

DESCRIPTION

TITLE

MIXED SILVER POWDER, METHOD OF PRODUCING SAME, AND
METAL PASTE FOR BONDING

TECHNICAL FIELD

[0001] The present disclosure relates to a mixed silver powder, a method of producing the same, and a metal paste for bonding.

BACKGROUND

[0002] Solder is conventionally used as a bonding material for bonding members. However, due to the low melting point of solder, it has been difficult to use solder with power device elements formed of silicon carbide, gallium nitride, etc. that have a high operating temperature. Consequently, metal pastes that contain metal nanoparticles having high heat resistance are currently being used as bonding materials.

[0003] For example, Patent Literature (PTL) 1 discloses a metal paste for bonding that contains a metal nanoparticle powder of silver nanoparticles or the like having an aggregated particle diameter of 1 μm or more as a paste component. When two members are bonded using this metal paste for bonding, it is possible to obtain an assembly having high bonding strength.

CITATION LIST

Patent Literature

[0004] PTL 1: JP 2014-224296 A

SUMMARY

(Technical Problem)

[0005] In bonding using a metal paste for bonding, it is desirable for a metal bonding layer to have high thermal conductivity from a viewpoint of heat dissipation in the metal bonding layer.

[0006] Accordingly, an object of the present disclosure is to provide a mixed silver powder that can impart high thermal conductivity to a metal bonding layer, a method of producing this mixed silver powder, and a metal paste for bonding containing this mixed silver powder.

(Solution to Problem)

[0007] As a result of diligent and extensive research conducted to solve the problem described above, the inventors completed the present disclosure set forth below.

5 **[0008]** Specifically, primary configurations of the present disclosure for solving the problem described above are as follows.

[0009] [1] A mixed silver powder for which, in a particle size distribution with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis that is determined through wet measurement using a laser
10 diffraction particle size distribution measurement instrument,

the particle size distribution includes a first peak and a second peak that each have a volume distribution proportion of 1% or more,

a relationship between a particle diameter d_{M1} of the first peak and a particle diameter d_{M2} of the second peak satisfies formula (I) and formula (II),
15 shown below:

$$d_{M1} < d_{M2} \cdots (I)$$

$$4.5 \mu\text{m} \leq d_{M2} - d_{M1} \leq 16.0 \mu\text{m} \cdots (II)$$

and a relationship between a volume distribution proportion A of whichever of the first peak and the second peak has a smaller volume
20 distribution proportion and a volume distribution proportion B that is a minimum volume distribution proportion between the first peak and the second peak satisfies formula (III) or formula (IV), shown below:

$$1.2 \leq A/B \cdots (III)$$

$$0 = B/A \cdots (IV).$$

25 **[0010]** [2] The mixed silver powder according to [1], wherein more than 50% of the volume distribution proportion of the first peak originates from a spherical silver powder, and more than 50% of the volume distribution proportion of the second peak originates from a flake-like silver powder.

[0011] [3] The mixed silver powder according to [1] or [2], wherein

30 d_{M1} is not less than $0.5 \mu\text{m}$ and not more than $1.5 \mu\text{m}$, and

d_{M2} is not less than $5.0 \mu\text{m}$ and not more than $17.5 \mu\text{m}$.

[0012] [4] The mixed silver powder according to any one of [1] to [3], wherein a ratio of ignition loss relative to BET specific surface area of the mixed silver powder is 0.65 or less.

35 **[0013]** [5] The mixed silver powder according to any one of [1] to [4], wherein the mixed silver powder has a tap density of 3.5 g/cm^3 or more.

[0014] [6] A method of producing a mixed silver powder comprising a mixing step of mixing a first silver powder and a second silver powder, wherein, in particle size distributions with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis that are respectively determined
5 through wet measurement of the first silver powder and the second silver powder using a laser diffraction particle size distribution measurement instrument,

a relationship between a particle diameter d_{s1} of a peak where volume distribution proportion is at a maximum for the first silver powder and a
10 particle diameter d_{s2} of a peak where volume distribution proportion is at a maximum for the second silver powder satisfies formula (i) and formula (ii), shown below:

$$d_{s1} < d_{s2} \cdots (i)$$

$$4.6 \mu\text{m} \leq d_{s2} - d_{s1} \leq 16.0 \mu\text{m} \cdots (ii)$$

15 and a relationship between a 94th percentile diameter D_{94} of the first silver powder and a 6th percentile diameter D_6 of the second silver powder satisfies formula (iii), shown below:

$$D_{94} \leq D_6 \cdots (iii).$$

[0015] [7] The method of producing a mixed silver powder according to [6],
20 wherein the first silver powder is a spherical silver powder, and the second silver powder is a flake-like silver powder.

[0016] [8] The method of producing a mixed silver powder according to [7], wherein

the spherical silver powder has a 50th percentile diameter D_{50} of not
25 less than $0.5 \mu\text{m}$ and not more than $1.5 \mu\text{m}$, a tap density of 2.0 g/cm^3 or more, and a BET specific surface area of not less than $0.6 \text{ m}^2/\text{g}$ and not more than $2.2 \text{ m}^2/\text{g}$, and

the flake-like silver powder has a 50th percentile diameter D_{50} of not
less than $5.0 \mu\text{m}$ and not more than $17.5 \mu\text{m}$, a tap density of 2.0 g/cm^3 or more,
30 a BET specific surface area of not less than $0.2 \text{ m}^2/\text{g}$ and not more than $2.0 \text{ m}^2/\text{g}$, and an aspect ratio of 3 or more.

[0017] [9] A metal paste for bonding comprising the mixed silver powder according to any one of [1] to [5].

(Advantageous Effect)

35 **[0018]** According to the present disclosure, it is possible to provide a mixed silver powder that can impart high thermal conductivity to a metal bonding

layer, a method of producing this mixed silver powder, and a metal paste for bonding containing this mixed silver powder.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0019]** In the accompanying drawings:

FIG. 1 is a schematic view for describing an evaluation method of shear strength in examples;

FIG. 2 is a graph illustrating a particle size distribution of a silver powder according to Example 1;

10 FIG. 3 is a graph illustrating a particle size distribution of a silver powder according to Example 2;

FIG. 4 is a graph illustrating a particle size distribution of a silver powder according to Example 3;

15 FIG. 5 is a graph illustrating a particle size distribution of a silver powder according to Example 4;

FIG. 6 is a graph illustrating a particle size distribution of a silver powder according to Example 5;

FIG. 7 is an SEM photograph ($\times 2,000$) of a flake-like silver powder A;

FIG. 8 is an SEM photograph ($\times 2,000$) of a flake-like silver powder B;

20 FIG. 9 is an SEM photograph ($\times 2,000$) of a flake-like silver powder C;

FIG. 10 is an SEM photograph ($\times 2,000$) of a flake-like silver powder D;

FIG. 11 is an SEM photograph ($\times 2,000$) of a flake-like silver powder E;

25 FIG. 12 is an SEM photograph ($\times 2,000$) of a spherical silver powder A;

FIG. 13 is an SEM photograph ($\times 20,000$) of the spherical silver powder A;

FIG. 14 is an SEM photograph ($\times 2,000$) of a spherical silver powder B;

30 FIG. 15 is an SEM photograph ($\times 2,000$) of the silver powder according to Example 1;

FIG. 16 is an SEM photograph ($\times 2,000$) of the silver powder according to Example 2;

FIG. 17 is an SEM photograph ($\times 2,000$) of the silver powder according to Example 3;

35 FIG. 18 is an SEM photograph ($\times 2,000$) of the silver powder according to Example 4;

FIG. 19 is an SEM photograph ($\times 2,000$) of the silver powder according to Example 5;

FIG. 20 is an SEM photograph ($\times 2,000$) of a silver powder according to Comparative Example 4;

5 FIG. 21 is an SEM photograph ($\times 2,000$) of a silver powder according to Comparative Example 5;

FIG. 22 is an SEM photograph ($\times 2,000$) of a silver powder according to Comparative Example 6;

10 FIG. 23 is an SEM photograph ($\times 2,000$) of a silver powder according to Comparative Example 7;

FIG. 24 is a graph illustrating a particle size distribution of a silver powder according to Comparative Example 1;

FIG. 25 is a graph illustrating a particle size distribution of a silver powder according to Comparative Example 2;

15 FIG. 26 is a graph illustrating a particle size distribution of a silver powder according to Comparative Example 3;

FIG. 27 is a graph illustrating a particle size distribution of the silver powder according to Comparative Example 4;

20 FIG. 28 is a graph illustrating a particle size distribution of the silver powder according to Comparative Example 5;

FIG. 29 is a graph illustrating a particle size distribution of the silver powder according to Comparative Example 6; and

FIG. 30 is a graph illustrating a particle size distribution of the silver powder according to Comparative Example 7.

25

DETAILED DESCRIPTION

[0020] (Terminology and measurement methods)

First, terminology, measurement methods, and so forth in the present specification are described in advance of describing embodiments.

30 **[0021]** <Particle size distribution measurement method>

In the present specification, a 6th percentile particle diameter (D_6), a 10th percentile particle diameter (D_{10}), a 50th percentile particle diameter (D_{50}), a 90th percentile particle diameter (D_{90}), and a 94th percentile particle diameter (D_{94}), by volume, of each silver powder and a distribution thereof were measured by the following method.

