

SOLDER PASTE FOR BALL GRID ARRAY

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BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The present invention relates to a bump-forming solder paste for ball grid array, and a ball grid array in which bumps have been formed using the said solder paste.

10 2. Description of the Related Art

Following the introduction in recent years of LSIs with larger sizes and higher speeds, semiconductor packages have come to have an increased number of leads and narrower lead pitch. Although 0.5 mm-pitch-mounted quad flat packages (QFPs) are manufactured in volume, it is feared that 0.4 mm- and 0.3 mm-pitch-mounting will increase costs due to lead distortion and defective soldering, such as unsoldered leads and bridging between leads caused by the narrow pitch.

20 Thus ball grid arrays (BGA) 3 have been developed. BGA is a surface-mounting type semiconductor package as shown in Fig. 1 where spherical solder bumps are formed on substrates of various kinds. Since the leads of spherical solder (spherical solder bumps 2) are arrayed in two dimensions on a substrate 1, it provides wider lead pitch as compared with QFP packages and obviates solder ball distortion. Thus soldering defects during volume production are expected to decrease drastically as compared with QFP.

30 Currently, spherical solder bumps for BGA are formed by soldering prearranged solder balls onto pads on a substrate. However, it is difficult to prevent dislocation of solder balls after they are supplied to specified positions. Also, the process requires a large amount of special jigs and involves a high production cost owing to expensive solder balls.

35

Against this background, a new process is now

increasingly used where spherical solder bumps are formed on a BGA substrate by printing and reflowing solder paste. In this process, solder bumps can be formed by solder paste printing and reflowing processes which have already been employed in surface mounting. Thus conventional printing machines and reflow furnaces can be used and no special equipment or jig is necessary. Also, solder paste is less expensive than solder balls. The new process is therefore expected to result in lower production cost.

However, under the above-mentioned process of forming spherical solder bumps on a BGA substrate by printing and reflowing conventional solder paste, a defect unique to BGA occurs where some of the balls are formed outside the specified pad positions.

The present invention relates to a bump-forming solder paste for ball grid arrays involving no defect when spherical solder bumps are formed on a substrate by printing and reflowing the solder paste, and a ball grid array in which bumps have been formed using the said solder paste.

SUMMARY OF THE INVENTION

The inventors of the present invention have conducted extensive research concerning solder paste that will not give rise to defects unique to ball grid array such as dislocation of balls formed by printing and reflowing solder paste. As a result, the inventors have found that the use of a solder paste of the present invention obviates the defects.

That is, the present invention provides a bump-forming solder paste for a ball grid array comprising a mixture of flux and alloy powders containing two or more kinds of solder alloy powders with different compositions, each of said solder powders having a liquidus temperature below the reflow temperature, at least one of said solder alloy powders having a difference of 10°C or more between liquidus and solidus,



the average composition of the alloy powders being 58 - 65% by weight of tin and 35 - 42% by weight of lead, or 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.

5 The present invention also provides a ball array in which bumps have been formed using the solder paste as above.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 is a plan view of an example of ball grid array under the present invention;

Fig. 2 shows a part of A-A' cross section;

Fig. 3 shows an example of a semiconductor package;

Fig. 4 is a sectional view at the time of printing under conventional printing methods;

15 Fig. 5 is a sectional view at the time of printing when BGA bumps are formed by printing; and

Fig. 6 shows a solder ball which has been dislocated.

DETAILED DESCRIPTION OF THE INVENTION

20 In ordinary solder paste printing, as shown in Fig. 4, a solder paste 9 is printed on every pad 8 of a substrate and covers almost the same area. In the case of bump formation for BGA, a bigger volume of solder paste should be supplied since spherical bumps larger
25 than the pads must be formed. Thus, as shown in Fig. 5, it is necessary to print solder paste 9 in a way substantially projecting from a pad 8. After reflow, some of the solder balls are formed out of the positions of pads as shown in Fig. 6: a problem unique to BGA.
30 This phenomenon is considered to be attributable to the fact that, when a solder paste consisting only of an alloy powder with close-to-eutectic composition starts to melt as heated at the outskirts of pads, the unmolten portion of the solder paste remains in the form of solid-
35 phase powder and therefore cannot maintain its shape, meaning that the unmolten portion of the paste is absorbed, as balls are formed, into the liquid portion



that melted first. If the solder paste under the present invention is used, no dislocation of balls occur. It is supposed that, because the said solder paste contains alloy powder with a melting range, the solder paste, when heated from the outside, has a region of coexisting solid and liquid phases and even in the inside of the unmolten portion of the solder paste there is a partial liquid phase, enabling it to maintain the shape owing to surface tension of the said liquid phase and ensuring that balls are formed right on the pads.

Since ball dislocation during formation of BGA bumps with solder paste is considered to occur because of the above-mention mechanism, it is necessary to ensure that at least one alloy powder has a difference between its liquidus and its solidus so as to prevent the said mechanism from working. The difference should be at least 10°C or more, preferably 20°C or more.

Under the present invention, each alloy powder in the solder paste should have a liquidus temperature lower than the reflow temperature. The reason is that if the liquidus temperature is higher than the reflow temperature, an alloying process toward average composition does not proceed smoothly and it becomes necessary to raise the reflow temperature or prolong the reflow time, putting heavy thermal load on semiconductor chips and substrates. Also, alloying is not satisfactorily achieved at an ordinary reflow temperature and time, resulting in insufficient luster of solder and in mechanical strength being lower than that of average-composition solder. Therefore the present invention uses alloy powders having liquidus temperatures lower than the reflow temperatures.

