

DESCRIPTION**TITLE OF THE INVENTION:**

METHOD FOR PRODUCING CIRCUIT BOARD

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TECHNICAL FIELD

[0001] The present invention relates to a method for producing a circuit board.

10 **BACKGROUND ART**

[0002] In manufacturing of a semiconductor package such as a wafer-level package (WLP) or a panel-level package (PLP), a circuit board such as a redistribution board is generally formed by placing a curable resin material on a wafer or on a panel board and curing it to form an insulating layer, then forming a conductive layer on the insulating layer, and repeating this process to form a multilayer (for example, Patent Literature 1).

20 **RELATED ART REFERENCE****Patent Literature**

[0003] Patent Literature 1: Japanese Patent Application Laid-open No. 2012-015191

25 **SUMMARY OF INVENTION****PROBLEM TO BE SOLVED BY THE INVENTION**

[0004] As an electronic device is developed more sophisticated, a circuit board used in a semiconductor package is required to have a finer wiring. However, conventional methods for forming a conductive layer on an insulating layer have limitation in achieving a fine wiring.

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[0005] In addition, an insulating layer used in a circuit board sometimes contains an inorganic filler such as silica in order to achieve properties such as a low thermal expansion coefficient and a low dielectric loss tangent, but in these cases, it is even more difficult to achieve a fine wiring.

[0006] The present invention provides a novel method for producing a circuit board that enables to form a conductor circuit in a fine pattern even when the insulating layer contains an inorganic filler.

MEANS FOR SOLVING PROBLEM

[0007] In order to solve the problems described above, the inventors of the present invention carried out an extensive investigation, and as a result, it was found that these problems could be solved by a method for producing a circuit board having the configuration described below, thereby resulting in completion of the present invention.

[0008] That is, the present invention includes the following contents.

<1> A method for producing a circuit board, the method comprising the following steps (X), (Y) and (Z):

(X) forming a first conductor circuit on a metal layer of a substrate with the metal layer attached thereto;

(Y) forming a resin composition layer by using a resin composition so as to embed the first conductor circuit formed on the metal layer, and then curing the resin composition layer to form an insulating layer; and

(Z) removing the substrate with the metal layer attached thereto to form a circuit board having a first main surface in which the first conductor circuit is exposed, wherein

the resin composition comprises an epoxy resin, a curing agent and an inorganic filler.

<2> The method according to <1>, wherein a content of the inorganic filler in the resin composition is in a range of 20% or more by mass to 75% or less by mass when nonvolatile components in the resin composition are defined as 100% by mass.

<3> The method according to <1> or <2>, wherein an average particle diameter of the inorganic filler is 0.6 μm or less.

<4> The method according to any one of <1> to <3>, wherein the inorganic filler is silica.

<5> The method according to any one of <1> to <4>, wherein a minimum melt viscosity of the resin composition is 5,000 poise or less.

<6> The method according to any one of <1> to <5>, wherein a thickness of the metal layer is less than 0.5 μm .

<7> The method according to any one of <1> to <6>, wherein an arithmetic mean roughness R_a of a surface of the metal layer is 200 nm or less, and TTV, which is a difference between a maximum value and a minimum value of a height of the surface of the metal layer measured in a thickness direction of the substrate with the metal layer attached thereto, is 50 μm or less.

<8> The method according to any one of <1> to <7>, wherein in the substrate with the metal layer attached thereto, the substrate is selected from a metal substrate whose composition is different from that of the metal layer, an inorganic substrate, and an organic substrate.

<9> The method according to any one of <1> to <8>, wherein the step (Z) is carried out by removing the metal layer after removing the substrate.

<10> The method according to any one of <1> to <9>, wherein the step (X) comprises

(X-1) forming a photoresist on the metal layer, and then irradiating the photoresist with light and developing the photoresist to expose the metal layer corresponding to a circuit pattern of the first conductor circuit to be formed, and

(X-2) forming a conductive layer on the exposed metal layer to form the first conductor circuit.

<11> The method according to any one of <1> to <10>, wherein the first conductor circuit comprises a trench type conductor circuit.

<12> The method according to any one of <1> to <11>, wherein the step (Y) comprises laminating a resin sheet that includes a support film and a resin composition layer formed on the support film onto the substrate such that the resin composition layer is in contact with the first conductor circuit.

<13> The method according to any one of <1> to <12>, the method comprising the following steps, after the step (Y):

(i) forming a second conductor circuit on a surface of the insulating layer; and

(ii) forming a resin composition layer so as to embed the second conductor circuit, and then curing the resin composition layer to form an insulating layer.

<14> The method according to any one of <1> to <13>, wherein the circuit board is for a semiconductor package.

<15> A circuit board having a first main surface and a second main surface, the circuit board comprising:

a trench type conductor circuit in the first main surface, wherein

a minimum line/space ratio (L/S) of the trench type conductor circuit is $2/2\ \mu\text{m}$ or less,

in a cross section in a direction Y that is perpendicular to the first main surface and also perpendicular to a direction of extension of the trench type conductor circuit, an angle difference between a straight line direction y1 defined by a side wall of the trench type conductor circuit and the direction Y is 20° or less, and

an insulating layer defining the first main surface together with the trench type conductor circuit comprises a cured product of a resin composition comprising an epoxy resin, a curing agent and an inorganic filler.

<16> The circuit board according to <15>, wherein the trench type conductor circuit has an inverse tapered shape in which a width thereof increases from the first main surface toward a depth direction of the circuit board.

<17> The circuit board according to <15> or <16>, wherein a ratio of a thickness T to a width W of the trench type conductor circuit (T/W) in the cross section in the direction Y perpendicular to the first main surface and also perpendicular to the direction of extension of the trench type conductor circuit is 1.5 or more.

<18> The circuit board according to any one of <15> to <17>, wherein in the cross section in the direction Y perpendicular to the first main surface and also perpendicular to the direction of extension of the trench type conductor circuit, an exposed surface of the trench type conductor circuit is dented by $0.05W$ or more from an exposed surface of the insulating layer defining the first main surface together with the trench type conductor circuit.

<19> The circuit board according to any one of <15> to <18>, wherein the circuit board has a multilayered structure having two or more circuit layers.

<20> A semiconductor package comprising:

the circuit board according to any one of <15> to <19>; and

a semiconductor chip formed on the first main surface
5 so as to be electrically connected to the trench type conductor circuit of the circuit board.

<21> The semiconductor package according to <20>, wherein the semiconductor package is a Fan-Out type package.

10 **EFFECT OF THE INVENTION**

[0009] According to the present invention, it is possible to provide a novel method for producing a circuit board that enables to form a conductor circuit in a fine pattern even when the insulating layer contains an
15 inorganic filler.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a schematic drawing (1) to illustrate the method for producing a circuit board in an embodiment
20 of the present invention (hereinafter simply referred to as "production method of circuit board").

FIG. 2 is a schematic drawing (2) to illustrate the production method of circuit board.

FIG. 3 is a schematic drawing (3) to illustrate the
25 production method of circuit board.

FIG. 4 is a schematic drawing (4) to illustrate the production method of circuit board.

FIG. 5 is a schematic drawing (5) to illustrate the production method of circuit board.

30 FIG. 6 is a schematic drawing (6) to illustrate the production method of circuit board.

FIG. 7 is a schematic drawing (7) to illustrate the production method of circuit board.

FIG. 8 is a schematic drawing (8) to illustrate the production method of circuit board.

FIG. 9 is a schematic drawing (9) to illustrate the production method of circuit board.

5 FIG. 10 is a schematic drawing (10) to illustrate the production method of circuit board.

FIG. 11 is a schematic drawing (11) to illustrate the production method of circuit board.

10 FIG. 12 is a schematic drawing (12) to illustrate the production method of circuit board.

FIG. 13 is a schematic drawing (13) to illustrate the production method of circuit board.

FIG. 14 is a schematic drawing (14) to illustrate the production method of circuit board.

15 FIG. 15 is a schematic drawing (15) to illustrate the production method of circuit board.

FIG. 16 is a schematic drawing (16) to illustrate the production method of circuit board.

20 FIG. 17 is a schematic drawing (17) to illustrate the production method of circuit board.

FIG. 18 is a schematic drawing (18) to illustrate the production method of circuit board.

FIG. 19 is a schematic drawing (19) to illustrate the production method of circuit board.

25 FIG. 20 is a schematic drawing (20) to illustrate the production method of circuit board.

FIG. 21 is a schematic drawing (21) to illustrate the production method of circuit board.

30 FIG. 22 is a schematic drawing (22) to illustrate the production method of circuit board.

FIG. 23 is a schematic drawing (23) to illustrate the production method of circuit board. FIG. 23 is also a

schematic drawing of a circuit board in an embodiment of the present invention.

FIG. 24 is a schematic drawing (1) to illustrate the semiconductor package in an embodiment of the present invention.

FIG. 25 is a schematic drawing (2) to illustrate the semiconductor package in an embodiment of the present invention.

FIG. 26 is a schematic diagram (3) to illustrate the semiconductor package in an embodiment of the present invention.

EMBODIMENT FOR CARRYING OUT THE INVENTION

[0011] Before specifically describing the production method of circuit board according to the present invention, the "resin composition" used in the production method according to the present invention will be described.

[0012] <Resin Composition>

In the production method of circuit board according to the present invention, a resin composition layer is formed so as to embed a conductor circuit, and then the resin composition layer is cured to form an insulating layer. From the viewpoints of achieving to embed the conductor circuit and to exhibit a sufficient insulation after curing, the resin composition containing an epoxy resin, a curing agent and an inorganic filler is used to form the resin composition layer.

[0013] -Epoxy Resin-

Examples of the epoxy resin may include a bixylenol type epoxy resin, a bisphenol A type epoxy resin, a bisphenol F type epoxy resin, a bisphenol S type epoxy resin, a bisphenol AF type epoxy resin, a dicyclopentadiene type epoxy resin, a trisphenol type epoxy resin, a naphthol

novolac type epoxy resin, a phenol novolac type epoxy resin, a tert-butyl-catechol type epoxy resin, a naphthalene type epoxy resin, a naphthol type epoxy resin, an anthracene type epoxy resin, a glycidylamine type epoxy resin, a glycidyl ester type epoxy resin, a cresol novolac type epoxy resin, a biphenyl type epoxy resin, a linear aliphatic epoxy resin, an epoxy resin having a butadiene structure, an alicyclic epoxy resin, a heterocyclic epoxy resin, an epoxy resin having a spiro ring, a cyclohexane type epoxy resin, a cyclohexanedimethanol type epoxy resin, a naphthylene ether type epoxy resin, a trimethylol type epoxy resin, and a tetraphenylethane type epoxy resin. As the epoxy resin, one type thereof may be solely used, and two or more types thereof may also be used in combination.

[0014] It is preferable that the resin composition include, as the epoxy resin, the epoxy resin having two or more epoxy groups within one molecule. From the viewpoint of notably achieving the desired effects of the present invention, the ratio of the epoxy resin having two or more epoxy groups per molecule is preferably 50% or more by mass, more preferably 60% or more by mass, and especially preferably 70% or more by mass, when the nonvolatile component in the epoxy resin is defined as 100% by mass.

[0015] The epoxy resin may be classified into epoxy resins in a liquid state at a temperature of 20°C (hereinafter referred to as a "liquid epoxy resin") and epoxy resins in a solid state at a temperature of 20°C (hereinafter referred to as a "solid epoxy resin"). The resin composition may contain, as the epoxy resin, only the liquid epoxy resin, or only the solid epoxy resin. However, from the viewpoint of notably achieving the advantageous effects of the present invention, it is

preferable to contain the liquid epoxy resin and the solid epoxy resin in combination.

[0016] As for the liquid epoxy resin, the liquid epoxy resin having two or more epoxy groups per molecule is preferable.

[0017] As the liquid epoxy resin, a bisphenol A type epoxy resin, a bisphenol F type epoxy resin, a bisphenol AF type epoxy resin, a naphthalene type epoxy resin, a glycidyl ester type epoxy resin, a glycidylamine type epoxy resin, a phenol novolac type epoxy resin, an alicyclic epoxy resin having an ester backbone, a cyclohexane type epoxy resin, a cyclohexanedimethanol type epoxy resin, a glycidylamine type epoxy resin, and an epoxy resin having a butadiene structure are preferable. Among them, a bisphenol A type epoxy resin and a bisphenol F type epoxy resin are more preferable.

[0018] Specific examples of the liquid epoxy resin may include "HP4032", "HP4032D", and "HP4032SS" (these are naphthalene type epoxy resins), all manufactured by DIC Corp.; "828US", "jER828EL", "825", and "Epikote 828EL" (these are bisphenol A type epoxy resins), all manufactured by Mitsubishi Chemical Corp.; "jER807" and "1750" (both are bisphenol F type epoxy resins), both manufactured by Mitsubishi Chemical Corp.; "jER152" (a phenol novolac type epoxy resin) manufactured by Mitsubishi Chemical Corp.; "630" and "630LSD" (both are glycidylamine type epoxy resins), both manufactured by Mitsubishi Chemical Corp.; "ZX1059" (a mixture of a bisphenol A type epoxy resin and a bisphenol F type epoxy resin) manufactured by Nippon Steel Chemical & Material Co., Ltd.; "EX-721" (a glycidyl ester type epoxy resin) manufactured by Nagase ChemteX Corp.; "Celloxide 2021P" (an alicyclic epoxy resin having an ester backbone) manufactured by Daicel Corp.; "PB-3600" (an epoxy

resin having a butadiene backbone) manufactured by Daicel Corp.; and "ZX1658" and "ZX1658GS" (both are liquid 1,4-glycidylcyclohexane type epoxy resins), both manufactured by Nippon Steel Chemical & Material Co., Ltd. These may be
5 used alone or in combination of two or more types thereof.

[0019] As for the solid epoxy resin, a solid epoxy resin having three or more epoxy groups per molecule is preferable, while an aromatic solid epoxy resin having three or more epoxy groups per molecule is more preferable.