35

After adding 0.1 g of the silver powder to 40 mL of isopropyl alcohol

(IPA) and performing 2 minutes of dispersing using an ultrasonic homogenizer (device name: US-150T; produced by NISSEI Corporation; 19.5 kHz; tip diameter: 18 mm), wet measurement was performed using a laser diffraction particle size distribution measurement instrument (Microtrac MT-3300 EXII produced by MicrotracBEL Corp.). Note that only in the case of a silver powder (spherical silver powder A) of Comparative Example 2 described further below, 0.1 g of the silver powder was added to 40 mL of a polyvinylpyrrolidone (PVP) solution (solvent: isopropyl alcohol) of 1 weight% in concentration and was subjected to 2 minutes of dispersing using the ultrasonic homogenizer to obtain a sample for measurement.

In the present disclosure, measurement was performed by the method described above to obtain a graph of a particle size distribution where the vertical axis is the volume distribution proportion (units: %), calculated by volume, and the horizontal axis is the particle diameter (units: μm). This graph of the particle size distribution is a histogram, and the volume distribution proportion referred to above is a value determined by dividing a cumulative value of particle volume for each particle diameter interval by the total volume of measured particles. Note that measurement was performed such that for particle diameter intervals on the horizontal axis, a ratio of minimum values of particle diameters in adjacent intervals was 1.09.

Note that in the present specification, a “peak” in the particle size distribution described above refers to a point where the particle diameter is at a minimum in an interval where the volume frequency distribution proportion described above is a local maximum. Note that in identification of a peak, an interval having a smaller particle diameter is adopted in a situation in which intervals having the same value for the volume distribution proportion are adjacent.

[0022] <Ignition loss (Ig-loss) of silver powder>

The ignition loss (Ig-loss) of a silver powder was determined according to “ignition loss (%) = $[(w_1 - w_2)/w_1] \times 100$ ” by measuring the weight (w_1) of 2 g of a silver powder sample, loading the silver powder sample into a magnetic crucible, intensely heating the silver powder sample at 800°C for 30 minutes, and subsequently cooling the silver powder sample and measuring the weight (w_2) thereof.

[0023] <BET specific surface area>

Using a specific surface area measurement instrument (Macsorb HM-

model 1210 produced by Mountech Co., Ltd.) in which the BET method is adopted, 3 g of a silver powder was loaded into a measurement cell, a carrier gas in which 70 volume% of He gas and 30 volume% of nitrogen gas were mixed was passed through the measurement cell to perform 10 minutes of
5 deaeration at 60°C, and then the BET specific surface area was determined by the single-point BET method.

[0024] <Tap density (TAP)>

The tap density of a silver powder is the apparent density of the silver powder in a vessel after a specific amount of the silver powder is measured out
10 and loaded into a vessel having a specific volume, and then an operation of dropping the vessel from a specific height is performed a specific number of times (hereinafter, also referred to as “after tapping”), and this tap density was determined by dividing the weight of the silver powder in the vessel by the apparent volume of the silver powder in the vessel.

15 Specifically, the tap density of a silver powder was determined using a tap density measurement instrument (bulk specific gravity measurement instrument SS-DA-2 produced by Shibayama Scientific Co., Ltd.) by measuring out 30 g of the silver powder, loading the silver powder into a vessel (20 mL test tube), performing tapping 1,000 times with a height of 20 mm, and
20 then dividing the weight of the silver powder (i.e., 30 g) by the apparent volume (mL) of the silver powder after tapping. Note that for a flake-like silver powder B, a flake-like silver powder C, and silver powders according to Comparative Examples 4 and 5 that are described further below, the measured out weight of the silver powder was set as 15 g, and the weight of the silver powder (i.e., 15
25 g) was divided by the apparent volume (mL) of the silver powder after tapping to determine the tap density of the silver powder.

[0025] <Average aspect ratio>

The average aspect ratio can be calculated by “average aspect ratio = D_{50}/t ” (t indicates the thickness) when a uniform model for disc particles is
30 adopted. Moreover, the thickness t (units: μm) can be calculated by “ $t = D_{50}/((\rho \times (D_{50}/2) \times \text{BET specific surface area}) - 2)$ ” (ρ indicates the particle density).

Accordingly, the average aspect ratio of a silver powder in the present specification was calculated according to “average aspect ratio = $(10.49 \times (D_{50}/2) \times \text{BET}) - 2$ ” using D_{50} of the silver powder, the BET specific surface
35 area of the silver powder, and the true density of the silver powder (10.49 g/cm^3) as ρ .

[0026] <Spherical silver powder>

The term “spherical silver powder” as used in the present specification refers to a silver powder having a shape that is close to that of a sphere and that is a shape for which the average aspect ratio described above is less than 2.

[0027] <Flake-like silver powder>

The term “flake-like silver powder” as used in the present specification refers to a silver powder having a shape for which the average aspect ratio described above is 2 or more and encompasses flat plate, thin cuboid, slice, and scaly shapes.

[0028] (Mixed silver powder)

A mixed silver powder according to the present disclosure is a mixed silver powder for which, in a particle size distribution with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis (hereinafter, also referred to simply as a “particle size distribution”) that is determined through wet measurement using a laser diffraction particle size distribution measurement instrument, the particle size distribution includes a first peak and a second peak that each have a volume distribution proportion of 1% or more, and a relationship between a particle diameter d_{M1} of the first peak and a particle diameter d_{M2} of the second peak satisfies formula (I) and formula (II), shown below.

$$d_{M1} < d_{M2} \cdots (I)$$

$$4.5 \mu\text{m} \leq d_{M2} - d_{M1} \leq 16.0 \mu\text{m} \cdots (II)$$

Moreover, the mixed silver powder according to the present disclosure has at least one valley between the first peak and the second peak in the particle size distribution of the mixed silver powder as a result of the difference ($d_{M2} - d_{M1}$) between the particle diameter d_{M2} of the second peak and the particle diameter d_{M1} of the first peak being within the range set forth above and the two peaks being separated by the range set forth above as indicated in formula (II). The mixed silver powder according to the present disclosure is a mixed silver powder for which a relationship between a volume distribution proportion A of whichever of the first peak and the second peak has a smaller volume distribution proportion and a volume distribution proportion B for a position where volume distribution proportion is at a minimum in a valley between the first peak and the second peak satisfies formula (III) or formula (IV), shown below.

$$1.2 \leq A/B \dots (III)$$

$$0 = B/A \dots (IV)$$

With a mixed silver powder such as set forth above, it is possible to impart high thermal conductivity to a metal bonding layer. The reason for this is presumed to be that silver particles having a small particle diameter and high sinterability that form the first peak infiltrate gaps between silver particles having a large particle diameter that form the second peak and fulfill a role of increasing electrical conduction paths between the silver particles having a large particle diameter in a metal bonding layer, and also that an effect of reducing the number of particles through use of large silver particles and an effect of increasing contact surface between large silver particles can be achieved.

It is preferable that only two peaks having a volume distribution proportion of 1% or more are present in the particle size distribution of the mixed silver powder. However, in a case in which three or more peaks having a volume distribution proportion of 1% or more are present, the first peak and the second peak are defined as two peaks having large volume distribution proportions.

[0029] In the particle size distribution of the mixed silver powder, the difference ($d_{M2} - d_{M1}$) between the particle diameter d_{M2} of the second peak and the particle diameter d_{M1} of the first peak is 4.5 μm or more, and preferably 6.0 μm or more, and is 16.0 μm or less, and preferably 13.0 μm or less.

[0030] In the mixed silver powder according to the present disclosure, the relationship between the volume distribution proportion A and the volume distribution proportion B is not specifically limited so long as it satisfies formula (III) or formula (IV), but this relationship preferably satisfies formula (III).

A ratio (A/B) of the volume distribution proportion A relative to the volume distribution proportion B in the particle size distribution of the mixed silver powder is 1.2 or more, and preferably 1.5 or more.

On the other hand, the ratio (A/B) of the volume distribution proportion A relative to the volume distribution proportion B may be 1.5 or less, or may be 1.25 or less, for example.

[0031] The volume distribution proportion A is not specifically limited so long as it satisfies the relationship in formula (III), but is preferably 1.0% or more, and more preferably 1.6% or more, and is preferably 4.0% or less, and more

preferably 3.0% or less.

[0032] The volume distribution proportion B is not specifically limited so long as it satisfies the relationship in formula (III), but is preferably 0.5% or more, and more preferably 0.7% or more, and is preferably 3.0% or less, and more
5 preferably 2.0% or less.

[0033] In the particle size distribution of the mixed silver powder, it is preferable that more than 50% of the volume distribution proportion of the first peak originates from a spherical silver powder and that more than 50% of the volume distribution proportion of the second peak originates from a flake-like
10 silver powder.

When more than 50% of the volume distribution proportion of the first peak originates from a spherical silver powder and more than 50% of the volume distribution proportion of the second peak originates from a flake-like silver powder, fine spherical silver particles having a small particle diameter
15 and high sinterability readily infiltrate gaps between flake-like silver particles having a large particle diameter and fulfill a role of increasing electrical conduction paths between the flake-like silver particles having a large particle diameter in a metal bonding layer, and it is also possible to achieve an effect of reducing the number of particles of the flake-like silver powder and an effect
20 of further increasing contact area between flake-like silver particles having flat surfaces.

It is preferable that 70% or more, and more preferable that 90% or more of the volume distribution proportion of the first peak originates from a spherical silver powder. Moreover, it is even more preferable that 100% of the
25 volume distribution proportion of the first peak originates from a spherical silver powder (i.e., that the first peak originates from only a spherical silver powder).