So-called eutectic the solder (average composition: 58 - 65% by weight of tin and 35 - 42% by weight of lead) or so-called silver-containing solder (60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver) is used under the present invention because



both of them give good wettability and high mechanical strength as alloys. These compositions are also commonly used for bonding of electronics parts. The reflow temperature of these types of solder is generally in a range of 210°C to 240°C, particularly around 230°C. In the case of the average composition of 58 - 65% by weight of tin and 35 - 42% by weight of lead, it is desirable to mix an alloy powder containing 45 - 60% by weight of tin and 40 - 55% by weight of lead, and an alloy powder containing 70 - 100% by weight of tin and 0 - 30% by weight of lead, to make a solder composition having liquidus temperature not exceeding reflow temperature and a difference of 10°C or more between liquidus and solidus. In this case, tin can be used alone because its melting point is as low as 232°C.

A more desirable case is a mixture of an alloy powder containing 50 - 60% by weight of tin and 40 - 50% by weight of lead and an alloy powder containing 70 - 85% by weight of tin and 15 - 30% by weight of lead. It is also possible to mix an alloy powder containing 58 - 65% by weight of tin and 35 - 42% by weight of lead with the above mixture of alloy powders. When average composition is adjusted to 60 - 65% by weight of tin, 34 - 38% by weight of lead and 1 - 3% by weight of silver, it is desirable, in view of liquidus temperature, to mix an alloy powder containing 45 - 60% by weight of tin, 40 - 55% by weight of lead and 0 - 3% by weight of silver, and an alloy powder containing 70 - 100% by weight of tin, 0 - 30% by weight of lead, and 0 - 3% by weight of silver. A more desirable case is to mix an alloy powder containing 50 - 60% by weight of tin, 40 - 50% by weight of lead, and 0 - 3% by weight of silver, and an alloy powder containing 70 - 85% by weight of tin, 15 - 30% by weight of lead, and 0 - 3% by weight of silver. It is also possible to further mix with the above mixture an alloy powder containing 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by



weight of silver.

Besides the present invention, other inventions have been disclosed wherein two or more kinds of alloy powders with different compositions are mixed to make a solder paste. (For example, Japanese Unexamined Patent Publication Nos. Hei 3-13952, Sho 57-66993, Sho 63-149094, Sho 63-154288, Hei 1-241395, Hei 1-271094, Hei 1-266987, Hei 2-117794, Hei 2-211995, Hei 4-22595, and Hei 4-29365.)

However, most of them disclose bismuth- or indium-containing low-melting point solder in their working examples that are quite different from the solder compositions of the present invention. Although Japanese Unexamined Patent Publication Sho 63-154288 and Hei 2-117794 include working examples that do not contain bismuth or indium, the liquidus temperature of each solder alloy is higher than the reflow temperature and therefore these inventions are different from the present invention. The other inventions do not contain any description concerning formation of bumps for ball grid arrays.

Moreover, the use of such a solder paste will require higher reflow temperatures and longer reflow times, resulting either in high thermal load on semiconductor chips and substrates or in poor luster, low wettability and insufficient strength due to incomplete alloying. Thus only the solder paste of the present invention can form bumps of high quality for ball grid arrays without defects. Meanwhile, the use of alloy powder with too high a liquidus temperature is disadvantageous in that it requires use of alloy powder having high tin content so as to adjust the average composition. As to this composition, it should be pointed out that atomizing for powder production is a difficult process and resulting solder paste is unstable because the powder surface is active, readily reacting with flux. Any alloy powder used in the present



invention is not particularly limited in terms of its shape and particle size. The shape can be spherical or irregular, and the particle size of approximately 73 μ (200 mesh) or under are to be used.

5 Flux for the solder paste of the present invention comprises a resin, a solvent, a thixotropic agent, an activator, and other additives. The materials are those commonly used as flux for solder paste and there are no particular limitations.

10 Examples of resins used in the said solder paste include rosin such as natural rosin and modified rosin, water-soluble resin and polymer. Examples of solvents include alcohols, glycols and ethers. Examples of thixotropic agents include castor oil, wax, petrochemical
15 polymers, and amides. Examples of activators include monocarboxylic acid, dicarboxylic acid, amines, amides, imides, amine salts, and halides. Examples of other additives include thickening agents, surfactants, fluidity conditioners, corrosion inhibitors and
20 antifoaming agents.

 The weight percent of flux in the said solder paste is not particularly limited. For printing application, however, a range of 9 - 12% by weight is common. The solid content in the flux, such as rosin, is not
25 particularly limited and can be in the wide range of 10 - 70% by weight.

 In accordance with the present invention, the kind of substrate for the ball grid array is not particularly limited. For example, printed circuit board (glass-
30 epoxy, paper-phenol, etc.), flexible board, ceramics board and TAB substrate can be used. A semiconductor chip is bonded to one side for electrical connection with circuit through wire bonding or solder bumps. On the other side, solder pads are set in array. The said
35 solder paste is printed with a printer using stencil or mesh screen and supplied to each pad, and then heated in a reflow furnace for melting. In this way, high-quality



spherical solder bumps can be formed. The atmosphere of the reflow furnace is not particularly limited and air, an inactive atmosphere such as nitrogen, or a reducing atmosphere such as hydrogen and acids, can be used.

5

EXAMPLES

For Examples 1 through 6 and Comparative Examples 1 and 2, solder paste was prepared through kneading at the ratios described below. The solder paste thus obtained was printed and melted through reflow at 230°C, and bumps were formed to produce a BGA. The results are shown in Table 1.

