 parts by mass, 0.3 to 9.0 parts by mass, 0.5 to 8.0 parts by mass, 0.8 to 7.0 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 component (B).

[0052] (Thermal polymerization initiator)

From the viewpoint of accelerating a polymerization reaction of a thermally polymerizable crosslinking agent, the photosensitive resin composition according to the present embodiment may further contain a thermal polymerization initiator as a component (D). The component (D) is preferably a compound that decomposes when heated during curing to generate radicals and accelerates a polymerization reaction

between the component (A) and the component (B). Examples of the component (D) include an organic peroxide.

[0053] Examples of the organic peroxide include methyl ethyl ketone peroxide, methyl cyclohexanone peroxide, methyl acetoacetate peroxide, acetyl acetone 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-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-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, isobutylidene peroxide, 3,5,5-trimethylhexanoyl peroxide, octanoyl peroxide, lauroyl peroxide, cinnamic acid peroxide, 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' -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-ethylhexanoylperoxy)hexane, 1,1,3,3-tetramethylbutyl peroxy-2-ethylhexanoate, 1-cyclohexyl-1-methylethyl peroxy-2-ethylhexanoate, t-hexyl peroxy-2-ethylhexanoate, t-butyl peroxy-2-ethylhexanoate, t-butyl peroxyisobutyrate, t-butyl peroxy maleic acid, t-butyl peroxy laurate, t-butyl peroxy-3,5,5-trimethylhexanoate, t-butyl peroxyisopropyl monocarbonate, t-butyl peroxy-2-ethylhexyl monocarbonate, 2,5-dimethyl-2,5-bis(benzoylperoxy)hexane, t-butyl peroxyacetate, t-hexyl peroxybenzoate, t-butyl peroxy-m-toluoyl benzoate, t-butyl peroxybenzoate, bis(t-butylperoxy) isophthalate, t-butyl peroxyallyl monocarbonate, and 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone.

[0054] The content of the component (D) is not particularly limited but may be 0.1 to 10.0 parts by mass, 0.5 to 5.0 parts by mass, 0.6 to 4.0 parts by mass, or 0.7 to 3.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and component (B).

[0055] (Coupling agent)

From the viewpoint of improving the adhesion of a cured product of the photosensitive resin composition, the photosensitive resin composition according to the present embodiment may further contain a coupling agent. 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.

[0056] Examples of a silane coupling agent having a vinyl group include

KBM-1003 and KBE-1003 (trade names manufactured by Shin-Etsu Chemical Co., Ltd.; hereinafter, the same). Examples of a silane coupling agent having an epoxy group include KBM-303, 402, 403, KBE-402, 403, X-12-981S, and X-12-984S. Examples of a silane coupling agent having a styryl group include KBM-1403. Examples of a silane coupling agent having a methacryloyl group include KBM-502, KBM-503, KBE-502, and KBE-503. Examples of a silane coupling agent having an acryloyl group include KBM-5103, X-12-1048, and X-12-1050. Examples of a silane coupling agent having an amino group include KBM-602, 603, 903, 573, 575, KBE-903, 9103P, and X-12-972F. Examples of a silane coupling agent having a ureido group include KBE-585. Examples of a silane coupling agent having an isocyanate group include KBE-9007 and X-12-1159L. Examples of a silane coupling agent having an isocyanurate group include KBM-9659. Examples of a silane coupling agent having a mercapto group include KBM-802, 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 agent can be used singly or in combination of two or more kinds thereof.

[0057] The content of the silane coupling agent may be 0.01 to 10 parts by mass, 0.1 to 8.0 parts by mass, 0.2 to 7.0 parts by mass, 0.3 to 6.0 parts by mass, or 0.5 to 5.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and component (B).

