DESCRIPTION

Title of Invention: PRODUCTION METHOD FOR JOINT STRUCTURE AND JOINING METHOD FOR JOINED BODIES

Technical Field

[0001]

The present invention relates to a method for producing a bonded structure formed by bonding two bonding target materials, and a method for bonding the bonding target materials.

Background Art

[0002]

In recent years, semiconductor devices known as power devices have come into widespread use as power conversion and control devices, such as inverters. Unlike integrated circuits such as memory and microprocessors, power devices are designed to control high currents, and therefore generate a large amount of heat during operation. Therefore, the solder used to mount power devices must be heat resistant. However, lead-free solder currently in use has the disadvantage of being less heat resistant than regular lead-containing solder.

[0003]

Instead of using solder, various technologies have been proposed that use pastes containing metal microparticles that limit the use of harmful chemicals, which are then applied to a target object using various coating methods and fired. For example, Patent Literature 1 proposes a method of manufacturing a power module, involving: applying, to an insulating substrate, a sinterable metal bonding material made by dispersing silver nanoparticles in an organic solvent; drying the bonding material; then placing a power semiconductor device thereon and temporarily fixing the same; and then sintering the bonding material.

Citation List

Patent Literature

[0004]

Patent Literature 1: JP 2019-186457 A

Summary of Invention

[0005]

With the technology described in Patent Literature 1, depending on such conditions as the drying conditions, temporary fixing conditions and sintering conditions, the bonding material may protrude beyond the periphery of the power semiconductor device, resulting in insufficient bonding strength or misalignment of the power semiconductor device. Therefore, an objective of the present invention is to provide a method for producing a bonded structure that can successfully bond together the bonding target materials without causing misalignment or detachment of the bonding target materials.

[0006]

An aspect of the present invention provides a method for producing a bonded structure in which a first bonding target material and a second bonding target material are bonded with a bonding layer interposed between the first bonding target material and the second bonding target material,

the method comprising:

a step of applying a bonding composition to the first bonding target material to form a wet coating film, the bonding composition containing copper powder and an organic substance that is liquid at 25°C;

a step of removing the organic substance from the wet coating film to obtain a dry coating film;

a step of temporarily fixing the second bonding target material to the dry coating film by applying pressure, to obtain a laminate in which the first bonding target material, the dry coating film, and the second bonding target material are layered in this order; and

a step of heating the laminate under pressure to sinter the copper powder in the dry coating film, and bonding the first bonding target material and the second bonding target material by the bonding layer formed by sintering,

wherein the organic substance contains a first organic substance, and

the first organic substance has a boiling point of 230°C or higher and lower than

300°C, and a viscosity of 100 mPa·s or higher at 25°C and at a shear rate of 10 s^{-1}.

[0007]

Another aspect of the present invention provides a method for bonding a first bonding target material and a second bonding target material with a bonding layer interposed between the first bonding target material and the second bonding target material,

the method comprising:

a step of applying a bonding composition to the first bonding target material to form a wet coating film, the bonding composition containing copper powder and an organic substance that is liquid at 25°C;

a step of removing the organic substance from the wet coating film to obtain a dry coating film;

a step of temporarily fixing the second bonding target material to the dry coating film by applying pressure, to obtain a laminate in which the first bonding target material, the dry coating film, and the second bonding target material are layered in this order; and

a step of heating the laminate under pressure to sinter the copper powder in the dry coating film, and bonding the first bonding target material and the second bonding target material by the bonding layer formed by sintering,

wherein the organic substance contains a first organic substance, and

the first organic substance has a boiling point of 230°C or higher and lower than 300°C, and a viscosity of 100 mPa·s or higher at 25°C and at a shear rate of 10 s^{-1}.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a flow diagram showing one embodiment of a method for producing a bonded structure of the present invention (a flow diagram up to production of a laminate).

[Fig. 2] Fig. 2 is a plan view showing a part of an outer edge of a dry coating film before and after placement of a second bonding target material.

Description of Embodiments

[0009]

The present invention will be described below according to preferred embodiments thereof. The present invention relates to a method for producing a bonded structure in which two bonding target materials, i.e., a first bonding target material and a second bonding target material, are bonded with a bonding layer interposed therebetween. This production method can be broadly divided into the following steps.

(1) A step of applying a bonding composition containing copper powder and an organic substance that is liquid at 25°C (hereinafter also referred to as “liquid organic substance”) to the first bonding target material to form a wet coating film (wet coating film forming step).

(2) A step of removing the liquid organic substance from the wet coating film to obtain a dry coating film (dry coating film forming step).

(3) A step of temporarily fixing the second bonding target material to the dry coating film by applying pressure to obtain a laminate in which the first bonding target material, the dry coating film, and the second bonding target material are layered in this order (laminate forming step).

(4) A step of heating the laminate under pressure to sinter the copper powder in the dry coating film, and bonding the first and second bonding target materials by a bonding layer formed by sintering (bonding step).

Each step will be described below with reference to Fig. 1. Fig. 1 is a flow diagram showing one embodiment of a method for producing a bonded structure of the present invention.

[0010]

(1) Wet Coating Film Forming Step:

First, as shown in Fig. 1(a), a first bonding target material 11 is prepared, and a bonding composition is applied to one surface 11a of the first bonding target material 11 to form a wet coating film 13a. The bonding composition contains copper powder and a liquid organic substance.

The method for applying the bonding composition is not particularly limited. The wet coating film 13a can be formed by, for example, a screen printing method, a gravure printing method, a dispense printing method, a reverse coating method, a doctor blade method, or the like.

[0011]

From the viewpoint of ensuring sufficient bonding strength, the average thickness of the wet coating film 13a is preferably 20 μm or more, more preferably 30 μm or more, and even more preferably 35 μm or more.

Furthermore, from the viewpoint of readily smoothing the coating film and preventing cracking of the coating film after drying, the average thickness of the wet coating film 13a is preferably 500 μm or less, more preferably 450 μm or less, and even more preferably 400 μm or less.

[0012]

The application area of the bonding composition may be such that the wet coating film 13a formed by application extends beyond the periphery of a second bonding target material 12 described later, or the two may be the same area, or the wet coating film 13a formed by application may be smaller in area than the periphery of the later-described second bonding target material 12.

In the embodiment illustrated in Fig. 1, the application area of the bonding composition is set so that the wet coating film 13a formed by application extends beyond the periphery of the second bonding target material 12. By setting the application area to such an extent, the first bonding target material 11 and the second bonding target material 12 can be bonded more reliably.