10

Table 1

	Percent defective inspherical bumps (Out of 3,240 positions on one BGA)
Example 1	0.0
15 Example 2	0.0
Example 3	0.0
Example 4	0.0
Example 5	0.0
Example 6	0.0
20 Comparative Example 1	0.8
Comparative Example 2	1.2

25

Example 1

Parts by weight

Alloy powder A (50 wt% Sn - 50 wt% Pb)	60.0
Liquidus temperature 212°C, Solidus temperature 183°C, Size 22 - 53 µm	
30 Alloy powder B (80 wt% Sn - 20 wt% Pb)	30.0
Liquidus temperature 202°C, Solidus temperature 183°C, Size 22 - 53 µm	
Polymerized rosin	3.0
Disproportionated rosin	2.0
35 Diethylene glycol monohexyl ether	3.9



Hydrogenated castor oil	0.5
Cyclohexylamine HBr	0.1
Adipic acid	0.5

Example 2

5		Parts by weight
	Alloy powder C (45 wt% Sn - 55 wt% Pb)	43.0
	Liquidus temp. 202°C, Solidus	
	temp. 183°C, Size 22 - 45 µm	
	Alloy powder B (80 wt% Sn - 20 wt% Pb)	47.0
10	Polymerized rosin	3.0
	Disproportionated rosin	2.2
	Diethylene glycol monobutyl ether	3.9
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
15	Adipic acid	0.3

Example 3

		Parts by weight
	Alloy powder D (55 wt% Sn - 45 wt% Pb)	40.5
	Liquidus temp. 201°C, Solidus	
20	temp. 183°C, Size 22 - 38 µm	
	Alloy powder E (70 wt% Sn - 30 wt% Pb)	40.5
	Liquidus temp. 190°C, Solidus	
	temp. 183°C, Size 22 - 38 µm	
	Alloy powder F (63 wt% Sn - 37 wt% Pb)	9.0
25	Eutectic temp. 183°C, Size 22 - 45 µm	
	Polymerized rosin	2.0
	Disproportionated rosin	1.0
	Propylene glycol monophenyl ether	5.9
	Hydrogenated castor oil	0.7
30	Isopropylamine HBr	0.1
	Succinic acid	0.3

Example 4

		Parts by weight
	Alloy powder G (46 wt% Sn - 51 wt% Pb - 3 wt% Ag)	30.0
35	Liquidus temp. 200°C, Solidus	
	temp. 178°C, Size 10 - 30 µm	
	Alloy powder H (80 wt% Sn - 18 wt% Pb - 2 wt% Ag)	60.0



Liquidus temp. 200°C, Solidus temp. 178°C,

Size 10 - 30 μ m

	Polymerized rosin	3.4
	Disproportionated rosin	3.0
5	α -terpineol	2.5
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
	Lauric acid	0.5

Example 5

10		Parts by weight
	Alloy powder I (50 wt% Sn - 48 wt% Pb - 2 wt% Ag)	45.0
	Liquidus temp. 210°C, Solidus temp. 178°C,	
	Size 22 - 45 μ m	
	Alloy powder H (80 wt% Sn - 18 wt% Pb - 2 wt% Ag)	45.0
15	Polymerized rosin	2.4
	Disproportionated rosin	2.4
	α -terpineol	4.1
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
20	Lauric acid	0.5

Example 6

		Parts by weight
	Alloy powder J (55 wt% Sn - 43 wt% Pb - 2 wt% Ag)	35.0
	Liquidus temp. 199°C, Solidus temp. 178°C,	
25	Size 22 - 45 μ m	
	Alloy powder K (70 wt% Sn - 28 wt% Pb - 2 wt% Ag)	35.0
	Liquidus temp. 200°C, Solidus temp. 178°C,	
	Size 22 - 45 μ m	
	Alloy powder L (62wt% Sn - 36 wt% Pb - 2wt% Ag)	20.0
30	Eutectic temp. 178°C, Size 22 - 45 μ m	
	Hydrogenated rosin	6.0
	Diethylene glycol monobutyl ether	2.9
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
35	Caprylic acid	0.5

Comparative Example 1

Parts by weight

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	Alloy powder F (63 wt% Sn - 37 wt% Pb)	90.0
	Hydrogenated rosin	6.0
	α -terpineol	2.9
	Hydrogenated castor oil	0.5
5	Cyclohexylamine HBr	0.1
	Succinic acid	0.5

Comparative Example 2

		Parts by weight
	Alloy powder L (62 wt% Sn - 36 wt% Pb - 2 wt% Ag)	90.0
10	Polymerized rosin	2.0
	Disproportionated rosin	4.0
	Diethylene glycol monohexyl ether	2.9
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
15	Adipic acid	0.5

As seen from the above explanation, high-quality bumps for ball grid array can be formed with high yield by the use of solder paste produced by kneading of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of the alloy powder having liquidus temperature below reflow temperature, at least one of the alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powder being 58 - 65% by weight of tin and 35 - 42% by weight of lead, or 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.

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CLAIMS

1. A bump-forming solder paste for a ball grid array comprising a mixture of flux and alloy powders comprising two or more kinds of alloy powders with
5 different compositions, each of said alloy powders having liquidus temperature below a reflow temperature, at least one of said alloy powders having a difference of 10°C or more between liquidus and solidus, the average
composition of the entire alloy powders being 58 - 65% by
10 weight of tin and 35 - 42% by weight of lead.

2. The bump-forming solder paste for a ball grid array according to Claim 1, wherein said mixture of alloy powders comprises an alloy powder containing 45 - 60% by weight of tin and 40 - 55% by weight of lead and an alloy
15 powder containing 70 - 100% by weight of tin and 0 - 30% by weight of lead.

3. The bump-forming solder paste for a ball grid array according to Claim 1, wherein said mixture of alloy powders comprises an alloy powder containing 50 - 60% by weight of tin and 40 - 50% by weight of lead and an alloy
20 powder containing 70 - 85% by weight of tin and 15 - 30% by weight of lead.