10 [0020] As the solid epoxy resin, a bixylenol type epoxy resin, a naphthalene type epoxy resin, a naphthalene type four-functional epoxy resin, a cresol novolac type epoxy resin, a dicyclopentadiene type epoxy resin, a trisphenol type epoxy resin, a naphthol type epoxy resin, a biphenyl
15 type epoxy resin, a naphthylene ether type epoxy resin, an anthracene type epoxy resin, a bisphenol A type epoxy resin, a bisphenol AF type epoxy resin, and a tetraphenylethane type epoxy resin are preferable. Among them, a bixylenol type epoxy resin, a naphthalene type
20 epoxy resin, a naphthylene ether type epoxy resin, and a bisphenol AF type epoxy resin are more preferable.

[0021] Specific examples of the solid epoxy resin may include "HP4032H" (a naphthalene type epoxy resin), "HP-4700" and "HP-4710" (both are naphthalene type four-
25 functional epoxy resins), "N-690" (a cresol novolac type epoxy resin), "N-695" (a cresol novolac type epoxy resin), "HP-7200", "HP-7200HH" and "HP-7200H" (these are dicyclopentadiene type epoxy resins), "EXA-7311", "EXA-7311-G3", "EXA-7311-G4", "EXA-7311-G4S", "HP6000", and
30 "HP6000L" (these are naphthylene ether type epoxy resins), all manufactured by DIC Corp.; "EPPN-502H" (a trisphenol type epoxy resin), "NC7000L" (a naphthol novolac type epoxy resin), "NC3000H", "NC3000", "NC3000L", and "NC3100" (these

are biphenyl type epoxy resins), all manufactured by Nippon Kayaku Co., Ltd.; "ESN475V" (a naphthalene type epoxy resin), "ESN485" (a naphthol novolac type epoxy resin), both manufactured by Nippon Steel Chemical & Material Co., Ltd.; "YX4000H" and "YL6121" (both are biphenyl type epoxy resins), "YX4000HK" (a bixylenol type epoxy resin), and "YX8800" (an anthracene type epoxy resin), all manufactured by Mitsubishi Chemical Corp.); "PG-100" and "CG-500", both manufactured by Osaka Gas Chemicals Co., Ltd.; and "YX7760" (a bisphenol AF type epoxy resin), "YL7800" (a fluorene type epoxy resin), "jER1010" (a solid bisphenol A type epoxy resin), and "jER1031S" (a tetraphenylethane type epoxy resin), all manufactured by Mitsubishi Chemical Corp. These may be used alone or in combination of two or more types thereof.

[0022] When a combination of the liquid epoxy resin and the solid epoxy resin is used as the epoxy resin, the mass ratio of them (liquid epoxy resin : solid epoxy resin) is preferably in the range of 1:0.1 to 1:20, more preferably in the range of 1:0.3 to 1:15, and especially preferably in the range of 1:0.5 to 1:10. When the mass ratio of the liquid epoxy resin to the solid epoxy resin is within this range, the desired effects of the present invention can be notably achieved. In addition, when used in the form of a resin sheet, this usually provides a moderate adhesion. In addition, when used in the form of a resin sheet, this usually provides a sufficient flexibility and improves a handling property. In addition, in general, a cured product having a sufficient breaking strength can be obtained.

[0023] The equivalent weight of the epoxy group of the epoxy resin is preferably in the range of 50 to 5,000 g/eq., more preferably in the range of 50 to 3,000 g/eq.,

still more preferably in the range of 80 to 2,000 g/eq.,
and further still more preferably in the range of 110 to
1,000 g/eq. Within this range, the resin composition can
provide the cured product thereof having a sufficient
5 crosslinking density. The equivalent weight of the epoxy
group is a mass of the epoxy resin containing one
equivalent of epoxy groups and may be measured according to
JIS K7236.

[0024] From the viewpoint of notably achieving the
10 desired effects of the present invention, the weight-
average molecular weight (Mw) of the epoxy resin is
preferably in the range of 100 to 5,000, more preferably in
the range of 250 to 3,000, and still more preferably in the
range of 400 to 1,500. The weight-average molecular weight
15 of the epoxy resin is the weight-average molecular weight
in terms of polystyrene measured by a gel permeation
chromatography (GPC) method.

[0025] From the viewpoint of obtaining the cured product
having a good mechanical strength and insulation
20 reliability, the content of the epoxy resin is preferably
10% or more by mass, more preferably 15% or more by mass,
and still more preferably 20% or more by mass, when the
nonvolatile components in the resin composition are defined
as 100% by mass. From the viewpoint of notably achieving
25 the desired effects of the present invention, the upper
limit of the content of the epoxy resin is preferably 90%
or less by mass, more preferably 85% or less by mass, and
especially preferably 45% or less by mass, 40% or less by
mass, or 35% or less by mass.

30 [0026] From the viewpoint of notably achieving the
advantageous effects of the present invention, the content
of the epoxy resin is preferably 20% or more by mass, more
preferably 30% or more by mass, still more preferably 40%

or more by mass, or 50% or more by mass, and preferably 90% or less by mass, more preferably 85% or less by mass, and still more preferably 80% or less by mass, when the resin components in the resin composition are defined as 100% by mass. In the present invention, "resin component" as used in the resin composition refers to the nonvolatile components constituting the resin composition other than the inorganic filler described later.

[0027] -Curing Agent-

Examples of the curing agent may include an active ester-based curing agent, a phenol-based curing agent, a naphthol-based curing agent, a benzoxazine-based curing agent, a cyanate ester-based curing agent, a carbodiimide-based curing agent, an amine-based curing agent, and an acid anhydride-based curing agent. The curing agent may be used alone or in combination of two or more types thereof.

[0028] As the active ester-based curing agent, a resin having one or more active ester groups per molecule can be used. In particular, as the active ester-based curing agent, a compound having two or more highly active ester groups per molecule, such as phenol esters, thiophenol esters, N-hydroxyamine esters, and esters of heterocyclic hydroxy compounds, is preferably used. The active ester-based curing agent is preferably obtained by a condensation reaction of a carboxylic acid compound and/or a thiocarboxylic acid compound with a hydroxy compound and/or a thiol compound. Particularly, from the viewpoint of improving heat resistance, an active ester-based curing agent obtained from a carboxylic acid compound and a hydroxy compound is preferable, and an active ester-based curing agent obtained from a carboxylic acid compound and a phenol compound and/or a naphthol compound is more preferable.

[0029] Examples of the carboxylic acid compound may include benzoic acid, acetic acid, succinic acid, maleic acid, itaconic acid, phthalic acid, isophthalic acid, terephthalic acid, and pyromellitic acid.

5 [0030] Examples of the phenol compound and naphthol compound may include hydroquinone, resorcin, bisphenol A, bisphenol F, bisphenol S, phenolphthalin, methylated bisphenol A, methylated bisphenol F, methylated bisphenol S, phenol, o-cresol, m-cresol, p-cresol, catechol, α -
10 naphthol, β -naphthol, 1,5-dihydroxynaphthalene, 1,6-dihydroxynaphthalene, 2,6-dihydroxynaphthalene, dihydroxybenzophenone, trihydroxybenzophenone, tetrahydroxybenzophenone, phloroglucine, benzenetriol, a dicyclopentadiene-type diphenol compound, and phenol
15 novolac. The "dicyclopentadiene-type diphenol compound" is a diphenol compound obtained by condensation of one dicyclopentadiene molecule with two phenol molecules.

[0031] Preferable specific examples of the active ester-based curing agent may include an active ester compound
20 including a dicyclopentadiene-type diphenol structure, an active ester compound including a naphthalene structure, an active ester compound including an acetylated material of phenol novolac, and an active ester compound including a benzoylated material of phenol novolac. Among them, more
25 preferable are an active ester compound including a naphthalene structure and an active ester compound including a dicyclopentadiene-type diphenol structure. The "dicyclopentadiene type diphenol structure" represents a divalent structural unit formed of phenylene-
30 dicyclopentylene-phenylene.

[0032] Examples of the commercially available product of the active ester-based curing agent may include: as the active ester-based curing agent containing a

dicyclopentadiene type diphenol structure, "EXB9451",
"EXB9460", "EXB9460S", "HPC-8000-65T", "HPC-8000H-65TM",
and "EXB-8000L-65TM" (all manufactured by DIC Corp.); as
the naphthalene-based active ester-based curing agent
5 containing a naphthalene structure, "EXB9416-70BK", "EXB-
8100L-65T", "EXB-8150L-65T", "EXB-8150-65T", "HPC-8150-
60T", "HPC-8150-62T", and "HPB-8151-62T" (all manufactured
by DIC Corp.), as well as "PC1300-02-65T" (manufactured by
Air Water, Inc.); as the active ester-based curing agent
10 containing acetylated phenol novolac, "DC808" (manufactured
by Mitsubishi Chemical Corp.); as the active ester-based
curing agent containing a benzoylated phenol novolac,
"YLH1026" (manufactured by Mitsubishi Chemical Corp.); as
the active ester-based curing agent that is an acetylated
15 phenol novolac, "DC808" (manufactured by Mitsubishi
Chemical Corp.); as the active ester-based curing agent
that is a benzoylated phenol novolac, "YLH1026"
(manufactured by Mitsubishi Chemical Corp.), "YLH1030"
(manufactured by Mitsubishi Chemical Corp.), "YLH1048"
(manufactured by Mitsubishi Chemical Corp.), and "EXB-8500-
20 65T" (manufactured by DIC Corp.).

[0033] From the viewpoint of notably achieving the
advantageous effects of the present invention, the content
of the active ester-based curing agent is preferably 1% or
25 more by mass, more preferably 2% or more by mass, still
more preferably 4% or more by mass, and preferably 50% or
less by mass, more preferably 40% or less by mass, and
still more preferably 30% or less by mass, when the
nonvolatile components in the resin composition are defined
30 as 100% by mass.

[0034] From the viewpoint of notably achieving the
advantageous effects of the present invention, the content
of the active ester-based curing agent is preferably 5% or

more by mass, more preferably 10% or more by mass, still more preferably 15% or more by mass, and preferably 70% or less by mass, more preferably 60% or less by mass, and still more preferably 50% or less by mass, when the resin components in the resin composition are defined as 100% by mass.

[0035] As for the phenol-based curing agent and the naphthol-based curing agent, from the viewpoints of a heat resistance and a moisture resistance, these agents having a novolac structure are preferable. From the viewpoint of the adhesion to a conductive layer, a nitrogen-containing phenol-based curing agent and a nitrogen-containing naphthol-based curing agent are preferable, and a phenol-based curing agent having a triazine backbone and a naphthol-based curing agent having a triazine backbone are more preferable.

[0036] Specific examples of the phenol-based curing agent and the naphthol-based curing agent may include: "MEH-7700", "MEH-7810", and "MEH-7851", all manufactured by Meiwa Plastic Industries, Ltd.; "NHN", "CBN", and "GPH", all manufactured by Nippon Kayaku Co., Ltd.; "SN170", "SN180", "SN190", "SN475", "SN485", "SN495", "SN-495V", "SN375", and "SN395", all manufactured by Nippon Steel Chemical & Material Co., Ltd.; and "TD-2090", "LA-7052", "LA-7054", "LA-1356", "LA-3018-50P", and "EXB-9500", all manufactured by DIC Corp.

[0037] Specific examples of the benzoxazine-based curing agent may include "JBZ-OD100" (benzoxazine ring equivalent of 218 g/eq.), "JBZ-OP100D" (benzoxazine ring equivalent of 218 g/eq.) and "ODA-BOZ" (benzoxazine ring equivalent of 218 g/eq.), all manufactured by JFE Chemical Corp.; "P-d" (benzoxazine ring equivalent of 217 g/eq.) and "F-a" (benzoxazine ring equivalent of 217 g/eq.), both

manufactured by Shikoku Chemicals Corp.; and "HFB2006M" (benzoxazine ring equivalent of 432 g/eq.) manufactured by Showa High Polymer Co., Ltd.

[0038] Examples of the cyanate ester-based curing agent
5 may include: bifunctional cyanate compounds such as bisphenol A dicyanate, polyphenol cyanate, oligo(3-methylene-1,5-phenylenecyanate), 4,4'-methylenebis(2,6-dimethylphenylcyanate), 4,4'-ethylidene diphenyl dicyanate, hexafluorobisphenol A dicyanate, 2,2-bis(4-
10 cyanate)phenylpropane, 1,1-bis(4-cyanatephenylmethane), bis(4-cyanate-3,5-dimethylphenyl)methane, 1,3-bis(4-cyanatephenyl-1-(methylethylidene))benzene, bis(4-cyanatephenyl)thioether, and bis(4-cyanatephenyl) ether; a polyfunctional cyanate compound derived from a phenol
15 novolac or a cresol novolac; and a prepolymer in which these cyanate compounds are partly triazinized. Specific examples of the cyanate ester-based compound may include "PT30", "PT30S", and "PT60" (all are phenol novolac type polyfunctional cyanate esters); "ULL-950S" (a
20 polyfunctional cyanate ester), and "BA230" and "BA230S75" (prepolymers in which bisphenol A dicyanate is partly or entirely triazinized to form a trimer) manufactured by Lonza Japan Ltd.

[0039] Specific examples of the carbodiimide-based
25 curing agent may include "Carbodilite" (registered trademark) V-03 (carbodiimide equivalent of 216 g/eq.), V-05 (carbodiimide equivalent of 216 g/eq.), V-07 (carbodiimide group equivalent of 200 g/eq.), and V-09 (carbodiimide group equivalent of 200 g/eq.), all
30 manufactured by Nisshinbo Chemical Inc.; and Stabaxol (registered trademark) P (carbodiimide equivalent of 302 g/eq.) manufactured by Rhein Chemie GmbH.

[0040] Examples of the amine-based curing agent may include a resin having one or more amino groups per molecule, and examples thereof may include an aliphatic amine, a polyether amine, an alicyclic amine, and an aromatic amine. Among them, an aromatic amine is preferable from the viewpoint of achieving the desired effects of the present invention. As for the amine-based curing agent, a primary amine or a secondary amine is preferable, and a primary amine is more preferable.