[0058] (Rust inhibitor)

From the viewpoint of suppressing corrosion of copper wiring or preventing discoloration of copper wiring, the photosensitive resin

composition according to the present embodiment may further contain a rust inhibitor. Examples of the rust inhibitor include a triazole derivative such as benzotriazole, and a tetrazole derivative. Regarding the rust inhibitor, one kind thereof may be used alone, or two or more kinds thereof may be used in combination.

[0059] The content of the rust inhibitor may be 0.01 to 10 parts by mass, 0.1 to 5.0 parts by mass, 0.3 to 4.0 parts by mass, or 0.5 to 3.0 parts by mass, with respect to 100 parts by mass of the total amount of the component (A) and component (B).

[0060] (Polymerization inhibitor)

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

[0061] 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-toluiquinone, tannic acid, para-benzylaminophenol, tris(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)isocyanuric acid, and nitrosoamine. Regarding the polymerization inhibitor, one kind thereof may be used alone, or two or more kinds thereof may be used in combination.

[0062] The content of the polymerization inhibitor may be 0.01 to 10 parts by mass, 0.05 to 5.0 parts by mass, 0.10 to 2.0 parts by mass, or 0.15 to 1.0 part by mass, with respect to 100 parts by mass of the total

amount of the component (A) and component (B).

[0063] (Photosensitizer)

From the viewpoint of achieving both the maintenance of the residual film ratio over a wide range of exposure amounts and satisfactory resolution, the photosensitive resin composition may further contain a sensitizer.

[0064] 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, diacetylbenzil, benzyl dimethyl ketal, benzyl diethyl ketal, diphenyl disulfide, anthracene, phenanthrenequinone, riboflavin tetrabutyrates, acridine orange, erythrosine, 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, 3-ketocoumarin compound, biscoumarin compound, N-phenylglycine, N-phenyldiethanolamine, and 3,3',4,4'-tetra(t-butylperoxycarbonyl)benzophenone. The sensitizer may be used singly or in combination of two or more kinds thereof.

[0065] 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 component (A).

[0066] (Solvent)

When the photosensitive resin composition according to the present embodiment contains a solvent for dissolving or dispersing each component, application on a substrate can be facilitated, and a coating film having a uniform thickness can be formed. Regarding the solvent, one kind thereof may be used alone, or two or more kinds thereof may be used in combination.

[0067] 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, and carbitol acetate; and amide-based solvents such as N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, 3-methoxy-N,N-dimethylpropanamide, and 3-butoxy-N,N-dimethylpropanamide.

[0068] The blending amount of the solvent is not particularly limited but may be an amount such that the solid content in the photosensitive resin composition is 5% to 60% by mass, 10% to 50% by mass, or 15% to 40% by mass.

[0069] The means, conditions, and the like for the preparation of the photosensitive resin composition are not particularly limited. For example, a method of stirring and mixing each main component in a predetermined blending amount sufficiently uniformly using a mixer or the like, and then kneading the mixture using a mixing roll, an extruding machine, a kneader, a roll, an extruder, or the like, may be mentioned. The kneading method is not particularly limited.

[0070] The relative dielectric constant at 10 GHz of a cured product of the photosensitive resin composition according to the present embodiment may be 2.80 or less, 2.75 or less, or 2.70 or less. The dielectric loss tangent at 10 GHz of a cured product of the photosensitive resin composition 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 can be measured by the method described in the Examples, using a cured film of the photosensitive resin composition.

[0071] The photosensitive resin composition according to the present embodiment is capable of forming a fine pattern. The photosensitive resin composition according to the present embodiment is capable of forming an insulating film that exhibits low dielectric characteristics and also has excellent insulation reliability. A semiconductor element including an interlayer insulating layer formed from a cured product of the above-mentioned photosensitive resin composition, and an electronic device including the semiconductor element can be produced. The semiconductor element can have improved high frequency characteristics by having a rewiring layer containing a cured product of the photosensitive resin composition according to the present

embodiment. The semiconductor element may be, for example, a memory, a package, or the like, which has a multilayer wiring structure, a rewiring structure, or the like. Examples of the electronic device include a mobile phone, a smartphone, a tablet type terminal, a personal computer, and a hard disk suspension. By providing a patterned cured film formed from the photosensitive resin composition of the present embodiment, a semiconductor element and an electronic device having excellent reliability can be provided.