4. The bump-forming solder paste for a ball grid array according to Claim 1, wherein said mixture of alloy
25 powders comprises an alloy powder containing 45 - 60% by weight of tin and 40 - 55% by weight of lead, an alloy powder containing 70 - 100% by weight of tin and 0 - 30% by weight of lead, and an alloy powder containing
58 - 65% by weight of tin and 35 - 42% by weight of lead.

30 5. The bump-forming solder paste for a ball grid array according to Claim 1, wherein said mixture of alloy powders comprises an alloy powder containing 50 - 60% by weight of tin and 40 - 50% by weight of lead, an alloy powder containing 70 - 85% by weight of tin and 15 - 30%
35 by weight of lead, and an alloy powder containing 58 - 65% by weight of tin and 35 - 42% by weight of lead.

6. The bump-forming solder paste for a ball grid





array according to any one of Claims 1 to 5 wherein said reflow temperature is in a range of 210°C to 240°C.

5 7. The bump-forming solder paste for a ball grid array according to Claim 6 wherein said reflow temperature is about 230°C.

10 8. A bump-forming solder paste for a ball grid array, comprising a mixture of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of said alloy powders having
15 liquidus temperature below reflow temperature, at least one of said alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powder being 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.

20 9. The bump-forming solder paste for a ball grid array according to Claim 8 wherein said mixture of alloy powders comprises an alloy powder containing 45 - 60% by weight of tin, 40 - 55% by weight of lead and 0 - 3% by weight of silver and an alloy powder containing 70 - 100% by weight of tin, 0 - 30% by weight of lead and 0 - 3% by weight of silver.

25 10. The bump-forming solder paste for a ball grid array according to Claim 8 wherein said mixture of alloy powders comprises an alloy powder containing 50 - 60% by weight of tin, 40 - 50% by weight of lead and 0 - 3% by weight of silver and an alloy powder containing 70 - 85% by weight of tin, 15 - 30% by weight of lead and 0 - 3% by weight of silver.

30 11. The bump-forming solder paste for a ball grid array according to Claim 8 wherein said mixture of alloy powders comprises an alloy powder containing 45 - 60% by weight of tin, 40 - 55% by weight of lead and 0 - 3% by weight of silver and an alloy powder containing 70 - 100%
35 by weight of tin, 0 - 30% by weight of lead and 0 - 3% by weight of silver and an alloy powder containing 60 - 65% weight of tin 34 - 38% weight of lead and 1 - 3% weight





of silver.

12. The bump-forming solder paste for a ball grid array according to Claim 8 wherein said mixture of alloy powders comprises an alloy powder containing 50 - 60% by weight of tin, 40 - 50% by weight of lead and 0 - 3% by weight of silver, an alloy powder containing 70 - 85% by weight of tin, 15 - 30% by weight of lead and 0 - 3% by weight of silver, and an alloy powder containing 60 - 65% by weight of tin, 34 - 38% by weight of lead and 1 - 3% by weight of silver.

13. The bump-forming solder paste for a ball grid array according to any one of claims 8 to 12 wherein said reflow temperature is in a range of 210°C to 240°C.

14. The bump-forming solder paste for a ball grid array according to claim 13 wherein said reflow temperature is about 230°C.

15. A ball grid array in which bumps have been formed using any one of the solder pastes described in Claim 1 through Claim 14.

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SOLDER PASTE FOR BALL GRID ARRAY

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ABSTRACT OF THE DISCLOSURE

High-quality bumps for a ball grid array can be formed with high yield by the use of solder paste
10 produced by kneading of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of the alloy powder having liquidus temperature below reflow temperature, at least one of the alloy powders having a difference of 10°C or more between
15 liquidus and solidus, the average composition of the entire alloy powder being 58 - 65% by weight of tin and 35 - 42% by weight of lead, or 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.