Specific examples of the amine-based curing agent may include 4,4'-methylenebis(2,6-dimethylaniline), diphenyldiaminosulfone, 4,4'-diaminodiphenylmethane, 4,4'-diaminodiphenylsulfone, 3,3'-diaminodiphenylsulfone, m-phenylenediamine, m-xylylenediamine, diethyltoluenediamine, 4,4'-diaminodiphenyl ether, 3,3'-dimethyl-4,4'-diaminobiphenyl, 2,2'-dimethyl-4,4'-diaminobiphenyl, 3,3'-dihydroxybenzidine, 2,2-bis(3-amino-4-hydroxyphenyl)propane, 3,3-dimethyl-5,5-diethyl-4,4-diphenylmethanediamine, 2,2-bis(4-aminophenyl)propane, 2,2-bis(4-(4-aminophenoxy)phenyl)propane, 1,3-bis(3-aminophenoxy)benzene, 1,3-bis(4-aminophenoxy)benzene, 1,4-bis(4-aminophenoxy)benzene, 4,4'-bis(4-aminophenoxy)biphenyl, bis(4-(4-aminophenoxy)phenyl)sulfone, and bis(4-(3-aminophenoxy)phenyl)sulfone. Commercially available amine-based curing agents may be used, and Examples thereof may include "KAYABOND C-200S", "KAYABOND C-100", "KAYAHARD A-A", "KAYAHARD A-B", and "KAYAHARD A-S", all manufactured by Nippon Kayaku Co., Ltd.; and "EPICURE W" manufactured by Mitsubishi Chemical Corp.

[0041] Examples of the acid anhydride-based curing agent may include a compound having one or more acid anhydride groups per molecule. Specific examples of the acid

anhydride-based curing agent may include phthalic
 anhydride, tetrahydrophthalic anhydride, hexahydrophthalic
 anhydride, methyltetrahydrophthalic anhydride,
 methylhexahydrophthalic anhydride, methylnadic anhydride,
 5 hydrogenated methylnadic anhydride, trialkyl
 tetrahydrophthalic anhydride, dodecenylsuccinic anhydride,
 5-(2,5-dioxotetrahydro-3-furanyl)-3-methyl-3-cyclohexene-
 1,2-dicarboxylic anhydride, trimellitic anhydride,
 pyromellitic anhydride, benzophenone tetracarboxylic
 10 dianhydride, biphenyl tetracarboxylic dianhydride,
 naphthalene tetracarboxylic dianhydride, oxydiphthalic
 dianhydride, 3,3'-4,4'-diphenylsulfone tetracarboxylic
 dianhydride, 1,3,3a,4,5,9b-hexahydro-5-(tetrahydro-2,5-
 dioxo-3-furanyl)-naphtho[1,2-C]furan-1,3-dione,
 15 ethyleneglycol bis(anhydrotrimellitate), and a polymer type
 acid anhydride such as a styrene-maleic acid resin, which
 is a copolymer of styrene and maleic acid.

[0042] The mass ratio of the epoxy resin to the curing
 agent in terms of the ratio of [total number of the epoxy
 20 groups in the epoxy resins] : [total number of the reactive
 groups in the curing agent] is preferably in the range of
 1:0.01 to 1:5, more preferably in the range of 1:0.05 to
 1:3, and still more preferably in the range of 1:0.1 to
 1:2. The "number of the epoxy group in the epoxy resin" is
 25 the sum of all the values obtained by dividing the mass of
 the nonvolatile component of the epoxy resin present in the
 resin composition by the epoxy equivalent. The "number of
 the active group of the curing agent" is the sum of all the
 values obtained by dividing the mass of the nonvolatile
 30 component of the curing agent present in the resin
 composition by the active group equivalent. When the mass
 ratio of the epoxy resin to the curing agent falls within

the range described above, the cured product having an excellent flexibility can be obtained.

[0043] From the viewpoint of notably achieving the advantageous effects of the present invention, the content of the curing agent is preferably 1% or more by mass, more preferably 3% or more by mass, still more preferably 5% or more by mass, and preferably 50% or less by mass, more preferably 40% or less by mass, and still more preferably 30% or less by mass, when the nonvolatile components in the resin composition are defined as 100% by mass.

[0044] From the viewpoint of notably achieving the advantageous effects of the present invention, the content the curing agent is preferably 5% or more by mass, more preferably 10% or more by mass, still more preferably 15% or more by mass, or 20% or more by mass, and preferably 70% or less by mass, more preferably 60% or less by mass, and still more preferably 50% or less by mass, when the resin components in the resin composition are defined as 100% by mass.

[0045] -Inorganic Filler-

Examples of the inorganic filler may include silica, alumina, aluminosilicate, glass, cordierite, silicon oxide, barium sulfate, barium carbonate, talc, clay, mica powder, zinc oxide, hydrotalcite, boehmite, aluminum hydroxide, magnesium hydroxide, calcium carbonate, magnesium carbonate, magnesium oxide, boron nitride, aluminum nitride, manganese nitride, aluminum borate, strontium carbonate, strontium titanate, calcium titanate, magnesium titanate, bismuth titanate, titanium oxide, zirconium oxide, barium titanate, barium titanate zirconate, barium zirconate, calcium zirconate, zirconium phosphate, and zirconium phosphate tungstate. Among these, calcium carbonate and silica are preferable, and silica is

especially preferable. Examples of the silica may include amorphous silica, fused silica, crystalline silica, synthesized silica, and hollow silica. Spherical silica is preferable as the silica. The inorganic filler may be used
5 alone or in combination of two or more types thereof.

[0046] Examples of the commercially available product of the inorganic filler may include: "UFP-30" manufactured by Denka Co., Ltd.; "SP60-05", "SP507-05", and "SPH516-05", all manufactured by Nippon Steel Chemical & Material Co.,
10 Ltd.; "YC100C", "YA050C", "YA050C-MJE", and "YA010C", all manufactured by Admatechs Co., Ltd.; "Silfil NSS-3N", "Silfil NSS-4N", and "Silfil NSS-5N", all manufactured by Tokuyama Corp.; and "SC2500SQ" manufactured by Admatechs Co., Ltd.

[0047] From the viewpoint of exhibiting an excellent insulation in an extremely fine pattern, such as the minimum line/space ratio (L/S) of 2/2 μm or less, the average particle diameter of the inorganic filler is preferably 0.6 μm or less, more preferably 0.5 μm or less,
20 still more preferably 0.4 μm or less, and preferably 0.01 μm or more, more preferably 0.02 μm or more, and still more preferably 0.03 μm or more.

[0048] The specific surface area of the inorganic filler is preferably 1 m^2/g or more, more preferably 2 m^2/g or
25 more, and still more preferably 3 m^2/g or more. Although the upper limit value thereof is not particularly restricted, the value is preferably 60 m^2/g or less, 50 m^2/g or less, or 40 m^2/g or less. The specific surface area can be calculated by means of a BET multipoint method,
30 in which a nitrogen gas is adsorbed onto the sample surface in accordance with a BET method by using a specific surface area measurement apparatus (Macisorb HM-1210, manufactured by Mountech Co., Ltd.).

[0049] The inorganic filler is preferably treated with a surface treatment agent from the viewpoint of improving the moisture resistance and dispersion property of the inorganic filler. Examples of the surface treatment agent
5 may include a vinylsilane-based coupling agent, a (meth)acrylic coupling agent, a fluorine-containing silane coupling agent, an aminosilane-based coupling agent, an epoxysilane-based coupling agent, a mercaptosilane-based coupling agent, a silane-based coupling agent, an
10 alkoxy silane, an organosilazane compound, and a titanate-based coupling agent. Among these, from the viewpoint of notably achieving the advantageous effects of the present invention, a vinylsilane-based coupling agent, a (meth)acrylic coupling agent, and an aminosilane-based
15 coupling agent are preferable, and an aminosilane-based coupling agent is more preferred. The surface treatment agent may be used alone or in combination of two or more types thereof.

[0050] Examples of the commercially available product of the surface treatment agent may include "KBM1003" (vinyl triethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBM503" (3-methacryloxypropyl triethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBM403" (3-glycidoxypropyl trimethoxysilane) manufactured by Shin-Etsu
25 Chemical Co., Ltd., "KBM803" (3-mercaptopropyl trimethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBE903" (3-aminopropyl triethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBM573" (N-phenyl-3-aminopropyl trimethoxysilane) manufactured by Shin-Etsu
30 Chemical Co., Ltd., "SZ-31" (hexamethyl disilazane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBM103" (phenyl trimethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd., "KBM-4803" (long chain epoxy type

silane coupling agent) manufactured by Shin-Etsu Chemical Co., Ltd., and "KBM-7103" (3,3,3-trifluoropropyl trimethoxysilane) manufactured by Shin-Etsu Chemical Co., Ltd.

5 [0051] From the viewpoint of enhancing dispersion of the inorganic filler, the degree of the surface treatment by means of the surface treatment agent is preferably within a prescribed range. Specifically, the inorganic filler is surface-treated with preferably 0.2 to 5 parts by mass of
10 the surface treatment agent, more preferably 0.2 to 3 parts by mass of the surface treatment agent, and still more preferably 0.3 to 2 parts by mass of the surface treatment agent, on the basis of 100 parts by mass of the inorganic filler.

15 [0052] The degree of surface treatment with the surface treatment agent can be evaluated based on the amount of carbon per unit surface area of the inorganic filler. From the viewpoint of improving dispersibility of the inorganic filler, the amount of carbon per unit surface area of the
20 inorganic filler is preferably 0.02 mg/m² or more, more preferably 0.1 mg/m² or more, and still more preferably 0.2 mg/m² or more. In terms of preventing an increase in the melt viscosity of a resin varnish and the melt viscosity in a sheet form, the amount of carbon per unit surface area of
25 the inorganic filler is preferably 1 mg/m² or less, more preferably 0.8 mg/m² or less, and still more preferably 0.5 mg/m² or less.

[0053] The amount of carbon per unit surface area of the inorganic filler can be measured after washing the
30 inorganic filler which has been subjected to the surface treatment with using a solvent (such as methyl ethyl ketone (MEK)). Specifically, a sufficient amount of MEK is added, as the solvent, to the inorganic filler the surface of

which is treated with a surface treatment agent, and the resultant mixture is subjected to ultrasonic washing at 25°C for 5 minutes. A supernatant liquid is removed and a solid content is dried. Thereafter, the amount of carbon per unit surface area of the inorganic filler can be measured with a carbon analyzer. As the carbon analyzer "EMIA-320V" manufactured by HORIBA Ltd., or the like can be used.

[0054] From the viewpoint of sufficiently lowering the thermal expansion coefficient and dielectric loss tangent of the insulating layer, the content of the inorganic filler in the resin composition (and thus the content of the inorganic filler in the resin composition layer and in the insulating layer) is preferably 20% or more by mass, more preferably 30% or more by mass, and still more preferably 40% or more by mass, when the nonvolatile components in the resin composition are defined as 100% by mass. As described later, when the insulating layer contains the inorganic filler, it has been difficult to form a trench type conductor circuit in a fine pattern. In contrast, the method according to the present invention, the trench type conductor circuit having an extremely fine pattern can be formed even when the content of the inorganic filler is further increased. For example, the content of the inorganic filler in the resin composition may be increased to the level of even 45% or more by mass, or 50% or more by mass, or 55% or more by mass. The upper limit of the content of the inorganic filler is preferably 75% or less by mass, more preferably 70% or less by mass, and still more preferably 65% or less by mass.

[0055] The resin composition may further contain other components. Examples of the other components may include a

curing accelerator, a thermoplastic resin, and other additive. Hereinafter, each component will be described.

[0056] -Curing Accelerator-

The resin composition may contain a curing
5 accelerator. Examples of the curing accelerator may include a phosphorus-based curing accelerator, an amine-based curing accelerator, an imidazole-based curing accelerator, a guanidine-based curing accelerator, and a metal-based curing accelerator. Among them, an amine-based
10 curing accelerator and an imidazole-based curing accelerator are preferable, and an amine-based curing accelerator is more preferable. The curing accelerator may be used alone or in combination of two or more types thereof.

15 [0057] Examples of the phosphorous-based curing accelerator may include triphenylphosphine, a phosphonium borate compound, tetraphenylphosphonium tetraphenylborate, n-butylphosphonium tetraphenylborate, tetrabutylphosphonium decanoate salt, (4-methylphenyl) triphenylphosphonium
20 thiocyanate, tetraphenylphosphonium thiocyanate, and butyl triphenylphosphonium thiocyanate. Among them, triphenylphosphine and tetrabutylphosphonium decanoate salt are preferable.

[0058] Examples of the amine-based curing accelerator
25 may include trialkylamines such as triethylamine and tributylamine, 4-dimethylaminopyridine, benzyldimethylamine, 2,4,6-tris(dimethylaminomethyl)phenol, and 1,8-diazabicyclo(5,4,0)-undecene. Among them, 4-dimethylaminopyridine and 1,8-diazabicyclo(5,4,0)-undecene
30 are preferable.

[0059] Examples of the imidazole-based curing accelerator may include 2-methylimidazole, 2-undecylimidazole, 2-heptadecylimidazole, 1,2-

dimethylimidazole, 2-ethyl-4-methylimidazole, 1,2-dimethylimidazole, 2-ethyl-4-methylimidazole, 2-phenylimidazole, 2-phenyl-4-methylimidazole, 1-benzyl-2-methylimidazole, 1-benzyl-2-phenylimidazole, 1-cyanoethyl-
 5 2-methylimidazole, 1-cyanoethyl-2-undecylimidazole, 1-cyanoethyl-2-ethyl-4-methylimidazole, 1-cyanoethyl-2-phenylimidazole, 1-cyanoethyl-2-undecylimidazolium trimellitate, 1-cyanoethyl-2-phenylimidazolium trimellitate, 2,4-diamino-6-[2'-methylimidazolyl-(1')]-
 10 ethyl-s-triazine, 2,4-diamidino-6-[2'-undecylimidazolyl-(1')]-ethyl-s-triazine, 2,4-diamidino-6-[2'-ethyl-4'-methylimidazolyl-(1')]-ethyl-s-triazine, a 2,4-diamidino-6-[2'-methylimidazolyl-(1')]-ethyl-s-triazine isocyanurate adduct, a 2-phenylimidazole isocyanurate adduct, 2-phenyl-
 15 4,5-dihydroxymethylimidazole, 2-phenyl-4-methyl-5-hydroxymethylimidazole, 2,3-dihydro-1H-pyrrolo[1,2-a]benzimidazole, 1-dodecyl-2-methyl-3-benzylimidazolium chloride, 2-methylimidazoline, 2-phenylimidazoline, as well as adducts of these imidazole compounds with an epoxy
 20 resin. Among them, 2-ethyl-4-methylimidazole and 1-benzyl-2-phenylimidazole are preferable.

