

OPTICAL WAVEGUIDE-FORMING PASTE COMPOSITION AND OPTICAL WAVEGUIDE USING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001]

The present invention relates to an optical waveguide-forming paste composition. More specifically, the present invention relates to an optical waveguide-forming paste composition including an organic material and barium sulfate particles dispersed therein and to an optical waveguide using the composition.

2. Description of the Related Art

[0002]

Paste compositions including organic materials such as resins and inorganic particles dispersed therein and cured materials obtained by curing such paste compositions are widely used for printing paints, lubricants, cosmetics, adhesives, release agents, components of displays or circuit boards, and so on. The purposes of dispersing inorganic particles in resins include imparting excellent properties such as thermo-mechanical properties, electromagnetic properties, and optical properties, which are not achievable only with resins, and reducing the content of resins and

making the manufacturing cost low in a case where the resins used are expensive. In recent years, there have been attempts to use very small inorganic particles with particle diameters of several tens to several nanometers for dispersions for the purpose of improving the surface flatness or transparency of materials or meeting requirements for micro-machining of semiconductors or the like in various technical fields. Particularly in the field of optical interconnection technology, there have been investigations to develop techniques for dispersing inorganic particles with particle diameters of several tens to several nanometers into resins so that temperature-dependent changes in the refractive index or the dimension of optical waveguide materials can be suppressed, while the transparency of the materials can be ensured.

[0003]

A method for dispersing inorganic particles into a resin includes first preparing a dispersion solution containing an organic solvent and inorganic particles well dispersed therein and then mixing the dispersion solution with a resin. Commercially available inorganic particles with a mean particle diameter of several tens to several nanometers are often provided in the form of agglomerates (secondary particles) with a mean particle diameter of several tens μm in which individual particles (primary particles) are moderately agglomerated. In order to prepare a dispersion solution of

inorganic particles with a mean particle diameter of several tens to several nanometers, therefore, the secondary particles should be deagglomerated in an organic solvent and a dispersion solution containing stably dispersed primary particles should be prepared. However, in such a case where primary particles have a mean particle diameter of less than 50 nm, once dispersed particles may be frequently agglomerated to make a further dispersion process difficult in many cases, because the ratio of the surface area to the volume of the particles is significantly high.

[0004]

Therefore, there is disclosed a method that includes adding an organic material having a certain functional group or the like at its end, called a dispersant, so that the functional group of the dispersant is located on the surface of the inorganic particles to inhibit the contact between the inorganic particles, which can suppress reagglomeration of primary particles and improve the dispersibility. As an example of this technique, there is proposed a nickel colloid solution containing nickel colloid particles with a mean particle diameter of 20 to 40 nm, a non-polar high-molecular pigment dispersant, and an organic solvent (see for example Patent Literature 1). There is also disclosed a method of using a dispersant to disperse barium sulfate particles into an organic solvent (see for example Patent Literature 2).

[0005]

However, when a cured material is produced by a method including mixing a resin and a dispersion solution of inorganic particles prepared with conventionally known dispersants to form a paste composition and then curing the paste composition to form a cured material in which the inorganic particles are dispersed, the curing reaction of the resin by photoirradiation or heating is more likely to be insufficient, than when no inorganic particles are used. Therefore, the resulting cured material may have low thermomechanical properties. In addition, when photolithographic patterning is performed on a film produced with a paste composition containing inorganic particles and an optically curable resin, the exposed area may be insufficiently cured so that the composition may be eluted during development to form an unclearly patterned portion, or the non-exposed area may have low solubility so that a paste composition residue may be produced during development. Therefore, photolithographically produced optical waveguides may have large optical propagation loss.

[0006]

It is also known that addition of a polymerizable group-containing phosphoric ester monomer in the process of curing a resin can produce an advantageous effect such as an improvement in the antistatic performance or flame retardancy

of the cured material or an improvement in the dispersibility of pigments (particles) dispersed in the resin (see Patent Literature 3).

[0007]

In general, the dispersibility of pigments (particles) significantly depends on whether the pigment used is an organic or inorganic material. Even among the inorganic pigments, however, for example, barium sulfate particles significantly differ in surface potential, surface smoothness or the like from alumina particles, and, therefore, a certain additive effective in improving the dispersibility of one may reduce the dispersibility of the other. Patent Literature 3 only discloses that inorganic pigments may be used and does not specifically disclose the type of inorganic pigments that can influence the dispersibility as mentioned above.

Patent Literature 1: Japanese Patent Application Laid-Open (JP-A) No. 2004-124237 (Claims and Examples)

Patent Literature 2: JP-A No. 2006-106708 (page 18)

Patent Literature 3: JP-A No. 2003-146992 (page 2)

SUMMARY

Problems to be Solved by the Disclosure

[0008]

When barium sulfate particles with a mean particle diameter of 1 nm or more to 50 nm or less are used as a

component in an optical waveguide-forming paste composition, addition of conventionally known dispersants to disperse the particles may cause an insufficient curing reaction of the paste composition upon photoirradiation or heating or may cause a difficulty in performing development when photolithographic patterning is performed on a film produced with the paste composition, as mentioned above.

[0009]

In view of the problems with the conventional art, an object of the present disclosure is to provide an optical waveguide-forming paste composition that allows reliable curing and provides excellent developability.

Means for Solving the Problems

[0010]

The present disclosure is directed to an optical waveguide-forming paste composition including (A) barium sulfate particles with a mean particle diameter of 1 nm or more to 50 nm or less, (B) a compound having a polymerizable group and a carboxyl group, or a phosphoric ester compound having a polymerizable group, and (C) an organic solvent. The present disclosure is also directed to an optical waveguide including a cured material produced by curing the optical waveguide-forming paste composition.

Effects of the Disclosure

[0011]

The optical waveguide-forming paste composition of the present disclosure is reliably cured by photoirradiation or heating. When photolithographic patterning is performed, the optical waveguide-forming paste composition of the present disclosure provides very good curability for the exposed area and very good developability for the non-exposed area. The use of the optical waveguide-forming paste composition of the present disclosure allows production of optical waveguides having low temperature-dependent change rate of refractive index, small coefficient of linear expansion, and low optical propagation loss.

BRIEF DESCRIPTION OF THE DRAWINGS

[0138]

Fig. 1 is a schematic diagram showing a channel optical waveguide structure; and

Fig. 2 is a schematic diagram showing a slab optical waveguide structure.

DESCRIPTION OF REFERENCE SYMBOLS

[0140]

In the drawings, reference numeral 1 represents a core, 2 a cladding, and 3 an optical signal.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012]

The optical waveguide-forming paste composition of the present invention (hereinafter referred to as "the paste composition") includes (A) barium sulfate particles, (B) a compound having a polymerizable group and a carboxyl group, or a phosphoric ester compound having a polymerizable group, and (C) an organic solvent. Hereinafter, unless otherwise stated, the term "compound A" refers to the compound having a polymerizable group and a carboxyl group, or the phosphoric ester compound having a polymerizable group.

[0013]

In the paste composition of the present invention, the compound A has the function of dispersing barium sulfate particles. The carboxyl group or the phosphoric ester bond moiety of the compound A interacts with barium sulfate particles so that the surface of the barium sulfate particles can be covered with the compound A. It is considered that the polymerizable group of the compound A placed over the surface of the barium sulfate particles can face outward and be compatible with the organic solvent and other compounds in the paste composition to allow the barium sulfate particles to form a stable dispersion.

[0014]

The polymerizable group of the compound A is an organic group capable of allowing polymerization to proceed through a polyaddition reaction, a radical reaction, or the like caused by light or heat. In the paste composition of the present invention, the compound A is involved in polymerization so that curing can be allowed to proceed rapidly and reliably.

[0015]

In the present invention, the compound A itself is optically or thermally polymerized to form a matrix resin in a cured material. Therefore, the compound A used in the present invention can function not only to serve as a dispersant for the barium sulfate particles but also to form a matrix resin. If a dispersant having no polymerizable group is used to disperse barium sulfate into a matrix-forming resin having a polymerizable group, barium sulfate particles may migrate and gather in the process of polymerization of the matrix resin so that their dispersibility can be reduced. In contrast, when the paste composition of the present invention is used, the dispersibility of barium sulfate particles can be kept high even in the cured material, because polymerization proceeds while the barium sulfate particles are captured by the compound A. Therefore, the cured material has a high level of transparency and surface flatness.

[0016]

In addition, the compound A in the paste composition may

be cured by light so that photolithographic patterning may be performed. In this case, polymerization proceeds, while the barium sulfate particles are captured by the compound A in the exposed area, so that a strong network can be formed with the barium sulfate particles serving as starting points and that swelling or dissolution of the exposed area can be prevented during development, which leads to the formation of a clear pattern.

[0017]

In order to well disperse the barium sulfate particles, the polymerizable group of the compound A preferably has a high affinity for the organic solvent and other compounds in the paste composition. Examples of such a polymerizable group include vinyl, acrylate, methacrylate, epoxyacrylate, epoxymethacrylate, and epoxy groups.

[0018]

Besides the polymerizable group, the compound A has a carboxyl group. The carboxyl group of the compound A interacts with the barium sulfate particles so that the surface of the barium sulfate particles can be covered with the compound A and that the barium sulfate particles can be dispersed. When the compound A in the paste composition of the present invention is cured by light in photolithographic patterning, the non-exposed area can be rapidly dissolved in a developing solution, because the compound A has a carboxyl group, whose

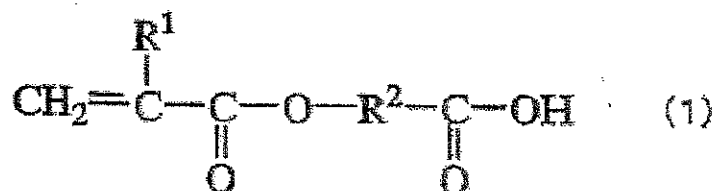
polarity is high, and, therefore, the residue left in the non-exposed area during development can be reduced.

[0019]

The compound A used in the present invention is preferably represented by the following formula (1):

[0020]

Formula 1

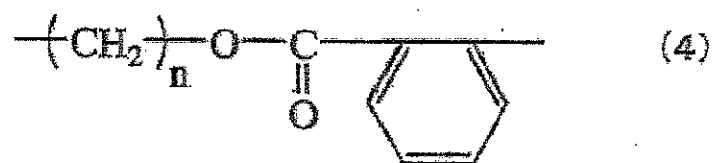
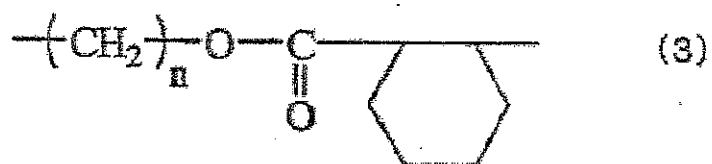
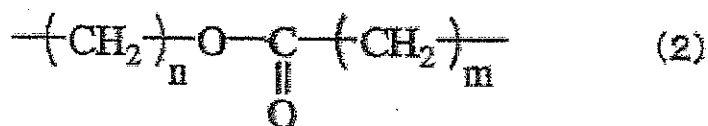


[0021]

In the formula (1), R¹ represents a hydrogen atom or a methyl group, and R² represents a bivalent group represented by any one of the following formulae (2) to (4):

[0022]

Formula 2



[0023]

In the formulae (2) to (4), n and m are each an integer of 1 to 3.

[0024]

In the formula (1), the polymerizable group is an acrylate group when R^1 is a hydrogen atom, or a methacrylate group when R^1 is a methyl group. The acrylate or methacrylate group has an unsaturated bond and therefore is capable of undergoing radical polymerization upon photoirradiation or heating. In the process of radical polymerization using light, a photolithographic method including exposure to light through a photomask may be performed to form patterned wirings or the like. The acrylate group having a hydrogen atom for R^1 is preferred because of its higher polymerizing ability.

[0025]

The smaller the n and m values in the formulae (2) to (4), the larger the number of the polymerizable groups and the carboxyl groups per unit weight, which means better polymerizing ability and better dispersibility of the barium sulfate particles. On the other hand, as the n and m values increase, the steric hindrance effect produced by the compound A located on the barium sulfate particles increases so that the dispersibility can increase. Therefore, n and m are each preferably 2, which means an ethylene group having two carbon atoms.

[0026]

In the compound represented by the formula (1), R^1 is preferably a hydrogen atom, and R^2 is preferably a bivalent group represented by the formula (4). In this case, n is preferably 2 for the reason described above. When such a compound is used, higher polymerizing ability and higher developability can be provided, and better dispersibility of the barium sulfate particles can also be provided, which allows a reduction in the mean particle diameter of the dispersed barium sulfate particles so that a cured material with improved transparency can be produced from the paste composition. In this case, therefore, an optical waveguide with low optical propagation loss can be obtained.

[0027]

Examples of the compound A represented by the formula (1)

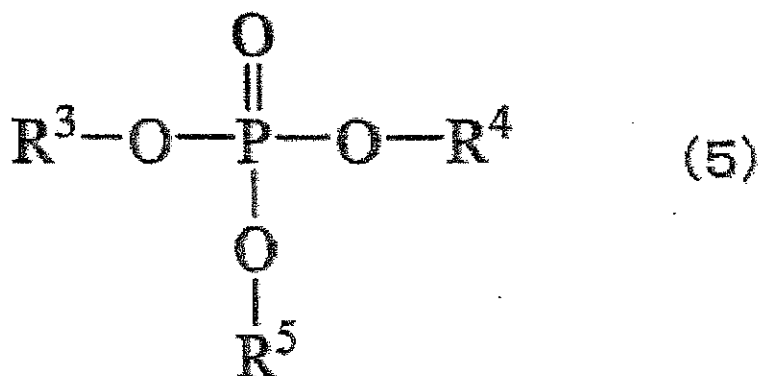
used in the present invention include HOA-MS (trade name) in which R^1 in the formula (1) is a hydrogen atom, R^2 is represented by the formula (2), and n and m are each 2, HOA-HH (trade name) in which R^1 in the formula (1) is a hydrogen atom, R^2 is represented by the formula (3), and n is 2, and HOA-MPL (trade name) in which R^1 in the formula (1) is a hydrogen atom, R^2 is represented by the formula (4), and n is 2, each manufactured by KYOEISHA CHEMICAL Co., LTD.

[0028]

On the other hand, the compound A represented by the formula (5) below is also preferably used.