[0013]

(2) Dry Coating Film Forming Step:

Next, as shown in Fig. 1(b), the liquid organic substance is removed from the wet coating film 13a to obtain a dry coating film 13b. By removing the liquid organic substance from the wet coating film 13a, the shape retention of the dry coating film 13b is improved.

[0014]

In the step shown in Fig. 1(b), from the viewpoint of temporarily fixing the later-described second bonding target material 12 to the dry coating film 13b successfully, it is preferable to remove the liquid organic substance so that the average thickness of the dry coating film 13b is 20 μm or more, more preferably 25 μm or more, and even more

preferably 30 μm or more.

On the other hand, from the viewpoint of making it easier to obtain a smooth coating film and preventing cracking of the coating film after drying, it is preferable to remove the liquid organic substance in the drying step so that the average thickness of the dry coating film 13b is 400 μm or less, more preferably 350 μm or less, and even more preferably 300 μm or less.

[0015]

If an excessive amount of liquid organic substance remains in the dry coating film 13b, the dry coating film 13b may become soft, reducing the temporary fixing strength of the second bonding target material 12 to the dry coating film 13b or reducing the bonding strength between the first bonding target material 11 and the second bonding target material 12 after sintering. Furthermore, when the first bonding target material 11 and the second bonding target material 12 are bonded, the dry coating film 13b may protrude outside the first bonding target material 11 and the second bonding target material 12 in a plan view. To effectively suppress these problems, in the step shown in Fig. 1(b), it is preferable to sufficiently increase the amount of volatilization of the liquid organic substance contained in the wet coating film 13a to reduce the amount of liquid organic substance remaining in the dry coating film 13b. In this step, it is preferable to remove the liquid organic substance from the wet coating film 13a to such an extent that the dry coating film 13b has no fluidity. The presence/absence of fluidity in the dry coating film 13b is determined as follows. For example, when the dry coating film 13b has a rectangular or approximately rectangular shape of x [mm] × y [mm] (x and y are numbers satisfying $x \geq y$) in a plan view, a second bonding target material 12 having a size of 5x/6 [mm] × 5y/6 [mm] in a plan view is placed on the dry coating film 13b at 25°C. If an excessive amount of liquid organic substance remains in the dry coating film 13b and the dry coating film 13b has fluidity, placing the second bonding target material 12 under the above conditions will cause the dry coating film 13b to deform and shift from its original position (the position before placing the second bonding target material 12). Therefore, if the dry coating film 13b is shifted by x/5 [mm] or more from its original position after placing the second bonding target material 12, it is determined that the dry coating film 13b has fluidity, and if it is shifted by less than x/5 [mm], it is determined that the dry coating film 13b has no fluidity.

The deviation of the dry coating film 13b after placing the second bonding target

material 12 is defined as follows. That is, as shown in Fig. 2, the outer edge of the dry coating film 13b before placing the second bonding target material 12 is defined as C1, and the normal to C1 at an arbitrary point P on C1 is defined as L. The intersection of the normal L and the outer edge C2 of the dry coating film 13b after placing the second bonding target material 12 is defined as Q. Note, however, that if there are multiple intersections between the normal L and the outer edge C2, the intersection having the shortest distance from point P among the intersections is defined as Q. Then, point P on C1 is selected so that the distance PQ between point P and point Q becomes the greatest, and that distance PQ is defined as the deviation of the dry coating film 13b.

[0016]

It is, however, preferable that a trace amount of liquid organic substance remains in the dry coating film 13b, from the viewpoint of increasing the temporary fixing strength of the second bonding target material 12 to the dry coating film 13b, and from the viewpoint of increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 in the intended bonded structure.

[0017]

From the viewpoint of sufficiently removing the liquid organic substance contained in the wet coating film 13a, in the step shown in Fig. 1(b), it is preferable to dry the wet coating film 13a so that the mass of the wet coating film 13a is reduced by 15 mass% or more, more preferably 16 mass% or more, even more preferably 17 mass% or more, and particularly preferably 18 mass% or more.

On the other hand, from the viewpoint of increasing the temporary fixing strength of the second bonding target material 12 to the dry coating film 13b, and from the viewpoint of increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 in the intended bonded structure, in the dry coating film forming step, it is preferable to remove the liquid organic substance from the wet coating film 13a by drying the wet film so that the mass of the wet coating film 13a is reduced by 30 mass% or less, more preferably by 29 mass% or less, and even more preferably by 28 mass% or less.

A method for measuring the rate of mass loss of the wet coating film 13a will be explained in the examples below.

[0018]

From the viewpoint of increasing the temporary fixing strength of the second bonding target material 12 to the dry coating film 13b, and from the viewpoint of increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 after sintering, it is preferable to remove the liquid organic substance from the wet coating film 13a so that the content of the liquid organic substance in the dry coating film 13b becomes 25 parts by mass or less, more preferably 24 parts by mass or less, and even more preferably 23 parts by mass or less, when the content of the liquid organic substance in the wet coating film 13a is 100 parts by mass.

As mentioned above, it is preferable that a trace amount of liquid organic substance remains in the dry coating film 13b. Therefore, when the content of the liquid organic substance in the wet coating film 13a is taken as 100 parts by mass, it is preferable to remove the liquid organic substance from the wet coating film 13a so that the content of the liquid organic substance in the dry coating film 13b is 5 parts by mass or more, more preferably 6 parts by mass or more, and even more preferably 7 parts by mass or more.

[0019]

From the viewpoint of sufficiently reducing the liquid organic substance remaining in the dry coating film 13b, in this step, it is preferable to heat the wet coating film 13a to 100°C or higher, more preferably to 105°C or higher, and even more preferably to 110°C or higher.

Furthermore, from the viewpoint of keeping the amount of remaining liquid organic substance in the dry coating film 13b within the above-mentioned range, in this step, it is preferable to heat the wet coating film 13a to 200°C or lower, more preferably to 190°C or lower, even more preferably to 180°C or lower, and particularly preferably to 160°C or lower.

From a similar viewpoint, when the drying step is carried out under atmospheric pressure, the heating time of the wet coating film 13a is preferably 10 minutes or more, more preferably 15 minutes or more, even more preferably 20 minutes or more, and preferably 60 minutes or less, more preferably 50 minutes or less, even more preferably 40 minutes or less.

[0020]

The formation of the dry coating film 13b by heating the wet coating film 13a can be carried out in an atmosphere of an inert gas such as nitrogen gas or argon gas, or in the air. Heating may also be carried out under reduced pressure.

There are no particular limitations on the heating means, and for example, it is possible to employ a heating means such as blowing hot air, irradiating with infrared rays, or heating in a heating furnace.