It is preferable that 70% or more, and more preferable that 90% or more of the volume distribution proportion of the second peak originates from a
30 flake-like silver powder. Moreover, it is even more preferable that 100% of the volume distribution proportion of the second peak originates from a flake-like silver powder (i.e., that the second peak originates from only a flake-like silver powder).

[0034] In the particle size distribution of the mixed silver powder, d_{M1} is not
35 less than 0.5 μm and not more than 1.5 μm , and d_{M2} is not less than 5 μm and not more than 17.5 μm .

When d_{M1} and d_{M2} are within the ranges set forth above, it is possible to achieve a balance of both high sinterability through fine silver powder and an effect of reducing the number of particles and an effect of increasing contact surface between large silver particles through large silver powder.

5 d_{M1} is preferably $0.6\ \mu\text{m}$ or more, and more preferably $0.8\ \mu\text{m}$ or more, and is preferably $1.4\ \mu\text{m}$ or less, and more preferably $1.3\ \mu\text{m}$ or less.

d_{M2} is preferably $6.0\ \mu\text{m}$ or more, and more preferably $7.0\ \mu\text{m}$ or more, and is preferably $16.0\ \mu\text{m}$ or less, and more preferably $11.0\ \mu\text{m}$ or less.

[0035] D_{10} of the mixed silver powder is preferably $0.3\ \mu\text{m}$ or more, and more
10 preferably $0.4\ \mu\text{m}$ or more, and is preferably $1.5\ \mu\text{m}$ or less, and more preferably $1.2\ \mu\text{m}$ or less.

When D_{10} of the mixed silver powder is $0.3\ \mu\text{m}$ or more, fine silver particles having a small particle diameter can densely infiltrate gaps between large silver particles.

15 On the other hand, when D_{10} of the mixed silver powder is $1.5\ \mu\text{m}$ or less, the good sinterability of small silver particles can be exploited.

[0036] D_{50} of the mixed silver powder is preferably $1.0\ \mu\text{m}$ or more, and more preferably $1.1\ \mu\text{m}$ or more, and is preferably $8.0\ \mu\text{m}$ or less, and more preferably $6.0\ \mu\text{m}$ or less.

20 **[0037]** D_{90} of the mixed silver powder is preferably $7.0\ \mu\text{m}$ or more, and more preferably $8.0\ \mu\text{m}$ or more, and is preferably $20.0\ \mu\text{m}$ or less, and more preferably $17.0\ \mu\text{m}$ or less.

When D_{90} of the mixed silver powder is $7.0\ \mu\text{m}$ or more, the effect of reducing large silver particles and contact area between silver particles can be
25 increased in a metal bonding layer.

On the other hand, when D_{90} of the mixed silver powder is $20.0\ \mu\text{m}$ or less, gaps between large silver particles are not excessively wide, and silver particles having a small particle diameter can densely infiltrate the gaps.

[0038] In the mixed silver powder, $(D_{90} - D_{10})/D_{50}$ is preferably 1.8 or more,
30 and more preferably 1.9 or more, and is preferably 10.0 or less, and more preferably 7.2 or less.

When $(D_{90} - D_{10})/D_{50}$ is within any of the ranges set forth above, packing of a metal bonding layer improves because fine silver powder having a small particle diameter and silver powder having a large particle diameter
35 mix together to a certain degree, and silver particles having a small particle diameter can densely infiltrate gaps between large particles.

[0039] The tap density of the mixed silver powder is preferably 3.5 g/cm^3 or more, and more preferably 5.0 g/cm^3 or more, and is preferably 7.0 g/cm^3 or less, and more preferably 6.3 g/cm^3 or less.

When the tap density of the mixed silver powder is 3.5 g/cm^3 or more,
5 packing of a metal bonding layer improves.

On the other hand, when the tap density of the mixed silver powder is 7.0 g/cm^3 or more, this may result in excessively high packing, hardening and embrittlement of a bonding material, and the occurrence of cracking or the like due to warping caused by thermal stress, for example.

10 **[0040]** The BET specific surface area of the mixed silver powder is preferably $0.61 \text{ m}^2/\text{g}$ or more, and more preferably $0.65 \text{ m}^2/\text{g}$ or more, and is preferably $1.40 \text{ m}^2/\text{g}$ or less, and more preferably $1.00 \text{ m}^2/\text{g}$ or less.

When the BET specific surface area of the mixed silver powder is $0.61 \text{ m}^2/\text{g}$ or more, sufficient contact area between particles can be ensured.

15 On the other hand, when the BET specific surface area of the mixed silver powder is $1.40 \text{ m}^2/\text{g}$ or less, good viscosity of a paste used to form a metal bonding layer can be maintained.

[0041] In the mixed silver powder, a ratio (Ig-loss/BET specific surface area) of the ignition loss (Ig-loss) relative to the BET specific surface area is
20 preferably 0.15 or more, and more preferably 0.30 or more, and is preferably 0.65 or less, and more preferably 0.57 or less.

When “Ig-loss/BET specific surface area” of the mixed silver powder is 0.15 or more, the silver powder can be dispersed well.

On the other hand, when “Ig-loss/BET specific surface area” of the
25 mixed silver powder is 0.65 or less, the amount of impurities between particles can be restricted to a low level, which makes it possible to reduce resistance between particles after heating and improve thermal conductivity of a metal bonding layer.

The ratio of the ignition loss (Ig-loss) relative to the BET specific
30 surface area is a value obtained when the value of ignition loss (Ig-loss) in the silver powder, in units of mass%, is divided by the BET specific surface area of the silver powder, in units of m^2/g . Note that the units of “Ig-loss/BET specific surface area” are “mass%·g/m²”, though these units are omitted in the present specification.

35 **[0042]** The mixed silver powder according to the present disclosure may be a mixture that contains a first silver powder and a second silver powder described

below in specific proportions but is not specifically limited thereto so long as it satisfies the relationships in formulae (I) to (IV).

[0043] (Method of producing mixed silver powder)

A method of producing a mixed silver powder (hereinafter, also referred to simply as a “production method”) according to the present disclosure is a method including a mixing step of mixing a first silver powder and a second silver powder, wherein, in particle size distributions with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis that are respectively determined through wet measurement of the first silver powder and the second silver powder using a laser diffraction particle size distribution measurement instrument, a relationship between a particle diameter d_{s1} of a peak where volume distribution proportion is at a maximum for the first silver powder and a particle diameter d_{s2} of a peak where volume distribution proportion is at a maximum for the second silver powder satisfies formula (i) and formula (ii), shown below:

$$d_{s1} < d_{s2} \cdots (i)$$

$$4.6 \mu\text{m} \leq d_{s2} - d_{s1} \leq 16.0 \mu\text{m} \cdots (ii)$$

and a relationship between a 94th percentile diameter D_{94} of the first silver powder and a 6th percentile diameter D_6 of the second silver powder satisfies formula (iii), shown below:

$$D_{94} \text{ of first silver powder} \leq D_6 \text{ of second silver powder} \cdots (iii).$$

With a mixed silver powder such as set forth above, it is possible to obtain a mixed silver powder that can impart high thermal conductivity to a metal bonding layer.

Moreover, the mixed silver powder according to the present disclosure set forth above can be obtained by the production method according to the present disclosure.

Note that no specific limitations are placed on the means by which the first silver powder and the second silver powder are mixed in the mixing step of the production method according to the present disclosure, and the mixing can be performed using a stirring device such as a Henschel mixer or a sample mill.

[0044] In the particle size distributions of the first silver powder and the second silver powder, a difference ($d_{s2} - d_{s1}$) between the particle diameter d_{s2} of the peak where the volume distribution proportion is at a maximum for the second silver powder and the particle diameter d_{s1} of the peak where the

volume distribution proportion is at a maximum for the first silver powder is 4.6 μm or more, and preferably 6.0 μm or more, and is 16.0 μm or less, and preferably 12.0 μm or less.

5 **[0045]** In the particle size distributions of the first silver powder and the second silver powder, a difference ($D_6 - D_{94}$) between the 6th percentile diameter D_6 of the second silver powder and the 94th percentile diameter D_{94} of the first silver powder is preferably 0.0 μm or more, and more preferably 0.1 μm or more, and is preferably 3.0 μm or less, and more preferably 2.5 μm or less.

10 **[0046]** A mass proportion of the first silver powder relative to the total mass of the first silver powder and the second silver powder is preferably 10 mass% or more, and more preferably 20 mass% or more, and is preferably 90 mass% or less, and more preferably 80 mass% or less.

15 When the mass proportion of the first silver powder relative to the total mass of the first silver powder and the second silver powder is within any of the ranges set forth above, fine silver powder having a small particle diameter and large flake silver powder mix together to a certain degree, silver particles having a small particle diameter can densely infiltrate gaps between large particles, packing of a metal bonding layer improves, and the effects of each
20 of the silver powders can be exhibited.

[0047] In the particle size distribution of the first silver powder, d_{S1} is preferably 0.4 μm or more, and more preferably 0.7 μm or more, and is preferably 1.5 μm or less, and more preferably 1.3 μm or less.

25 **[0048]** In the particle size distribution of the first silver powder, the volume distribution proportion of the peak where the volume distribution proportion is at a maximum for the first silver powder is preferably 4.0% or more, and more preferably 5.0% or more, and no specific limitations are placed on the upper limit thereof.

30 **[0049]** The shape of the first silver powder is not specifically limited but is preferably spherical. In other words, the first silver powder is preferably a spherical silver powder.