[0029]

Formula 3

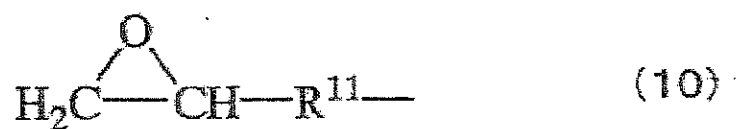
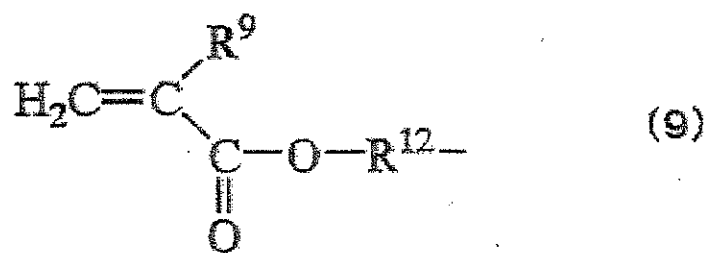
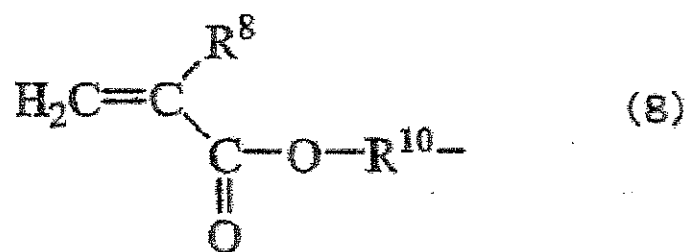
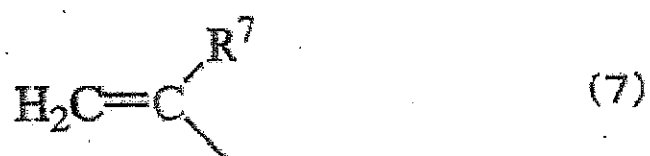
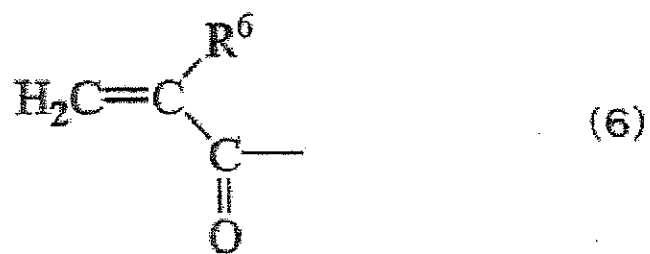


[0030]

In the formula (5), R^3 to R^5 each represent a monovalent group represented by any one of the following formulae (6) to (10), or a hydrogen atom, and R^3 to R^5 may be the same or different, provided that not all of R^3 to R^5 are hydrogen atoms.

[0031]

Formula 4

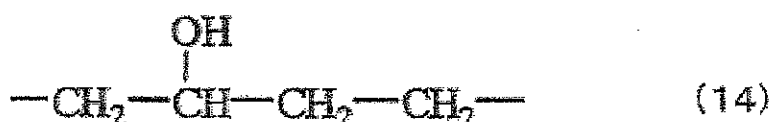
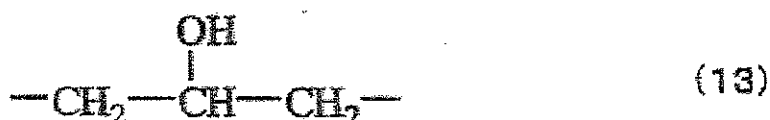


[0032]

In the formulae (6) to (10), R^6 to R^9 each represent a hydrogen atom or a methyl group, R^{10} and R^{11} each represent a bivalent group of 1 to 10 carbon atoms, preferably a bivalent hydrocarbon group of 1 to 10 carbon atoms, more preferably an alkyl group of two carbon atoms, and R^{12} represents a bivalent group of 1 to 10 carbon atoms having a hydroxyl group, preferably an organic group represented by any one of the following formulae (13) to (15):

[0033]

Formula 5



[0034]

As the compound A represented by the formula (5), a phosphoric monoester in which any two of R^3 to R^5 are each a hydrogen atom is preferred to a phosphoric diester in which

any one of R^3 to R^5 is a hydrogen atom, because the former can further increase the dispersibility of the barium sulfate particles than the latter. The phosphoric diester is preferred to a phosphoric triester in which none of R^3 to R^5 is a hydrogen atom, because the former can further increase the dispersibility of the barium sulfate particles than the latter.

[0035]

The monovalent group represented by any one of the formulae (6) to (9) has an acrylate or methacrylate group and is capable of undergoing radical polymerization upon photoirradiation or heating. The monovalent group represented by the formula (10) is capable of undergoing ionic polymerization upon photoirradiation or heating. The acrylate group in which R^6 to R^9 are each a hydrogen atom is preferred because of its higher polymerizing ability.

[0036]

The smaller the number of carbon atoms in each of R^{10} to R^{12} in the formulae (8) to (10), the larger the number of the polymerizable groups and the phosphoric ester bond moieties per unit weight, which means better polymerizing ability and better dispersibility of the barium sulfate particles. As the number of carbon atoms in each of R^{10} to R^{12} increase, the steric hindrance effect produced by the compound A located on the barium sulfate particles increases so that the dispersibility can increase. Therefore, the number of carbon

atoms in each of R^{10} to R^{12} is preferably from 1 to 4.

[0037]

In the compound represented by the formula (5), at least one of R^3 to R^5 is particularly preferably a monovalent group represented by the formula (8) in which R^{10} is more preferably a bivalent hydrocarbon group of 1 to 3 carbon atoms. In addition, at least one of R^3 to R^5 in the formula (5) is preferably a monovalent group represented by the formula (9), and R^{12} in the formula (9) is preferably a bivalent hydrocarbon group of 2 to 3 carbon atoms having a hydroxyl group.

[0038]

Examples of the compound A represented by the formula (5) used in the present invention include LIGHT-ACRYLATE P-1A (trade name) manufactured by KYOEISHA CHEMICAL Co., LTD. (a phosphoric monoester having an acrylate group), LIGHT-ESTER P-1M (trade name) manufactured by KYOEISHA CHEMICAL Co., LTD. (a phosphoric monoester having a methacrylate group), LIGHT-ESTER P-2M (trade name) manufactured by KYOEISHA CHEMICAL Co., LTD. (a phosphoric diester having a methacrylate group), and RDX 63182 manufactured by DAICEL-CYTEC COMPANY LTD. (a phosphoric diester having an epoxyacrylate group). One or more types of the compound A may be used in the present invention.

[0039]

The temperature-dependent change in the physical properties of the cured material produced from the paste .

composition of the present invention is very small, and, for example, the temperature-dependent refractive-index change rate or linear expansion coefficient is small. Dispersants used to increase the dispersibility of inorganic particles may inhibit a curing reaction of a resin in a paste composition or increase the temperature-dependent refractive-index change rate or linear expansion coefficient of a cured material produced from a paste composition so that the properties of the cured material may be degraded. It has been therefore preferred that the dispersant content should be as low as possible. In the present invention, the compound A itself, which contributes to the dispersibility of the barium sulfate particles, is polymerizable or curable or can be involved in the polymerization with a resin as described later, so that degradation of the properties of the cured material, such as an increase in the temperature-dependent refractive-index change rate or linear expansion coefficient, can be prevented.

[0040]

The paste composition of the present invention may also contain any other matrix-forming resin, although the compound A can be polymerized to form a matrix in a cured material as described above. Examples of such a resin that may be used to form a matrix include heat or UV curing resins having a polymerizable group, such as polyamic acid, vinyl resins, norbornene resins, epoxy resins, acrylate resins, methacrylate

resins, epoxyacrylate resins, epoxymethacrylate resins, cyanate resins, bismaleimide-triazine resins, benzocyclobutene resins, and siloxane resins; and thermoplastic resins such as aramid resins, polystyrene, polyether imide, polyphenylene ether, and thermoplastic polyimide. One or more of these resins may be used alone or in any appropriate mixture ratio.

[0041]

For applications requiring heat resistance or the like in the process, polymerizable group-containing resins such as heat or UV curing resins are preferred among the resins listed above. When the cured material produced from the paste composition is used for optical waveguide-forming materials which require transparency, epoxy resins, acrylate resins, methacrylate resins, epoxyacrylate resins, epoxymethacrylate resins, siloxane resins, or the like are preferably used. In particular, UV curing resins are preferably selected, because patterned optical waveguides can be formed by photolithographic method using them.

[0042]

In the present invention, the polymerizable groups of the heat or UV curing resin may be polymerized with one another, or the polymerizable group of the heat or UV curing resin may be polymerized with the polymerizable group of the compound A. The polymers formed in the cured material according to the present invention may include various types of polymers such

as (a) a polymer of the compound A, (b) a polymer of the compound A and the resin, and (c) a polymer of only the resin, and the barium sulfate particles may be dispersed in these polymers. Unless otherwise stated, each of the polymers (a) to (c) in the cured material produced from the paste composition will be simply referred to as the "polymer."

[0043]

In the cured material obtained from the paste composition, one or more of the polymers (a) to (c) may exist alone or in combination depending on the components of the paste composition, such as the compound A, the resin, and a polymerization initiator.

[0044]

For example, when the polymerizable group of the compound A and the polymerizable group of the resin are each an acrylate group, a relatively large amount of the compound A exists in the vicinity of the barium sulfate particles, and, therefore, a relatively large amount of the polymer (a) exists in the vicinity of the barium sulfate particles, a relatively large amount of the polymer (c) exists in a region distant from the barium sulfate particles, and the polymer (b) exists in an intermediate region between them. In another example, a cured material including the polymers (a) and (c) may be produced from the paste composition containing the compound A having an acrylate group as the polymerizable group and a

resin having an epoxy group as the polymerizable group. Alternatively, different resins may be used. In such a case, for example, the compound A having an acrylate group as the polymerizable group, a resin having an epoxyacrylate group as the polymerizable group, and another resin having an epoxy group as the polymerizable group may be used, and the three components may be copolymerized to form the polymer (b).

[0045]

When the polymer in the cured material according to the present invention has a refractive index close to that of the barium sulfate particles, the Rayleigh scattering of light in the cured material is low so that the cured material can have high transparency. For transparency requiring applications such as optical materials, the types and mixing ratio of the compound A and the resin are preferably determined so that a polymer having the desired refractive index can be produced. Since barium sulfate has a refractive index of 1.6, the resulting polymer preferably has a refractive index close to 1.6, more preferably a refractive index of 1.6, in order to provide high transparency.

[0046]

The polymer is produced from components of the paste composition other than the barium sulfate particles, such as a dispersant and the resin. Therefore, the type and amount of each material to be mixed are preferably determined so that

the resulting polymer can have a refractive index close to 1.6. When different materials having different refractive indices are mixed to form a polymer having a certain refractive index, it is preferred that each material should have a refractive index close to the desired refractive index so that a polymer with small variations in refractive index can be easily produced.

[0047]

The examples of the compound A listed above, HOA-MS, HOA-HH, HOA-MPL, LIGHT-ACRYLATE P-1A, LIGHT-ESTER P-1M, LIGHT-ESTER P-2M, and RDX 63182, have refractive indices of 1.46, 1.48, 1.52, 1.47, 1.47, 1.47, and 1.54, respectively. For optical material applications such as optical waveguides, HOA-MPL or RDX 63182, of which refractive index is close to that of barium sulfate, is preferably used, because a cured material with good transparency can be easily produced from the paste composition containing it.

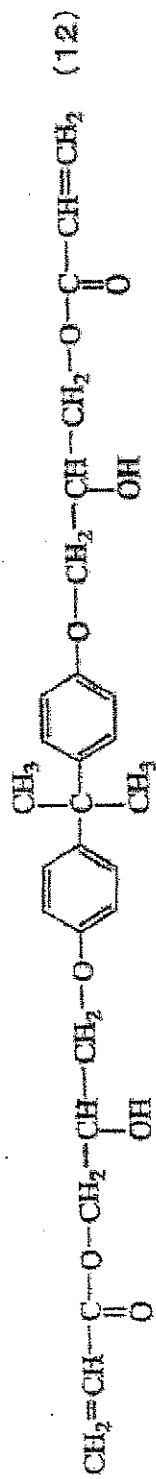
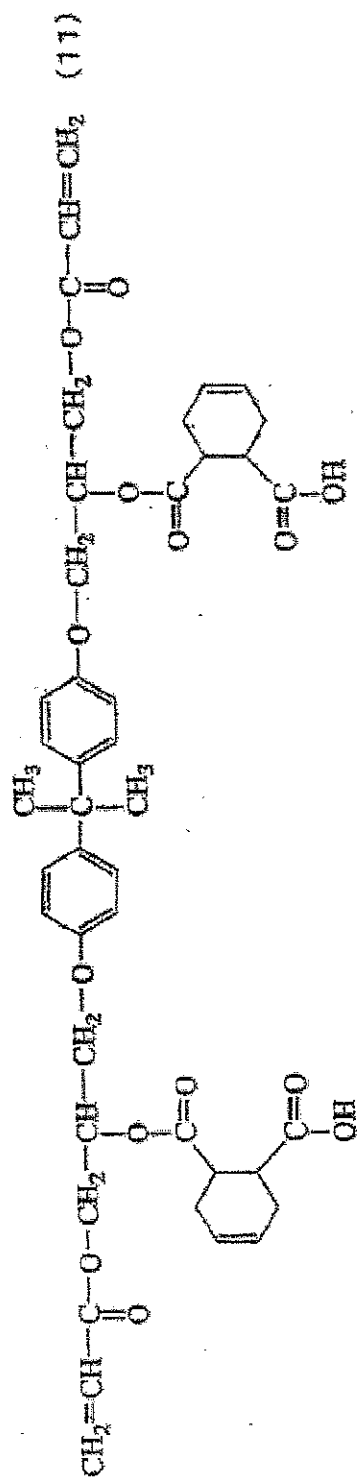
[0048]

When the cured material produced from the paste composition of the present invention is used for optical waveguide materials requiring heat resistance and transparency, the polymerizable group of the heat or UV curing resin is preferably an epoxy, acrylate, methacrylate, epoxyacrylate, or epoxymethacrylate group. When an epoxy resin or the like is cationically polymerized, the activated cations may adsorb to

the barium sulfate particles to slow down the polymerization reaction. Therefore, acrylate resins, methacrylate resins, epoxyacrylate resins, or epoxymethacrylate resins are preferred, because they are suitable for radical polymerization. Optical interconnection materials should preferably have a refractive index close to that of the barium sulfate particles as described above. Examples of such materials include an acrylate resin represented by the formula (11) below (1.55 in refractive index) and an epoxyacrylate resin represented by the formula (12) below (1.56 in refractive index). When photolithographic patterning is performed using the paste composition, the resin represented by the formula (11) below is preferably selected so that the residue in the non-exposed area can be reduced during development. The resin represented by the formula (12) below is also preferably selected so that a cured material with low temperature-dependent change rate of refractive index and small coefficient of linear expansion can be produced from the paste composition.

[0049]

Formula 6



[0050]

The amount of the compound A in the paste composition of the present invention is preferably from 5 parts by weight or more to 20 parts by weight or less, based on 100 parts by weight of the barium sulfate particles. The compound A in an amount of 5 parts by weight or more based on the amount of the barium sulfate particles can increase the dispersibility of the barium sulfate particles and reduce the size of the dispersed barium sulfate particles so that a cured material with improved transparency can be produced from the paste composition of the present invention. In this case, optical waveguides with low optical propagation loss can be obtained. Considering the difference between the refractive indices of the compound A and barium sulfate, a cured material with improved transparency can be produced from the paste composition containing the compound A in an amount of 20 parts by weight or less based on the amount of the barium sulfate particles. In this case, optical waveguides with low optical propagation loss can be obtained.

[0051]

The preferred content of the compound A in paste composition of the present invention (based on the total amount of the paste composition) may differ between the case where a polymer of only the compound A is produced by curing and the case where a polymer of the compound A and a resin is

produced by curing. For example, when the compound A alone is polymerized to form a cured material in the mode (a), the content of the compound A is preferably, but not limited to, from 20% by weight or more to 70% by weight or less, based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent. When the content of the compound A is 20% by weight or more based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent, the resulting cured material can have improved cracking resistance and adhesion to substrates and high resistance to cohesive fracture. The content of the compound A is more preferably 30% by weight or more based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent, so that the effects can be enhanced. When the content of the compound A is 70% by weight or less based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent, the resulting cured material can have low temperature-dependent change rate of refractive index and small coefficient of linear expansion. The content of the compound A is more preferably 50% by weight or more based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent, so that the effects can be enhanced.