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1/3

Fig.1

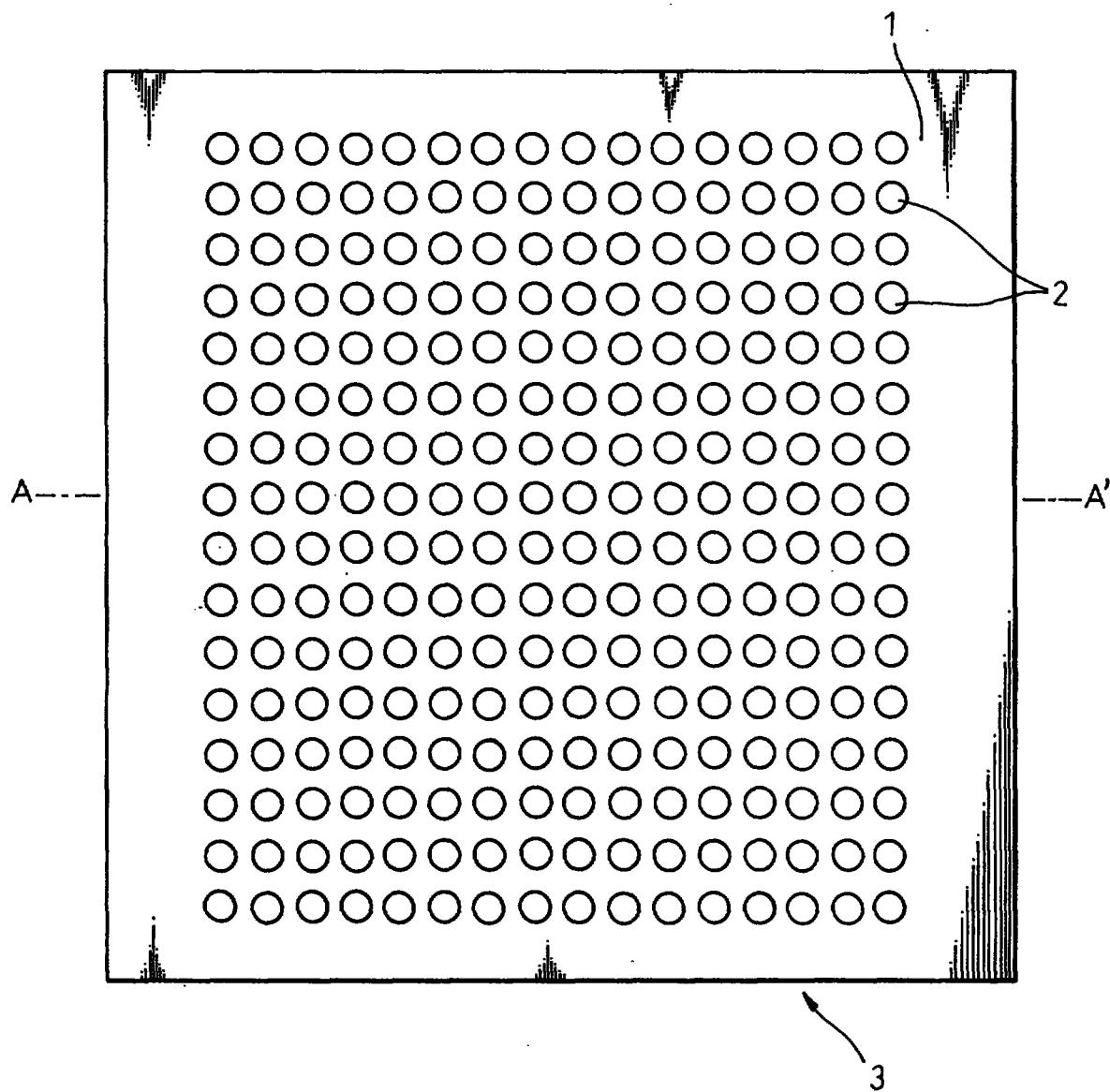


Fig.2

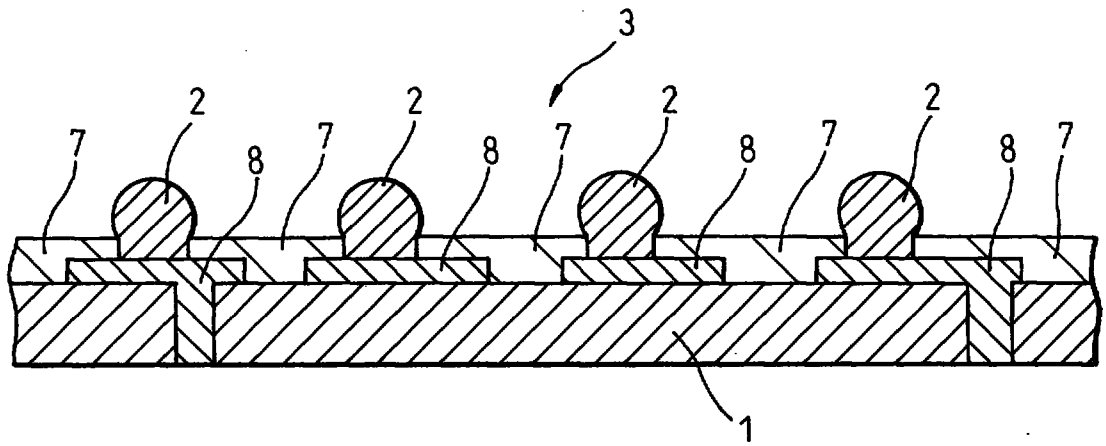


Fig.3

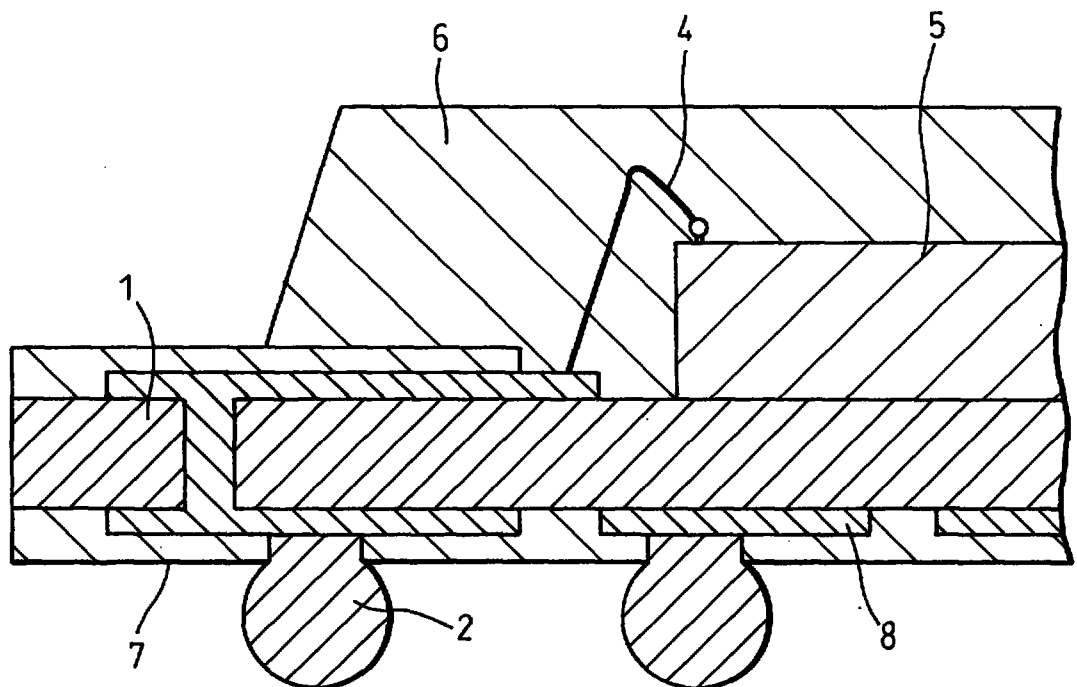


Fig. 4

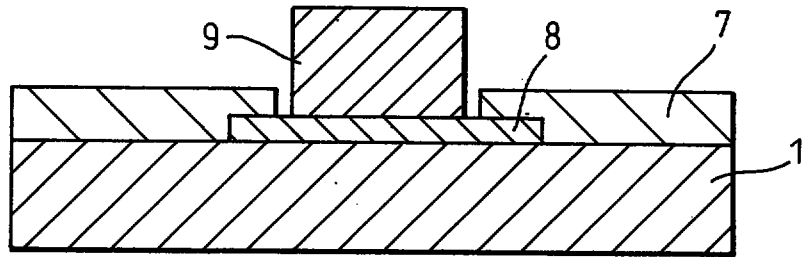


Fig. 5

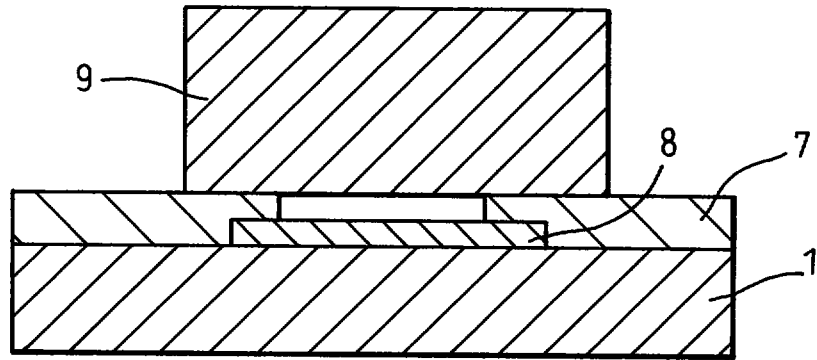
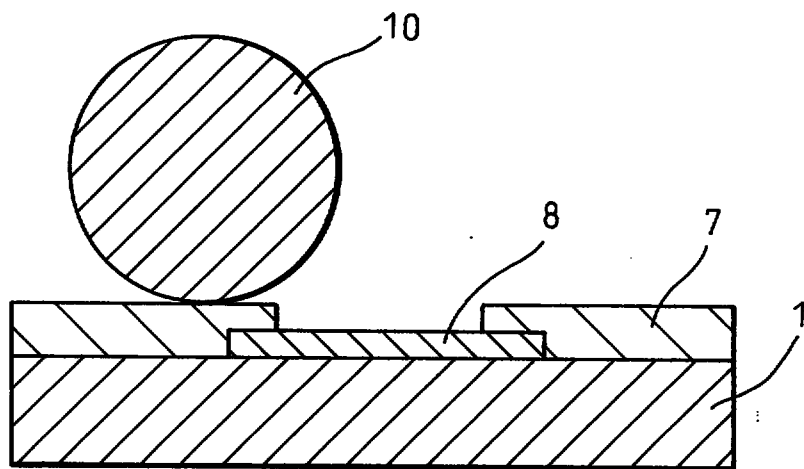


Fig. 6



SOLDER PASTE FOR BALL GRID ARRAY

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The present invention relates to a bump-forming solder paste for ball grid array, and a ball grid array in which bumps have been formed using the said solder paste.

10 2. Description of the Related Art

Following the introduction in recent years of LSIs with larger sizes and higher speeds, semiconductor packages have come to have an increased number of leads and narrower lead pitch. Although 0.5 mm-pitch-mounted quad flat packages (QFPs) are manufactured in volume, it is feared that 0.4 mm- and 0.3 mm-pitch-mounting will increase costs due to lead distortion and defective soldering, such as unsoldered leads and bridging between leads caused by the narrow pitch.

20 Thus ball grid arrays (BGA) 3 have been developed. BGA is a surface-mounting type semiconductor package as shown in Fig. 1 where spherical solder bumps are formed on substrates of various kinds. Since the leads of spherical solder (spherical solder bumps 2) are arrayed in two dimensions on a substrate 1, it provides wider lead pitch as compared with QFP packages and obviates solder ball distortion. Thus soldering defects during volume production are expected to decrease drastically as compared with QFP.