[0050] D_{10} of the first silver powder is preferably 0.1 μm or more, and more preferably 0.2 μm or more, and is preferably 0.7 μm or less, and more preferably 0.4 μm or less.

35 **[0051]** D_{50} of the first silver powder is preferably 0.5 μm or more, and more preferably 0.6 μm or more, and is preferably 1.5 μm or less, and more

preferably 1.2 μm or less.

[0052] D_{90} of the first silver powder is preferably 0.8 μm or more, and more preferably 1.2 μm or more, and is preferably 1.9 μm or less, and more preferably 1.6 μm or less.

- 5 **[0053]** D_{94} of the first silver powder is preferably 0.9 μm or more, and more preferably 1.3 μm or more, and is preferably 2.0 μm or less, and more preferably 1.8 μm or less.

When the values of D_{10} , D_{50} , D_{90} , and D_{94} of the first silver powder are within any of the ranges set forth above, the first silver powder can densely
10 infiltrate gaps between large particles without deterioration of sinterability.

[0054] The tap density of the first silver powder is preferably 2.0 g/cm^3 or more, and more preferably 3.5 g/cm^3 or more, and is preferably 7.0 g/cm^3 or less, and more preferably 6.0 g/cm^3 or less.

When the tap density of the first silver powder is 2.0 g/cm^3 or more,
15 packing of a metal bonding layer can be improved.

On the other hand, when the tap density of the first silver powder is 7.0 g/cm^3 or more, this may result in excessively high packing, hardening and embrittlement of a bonding material, and the occurrence of cracking or the like due to warping caused by thermal stress, for example.

- 20 **[0055]** The BET specific surface area of the first silver powder is preferably 0.6 m^2/g or more, and more preferably 0.8 m^2/g or more, and is preferably 2.2 m^2/g or less, and more preferably 1.8 m^2/g or less.

When the BET specific surface area is 0.6 m^2/g or more, sinterability can be improved.

- 25 On the other hand, when the BET specific surface area is 2.2 m^2/g or less, good viscosity of a paste that is used to form a metal bonding layer containing a mixed silver powder can be maintained.

[0056] In the first silver powder, a ratio (Ig-loss/BET specific surface area) of the ignition loss (Ig-loss) relative to the BET specific surface area is preferably
30 0.15 or more, and more preferably 0.20 or more, and is preferably 0.65 or less, and more preferably 0.57 or less.

When “Ig-loss/BET specific surface area” of the first silver powder is 0.15 or more, dispersibility of the silver powder can be improved.

- On the other hand, when “Ig-loss/BET specific surface area” of the first
35 silver powder is 0.65 or less, the amount of impurities between particles can be restricted to a low level, which makes it possible to reduce resistance

between particles after heating and improve thermal conductivity of a metal bonding layer.

[0057] In the particle size distribution of the second silver powder, d_{s2} is preferably 5.0 μm or more, and more preferably 7.0 μm or more, and is
5 preferably 17.5 μm or less, and more preferably 16.0 μm or less.

[0058] In the particle size distribution of the second silver powder, the volume distribution proportion of the peak where the volume distribution proportion is at a maximum for the second silver powder is preferably 4.0% or more, and more preferably 5.0% or more, and no specific limitations are placed on the
10 upper limit thereof.

[0059] The shape of the second silver powder is not specifically limited but is preferably flake-like. In other words, the second silver powder is preferably a flake-like silver powder.

In a case in which the second silver powder is a flake-like silver powder,
15 the aspect ratio of the flake-like silver powder is preferably 3 or more, and more preferably 8 or more, and is preferably 40 or less, and more preferably 30 or less.

When the aspect ratio of the flake-like silver powder is 3 or more, flat surface portions are sufficiently present in the individual silver particles, and
20 contact area between the particles can be ensured.

On the other hand, when the aspect ratio of the flake-like silver powder is 40 or less, good packing of a metal bonding layer can be ensured.

[0060] D_6 of the second silver powder is preferably 1.0 μm or more, and more preferably 1.4 μm or more, and is preferably 5.0 μm or less, and more
25 preferably 4.0 μm or less.

[0061] D_{10} of the second silver powder is preferably 1.5 μm or more, and more preferably 2.0 μm or more, and is preferably 7.0 μm or less, and more preferably 5.0 μm or less.

[0062] D_{50} of the second silver powder is preferably 5.0 μm or more, and more preferably 6.0 μm or more, and is preferably 17.5 μm or less, and more
30 preferably 13.0 μm or less.

[0063] D_{90} of the second silver powder is preferably 8.0 μm or more, and more preferably 12.0 μm or more, and is preferably 25.0 μm or less, and more preferably 22.0 μm or less.

35 When D_6 , D_{10} , D_{50} , and D_{90} of the second silver powder are within any of the ranges set forth above, mixing compatibility with the first silver powder

is good because there is little silver powder that is not flaked and few particles that are excessively flaked, and packing of a metal bonding layer can be improved.

[0064] The tap density of the second silver powder is preferably 2.0 g/cm³ or more, and more preferably 4.0 g/cm³ or more, and is preferably 7.0 g/cm³ or less, and more preferably 6.5 g/cm³ or less.

When the tap density of the second silver powder is 2.0 g/cm³ or more, there are few particles that are excessively flaked, and packing of a metal bonding layer can be improved.

On the other hand, when the tap density of the second silver powder is 7.0 g/cm³ or less, flat surfaces of particles are sufficiently present, and contact area between particles can be ensured.

[0065] The BET specific surface area of the second silver powder is preferably 0.2 m²/g or more, and more preferably 0.25 m²/g or more, and is preferably 2.0 m²/g or less, and more preferably 1.2 m²/g or less.

When the BET specific surface area is 0.2 m²/g or more, flat surfaces of particles are sufficiently present, and contact area can be ensured.

On the other hand, when the BET specific surface area is 2.0 m²/g or less, there are few excessively flaked particles or fine particles, and the effects of the large flake silver powder can be improved.

[0066] In the second silver powder, a ratio (Ig-loss/BET specific surface area) of the ignition loss (Ig-loss) relative to the BET specific surface area is preferably 0.15 or more, and more preferably 0.20 or more, and is preferably 0.65 or less, and more preferably 0.57 or less.

When “Ig-loss/BET specific surface area” of the second silver powder is 0.15 or more, dispersibility of the silver powder can be improved.

On the other hand, when “Ig-loss/BET specific surface area” of the second silver powder is 0.65 or less, the amount of impurities between particles can be restricted to a low level, which makes it possible to reduce resistance between particles after heating and improve thermal conductivity of a metal bonding layer.

[0067] In one embodiment, it is preferable that the first silver powder is a spherical silver powder and the second silver powder is a flake-like silver powder.

When the first silver powder is a spherical silver powder and the second silver powder is a flake-like silver powder, the small spherical silver powder

can densely infiltrate between the large flake-like silver particles and can fulfill a role of increasing electrical conduction paths between the flake-like silver particles having a large particle diameter in a metal bonding layer, and it is also possible to achieve an effect of reducing the number of particles of the flake-like silver powder and an effect of increasing contact area between the flake-like silver particles having flat surfaces.

[0068] In one embodiment, in a case in which the first silver powder is a spherical silver powder and the second silver powder is a flake-like silver powder, it is preferable that the spherical silver powder has a 50th percentile diameter D_{50} of not less than 0.5 μm and not more than 1.5 μm , a tap density of 2.0 g/cm^3 or more, and a BET specific surface area of not less than 0.6 m^2/g and not more than 2.2 m^2/g , and the flake-like silver powder has a 50th percentile diameter D_{50} of not less than 5.0 μm and not more than 17.5 μm (or not more than 16 μm), a tap density of 2.0 g/cm^3 or more, a BET specific surface area of not less than 0.2 m^2/g and not more than 2.0 m^2/g , and an aspect ratio of 3 or more.

When the spherical silver powder and the flake-like silver powder have the characteristics set forth above, fine spherical silver particles having a small particle diameter and high sinterability readily infiltrate gaps between flake-like silver particles having a large particle diameter and fulfill a role of increasing electrical conduction paths between the flake-like silver particles having a large particle diameter in a metal bonding layer, and it is also possible to achieve an effect of reducing the number of particles of the flake-like silver powder and an effect of increasing contact area between flake-like silver particles having flat surfaces.

[0069] Note that the first silver powder and the second silver powder can be produced by conventional methods that are commonly known without any specific limitations.

[0070] (Metal paste for bonding)

A metal paste for bonding according to the present disclosure contains the mixed silver powder according to the present disclosure set forth above. As a result of containing the mixed silver powder according to the present disclosure, the metal paste for bonding according to the present disclosure can impart high thermal conductivity to a metal bonding layer.

Note that the metal paste for bonding normally contains a solvent. The solvent is not specifically limited and may be water, a monohydric alcohol, a

polyol, an ether compound, a glycol ether acetate, a nitrogen-containing ring compound, an ester compound, or the like, for example.

The monohydric alcohol may be 1-octanol, terpineol, texanol, phenoxypropanol, 1-decanol, 1-dodecanol, 1-tetradecanol, Terusolve MTPH
5 (produced by Nippon Terpene Chemicals, Inc.), dihydroterpinylxyethanol (produced by Nippon Terpene Chemicals, Inc.), Terusolve TOE-100 (produced by Nippon Terpene Chemicals, Inc.), Terusolve DTO-210 (produced by Nippon Terpene Chemicals, Inc.), or the like, for example.