[0052]

On the other hand, when the polymer (b) or (c) is produced to form a cured material, the total content of the compound A and the resin is preferably 20% by weight or more, more preferably 30% by weight or more, based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent. The total content of the compound A and the resin is preferably 70% by weight or less, more preferably 50% by weight or less, based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent. The reason why the range is preferred is the same as described above for the mode (a). The mixing ratio of the compound A and the resin may be determined as needed depending on the composition ratio of the polymer of the compound A and the resin to be produced. In this case, the content of the compound A is preferably 1% by weight or more based on the amount of the barium sulfate particles so that the dispersibility of the barium sulfate particles can be improved.

[0053]

When the polymerizable group-containing resin is used, the polymerization properties of the compound A and the resin should preferably be taken into account when the mixing ratio between them is determined. Specifically, the mixing ratio of the compound A and the resin may differ between the case (b1)

where the compound A and the polymerizable group-containing resin are each independently polymerized, the case (b2) where the polymerizable group-containing resin is polymerized from a molecule of the compound A as a starting point into a chain, and the case (b3) where the compound A and the polymerizable group-containing resin are alternately polymerized. In an example of the case (b3), the compound A having an epoxyacrylate group as the polymerizable group and an epoxy resin may be alternately polymerized. In this case, the number of the polymerizable groups should preferably be the same between both materials.

[0054]

In order to accelerate the polymerization of the compound A and the resin, the paste composition of the present invention may also contain a polymerization initiator capable of producing an active species such as a radical, cation or anion. There are different polymerization initiators capable of being activated by photoirradiation or heat treatment, and they may be selected and used depending on the intended use. When the paste composition is formed into a film and then subjected to photolithographic patterning, a polymerization initiator capable of being activated by photoirradiation should be used. For example, oxime, benzophenone, triazine, or benzotriazole polymerization initiators can produce radicals upon UV irradiation. Phosphonium, sulfonium, or iodonium

polymerization initiators can produce cations upon UV irradiation.

[0055]

The paste composition of the present invention contains barium sulfate with a mean particle diameter of 1 nm or more to 50 nm or less. As used herein, the term "mean particle diameter" indicates number average particle diameter. In the paste composition, the barium sulfate particles may exist in the form of primary particles, which are completely deagglomerated, and in the form of agglomerates of a plurality of primary particles. Therefore, the particle diameter of the barium sulfate particles in the paste composition is intended to include the particle diameter of the non-agglomerated primary particles and the particle diameter of agglomerates of the primary particles. In order to produce a paste composition containing dispersed barium sulfate particles with a mean particle diameter of 50 nm or less, it is necessary to use barium sulfate particles in which primary particles have a mean particle diameter of 50 nm or less. For example, BF-40 manufactured by SAKAI CHEMICAL INDUSTRY CO., LTD. (10 nm in mean primary particle diameter) satisfies the requirement. The mean particle diameter of the barium sulfate particles in the paste composition may be measured by a method that includes directly observing the particles with a SEM (scanning electron microscope) or a TEM (transmission electron microscope) and

calculating the number average of particle diameters. When the mean particle diameter of the barium sulfate particles in the paste composition is 50 nm or less, improved uniformity can be provided for each of the paste composition and the cured material, and Rayleigh scattering of light caused by the barium sulfate particles can be small so that high transparency can be provided. Optical waveguides with low optical propagation loss can be produced using such a paste composition. When the mean particle diameter of the barium sulfate particles dispersed in the paste composition is 30 nm or less, Rayleigh scattering of light caused by the barium sulfate particles in the cured material produced from the paste composition can be very small so that the cured material can exhibit transparency as high as that of a cured material produced from a barium sulfate particle-free composition. Optical waveguides with very low optical propagation loss can be produced using such a material. On the other hand, when the barium sulfate particles have a particle diameter of 1 nm or more, the specific surface area of the particles is small relative to their volume so that the particles can have high dispersibility.

[0056]

In the present invention, the content of the barium sulfate particles in the paste composition is preferably from 30% by weight or more to 80% by weight or less based on the

amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent. When the content of the barium sulfate particles is 30% by weight or more based on the amount of the solid components in the paste composition, a cured material with reduced temperature-dependent change rate of refractive index and reduced coefficient of linear expansion can be produced from the paste composition. The content of the barium sulfate particles is preferably 50% by weight or more based on the amount of the solid components in the paste composition. When the content of the barium sulfate particles is 80% by weight or less based on the amount of the solid components in the paste composition, cracking resistance and adhesion to substrates can be improved, and high resistance to cohesive fracture can be provided. When such a material is used, a cured material with high transparency can be obtained, and, therefore, optical waveguides with low optical propagation loss can be obtained. The content of the barium sulfated particles is preferably 70% by weight or less based on the amount of the solid components in the paste composition so that the residue left in the non-exposed area during development can be reduced in the process of photolithographic patterning.

[0057]

The paste composition of the present invention contains

an organic solvent. Examples of the organic solvent include N,N-dimethylacetamide, N-methyl-2-pyrrolidone, dimethylimidazolidinone, dimethylsulfoxide, γ -butyrolactone, ethyl lactate, 1-methoxy-2-propanol, 1-ethoxy-2-propanol, ethylene glycol mono-n-propyl ether, diacetone alcohol, and tetrahydrofurfuryl alcohol.

[0058]

The paste composition of the present invention preferably contains a silane coupling agent. When a silane coupling agent is used, thinning or peeling of a patterned portion in an exposed area and cracking can be reduced and suppressed in the process of photolithographic patterning so that clear patterns can be formed and that the residue left in the non-exposed area can be further reduced. In general, silane coupling agents are known to be effective in improving adhesion between inorganic and organic materials. In the present invention, the silane coupling agent is expected to be effective in improving adhesion between the resin component and the inorganic component in the composition or adhesion between the resin component in the composition and an inorganic substrate such as a silicon wafer and effective in reducing cracking and thinning or peeling of a patterned portion in an exposed area in the process of photolithographic patterning. It is also considered that the residue in the non-exposed area can be effectively reduced in the process of photolithographic

patterning, for the reason described below. When a developing solution is brought into contact with the non-exposed area, the resin and the compound A are eluted, and the barium sulfate particles captured by the compound A are also eluted. As the compound A is dissociated from the barium sulfate particles during the development process, the barium sulfate particles with exposed surfaces can agglomerate with each other along with the resin or the like in the vicinity to form a development residue. In the presence of a silane coupling agent, however, the binding force between the compound A (an organic component) and the barium sulfate particles (an inorganic component) is made stronger by the silane coupling agent so that the dispersibility of the barium sulfate particles can be maintained during the development, while the composition can be rapidly dissolved, and as a result, the residue is less likely to form.

[0059]

Preferred examples of the silane coupling agent include 3-glycidoxypropyltrimethoxysilane, 3-glycidoxypropyltriethoxysilane, 3-methacryloxypropyltrimethoxysilane, 3-methacryloxypropyltriethoxysilane, N-2(aminoethyl)3-aminopropyltrimethoxysilane, N-2(aminoethyl)3-aminopropyltriethoxysilane, 3-isocyanatopropyltrimethoxysilane, and 3-isocyanatopropyltriethoxysilane. The content of the

silane coupling agent in the paste composition is preferably from 0.1% by weight or more to 10% by weight or less based on the amount of the solid components in the paste composition, exclusive of volatile components such as the organic solvent. When the content of the silane coupling agent is 0.1% by weight or more based on the amount of the solid components in the paste component, the silane coupling agent can sufficiently produce the above effect. Common silane coupling agents including those listed above have refractive indices of 1.45 or less, which are significantly different from that of the barium sulfate particles. Therefore, the content of the silane coupling agent should preferably be 10% by weight or less based on the amount of the solid components in the paste composition so that Rayleigh scattering can be reduced and that transparency can be improved.

[0060]

The paste composition of the present invention may also contain a dispersant other than the compound A. The amount of the dispersant other than the compound A is preferably from 5 parts by weight or more to 20 parts by weight or less based on 100 parts by weight of the barium sulfate particles. At least 5 parts by weight of the dispersant other than the compound A can be significantly effective in improving the dispersibility of the barium sulfate particles. When the amount of the dispersant is 20 parts by weight or less, a cured material

with low temperature-dependent change rate of refractive index and small coefficient of linear expansion can be produced from the paste composition.

[0061]

Next, methods for producing the paste composition of the present invention are described in detail below. First, a description is given of methods for producing a dispersion solution of barium sulfate particles in an organic solvent.

[0062]

Barium sulfate particles (containing secondary particles and agglomerates) with a mean primary particle diameter of 50 nm or less, the compound A, and an organic solvent, and optionally an additional resin, a pH adjusting agent, a polymerization inhibitor, or the like are mixed in a specific proportion and stirred. Immediately after the mixing, the surface of the barium sulfate particles may be covered with an air layer so that the barium sulfate particles may be insufficiently wetted with the organic solvent to increase the viscosity. In such a case, the mixture is preferably stirred with a rotating blade or the like for a relatively long time until the barium sulfate particles are completely wetted with the organic solvent.

[0063]

In the process of mixing the barium sulfate particles, the whole amount of the resin necessary for the production of

the desired cured material or a partial amount thereof may be added. The resin and the barium sulfate particles can be more uniformly mixed when the resin is added before a dispersion process than when the resin is added after a dispersion process. When the resin is added before the dispersion process, however, the viscosity of the dispersion solution may increase to reduce the efficiency of the dispersion process, or after the dispersion process, the dispersion solution may have low storage stability. All the necessary amount of the compound A may be added before the dispersion process, or part of the necessary amount may be added before the dispersion process, and the remainder may be added after the dispersion process. Alternatively, the compound A and other materials may be added gradually, while the viscosity and any other state of the dispersion solution are measured during the dispersion process.

[0064]

A polymerization initiator, a defoaming agent, an antioxidant, a polymerization inhibitor, a plasticizer, a silane coupling agent, or any other material necessary for the production of the desired cured material may also be added. In view of the storage stability of the dispersion solution, a polymerization initiator or the like should preferably be added immediately before the preparation of the paste composition is completed.

[0065]

The barium sulfate particles (including secondary particles and agglomerates), the compound A, the organic solvent, and other necessary materials may be mixed and stirred, and then the barium sulfate particles may be subjected to the dispersion process using a dispersing device.

[0066]

For example, the dispersing device may be a bead mill such as ULTRA APEX MILL (trade name) manufactured by KOTOBUKI INDUSTRIES CO., LTD. or STAR MILL (trade name) manufactured by ASHIZAWA FINETECH LTD. The beads used in the bead mill preferably have a mean particle diameter of 0.01 mm or more to 0.5 mm or less. When the beads have a mean particle diameter of 0.5 mm or less, the barium sulfate particles can be frequently brought into contact with the beads in the bead mill so that a sufficient dispersing effect can be obtained. When the beads have a mean particle diameter of 0.01 mm or more, each bead can have large momentum so that sufficient shearing stress can be obtained for dispersion of the agglomerated barium sulfate particles.

[0067]

Ceramic beads, glass beads, metal beads, or the like may be used. Examples of the material of beads include soda glass, quartz, titania, silicon nitride, silicon carbide, alumina, zirconia, zirconium silicate, steel, and stainless steel. In particular, zirconia beads are preferably used, because of

their high hardness.

[0068]

Dispersion with a bead mill may be performed in a single process using small beads or performed while the size of beads is changed stepwise. For example, a dispersion process using beads with a particle diameter of 0.5 mm may be performed first until the particle diameter of the dispersed barium sulfate particles reaches about 100 nm, and then another dispersion process using much smaller beads may be performed.

[0069]

The time to be spent for the dispersion process may be appropriately determined depending on the type and composition ratio of the components of the dispersion solution, such as the barium sulfate particles, the compound A, and the organic solvent. A sample may preferably be taken from the dispersion solution at regular intervals to determine the mean particle diameter of the barium sulfate particles in the dispersion solution so that changes in the dispersion state can be monitored over time and the time to end the dispersion process can be determined. The particle diameter of the barium sulfate particles in the dispersion solution may be measured with a dynamic light scattering meter such as Zetasizer Nano ZS (trade name) manufactured by Sysmex Corporation. Next, a description is given of methods of producing the paste composition by mixing the dispersion solution obtained as

described above with the resin and so on. However, when all the materials necessary for the production of the cured material are mixed to form the dispersion solution, the dispersion solution obtained by the method described above corresponds to the paste composition of the present invention.

[0070]

When the resin is added to a dispersion solution of the barium sulfate particles, the type and the amount of the resin to be mixed should be selected depending on the components of the dispersion solution, such as the compound A. When the paste composition containing dispersed barium sulfate particles according to the present invention is used for the production of an optical waveguide, the polymer produced from the compound A and the resin preferably has a refractive index close to that of the barium sulfate particles (1.6) so that an optical waveguide with low optical propagation loss can be produced. In the process of mixing the dispersion solution and the resin, the dispersion solution may be added to the resin until a specific amount is reached, or the resin may be added to the dispersion solution until a specific amount is reached. The compound A may be further added to adjust the composition while the paste composition is prepared.

[0071]

The paste composition produced by mixing specific amounts of the dispersion solution and the resin may be subjected to a

process using a ball mill or a roll mill so that it can be more homogeneous. When air bubbles are incorporated into the paste composition in the mixing process, the air bubbles should be removed by standing, placing under reduced pressure, or using a mixing defoamer so that incorporation of air bubbles into a cured material produced from the paste composition can be avoided.

[0072]

In order to adjust the viscosity of the paste composition, the organic solvent may be further added, or an adequate amount of the organic solvent may be removed by heating or under reduced pressure. The polymerization reaction of the compound A or the resin may also be allowed to moderately proceed by heating or photoirradiation.

[0073]

The paste composition produced as described above may be cured to form a cured material containing the barium sulfate particles dispersed in a polymer.

[0074]

Next, a description is given of some examples of the method for curing the paste composition of the present invention. First, the paste composition may be applied to a substrate and spread into a film or strings, poured into a mold, or subjected to any other forming process, and then the organic solvent may be removed from the paste composition by

heat treatment. Examples of methods for removing the organic solvent include heating and drying in an oven or on a hot plate, vacuum drying, and heating by electromagnetic waves such as infrared rays or microwaves. If the organic solvent is insufficiently removed in this process, the next curing process may produce a composition in an uncured state or with poor thermo-mechanical properties.

[0075]

After the organic solvent is removed, a curing reaction of the paste composition is allowed to proceed by heat treatment, photoirradiation or the like, according to the mechanism of curing of the compound A or the resin in the paste composition used. In this case, different processes may be combined in order to allow the curing to completely proceed, for example, heat treatment may be performed after photoirradiation. In an environment at 100°C or higher, heat treatment is preferably performed under an inert atmosphere such as nitrogen so that oxidation of the polymer can be inhibited. Also when the composition is cured by photoirradiation using a polymerization initiator capable of producing radicals, whose activity may be quenched by oxygen, the treatment is preferably performed under an inert atmosphere such as nitrogen, so that the polymerization is not inhibited.

[0076]

When photolithographic patterning is performed, the process may include first applying the paste composition to a substrate, removing the organic solvent, and then applying light corresponding to the curing wavelength band of the paste composition through a mask that is designed to allow light to pass through a necessary portion corresponding to a certain pattern. The light source may be an ultra-high pressure mercury vapor lamp, a metal halide lamp, a halogen lamp, a helium-neon laser, a YAG laser, or the like. An exposure system such as an ultra-high pressure mercury vapor lamp exposure system PEM-6M (manufactured by UNION OPTICAL CO., LTD.) may be used. When the mechanism of curing of the paste composition is radical polymerization, exposure to light is preferably performed under a nitrogen atmosphere so that radical reaction species can be prevented from being deactivated by oxidation. In order to increase the resolution of the pattern, light applied in the exposure system should preferably have a high degree of parallelization. Also, in order to reduce the influence of diffracted light caused by the mask, the mask should preferably be in contact with the substrate, or the gap between the mask and the substrate should preferably be reduced.