Examples

[0072] Hereinafter, the present disclosure will be described in more detail by way of Examples; however, the present invention is not intended to be limited to these Examples.

[0073] [Synthesis of maleimide compound]

In order to synthesize a maleimide compound, the following components (a1) to (a3), an acid catalyst, and a solvent were prepared.

(Component (a1))

BPAF: 9,9-Bis(3,4-dicarboxyphenyl)fluorenic dianhydride
(manufactured by JFE Chemical Corporation, trade name "BPAF")

PMDA: Pyromellitic anhydride (manufactured by Daicel Corporation)

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

(Component (a2))

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")

TAEA: Tris(2-aminoethyl)amine (manufactured by Tokyo Chemical Industry Co., Ltd.)

(Component (a3))

Maleic anhydride (manufactured by Fuso Chemical Co., Ltd.)

5 (Acid catalyst)

Aqueous solution of methanesulfonic acid (manufactured by BASF SE, trade name "Lutropur MSA")

(Solvent)

10 Pseudocumene (manufactured by Toyo Gosei Co., Ltd., aromatic high-boiling point solvent)

SOLMIX A-11 (manufactured by Japan Alcohol Trading Co., Ltd., alcohol-based solvent)

Toluene (manufactured by Yamaichi Chemical Industries Co., Ltd.)

15 γ -Butyrolactone (manufactured by FUJIFILM Wako Pure Chemical Corporation)

[0074] (Synthesis Example 1)

20 29.22 parts by mass of 9,9-bis(3,4-dicarboxyphenyl)fluorenic dianhydride (BPAF), 125.71 parts by mass of pseudocumene, 26.95 parts by mass of SOLMIX A-11, and 29.00 parts by mass of γ -butyrolactone were introduced into a 0.3-L flask container equipped with a condenser, a nitrogen inlet tube, a thermocouple, and a stirrer. After the introduction, the temperature was raised to 80°C and kept at that temperature for 0.5 hours, 31.95 parts by mass of dimer diamine (DDA) was added dropwise thereto, and then 5.41 parts by mass of 4,4'-diamino-2,2'-dimethylbiphenyl (mTBHG) was added thereto. After the

25 addition, 1.63 parts by mass of an aqueous solution of methanesulfonic

acid was added thereto, and the temperature was raised to 160°C. After the temperature rise, 40.00 parts by mass of toluene was added to the mixture, a dehydration ring-closing reaction was carried out at 160°C for 1 hour, water and alcohol in the reaction liquid were removed, and a polyimide resin as an intermediate was obtained. Subsequently, the polyimide resin was cooled to 130°C, 6.25 parts by mass of maleic anhydride was added thereto, the temperature was raised to 160°C, a dehydration ring-closing reaction was carried out at 160°C for 4 hours, water in the reaction liquid was removed, and a maleimide compound was obtained.

[0075] The maleimide compound was placed in a separatory funnel, 500 parts by mass of pure water was introduced therein, and the separatory funnel was shaken to mix the contents and allowed to stand still. After the standing, an aqueous layer and an organic layer were separated, and then only the organic layer was collected. The collected organic layer was introduced into a 1-L glass container equipped with a condenser, a nitrogen inlet tube, a thermocouple, a stirrer, and a vacuum pump, the temperature was raised to 88°C to 93°C, water was removed, subsequently the temperature was raised to 100°C, the solvent was partially removed for 0.5 hours at a pressure reduced by 0.1 MPa from the atmospheric pressure, and a solution of a maleimide compound (A-1) of the component (A) was obtained.