The polyol may be 3-methyl-1,3-butanediol, 2-ethyl-1,3-hexanediol
10 (octanediol), hexyl diglycol, 2-ethylhexyl glycol, dibutyl diglycol, glycerin, dihydroxyterpineol, 3-methylbutane-1,2,3-triol (Isoprene triol A (IPTL-A) produced by Nippon Terpene Chemicals, Inc.), 2-methylbutane-1,2,4-triol (Isoprene triol B (IPTL-B) produced by Nippon Terpene Chemicals, Inc.), or the like, for example.

15 The ether compound may be butyl carbitol, diethylene glycol monobutyl ether, terpinyl methyl ether (produced by Nippon Terpene Chemicals, Inc.), dihydroterpinyl methyl ether (produced by Nippon Terpene Chemicals, Inc.), or the like, for example.

The glycol ether acetate may be butyl carbitol acetate, diethylene
20 glycol monobutyl ether acetate, ethylene glycol monomethyl ether acetate, ethylene glycol monoethyl ether acetate, diethylene glycol monoethyl ether acetate, or the like, for example.

The nitrogen-containing ring compound may be 1-methylpyrrolidinone, pyridine, or the like, for example.

25 The ester compound may be γ -butyrolactone, methoxybutyl acetate, methoxypropyl acetate, ethyl lactate, 3-hydroxy-3-methylbutyl acetate, dihydroterpinyl acetate, Terusolve IPG-2Ac (produced by Nippon Terpene Chemicals, Inc.), Terusolve THA-90 (produced by Nippon Terpene Chemicals, Inc.), Terusolve THA-70 (produced by Nippon Terpene Chemicals, Inc.), or the
30 like, for example.

One of the solvents listed above may be used individually, or two or more of the solvents listed above may be used in combination.

EXAMPLES

35 **[0071]** The following provides an even more detailed description of the present disclosure using examples. However, the present disclosure is not in

any way limited by the following examples.

Note that BET specific surface area, particle size distribution, ignition loss (Ig-loss), tap density, and average aspect ratio were measured or calculated by the previously described methods.

5 **[0072]** (Preparation of flake-like silver powder A)

First, 167.1 kg of 26 wt% ammonia aqueous solution was added to 2,922 kg of silver nitrate aqueous solution containing 68.8 kg of silver as a silver ion aqueous solution so as to produce a silver ammine complex aqueous solution. In addition, 266 kg of 6 wt% hydrazine aqueous solution as a
10 reductant was added to this silver ammine complex aqueous solution to obtain a first liquid. The addition rate of the reductant was set as 80 L/min. The first liquid was in the form of a slurry containing silver particles.

The first liquid was subjected to filtration, water washing, and subsequent drying to yield a precursor silver powder. The precursor silver
15 powder was formed of uniformly sized silver particles in an aggregated state.

After loading 15.5 kg of the precursor silver powder into a Henschel mixer (FM mixer produced by Mitsui Mining Co., Ltd.; model: FM75; SO stirring blade used) and performing 1 minute of stirring thereof at 900 rpm, 49.6 g of palmitic acid (0.32 wt% relative to weight of precursor silver powder
20 (calculated by $49.6 \text{ g of palmitic acid} / 15,500 \text{ g of precursor silver powder} \times 100$)) was added as a lubricant and was mixed and stirred therewith for 20 minutes at a stirring blade rotation speed of 2,600 rpm (lubricant mixing step). This step was performed for a plurality of batches to yield a lubricant-treated silver powder having the lubricant dispersed on the surfaces of silver particles.

25 Together with 313.2 kg of SUS balls (diameter: 1.6 mm), 31 kg of the lubricant-treated silver powder that had been obtained was loaded into a tumbling ball mill having an internal diameter of 60 cm and a length of 40 cm and was subjected to flaking treatment under conditions of a rotation speed of 21 rpm and a treatment time of 7 hours. The balls and the flaking-treated silver
30 powder present after treatment were separated using a vibratory sieve.

After adding 30 kg of the flaking-treated silver powder into approximately 35 L of Neoethanol that had been adjusted to 28°C or higher and performing 30 minutes of stirring thereof, solid-liquid separation was performed using a pressurized filter, and then drying was performed. After
35 drying, 14 kg of the flaking-treated silver powder was loaded into a Henschel mixer (FM mixer produced by Mitsui Mining Co., Ltd.; model: FM75; SO

stirring blade used), was stirred for 1 minute at 900 rpm, and was subsequently subjected to 15 minutes of disintegration at 2,600 rpm. In addition, a dry sifting machine (produced by Freund-Turbo Corporation; model TS125×200/24 μ m opening size screen) was used to perform sifting so as to remove coarse particles from the disintegration-treated silver powder and yield a flake-like silver powder A. The results of various measurements of the flake-like silver powder A are shown in Table 1. Moreover, an SEM photograph (×2,000) of the flake-like silver powder A is presented in FIG. 7.

[0073] (Preparation of flake-like silver powder B)

FA-S-10 produced by DOWA ELECTRONICS MATERIALS CO., LTD. was prepared as a flake-like silver powder B. The results of various measurements of the flake-like silver powder B are shown in Table 1. Moreover, an SEM photograph (×2,000) of the flake-like silver powder B is presented in FIG. 8.

[0074] (Preparation of flake-like silver powder C)

FA-S-18 produced by DOWA ELECTRONICS MATERIALS CO., LTD. was prepared as a flake-like silver powder C. The results of various measurements of the flake-like silver powder C are shown in Table 1. Moreover, an SEM photograph (×2,000) of the flake-like silver powder C is presented in FIG. 9.

[0075] (Preparation of flake-like silver powder D)

First, 167.1 kg of 26 wt% ammonia aqueous solution was added to 2,922 kg of silver nitrate aqueous solution containing 68.8 kg of silver as a silver ion aqueous solution so as to produce a silver ammine complex aqueous solution. In addition, 266 kg of 6 wt% hydrazine aqueous solution as a reductant was added to this silver ammine complex aqueous solution to obtain a first liquid. The addition rate of the reductant was set as 80 L/min. The first liquid was in the form of a slurry containing silver particles.

Once 5 minutes has passed from the end point of addition of the reductant, 68.8 g of oleic acid (0.1 wt% relative to weight of silver contained in silver ammine complex aqueous solution (calculated by $68.8 \text{ g of oleic acid} / 68,800 \text{ g of silver} \times 100$)) was added as a surface treatment agent. After addition of the surface treatment agent, 5 minutes of stirring was performed to yield a second liquid. The second liquid was in the form of a slurry.

The second liquid was subjected to filtration, water washing, and subsequent drying to yield a precursor silver powder. The precursor silver

powder was formed of uniformly sized silver particles in an aggregated state.

After loading 16.25 kg of the precursor silver powder into a Henschel mixer (FM mixer produced by Mitsui Mining Co., Ltd.; model: FM75; SO stirring blade used) and performing 1 minute of stirring thereof at 900 rpm, 5 37.4 g of oleic acid (0.23 wt% relative to weight of precursor silver powder (calculated by $37.4 \text{ g of oleic acid} / 16,250 \text{ g of precursor silver powder} \times 100$)) was added as a lubricant and was mixed and stirred therewith for 20 minutes at a stirring blade rotation speed of 2,600 rpm (lubricant mixing step). This step was performed for a plurality of batches to yield a lubricant-treated silver 10 powder having the lubricant dispersed on the surfaces of silver particles.

A vibratory mill (model FVR-20 produced by Chuo Kakohki Co., Ltd.) was charged with 32 kg of the lubricant-treated silver powder and 256 kg of SUS balls (diameter: 1.6 mm) and was used to perform 135 minutes of treatment with a vibration frequency of 780 vpm as flaking treatment so as to 15 cause flaking of the lubricant-treated silver powder and obtain a flaking-treated silver powder. The flaking-treated silver powder was separated from the SUS balls and was then stirred at 2,600 rpm for 25 minutes using the previously described Henschel mixer to cause disintegration. In addition, a dry sifting machine (produced by Freund-Turbo Corporation; model TS125×200/27 μm 20 opening size screen) was used to perform sifting so as to remove coarse particles from the disintegration-treated silver powder and yield a flake-like silver powder D (disintegration-treated silver powder after sifting). The results of various measurements of the flake-like silver powder D are shown in Table 1. Moreover, an SEM photograph ($\times 2,000$) of the flake-like silver powder D is 25 presented in FIG. 10.

[0076] (Preparation of flake-like silver powder E)

A silver ammine complex aqueous solution was produced by adding 122.1 kg of 26.28 wt% ammonia aqueous solution to 2,411 kg of silver nitrate aqueous solution containing 64.8 kg of silver. In addition, 6 kg of 31.15 wt% 30 sodium hydroxide aqueous solution was added to the produced silver ammine complex aqueous solution, and then 158.4 kg of 37 wt% formalin aqueous solution was added as a reductant.

Once addition of the reductant was complete, 360 g (0.56 wt% relative to weight of silver contained in silver ammine complex aqueous solution (0.09 35 wt% in terms of amount of stearic acid)) of Selosol 920 (produced by Chukyo Yushi Co., Ltd.; containing 15.5 wt% of stearic acid) was added as a surface

treatment agent to produce a slurry containing a precursor silver powder.

The slurry was subjected to filtration, water washing, and subsequent drying to yield the precursor silver powder. The precursor silver powder was formed of uniformly sized silver particles in an aggregated state.