[0060] Examples of the imidazole-based curing accelerator may include a commercially available product such as "P200-H50" manufactured by Mitsubishi Chemical
 25 Corp.

[0061] Examples of the guanidine-based curing accelerator may include dicyandiamide, 1-methylguanidine, 1-ethylguanidine, 1-cyclohexylguanidine, 1-phenylguanidine, 1-(o-tolyl)guanidine, dimethylguanidine, diphenylguanidine,
 30 trimethylguanidine, tetramethylguanidine, pentamethylguanidine, 1,5,7-triazabicyclo[4.4.0]deca-5-ene, 7-methyl-1,5,7-triazabicyclo[4.4.0]deca-5-ene, 1-methylbiguanide, 1-ethylbiguanide, 1-n-butylbiguanide, 1-n-

octadecylbiguanide, 1,1-dimethylbiguanide, 1,1-diethylbiguanide, 1-cyclohexylbiguanide, 1-allylbiguanide, 1-phenylbiguanide, and 1-(o-tolyl)biguanide. Among them, dicyandiamide and 1,5,7-triazabicyclo[4.4.0]deca-5-ene are
5 preferable.

[0062] Examples of the metal-based curing accelerator may include organic metal complexes or organic metal salts of metals such as cobalt, copper, zinc, iron, nickel, manganese, and tin. Specific examples of the organic metal
10 complex may include organic cobalt complexes such as cobalt (II) acetylacetonate and cobalt (III) acetylacetonate; organic copper complexes such as copper (II) acetylacetonate; organic zinc complexes such as zinc (II) acetylacetonate; organic iron complexes such as iron (III)
15 acetylacetonate; organic nickel complexes such as nickel (II) acetylacetonate; and organic manganese complexes such as manganese (II) acetylacetonate. Examples of the organic metal salt may include zinc octylate, tin octylate, zinc naphthenate, cobalt naphthenate, tin stearate, and zinc
20 stearate.

[0063] From the viewpoint of notably achieving the advantageous effects of the present invention, the content of the curing accelerator is preferably 0.01% or more by mass, more preferably 0.02% or more by mass, especially
25 preferably 0.03% or more by mass, and preferably 3% or less by mass, more preferably 1% or less by mass, and especially preferably 0.5% or less by mass, when the nonvolatile components in the resin composition are defined as 100% by mass.

30 [0064] From the viewpoint of notably achieving the advantageous effects of the present invention, the content of the curing accelerator is preferably 0.01% or more by mass, more preferably 0.05% or more by mass, still more

preferably 0.1% or more by mass, and preferably 3% or less by mass, more preferably 2% or less by mass, and still more preferably 1% or less by mass, when the resin components in the resin composition are defined as 100% by mass.

5 [0065] -Thermoplastic resin-

The resin composition may contain a thermoplastic resin. Examples of the thermoplastic resin may include a phenoxy resin, a polyvinyl acetal resin, a polyolefin resin, a polyimide resin, a polyamide-imide resin, a
10 polyetherimide resin, a polysulfone resin, a polyethersulfone resin, a polyphenylene ether resin, a polyether ether ketone resin, and a polyester resin. Among them, a phenoxy resin is preferable. The thermoplastic resin may be used alone or in combination of two or more
15 types thereof.

[0066] The weight-average molecular weight of the thermoplastic resin in terms of polystyrene is preferably 38,000 or more, more preferably 40,000 or more, and still more preferably 42,000 or more. The upper limit thereof is
20 preferably 100,000 or less, more preferably 70,000 or less, and still more preferably 60,000 or less. The weight-average molecular weight of the thermoplastic resin in terms of polystyrene is measured by a gel permeation chromatography (GPC) method. Specifically, the weight-
25 average molecular weight of the thermoplastic resin in terms of polystyrene can be calculated using a calibration curve of the standard polystyrene from the measured value obtained using the measuring instrument of LC-9A/RID-6A manufactured by Shimadzu Corp., the column Shodex of K-
30 800P/K-804L/K-804L manufactured by Showa Denko K. K., and the mobile phase of chloroform or the like under the column temperature of 40°C.

[0067] Examples of the phenoxy resin may include phenoxy resins having one or more backbones selected from the group consisting of a bisphenol A backbone, a bisphenol F backbone, a bisphenol S backbone, a bisphenol acetophenone backbone, a novolac backbone, a biphenyl backbone, a fluorene backbone, a dicyclopentadiene backbone, a norbornene backbone, a naphthalene backbone, an anthracene backbone, an adamantane backbone, a terpene backbone, and trimethylcyclohexane backbone. The phenoxy resin may be terminated with any functional group, such as a phenolic hydroxyl group and an epoxy group. The phenoxy resin may be used alone or in combination of two or more types thereof. Specific examples of the phenoxy resin may include "1256" and "4250" (both are phenoxy resins containing a bisphenol A backbone), "YX8100" (a phenoxy resin containing a bisphenol S backbone), and "YX6954" (a phenoxy resin containing a bisphenol acetophenone backbone), all manufactured by Mitsubishi Chemical Corp.; other examples include "FX280" and "FX293" manufactured by Nippon Steel Chemical & Material Co., Ltd., as well as "YX7800BH40", "YL7500BH30", "YX6954BH30", "YX7553", "YX7553BH30", "YL7769BH30", "YL6794", "YL7213", "YL7290", and "YL7482", all manufactured by Mitsubishi Chemical Corp.

[0068] Examples of the polyvinyl acetal resin may include a polyvinyl formal resin and a polyvinyl butyral resin, between which a polyvinyl butyral resin is preferable. Specific examples of the polyvinyl acetal resin may include "Denka Butyral 4000-2", "Denka Butyral 5000-A", "Denka Butyral 6000-C", and "Denka Butyral 6000-EP", all manufactured by Denka Co., Ltd., as well as S-LEC BH series, BX series (for example, BX-5Z), KS series (for example, KS-1), BL series, and BM series, all manufactured by Sekisui Chemical Co., Ltd.

[0069] Specific examples of the polyimide resin may include "Rikacoat SN20" and "Rikacoat PN20", both manufactured by New Japan Chemical Co., Ltd. Specific examples of the polyimide resin may also include a linear
5 polyimide obtained by reacting a bifunctional hydroxyl-terminated polybutadiene, a diisocyanate compound, and a tetrabasic acid anhydride (polyimide described in Japanese Patent Application Laid-open No. 2006-37083), as well as a modified polyimide containing a polysiloxane backbone
10 (polyimide described in Japanese Patent Application Laid-open No. 2002-12667, Japanese Patent Application Laid-open No. 2000-319386, etc.).

[0070] Specific examples of the polyamide-imide resin include "Vylomax HR11NN" and "Vylomax HR16NN" manufactured
15 by Toyobo Co., Ltd. Specific examples of the polyamide-imide resin also include modified polyamide-imides such as "KS9100" and "KS9300" (polyamide-imide containing a polysiloxane backbone) manufactured by Hitachi Chemical Co., Ltd.

[0071] Specific examples of the polyethersulfone resin may include "PES5003P" manufactured by Sumitomo Chemical Co., Ltd. Specific examples of the polyphenylene ether resin may include "OPE-2St 1200", an oligophenylene ether
20 styrene resin manufactured by Mitsubishi Gas Chemical Co., Inc. Specific examples of the polyether ether ketone resin may include "Sumiploy K" manufactured by Sumitomo Chemical Co., Ltd. Specific example of the polyetherimide resin may include "Ultem" manufactured by GE Company.

[0072] Specific examples of the polysulfone resin may
30 include polysulfone "P1700" and "P3500" manufactured by Solvay Advanced Polymers LLC.

[0073] Examples of the polyolefin resin may include low-density polyethylene, ultra low-density polyethylene, and

high-density polyethylene; ethylenic copolymers such as ethylene-vinyl acetate copolymers, ethylene-ethyl acrylate copolymers, and ethylene-methyl acrylate copolymers; and polyolefin elastomers such as polypropylene and ethylene-propylene block copolymers.

5 [0074] Examples of the polyester resin may include a polyethylene terephthalate resin, a polyethylene naphthalate resin, a polybutylene terephthalate resin, a polybutylene naphthalate resin, a polytrimethylene
10 terephthalate resin, a polytrimethylene naphthalate resin, and a polycyclohexanedimethyl terephthalate resin.

[0075] Among these, as for the thermoplastic resin, the phenoxy resin and the polyvinyl acetal resin are preferable. Accordingly, in a preferable embodiment, the
15 resin composition contains one or more thermoplastic resins selected from the group consisting of the phenoxy resin and the polyvinyl acetal resin. Among these, as for the thermoplastic resin, the phenoxy resin is preferable, and the phenoxy resin having the weight-average molecular
20 weight of 40,000 or more is especially preferable.

[0076] From the viewpoint of notably achieving the advantageous effects of the present invention, the content of the thermoplastic resin is preferably 0.1% or more by mass, more preferably 0.3% or more by mass, and still more
25 preferably 0.5% or more by mass, when the nonvolatile components in the resin composition are defined as 100% by mass. The upper limit thereof is preferably 5% or less by mass, more preferably 4% or less by mass, and still more preferably 3% or less by mass.

30 [0077] From the viewpoint of notably achieving the advantageous effects of the present invention, the content of the thermoplastic resin is preferably 0.5% or more by mass, more preferably 1% or more by mass, still more

preferably 1.5% or more by mass, and preferably 10% or less by mass, more preferably 8% or less by mass, and still more preferably 5% or less by mass, when the resin components in the resin composition are defined as 100% by mass.

5 [0078] -Other Additives-

The resin composition according to the present invention may further contain other additives. Examples of such additive may include organic fillers such as rubber particles; organometallic compounds such as an organocopper
10 compound, an organozinc compound, and an organocobalt compound; colorants such as phthalocyanine blue, phthalocyanine green, iodine green, diazo yellow, crystal violet, titanium oxides, and carbon black; leveling agents such as a silicone type leveling agent and an acrylic
15 polymer type leveling agent; thickening agents such as benton and montmorillonite; defoaming agents such as a silicone type defoaming agent, an acrylic type defoaming agents, a fluorine type defoaming agent, and a vinyl resin type defoaming agent; adhesion assisting agents such as
20 urea silane; adhesion enhancers such as a triazole type adhesion enhancer, a tetrazole-type adhesion enhancer, and a triazine type adhesion enhancer; antioxidants such as a hindered phenol type antioxidant; fluorescent brighteners such as a stilbene derivative; surfactants such as a
25 fluorine type surfactant and a silicone type surfactant; flame retardants such as a phosphorus type flame retardant (for example, a phosphate ester compound, a phosphazene compound, a phosphinic acid compound, and red phosphorous), a nitrogen type flame retardant (for example, melamine
30 sulfate), a halogen type flame retardant, and an inorganic type flame retardant (for example, antimony trioxide); dispersants such as a phosphate ester type dispersant, a polyoxyalkylene type dispersant, an acetylene type

dispersant, a silicone type dispersant, an anionic dispersant, and a cationic dispersant; stabilizers such as a borate type stabilizer, a titanate type stabilizer, an aluminate type stabilizer, a zirconate type stabilizer, an isocyanate type stabilizer, a carboxylic acid type stabilizer, and a carboxylic acid anhydride type stabilizer. These additives may be used alone or in combination of two or more types thereof. The content of the additive described above may be determined in accordance with the properties required to the insulating layer.

[0079] The method for preparing the resin composition is not particularly limited, and it may include, for example, mixing and dispersing the blended components, together with a solvent and so forth as necessary, by using a rotary mixer or the like.

[0080] From the viewpoint of embedding a conductor circuit and retaining the conductor circuit without collapsing, the minimum melt viscosity of the resin composition (and thus the resin composition layer) is preferably 5,000 poise or less, more preferably 4,500 poise or less, and still more preferably 4,000 poise or less. From the viewpoint of preventing seepage during formation of the resin composition layer and improving processability, the minimum melt viscosity is preferably 100 poise or more, more preferably 200 poise or more, and still more preferably 300 poise or more. The minimum melt viscosity of the resin composition can be obtained by measuring the melt viscosity using a dynamic viscoelasticity method, as described in the section of <Measurement of Minimum Melt Viscosity> described later.

[0081] Hereinafter, the present invention will be described specifically in accordance with suitable

embodiments. In the description below, drawings are sometimes referred. In these drawings, the shape, size, and arrangement of the composition elements are schematically illustrated in order to merely help for understanding of the present invention. The present invention is not limited by the description below, and thus, each of the composition elements may be changed as appropriate as long as the change does not deviate from the gist of the present invention.

10 [0082] [Production method of circuit board]

The production method of circuit board according to the present invention (hereinafter sometimes simply referred to as "method of the present invention") is characterized in that the method includes the following steps (X), (Y) and (Z):

(X) forming a first conductor circuit on a metal layer of a substrate with the metal layer attached thereto;

(Y) forming a resin composition layer using the resin composition so as to embed the first conductor circuit formed on the metal layer, followed by curing the resin composition layer to form an insulating layer; and

(Z) removing the substrate with the metal layer attached thereto to form a circuit board having a first main surface in which the first conductor circuit is exposed.