[0076] (Synthesis Examples 2 to 7)

Solutions of maleimide compounds (A-2) to (A-7) were obtained in the same manner as in Synthesis Example 1, except that the blending amount of each component was changed as shown in Table 1.

[0077] (Non-volatile content)

0.75 g $\pm$ 0.25 g of a solution of a maleimide compound was weighed out using a precision balance and placed in a metal Petri dish, the solution was dried in a hot air dryer at 150°C for 0.5 hours, and the non-volatile content (NV) was calculated from the following formula.

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

W1: Mass (g) of blank metal Petri dish

W2: Mass (g) of the solution of the maleimide compound before drying

W3: Mass (g) of the metal Petri dish + maleimide compound after drying

[0078] (Weight average molecular weight)

The weight average molecular weight (Mw) of a maleimide compound was measured by GPC (gel permeation chromatography). A sample was obtained by dissolving the maleimide compound in tetrahydrofuran (THF) to a concentration of 3% by mass, 50 μ L of the sample was injected into columns heated to 30°C (one unit of GL-R420, one unit of GL-R430, and one unit of GL-R440 (all manufactured by Hitachi High-Tech Fielding Corporation), and measurement was performed using THF as a developing solvent under the conditions of a flow rate of 1.6 mL/min. Incidentally, an L-3350 RI detector (manufactured by Hitachi, Ltd.) was used as the detector, and the Mw was calculated from the elution time based on a molecular weight/elution time curve created using polystyrene standards (manufactured by Tosoh Corporation).

[0079] [Table 1]

		A-1	A-2	A-3	A-4	A-5	A-6	A-7
Component (a1)	BPAF	29.22	18.88	19.77	18.91	20.46	18.48	18.48
	PMDA	-	-	9.41	9.00	9.73	8.80	8.80
	BPDA	-	12.12	-	-	-	-	-
Component (a2)	DDA	31.95	40.21	42.09	29.53	28.19	25.98	27.57
	mTBHG	5.41	6.82	7.13	11.68	11.15	10.28	10.85
	TAEA	-	-	-	-	-	1.052	0.52
Component (a3)	Maleic anhydride	6.25	7.87	8.24	8.09	4.63	7.93	7.93
Acid catalyst	Aqueous solution of methanesulfonic acid	1.63	2.06	2.15	2.11	1.21	3.84	3.86
Solvent	Pseudocumene	125.71	125	130.84	131.01	131.65	123.49	125.90
	SOLMIX A-11	26.95	27.87	29.18	29.11	28.99	33.45	33.60
	Toluene	40.00	40.00	40.00	40.00	40.00	40.00	40.00
	γ -Butyrolactone	29.00	31.00	31.00	30.00	30.00	29.94	33.25
NV (% by mass)		50.4	55.4	55.2	43.5	39.6	39.2	42.9
Mw		11500	11200	10800	9300	17300	16900	11900

[0080] The following compounds were prepared as the component (B).

A-9300: Tris(2-acryloyloxyethyl) isocyanurate (manufactured by Shin-Nakamura Chemical Co., Ltd., trade name)

5 TAIC: Triallyl isocyanurate (manufactured by Mitsubishi Chemical Corporation, trade name “TAIC”, number of allyl groups: 3)

A-DOD-N: 1,10-Decanediol diacrylate (manufactured by Shin-Nakamura Chemical Co., Ltd., trade name)

10 DOD-N: 1,10-Decanediol dimethacrylate (manufactured by Shin-Nakamura Chemical Co., Ltd., trade name)

A-DOG: Dioxane glycol diacrylate (manufactured by Shin-Nakamura Chemical Co., Ltd., trade name)

15 [0081] 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”)

5 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.)

10 [0082] [Photosensitive resin composition]

Each component in the blending amount (parts by mass, solid content) shown in Table 2 and 210 parts by mass of a solvent were mixed, and the mixture was stirred at 25°C for 30 minutes and then filtered through a filter having a pore size of 0.5 μm to prepare photosensitive resin compositions of Examples 1 to 6. Each component in the blending amount (parts by mass, solid content) shown in Table 3 and 210 parts by mass of a solvent were mixed, and the mixture was stirred at 25°C for 30 minutes and then filtered through a filter having a pore size of 0.5 μm to prepare photosensitive resin compositions of Examples 7 to 9.