5 The precursor silver powder was measured out in an amount of 32.2 kg, was loaded into a Henschel mixer (FM mixer produced by Mitsui Mining Co., Ltd.; model: FM75; SO stirring blade used), and was stirred at a stirring blade rotation speed of 1,200 rpm for 1 minute to cause disintegration. Thereafter, 64.4 g (0.2 wt% relative to weight of precursor silver powder) of stearic acid
10 was added as a lubricant, and a further 20 minutes of stirring was performed at a stirring blade rotation speed of 1,200 rpm. This yielded a lubricant-treated silver powder having the lubricant dispersed on the surfaces of silver particles.

A vibratory mill (model FVR-20 produced by Chuo Kakohki Co., Ltd.) was charged with 32 kg of the lubricant-treated silver powder and 256 kg of
15 SUS balls (diameter: 1.6 mm) and was used to perform 60 minutes of treatment with a vibration frequency of 1,442 vpm as flaking treatment so as to cause flaking of the lubricant-treated silver powder and obtain a flaking-treated silver powder. In addition, a dry sifting machine (produced by Freund-Turbo Corporation; model TS125×200/27 μ m opening size screen) was used to
20 perform sifting so as to remove coarse particles and yield a flake-like silver powder E (flaking-treated silver powder after sifting). The results of various measurements of the flake-like silver powder E are shown in Table 1. Moreover, an SEM photograph ($\times 2,000$) of the flake-like silver powder E is presented in FIG. 11.

25 **[0077]** (Preparation of spherical silver powder A)

A silver ammine complex aqueous solution was obtained by adding 157.46 g of industrial ammonia water of 28 mass% in concentration to 3,618.2 g of silver nitrate aqueous solution containing 51.78 g of silver. After adding 9.60 g of sodium hydroxide aqueous solution of 20 mass% in concentration to
30 this silver ammine complex aqueous solution and adjusting the liquid temperature to 25°C, 140.42 g of 7.3 mass% hydrazine aqueous solution was added as a reductant under stirring to yield a slurry containing silver particles.

With respect to the obtained slurry containing silver particles, 5.93 g of 3.54 mass% oleic acid ethanol solution was added and stirred therewith.

35 The stirring was stopped to cause sedimentation of silver particles, and then the liquid in which the silver particles had sedimented was filtered. Water

washing was performed until the electrical conductivity of liquid after passing of water reached 0.5 mS/m or less, and then vacuum drying was performed at 73°C.

A sample mill (SK-M10 produced by Kyoritsu Riko) was charged with
5 120 g of silver powder obtained by repeating the steps described above three times and was used to perform disintegration twice for 90 seconds to yield a spherical silver powder A. The results of various measurements of the spherical silver powder A are shown in Table 1. Moreover, SEM photographs of the spherical silver powder A are presented in FIG. 12 ($\times 2,000$ SEM photograph)
10 and FIG. 13 ($\times 20,000$ SEM photograph).

[0078] (Preparation of spherical silver powder B)

A silver ammine complex aqueous solution was obtained by adding
128.2 g of industrial ammonia water of 28 mass% in concentration to 3,790.3 g of silver nitrate aqueous solution containing 58.91 g of silver. After adding
15 9.43 g of nitric acid aqueous solution of 80 mass% in concentration to this silver ammine complex aqueous solution, further adding 0.619 g of 5 mass% polyethyleneimine 600 (PEI 600) aqueous solution, and adjusting the liquid temperature to 25°C, 338.0 g of 2.5 mass% hydrazine aqueous solution was added as a reductant under stirring to yield a slurry containing silver particles.

20 With respect to the obtained slurry containing silver particles, 4.94 g of 1.55 mass% stearic acid emulsion solution was added and stirred therewith.

The stirring was stopped to cause sedimentation of silver particles, and then the liquid in which the silver particles had sedimented was filtered. Water washing was performed until the electrical conductivity of liquid after passing
25 of water reached 0.5 mS/m or less, and then vacuum drying was performed at 73°C.

A sample mill (SK-M10 produced by Kyoritsu Riko) was charged with
120 g of silver powder obtained by repeating the steps described above three times and was used to perform disintegration twice for 90 seconds to yield a
30 spherical silver powder B. The results of various measurements of the spherical silver powder B are shown in Table 1. Moreover, an SEM photograph ($\times 2,000$) of the spherical silver powder B is presented in FIG. 14.

[0079] [Table 1]

	BET [m ² /g]	Particle size distribution							TAP [g/cm ³]	Ig-loss/ BET	Average aspect ratio
		D ₆ [μm]	D ₁₀ [μm]	D ₅₀ [μm]	D ₉₀ [μm]	D ₉₄ [μm]	Peak where volume distribution proportion is at maximum				
							Particle diameter d _s [μm]	Volume distribution proportion [%]			
Flake-like silver powder A	0.60	2.1	2.6	6.7	13.0	15.1	8.5	6.3	5.3	0.57	19
Flake-like silver powder B	1.41	0.6	0.8	2.2	5.6	6.8	3.0	4.4	3.1	0.48	14
Flake-like silver powder C	1.76	1.1	1.4	3.9	8.4	9.8	5.0	5.0	2.1	0.54	34
Flake-like silver powder D	0.32	1.1	1.4	3.4	7.8	10.9	3.0	4.7	4.5	1.02	4
Flake-like silver powder E	0.48	1.5	1.9	4.3	11.6	14.7	3.9	4.9	4.4	1.83	9
Spherical silver powder A	0.99	0.2	0.3	0.7	1.4	1.7	0.8	6.6	4.9	0.36	1.6
Spherical silver powder B	0.21	1.5	1.8	2.9	4.7	5.3	3.0	10.7	6.1	0.86	1.2

[0080] (Example 1)

The spherical silver powder A, which corresponds to a first silver powder, and the flake-like silver powder A, which corresponds to a second silver powder, were loaded into a Henschel mixer (FM mixer produced by Mitsui Mining Co., Ltd.; model: FM75; SO stirring blade used) such that the mass ratio thereof was 50:50 (first silver powder:second silver powder) and the total amount thereof was 24.8 kg and were subjected to mixing and stirring at 900 rpm for 1 minute and at 1,500 rpm for 25 minutes. Thereafter, a dry sifting machine (produced by Freund-Turbo Corporation; model TS125×200/33 μm opening size screen) was used to perform sifting so as to remove coarse particles and yield a silver powder (mixed silver powder) according to Example 1. Note that the difference ($d_{s2} - d_{s1}$) between d_{s2} of the flake-like silver powder A, which corresponds to a second silver powder, and d_{s1} of the spherical silver powder A, which corresponds to a first silver powder, is 7.7 μm . Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Example 1 was used to perform various measurements. The results are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Example 1 is illustrated in FIG. 2, and an SEM photograph ($\times 2,000$) of the silver powder according to Example 1 is presented in FIG. 15.

[0081] (Thermal conductivity)

<Formation of evaluation film>

A 30 mL plastic pot was charged with 27.9 g of the silver powder according to Example 1 and 2.1 g of 1-octanol (produced by FUJIFILM Wako Pure Chemical Corporation) as a solvent, and then a propeller-less planetary stirring and defoaming device (V-mini300 produced by EME, Inc.) was used to perform kneading four times at a revolution speed of 1,400 rpm for 30 seconds to yield a paste for evaluation film formation (metal paste for bonding). The paste for evaluation film formation was used to form a coating film on an alumina substrate using a squeegee and a metal mask of 10.5 mm $\times$ 10.5 mm with a plate thickness of 50 μm . The alumina substrate on which the coating film had been formed was placed in a firing furnace and was subjected to non-pressurized firing to form an evaluation film. The non-pressurized firing was performed by heating to 250°C at 3.75°C/min and holding for 1 hour after reaching a temperature of 250°C in a nitrogen atmosphere.

[0082] <Thickness measurement of evaluation film>

For each obtained evaluation film, a step between a section where the film had not been printed on the alumina substrate and a section where the evaluation film was present was measured using a surface roughness meter (SURFCOM 480B-12 produced by Tokyo Seimitsu Co., Ltd.) in order to measure the average thickness of the evaluation film.

[0083] <Measurement of thermal conductivity of evaluation film>

A four probe-type measurement instrument (Loresta-GX MCP-T700 produced by Mitsubishi Chemical Analytech Co., Ltd.) was used to measure the volume resistivity of each obtained evaluation film under a condition of a room temperature of 25°C, and then the thermal conductivity of the evaluation film was calculated from the volume resistivity and the temperature by the Wiedemann-Franz law. The results are shown in Table 3. Note that the Wiedemann-Franz law is indicated by the following formula.

$$K/\sigma = LT \cdots (1)$$

In formula (1), K represents thermal conductivity [W/K·m], σ represents electrical conductivity [S/m], L represents the Lorenz number (2.44×10^{-8} [W Ω /K²]), and T represents temperature [K]. Moreover, the electrical conductivity σ can be determined by “1/ ρ ”, where ρ represents volume resistivity [Ω ·m].

[0084] (Bonding strength)

<Production of bonding layer for evaluation>

A 10 mm × 10 mm × 1 mm copper plate that had been degreased with ethanol and subsequently treated with 10% sulfuric acid and a 2 mm × 2 mm × 0.3 mm Si chip having Au at a rear surface electrode were prepared. Next, a metal mask of 50 μ m in thickness was arranged on the copper plate, and the metal paste for bonding was printed with a size of 2 mm × 2 mm. Next, the Si chip was arranged on the bonding material that had been applied onto the copper plate, and the thickness between the bonding material and the Si chip was adjusted to 13 μ m. Next, a firing furnace was used to raise the temperature from 25°C to 250°C at a heating rate of 3.75°C/min in a nitrogen atmosphere, the temperature was held at 250°C for 60 minutes to perform main firing, and silver in the silver paste was caused to undergo sintering to form a silver bonding layer and thereby bond the Si chip to the copper plate through the silver bonding layer.