Furthermore, the production method of circuit board according to the present invention is also characterized in that the resin composition contains an epoxy resin, a curing agent and an inorganic filler.

30 [0083] In the method of the present invention, after a conductor circuit is formed on a metal layer of the substrate with the metal layer attached thereto, an insulating layer is formed so as to embed the conductor

circuit and then the substrate with the metal layer attached thereto is removed to expose the conductor circuit. According to the method of the present invention, it is not required the process of selectively removing the metal layer (a seed layer) by etching at the unformed portion of the conductor circuit. It is thus advantageous because the conductor circuit is prevented from being affected by etching, and thus it enables to form a wiring (a conductor circuit) in a fine pattern. In addition, the cross sectional area of the conductor circuit is kept, so that the conductor circuit having excellent electrical characteristics can be formed. Furthermore, the conductor circuit having a high aspect ratio can be formed, which is advantageous for improving the reliability of the pad/chip junction and increasing the density by reducing the pad diameter. According to the method of the present invention, the metal layer is removed by etching or the like to make the conductor circuit aperture to a dented shape. This is advantageous for improving the strength and reliability of the pad/wiring junction formed thereon. In this regard, when forming a trench type conductor circuit, in a conventional technology, a trench (groove) was generally formed by laser processing of the insulating layer, and then the trench was filled with a conductor using a sputtering method or the like to form the trench type conductor circuit. In this technology, there was a limit in the fine wiring, and especially when the insulating layer contains an inorganic filler, the fine wiring was even more difficult. In contrast, with the method of the present invention, the trench type conductor circuit having an extremely fine pattern can be formed, such as the minimum line/space ratio (L/S) of $2/2\ \mu\text{m}$ or less, even when the insulating layer contains the inorganic

filler. Therefore, the present invention significantly contributes to a fine wiring of a circuit board, and thus, to enhancement of the functionality of a semiconductor package.

5 [0084] <Step (X)>

In the step (X), a first conductor circuit is formed on a metal layer of the substrate with the metal layer attached thereto.

[0085] -Substrate with Metal Layer Attached thereto-

10 The substrate with a metal layer attached thereto used in the step (X) is not particularly limited as long as it includes the substrate and the metal layer formed on the substrate.

[0086] In the substrate with the metal layer attached
15 thereto, the metal layer functions as a seed layer for forming the conductor circuit, and the substrate functions as a support for the metal layer. The material of the substrate is not particularly limited, and any substrate selected from a metal substrate, an inorganic substrate,
20 and an organic substrate may be used. In a suitable embodiment, the substrate is selected from a metal substrate whose composition is different from that of the metal layer, an inorganic substrate, and an organic substrate.

25 [0087] As for the metal substrate whose composition is different from that of the metal layer, the constituent material (metal material) thereof is not particularly limited as long as the composition thereof is different from that of the metal layer. Examples of the metal
30 material may include copper, aluminum, and alloys of these metals and other metals (for example, tin, chromium, silver, magnesium, nickel, zirconium, silicon, and titanium). The thickness of the metal substrate is not

particularly limited and may be, for example, in the range of 0.1 mm to 5 mm.

[0088] Examples of the inorganic substrate may include a glass substrate, a ceramic substrate and the like, and
5 examples of the organic substrate may include a substrate made of a plastic material. The material of the glass substrate is not particularly limited, and various glass materials such as a borosilicate glass, a quartz glass, a lead glass, and a soda lime glass may be used. The
10 material of the ceramic substrate is not particularly limited, and various ceramic materials such as alumina and zirconia may be used. Examples of the plastic material may include: polyesters such as polyethylene terephthalate (PET) and polyethylene naphthalate (PEN); polycarbonate
15 (PC); acryls such as polymethyl methacrylate (PMMA); cyclic polyolefins; triacetyl cellulose (TAC); polyether sulfide (PES); polyether ketone; and polyimide. Composite materials such as a fiber-reinforced plastic may also be used. The thickness of the inorganic substrate and of the
20 organic substrate is not particularly limited, and may be determined as appropriate in accordance with the type thereof. The thickness thereof may be, for example, in the range of 0.1 mm to 5 mm.

[0089] The substrate with the metal layer attached
25 thereto includes the metal layer formed on the substrate. The surface of the substrate on the side where the metal layer is formed is preferably smooth and flat. The metal material constituting the metal layer is not particularly limited as long as a conductive layer can be formed on the
30 surface of the metal layer. Examples thereof may include copper, palladium, gold, platinum, silver, aluminum, and alloys of these with other metals (for example, tin, chromium, magnesium, nickel, zirconium, silicon, and

titanium). The metal layer on the substrate can be formed, for example, by sputtering, electroless plating, or attaching ultra-thin metal foil, and among them, sputtering is especially preferable.

5 [0090] In the substrate with the metal layer attached thereto, the thickness of the metal layer is preferably less than 0.5 μm , less than 0.3 μm , less than 0.2 μm , or less than 0.1 μm , from the viewpoints of forming a uniform dented shape in the conductor circuit aperture after the
10 metal layer is removed by etching or the like, and of improving the yield. Although the lower limit of the thickness of the metal layer is not particularly limited, it may be, for example, 0.01 μm or more, 0.02 μm or more, or 0.03 μm or more, from the viewpoint of readily forming
15 the first conductor circuit described later.

[0091] In the present invention, a case that the metal layer is "formed on the substrate" may include the case where the metal layer is formed in contact with (directly to) the substrate as well as the case where the metal layer
20 is formed on the substrate via another layer.

[0092] Here, the other layer is not particularly limited as long as it does not impair the advantageous effects of the present invention. Examples thereof may include an adhesive layer that enables the metal layer to be formed on
25 the substrate with good adhesion and a release layer that enables the substrate to be peeled off from the metal layer. Any conventionally known adhesive layer or release layer may be used as long as it can perform the intended function. When the substrate with the metal layer attached
30 thereto has a release layer between the metal layer and the substrate, this is suitable because the substrate can be removed by peeling-off at the step (Z) described later, and the circuit board having the first main surface in which

the first conductor circuit (a trench type conductor circuit) is exposed can be readily formed. Thus, in a preferable embodiment, the substrate with the metal layer attached thereto includes the release layer between the substrate and the metal layer.

[0093] The release layer is not particularly limited as long as the substrate can be peeled off from the metal layer, and examples thereof may include an alloy layer formed of an element selected from the group consisting of Cr, Ni, Co, Fe, Mo, Ti, W, and P, as well as an organic film that evaporates (sublimates) by an active energy beam (International Publication No. 2018/025957).

[0094] In the substrate with the metal layer attached thereto, the arithmetic mean roughness Ra of the surface of the metal layer on which the conductor circuit is formed is preferably 200 nm or less, more preferably 150 nm or less, still more preferably 100 nm or less, 80 nm or less, 60 nm or less, 50 nm or less, 40 nm or less, or 20 nm or less, from the viewpoint of forming the first conductor circuit in a fine pattern. The lower limit of Ra is not particularly limited, and may be, for example, 1 nm or more, 2 nm or more, or 3 nm or more. Thus, in an embodiment, the arithmetic mean roughness Ra of the metal layer surface is 200 nm or less.

[0095] In the substrate with the metal layer attached thereto, TTV (Total Thickness Variation), which is the difference between the maximum and minimum values of the height of the metal layer surface measured in the thickness direction of the substrate with the metal layer attached thereto, is preferably 50 μm or less, more preferably 40 μm or less, still more preferably 30 μm or less, 20 μm or less, 15 μm or less, 10 μm or less, 7 μm or less, or 5 μm or less, from the viewpoint of forming the first conductor

circuit in a fine pattern. The lower limit of the TTV is not particularly limited, and may be, for example, 1 μm or more, 2 μm or more, or 3 μm or more. Therefore, in an embodiment, TTV, which is the difference between the maximum and minimum values of the height of the metal layer surface measured in the thickness direction of the substrate with the metal layer attached thereto, is 50 μm or less.

[0096] -Formation of First Conductor Circuit-

10 In the present invention, the first conductor circuit is formed on the metal layer of the substrate with the metal layer attached thereto.

[0097] Formation of the first conductor circuit may be carried out according to a known method for forming a circuit, such as a semi-additive method and a full-additive method. Therefore, in an embodiment, the step (X) includes

15 (X-1) forming a photoresist on the metal layer, and then irradiating the photoresist with light and developing the photoresist to expose the metal layer corresponding to the circuit pattern of the first conductor circuit to be formed, and

20 (X-2) forming a conductive layer on the exposed metal layer to form the first conductor circuit.

[0098] A conventionally known photoresist that can be developed to an intended conductor circuit pattern may be used as the photoresist, and any of a film photoresist (dry film photoresist) and a liquid photoresist may be used.

[0099] In particular, from the viewpoint of further achieving the advantageous effects of the present invention, specifically, capable of forming the first conductor circuit in a fine pattern, it is preferable to form the first conductor circuit in accordance with the semi-additive method. Therefore, in the step (X-2)

described above, it is preferable to form the conductive layer by an electrolytic plating using the exposed metal layer as a plating seed layer.

[0100] In the method of the present invention, the
5 substrate with the metal layer attached thereto is removed in the step (Z) described later, and thus it is not necessary to remove by etching the metal layer (seed layer) in the area where the circuit is not formed, which is performed in the usual semi-additive method. In the
10 conventional technologies, even a part of the conductor circuit was also removed during such etching, so that there had been the case that the cross sectional area of the conductor circuit could not be kept. This problem is especially noticeable when forming the conductor circuit
15 having a small L/S ratio, so that this has been a problem in formation of the conductor circuit in a fine pattern. In contrast, with the method of the present invention, the conductor circuit is formed on the metal layer of the substrate with the metal layer attached thereto, and the
20 insulating layer is formed so as to embed the conductor circuit, and then the substrate with the metal layer attached thereto is removed to expose the conductor circuit. This prevents the conductor circuit from being affected by etching and thus enables to form the first
25 conductor circuit having an intended sectional area with a fine pattern.

[0101] In the present invention, the first conductor circuit can be formed in a fine pattern. Specifically, it is possible to form the conductor circuit having the
30 minimum line/space ratio (L/S) of preferably 5/5 μm or less, more preferably 3/3 μm or less, and still more preferably 2/2 μm or less. In the present invention, the first conductor circuit can be formed even having L/S of

1.5/1.5 μm or less, or 1/1 μm or less. Therefore, in a preferable embodiment, the minimum line/space ratio (L/S) of the first conductor circuit is 2/2 μm or less.

[0102] The thickness of the conductive layer to form the first conductor circuit may be determined in accordance with a specific design of the circuit board. In the present invention, it is possible to form the conductor circuit having a fine pattern with the aspect ratio (ratio T/W with the thickness T and line width W of the conductive layer) of preferably 1.5 or more, more preferably 2 or more, 2.5 or more, or 3 or more.

[0103] Hereinafter, one example of the step (X) will be described with reference to FIG. 1 through FIG. 9.

[0104] Firstly, the substrate with the metal layer attached thereto is prepared (FIG. 1). FIG. 1 illustrates the example of the substrate with the metal layer attached thereto (the metal layer-attached substrate) 10, which includes a substrate 1 and a metal layer 2 formed on the substrate. The suitable range of an arithmetic mean roughness Ra of a surface 10a of the metal layer 2 has been described above. The surface roughness of other main surface 10b that is opposite to the surface 10a is not particularly limited. The suitable range of TTV, which is the difference between the maximum and minimum values of the height of the metal layer surface measured in the thickness direction of the metal layer-attached substrate, has been also described above.

[0105] Next, a first conductor circuit is formed on the metal layer 2 (surface 10a) of the metal layer-attached substrate 10. Specifically, a photoresist 20 is formed on the metal layer 2 of the metal layer-attached substrate 10 (FIG. 2), and then, the photoresist is irradiated with light and developed to expose the metal layer corresponding

to a circuit pattern of the first conductor circuit to be formed (FIG. 3). Next, a conductive layer 30 is formed on the exposed metal layer thereby forming the first conductor circuit formed of these conductive layers 30 (FIG. 4; the numerical symbol for the first conductor circuit is also designated as 30 for convenience). With the method of the present invention, the first conductor circuit can be formed in a fine pattern as described before. After forming the first conductor circuit, the photoresist 20 is removed (FIG. 5).

[0106] The intended circuit pattern and interlayer connection pattern may be formed by carrying out the formation of the conductive layer multiple times by means of the photoresist. For example, a second photoresist 21 is formed on the metal layer of the first conductor circuit 30 (FIG. 6), and the photoresist is irradiated with light and developed to expose the conductive layer 30 (first conductor circuit 30) corresponding to the interlayer connection pattern (FIG. 7). Next, a conductive layer is formed on the exposed first conductor circuit 30 to form an interlayer connecting conductor (in FIG. 8, the conductive layer 30 in the center corresponds to the interlayer connecting conductor). After forming the interlayer connecting conductor, the second photoresist 21 is removed (FIG. 9).

[0107] FIG. 3 through FIG. 9 illustrates the example of forming the first conductor circuit using the photoresist 20 and then forming the interlayer connecting conductor using the photoresist 21, but the procedure is not limited as long as the first conductor circuit can be formed on the metal layer. For example, the photoresist 20 may be irradiated with light and developed to expose the metal layer of the substrate corresponding to the interlayer

connection pattern first, and then the conductive layer (interlayer connecting conductor) may be formed on the exposed metal layer. In such a case, after forming the interlayer connecting conductor, the photoresist 20 may be irradiated with light and developed to expose the metal layer of the substrate corresponding to the circuit pattern of the first conductor circuit to be formed without removing the photoresist 20, and then the conductive layer may be formed on the exposed metal layer to form the first conductor circuit.

[0108] <Step (Y)>

In the step (Y), a resin composition layer is formed by the resin composition so as to embed the first conductor circuit, and then, the resin composition layer is cured to form an insulating layer.

[0109] -Resin Composition Layer-

As described above, from the viewpoints of enabling the first conductor circuit to be formed so as to be embedded and of exhibiting sufficient insulation after curing, the resin composition layer is formed using the resin composition containing an epoxy resin, a curing agent and an inorganic filler. The resin composition has been described in the section of <Resin Composition> above.