[0021]

(3) Laminate Forming Step:

Once the dry coating film 13b has been formed, the second bonding target material 12 is then placed on the dry coating film 13b as shown in Fig. 1(c). The second bonding target material 12 is preferably placed on the dry coating film 13b so that the dry coating film 13b extends beyond the periphery of the second bonding target material 12. However, the second bonding target material 12 may be placed so that the periphery of the second bonding target material 12 coincides with the periphery of the dry coating film 13b, or the second bonding target material 12 may be placed so that the second bonding target material 12 extends beyond the periphery of the dry coating film 13b.

[0022]

In this embodiment, a temporary fixing agent may or may not be applied between the dry coating film 13b and the second bonding target material 12 prior to placing the second bonding target material 12 on the dry coating film 13b. As described below, the bonding composition used to manufacture the dry coating film 13b contains a trace amount of a highly viscous first organic substance, so the second bonding target material 12 can be temporarily fixed to the dry coating film 13b without using a temporary fixing agent. As such, the production method of this embodiment makes it possible to omit the step of applying a temporary fixing agent, thereby simplifying the production steps and shortening the production time. Note that while the present invention does not require the use of a temporary fixing agent, the use of a temporary fixing agent is not precluded. Examples of temporary fixing agents may include monoalcohols, polyhydric alcohols, polyhydric alcohol alkyl ethers, polyhydric alcohol aryl ethers, esters, heterocyclic compounds, amides, amines, saturated hydrocarbons, cyclic terpene alcohols and their derivatives, ketones, and carboxylic acids.

[0023]

At least a portion of the highly viscous first organic substance (described in detail below) contained in the bonding composition remains in the dry coating film 13b. Therefore, by applying pressure to the second bonding target material 12 placed on the dry coating film 13b (i.e., by pressing the second bonding target material 12 into the dry coating film 13b), the second bonding target material 12 can be temporarily fixed to the dry coating film 13b. This results in a laminate 14 that is composed, in order, of the first bonding target material 11, the dry coating film 13b, and the second bonding target material 12. The second bonding target material 12 can be directly pressed into the dry coating film 13b using a jig (not shown) used when placing the second bonding target material 12.

In this specification, “temporary fixation” refers to a state in which the first bonding target material 11 and the second bonding target material 12 are temporarily fixed together, and refers to a state in which, although the fixed state may change when a large external force is applied, the fixed state does not change when applying a small external force (for example, a force that would cause either the first bonding target material 11 or the second bonding target material 12 to fall under its own weight when a laminate of the first bonding target material 11 and the second bonding target material 12 is placed in a manner that the bonding surfaces of both bonding target materials 11 and 12 are facing vertically).

[0024]

The pressure when the second bonding target material 12 is pressed into the dry coating film 13b is preferably 0.1 MPa or more, more preferably 0.2 MPa or more, and even more preferably 0.3 MPa or more, from the viewpoint of temporarily fixing the second bonding target material 12 appropriately by the dry coating film 13b and from the viewpoint of sufficiently increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 in the subsequent bonding step. Furthermore, the pressure when the second bonding target material 12 is pressed into the dry coating film 13b is preferably 5 MPa or less, more preferably 4.5 MPa or less, and even more preferably 4.0 MPa or less.

[0025]

The time for which the pressure is maintained after the target pressure is reached

is preferably 0.01 seconds or more, and more preferably 0.1 seconds or more, from the viewpoint of temporarily fixing the second bonding target material 12 appropriately by the dry coating film 13b and from the viewpoint of sufficiently increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 in the subsequent bonding step.

Furthermore, the time for which the pressure is maintained after the target pressure is reached is not particularly limited as long as it does not significantly reduce productivity, and can be, for example, 5 seconds or less.

[0026]

During the temporary fixation, the second bonding target material 12 and/or the dry coating film 13b may be at room temperature or may be heated. From the viewpoint of temporarily fixing the second bonding target material 12 appropriately by the dry coating film 13b, it is preferable to heat the second bonding target material 12 and/or the dry coating film 13b when pressing the second bonding target material 12 into the dry coating film 13b. In other words, it is preferable to temporarily fix the second bonding target material 12 to the dry coating film 13b by applying pressure and heat.

Specifically, the heating temperature of the second bonding target material 12 is preferably 15°C or higher, more preferably 18°C or higher, even more preferably 20°C or higher, and preferably 300°C or lower, more preferably 270°C or lower, even more preferably 250°C or lower.

The heating temperature of the dry coating film 13b is preferably 15°C or higher, more preferably 18°C or higher, even more preferably 20°C or higher, and preferably 230°C or lower, more preferably 220°C or lower, even more preferably 210°C or lower.

By setting the heating temperature within the above range, it is possible to temporarily fix the second bonding target material 12 appropriately while suppressing an excessive decrease in the amount of liquid organic substance remaining in the dry coating film 13b.

[0027]

When the second bonding target material 12 is temporarily fixed by applying pressure while heating the second bonding target material 12 and/or the dry coating film 13b, it is not necessary to sinter the copper powder in the dry coating film 13b by this heating and pressurizing treatment. The reason for this is that, as will be described later,

the dry coating film 13b contains a trace amount of a highly viscous first organic substance (described in detail later), and therefore the temporary fixing strength of the second bonding target material 12 can be sufficiently increased without sintering the copper powder. In this way, by performing the laminate forming step under conditions that do not sinter the copper powder in the dry coating film 13b, the sintering of the copper powder can be sufficiently promoted in the subsequent bonding step, thereby further increasing the bonding strength and bonding reliability of the resulting bonded structure.

The conditions under which the copper powder does not sinter include, for example, conditions where the heating temperature of the second bonding target material 12 and the dry coating film 13b is 250°C or lower and the heating time is less than 50 seconds.

[0028]

Once the second bonding target material 12 is temporarily fixed, the position of the second bonding target material 12 relative to the first bonding target material 11 is less likely to shift even if an external force is applied to the laminate 14. Therefore, when the laminate 14 is transported to a firing furnace for the next step, such as the bonding step described below, it is possible to maintain a stable positional relationship between the first bonding target material 11 and the second bonding target material 12.

[0029]

(4) Bonding Step:

The laminate 14 formed by temporarily fixing the second bonding target material 12 by the dry coating film 13b is then subjected to a bonding step. In the bonding step, the laminate 14 is heated under pressure to sinter the copper powder in the dry coating film 13b, and the first bonding target material 11 and the second bonding target material 12 are bonded together by a bonding layer formed by the sintering.