20 [0083] (Tg)

A photosensitive resin composition was spin-coated on a silicon wafer with a Cu sputtered film and then heated and dried at 90°C for 5 minutes, and a resin film having a thickness of 14 μm was formed. Next, the resin film was exposed to light in a patterned manner using a mask aligner exposure machine (manufactured by Mikasa Co., Ltd., MA-20) under the conditions of an exposure amount of 1000 mJ/cm² so as to

form a resin film having a width of 10 mm, and then the resin film was heated under the conditions of 100°C for 1 minute. The resin film after exposure was developed (immersed) using a developing solution (mixed liquid of cyclopentanone and propylene glycol monomethyl ether acetate) at 25°C for 30 seconds, subsequently washed with propylene glycol monomethyl ether acetate, and cured at 200°C for 2 hours in a nitrogen atmosphere. The silicon wafer on which a patterned cured film was formed was immersed in an aqueous solution of ammonium persulfate, and the cured film was peeled from the silicon wafer. The cured film was washed with pure water, and a strip-shaped resin film having a width of 10 mm was obtained. 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 distance between chucks of 20 mm and a measurement temperature range of -50°C to 350°C.

[0084] (Photosensitive characteristics)

A photosensitive resin composition was spin-coated on a silicon wafer and then heated and dried at 90°C for 5 minutes to form a resin film having a thickness of 7 μm. Next, the resin film was patternwise exposed using a mask aligner exposure machine (MA-20) under the conditions of an exposure amount of 1000 mJ/cm² and then heated under the conditions of 100°C for 1 minute. The silicon wafer on which the resin film after exposure was formed was developed (immersed) using a developer solution (mixed liquid of cyclopentanone and propylene glycol monomethyl ether acetate) at 25°C for 15 seconds and then

washed with propylene glycol monomethyl ether acetate. For the resin film after development, the presence or absence of cracks was checked with a metallurgical microscope. A case in which these defects could not be identified was rated as “A”, and a case in which defects were identified was rated as “B”.

[0085] (Adhesion)

A photosensitive resin composition was spin-coated on a silicon wafer with a Cu sputtered film and then heated and dried at 90°C for 5 minutes, and a resin film was formed. Next, the entire surface exposed using a mask aligner exposure machine (MA-20) under the conditions of an exposure amount of 1000 mJ/cm², and then the resin film was 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 in a nitrogen atmosphere, and a cured film having a thickness of 5 μm was formed on the silicon wafer. The silicon wafer on which the cured film was formed was introduced into an environment at a temperature of 121°C and a humidity of 100% for 100 hours, and a pressure cooker test (PCT test) was carried out. After the test, eleven cuts were made in the cured film horizontally and vertically at intervals of 1 mm using a crosscut guide (manufactured by Kotec, Ltd., trade name “CCJ-1”) and a cutter (NT Cutter eA-300), and 100 grids were created. Cellophane tape (manufactured by Nichiban Co., Ltd., trade name “CT1535”) was firmly pressure-bonded to the grid sections, and then the tape was ripped, and the number of grids that remained unpeeled was evaluated. The same evaluation was carried out three times, and the average values of the average results are described in Table 2.