[0077]

During exposure, applied light can be scattered inside the paste composition after drying so that the pattern edge

can be distorted. For this case, a UV absorber is preferably added to the paste composition so that the UV absorber can absorb faint light leaking from the exposed area to prevent scattering, which can keep the pattern edge sharp. After drying, scattering inside the paste composition is mainly caused by Rayleigh scattering from the barium sulfate particles. The shorter the wavelength of light, the larger the scattering. Therefore, a UV absorber capable of selectively absorbing short-wavelength light is also preferably used. A filter to cut short-wavelength light may also be placed between the light source and the mask so that scattering can be prevented.

[0078]

In order to allow the curing reaction to further proceed after the exposure, the substrate may be stored at room temperature for a certain period of time, or heat treatment may be performed.

[0079]

After the exposure process, the substrate may be immersed in a developing solution so that the paste composition can be removed from the non-exposed area. The substrate on which the patterned cured material is formed may be washed and dried. Heat treatment may be further performed to allow the curing reaction to proceed.

[0080]

The paste composition or the cured material according to the present invention is preferably used to form optical waveguides. Optical waveguides are formed on circuit boards for electrical appliances and so on and have the function of transmitting optical signals between ICs mounted on the boards. An optical waveguide includes a core to transmit optical signals and a cladding surrounding the core and having a refractive index lower than that of the core. Figs. 1 and 2 show a channel optical waveguide structure and a slab optical waveguide structure, respectively. The channel optical waveguide has a structure including a linear core 1 and a cladding 2 surrounding the periphery of the core 1. The slab optical waveguide has a structure including a layer core 1 and layer claddings 2 with which the upper and lower sides of the core 1 are covered. The paste composition of the present invention may be used to form both or one of the core and the cladding.

[0081]

Patterning by photoirradiation is possible with the paste composition of the present invention. Therefore, the paste composition of the present invention is preferably used as a core-forming material so that various shapes of optical waveguides can be easily produced. There is preferably a large difference between the refractive indices of the core and the cladding, so that the transmitted light-trapping effect can be

high.

[0082]

The refractive indices and the thicknesses of the cladding and the core in an optical waveguide may be arbitrarily selected depending on the design of the optical waveguide. In the case of a multimode optical waveguide, it is appropriate that the difference between the refractive indices of the core and the cladding should be large and that the core should be made thick. In the case of a single mode optical waveguide, the difference between the refractive indices of the core and the cladding should be small, and the core should be made thin so that single mode transmission can be achieved.

[0083]

For example, the channel optical waveguide may be manufactured by the method described below. The paste composition for forming an under-cladding is applied to a substrate such as a glass substrate, a silicon wafer, a glass epoxy substrate, or a plastic film. The coating is dried and cured to form an under-cladding. The paste composition for forming a core is then applied to the under-cladding, and the coating is dried to form a film-shaped core. The film-shaped core is then patterned into a waveguide. When the paste composition for forming the core is polymerized by photoirradiation, the patterning may be performed by photolithographic method. Alternatively, when the paste

composition for forming the core is polymerized by heat, the patterning may be performed by reactive ion etching or the like. The paste composition for forming an over-cladding is then applied to the core, and the coating is dried and cured to form an over-cladding.

[0084]

Examples of the method for forming the coating film include, but are not limited to, methods using a spinner, screen printing, a blade coater, a die coater, or any other coating devices.

EXAMPLES

[0085]

The present invention is more specifically described with some examples below which are not intended to limit the scope of the invention. Some chemical compounds used in the examples are abbreviated as follows: DMAc, N,N-dimethylacetamide; THFA, tetrahydrofurfuryl alcohol.

The properties of each of dispersion solutions of barium sulfate particles, cured materials produced from paste compositions, and optical waveguides were measured by the methods described below.

[0086]

Method for Measuring the Refractive Index of Cured
Materials Produced from Paste Compositions

The refractive index of a film-shaped cured material produced from a paste composition was determined using Prism Coupler 2010 manufactured by Metricon Corporation at a wavelength of 850 nm and a temperature of 25°C. The refractive index was also measured with this equipment at 40°C, 60°C, 80°C, and 100°C. The slope of the four points was obtained by a least-squares method, and a temperature-dependent change in the refractive index (temperature dependency of the refractive index) was calculated.

[0087]

Method for Measuring Optical Propagation Loss of Optical Waveguide

The measurement was performed by the cut-back method according to the JPCA standard (JPCA-PE02-05-01S-2004). Multimode optical fibers each with a core diameter of 50 μm and a numerical aperture of 0.28 were used on the input and output sides. The measurement temperature was 23°C, and the wavelength of the measurement light source was 850 nm.

[0088]

Method for Measuring Mean Particle Diameter of Raw Barium Sulfate Particles Agglomerated before Dispersion Solution Preparation

The measurement was performed using an optical microscope as shown below. The particles were placed on a transparent plate such as a glass plate, and the transparent plate on

which the particles were placed was mounted on the observation stage of the optical microscope. Light was applied from beneath the transparent plate. The transmitted light images of the particles captured through a CCD camera ADP-240M (manufactured by FLOVEL CO., LTD.) attached instead of an eye lens to an optical microscope were stored as digital images in a computer. The spherically approximated particle diameters of any observed 100 particles were determined using an image processing software FlvFs (manufactured by FLOVEL CO., LTD.), and the number average particle diameter was calculated therefrom.

[0089]

Method for Measuring Mean Particle Diameter of Barium Sulfate Particles in Dispersion Solution

A drop of the dispersion solution was put on a carbon-evaporated collodion film. After the solvent was removed by drying, the barium sulfate particles were observed using a transmission electron microscope H-7100FA (manufactured by Hitachi Ltd.) at an accelerating voltage of 100 kV. The observed images were stored as digital images in a computer. The spherically approximated particle diameters of any observed 100 particles were determined using an image processing software FlvFs (manufactured by FLOVEL CO., LTD.), and the number average particle diameter was calculated therefrom. When primary particles were agglomerated, the

particle diameters of the agglomerates were measured.

[0090]

Method for Measuring Mean Particle Diameter of Barium Sulfate Particles in Paste Composition

A drop of the paste composition was put on a carbon-evaporated collodion film. After the solvent was removed by drying, the barium sulfate particles were observed using a transmission electron microscope H-7100FA (manufactured by Hitachi Ltd.) at an accelerating voltage of 100 kV. The observed images were stored as digital images in a computer. The spherically approximated particle diameters of any observed 100 particles were determined using an image processing software FlvFs (manufactured by FLOVEL CO., LTD.), and the number average particle diameter was calculated therefrom. When primary particles were agglomerated, the particle diameters of the agglomerates were measured.

[0091]

Method for Measuring Coefficient of linear Expansion of Cured Material Produced from Paste Composition

The cured material produced from the paste composition was measured for dimensional change under an indentation load of 50 mN using a TMA meter TMA/SS6100 manufactured by SSI Nano Technology Inc. in the process of heating it from room temperature to 120°C and then cooling it to room temperature in a nitrogen atmosphere. The average coefficient of linear

expansion during heating and cooling between 50°C and 70°C was calculated. In order to eliminate the temperature history of the coefficient of linear expansion, the heating and cooling process was sequentially repeated twice, and the result of the second measurement was used as the displacement value.

[0092]

Preparation of Dispersion Solutions

Dispersion solutions A to P were prepared as described below. Barium sulfate secondary particles BF-40 (15 μ m in mean secondary particle diameter, 10 nm in mean primary particle diameter, manufactured by SAKAI CHEMICAL INDUSTRY CO., LTD.), a dispersant, and an organic solvent were mixed in the respective amounts shown in Table 1, and the mixture was processed in a homogenizer EXCEL AUTO (trade name) manufactured by NIHONSEIKI KAISHA LTD. at a rotary blade end peripheral speed of 5 m/second for 1 hour, so that the barium sulfate particles were dispersed.

[0093]

The homogenized dispersion solution was subjected to a dispersion process using a bead mill ULTRA APEX MILL UAM-015 (trade name) manufactured by KOTOBUKI INDUSTRIES CO., LTD. The beads were made of zirconia and had a mean particle diameter of 0.05 mm (YTZ Ball manufactured by NIKKATO CORPORATION). The beads were charged in an amount of 400 g. The peripheral speed of the rotor of the bead mill was 9.5 m/second, and the

feeding pressure was 0.1 MPa. The dispersion process time was 10 hours for dispersions A to O and 1 hour for dispersion P. After the dispersion process was completed, the liquid was collected so that the dispersion solution of the barium sulfate particles was obtained. Table 1 also shows the mean particle diameter of the barium sulfate particles in the dispersion solution at the end of the dispersion process.

[0094]

In Table 1, HOA-MPL (trade name) and HOA-HH (trade name) manufactured by KYOEISHA CHEMICAL Co., LTD. each used as a dispersant are compounds each having a polymerizable group and a carboxyl group, LIGHT-ESTER P-1M (trade name) manufactured by KYOEISHA CHEMICAL Co., LTD. and RDX 63182 (trade name) manufactured by DAICEL-CYTEC COMPANY LTD. are phosphoric ester compounds each having a polymerizable group, and Disperbyk-111 (trade name) manufactured by BYK-Chemie Japan KK is a phosphoric ester compound having no polymerizable group.

[0095]

Table 1

[0096]

Example 1

A paste composition was prepared by mixing 9.8 g of the dispersion solution A, 5 g of a resin represented by the formula (11), 0.1 g of a UV-activatable oxime-type

polymerization initiator OXE02 (manufactured by Chiba Specialty Chemicals K.K.), and 0.2 g of a silane coupling agent KBM403 (trade name, manufactured by Shin-Etsu Chemical Co., Ltd., chemical name: 3-glycidoxypyrpyltrimethoxysilane) in a ball mill. The content of the barium sulfate particles in the paste composition was 40% by weight based on the amount of the solid components in the paste composition, exclusive of the organic solvent. The barium sulfate particles in the paste composition had a mean particle diameter of 26 nm. The paste composition was applied to a quartz substrate with a spin coater. The coating was dried in air at 80°C for 1 hour using an oven and then exposed to 50 mJ/cm² of ultraviolet light using an ultra-high pressure mercury vapor lamp exposure system (PEM-6M, manufactured by UNION OPTICAL CO., LTD.) so that the paste composition was cured to form a 10 µm-thick film-shaped cured material. At a wavelength of 850 nm and a temperature of 25°C, the film-shaped cured material had a refractive index of 1.556 and a temperature-dependent change rate of refractive index of 51 ppm/°C.

[0097]

On the other hand, a cured material for use in evaluation of linear expansion coefficient was produced using the paste composition as described below. A Teflon (registered trademark) tape of 10 mm x 10 mm was attached to a f4 inch silicon wafer, and a 5 mm-long cut piece of a Teflon

(registered trademark) tube with an inner diameter of 8 mm was placed thereon. The paste composition obtained as described above was charged into the Teflon (registered trademark) tube in such a manner that the liquid level reached 1 mm. Thereafter, the paste composition was dried in air at 80° C for 1 hour using an oven and then exposed to 50 mJ/cm² of ultraviolet light using an ultra-high pressure mercury vapor lamp exposure system (PEM-6M, manufactured by UNION OPTICAL CO., LTD.) so that the paste composition was cured to form a cured material with a bottom diameter of 8 mm and a thickness of 1 mm. The resulting cured material was removed from the Teflon (registered trademark) tube, and the linear expansion coefficient of the cured material was measured in the thickness direction to be 44 ppm/°C.

[0098]

In addition, an optical waveguide was produced using the paste composition as described below. A liquid epoxy resin (#314, manufactured by EPOXY TECHNOLOGY, INC.) was applied to a 4 inch silicon wafer with a spin coater. The coating was dried in air at 80° C for 1 hour using an oven and then cured by heating in nitrogen at 150° C for 1 hour to form a 5 μ m-thick under-cladding. The refractive index of the under-cladding was measured at a wavelength of 850 nm and a temperature of 25° C to be 1.502. Thereafter, the paste composition was applied with a spin coater to the under-

cladding formed on the quartz substrate, and then dried in air at 80°C for 1 hour to form a 50 μm -thick dried paste composition film. The resulting film was exposed to 50 mJ/cm^2 of ultraviolet light through a quartz mask using an ultra-high pressure mercury vapor lamp exposure system (PEM-6M, manufactured by UNION OPTICAL CO., LTD.). The quartz mask had a 50 μm -wide, 9 cm-long slit, and the portion other than the slit was for blocking light. After the exposure, the substrate was immersed in a developing solution P-7G (manufactured by TOKYO OHKA KOGYO CO., LTD.) for 5 minutes so that the non-exposed film was removed. As a result, a 50 μm -wide 9 cm-long core was formed. After the development, the patterned portion had a clear rectangle shape with no cracking. No residue was observed in the non-exposed area, and the developability was good.

[0099]

The same material as for the under-cladding was further applied thereto with a spin coater. The coating was dried at 80°C for 1 hour and then cured by heating in nitrogen at 150°C for 1 hour to form a 5 μm -thick over-cladding, so that an optical waveguide was obtained.

[0100]

Both ends of the optical waveguide together with the substrate were cut using a dicing machine, and its optical propagation loss was measured to be 0.3 dB/cm.

[0101]

Examples 2 to 290

Each of the paste compositions of the formulations shown in Tables 2 to 31 was prepared by the same method as that in Example 1 and then used to form a cured material for use in evaluation of physical properties and to form an optical waveguide, except that the compound A used to form the dispersion solution was further added in place of the resin in the process of preparing the paste composition in each of Examples 209 to 226. The results of the evaluation are shown in Tables 2 to 31, in which the resins A and B are represented by the formulae (11) and (12), respectively, and the chemical name of the silane coupling agent KBM503 (trade name) manufactured by Shin-Etsu Chemical Co., Ltd. is 3-methacryloxypropyltrimethoxysilane.

[0102]

In some examples, a thin film-like residue was present on the surface of the substrate in the non-exposed area after the development in the process of forming the optical waveguide. In such cases, the comment "residue present in non-exposed area" is entered in the section of Developability in Tables 2 to 31. In some examples, a cracked portion or portions were observed in the core after the development in the process of forming the optical waveguide. In such cases, the comment "cracking of core" is entered in the section of Developability

in Tables 2 to 31.

[0103]

Table 2

[0133]

Comparative Examples 1 and 2

Each of the paste compositions of the formulations shown in Tables 32 and 33 was prepared by the same method as that in Example 1 and then used to form a cured material for use in evaluation of physical properties and to form an optical waveguide. The results of the evaluation are shown in Tables 32 and 33. The resulting cured materials were soft because of insufficient polymerization, and it was impossible to evaluate the refractive index and the linear expansion coefficient. In addition, the non-exposed area was whitened during the development in the process of forming the optical waveguide. The non-exposed area was not removed by the immersion for 5 minutes, and it was removed by shaking the substrate for 20 minutes in the immersion process. A thin film-like residue was present on the surface of the substrate in the non-exposed area. The patterned optical waveguide in the exposed area had a gentle convex shape. The measurement of optical propagation loss was attempted but failed, because the loss was so large

that the propagated light intensity was below the detection limit.

[0134]

Comparative Examples 3 and 4

Each of the paste compositions of the formulations shown in Tables 32 and 33 was prepared by the same method as that in Example 1 and then used to form a cured material for use in evaluation of physical properties and to form an optical waveguide. The results of the evaluation are shown in Tables 32 and 33. The temperature-dependency of the refractive index and the linear expansion coefficient were both relatively large. The non-exposed area was whitened during the development in the process of forming the optical waveguide. A several μm -thick film was left in the non-exposed area even after the shaking for 20 minutes in the developing solution. The measurement of optical propagation loss was attempted but failed, because the loss was so large that the propagated light intensity was below the detection limit.