Since the bonding step is performed at a different location from the above-described laminate forming step, the laminate 14 is moved to a heating device. While external forces such as vibrations may be applied to the laminate 14 during the movement, the second bonding target material 12 is temporarily fixed appropriately to the dry coating film 13b by the above-described laminate forming step, so that displacement and detachment of the second bonding target material 12 are suppressed. Note that if the

above-described heating device also serves as a device on which the second bonding target material 12 is placed, the laminate 14 may be heated in place without being moved.

[0030]

The heating temperature in the bonding step is preferably 180°C or higher, more preferably 200°C or higher, and preferably 450°C or lower, more preferably 400°C or lower, from the viewpoint of reliably sintering the copper particles in the dry coating film 13b and reliably increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12.

From a similar viewpoint, the heating time in the bonding step is preferably 1 minute or more, more preferably 2 minutes or more, and preferably 30 minutes or less, more preferably 25 minutes or less.

[0031]

From the viewpoint of appropriately fixing the second bonding target material 12 by the dry coating film 13b, the pressure applied in the bonding step is preferably 1 MPa or more, more preferably 2 MPa or more, even more preferably 3 MPa, and preferably 35 MPa or less, more preferably 32 MPa or less, even more preferably 30 MPa or less.

The atmosphere used in the bonding step may be, for example, an air atmosphere, an inert gas atmosphere, or a reducing atmosphere, among which an inert gas atmosphere or a reducing atmosphere is preferred.

[0032]

In the bonding step, it is preferable to sinter the copper powder so that the bonding strength between the first bonding target material 11 and the second bonding target material 12 is 32 MPa or more by appropriately selecting the firing conditions such as temperature, time, and pressure when sintering the copper powder. Moreover, the bonding strength between the first bonding target material 11 and the second bonding target material 12 is more preferably 35 MPa or more, and further preferably 40 MPa or more.

A method for measuring the bonding strength between the first bonding target material 11 and the second bonding target material 12 will be explained in the examples below.

[0033]

In the bonded structure obtained by the sintering step, it is preferable that the void fraction of the bonding layer bonding the first bonding target material 11 and the second bonding target material 12 is low. Specifically, the void fraction of the bonding layer is preferably 30% or less, more preferably 20% or less, and even more preferably 15% or less. The void fraction of the bonding layer is the ratio of the volume of voids in the bonding layer (i.e., space not occupied by the constituent material of the bonding layer) to the apparent volume of the bonding layer. For convenience, in measuring the void fraction, instead of the volume ratio, the occupied area ratio of voids on one surface of the bonding layer may be calculated and considered as the void fraction.

The void fraction of the bonding layer can be measured, for example, as follows. First, a 50 MHz probe is used in an ultrasonic imaging device (FineSAT FS300 III from Hitachi High-Tech Corporation) to analyze the bonding interface between the second bonding target material and the sintered copper powder body using the reflection method along the horizontal direction with a pitch of 30 μm in both the lateral and longitudinal directions, obtaining an ultrasonic flaw detection image (SAT image). When observing the delamination state of the bonding layer, the gain is set to 25 to 35 dB, and the delay and width of the S gate are adjusted so that the S gate peak position is on the surface of the first bonding target material. The F gate delay is adjusted to specify the observation range of the bonding layer, and the width is set to an appropriate peak width. The Z-axis coordinate of the probe is adjusted to maximize the amplitude of the observed peak, and observation is performed. The contrast of the observed image is adjusted using the automatic function. The bonded region of the second bonding target material in the obtained SAT image is binarized using image processing software (Image J), and the proportion of the black area (bonding rate; %) within the observed area is calculated. That is, after launching Image-J, select Analyze-Set measurement and check Area, Area fraction, and Limit to Threshold. Then, select File-Open, open the image data for which the bonding rate is to be calculated, and specify the range (A) of the second bonding target material in the image. Next, select Edit-Copy to system, copy the specified range (A), and then select File-New-System clipboard to paste the image of the specified range (A). Then, to clarify the bonded portion, select Image-Type-8bit, convert the image, and then select Image-Adjust-Threshold to adjust the image threshold to 100. Then, a black range (B) existing within the range (A) of the second bonding target material mounting portion in the adjusted image is designated. The black range (B) is a range where the

threshold value is 100 or less, and can be regarded as the bonded portion of the second bonding target material. The bonding rate (%) is calculated by dividing the area of (B) by the area of (A) and multiplying by 100. The void rate (%) can be calculated by subtracting the bonding rate (%) from 100.

[0034]

It is more preferable that any two among the temperature, pressure, and time when the copper powder is sintered in the bonding step are higher or longer than any two among the temperature, pressure, and time when the second bonding target material 12 is temporarily fixed to the dry coating film 13b in the laminate forming step. It is further preferable that all of the temperature, pressure, and time when the copper powder is sintered in the bonding step are higher and longer than the temperature, pressure, and time when the second bonding target material 12 is temporarily fixed to the dry coating film 13b in the laminate forming step.

By carrying out the laminate forming step and the bonding step under such conditions, the thermal energy required for temporary fixation can be reduced, and good bonding strength can be obtained during bonding under heat and pressure.

[0035]

By employing this fixing method, the intended bonded structure (not shown) can be obtained. In this bonded structure, the first bonding target material 11 and the second bonding target material 12 are in a state bonded via a bonding layer made of a sintered body of copper particles.

[0036]

Next, the bonding composition used in the above-mentioned bonding method through temporary fixation, as well as the first bonding target material 11 and second bonding target material 12, will be described.

[0037]

The bonding composition used in the present invention contains copper powder and a liquid organic substance, as described above. The bonding composition may further contain various adjusting agents.

[0038]

The shape of the copper particles constituting the copper powder contained in the bonding composition is not particularly limited, and either spherical or non-spherical particles may be used.

The expression “copper particles are spherical” means that they have a circularity coefficient of 0.85 or more. The circularity coefficient is calculated by taking a scanning electron microscope image of the copper particles and using the formula $4\pi S/L^2$, where S is the area of the two-dimensional projection image of the primary particle and L is the perimeter.

The expression “copper particles are non-spherical” means that the circularity coefficient is less than 0.85.

[0039]

Specific examples of non-spherical shapes include flat shapes, polyhedral shapes such as hexahedrons and octahedrons, spindle shapes, irregular shapes, etc. A flat shape refers to a shape having a pair of plate surfaces forming the main surfaces of the particle and side surfaces that intersect with these plate surfaces. The plate surfaces and side surfaces can each independently be flat, curved, or uneven.