30 Currently, spherical solder bumps for BGA are formed by soldering prearranged solder balls onto pads on a substrate. However, it is difficult to prevent dislocation of solder balls after they are supplied to specified positions. Also, the process requires a large amount of special jigs and involves a high production cost owing to expensive solder balls.

Against this background, a new process is now

Date 3.0 DEC 1996

- 2 -

increasingly used where spherical solder bumps are formed on a BGA substrate by printing and reflowing solder paste. In this process, solder bumps can be formed by solder paste printing and reflowing processes which have already been employed in surface mounting. Thus conventional printing machines and reflow furnaces can be used and no special equipment or jig is necessary. Also, solder paste is less expensive than solder balls. The new process is therefore expected to result in lower production cost.

However, under the above-mentioned process of forming spherical solder bumps on a BGA substrate by printing and reflowing conventional solder paste, a defect unique to BGA occurs where some of the balls are formed outside the specified pad positions.

The present invention relates to a bump-forming solder paste for ball grid arrays involving no defect when spherical solder bumps are formed on a substrate by printing and reflowing the solder paste, and a ball grid array in which bumps have been formed using the said solder paste.

SUMMARY OF THE INVENTION

The inventors of the present invention have conducted extensive research concerning solder paste that will not give rise to defects unique to ball grid array such as dislocation of balls formed by printing and reflowing solder paste. As a result, the inventors have found that the use of a solder paste of the present invention obviates the defects.