[0135]

Comparative Examples 5 to 10

Each of the paste compositions of the formulations shown in Tables 32 and 33 was prepared by the same method as that in Example 1 and then used to form a cured material for use in evaluation of physical properties and to form an optical waveguide. The results of the evaluation are shown in Tables

32 and 33.

[0136]

Table 32

INDUSTRIAL APPLICABILITY

[0139]

The optical waveguide-forming paste composition of the present invention is suitable for use in forming optical interconnections and other components to transmit information between LSIs on circuit boards which may be used in information-processing devices to make high-speed signal transmission, such as personal computers, hard-disc recorders, DVD recorders, game machines, and cellular phones.

Table 1

	Components of Dispersion Solution						Time for Dispersion Process (h)	Mean Particle Diameter (nm)
	Amount of Barium Sulfate (g)	Dispersant *HOA-MPL and HOA-HH are compounds each having a polymerizable group and a carboxyl group, LIGHT-ESTER P-1M and RDX 63182 are phosphoric ester compounds each having a polymerizable group. (Compound A)	Organic Solvent		Amount of Dispersant based on 100 parts by weight of Barium Sulfate (parts by weight)			
			Material	Amount (g)		Material		
Dispersion Solution A	200	HOA-MPL	30	THFA	270	15	10	22
Dispersion Solution B	200	HOA-MPL	8	THFA	292	4	10	33
Dispersion Solution C	200	HOA-MPL	14	THFA	286	7	10	24
Dispersion Solution D	200	HOA-MPL	60	THFA	240	30	10	26
Dispersion Solution E	200	HOA-HH	30	THFA	270	15	10	26
Dispersion Solution F	200	HOA-HH	8	THFA	292	4	10	37
Dispersion Solution G	200	HOA-HH	14	THFA	286	7	10	25
Dispersion Solution H	200	HOA-HH	60	THFA	240	30	10	26
Dispersion Solution I	200	LIGHT-ESTER P-1M	30	DMAC	270	15	10	19
Dispersion Solution J	200	LIGHT-ESTER P-1M	8	DMAC	292	4	10	31
Dispersion Solution K	200	LIGHT-ESTER P-1M	14	DMAC	286	7	10	20
Dispersion Solution L	200	LIGHT-ESTER P-1M	60	DMAC	240	30	10	21
Dispersion Solution M	200	RDX 63182	30	DMAC	270	15	10	29
Dispersion Solution N	200	Disperbyk-111	30	DMAC	270	15	10	31
Dispersion Solution O	200	Disperbyk-111	10	DMAC	290	5	10	40
Dispersion Solution P	200	HOA-MPL	30	THFA	270	15	1	49

Table 2

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 1	Dispersion Solution A	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	40	57
Example 2	Dispersion Solution A	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80
Example 3	Dispersion Solution A	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	76
Example 4	Dispersion Solution A	15.4	Resin A	3	OXE02	0.06	KBM403	0.12	60	38
Example 5	Dispersion Solution A	26.5	Resin A	1	OXE02	0.02	KBM403	0.04	80	20
Example 6	Dispersion Solution A	50.1	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 7	Dispersion Solution B	9.1	Resin A	5	OXE02	0.1	KBM403	0.2	40	57
Example 8	Dispersion Solution B	2.3	Resin A	5	OXE02	0.1	KBM403	0.2	15	81
Example 9	Dispersion Solution B	3.3	Resin A	5	OXE02	0.1	KBM403	0.2	20	76
Example 10	Dispersion Solution B	12.7	Resin A	3	OXE02	0.06	KBM403	0.12	60	37
Example 11	Dispersion Solution B	12.6	Resin A	1	OXE02	0.02	KBM403	0.04	80	18
Example 12	Dispersion Solution B	9.7	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	14
Example 13	Dispersion Solution C	9.3	Resin A	5	OXE02	0.1	KBM403	0.2	40	57
Example 14	Dispersion Solution C	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80
Example 15	Dispersion Solution C	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	75
Example 16	Dispersion Solution C	13.3	Resin A	3	OXE02	0.06	KBM403	0.12	60	38
Example 17	Dispersion Solution C	14.7	Resin A	1	OXE02	0.02	KBM403	0.04	80	20
Example 18	Dispersion Solution C	12.4	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 19	Dispersion Solution D	11.0	Resin A	5	OXE02	0.1	KBM403	0.2	40	57
Example 20	Dispersion Solution D	2.5	Resin A	5	OXE02	0.1	KBM403	0.2	15	81
Example 21	Dispersion Solution D	3.6	Resin A	5	OXE02	0.1	KBM403	0.2	20	76
Example 22	Dispersion Solution D	21.7	Resin A	3	OXE02	0.06	KBM403	0.12	60	39

Table 3

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 1	26	1.556	51	44	good	0.3
Example 2	23	1.552	56	52	good	0.3
Example 3	25	1.553	55	51	good	0.3
Example 4	27	1.562	44	37	good	0.3
Example 5	29	1.572	31	24	good	0.4
Example 6	32	1.575	25	18	Residue present in non-exposed area, Cracking of core	0.5
Example 7	37	1.558	52	46	good	0.6
Example 8	35	1.552	57	52	good	0.5
Example 9	35	1.553	56	50	good	0.6
Example 10	36	1.566	44	36	good	0.6
Example 11	39	1.578	33	25	good	0.7
Example 12	42	1.583	26	17	Residue present in non-exposed area, Cracking of core	0.8
Example 13	25	1.558	49	44	good	0.3
Example 14	24	1.552	55	51	good	0.3
Example 15	25	1.553	56	51	good	0.3
Example 16	27	1.565	44	37	good	0.3
Example 17	29	1.577	30	23	good	0.4
Example 18	31	1.581	24	18	Residue present in non-exposed area, Cracking of core	0.5
Example 19	27	1.554	52	43	good	0.5
Example 20	25	1.551	55	51	good	0.4
Example 21	25	1.552	55	51	good	0.5
Example 22	27	1.557	43	37	good	0.6

Table 4

Components of Paste Composition											
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)	
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)			
Example 23	Dispersion Solution A	9.8	Resin A	5	OXE02	0.1	KBM503	0.2	40	57	
Example 24	Dispersion Solution A	2.4	Resin A	5	OXE02	0.1	KBM503	0.2	15	80	
Example 25	Dispersion Solution A	3.4	Resin A	5	OXE02	0.1	KBM503	0.2	20	76	
Example 26	Dispersion Solution A	15.4	Resin A	3	OXE02	0.06	KBM503	0.12	60	38	
Example 27	Dispersion Solution A	26.5	Resin A	1	OXE02	0.02	KBM503	0.04	80	20	
Example 28	Dispersion Solution A	50.1	Resin A	0.5	OXE02	0.01	KBM503	0.02	85	15	
Example 29	Dispersion Solution B	9.1	Resin A	5	OXE02	0.1	KBM503	0.2	40	57	
Example 30	Dispersion Solution C	9.3	Resin A	5	OXE02	0.1	KBM503	0.2	40	57	
Example 31	Dispersion Solution D	11.0	Resin A	5	OXE02	0.1	KBM503	0.2	40	57	
Example 32	Dispersion Solution A	9.4	Resin A	5	OXE02	0.1	none	none	40	59	
Example 33	Dispersion Solution A	2.3	Resin A	5	OXE02	0.1	none	none	15	83	
Example 34	Dispersion Solution A	3.3	Resin A	5	OXE02	0.1	none	none	20	79	
Example 35	Dispersion Solution A	14.8	Resin A	3	OXE02	0.06	none	none	60	39	
Example 36	Dispersion Solution A	25.5	Resin A	1	OXE02	0.02	none	none	80	20	
Example 37	Dispersion Solution A	48.2	Resin A	0.5	OXE02	0.01	none	none	85	15	
Example 38	Dispersion Solution B	8.7	Resin A	5	OXE02	0.1	none	none	40	59	
Example 39	Dispersion Solution B	2.2	Resin A	5	OXE02	0.1	none	none	15	84	
Example 40	Dispersion Solution B	3.2	Resin A	5	OXE02	0.1	none	none	20	79	
Example 41	Dispersion Solution B	12.2	Resin A	3	OXE02	0.06	none	none	60	39	
Example 42	Dispersion Solution B	12.1	Resin A	1	OXE02	0.02	none	none	80	20	
Example 43	Dispersion Solution B	9.3	Resin A	0.5	OXE02	0.01	none	none	85	14	
Example 44	Dispersion Solution C	8.9	Resin A	5	OXE02	0.1	none	none	40	59	
Example 45	Dispersion Solution C	2.3	Resin A	5	OXE02	0.1	none	none	15	83	
Example 46	Dispersion Solution C	3.3	Resin A	5	OXE02	0.1	none	none	20	78	
Example 47	Dispersion Solution C	12.8	Resin A	3	OXE02	0.06	none	none	60	39	
Example 48	Dispersion Solution C	14.2	Resin A	1	OXE02	0.02	none	none	80	20	
Example 49	Dispersion Solution C	12.0	Resin A	0.5	OXE02	0.01	none	none	85	15	

Table 5

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 23	27	1.556	50	42	good	0.3
Example 24	24	1.552	55	52	good	0.3
Example 25	26	1.553	55	52	good	0.3
Example 26	27	1.562	43	38	good	0.3
Example 27	29	1.572	31	25	good	0.4
Example 28	33	1.578	24	19	Residue present in non-exposed area, Cracking of core	0.5
Example 29	35	1.558	51	44	good	0.6
Example 30	25	1.558	53	41	good	0.3
Example 31	25	1.554	53	42	good	0.5
Example 32	25	1.556	51	42	good	0.4
Example 33	22	1.552	55	51	good	0.3
Example 34	25	1.553	54	50	good	0.3
Example 35	26	1.562	44	37	good	0.4
Example 36	30	1.572	32	24	Cracking of core	0.4
Example 37	31	1.578	24	18	Residue present in non-exposed area, Cracking of core	0.5
Example 38	36	1.558	51	43	good	0.6
Example 39	35	1.552	56	52	good	0.5
Example 40	36	1.553	56	51	good	0.6
Example 41	36	1.566	43	36	good	0.6
Example 42	36	1.578	31	22	Cracking of core	0.7
Example 43	41	1.583	25	17	Residue present in non-exposed area, Cracking of core	0.8
Example 44	25	1.558	52	43	good	0.4
Example 45	25	1.552	56	51	good	0.3
Example 46	24	1.553	55	51	good	0.3
Example 47	26	1.565	43	37	good	0.4
Example 48	29	1.577	31	24	Cracking of core	0.4
Example 49	33	1.581	24	18	Residue present in non-exposed area, Cracking of core	0.5

Table 6

Components of Paste Composition									
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)	
Example 50	Dispersion Solution D	10.6	Resin A	5	OXE02	0.1	none	none	59
Example 51	Dispersion Solution D	2.4	Resin A	5	OXE02	0.1	none	none	84
Example 52	Dispersion Solution D	3.5	Resin A	5	OXE02	0.1	none	none	78
Example 53	Dispersion Solution D	20.9	Resin A	3	OXE02	0.06	none	none	40
Example 54	Dispersion Solution E	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	57
Example 55	Dispersion Solution E	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	80
Example 56	Dispersion Solution E	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	76
Example 57	Dispersion Solution E	15.4	Resin A	3	OXE02	0.06	KBM403	0.12	38
Example 58	Dispersion Solution E	26.5	Resin A	1	OXE02	0.02	KBM403	0.04	20
Example 59	Dispersion Solution E	50.1	Resin A	0.5	OXE02	0.01	KBM403	0.02	15
Example 60	Dispersion Solution F	9.1	Resin A	5	OXE02	0.1	KBM403	0.2	57
Example 61	Dispersion Solution G	9.3	Resin A	5	OXE02	0.1	KBM403	0.2	57
Example 62	Dispersion Solution H	11.0	Resin A	5	OXE02	0.1	KBM403	0.2	57
Example 63	Dispersion Solution E	9.4	Resin A	5	OXE02	0.1	none	none	59
Example 64	Dispersion Solution E	2.3	Resin A	5	OXE02	0.1	none	none	83
Example 65	Dispersion Solution E	3.3	Resin A	5	OXE02	0.1	none	none	79
Example 66	Dispersion Solution E	14.8	Resin A	3	OXE02	0.06	none	none	39
Example 67	Dispersion Solution E	25.5	Resin A	1	OXE02	0.02	none	none	20
Example 68	Dispersion Solution E	48.2	Resin A	0.5	OXE02	0.01	none	none	15
Example 69	Dispersion Solution F	8.7	Resin A	5	OXE02	0.1	none	none	59
Example 70	Dispersion Solution G	8.9	Resin A	5	OXE02	0.1	none	none	59
Example 71	Dispersion Solution H	10.6	Resin A	5	OXE02	0.1	none	none	59

Table 7

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 50	24	1.554	51	43	good	0.5
Example 51	23	1.551	56	51	good	0.4
Example 52	24	1.552	55	51	good	0.5
Example 53	26	1.557	43	37	good	0.6
Example 54	30	1.553	52	44	good	0.5
Example 55	29	1.551	56	51	good	0.3
Example 56	30	1.551	55	51	good	0.4
Example 57	31	1.555	43	38	good	0.5
Example 58	34	1.560	33	25	good	0.5
Example 59	39	1.561	27	20	Residue present in non-exposed area, Cracking of core	0.6
Example 60	42	1.557	51	43	good	0.7
Example 61	33	1.556	51	44	good	0.5
Example 62	32	1.547	50	44	good	0.6
Example 63	29	1.553	52	43	good	0.5
Example 64	30	1.551	55	52	good	0.3
Example 65	29	1.551	54	51	good	0.4
Example 66	30	1.555	44	36	good	0.5
Example 67	33	1.560	31	24	Cracking of core	0.5
Example 68	40	1.561	25	18	Residue present in non-exposed area, Cracking of core	0.6
Example 69	43	1.557	51	43	good	0.7
Example 70	31	1.556	51	43	good	0.5
Example 71	31	1.547	52	44	good	0.6

Table 8

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 72	Dispersion Solution A	9.8	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 73	Dispersion Solution A	2.4	Resin B	5	OXE02	0.1	KBM403	0.2	15	80
Example 74	Dispersion Solution A	3.4	Resin B	5	OXE02	0.1	KBM403	0.2	20	76
Example 75	Dispersion Solution A	15.4	Resin B	3	OXE02	0.06	KBM403	0.12	60	38
Example 76	Dispersion Solution A	26.5	Resin B	1	OXE02	0.02	KBM403	0.04	80	20
Example 77	Dispersion Solution A	50.1	Resin B	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 78	Dispersion Solution B	9.1	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 79	Dispersion Solution C	9.3	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 80	Dispersion Solution D	11.0	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 81	Dispersion Solution A	9.4	Resin B	5	OXE02	0.1	none	none	40	59
Example 82	Dispersion Solution A	2.3	Resin B	5	OXE02	0.1	none	none	15	83
Example 83	Dispersion Solution A	3.3	Resin B	5	OXE02	0.1	none	none	20	79
Example 84	Dispersion Solution A	14.8	Resin B	3	OXE02	0.06	none	none	60	39
Example 85	Dispersion Solution A	25.5	Resin B	1	OXE02	0.02	none	none	80	20
Example 86	Dispersion Solution A	48.2	Resin B	0.5	OXE02	0.01	none	none	85	15
Example 87	Dispersion Solution B	8.7	Resin B	5	OXE02	0.1	none	none	40	59
Example 88	Dispersion Solution C	8.9	Resin B	5	OXE02	0.1	none	none	40	59
Example 89	Dispersion Solution D	10.6	Resin B	5	OXE02	0.1	none	none	40	59