[0040]

The copper powder may contain copper particles of two or more different shapes. In particular, it is preferable for the copper powder to contain flat copper particles and spherical copper particles, from the viewpoint of obtaining a bonded structure with high bonding strength. It may also contain copper particles of similar shape but different particle sizes, or multiple copper particles of different shapes and particle sizes.

[0041]

When the copper particles are spherical, the particle size is determined by the following method. That is, 50 or more primary copper particles with clear outlines are selected using an image observed under a scanning electron microscope at a magnification within the range from 10,000 to 150,000 times, and the Heywood diameter of each particle is measured. Next, the volume of the particle is calculated from the obtained Heywood diameter, assuming that the particle is a perfect sphere, and the

volume-cumulative particle size at 50 vol% of the cumulative volume is taken as the particle size of the copper particles.

[0042]

When the copper particles making up the copper powder are spherical, it is preferable that their particle size is greater than 0.10 μm, more preferably 0.11 μm or greater, and even more preferably 0.12 μm or greater. On the other hand, the particle size of the copper particles is preferably 0.55 μm or less, and even more preferably 0.5 μm or less. When the copper particles have a particle size exceeding 0.1 μm, shrinkage cracks are less likely to occur when the dry coating film 13b is fired to form a sintered body (bonding layer). On the other hand, setting the particle size of the copper particles to 0.55 μm or less ensures sufficient sintering of the copper particles present in the dry coating film 13b.

[0043]

When the copper particles are flat, the particle size is determined using the following method. That is, images of the copper particles with clear outlines are obtained using a scanning electron microscope at a magnification within the range from 500 to 50,000 times, and the images are then analyzed. Specifically, the flat copper particle is rotated 360 degrees in a direction horizontal to its plate surface, and a virtual circumscribing rectangle is drawn for each two-dimensional projection image. The direction in which the circumscribing rectangle exhibits the maximum side length is regarded as the major axis of the particle. At least 50 particles are randomly selected, and the major axes are measured. The arithmetic average of these values is calculated and used as the particle size. For image analysis, for example, Mountec’s Mac-View, an image analysis particle size distribution software, is used.

[0044]

When the copper particles are flat, the particle size is preferably 0.3 μm or greater, more preferably 0.5 μm or greater, even more preferably 1 μm or greater, and preferably 50 μm or less, more preferably 40 μm or less, and even more preferably 20 μm or less. By having a particle size within this range, when combined with spherical copper particles, cracking of the sintered body due to excessive volumetric shrinkage of the dry

coating film 13b is prevented, while the dry coating film 13b has excellent sinterability.

[0045]

The copper powder content in the bonding composition is preferably 50 mass% or more, more preferably 60 mass% or more, and preferably 95 mass% or less, more preferably 90 mass% or less, from the viewpoint of increasing the packability of the copper powder and achieving sufficient bonding strength.

[0046]

The copper particles may or may not be surface-treated. Using surface-treated copper particles can suppress excessive aggregation of the copper particles.

[0047]

The bonding composition contains a liquid organic substance. The content of the liquid organic substance in the bonding composition is preferably 10 mass% or more, more preferably 11 mass% or more, even more preferably 12 mass% or more, and preferably 30 mass% or less, more preferably 29 mass% or less, even more preferably 28 mass% or less.

When the bonding composition contains 10 mass% or more of a liquid organic substance, it is possible to achieve both good dispersibility and printability.

Furthermore, when the bonding composition contains 30 mass% or less of a liquid organic substance, the bonding strength of the bonded body obtained after the bonding step can be further increased.

[0048]

The liquid organic substance contained in the bonding composition includes an organic substance (hereinafter also referred to as “first organic substance”) having a boiling point of 230°C or higher and lower than 300°C and a viscosity of 100 mPa·s or higher at 25°C and at a shear rate of 10 s^{-1}. Because the first organic substance has the above-mentioned boiling point and viscosity, a trace amount thereof can remain stably even after the dry coating film forming step, thereby enabling temporary fixation of the second bonding target material 12 to the dry coating film 13b. From this viewpoint, the boiling point of the first organic substance is preferably 230°C or higher, more preferably

235°C or higher. Furthermore, from the viewpoint of improving the reliability of the bonding composition after bonding, it is preferably 290°C or lower, and even more preferably 280°C or lower.

[0049]

From the viewpoint of temporarily fixing the second bonding target material 12 to the dry coating film 13b successfully, the viscosity of the first organic substance at 25°C and at a shear rate of 10 s^{-1} is 100 mPa·s or higher, preferably 110 mPa·s or higher, more preferably 120 mPa·s or higher, and particularly preferably 140 mPa·s or higher. Furthermore, from the viewpoint of ease of handling during paste preparation, the viscosity of the first organic substance at 25°C and at a shear rate of 10 s^{-1} is preferably 5000 mPa·s or less, more preferably 4000 mPa·s or less, even more preferably 3000 mPa·s or less, even more preferably 2000 mPa·s or less, still more preferably 1000 mPa·s or less, and particularly preferably 500 mPa·s or less.

The viscosity of the first organic substance can be measured using a rheometer (for example, a MARS III rheometer manufactured by Thermo Scientific). The conditions for measuring the viscosity of the first organic substance are as follows.

Measurement mode: Shear rate dependency measurement
Sensor: Parallel type (Φ60 mm)
Measurement temperature: 25°C
Gap: 0.300 mm
Shear rate: 0.05 to 120.01 s^{-1}
Measurement time: 2 minutes

[0050]

From the viewpoint of promoting sintering of the copper powder during the bonding step, it is preferable that the first organic substance be a compound having a plurality of hydroxy groups.

[0051]

Examples of the first organic substance may include 2-ethyl-1,3-hexanediol (hereinafter also referred to as “octylene glycol”), 3-methyl-1,5-pentanediol,

2,4-diethyl-1,5-pentanediol, and 1,5-pentanediol.

[0052]

The bonding composition may contain an organic substance other than the first organic substance (hereinafter also referred to as “second organic substance”). There is no limitation on the type of the second organic substance. The second organic substance may have a boiling point of lower than 230°C, or 300°C or higher, or may have a melting point of 230°C or higher and lower than 300°C. Furthermore, the viscosity of the second organic substance at 25°C and at a shear rate of 10 s^{-1} may be less than 100 mPa·s or may be 100 mPa·s or higher.

[0053]

From the viewpoint of temporarily fixing the second bonding target material 12 by the dry coating film 13b appropriately and from the viewpoint of sufficiently increasing the bonding strength between the first bonding target material 11 and the second bonding target material 12 in the bonding step, the content of the first organic substance in the bonding composition is preferably 10 mass% or more, more preferably 11 mass% or more, even more preferably 12 mass% or more, and preferably 30 mass% or less, more preferably 29 mass% or less, even more preferably 28 mass% or less.