[0110] The step (Y) may be carried out by applying the resin composition in a varnish state, or may be carried out by previously forming the resin composition layer containing the resin composition followed by laminating the resin composition layer.

[0111] In a preferable embodiment, the step (Y) includes laminating a resin sheet, which includes a support film and the resin composition layer on the support film, onto the metal layer-attached substrate on which the first conductor

circuit has been formed such that the resin composition layer is in contact with the first conductor circuit.

[0112] Examples of the support film may include a film formed of a plastic material, metal foil, and a release
5 paper. Among them, a film formed of a plastic material and metal foil are preferable. When the film formed of a plastic material is used as the support film, examples of the plastic material may include polyesters such as PET and PEN, PC, and acrylic resins such PMMA, as
10 well as a cyclic polyolefin, TAC, PES, polyether ketone, and polyimide. In the case that metal foil is used as the support film, examples of the metal foil may include copper foil and aluminum foil. Among them, copper foil is preferable. As for the copper foil, the foil formed of a
15 copper single metal or an alloy of copper with other metal (for example, tin, chromium, silver, magnesium, nickel, zirconium, silicon, and titanium) may be used. The support film may be subjected to a mat treatment, a corona treatment, or an antistatic treatment on the surface to be
20 in contact with the resin composition layer. As for the support, a release layer-attached support that has a release layer on the surface to be in contact with the resin composition layer may be used.

[0113] The resin sheet can be produced, for example, by
25 applying the resin composition as it is or as the resin varnish, which is prepared by dissolving the resin composition into an organic solvent, onto the support by means of a die coater or the like, followed by drying it to form the resin composition layer.

30 [0114] In the resin sheet, the thickness of the resin composition layer is not particularly limited as long as the first conductor circuit can be embedded, and it may be

determined as appropriate in accordance with a specific design.

[0115] The lamination of the resin sheet is not particularly limited as long as the resin composition layer
5 can be laminated so as to embed the first conductor circuit. For example, the resin sheet can be thermal pressed from the support film side onto the metal layer-attached substrate. Examples of a member used for thermal pressing the resin sheet to the metal layer-attached
10 substrate (hereinafter, referred to as a "thermal pressing member") include a heated metal plate (such as a SUS mirror plate) and a metal roll (a SUS roll). At this time, it is preferable that the thermal pressing member is not pressed directly to the resin sheet but is pressed against the
15 resin sheet in a state that an elastic material such as heat resistant rubber intervenes therebetween so that the resin sheet may well follow the surface irregularity of the metal layer-attached substrate based on the first conductor circuit and the interlayer connecting conductor.

[0116] The lamination of the resin sheet may be carried out by a vacuum lamination method. In the vacuum lamination method, the thermal pressing temperature is preferably in the range of 60°C to 160°C, and more preferably in the range of 80°C to 140°C, and the thermal
25 pressing pressure is preferably in the range of 0.098 MPa to 1.77 MPa, and more preferably in the range of 0.29 MPa to 1.47 MPa, and the thermal pressing time is preferably in the range of 20 seconds to 400 seconds, and more preferably in the range of 30 seconds to 300 seconds. The lamination
30 is carried out preferably under the reduced pressure of 26.7 hPa or less. The lamination may be carried out by a vacuum laminator. Examples of the commercially available vacuum laminator may include a vacuum pressure laminator

manufactured by Meiki Co., Ltd., as well as a vacuum applicator and a batch type vacuum pressing laminator manufactured by Nikko-Materials Co., Ltd.

[0117] After the lamination, the laminated resin sheet
5 may be subjected to a smoothening treatment, for example, by pressing the thermal pressing member from the support film side of the resin sheet. A pressing condition for the smoothing treatment may be the same as the thermal pressing condition for the lamination described above. The
10 laminating and the smoothing treatment may be performed continuously using the vacuum laminator.

[0118] -Formation of Insulating Layer-

The resin composition layer is cured to form the insulating layer. With this, the insulating layer is
15 formed so as to embed the first conductor circuit.

[0119] The condition for thermal curing the resin composition layer is not particularly limited, and the condition usually employed in formation of the insulating layer of a circuit board may be used.

[0120] The thermal curing condition of the resin composition layer varies depending on the resin composition and so forth. In an embodiment, the curing temperature is preferably in the range of 120°C to 250°C, and more preferably in the range of 150°C to 240°C. The curing time
20 can be preferably in the range of 5 minutes to 240 minutes, and more preferably in the range of 10 minutes to 150 minutes.

[0121] When forming the resin composition layer (insulating layer) using the resin sheet, the support film
30 may be removed before curing the resin composition layer or after curing the resin composition layer.

[0122] Hereinafter, one example of the step (Y) will be described with referring to FIG. 10 and FIG. 11.

[0123] A resin composition layer 50 is formed so as to embed the first conductor circuit 30, followed by curing the resin composition layer to form an insulating layer 51 (FIG. 10). It is preferable that the insulating layer 51 is formed thickly enough to embed the first conductor circuit and the interlayer connecting conductor, followed by removing the excess insulating layer 51 by polishing to expose the interlayer connecting conductor, flattening and smoothing the insulating layer (FIG. 11). The polishing method is not particularly limited, and may be used, for example, a chemical mechanical polishing method as well as a mechanical polishing method such as buffing, belt polishing, and roll polishing.

[0124] After the step (Y), a multilayered circuit board can be formed by further forming a conductor circuit and an insulating layer.

[0125] Thus, in a preferable embodiment, the method according to the present invention further includes the following steps after the step (Y):

(i) forming a second conductor circuit on the surface of the insulating layer, and

(ii) forming a resin composition layer so as to embed the second conductor circuit followed by curing the resin composition layer to form an insulating layer.

[0126] -Step (i)-

In the step (i), the second conductor circuit is formed on the surface of the insulating layer.

[0127] The formation of the second conductor circuit may be conducted in accordance with a known circuit formation method such as a semi-additive or a full-additive method.

[0128] For example, when forming the second conductor circuit by a semi-additive method, a metal layer is formed on the surface of the insulating layer, a photoresist is

placed on the metal layer, and then the photoresist is irradiated with light and developed to expose a portion of the metal layer corresponding to an intended circuit pattern. After the conductive layer is formed by electroplating on the exposed metal layer, the photoresist is removed. Next, an unnecessary metal layer other than the conductive layer portion is removed by etching or the like to form the second conductor circuit having an intended wiring pattern.

[0129] When forming the second conductor circuit by semi-additive method, the metal layer that functions as the plating seed layer may be formed by a dry plating or by a wet plating. Examples of the dry plating may include: physical vapor deposition (PVD) methods such as sputtering, ion plating, and vacuum evaporation; and chemical vapor deposition (CVD) methods such as thermal CVD and plasma CVD. Examples of the wet plating may include an electroless plating method. From the viewpoint of forming a thin second conductor circuit, the metal layer is preferably thin, and may be, for example, 1 μm or less, 0.8 μm or less, 0.6 μm or less, 0.5 μm or less, 0.4 μm or less, or 0.2 μm or less. From the viewpoint of suppressing plating burn when forming the conductive layer by an electrolytic plating method, the lower limit of the thickness of the metal layer may be, for example, 0.01 μm or more, or 0.02 μm or more.

[0130] The line/space ratio (L/S) of the second conductor circuit and the thickness of the circuit conductive layer may be determined as appropriate in accordance with a specific design of the circuit board.

[0131] Hereinafter, one example of the step (i) will be described with referring to FIG. 12 through FIG. 17. In

the embodiment illustrated in the drawings, the second conductor circuit is formed by the semi-additive method.

[0132] A metal layer 31 is formed on the surface of the insulating layer obtained in the step (Y) (FIG. 12). Next, a photoresist 22 is formed on the metal layer 31 (FIG. 13), and then, the photoresist 22 is irradiated with light and developed to expose the metal layer 31 corresponding to the circuit pattern of the second conductor circuit to be formed (FIG. 14). Then, a conductive layer 30 is formed on the exposed metal layer by an electrolytic plating method (FIG. 15), which is followed by removal of the photoresist 22 (FIG. 16). Next, an unnecessary portion of the metal layer 31 other than the conductive layer portion is removed by etching or the like (FIG. 17), so that the second conductor circuit 30 can be formed on the surface of the insulating layer.

[0133] -Step (ii)-

In the step (ii), a resin composition layer is formed to embed the second conductor circuit, and then, the resin composition layer is cured to form an insulating layer.

[0134] The process (ii) may be carried out in the same manner as the process (Y) described before. The composition of the resin composition used to form the resin composition layer has been described in the section of <Resin Composition> above, and the composition of the resin sheet has been described in the process (Y). The resin composition used to form the resin composition layer at the process (ii) may be the same composition as or different from the composition of the resin composition used in the process (Y).

[0135] By repeating the step (i) and the step (ii) N times, a circuit board having N+1 circuit layers can be produced. In production of the multilayered circuit board

like this, after the n^{th} step (ii) and before the $n+1^{\text{th}}$ step (i), the step of perforating the insulating layer and the step of subjecting the insulating layer to a desmear treatment may be carried out. These steps may be carried out in accordance with various methods known to those skilled in the art for production of a circuit board. With this, by forming a via conductor at the $n+1^{\text{th}}$ step (i), the interlayer connection can be employed.

[0136] Hereinafter, one example of the step (ii) and the procedure for forming the via conductor will be described with referring to FIG. 18 through FIG. 20.

[0137] A resin composition layer 50 is formed so as to embed the second conductor circuit 30 on the insulating layer 51, and then the resin composition layer is cured to form the insulating layer 51 (FIG. 18). In FIG. 18, the boundary between the insulating layer 51 formed at the step (Y) and the resin composition layer 50 (insulating layer 51) formed at the step (ii) is indicated by a dotted line, but the insulating layer formed at the step (ii) is integrated with the insulating layer formed at the step (Y) to form the insulating layer 51. Next, in accordance with an intended interlayer connection pattern, the insulating layer is perforated to form a via hole 51v (FIG. 19).

After the desmear treatment, a conductor can be formed in the via hole 51v to form a via conductor 30 (FIG. 20).

[0138] FIG. 12 through FIG. 20 illustrate the example in which the step (i) and the step (ii) are carried out once; but as described before, by repeating the step (i) and the step (ii) N times, a circuit board having N+1 circuit layers can be produced.

[0139] <Step (Z)>

In a step (Z), the metal layer-attached substrate is removed to form a circuit board having a first main surface in which the first conductor circuit is exposed.

[0140] The step (Z) can be carried out either by
5 removing the metal layer and the substrate simultaneously or by removing the substrate and then removing the metal layer, depending on the type of the metal layer and substrate used. The step (Z) may be carried out, for example, by etching, chemical/mechanical polishing, or the
10 like. For example, the substrate may be removed by chemical/mechanical polishing or the like followed by removal of the metal layer by etching or the like. For example, when the metal layer-attached substrate having a release layer between the metal layer and the substrate is
15 used, the step (Z) may be carried out by the method in which the substrate is peeled off followed by removal of the metal layer by etching, chemical/mechanical polishing, or the like.

[0141] Hereinafter, one example of the step (Z) will be
20 described with referring to FIG. 20 through FIG. 23. The illustrated embodiment describes the procedure for removal of the substrate when the metal layer-attached substrate having the release layer between the metal layer and the substrate is used.

[0142] In the metal layer-attached substrate 10, the
25 substrate 1 is peeled off from the metal layer 2 (FIG. 20 and FIG. 21, in which the release layer is not illustrated). Next, the metal layer 2 derived from the metal layer-attached substrate is removed by etching,
30 chemical/mechanical polishing, or the like (FIG. 22 and FIG. 23). In this way, there is formed a circuit board 100 having a first main surface 100a in which the first conductor circuit 30 is exposed. As illustrated in FIG.

23, the circuit board 100 includes the first conductor circuit 30 formed as the trench type conductor circuit in the first main surface 100a.

[0143] With the method of the present invention, even
5 when the insulating layer contains the inorganic filler, it is possible to form the trench type conductor circuit having an extremely fine pattern, such as the minimum line/space ratio (L/S) of 2/2 μm or less. Therefore, the circuit board that is produced by the method according to
10 the present invention can be suitably used as the circuit board such as a redistribution board (circuit board for a semiconductor package) in the production of a semiconductor package.

[0144] [Circuit Board]

15 With the method of the present invention, the circuit board having the conductor circuit of an extremely fine pattern can be produced. The present invention also provides the circuit board as described above.

[0145] In an embodiment, the circuit board according to
20 the present invention is characterized in that the circuit board has

a first main surface and a second main surface, and includes

a trench type conductor circuit in the first main
25 surface,

a minimum line/space ratio (L/S) of the trench type conductor circuit is 2/2 μm or less, and

the insulating layer defining the first main surface together with the trench type conductor circuit is a cured
30 product of a resin composition containing an epoxy resin, a curing agent and an inorganic filler.

[0146] Hereinafter, the features of the circuit board according to the present invention will be described with referring to FIG. 23.

[0147] As illustrated in FIG. 23, the circuit board 100 in an embodiment of the present invention has the first main surface 100a and the second main surface 100b, and includes the first conductor circuit 30 that is exposed in the first main surface. The circuit board 100 also includes the insulating layer 51 that defines the first main surface 100a together with the first conductor circuit 30, and is arranged so as to embed the first conductor circuit 30. That is, the circuit board 100 in an embodiment of the present invention includes the trench type conductor circuit 30 (first conductor circuit 30) in the first main surface 100a. In FIG. 23, the trench type conductor circuit exposed in the first main surface extends in the paper from the front to the back (i.e., in the Z direction when the paper is defined as the X-Y plane).

[0148] In the circuit board 100 in an embodiment of the invention, the trench type conductor circuit 30 (the first conductor circuit 30) exposed in the first main surface 100a has an extremely fine pattern, in which the minimum line/space ratio (L/S) is 2/2 μm or less, more preferably 1/1 μm or less.