[0085] <Shear strength evaluation>

The shear strength of a test specimen obtained as described above was

measured as illustrated in FIG. 1 using a Bondtester SERIES 4000Plus (produced by Nordson Dage).

Specifically, the test specimen is composed of a copper substrate 3, a silver bonding layer 2 that has been formed thereon, and a Si element 1 that is bonded to the copper substrate 3 through the silver bonding layer 2 that has been formed thereon. A shear tool 4 was set at 5 mm/min and was used to apply force from a side surface of the Si element 1 in a horizontal direction relative to the copper substrate 3. The force at which breaking occurred was divided by the area of the bottom surface of the Si element to determine the shear strength of the test specimen, and this shear strength was taken to be the bonding strength of the silver bonding layer. Note that this test was performed such that a lower end of the shear tool 4 came into contact at a position at a height of 50 μm from the copper substrate 3.

The bonding strength was evaluated for Example 1 and the subsequently described Comparative Examples 1 and 2 as representative examples. The results are shown in Table 3.

[0086] (Example 2)

A silver powder (mixed silver powder) according to Example 2 was obtained in the same way as in Example 1 with the exception that the mass ratio of the first silver powder and the second silver powder was changed to 30:70 (first silver powder:second silver powder). Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Example 2 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Example 2 is illustrated in FIG. 3, and an SEM photograph ($\times 2,000$) of the silver powder according to Example 2 is presented in FIG. 16.

[0087] (Example 3)

A silver powder (mixed silver powder) according to Example 3 was obtained by mixing and stirring the spherical silver powder A, which corresponds to a first silver powder, and the flake-like silver powder A, which corresponds to a second silver powder, using a sample mill (SK-M10 produced by Kyoritsu Riko) for 1.5 minutes such that the mass ratio thereof was 70:30 (first silver powder:second silver powder) and the total amount thereof was 120 g, and subsequently performing sifting using a sieve with an opening size of 40 μm in order to remove coarse particles. Details of first and second silver

powders, etc. are shown in Table 2.

The silver powder according to Example 3 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Example 3 is illustrated in FIG. 4, and an SEM photograph ($\times 2,000$) of the silver powder according to Example 3 is presented in FIG. 17.

[0088] (Example 4)

A silver powder (mixed silver powder) according to Example 4 was obtained in the same way as in Example 3 with the exception that the mass ratio of the first silver powder and the second silver powder was changed to 20:80 (first silver powder:second silver powder). Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Example 4 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Example 4 is illustrated in FIG. 5, and an SEM photograph ($\times 2,000$) of the silver powder according to Example 4 is presented in FIG. 18.

[0089] (Example 5)

A silver powder (mixed silver powder) according to Example 5 was obtained in the same way as in Example 3 with the exception that the mass ratio of the first silver powder and the second silver powder was changed to 80:20 (first silver powder:second silver powder). Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Example 5 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Example 5 is illustrated in FIG. 6, and an SEM photograph ($\times 2,000$) of the silver powder according to Example 5 is presented in FIG. 19.

[0090] (Comparative Example 1)

The flake-like silver powder A was used by itself to perform various measurements and evaluations. Details of first and second silver powders, etc. are shown in Table 2, and the results of various measurements and evaluations are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Comparative Example 1 is illustrated in FIG. 24.

[0091] (Comparative Example 2)

The flake-like silver powder B was used by itself to perform various

measurements and evaluations. Details of first and second silver powders, etc. are shown in Table 2, and the results of various measurements and evaluations are shown in Table 3. Moreover, a particle size distribution of the silver powder according to Comparative Example 2 is illustrated in FIG. 25.

5 **[0092]** (Comparative Example 3)

The spherical silver powder A was used by itself to perform various measurements and evaluations. Details of first and second silver powders, etc. are shown in Table 2, and the results of various measurements and evaluations are shown in Table 3. Moreover, a particle size distribution of the silver powder
10 according to Comparative Example 3 is illustrated in FIG. 26.

[0093] (Comparative Example 4)

A silver powder (mixed silver powder) according to Comparative Example 4 was obtained by mixing and stirring the spherical silver powder A, which corresponds to a first silver powder, and the flake-like silver powder B,
15 which corresponds to a second silver powder, using a coffee mill (Melitta Electric Coffee Mill ECG-62 produced by Melitta Japan Ltd.) for 40 seconds such that the mass ratio thereof was 20:80 (first silver powder:second silver powder) and the total amount thereof was 50 g. Note that the difference ($d_{S2} - d_{S1}$) between d_{S2} of the flake-like silver powder B, which corresponds to a
20 second silver powder, and d_{S1} of the spherical silver powder A, which corresponds to a first silver powder, is 2.2 μm . Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Comparative Example 4 was used to perform various measurements and evaluations. The results are shown in Table
25 3. Moreover, an SEM photograph ($\times 2,000$) of the silver powder according to Comparative Example 4 is presented in FIG. 20, and a particle size distribution of the silver powder according to Comparative Example 4 is illustrated in FIG.
27.

[0094] (Comparative Example 5)

30 A silver powder (mixed silver powder) according to Comparative Example 5 was obtained by mixing and stirring the spherical silver powder A, which corresponds to a first silver powder, and the flake-like silver powder C, which corresponds to a second silver powder, using a coffee mill (Melitta Electric Coffee Mill ECG-62 produced by Melitta Japan Ltd.) for 40 seconds
35 such that the mass ratio thereof was 30:70 (first silver powder:second silver powder) and the total amount thereof was 50 g. Note that the difference ($d_{S2} -$

d_{s1}) between d_{s2} of the flake-like silver powder C, which corresponds to a second silver powder, and d_{s1} of the spherical silver powder A, which corresponds to a first silver powder, is 4.2 μm . Details of first and second silver powders, etc. are shown in Table 2.

5 The silver powder according to Comparative Example 5 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, an SEM photograph ($\times 2,000$) of the silver powder according to Comparative Example 5 is presented in FIG. 21, and a particle size distribution of the silver powder according to Comparative Example 5 is illustrated in FIG.
10 28.

[0095] (Comparative Example 6)

A silver powder (mixed silver powder) according to Comparative Example 6 was obtained by mixing and stirring the spherical silver powder B, which corresponds to a first silver powder, and the flake-like silver powder D,
15 which corresponds to a second silver powder, using a sample mill (SK-M10 produced by Kyoritsu Riko) for 1.5 minutes such that the mass ratio thereof was 30:70 (first silver powder:second silver powder) and the total amount thereof was 120 g, and subsequently performing sifting using a sieve with an opening size of 40 μm in order to remove coarse particles. Note that the
20 difference ($d_{s2} - d_{s1}$) between d_{s2} of the flake-like silver powder D, which corresponds to a second silver powder, and d_{s1} of the spherical silver powder B, which corresponds to a first silver powder, is 0.0 μm . Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Comparative Example 6 was used to perform various measurements and evaluations. The results are shown in Table
25 3. Moreover, an SEM photograph ($\times 2,000$) of the silver powder according to Comparative Example 6 is presented in FIG. 22, and a particle size distribution of the silver powder according to Comparative Example 6 is illustrated in FIG.
29.

30 **[0096]** (Comparative Example 7)

A silver powder (mixed silver powder) according to Comparative Example 7 was obtained by mixing and stirring the spherical silver powder B, which corresponds to a first silver powder, and the flake-like silver powder E, which corresponds to a second silver powder, using a sample mill (SK-M10
35 produced by Kyoritsu Riko) for 1.5 minutes such that the mass ratio thereof was 30:70 (first silver powder:second silver powder) and the total amount

thereof was 120 g, and subsequently performing sifting using a sieve with an opening size of 40 μm in order to remove coarse particles. Note that the difference ($d_{S2} - d_{S1}$) between d_{S2} of the flake-like silver powder E, which corresponds to a second silver powder, and d_{S1} of the spherical silver powder
5 B, which corresponds to a first silver powder, is 0.9 μm . Details of first and second silver powders, etc. are shown in Table 2.

The silver powder according to Comparative Example 7 was used to perform various measurements and evaluations. The results are shown in Table 3. Moreover, an SEM photograph ($\times 2,000$) of the silver powder according to
10 Comparative Example 7 is presented in FIG. 23, and a particle size distribution of the silver powder according to Comparative Example 7 is illustrated in FIG. 30.