From a similar viewpoint, the bonding composition preferably contains 15 parts by mass or more, more preferably 16 parts by mass or more, and even more preferably 17 parts by mass or more of the first organic substance per 100 parts by mass of the copper powder. Also, the bonding composition preferably contains 45 parts by mass or less, more preferably 40 parts by mass or less, and even more preferably 35 parts by mass or less of the first organic substance per 100 parts by mass of the copper powder.

From the viewpoint of the printability, dispersibility, and temporary fixability of the bonding composition, the content of the second organic substance in the bonding composition is preferably 2 mass% or more, more preferably 3 mass% or more, even more preferably 4 mass% or more, and preferably 20 mass% or less, more preferably 18 mass% or less, even more preferably 17 mass% or less.

[0054]

From the viewpoint of improving the coatability or printability of the bonding

composition and of successfully performing temporary fixing, the content of organic substance in the bonding composition is preferably 9 mass% or more, more preferably 10 mass% or more, and even more preferably 11 mass% or more. Furthermore, the content of organic substance in the bonding composition is preferably 35 mass% or less, more preferably 33 mass% or less, and even more preferably 30 mass% or less.

[0055]

From the viewpoint of promoting sintering of the copper powder in the bonding step, the bonding composition preferably contains at least one type of reducing substance. The reducing substance may be the first organic substance, the second organic substance, or an inorganic substance.

Examples of the reducing substance may include monoalcohols, amino alcohols, polyhydric alcohols, citric acid, oxalic acid, formic acid, ascorbic acid, aldehydes, hydrazine and its derivatives, hydroxylamine and its derivatives, dithiothreitol, phosphite, hydrophosphite, phosphorous acid and its derivatives, etc. Among these, it is preferable that the bonding composition contains an amino alcohol and/or a polyhydric alcohol as the reducing substance.

As the amino alcohol contained in the bonding composition, from the viewpoint of increasing its reducing power, it is possible to use an amino alcohol having preferably two or more hydroxy groups, more preferably three or more, even more preferably four or more, and particularly preferably five or more hydroxy groups.

From the viewpoint of sufficiently promoting sintering of the copper powder in the bonding step and from the viewpoint of ensuring a sufficient content of components other than amino alcohol, when the bonding composition contains an amino alcohol, the content of the amino alcohol in the bonding composition is preferably 0.0001 mass% or more, more preferably 0.0002 mass% or more, and even more preferably 0.0003 mass% or more. Furthermore, the content of the amino alcohol in the bonding composition is preferably 5 mass% or less, more preferably 4 mass% or less, and even more preferably 3.5 mass% or less.

[0056]

Examples of polyhydric alcohols contained in the bonding composition may include glycerin, 1,2,6-hexanetriol, polytetramethylene glycol, polypropylene glycol, and polyethylene glycol. From the viewpoint of promoting sintering of the copper powder

during the bonding step, polyhydric alcohols contained in the bonding composition preferably have a number-average molecular weight of 20 or more, more preferably 50 or more, even more preferably 100 or more, and preferably 10,000 or less, more preferably 5,000 or less, and even more preferably 4,000 or less. When the bonding composition contains a polyhydric alcohol, from the viewpoint of sufficiently promoting sintering of the copper powder during the bonding step and ensuring a sufficient content of components other than the polyhydric alcohol, the content of the polyhydric alcohol in the bonding composition is preferably 0.1 mass% or more, more preferably 0.15 mass% or more, even more preferably 0.2 mass% or more, and preferably 10 mass% or less, more preferably 9 mass% or less, and even more preferably 8 mass% or less.

[0057]

From the viewpoint of temporarily fixing the second bonding target material 12 to the dry coating film 13b more reliably and from the viewpoint of promoting sintering of the copper powder during the bonding step, the bonding composition preferably contains the first organic substance and one or two or more reducing substances different from the first organic substance, more preferably contains the first organic substance and an amino alcohol or polyethylene glycol, even more preferably contains the first organic substance and polyethylene glycol, and particularly preferably contains the first organic substance, polyethylene glycol, and an amino alcohol.

[0058]

The bonding composition may contain components other than those described above, such as a viscosity adjuster and a surface tension adjuster.

The viscosity adjuster is preferably one that can adjust the viscosity of the bonding composition, preferably within the viscosity range described below, and examples thereof may include ketones, esters, alcohols, glycols, hydrocarbons, and polymers.

The surface tension adjuster is preferably one that can adjust the surface tension of the wet coating film 13a, and examples thereof may include acrylic surfactants, silicone surfactants, alkyl polyoxyethylene ethers, polymers such as fatty acid glycerol esters, and monomers such as alcohols, hydrocarbons, esters, and glycols.

[0059]

From the viewpoint of improving the coatability or printability of the bonding composition, the viscosity of the bonding composition is preferably 5 Pa·s or higher, more preferably 7 Pa·s or higher, and preferably 100 Pa·s or less, more preferably 80 Pa·s or less, under conditions of 25°C and a shear rate of 10 s^{-1}.

The viscosity of the bonding composition can be measured by the same method as the method for measuring the viscosity of the first organic substance described above.

[0060]

There are no particular restrictions on the type of the first bonding target material 11 and the second bonding target material 12. In general, it is preferable that both the first bonding target material 11 and the second bonding target material 12 contain a metal on the surfaces to be bonded. For example, at least one of the first bonding target material 11 and the second bonding target material 12 can be a member having a surface made of metal. A “metal” refers to a metal itself that does not form a compound with other elements, or an alloy of two or more metals. Examples of such metals may include copper, silver, gold, aluminum, palladium, or nickel, or an alloy made of a combination of two or more of these.

[0061]

If at least one of the first bonding target material 11 and the second bonding target material 12 is a member having a surface made of metal, it is generally preferable that the surface made of metal be flat, but in some cases it may be curved.

[0062]

Specific examples of the first bonding target material 11 and the second bonding target material 12 may each independently include, for example, a spacer or heat sink made of the above-mentioned metal, a semiconductor device, and a substrate having at least one of the above-mentioned metals on its surface.

The substrate may be, for example, an insulating substrate having a metal layer, such as copper, on the surface of a ceramic or aluminum nitride plate.

When a semiconductor device is used as the first bonding target material 11 and/or the second bonding target material 12, the semiconductor device contains one or

more elements such as Si, Ga, Ge, C, N, and As.