[0149] In the circuit board 100 in an embodiment of the present invention, the insulating layer 51 that defines the first main surface 100a together with the trench type conductor circuit 30 (the first conductor circuit 30) is formed of a cured product of the resin composition containing an epoxy resin, a curing agent and an inorganic filler. The resin composition has been described in the section of <Resin Composition> above. From the viewpoint of achieving the characteristics such as a low thermal

expansion coefficient and a low dielectric loss tangent, the insulating layer contains the inorganic filler. As described before, when the insulating layer contains an inorganic filler, it has been difficult to form the trench
5 type conductor circuit having a fine pattern. In contrast, by the method of the present invention, the trench type conductor circuit having an extremely fine pattern can be formed even when the insulating layer contains the inorganic filler, and moreover, even when the content of
10 the inorganic filler is so high. The content of the inorganic filler in the insulating layer is preferably 20% or more by mass, more preferably 30% or more by mass, and still more preferably 40% or more by mass. In addition, the content is preferably 75% or less by mass, more
15 preferably 70% or less by mass, and still more preferably 65% or less by mass. Thus, in a preferable embodiment, the content of the inorganic filler in the insulating layer that defines the first main surface together with the trench type conductor circuit is 20% or more by mass. In
20 the above, the inorganic filler and the amount thereof in the insulating layer formed so as to embed the trench type conductor circuit have been described, but the same composition may be applied to all the insulating layers constituting the circuit board, as described in the section
25 of [Production method of circuit board] above.

[0150] It is preferable that the circuit board according to the present invention have a multilayered structure having two or more circuit layers (including the first conductor circuit). The number of the circuit layer may be
30 determined in accordance with a specific design of the circuit board, in which the preferable number is 3 or more, 4 or more, or 5 or more. The upper limit of the number of the circuit layer is not particularly limited, and may be,

for example, 50 or less, 40 or less, or 30 or less. The method for producing the multilayered circuit board has already been described in the section of [Production method of circuit board] above.

5 [0151] -Cross Sectional Shape of Trench Type Conductor Circuit-

With the method of the present invention, the trench type conductor circuit having a favorable cross sectional shape can be formed. Specifically, in the cross section in
10 direction Y that is perpendicular to the first main surface 100a and also perpendicular to a direction of extension of the trench type conductor circuit 30 (i.e., the cross section illustrated in FIG. 23, in which the direction Y is the vertical direction in FIG. 23), the cross sectional
15 shape is characterized in that the angle difference between the straight line direction y1 defined by the side wall of the trench type conductor circuit 30 and the direction Y is 20° or less.

[0152] The angle difference between the direction y1 and
20 the direction Y is preferably 15° or less, more preferably 10° or less, still more preferably 8° or less, 6° or less, 5° or less, 4° or less, 2° or less, or 1° or less, and even the trench type conductor circuit can be formed with the angle difference of substantially 0°.

25 [0153] In this regard, when the trench type conductor circuit is formed by a conventional technology of forming the conductor circuit on the insulating layer, there has been a tendency to result in a tapered conductor circuit in which the width thereof decreases from the main surface
30 (the first main surface) where the conductor circuit is exposed toward the depth direction of the circuit board. This tendency (a degree of a taper angle and the like) was more pronounced when the insulating layer containing an

inorganic filler (especially when the content of the inorganic filler was high). In contrast, in the circuit board produced by the method of the present invention, the trench type conductor circuit having a favorable cross sectional shape can be formed as described above even when the insulating layer contains the inorganic filler, and moreover, even when the content of the inorganic filler is high. Unlike the circuit board produced by a conventional technology of forming the conductor circuit on the insulating layer, the circuit board produced by the method of the present invention tends to result in an inversely tapered conductor circuit in which the width thereof increases from the first main surface toward the depth direction of the circuit board. Thus, in an embodiment, the trench type conductor circuit has the inversely tapered shape in which the width thereof increases from the first main surface toward the depth direction of the circuit board.

[0154] -Surface Properties of First main surface-

In the circuit board according to the present invention, the arithmetic mean roughness Ra of the first main surface is preferably 200 nm or less, more preferably 150 nm or less, and still more preferably 100 nm or less, 80 nm or less, 60 nm or less, 50 nm or less, 40 nm or less, or 20 nm or less. The lower limit of Ra is not particularly limited, and may be, for example, 1 nm or more, 2 nm or more, or 3 nm or more. Accordingly, in a preferable embodiment, the arithmetic mean roughness Ra of the first main surface of the circuit board according to the present invention is 200 nm or less.

[0155] From the viewpoint of forming the first conductor circuit in a fine pattern, TTV, which is the difference between the maximum and minimum values of the height of the

first main surface measured in the thickness direction of the circuit board, is preferably 50 μm or less, more preferably 40 μm or less, more preferably 30 μm or less, 20 μm or less, 15 μm or less, 10 μm or less, 7 μm or less, or
5 5 μm or less. The lower limit of the TTV is not particularly limited, and may be, for example, 1 μm or more, 2 μm or more, or 3 μm or more. Accordingly, in an embodiment, TTV, which is the difference between the maximum and minimum height of the first main surface
10 measured in the thickness direction of the circuit board, is 50 μm or less.

[0156] In production of a semiconductor package, a semiconductor chip is electrically connected to the first main surface of the circuit board (specifically, the first
15 conductor circuit (the trench type conductor circuit)). In the circuit board according to the present invention, the semiconductor chip can be connected easily and accurately.

[0157] -Aspect Ratio of Trench Type Conductor Circuit-
With the method according to the present invention,
20 the trench type conductor circuit having a fine pattern with a high aspect ratio can be formed. Specifically, in the cross section in the direction Y perpendicular to the first main surface 100a and also perpendicular to the direction of extension of the trench type conductor circuit
25 30 (i.e., the cross section illustrated in FIG. 23), the ratio of thickness T to width W of the trench type conductor circuit (T/W) is preferably 1.5 or more, more preferably 2 or more, 2.5 or more, or 3 or more. The upper limit of the aspect ratio (T/W) may be, for example, 10 or
30 less, or 8 or less. When the width W varies in the depth direction in the cross section in the direction Y, such as when the trench type conductor circuit has the inversely

tapered shape as described before, the maximum value of the width W is used to calculate the aspect ratio (T/W).

[0158] -Shape of Aperture (Exposed Surface) of Trench Type Conductor Circuit-

5 With the method of removing the substrate to expose the first conductor circuit according to the present invention, there can be a case that a portion of the first conductor circuit is removed together with the substrate. For example, a part of the first conductor circuit can be
10 removed by removing the metal layer by etching or the like after the substrate is peeled off. Thus, in an embodiment, in the cross section in the direction Y perpendicular to the first main surface 100a and also perpendicular to the direction of extension of the trench type conductor circuit
15 30 (i.e., the cross section described in FIG. 23), the aperture (exposed surface) of the trench type conductor circuit 30 is dented by $0.05W$ or more than the exposed surface of the insulating layer 51 that defines the first main surface together with the trench type conductor
20 circuit 30. Here, W represents the width W of the trench type conductor circuit in the cross section, as described above. The dent may be made $0.06W$ or more, $0.08W$ or more, or $0.1W$ or more, and the upper limit thereof may be, for example, $0.5W$ or less, $0.4W$ or less, or $0.3W$ or less.

25 [0159] In an embodiment, the trench type conductor circuit has an inversely tapered shape in which the width thereof increases from the first main surface toward the depth direction of the circuit board and has a dented shape on the first main surface side where the width is narrower.

30 [0160] As described before, the circuit board according to the present invention can be suitably used as a circuit board such as a redistribution board (circuit board for semiconductor package) in production of a semiconductor

package. In production of the semiconductor package, the first main surface of the circuit board (specifically, the first conductor circuit (trench type conductor circuit)) is electrically connected to a semiconductor chip. A board
5 connection terminal such as a bump is formed on the second main surface of the circuit board (100b in FIG. 23).

[0161] [Semiconductor Package]

A semiconductor package can be produced using the circuit board according to the present invention. The
10 present invention also provides the semiconductor package like this.

[0162] In an embodiment, the semiconductor package according to the present invention includes the circuit board according to the present invention and the
15 semiconductor chip formed on the first main surface so as to be electrically connected to the trench type conductor circuit (first conductor circuit) of the circuit board.

[0163] Referring to FIG. 24 through FIG. 26, the composition and production procedure of the semiconductor
20 package according to the present invention will be described below.

[0164] The semiconductor package in an embodiment of the present invention is produced by forming a semiconductor chip 110 on the first main surface 100a so as to be
25 electrically connected to the trench type conductor circuit (first conductor circuit 30) of the circuit board 100 (FIG. 24, in which a conductor circuit such as the first conductor circuit is not illustrated). Next, a semiconductor package 200 may be formed by forming a
30 sealing layer 120 on the first main surface 100a of the circuit board 100 so as to embed the semiconductor chip 110, and individualizing if necessary (FIG. 25 and FIG. 26). The sealing layer 120 may be formed using a

conventionally known sealant (a sealing resin composition) used in production of a semiconductor package.

[0165] The semiconductor package according to the present invention may be any of a fan-in (Fan-In) type package and a fan-out (Fan-Out) type package. FIG. 24 through FIG. 26 illustrate the fan-out type package having the circuit board 100 that is larger in area than the semiconductor chip 110. When the semiconductor package according to the present invention is a fan-out type package, this is advantageous because the conductor circuit having a large area with a fine pattern can be formed, coupled with the inherent feature of the fan-out type package that the redistribution layer having a large area can be formed. Thus, in a preferable embodiment, the semiconductor package according to the present invention is a fan-out type package.

EXAMPLES

[0166] Hereinafter, the present invention will be specifically described by means of Examples. The present invention, however, is not limited to these Examples. In the following description, "part(s)" and "%" in terms of amounts represent "part(s) by mass" and "% by mass", respectively, unless otherwise specifically mentioned. Unless otherwise specifically mentioned, the temperature and pressure conditions are room temperature (25°C) and atmospheric pressure (1 atm), respectively.

[0167] <Inorganic Filler Used>

Inorganic Filler 1: this was obtained by treating 100 parts of spherical silica ("UFP-30", an average particle diameter of 0.3 μm , specific surface area of 30.7 m^2/g , manufactured by Denka Co., Ltd.) having the surface thereof treated with 2 parts of N-phenyl-3-

aminopropyltrimethoxysilane (KBM573, manufactured by Shin-Etsu Chemical Co., Ltd.).

[0168] <Preparation Example 1> (Preparation of Resin Composition 1)

5 Six parts of the bixylenol type epoxy resin ("YX4000HK", an epoxy equivalent of approximately 185, manufactured by Mitsubishi Chemical Corp.), 5 parts of the naphthalene type epoxy resin ("ESN475V", an epoxy equivalent of approximately 332, manufactured by Nippon
10 Steel Chemical & Material Co., Ltd.), 15 parts of the bisphenol AF type epoxy resin ("YX7760", an epoxy equivalent of approximately 238, manufactured by Mitsubishi Chemical Corp.), 2 parts of the naphthylene ether type epoxy resin ("HP6000L", an epoxy equivalent of
15 approximately 213, manufactured by DIC Corp.), 2 parts of the cyclohexane type epoxy resin ("ZX1658GS", an epoxy equivalent of approximately 135, manufactured by Mitsubishi Chemical Corp.), and 2 parts of the phenoxy resin ("YX7500BH30", a 1:1 solution of cyclohexanone:methyl ethyl
20 ketone (MEK) with the solid content of 30% by mass, Mw of 44,000, manufactured by Mitsubishi Chemical Corp.) were dissolved by heating with stirring in a mixed solvent made of 20 parts of a solvent naphtha and 10 parts of cyclohexanone. After cooling to room temperature, 4 parts
25 of the cresol novolac type curing agent containing a triazine backbone ("LA-3018-50P", a hydroxy equivalent of approximately 151, a 2-methoxypropanol solution with the solid content of 50%, manufactured by DIC Corp.), 12 parts of the active ester-based curing agent ("EXB-8000L-65TM",
30 an active group equivalent of approximately 220, a toluene solution with the nonvolatile content of 65% by mass, manufactured by DIC Corp.), 45 parts of Inorganic Filler 1, and 0.05 part of the amine type curing accelerator (4-

dimethylaminopyridine (DMAP)) were mixed, uniformly dispersed by means of a high-speed rotary mixer, and then filtrated through a cartridge filter ("SHP020", manufactured by ROKI TECHNO CO., LTD.), thus preparing

5 Resin Composition 1.

[0169] <Preparation Example 2> (Preparation of Resin Composition 2)

(1) Resin composition 2 was prepared in the same manner as Preparation Example 1, except that the amount of
10 Inorganic Filler 1 was changed from 45 parts to 65 parts.

[0170] [Example 1]

(1) Preparation of Resin Sheet

As the support, the PET film ("Lumirror R80", thickness of 38 μm , softening temperature of 130°C,
15 manufactured by Toray Industries, Inc., "release PET") treated with the alkyd resin type release agent ("AL-5", manufactured by Lintec Corp.) was used. Resin Composition 1 was applied uniformly onto the release agent of the support using a die coater so as to bring the thickness of
20 the resin composition layer after drying to 20 μm , which was then followed by drying at the temperature range from 70°C to 95°C for 4 minutes to form the resin composition layer on the release PET. Next, a rough surface of a polypropylene film ("Alphan MA-411", thickness of 15 μm ,
25 manufactured by Oji F-Tex Co., Ltd.) was laminated, as the protective film, to the surface of the resin composition layer that was not in contact with the support. With this, the resin sheet having a layer structure of release PET (support)\resin composition layer \protective film was
30 obtained.

[0171] (2) Method for Producing Circuit Board for Evaluation

The circuit board for evaluation was produced in accordance with the following procedure.

[0172] (2-1) Preparation of Substrate

A glass wafer (wafer thickness of 0.8 mm, 8 inch size)
5 was prepared as the substrate, and this was dried in an oven at 130°C for 30 minutes.