[0086] [Table 2]

Example		1	2	3	4	5	6
Component (A)	A-1	85.0	-	-	-	-	-
	A-2	-	85.0	-	-	-	-
	A-3	-	-	85.0	-	-	-
	A-4	-	-	-	85.0	-	-
	A-5	-	-	-	-	85.0	-
	A-6	-	-	-	-	-	85.0
Component (B)	A-9300	5.0	5.0	5.0	5.0	5.0	5.0
	TAIC	10.0	10.0	10.0	10.0	10.0	10.0
Component (C)	OXE01	3.0	3.0	3.0	3.0	3.0	3.0
	OXE02	2.0	2.0	2.0	2.0	2.0	2.0
Coupling agent		1.7	1.7	1.7	1.7	1.7	1.7
Polymerization inhibitor		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
Tg(°C)		133	116	108	165	167	182
Photosensitive characteristics		A	A	A	A	A	A
Adhesion		99	80	91	97	100	100

[0087] [Table 3]

Example		7	8	9
Component (A)	A-7	80.0	80.0	70.0
Component (B)	TAIC	-	-	25.0
	A-DOD-N	20.0	-	-
	DOD-N	-	20.0	-
	A-DOG	-	-	5.0
Component (C)	OXE01	7.0	7.0	7.0
	OXE02	20.	2.0	2.0
Coupling agent		1.7	1.7	5.1
Polymerization inhibitor		0.25	0.25	0.25
Rust inhibitor		1.7	1.7	1.7
Tg(°C)		-	-	164
Photosensitive characteristics		A	A	A
Adhesion		-	-	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), an amine (a2), and maleic anhydride (a3),

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

10 at least one of the tetracarboxylic acid dianhydride (a1) and the amine (a2) includes a compound having a biphenyl skeleton.

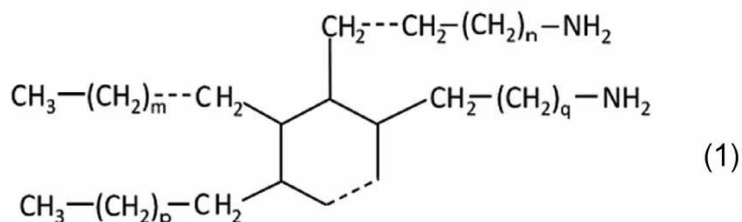
[Claim 2] The photosensitive resin composition according to claim 1, wherein the second amine contains at least one of 4,4'-diamino-2,2'-dimethylbiphenyl, 4,4'-diamino-2,2'-diethylbiphenyl, 4,4'-diamino-3,3'-dimethylbiphenyl, 4,4'-diamino-3,3'-diethylbiphenyl, 4,4'-diamino-3,3',5,5'-tetramethylbiphenyl, 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.

[Claim 3] The photosensitive resin composition according to claim 1, wherein the tetracarboxylic acid dianhydride (a1) contains at least one of 3,3',4,4'-biphenyltetracarboxylic acid dianhydride, 1,3,3a,4,5,9b-hexahydro-5(tetrahydro-2,5-dioxo-3-furanyl)naphtho[1,2-C]furan-1,3-dione, 9,9-bis(3,4-dicarboxyphenyl)fluorene dianhydride, and 9,9-bis[4-(3,4-dicarboxyphenoxy)phenyl]fluorene dianhydride.

25 [Claim 4] The photosensitive resin composition according to claim 1, wherein the dimer diamine contains at least one of a compound

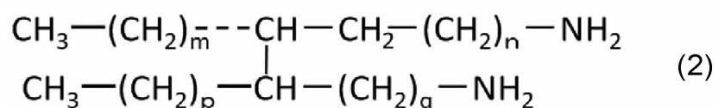
represented by the following general Formula (1) and a compound represented by the following general Formula (2):

[Chemical Formula 1]



5

[Chemical Formula 2]



wherein in Formulas (1) and (2), m, n, p, and q each represent an integer of 1 or greater 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; provided that when the bond indicated by a dashed line is a carbon-carbon double bond, Formulas (1) and (2) have a structure in which the number of hydrogen atoms bonded to each of the carbon atoms constituting the carbon-carbon double bond is one less than the number shown in Formula (1) or (2).

10

15 [Claim 5] The photosensitive resin composition according to claim 1, wherein the 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.

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[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.

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

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