[0063]

The first bonding target material 11 is preferably a substrate. The second bonding target material 12 is preferably a spacer, a heat sink, or a semiconductor device.

[0064]

A dried body of a bonding composition containing metal fine particles and an organic substance can also be used as at least one of the first bonding target material 11 and the second bonding target material 12. Specifically, a member having a metal surface can be used as the first bonding target material 11, and a dried body of a bonding composition containing metal fine particles and an organic substance can be used as the second bonding target material 12. When using a dried body of a bonding composition, it is preferable to coat the bonding composition on a support substrate made of a metal, such as copper, and dry it to produce a dried body.

[0065]

The bonded structures obtained using this production method are suitable for use in devices that handle large currents, such as automotive electronic circuits and electronic circuits equipped with power devices.

[0066]

Although the production method of the present invention has been described above based on preferred embodiments, the present invention is not limited to the above embodiments.

For example, when the wet coating film contains an organic substance that is solid at 25°C, during the dry coating film forming step, some or all of the organic substance that is solid at 25°C may be removed from the wet coating film, in addition to the liquid organic substance.

[0067]

The above-described embodiments of the present invention encompass the following technical ideas.

[1] A method for producing a bonded structure in which a first bonding target material and a second bonding target material are bonded with a bonding layer interposed between the first bonding target material and the second bonding target material,

the method comprising:

a step of applying a bonding composition to the first bonding target material to form a wet coating film, the bonding composition containing copper powder and an organic substance that is liquid at 25°C;

a step of removing the organic substance from the wet coating film to obtain a dry coating film;

a step of temporarily fixing the second bonding target material to the dry coating film by applying pressure, to obtain a laminate in which the first bonding target material, the dry coating film, and the second bonding target material are layered in this order; and

a step of heating the laminate under pressure to sinter the copper powder in the dry coating film, and bonding the first bonding target material and the second bonding target material by the bonding layer formed by sintering,

wherein the organic substance contains a first organic substance, and

the first organic substance has a boiling point of 230°C or higher and lower than 300°C, and a viscosity of 100 mPa·s or higher at 25°C and at a shear rate of 10 s^{-1}.

[2] The method for producing a bonded structure as set forth in clause [1], wherein any two among the temperature, pressure, and time when the copper powder is sintered are higher or longer than any two among the temperature, pressure, and time when the second bonding target material is temporarily fixed to the dry coating film.

[3] The method for producing a bonded structure as set forth in clause [1] or [2], wherein the organic substance is removed from the wet coating film to obtain the dry coating film having no fluidity.

[4] The method for producing a bonded structure as set forth in clause [3], wherein the organic substance is removed from the wet coating film so that a mass of the wet coating film is reduced by from 15 to 30 mass%.

[5] The method for producing a bonded structure as set forth in any one of clauses [1] to [4], wherein, when a content of the organic substance in the wet coating film is 100 parts by mass, the organic substance is removed from the wet coating film so that a content of the organic substance in the dry coating film becomes 25 parts by mass or less.

[6] The method for producing a bonded structure as set forth in any one of clauses [1] to [5], wherein the wet coating film is heated in an air atmosphere or an inert gas atmosphere at a temperature of from 100°C to 200°C for 10 minutes or more, to remove the organic substance and obtain the dry coating film.

[7] The method for producing a bonded structure as set forth in any one of clauses [1] to [6], wherein the bonding composition contains at least one reducing substance.

[8] The method for producing a bonded structure as set forth in clause [7], wherein at least one of the substances is an amino alcohol compound.

[9] The method for producing a bonded structure as set forth in any one of clauses [1] to [8], wherein the bonding composition contains from 15 to 45 parts by mass of the first organic substance per 100 parts by mass of the copper powder.

[10] The method for producing a bonded structure as set forth in any one of clauses [1] to [9], wherein the second bonding target material is temporarily fixed to the dry coating film by applying pressure and heat.

[11] The method for producing a bonded structure as set forth in any one of clauses [1] to [10], wherein at least one type of the first organic substance is a compound having a plurality of hydroxy groups.

[12] The method for producing a bonded structure as set forth in any one of clauses [1] to [11], wherein the laminate is obtained by temporarily fixing the second bonding target material to the dry coating film under a condition where the copper powder in the dry coating film does not sinter.

[13] The method for producing a bonded structure as set forth in any one of clauses [1] to [12], wherein the copper powder is sintered so that a bonding strength between the first bonding target material and the second bonding target material in the bonded structure is 30 MPa or more.

[14] A method for bonding a first bonding target material and a second bonding target material with a bonding layer interposed between the first bonding target material and the second bonding target material,

the method comprising:

a step of applying a bonding composition to the first bonding target material to form a wet coating film, the bonding composition containing copper powder and an organic substance that is liquid at 25°C;

a step of removing the organic substance from the wet coating film to obtain a

dry coating film;

a step of temporarily fixing the second bonding target material to the dry coating film by applying pressure, to obtain a laminate in which the first bonding target material, the dry coating film, and the second bonding target material are layered in this order; and

a step of heating the laminate under pressure to sinter the copper powder in the dry coating film, and bonding the first bonding target material and the second bonding target material by the bonding layer formed by sintering,

wherein the organic substance contains a first organic substance, and

the first organic substance has a boiling point of 230°C or higher and lower than 300°C, and a viscosity of 100 mPa·s or higher at 25°C and at a shear rate of 10 s^{-1}.

Examples

[0068]

The present invention will be explained in more detail below using examples. However, the scope of the present invention is not limited to these examples. Unless otherwise specified, “%” means “% by mass.”

[0069]

[Examples 1 to 4 and Comparative Examples 1 and 2]

(1) Preparation of Bonding Composition:

The bonding composition was prepared by mixing organic substance(s) and copper powder composed of spherical copper particles with a particle size of 0.1 to 0.2 μm and flat copper particles with a particle size of 4.5 μm, according to the mass ratio shown in Table 2. Note that PEG-300 refers to polyethylene glycol with a number-average molecular weight of 300, and Bis-tris refers to bis(2-hydroxyethyl)iminotris(hydroxymethyl)methane (an amino alcohol having five hydroxy groups). Both PEG-300 and Bis-tris have reducing properties. Table 1 shows the boiling points of organic substances which are in a liquid state at 25°C, as well as their viscosities at 25°C and at a shear rate of 10 s^{-1}, among the organic substances used in each example and comparative example. Note that in Table 1, “-” indicates unknown.

As is clear from Table 1, octylene glycol and 3-methyl-1,5-pentanediol correspond to the first organic substance, and hexylene glycol, diethylene glycol and PEG-300 correspond to the second organic substance.