That is, the present invention provides a bump-forming solder paste for a ball grid array comprising a mixture of flux and alloy powders containing two or more kinds of solder alloy powders with different compositions, wherein said mixture of alloy powders is comprised of one or more alloy powders containing 50 - 60% by weight of tin and 40 - 50% by weight of lead and one or more alloy powders containing 70 - 85% by

REPLACEMENT SHEET

Date: 30 DEC 1996

- 3 -

weight of tin and 15 - 30% by weight of lead, each of
said solder powders having a liquidus temperature below
the reflow temperature, at least one of said solder alloy
powders having a difference of 10°C or more between
5 liquidus and solidus, the average composition of the
alloy powders being 58 - 65% by weight of tin and
35 - 42% by weight of lead, or a bump-forming solder
paste for a ball grid array, comprising a mixture of flux
and alloy powders comprising two or more kinds of alloy
10 powders with different compositions, each of said alloy
powders having liquidus temperature below reflow
temperature, at least one of said alloy powders having a
difference of 10°C or more between liquidus and solidus,
the average composition of the entire alloy powder being
15 60 - 65% by weight of tin, 34 - 38% by weight of lead,
and 1 - 3% by weight of silver.

The present invention also provides a ball array in
which bumps have been formed using the solder paste as
above.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of an example of ball grid
array under the present invention;

Fig. 2 shows a part of A-A' cross section;

Fig. 3 shows an example of a semiconductor package;

25 Fig. 4 is a sectional view at the time of printing
under conventional printing methods;

Fig. 5 is a sectional view at the time of printing
when BGA bumps are formed by printing; and

30 Fig. 6 shows a solder ball which has been
dislocated.

DETAILED DESCRIPTION OF THE INVENTION

In ordinary solder paste printing, as shown in
Fig. 4, a solder paste 9 is printed on every pad 8 of a
substrate and covers almost the same area. In the case
35 of bump formation for BGA, a bigger volume of solder
paste should be supplied since spherical bumps larger
than the pads must be formed. Thus, as shown in Fig. 5,

30 DEC 1996

Date :

- 4 -

it is necessary to print solder paste 9 in a way substantially projecting from a pad 8. After reflow, some of the solder balls are formed out of the positions of pads as shown in Fig. 6: a problem unique to BGA.

5 This phenomenon is considered to be attributable to the fact that, when a solder paste consisting only of an alloy powder with close-to-eutectic composition starts to melt as heated at the outskirts of pads, the unmolten portion of the solder paste remains in the form of solid-
10 phase powder and therefore cannot maintain its shape, meaning that the unmolten portion of the paste is absorbed, as balls are formed, into the liquid portion that melted first. If the solder paste under the present invention is used, no dislocation of balls occur. It is
15 supposed that, because the said solder paste contains alloy powder with a melting range, the solder paste, when heated from the outside, has a region of coexisting solid and liquid phases and even in the inside of the unmolten portion of the solder paste there is a partial liquid
20 phase, enabling it to maintain the shape owing to surface tension of the said liquid phase and ensuring that balls are formed right on the pads.

Since ball dislocation during formation of BGA bumps with solder paste is considered to occur because of the
25 above-mentioned mechanism, it is necessary to ensure that at least one alloy powder has a difference between its liquidus and its solidus so as to prevent the said mechanism from working. The difference should be at least 10°C or more, preferably 20°C or more.

30 Under the present invention, each alloy powder in the solder paste should have a liquidus temperature lower than the reflow temperature. The reason is that if the liquidus temperature is higher than the reflow temperature, an alloying process toward average
35 composition does not proceed smoothly and it becomes necessary to raise the reflow temperature or prolong the reflow time, putting heavy thermal load on semiconductor

REPLACEMENT SHEET

Date 3.0 DEC 1996

- 5 -

chips and substrates. Also, alloying is not satisfactorily achieved at an ordinary reflow temperature and time, resulting in insufficient luster of solder and in mechanical strength being lower than that of average-composition solder. Therefore the present invention uses alloy powders having liquidus temperatures lower than the reflow temperatures.

So-called eutectic the solder (average composition: 58 - 65% by weight of tin and 35 - 42% by weight of lead) or so-called silver-containing solder (60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver) is used under the present invention because both of them give good wettability and high mechanical strength as alloys. These compositions are also commonly used for bonding of electronics parts. The reflow temperature of these types of solder is generally in a range of 210°C to 240°C, particularly around 230°C. In the case of the average composition of 58 - 65% by weight of tin and 35 - 42% by weight of lead, it is desirable to mix one or more alloy powders containing 50 - 60% by weight of tin and 40 - 50% by weight of lead, and one or more alloy powders containing 70 - 85% by weight of tin and 15 - 30% by weight of lead, to make a solder composition having liquidus temperature not exceeding reflow temperature and a difference of 10°C or more between liquidus and solidus. In this case, tin can be used alone because its melting point is as low as 232°C.

When average composition is adjusted to 60 - 65% by weight of tin, 34 - 38% by weight of lead and 1 - 3% by weight of silver, it is desirable, in view of liquidus temperature, to mix one or more alloy powders containing 45 - 60% by weight of tin, 40 - 55% by weight of lead and 0 - 3% by weight of silver, and one or more alloy powders containing 70 - 100% by weight of tin, 0 - 30% by weight of lead, and 0 - 3% by weight of silver. A more desirable case is to mix one or more alloy powders containing 50 - 60% by weight of tin, 40 - 50% by weight

REPLACEMENT SHEET

Date: 30 DEC 1996

- 6 -

of lead, and 0 - 3% by weight of silver, and one or more alloy powders containing 70 - 85% by weight of tin, 15 - 30% by weight of lead, and 0 - 3% by weight of silver. It is also possible to further mix with the
5 above mixture one or more alloy powders containing 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.