[0173] (2-2) Preparation of Substrate Attached with Metal Layer

A metal layer was formed on the surface of the glass
10 wafer. Specifically, a metal layer having the thickness of 200 nm (a Cu layer) was formed on the surface of the glass wafer using a sputtering device ("E-400S", manufactured by Canon Anelva Corp.).

[0174] (2-3) Formation of First Conductor Circuit

15 The first conductor circuit was formed in accordance with the semi-additive method. Specifically, the photoresist was formed on the metal layer of the substrate with the metal layer attached thereto, and then, this was irradiated with light and developed to expose the metal
20 layer corresponding to a comb blade pattern having the L/S ratio of 1.5/1.5 μm (line length of 1 mm). Next, the electrolytic plating with copper sulfate was carried out to form the conductive layer (the first conductor circuit) having the thickness of 3 μm on the exposed metal layer,
25 and then the photoresist was removed. Then, without performing etching the metal layer in the unformed portion of the first conductor circuit (seed etching), this was subjected to the process described in (2-4) below. Therefore, at this point, the conductive layer is
30 continuous.

[0175] (2-4) Lamination of Resin Sheet

The protective film was peeled off from the resin sheet to expose the resin composition layer. Next, using a

batch type vacuum pressing laminator ("CVP700", two-stage build-up laminator manufactured by Nikko-Materials Co., Ltd.), the resin composition layer was laminated onto one side of the substrate with the metal layer attached thereto so as to make the resin composition layer in contact with the first conductor circuit. The lamination was carried out by reducing the pressure for 30 seconds to an air pressure of 13 hPa or less, and then pressing for 45 seconds at 130°C and a pressure of 0.74 MPa. Next, it was subjected to a smoothening treatment by thermal pressing for 75 seconds at 120°C and 0.5 MPa. Then, the support was peeled off, and copper foil ("3EC-III" (35 µm) manufactured by Mitsui Mining & Smelting Co., Ltd.) was laminated on the exposed resin composition layer under the same conditions as before.

[0176] (2-5) Thermal Curing of Resin Composition

The laminate obtained in (2-4) above was heated at 100°C in an oven for 60 minutes, and then at 180°C in a different oven for 90 minutes to thermally cure the resin composition layer. In this way, Substrate A, in which a cured product of the resin composition layer (an insulating layer having the thickness of 20 µm) was formed on the metal layer of the substrate with the metal layer attached thereto so as to embed the first conductor circuit, was obtained.

[0177] (2-6) Polishing of Substrate

Substrate A was diced into individual pieces and polished from the substrate side (the glass wafer side). Although the exact thickness of the polished wafer was not measured, it was confirmed that the polishing did not reach the metal layer (the copper layer) and that a part of the glass wafer remained. This substrate is designated as Substrate B.

[0178] (2-7) Removal of Remaining Substrate by Etching

Substrate B was immersed in an aqueous solution of 5% hydrogen fluoride at 25°C for 30 minutes to completely remove the substrate (the glass wafer), so that the substrate having the metal layer exposed was obtained. This substrate is designated as Substrate C.

[0179] (2-8) Removal of Metal Layer

Substrate C was subjected to etching using an etching liquid ("WLC-C2" manufactured by Mitsubishi Gas Chemical Co., Inc.) to remove the metal layer, so that the circuit board having the first conductor circuit exposed was obtained. The resulting circuit board is designated as Evaluation Circuit Board A.

[0180] [Example 2]

Evaluation Circuit Board A was prepared in the same procedure as Example 1, except that Resin Composition 2 was used in place of Resin Composition 1.

[0181] (3) Measurement and Evaluation

The minimum melt viscosities of Resin Compositions 1 and 2, the specific dielectric constant and linear thermal expansion coefficient of the cured products of Resin Compositions 1 and 2, and the characteristics of Evaluation Circuit Board A were measured and evaluated as follows.

[0182] <Measurement of Minimum Melt Viscosity>

The melt viscosities of Resin Compositions 1 and 2 were measured using a dynamic viscoelasticity measurement instrument ("Rheosol-G3000", manufactured by UBM Corp.) to determine the minimum melt viscosity. Specifically, using 1 g of the sample resin composition, the dynamic viscoelastic modulus was measured by using a parallel plate having the diameter of 18 mm with the temperature raising rate of 5°C/minutes from the starting temperature of 60°C to 200°C, the temperature measurement interval of 2.5°C,

the oscillation of 1 Hz, and the strain of 1 deg; then, from the minimum value of the melt viscosity thereby obtained, the minimum melt viscosity (poise) was obtained.

[0183] <Measurement of Specific dielectric constant>

5 The resin sheet prepared using Resin Compositions 1 and 2 was heated at 180°C for 90 minutes to thermally cure the resin composition layer. The resulting cured resin composition layer was cut into a test piece having the size of 2 mm width and 80 mm length, and then, the specific
10 dielectric constant thereof was measured by the cavity resonance method using a cavity resonator perturbation dielectric constant measurement instrument ("CP521", manufactured by Kanto Electronics Application & Development Inc.) and a network analyzer ("E8362B", manufactured by
15 Agilent Technologies Japan, Ltd.) at 23°C and the frequency of 5.8 GHz. For each cured product, 2 test pieces were measured (n = 2) and the average value thereof was calculated.

[0184] <Measurement of Linear Thermal Expansion
20 Coefficient>

 The resin sheet prepared using Resin Compositions 1 and 2 was heated at 180°C for 90 minutes to thermally cure the resin composition layer. The cured resin composition layer thus obtained was cut into a test piece having the
25 size of 5 mm width and 15 mm length, and then, the thermomechanical analysis was conducted using a thermomechanical analyzer ("Thermo Plus TMA8310", manufactured by Rigaku Corp.) by a tensile weighting method. After mounting the test piece on the
30 aforementioned apparatus, 2 consecutive measurements were carried out with the load of 1 g and the temperature raising rate of 5°C/minute. The average linear thermal

expansion coefficient (ppm/°C) from 25°C to 150°C in the second measurement was calculated.

[0185] <Characterization of Evaluation Circuit Board A>

(1) Evaluation of Embeddability

5 Evaluation Circuit Board A was observed from the side of the first conductor circuit using a non-contact type interference microscope (manufactured by WYKO Corp.). The embeddability thereof was then evaluated in accordance with the following criteria.

10 Evaluation Criteria:

X: Poor embedding dent was observed due to the resin defect between the wires.

O: Poor embedding as described above was not observed.

[0186] (2) Evaluation of Insulation Property

15 The insulation reliability test was conducted with regard to Evaluation Circuit Board A. Specifically, a HAST testing instrument ("PM422", manufactured by Kusumoto Chemicals, Ltd.) was used at 130°C and humidity of 85% with applying the voltage of 3.3 V to both terminals of the
20 electrodes (bHAST). After 200 hours, Evaluation Circuit Board A was taken out and the resistance thereof was measured using a resistance measurement instrument ("ECM-100", manufactured by J-RAS Inc). The insulation property thereof was then evaluated in accordance with the following
25 criteria.

Evaluation Criteria:

x: Resistance of less than $10^8 \Omega$.

O: Resistance of $10^8 \Omega$ or more.

[0187] [Table 1]

(Table 1)

				Example 1	Example 2
Resin com position	No.			1	2
	Com ponent	Epoxy resin	YX4000HK	6	6
			ESN475V	5	5
			YX7760	15	15
			HP6000L	2	2
			ZX1658GS	2	2
		Curing agent	LA-3018-50P	4	4
			EXB-8000L-65TM	12	12
		Inorganic filler	Inorganic filler 1	45	65
		Therm oplastic resin	YL7500BH30	2	2
		Curing accelerator	DMAP	0.05	0.05
	Total nonvolatile com ponents			85.4	105.4
	Total resin com ponents			40.4	40.4
	Content of curing agent (% by m ass)* ¹			24.3	24.3
	Content of active ester-based curing agent (% by m ass)* ¹			19.3	19.3
	Content of inorganic filler (% by m ass)* ²			52.7	61.7
Eva luation result		Minimum melt viscosity [poise]		1500	4000
		Specific die lectric constant		3.1	3.2
		Linear thermal expansion coefficient [ppm/degC @25-150degC]		42	33
		Em beddability		○	○
		Insulating property		○	○

*¹ Content based on 100% by m ass of resin com ponents in resin com position*² Content based on 100% by m ass of nonvolatile com ponents in resin com position

[0188] In both Examples 1 and 2, the conductor circuit was formed with the fine pattern of L/S = 1.5/1.5 μm (line length of 1 mm). In Examples 1 and 2, it was confirmed that the formed insulating layer (a cured product of the resin composition) had excellent specific dielectric constant, linear thermal expansion coefficient, and insulation property, as well as excellent conductor circuit embeddability.

[0189] -Reference Signs List-

- 1 Substrate
- 2 Metal layer
- 10 Metal layer-attached substrate
- 10a Metal layer (first main surface)

- 10b Second main surface
- 20, 21, 22 Photoresist
- 30 Conductive layer (conductor circuit)
- 31 Metal layer (plating seed layer)
- 5 50 Resin composition layer
- 51 Insulating layer
- 51v Via
- 100 Circuit board
- 100a First main surface of circuit board
- 10 100b Second main surface of circuit board
- 110 Semiconductor chip
- 120 Encapsulating layer
- 200 Semiconductor package

CLAIMS

1. A method for producing a circuit board, the method comprising the following steps (X), (Y) and (Z):

5 (X) forming a first conductor circuit on a metal layer of a substrate with the metal layer attached thereto;

(Y) forming a resin composition layer by using a resin composition so as to embed the first conductor circuit formed on the metal layer, and then curing the resin composition layer to form an insulating layer; and

10

(Z) removing the substrate with the metal layer attached thereto to form a circuit board having a first main surface in which the first conductor circuit is exposed, wherein

15 the resin composition comprises an epoxy resin, a curing agent and an inorganic filler.

2. The method according to claim 1, wherein a content of the inorganic filler in the resin composition is in a range of 20% or more by mass to 75% or less by mass when nonvolatile components in the resin composition are defined as 100% by mass.

20

3. The method according to claim 1 or 2, wherein an average particle diameter of the inorganic filler is 0.6 μm or less.

25

4. The method according to any one of claims 1 to 3, wherein the inorganic filler is silica.

30

5. The method according to any one of claims 1 to 4, wherein a minimum melt viscosity of the resin composition is 5,000 poise or less.

6. The method according to any one of claims 1 to 5,
wherein a thickness of the metal layer is less than 0.5 μm .

5 7. The method according to any one of claims 1 to 6,
wherein an arithmetic mean roughness Ra of a surface of the
metal layer is 200 nm or less, and TTV, which is a
difference between a maximum value and a minimum value of a
height of the surface of the metal layer measured in a
10 thickness direction of the substrate with the metal layer
attached thereto, is 50 μm or less.

8. The method according to any one of claims 1 to 7,
wherein in the substrate with the metal layer attached
15 thereto, the substrate is selected from a metal substrate
whose composition is different from that of the metal
layer, an inorganic substrate, and an organic substrate.

9. The method according to any one of claims 1 to 8,
20 wherein the step (Z) is carried out by removing the metal
layer after removing the substrate.

10. The method according to any one of claims 1 to 9,
wherein the step (X) comprises
25 (X-1) forming a photoresist on the metal layer, and
then irradiating the photoresist with light and developing
the photoresist to expose the metal layer corresponding to
a circuit pattern of the first conductor circuit to be
formed, and
30 (X-2) forming a conductive layer on the exposed metal
layer to form the first conductor circuit.

11. The method according to any one of claims 1 to 10, wherein the first conductor circuit comprises a trench type conductor circuit.

5 12. The method according to any one of claims 1 to 11, wherein the step (Y) comprises laminating a resin sheet that includes a support film and a resin composition layer formed on the support film onto the substrate such that the resin composition layer is in contact with the first
10 conductor circuit.

13. The method according to any one of claims 1 to 12, the method comprising the following steps, after the step (Y):

(i) forming a second conductor circuit on a surface of
15 the insulating layer; and

(ii) forming a resin composition layer so as to embed the second conductor circuit, and then curing the resin composition layer to form an insulating layer.

20 14. The method according to any one of claims 1 to 13, wherein the circuit board is for a semiconductor package.

15. A circuit board having a first main surface and a second main surface, the circuit board comprising:

25 a trench type conductor circuit in the first main surface, wherein

a minimum line/space ratio (L/S) of the trench type conductor circuit is $2/2\ \mu\text{m}$ or less,

30 in a cross section in a direction Y that is perpendicular to the first main surface and also perpendicular to a direction of extension of the trench type conductor circuit, an angle difference between a straight line direction y1 defined by a side wall of the

trench type conductor circuit and the direction Y is 20° or less, and

an insulating layer defining the first main surface together with the trench type conductor circuit comprises a
5 cured product of a resin composition comprising an epoxy resin, a curing agent and an inorganic filler.

16. The circuit board according to claim 15, wherein the trench type conductor circuit has an inverse tapered shape
10 in which a width thereof increases from the first main surface toward a depth direction of the circuit board.

17. The circuit board according to claim 15 or 16, wherein a ratio of a thickness T to a width W of the trench type
15 conductor circuit (T/W) in the cross section in the direction Y perpendicular to the first main surface and also perpendicular to the direction of extension of the trench type conductor circuit is 1.5 or more.

20 18. The circuit board according to any one of claims 15 to 17, wherein in the cross section in the direction Y perpendicular to the first main surface and also perpendicular to the direction of extension of the trench type conductor circuit, an exposed surface of the trench
25 type conductor circuit is dented by $0.05W$ or more from an exposed surface of the insulating layer defining the first main surface together with the trench type conductor circuit.

30 19. The circuit board according to any one of claims 15 to 18, wherein the circuit board has a multilayered structure having two or more circuit layers.

20. A semiconductor package comprising:

the circuit board according to any one of claims 15 to 19; and

5 a semiconductor chip formed on the first main surface so as to be electrically connected to the trench type conductor circuit of the circuit board.

21. The semiconductor package according to claim 20,
wherein the semiconductor package is a Fan-Out type
10 package.