Table 9

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 72	25	1.566	50	37	good	0.4
Example 73	23	1.563	54	45	good	0.3
Example 74	24	1.563	53	43	good	0.3
Example 75	25	1.566	44	27	Residue present in non-exposed area	0.4
Example 76	29	1.574	32	16	Residue present in non-exposed area	0.4
Example 77	33	1.576	24	12	Residue present in non-exposed area, Cracking of core	0.5
Example 78	36	1.568	48	32	good	0.6
Example 79	25	1.568	49	35	good	0.4
Example 80	27	1.562	52	35	good	0.5
Example 81	23	1.566	51	35	Residue present in non-exposed area	0.4
Example 82	23	1.563	53	43	good	0.3
Example 83	24	1.563	53	43	good	0.3
Example 84	25	1.566	43	28	Residue present in non-exposed area	0.5
Example 85	28	1.574	32	16	Residue present in non-exposed area, Cracking of core	0.5
Example 86	32	1.576	23	12	Residue present in non-exposed area, Cracking of core	0.6
Example 87	34	1.568	49	31	Residue present in non-exposed area	0.7
Example 88	25	1.568	50	35	Residue present in non-exposed area	0.4
Example 89	27	1.562	51	33	Residue present in non-exposed area	0.5

Table 10

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 90	Dispersion Solution E	9.8	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 91	Dispersion Solution E	2.4	Resin B	5	OXE02	0.1	KBM403	0.2	15	80
Example 92	Dispersion Solution E	3.4	Resin B	5	OXE02	0.1	KBM403	0.2	20	76
Example 93	Dispersion Solution E	26.5	Resin B	1	OXE02	0.02	KBM403	0.04	80	20
Example 94	Dispersion Solution E	50.1	Resin B	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 95	Dispersion Solution F	9.1	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 96	Dispersion Solution G	9.3	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 97	Dispersion Solution H	11.0	Resin B	5	OXE02	0.1	KBM403	0.2	40	57
Example 98	Dispersion Solution E	9.4	Resin B	5	OXE02	0.1	none	none	40	59
Example 99	Dispersion Solution E	2.3	Resin B	5	OXE02	0.1	none	none	15	83
Example 100	Dispersion Solution E	3.3	Resin B	5	OXE02	0.1	none	none	20	79
Example 101	Dispersion Solution E	25.5	Resin B	1	OXE02	0.02	none	none	80	20
Example 102	Dispersion Solution E	48.2	Resin B	0.5	OXE02	0.01	none	none	85	15
Example 103	Dispersion Solution F	8.7	Resin B	5	OXE02	0.1	none	none	40	59
Example 104	Dispersion Solution G	8.9	Resin B	5	OXE02	0.1	none	none	40	59
Example 105	Dispersion Solution H	10.6	Resin B	5	OXE02	0.1	none	none	40	59

Table 11

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 90	30	1.555	52	38	good	0.5
Example 91	30	1.562	54	44	good	0.3
Example 92	29	1.562	53	41	good	0.4
Example 93	35	1.562	34	18	Residue present in non-exposed area	0.5
Example 94	40	1.562	26	13	Residue present in non-exposed area, Cracking of core	0.6
Example 95	42	1.567	51	36	good	0.7
Example 96	32	1.566	51	38	good	0.5
Example 97	33	1.555	53	39	good	0.6
Example 98	29	1.555	53	37	Residue present in non-exposed area	0.5
Example 99	29	1.562	55	44	good	0.3
Example 100	30	1.562	54	42	good	0.4
Example 101	34	1.562	33	15	Residue present in non-exposed area, Cracking of core	0.6
Example 102	39	1.562	24	12	Residue present in non-exposed area, Cracking of core	0.7
Example 103	43	1.567	48	35	Residue present in non-exposed area	0.8
Example 104	33	1.566	49	37	Residue present in non-exposed area	0.5
Example 105	31	1.555	51	37	Residue present in non-exposed area	0.6

Table 12

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 106	Dispersion Solution A	9.8	Resin A	2.5	OXE02	0.1	KBM403	0.2	40	57
			Resin B	2.5						
Example 107	Dispersion Solution A	2.4	Resin A	2.5	OXE02	0.1	KBM403	0.2	15	80
			Resin B	2.5						
Example 108	Dispersion Solution A	3.4	Resin A	2.5	OXE02	0.1	KBM403	0.2	20	76
			Resin B	2.5						
Example 109	Dispersion Solution A	15.4	Resin A	1.5	OXE02	0.06	KBM403	0.12	60	38
			Resin B	1.5						
Example 110	Dispersion Solution A	26.5	Resin A	0.5	OXE02	0.02	KBM403	0.04	80	20
			Resin B	0.5						
Example 111	Dispersion Solution A	50.1	Resin A	0.25	OXE02	0.01	KBM403	0.02	85	15
			Resin B	0.25						
Example 112	Dispersion Solution B	9.1	Resin A	2.5	OXE02	0.1	KBM403	0.2	40	57
			Resin B	2.5						
Example 113	Dispersion Solution B	2.3	Resin A	2.5	OXE02	0.1	KBM403	0.2	15	81
			Resin B	2.5						
Example 114	Dispersion Solution B	3.3	Resin A	2.5	OXE02	0.1	KBM403	0.2	20	76
			Resin B	2.5						
Example 115	Dispersion Solution B	12.7	Resin A	1.5	OXE02	0.06	KBM403	0.12	60	37
			Resin B	1.5						
Example 116	Dispersion Solution B	12.6	Resin A	0.5	OXE02	0.02	KBM403	0.04	80	18
			Resin B	0.5						
Example 117	Dispersion Solution B	9.7	Resin A	0.25	OXE02	0.01	KBM403	0.02	85	14
			Resin B	0.25						
Example 118	Dispersion Solution C	9.3	Resin A	2.5	OXE02	0.1	KBM403	0.2	40	57
			Resin B	2.5						
Example 119	Dispersion Solution C	2.4	Resin A	2.5	OXE02	0.1	KBM403	0.2	15	80
			Resin B	2.5						
Example 120	Dispersion Solution C	3.4	Resin A	2.5	OXE02	0.1	KBM403	0.2	20	75
			Resin B	2.5						
Example 121	Dispersion Solution C	13.3	Resin A	1.5	OXE02	0.06	KBM403	0.12	60	38
			Resin B	1.5						
Example 122	Dispersion Solution C	14.7	Resin A	0.5	OXE02	0.02	KBM403	0.04	80	20
			Resin B	0.5						
Example 123	Dispersion Solution C	12.4	Resin A	0.25	OXE02	0.01	KBM403	0.02	85	15
			Resin B	0.25						

Table 13

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 106	25	1.561	50	40	good	0.3
Example 107	24	1.557	55	48	good	0.3
Example 108	26	1.558	54	47	good	0.3
Example 109	26	1.565	42	33	good	0.3
Example 110	27	1.573	32	21	good	0.4
Example 111	31	1.576	25	16	Residue present in non-exposed area, Cracking of core	0.5
Example 112	37	1.563	51	41	good	0.6
Example 113	36	1.558	56	48	good	0.5
Example 114	35	1.559	53	46	good	0.6
Example 115	36	1.570	42	33	good	0.6
Example 116	39	1.581	30	20	good	0.7
Example 117	41	1.585	24	15	Residue present in non-exposed area, Cracking of core	0.8
Example 118	26	1.563	51	40	good	0.3
Example 119	24	1.558	55	47	good	0.3
Example 120	24	1.559	55	47	good	0.3
Example 121	26	1.569	43	33	good	0.3
Example 122	28	1.579	31	21	good	0.4
Example 123	30	1.582	25	16	Residue present in non-exposed area, Cracking of core	0.5

Table 14

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 124	Dispersion Solution D	11.0	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 125	Dispersion Solution D	2.5	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	81
Example 126	Dispersion Solution D	3.6	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76
Example 127	Dispersion Solution D	21.7	Resin A Resin B	1.5 1.5	OXE02	0.06	KBM403	0.12	60	39
Example 128	Dispersion Solution A	9.4	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 129	Dispersion Solution A	2.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	15	83
Example 130	Dispersion Solution A	3.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	20	79
Example 131	Dispersion Solution A	14.8	Resin A Resin B	1.5 1.5	OXE02	0.06	none	none	60	39
Example 132	Dispersion Solution A	25.5	Resin A Resin B	0.5 0.5	OXE02	0.02	none	none	80	20
Example 133	Dispersion Solution A	48.2	Resin A Resin B	0.25 0.25	OXE02	0.01	none	none	85	15
Example 134	Dispersion Solution B	8.7	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 135	Dispersion Solution C	8.9	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 136	Dispersion Solution D	10.6	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 137	Dispersion Solution E	9.8	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 138	Dispersion Solution E	2.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	80
Example 139	Dispersion Solution E	3.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76
Example 140	Dispersion Solution E	26.5	Resin A Resin B	0.5 0.5	OXE02	0.02	KBM403	0.04	80	20
Example 141	Dispersion Solution E	50.1	Resin A Resin B	0.25 0.25	OXE02	0.01	KBM403	0.02	85	15

Table 15

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 124	26	1.558	52	39	good	0.5
Example 125	25	1.557	55	48	good	0.4
Example 126	26	1.557	54	47	good	0.5
Example 127	27	1.559	42	33	good	0.6
Example 128	24	1.561	51	40	good	0.4
Example 129	23	1.557	56	47	good	0.3
Example 130	25	1.558	55	46	good	0.3
Example 131	26	1.565	43	32	good	0.4
Example 132	28	1.573	32	21	Cracking of core	0.4
Example 133	31	1.576	24	17	Residue present in non-exposed area, Cracking of core	0.5
Example 134	26	1.563	50	40	good	0.6
Example 135	25	1.563	51	39	good	0.4
Example 136	25	1.558	52	40	good	0.5
Example 137	29	1.557	52	40	good	0.5
Example 138	30	1.556	56	48	good	0.3
Example 139	30	1.557	55	47	good	0.4
Example 140	35	1.561	31	21	good	0.5
Example 141	40	1.562	25	16	Residue present in non-exposed area, Cracking of core	0.6

Table 16

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 142	Dispersion Solution F	9.1	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 143	Dispersion Solution G	9.3	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 144	Dispersion Solution H	11.0	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 145	Dispersion Solution E	9.4	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 146	Dispersion Solution E	2.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	15	83
Example 147	Dispersion Solution E	3.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	20	79
Example 148	Dispersion Solution E	25.5	Resin A Resin B	0.5 0.5	OXE02	0.02	none	none	80	20
Example 149	Dispersion Solution E	48.2	Resin A Resin B	0.25 0.25	OXE02	0.01	none	none	85	15
Example 150	Dispersion Solution F	8.7	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 151	Dispersion Solution G	8.9	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 152	Dispersion Solution H	10.6	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59

Table 17

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 142	44	1.562	50	41	good	0.7
Example 143	32	1.561	49	41	good	0.5
Example 144	30	1.551	52	40	good	0.6
Example 145	30	1.557	50	40	good	0.5
Example 146	28	1.556	54	47	good	0.3
Example 147	29	1.557	55	46	good	0.4
Example 148	36	1.561	30	20	Cracking of core	0.5
Example 149	39	1.562	24	15	Residue present in non-exposed area, Cracking of core	0.6
Example 150	42	1.562	50	41	good	0.7
Example 151	29	1.561	51	39	good	0.5
Example 152	31	1.551	50	39	good	0.6

Table 18

Components of Paste Composition												
Dispersion Solution	Resin	Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)					
		Sample	Amount (g)	Material	Amount (g)			Material	Amount (g)			
Example 153	Dispersion Solution I	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	40	57		
Example 154	Dispersion Solution I	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80		
Example 155	Dispersion Solution I	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	76		
Example 156	Dispersion Solution I	15.4	Resin A	3	OXE02	0.06	KBM403	0.12	60	38		
Example 157	Dispersion Solution I	26.5	Resin A	1	OXE02	0.02	KBM403	0.04	80	20		
Example 158	Dispersion Solution I	50.1	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15		
Example 159	Dispersion Solution J	9.1	Resin A	5	OXE02	0.1	KBM403	0.2	40	57		
Example 160	Dispersion Solution J	2.3	Resin A	5	OXE02	0.1	KBM403	0.2	15	81		
Example 161	Dispersion Solution J	3.3	Resin A	5	OXE02	0.1	KBM403	0.2	20	76		
Example 162	Dispersion Solution J	12.7	Resin A	3	OXE02	0.06	KBM403	0.12	60	37		
Example 163	Dispersion Solution J	12.6	Resin A	1	OXE02	0.02	KBM403	0.04	80	18		
Example 164	Dispersion Solution J	9.7	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	14		
Example 165	Dispersion Solution K	9.3	Resin A	5	OXE02	0.1	KBM403	0.2	40	57		
Example 166	Dispersion Solution K	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80		
Example 167	Dispersion Solution K	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	75		
Example 168	Dispersion Solution K	13.3	Resin A	3	OXE02	0.06	KBM403	0.12	60	38		
Example 169	Dispersion Solution K	14.7	Resin A	1	OXE02	0.02	KBM403	0.04	80	20		
Example 170	Dispersion Solution K	12.4	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15		
Example 171	Dispersion Solution L	11.0	Resin A	5	OXE02	0.1	KBM403	0.2	40	57		
Example 172	Dispersion Solution L	2.5	Resin A	5	OXE02	0.1	KBM403	0.2	15	81		
Example 173	Dispersion Solution L	3.6	Resin A	5	OXE02	0.1	KBM403	0.2	20	76		
Example 174	Dispersion Solution L	21.7	Resin A	3	OXE02	0.06	KBM403	0.12	60	39		

Table 19

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 153	21	1.552	51	44	good	0.4
Example 154	20	1.550	55	52	good	0.3
Example 155	21	1.551	54	51	good	0.3
Example 156	23	1.553	44	38	good	0.4
Example 157	26	1.556	31	24	Residue present in non-exposed area	0.4
Example 158	28	1.557	26	19	Residue present in non-exposed area, Cracking of core	0.5
Example 159	35	1.557	51	46	good	0.6
Example 160	33	1.552	56	53	good	0.5
Example 161	33	1.553	55	51	good	0.6
Example 162	36	1.563	43	36	good	0.7
Example 163	37	1.574	33	25	Residue present in non-exposed area	0.7
Example 164	38	1.578	25	16	Residue present in non-exposed area, Cracking of core	0.8
Example 165	22	1.556	49	44	good	0.4
Example 166	21	1.552	55	50	good	0.3
Example 167	22	1.552	55	49	good	0.3
Example 168	24	1.561	43	38	good	0.4
Example 169	26	1.569	30	23	Residue present in non-exposed area	0.4
Example 170	29	1.572	24	18	Residue present in non-exposed area, Cracking of core	0.5
Example 171	22	1.544	53	43	good	0.5
Example 172	21	1.548	55	51	good	0.4
Example 173	22	1.548	55	51	good	0.4
Example 174	23	1.539	43	37	good	0.6