The Bis-tris used in each of the examples and comparative examples is solid at 25°C.

[0070]

(2) Application of Bonding Composition to First Bonding Target Material:

A substrate (20 mm × 20 mm, thickness 2 mm) formed by layering copper and ceramic in the thickness direction was used as the first bonding target material. The bonding composition was printed on the copper-side surface of the substrate using a metal mask (6 mm × 6 mm, thickness 100 μm) to form a rectangular wet coating film.

The wet coating film was dried at 120°C for 30 minutes under the atmosphere shown in Table 2, to remove the liquid organic substance, thereby obtaining a dry coating film. Table 2 shows the mass loss rate of the wet coating film due to the removal of the liquid organic substance. The same table also shows the content of the liquid organic substance in the dry film when the content of the liquid organic substance in the wet coating film is 100 parts by mass. The content of the liquid organic substance in the dry film was calculated on the assumption that when the liquid organic substance was removed from the wet coating film to form a dry coating film, no components other than the liquid organic substance were removed from the wet coating film. In all of the examples and comparative examples, the dry coating film had no fluidity.

[0071]

The mass loss rate of the wet coating film was measured by the following method.

The mass of the substrate formed by layering copper and ceramic was measured using an electronic balance, and then the mass of the substrate including the wet coating film after printing the bonding composition was measured using the electronic balance. The mass of the wet coating film formed by printing was determined by subtracting the mass of the substrate before printing from the mass of the substrate including the wet coating film. The substrate including the wet coating film was then dried for a predetermined period of time, and the mass of the substrate including the dry coating film was measured using the electronic balance. The mass of the wet coating film reduced by drying was determined by subtracting the mass of the substrate including the dry coating film from the mass of the substrate including the wet coating film. The mass loss rate (%) of the wet coating film was calculated by dividing the mass of the wet coating film

reduced by drying by the mass of the wet coating film formed by printing and multiplying the result by 100.

[0072]

(3) Placing Second Bonding Target Material on Dry Coating Film:

Assuming a model component of a semiconductor power device as the second bonding target material, an Ag-plated SiC chip (5 mm × 5 mm × 1.92 mm, weight: 0.016 g) was prepared. The Ag-plated surface of the SiC chip was placed on the central portion of the dry coating film using a chip mounter.

[0073]

(4) Formation of Laminate:

After heating the SiC chip to 170°C, a pressure of 2.4 MPa was applied for 0.4 seconds from the side opposite the Ag-plated surface of the SiC chip, to press the SiC chip into the dry coating film, thereby temporarily fixing the SiC chip to form a laminate.

[0074]

(5) Firing of Laminate:

The laminate was moved to a firing furnace, and the laminate was subjected to pressure of 25 MPa in a nitrogen atmosphere, and then heated to 300°C and held for 5 minutes, to fire the coating film into a bonding layer, thereby obtaining a bonded structure.

[0075]

[Evaluation 1]

In the examples and comparative examples, the laminates obtained in “(4) Formation of Laminate” were turned upside down in one second, and visually observed to determine whether or not the SiC chip had fallen off. The results are shown in Table 2.

[0076]

[Evaluation 2]

In Examples 1 and 2, where no SiC chip detachment was observed in “Evaluation 1”, shear strength was measured by the following method to confirm the

bonding strength of the bonded structure obtained in "(5) Firing of Laminate". Shear strength is a value defined as "breaking load/bottom area of SiC chip". The results are shown in Table 2. In Table 2, "-" indicates not measured.

•Name of measurement device: Condor Sigma (manufactured by XYZTEC B.V.)

•Load cell: 200 kgf

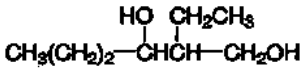
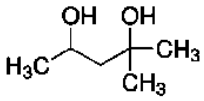
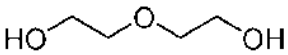
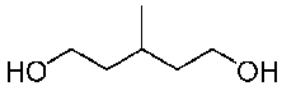
•Shear tool: Width: 6.0 mm; thickness: 2.0 mm; shaft: 1/4 inch (model number: T0S663060)

•Shear rate: 50 μm/s

•Shear height: 0.02 mm (the zero point was the top of the 6-mm-square printed coating film).

[0077]

[Table 1]

Organic substance in liquid state at 25°C	Structural formula	Boiling point (°C)	Viscosity (mPa·s)
Octylene glycol		244	170
Hexylene glycol		198	26
Diethylene glycol		244	27
3-Methyl-1,5-pentanediol		250	132
PEG-300	$H(OCH_2CH_2)_nOH$	-	50

[0078]

[Table 2]

		Example 1	Example 2	Example 3	Example 4	Comparative example 1	Comparative example 2
Copper powder	Spherical copper particles (mass%)	38.50	55.30	39.00	37.00	53.20	57.40
	Flat copper particles (mass%)	38.50	23.70	39.00	37.00	22.80	24.60
Organic substance	Octylene glycol (mass%)	21.46	15.14		26.00		
	Hexylene glycol (mass%)		1.83			18.94	16.36
	Diethylene glycol (mass%)					2.40	
	3-Methyl-1,5-pentanediol			20.44			
	PEG-300 (mass%)	1.46	3.95	1.48		0.76	1.558
	Bis-tris (mass%)	0.08	0.08	0.08		1.9	0.08
Content (parts by mass) of first organic substance per 100 parts by mass of copper powder in bonding composition		27.87	19.16	26.21	35.14	0	0
Atmosphere during drying of wet coating film		Nitrogen	Nitrogen	Nitrogen	Nitrogen	Nitrogen	Nitrogen
Mass loss rate of wet coating film (%)		20.7	15.3	20.7	23	20.8	14.7
Content (parts by mass) of liquid organic substance in dry coating film per 100 parts by mass of liquid organic substance in wet coating film		9.7	19.8	5.6	11.5	5.9	18
Whether or not second bonding target material fell off		No	No	No	No	Yes	Yes
Shear strength (MPa)		>40MPa	>40MPa	>40MPa	11MPa	-	-

[0079]

As is clear from Table 2, in Examples 1 to 4 which used octylene glycol or 3-methyl-1,5-pentanediol with a moderate viscosity, the first and second bonding target materials were successfully bonded together without the second bonding target material falling off, even though no temporary fixing agent was used. Furthermore, the bonding strength of the bonded structures manufactured in these examples was sufficiently high.

Industrial Applicability

[0080]

The present invention provides a bonded structure production method and a bonding method with which bonding target materials can be bonded together with a bonding material without causing displacement or detachment of the bonding target materials.