[0097] [Table 2]

	First silver powder			Second silver powder			Particle diameter difference ($d_{s2} - d_{s1}$) [μm]	First silver powder:Second silver powder (mass ratio)	
	Type	d_{s1} [μm]	D_{94} [μm]	Type	d_{s2} [μm]	D_6 [μm]			
Example	1	Spherical silver powder A	0.8	1.7	Flake-like silver powder A	8.5	2.1	7.7	50:50
	2	Spherical silver powder A	0.8	1.7	Flake-like silver powder A	8.5	2.1	7.7	30:70
	3	Spherical silver powder A	0.8	1.7	Flake-like silver powder A	8.5	2.1	7.7	70:30
	4	Spherical silver powder A	0.8	1.7	Flake-like silver powder A	8.5	2.1	7.7	20:80
	5	Spherical silver powder A	0.8	1.7	Flake-like silver powder A	8.5	2.1	7.7	80:20
Comparative Example	1	Flake-like silver powder A	8.5	15.1	-	-	-	-	-
	2	Flake-like silver powder B	3.0	6.8	-	-	-	-	-
	3	Spherical silver powder A	0.8	1.7	-	-	-	-	-
	4	Spherical silver powder A	0.8	1.7	Flake-like silver powder B	3.0	0.6	2.2	20:80
	5	Spherical silver powder A	0.8	1.7	Flake-like silver powder C	5.0	1.1	4.2	30:70
	6	Spherical silver powder B	3.0	5.3	Flake-like silver powder D	3.0	1.1	0.0	30:70
	7	Spherical silver powder B	3.0	5.3	Flake-like silver powder E	3.9	1.6	0.9	30:70

[0098] [Table 3]

	BET [m ² /g]	Peak data												TAP [g/cm ³]	lg-loss/ BET	Evaluation results		
		D ₁₀ [μm]	D ₅₀ [μm]	D ₉₀ [μm]	(D ₉₀ – D ₁₀)/ D ₅₀	Number of peaks [peaks]	First peak		Second peak		Particle diameter difference (d _{M2} – d _{M1}) [μm]	Volume distribution proportion A [%]	Volume distribution proportion B [%]					Volume distribution proportion A/ Volume distribution proportion B
							Particle diameter d _{M1} [μm]	Volume distribution proportion [%]	Particle diameter d _{M2} [μm]	Volume distribution proportion [%]								
Example	1	0.78	0.7	4.2	11.8	2.7	1.1	2.6	7.8	4.2	6.7	2.6	1.4	1.8	5.9	0.49	177	11.0
	2	0.69	0.8	5.3	11.5	2.0	1.1	1.7	8.5	5.5	7.4	1.7	1.4	1.3	6.1	0.51	176	-
	3	0.87	0.5	1.3	9.2	6.8	1.0	4.5	7.8	2.6	6.8	2.6	0.9	2.8	5.2	0.45	143	-
	4	0.65	0.9	5.6	11.4	1.9	1.0	1.3	7.8	5.7	6.8	1.3	1.0	1.3	5.8	0.57	160	-
	5	0.92	0.4	1.1	8.4	7.2	1.1	5.3	7.8	1.8	6.7	1.8	0.8	2.3	5.2	0.41	160	-
Comparative Example	1	0.60	2.6	6.7	13.0	1.6	1	8.5	6.3	-	-	-	-	-	5.3	0.57	17	0.0
	2	1.41	0.8	2.2	5.6	2.2	1	3.0	4.4	-	-	-	-	-	3.1	0.48	69	4.1
	3	0.99	0.3	0.7	1.4	1.6	1	0.8	6.6	-	-	-	-	-	4.9	0.36	70	-
	4	1.53	0.7	1.7	4.6	2.3	2	1.4	4.3	4.0	1.1	4.0	4.0	1.0	3.2	0.41	113	-
	5	1.72	1.0	2.8	6.6	2.0	1	3.3	4.9	-	-	-	-	-	2.3	3.00	23	-
	6	0.33	1.4	3.1	7.7	2.0	1	3.0	5.9	-	-	-	-	-	5.2	0.90	109	-
	7	0.53	1.2	2.7	6.3	1.8	1	2.8	6.7	-	-	-	-	-	5.6	1.12	82	-

[0099] As can clearly be seen from Table 3, high thermal conductivity can be imparted to a metal bonding layer by the silver powders (mixed silver powders) of Examples 1 to 5 for which, in a particle size distribution, the particle size distribution includes a first peak and a second peak that each have a volume distribution proportion of 1% or more, a relationship between a particle diameter d_{M1} of the first peak and a particle diameter d_{M2} of the second peak satisfies formula (I) and formula (II), shown below:

$$d_{M1} < d_{M2} \cdots (I)$$

$$4.5 \mu\text{m} \leq d_{M2} - d_{M1} \leq 16.0 \mu\text{m} \cdots (II)$$

and a relationship between a volume distribution proportion A of whichever of the first peak and the second peak has a smaller volume distribution proportion and a volume distribution proportion B that is a minimum volume distribution proportion between the first peak and the second peak satisfies formula (III) or formula (IV), shown below:

$$1.2 \leq A/B \cdots (III)$$

$$0 = B/A \cdots (IV).$$

[0100] It can also clearly be seen from Table 3 that a mixed silver that can impart high thermal conductivity to a metal bonding layer can be obtained through the production methods of Examples 1 to 5, which are each a method of producing a mixed silver powder including a mixing step of mixing a first silver powder and a second silver powder, wherein, in particle size distributions of the first silver powder and the second silver powder, a relationship between a particle diameter d_{S1} of a peak where volume distribution proportion is at a maximum for the first silver powder and a particle diameter d_{S2} of a peak where volume distribution proportion is at a maximum for the second silver powder satisfies formula (i) and formula (ii), shown below:

$$d_{S1} < d_{S2} \cdots (i)$$

$$4.6 \mu\text{m} \leq d_{S2} - d_{S1} \leq 16.0 \mu\text{m} \cdots (ii)$$

and a relationship between a 94th percentile diameter D_{94} of the first silver powder and a 6th percentile diameter D_6 of the second silver powder satisfies formula (iii), shown below:

$$D_{94} \leq D_6 \cdots (iii).$$

INDUSTRIAL APPLICABILITY

[0101] According to the present disclosure, it is possible to provide a mixed

silver powder that can impart high thermal conductivity to a metal bonding layer, a method of producing this mixed silver powder, and a metal paste for bonding containing this mixed silver powder.

5 REFERENCE SIGNS LIST

- [0102]** 1 Si element
2 silver bonding layer
3 copper substrate
4 shear tool

CLAIMS

- [Claim 1] A mixed silver powder for which, in a particle size distribution with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis that is determined through wet measurement using a laser diffraction particle size distribution measurement instrument,
- 5 the particle size distribution includes a first peak and a second peak that each have a volume distribution proportion of 1% or more,
- a relationship between a particle diameter d_{M1} of the first peak and a particle diameter d_{M2} of the second peak satisfies formula (I) and formula (II),
- 10 shown below:
- $$d_{M1} < d_{M2} \cdots (I)$$
- $$4.5 \mu\text{m} \leq d_{M2} - d_{M1} \leq 16.0 \mu\text{m} \cdots (II)$$
- and a relationship between a volume distribution proportion A of
- 15 whichever of the first peak and the second peak has a smaller volume distribution proportion and a volume distribution proportion B that is a minimum volume distribution proportion between the first peak and the second peak satisfies formula (III) or formula (IV), shown below:
- $$1.2 \leq A/B \cdots (III)$$
- 20
$$0 = B/A \cdots (IV).$$
- [Claim 2] The mixed silver powder according to claim 1, wherein more than 50% of the volume distribution proportion of the first peak originates from a spherical silver powder, and more than 50% of the volume distribution
- 25 proportion of the second peak originates from a flake-like silver powder.
- [Claim 3] The mixed silver powder according to claim 1, wherein
- d_{M1} is not less than $0.5 \mu\text{m}$ and not more than $1.5 \mu\text{m}$, and
- d_{M2} is not less than $5.0 \mu\text{m}$ and not more than $17.5 \mu\text{m}$.
- 30
- [Claim 4] The mixed silver powder according to claim 1, wherein a ratio of ignition loss relative to BET specific surface area of the mixed silver powder is 0.65 or less.
- 35 [Claim 5] The mixed silver powder according to claim 1, wherein the mixed silver powder has a tap density of 3.5 g/cm^3 or more.

[Claim 6] A method of producing a mixed silver powder comprising a mixing step of mixing a first silver powder and a second silver powder, wherein, in particle size distributions with volume distribution proportion on a vertical axis and particle diameter on a horizontal axis that are respectively determined through wet measurement of the first silver powder and the second silver powder using a laser diffraction particle size distribution measurement instrument,

a relationship between a particle diameter d_{s1} of a peak where volume distribution proportion is at a maximum for the first silver powder and a particle diameter d_{s2} of a peak where volume distribution proportion is at a maximum for the second silver powder satisfies formula (i) and formula (ii), shown below:

$$d_{s1} < d_{s2} \cdots (i)$$

$$4.6 \mu\text{m} \leq d_{s2} - d_{s1} \leq 16.0 \mu\text{m} \cdots (ii)$$

and a relationship between a 94th percentile diameter D_{94} of the first silver powder and a 6th percentile diameter D_6 of the second silver powder satisfies formula (iii), shown below:

$$D_{94} \leq D_6 \cdots (iii).$$

[Claim 7] The method of producing a mixed silver powder according to claim 6, wherein the first silver powder is a spherical silver powder, and the second silver powder is a flake-like silver powder.

[Claim 8] The method of producing a mixed silver powder according to claim 7, wherein

the spherical silver powder has a 50th percentile diameter D_{50} of not less than 0.5 μm and not more than 1.5 μm , a tap density of 2.0 g/cm^3 or more, and a BET specific surface area of not less than 0.6 m^2/g and not more than 2.2 m^2/g , and

the flake-like silver powder has a 50th percentile diameter D_{50} of not less than 5.0 μm and not more than 17.5 μm , a tap density of 2.0 g/cm^3 or more, a BET specific surface area of not less than 0.2 m^2/g and not more than 2.0 m^2/g , and an aspect ratio of 3 or more.

[Claim 9] A metal paste for bonding comprising the mixed silver powder

according to any one of claims 1 to 5.