Table 20

Components of Paste Composition												
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)		
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)				
Example 175	Dispersion Solution I	9.4	Resin A	5	OXE02	0.1	none	none	40	59		
Example 176	Dispersion Solution I	2.3	Resin A	5	OXE02	0.1	none	none	15	83		
Example 177	Dispersion Solution I	3.3	Resin A	5	OXE02	0.1	none	none	20	79		
Example 178	Dispersion Solution I	14.8	Resin A	3	OXE02	0.06	none	none	60	39		
Example 179	Dispersion Solution I	25.5	Resin A	1	OXE02	0.02	none	none	80	20		
Example 180	Dispersion Solution I	48.2	Resin A	0.5	OXE02	0.01	none	none	85	15		
Example 181	Dispersion Solution J	8.7	Resin A	5	OXE02	0.1	none	none	40	59		
Example 182	Dispersion Solution J	2.2	Resin A	5	OXE02	0.1	none	none	15	84		
Example 183	Dispersion Solution J	3.2	Resin A	5	OXE02	0.1	none	none	20	79		
Example 184	Dispersion Solution J	12.2	Resin A	3	OXE02	0.06	none	none	60	39		
Example 185	Dispersion Solution J	12.1	Resin A	1	OXE02	0.02	none	none	80	20		
Example 186	Dispersion Solution J	9.3	Resin A	0.5	OXE02	0.01	none	none	85	14		
Example 187	Dispersion Solution K	8.9	Resin A	5	OXE02	0.1	none	none	40	59		
Example 188	Dispersion Solution K	2.3	Resin A	5	OXE02	0.1	none	none	15	83		
Example 189	Dispersion Solution K	3.3	Resin A	5	OXE02	0.1	none	none	20	78		
Example 190	Dispersion Solution K	12.8	Resin A	3	OXE02	0.06	none	none	60	39		
Example 191	Dispersion Solution K	14.2	Resin A	1	OXE02	0.02	none	none	80	20		
Example 192	Dispersion Solution K	12.0	Resin A	0.5	OXE02	0.01	none	none	85	15		
Example 193	Dispersion Solution L	10.6	Resin A	5	OXE02	0.1	none	none	40	59		
Example 194	Dispersion Solution L	2.4	Resin A	5	OXE02	0.1	none	none	15	84		
Example 195	Dispersion Solution L	3.5	Resin A	5	OXE02	0.1	none	none	20	78		
Example 196	Dispersion Solution L	20.9	Resin A	3	OXE02	0.06	none	none	60	40		

Table 21

	Results				
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability
Example 175	23	1.552	51	43	good
Example 176	21	1.550	56	52	good
Example 177	21	1.551	55	51	good
Example 178	24	1.553	44	37	Residue present in non-exposed area
Example 179	27	1.556	30	25	Residue present in non-exposed area, Cracking of core
Example 180	28	1.557	25	18	Residue present in non-exposed area, Cracking of core
Example 181	35	1.557	53	46	good
Example 182	33	1.552	56	51	good
Example 183	34	1.553	56	50	good
Example 184	37	1.563	45	37	Residue present in non-exposed area
Example 185	38	1.574	33	25	Residue present in non-exposed area, Cracking of core
Example 186	40	1.578	26	17	Residue present in non-exposed area, Cracking of core
Example 187	22	1.556	49	44	good
Example 188	20	1.552	56	51	good
Example 189	20	1.552	55	50	good
Example 190	22	1.561	44	37	Residue present in non-exposed area
Example 191	26	1.569	31	22	Residue present in non-exposed area, Cracking of core
Example 192	28	1.572	25	19	Residue present in non-exposed area, Cracking of core
Example 193	21	1.544	53	44	good
Example 194	20	1.548	54	51	good
Example 195	21	1.548	54	50	good
Example 196	22	1.539	43	36	Residue present in non-exposed area
					0.6
					0.5
					0.4
					0.3
					0.3
					0.5
					0.5
					0.6
					0.7
					0.8
					0.9
					0.4
					0.3
					0.3
					0.5
					0.5
					0.6
					0.5
					0.4
					0.4
					0.6

Table 22

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 197	Dispersion Solution M	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	40	57
Example 198	Dispersion Solution M	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80
Example 199	Dispersion Solution M	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	76
Example 200	Dispersion Solution M	15.4	Resin A	3	OXE02	0.06	KBM403	0.12	60	38
Example 201	Dispersion Solution M	26.5	Resin A	1	OXE02	0.02	KBM403	0.04	80	20
Example 202	Dispersion Solution M	50.1	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 203	Dispersion Solution M	9.4	Resin A	5	OXE02	0.1	none	none	40	59
Example 204	Dispersion Solution M	2.3	Resin A	5	OXE02	0.1	none	none	15	83
Example 205	Dispersion Solution M	3.3	Resin A	5	OXE02	0.1	none	none	20	79
Example 206	Dispersion Solution M	14.8	Resin A	3	OXE02	0.06	none	none	60	39
Example 207	Dispersion Solution M	25.5	Resin A	1	OXE02	0.02	none	none	80	20
Example 208	Dispersion Solution M	48.2	Resin A	0.5	OXE02	0.01	none	none	85	15

Table 23

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 197	35	1.558	51	43	good	0.6
Example 198	34	1.552	54	52	good	0.5
Example 199	34	1.553	54	51	good	0.6
Example 200	37	1.565	45	37	good	0.6
Example 201	39	1.578	32	24	Residue present in non-exposed area	0.7
Example 202	40	1.582	26	20	Residue present in non-exposed area, Cracking of core	0.8
Example 203	36	1.558	52	44	good	0.6
Example 204	33	1.552	55	51	good	0.5
Example 205	34	1.553	55	49	good	0.6
Example 206	38	1.565	45	37	Residue present in non-exposed area	0.7
Example 207	39	1.578	31	25	Residue present in non-exposed area, Cracking of core	0.8
Example 208	41	1.582	28	19	Residue present in non-exposed area, Cracking of core	0.9

Table 24

Components of Paste Composition												
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)		
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)				
Example 209	Dispersion Solution I	9.8	Resin B	5	OXE02	0.1	KBM403	0.2	40	57		
Example 210	Dispersion Solution I	2.4	Resin B	5	OXE02	0.1	KBM403	0.2	15	80		
Example 211	Dispersion Solution I	3.4	Resin B	5	OXE02	0.1	KBM403	0.2	20	76		
Example 212	Dispersion Solution I	15.4	Resin B	3	OXE02	0.06	KBM403	0.12	60	38		
Example 213	Dispersion Solution I	26.5	Resin B	1	OXE02	0.02	KBM403	0.04	80	20		
Example 214	Dispersion Solution I	50.1	Resin B	0.5	OXE02	0.01	KBM403	0.02	85	15		
Example 215	Dispersion Solution J	9.1	Resin B	5	OXE02	0.1	KBM403	0.2	40	57		
Example 216	Dispersion Solution K	9.3	Resin B	5	OXE02	0.1	KBM403	0.2	40	57		
Example 217	Dispersion Solution L	11.0	Resin B	5	OXE02	0.1	KBM403	0.2	40	57		
Example 218	Dispersion Solution I	9.4	Resin B	5	OXE02	0.1	none	none	40	59		
Example 219	Dispersion Solution I	2.3	Resin B	5	OXE02	0.1	none	none	15	83		
Example 220	Dispersion Solution I	3.3	Resin B	5	OXE02	0.1	none	none	20	79		
Example 221	Dispersion Solution I	14.8	Resin B	3	OXE02	0.06	none	none	60	39		
Example 222	Dispersion Solution I	25.5	Resin B	1	OXE02	0.02	none	none	80	20		
Example 223	Dispersion Solution I	48.2	Resin B	0.5	OXE02	0.01	none	none	85	15		
Example 224	Dispersion Solution J	8.7	Resin B	5	OXE02	0.1	none	none	40	59		
Example 225	Dispersion Solution K	8.9	Resin B	5	OXE02	0.1	none	none	40	59		
Example 226	Dispersion Solution L	10.6	Resin B	5	OXE02	0.1	none	none	40	59		
Example 227	Dispersion Solution M	9.8	Resin B	5	OXE02	0.1	KBM403	0.2	40	57		
Example 228	Dispersion Solution M	2.4	Resin B	5	OXE02	0.1	KBM403	0.2	15	80		
Example 229	Dispersion Solution M	3.4	Resin B	5	OXE02	0.1	KBM403	0.2	20	76		
Example 230	Dispersion Solution M	26.5	Resin B	1	OXE02	0.02	KBM403	0.04	80	20		
Example 231	Dispersion Solution M	50.1	Resin B	0.5	OXE02	0.01	KBM403	0.02	85	15		

Table 25

	Results					Optical Propagation Loss (dB/cm)
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	
Example 209	24	1.560	50	37	good	0.4
Example 210	23	1.560	53	44	good	0.3
Example 211	23	1.560	53	43	good	0.3
Example 212	25	1.559	44	26	Residue present in non-exposed area	0.4
Example 213	28	1.559	31	16	Residue present in non-exposed area	0.4
Example 214	31	1.559	24	13	Residue present in non-exposed area, Cracking of core	0.5
Example 215	34	1.565	49	32	good	0.6
Example 216	22	1.564	49	35	good	0.4
Example 217	24	1.552	51	35	good	0.5
Example 218	21	1.560	51	36	Residue present in non-exposed area	0.4
Example 219	22	1.560	54	44	good	0.3
Example 220	23	1.560	53	43	good	0.3
Example 221	23	1.559	42	28	Residue present in non-exposed area	0.5
Example 222	27	1.559	32	17	Residue present in non-exposed area, Cracking of core	0.5
Example 223	32	1.559	22	12	Residue present in non-exposed area, Cracking of core	0.6
Example 224	34	1.565	49	30	Residue present in non-exposed area	0.7
Example 225	25	1.564	50	35	Residue present in non-exposed area	0.4
Example 226	26	1.552	52	33	Residue present in non-exposed area	0.5
Example 227	34	1.566	53	37	good	0.6
Example 228	33	1.562	54	44	good	0.5
Example 229	35	1.562	53	41	good	0.6
Example 230	38	1.580	34	18	Residue present in non-exposed area	0.8
Example 231	41	1.583	25	12	Residue present in non-exposed area, Cracking of core	0.9

Table 26

Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 232	Dispersion Solution I	9.8	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 233	Dispersion Solution I	2.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	80
Example 234	Dispersion Solution I	3.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76
Example 235	Dispersion Solution I	15.4	Resin A Resin B	1.5 1.5	OXE02	0.06	KBM403	0.12	60	38
Example 236	Dispersion Solution I	26.5	Resin A Resin B	0.5 0.5	OXE02	0.02	KBM403	0.04	80	20
Example 237	Dispersion Solution I	50.1	Resin A Resin B	0.25 0.25	OXE02	0.01	KBM403	0.02	85	15
Example 238	Dispersion Solution J	9.1	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 239	Dispersion Solution J	2.3	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	81
Example 240	Dispersion Solution J	3.3	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76
Example 241	Dispersion Solution J	12.7	Resin A Resin B	1.5 1.5	OXE02	0.06	KBM403	0.12	60	37
Example 242	Dispersion Solution J	12.6	Resin A Resin B	0.5 0.5	OXE02	0.02	KBM403	0.04	80	18
Example 243	Dispersion Solution J	9.7	Resin A Resin B	0.25 0.25	OXE02	0.01	KBM403	0.02	85	14
Example 244	Dispersion Solution K	9.3	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57
Example 245	Dispersion Solution K	2.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	80
Example 246	Dispersion Solution K	3.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	75
Example 247	Dispersion Solution K	13.3	Resin A Resin B	1.5 1.5	OXE02	0.06	KBM403	0.12	60	38
Example 248	Dispersion Solution K	14.7	Resin A Resin B	0.5 0.5	OXE02	0.02	KBM403	0.04	80	20
Example 249	Dispersion Solution K	12.4	Resin A Resin B	0.25 0.25	OXE02	0.01	KBM403	0.02	85	15

Table 27

	Results					
	Mean Particle Diameter in Paste Composition (μm)	Refractive Index	Temperature Dependency of the Refractive Index ($\text{ppm}/^\circ\text{C}$)	Coefficient of Linear Expansion ($\text{ppm}/^\circ\text{C}$)	Developability	Optical Propagation Loss (dB/cm)
Example 232	22	1.556	50	41	good	0.3
Example 233	21	1.555	54	49	good	0.3
Example 234	23	1.555	53	47	good	0.3
Example 235	25	1.557	40	33	good	0.3
Example 236	27	1.558	31	20	good	0.4
Example 237	32	1.558	24	16	Residue present in non-exposed area, Cracking of core	0.5
Example 238	36	1.561	51	41	good	0.6
Example 239	37	1.557	55	47	good	0.5
Example 240	34	1.558	53	46	good	0.6
Example 241	38	1.567	42	33	good	0.6
Example 242	39	1.577	29	21	good	0.7
Example 243	41	1.580	25	15	Residue present in non-exposed area, Cracking of core	0.8
Example 244	25	1.560	51	41	good	0.3
Example 245	23	1.556	56	48	good	0.3
Example 246	23	1.557	55	47	good	0.3
Example 247	25	1.564	44	34	good	0.3
Example 248	28	1.571	31	22	good	0.4
Example 249	30	1.574	24	17	Residue present in non-exposed area, Cracking of core	0.5

Table 28

Components of Paste Composition												
Dispersion Solution	Resin		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)				
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)						
Example 250	Dispersion Solution L	11.0	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57		
Example 251	Dispersion Solution L	2.5	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	81		
Example 252	Dispersion Solution L	3.6	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76		
Example 253	Dispersion Solution L	21.7	Resin A Resin B	1.5 1.5	OXE02	0.06	KBM403	0.12	60	39		
Example 254	Dispersion Solution I	9.4	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59		
Example 255	Dispersion Solution I	2.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	15	83		
Example 256	Dispersion Solution I	3.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	20	79		
Example 257	Dispersion Solution I	14.8	Resin A Resin B	1.5 1.5	OXE02	0.06	none	none	60	39		
Example 258	Dispersion Solution I	25.5	Resin A Resin B	0.5 0.5	OXE02	0.02	none	none	80	20		
Example 259	Dispersion Solution I	48.2	Resin A Resin B	0.25 0.25	OXE02	0.01	none	none	85	15		
Example 260	Dispersion Solution J	8.7	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59		
Example 261	Dispersion Solution K	8.9	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59		
Example 262	Dispersion Solution L	10.6	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59		
Example 263	Dispersion Solution M	9.8	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	40	57		
Example 264	Dispersion Solution M	2.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	15	80		
Example 265	Dispersion Solution M	3.4	Resin A Resin B	2.5 2.5	OXE02	0.1	KBM403	0.2	20	76		
Example 266	Dispersion Solution M	26.5	Resin A Resin B	0.5 0.5	OXE02	0.02	KBM403	0.04	80	20		
Example 267	Dispersion Solution M	50.1	Resin A Resin B	0.25 0.25	OXE02	0.01	KBM403	0.02	85	15		

Table 29

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Example 250	25	1.548	51	39	good	0.5
Example 251	24	1.553	55	48	good	0.4
Example 252	24	1.552	54	46	good	0.5
Example 253	27	1.543	42	33	good	0.6
Example 254	23	1.556	50	41	good	0.4
Example 255	21	1.555	55	47	good	0.3
Example 256	24	1.555	55	45	good	0.3
Example 257	25	1.557	42	32	good	0.4
Example 258	27	1.558	32	22	Cracking of core	0.4
Example 259	30	1.558	23	18	Residue present in non-exposed area, Cracking of core	0.5
Example 260	25	1.561	50	40	good	0.6
Example 261	24	1.560	51	39	good	0.4
Example 262	24	1.548	52	41	good	0.5
Example 263	34	1.562	52	40	good	0.5
Example 264	33	1.557	55	48	good	0.3
Example 265	34	1.558	55	47	good	0.4
Example 266	38	1.579	31	22	good	0.5
Example 267	41	1.583	24	16	Residue present in non-exposed area, Cracking of core	0.6

Table 30

Components of Paste Composition										
	Dispersion Solution		Compound A		Polymerization Initiator		Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
	Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)		
Example 268	Dispersion Solution M	9.4	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	40	59
Example 269	Dispersion Solution M	2.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	15	83
Example 270	Dispersion Solution M	3.3	Resin A Resin B	2.5 2.5	OXE02	0.1	none	none	20	79
Example 271	Dispersion Solution M	25.5	Resin A Resin B	0.5 0.5	OXE02	0.02	none	none	80	20
Example 272	Dispersion Solution M	48.2	Resin A Resin B	0.25 0.25	OXE02	0.01	none	none	85	15
Example 273	Dispersion Solution A	9.8	HOA-MPL	5	OXE02	0.1	KBM403	0.2	40	57
Example 274	Dispersion Solution A	2.4	HOA-MPL	5	OXE02	0.1	KBM403	0.2	15	80
Example 275	Dispersion Solution A	3.4	HOA-MPL	5	OXE02	0.1	KBM403	0.2	20	76
Example 276	Dispersion Solution A	15.4	HOA-MPL	3	OXE02	0.06	KBM403	0.12	60	38
Example 277	Dispersion Solution A	26.5	HOA-MPL	1	OXE02	0.02	KBM403	0.04	80	20
Example 278	Dispersion Solution A	50.1	HOA-MPL	0.5	OXE02	0.01	KBM403	0.02	85	15
Example 279	Dispersion Solution B	9.1	HOA-MPL	5	OXE02	0.1	KBM403	0.2	40	57
Example 280	Dispersion Solution C	9.3	HOA-MPL	5	OXE02	0.1	KBM403	0.2	40	57
Example 281	Dispersion Solution D	11.0	HOA-MPL	5	OXE02	0.1	KBM403	0.2	40	57
Example 282	Dispersion Solution A	9.4	HOA-MPL	5	OXE02	0.1	none	none	40	59
Example 283	Dispersion Solution A	2.3	HOA-MPL	5	OXE02	0.1	none	none	15	83
Example 284	Dispersion Solution A	3.3	HOA-MPL	5	OXE02	0.1	none	none	20	79
Example 285	Dispersion Solution A	14.8	HOA-MPL	3	OXE02	0.06	none	none	60	39
Example 286	Dispersion Solution A	25.5	HOA-MPL	1	OXE02	0.02	none	none	80	20
Example 287	Dispersion Solution A	48.2	HOA-MPL	0.5	OXE02	0.01	none	none	85	15
Example 288	Dispersion Solution B	8.7	HOA-MPL	5	OXE02	0.1	none	none	40	59
Example 289	Dispersion Solution C	8.9	HOA-MPL	5	OXE02	0.1	none	none	40	59
Example 290	Dispersion Solution D	10.6	HOA-MPL	5	OXE02	0.1	none	none	40	59

Table 31

	Results				
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability
Example 268	34	1.562	51	40	good
Example 269	32	1.557	54	47	good
Example 270	33	1.558	54	46	good
Example 271	38	1.579	30	22	Cracking of core
Example 272	40	1.583	24	16	Residue present in non-exposed area, Cracking of core
Example 273	23	1.531	53	43	good
Example 274	24	1.521	56	51	good
Example 275	24	1.523	55	52	good
Example 276	26	1.543	44	37	good
Example 277	29	1.565	30	23	Residue present in non-exposed area
Example 278	32	1.572	24	18	Residue present in non-exposed area, Cracking of core
Example 279	36	1.531	52	42	good
Example 280	26	1.531	52	43	good
Example 281	26	1.531	52	42	good
Example 282	25	1.531	54	42	good
Example 283	24	1.521	56	51	good
Example 284	25	1.523	55	51	good
Example 285	25	1.543	43	36	good
Example 286	28	1.565	31	24	Residue present in non-exposed area, Cracking of core
Example 287	31	1.572	24	17	Residue present in non-exposed area, Cracking of core
Example 288	35	1.531	51	42	good
Example 289	25	1.531	51	41	good
Example 290	27	1.531	52	40	good
					Optical Propagation Loss (dB/cm)
					0.6
					0.5
					0.6
					0.7
					0.8
					0.6
					0.5
					0.6
					0.7
					0.8
					0.9
					0.8
					0.6
					0.6

Table 32

	Components of Paste Composition										
	Dispersion Solution		Resin		Polymerization Initiator			Silane Coupling Agent		Content of Barium Sulfate based on Amount of Solid Components (% by weight)	Content of Compound A and Resin based on Amount of Solid Components (% by weight)
Sample	Amount (g)	Material	Amount (g)	Material	Amount (g)	Material	Amount (g)				
Comparative Example 1	Dispersion Solution N	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	40	51	
Comparative Example 2	Dispersion Solution N	9.4	Resin A	5	OXE02	0.1	none	none	40	53	
Comparative Example 3	Dispersion Solution O	9.1	Resin A	5	OXE02	0.1	KBM403	0.2	40	55	
Comparative Example 4	Dispersion Solution O	8.8	Resin A	5	OXE02	0.1	none	none	40	57	
Comparative Example 5	Dispersion Solution P	9.8	Resin A	5	OXE02	0.1	KBM403	0.2	40	57	
Comparative Example 6	Dispersion Solution P	2.4	Resin A	5	OXE02	0.1	KBM403	0.2	15	80	
Comparative Example 7	Dispersion Solution P	3.4	Resin A	5	OXE02	0.1	KBM403	0.2	20	76	
Comparative Example 8	Dispersion Solution P	15.4	Resin A	3	OXE02	0.06	KBM403	0.12	60	38	
Comparative Example 9	Dispersion Solution P	26.5	Resin A	1	OXE02	0.02	KBM403	0.04	80	20	
Comparative Example 10	Dispersion Solution P	50.1	Resin A	0.5	OXE02	0.01	KBM403	0.02	85	15	

Table 33

	Results					
	Mean Particle Diameter in Paste Composition (nm)	Refractive Index	Temperature Dependency of the Refractive Index (ppm/°C)	Coefficient of Linear Expansion (ppm/°C)	Developability	Optical Propagation Loss (dB/cm)
Comparative Example 1	35	Impossible to evaluate because of insufficient polymerization			Unclear pattern, Residue present in non-exposed area	
Comparative Example 2	34	Impossible to evaluate because of insufficient polymerization			Unclear pattern, Residue present in non-exposed area	
Comparative Example 3	52	1.557	74	67	Difficult to remove non-exposed area	1.0
Comparative Example 4	50	1.557	74	68	Difficult to remove non-exposed area	
Comparative Example 5	54	1.556	53	44	good	0.8
Comparative Example 6	55	1.552	58	53	good	0.9
Comparative Example 7	54	1.553	57	51	good	1.2
Comparative Example 8	56	1.562	46	38	good	1.5
Comparative Example 9	61	1.572	33	24	good	
Comparative Example 10	62	1.575	26	19	Residue present in non-exposed area, Cracking of core	2.3

What is claimed is:

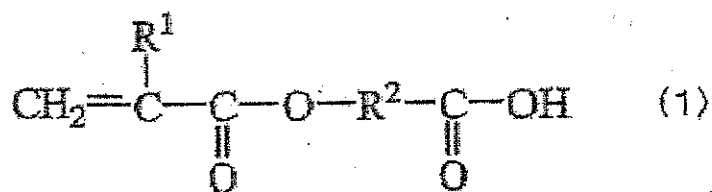
1. An optical waveguide-forming paste composition, comprising:

(A) barium sulfate particles with a mean particle diameter of 1 nm or more to 50 nm or less;

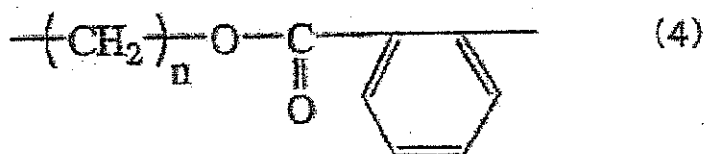
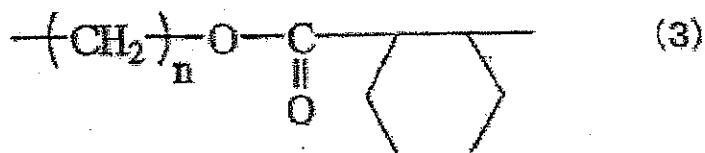
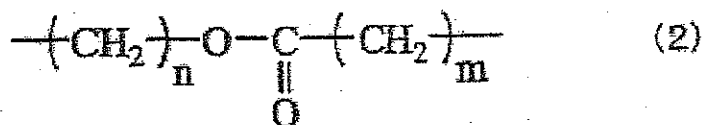
(B) a compound having a polymerizable group and a carboxyl group, or a phosphoric ester compound having a polymerizable group; and

(C) an organic solvent.

2. The optical waveguide-forming paste composition according to claim 1, wherein the compound having a polymerizable group and a carboxyl group comprises a compound represented by the formula (1):



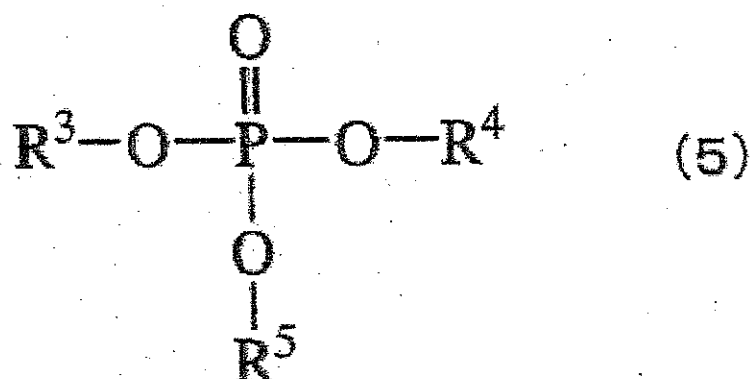
in the formula (1), R¹ represents a hydrogen atom or a methyl group, and R² represents a bivalent group represented by any one of the following formulae (2) to (4):



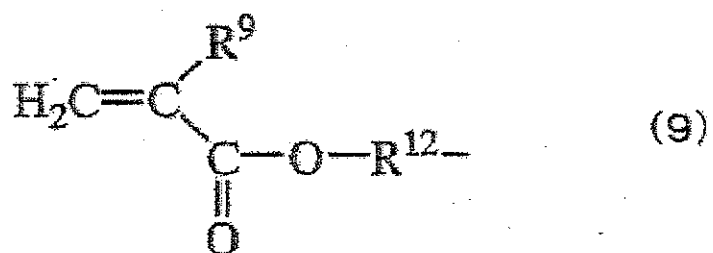
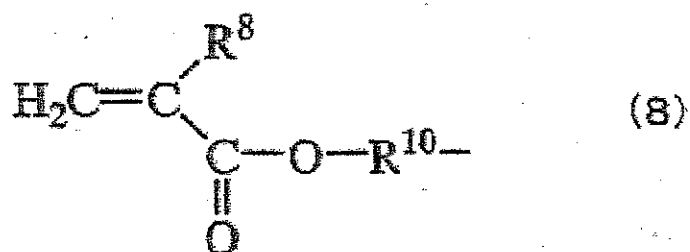
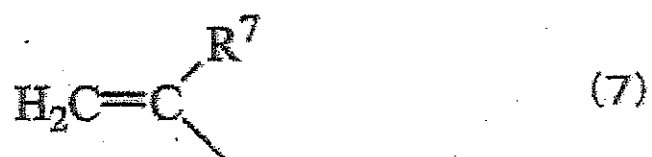
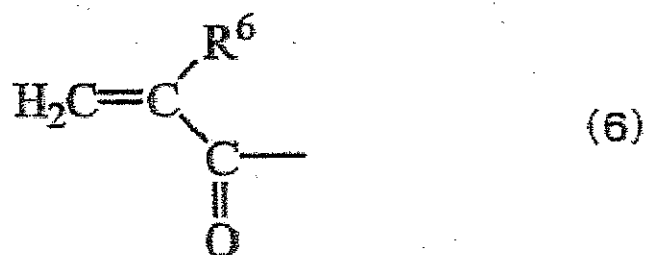
in the formulae (2) to (4), n and m each represent an integer of 1 to 3.

3. The optical waveguide-forming paste composition according to claim 2, wherein R^1 in the formula (1) is a hydrogen atom, R^2 is a bivalent group represented by the formula (4), and n is 2.

4. The optical waveguide-forming paste composition according to claim 1, wherein the phosphoric ester compound having a polymerizable group comprises a compound represented by the formula (5):



in the formula (5), R^3 to R^5 each represent a monovalent group represented by any one of the following formulae (6) to (10) or a hydrogen atom, and R^3 to R^5 may be the same or different, provided that not all of R^3 to R^5 are hydrogen atoms:



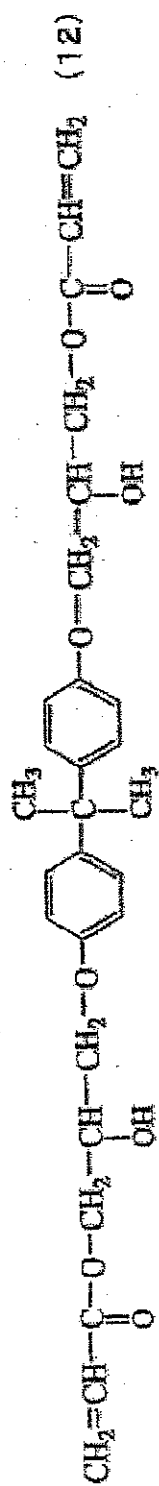
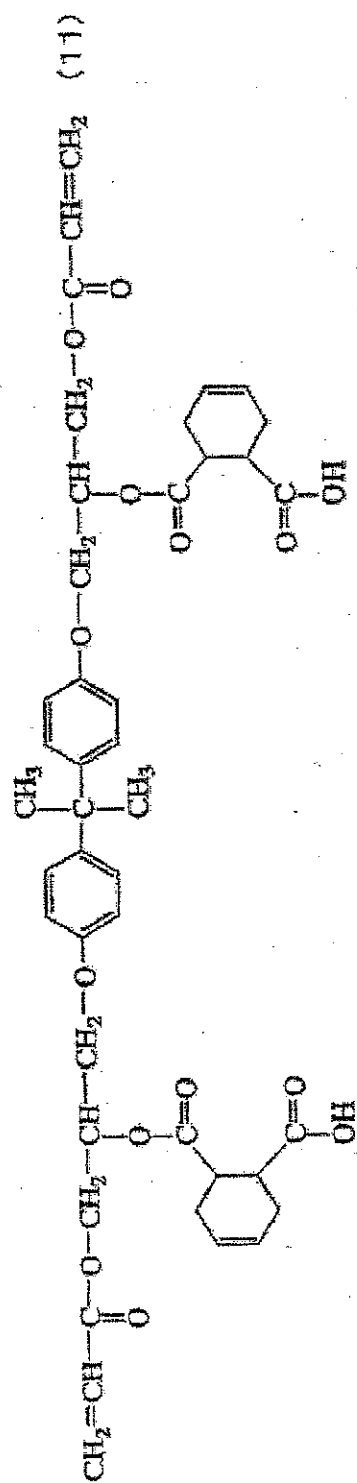
in the formulae (6) to (10) R^6 to R^9 each represent a hydrogen

atom or a methyl group. R^{10} and R^{11} each represent a bivalent group of 1 to 10 carbon atoms, and R^{12} represents a bivalent group of 1 to 10 carbon atoms having a hydroxyl group.

5. The optical waveguide-forming paste composition according to claim 4, wherein at least one of R^3 , R^4 and R^5 in the formula (5) is a monovalent group represented by the formula (8).

6. The optical waveguide-forming paste composition according to any one of claims 1 to 5, further comprising a resin having a polymerizable group.

7. The optical waveguide-forming paste composition according to claim 6, wherein the resin having a polymerizable group comprises a resin represented by the formula (11) or (12):



8. The optical waveguide-forming paste composition according to any one of claims 1 to 7, further comprising a silane coupling agent.

9. An optical waveguide, comprising a cured material produced by curing the optical waveguide-forming composition according to any one of claims 1 to 8.