Besides the present invention, other inventions have been disclosed wherein two or more kinds of alloy powders
10 with different compositions are mixed to make a solder paste. (For example, Japanese Unexamined Patent Publication Nos. Hei 3-13952, Sho 57-66993, Sho 63-149094, Sho 63-154288, Hei 1-241395, Hei 1-271094, Hei 1-266987, Hei 2-117794, Hei 2-211995, Hei 4-22595,
15 and Hei 4-29365.)

However, most of them disclose bismuth- or indium-containing low-melting point solder in their working examples that are quite different from the solder compositions of the present invention. Although Japanese
20 Unexamined Patent Publication Sho 63-154288 and Hei 2-117794 include working examples that do not contain bismuth or indium, the liquidus temperature of each solder alloy is higher than the reflow temperature and therefore these inventions are different from the present
25 invention. The other inventions do not contain any description concerning formation of bumps for ball grid arrays.

Moreover, the use of such a solder paste will require higher reflow temperatures and longer reflow
30 times, resulting either in high thermal load on semiconductor chips and substrates or in poor luster, low wettability and insufficient strength due to incomplete alloying. Thus only the solder paste of the present invention can form bumps of high quality for ball grid
35 arrays without defects. Meanwhile, the use of alloy powder with too high a liquidus temperature is disadvantageous in that it requires use of alloy powder

Date : 30 DEC 1996

- 7 -

having high tin content so as to adjust the average composition. As to this composition, it should be pointed out that atomizing for powder production is a difficult process and resulting solder paste is unstable because the powder surface is active, readily reacting with flux. Any alloy powder used in the present invention is not particularly limited in terms of its shape and particle size. The shape can be spherical or irregular, and the particle size of approximately 73 μ (200 mesh) or under are to be used.

Flux for the solder paste of the present invention comprises a resin, a solvent, a thixotropic agent, an activator, and other additives. The materials are those commonly used as flux for solder paste and there are no particular limitations.

Examples of resins used in the said solder paste include rosin such as natural rosin and modified rosin, water-soluble resin and polymer. Examples of solvents include alcohols, glycols and ethers. Examples of thixotropic agents include castor oil, wax, petrochemical polymers, and amides. Examples of activators include monocarboxylic acid, dicarboxylic acid, amines, amides, imides, amine salts, and halides. Examples of other additives include thickening agents, surfactants, fluidity conditioners, corrosion inhibitors and antifoaming agents.

The weight percent of flux in the said solder paste is not particularly limited. For printing application, however, a range of 9 - 12% by weight is common. The solid content in the flux, such as rosin, is not particularly limited and can be in the wide range of 10 - 70% by weight.

In accordance with the present invention, the kind of substrate for the ball grid array is not particularly limited. For example, printed circuit board (glass-epoxy, paper-phenol, etc.), flexible board, ceramics board and TAB substrate can be used. A semiconductor

REPLACEMENT SHEET

Date: 30 DEC 1996

- 8 -

chip is bonded to one side for electrical connection with circuit through wire bonding or solder bumps. On the other side, solder pads are set in array. The said solder paste is printed with a printer using stencil or mesh screen and supplied to each pad, and then heated in a reflow furnace for melting. In this way, high-quality spherical solder bumps can be formed. The atmosphere of the reflow furnace is not particularly limited and air, an inactive atmosphere such as nitrogen, or a reducing atmosphere such as hydrogen and acids, can be used.

EXAMPLES

For Examples 1 through 6 and Comparative Examples 1 and 2, solder paste was prepared through kneading at the ratios described below. The solder paste thus obtained was printed and melted through reflow at 230°C, and bumps were formed to produce a BGA. The results are shown in Table 1.

Table 1

	Percent defective inspherical bumps (Out of 3,240 positions on one BGA)
Example 1	0.0
Example 2	0.0
Example 3	0.0
Example 4	0.0
Comparative Example 1	0.8
Comparative Example 2	1.2

Example 1

30

Parts by weight

Alloy powder A (50 wt% Sn - 50 wt% Pb) 60.0

Liquidus temperature 212°C, Solidus
temperature 183°C, Size 22 - 53 μ m

Alloy powder B (80 wt% Sn - 20 wt% Pb) 30.0

35 Liquidus temperature 202°C, Solidus
temperature 183°C, Size 22 - 53 μ m

	Polymerized rosin	3.0
	Disproportionated rosin	2.0
	Diethylene glycol monohexyl ether	3.9
	Hydrogenated castor oil	0.5
5	Cyclohexylamine HBr	0.1
	Adipic acid	0.5

Example 2

		Parts by weight
	Alloy powder G (46 wt% Sn - 51 wt% Pb - 3 wt% Ag)	30.0
10	Liquidus temp. 200°C, Solidus temp. 178°C, Size 10 - 30 µm	
	Alloy powder H (80 wt% Sn - 18 wt% Pb - 2 wt% Ag)	60.0
	Liquidus temp. 200°C, Solidus temp. 178°C, Size 10 - 30 µm	
15	Polymerized rosin	3.4
	Disproportionated rosin	3.0
	α-terpineol	2.5
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
20	Lauric acid	0.5

Example 3

		Parts by weight
	Alloy powder I (50 wt% Sn - 48 wt% Pb - 2 wt% Ag)	45.0
	Liquidus temp. 210°C, Solidus temp. 178°C, Size 22 - 45 µm	
25	Alloy powder H (80 wt% Sn - 18 wt% Pb - 2 wt% Ag)	45.0
	Polymerized rosin	2.4
	Disproportionated rosin	2.4
	α-terpineol	4.1
30	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
	Lauric acid	0.5

Example 4

		Parts by weight
35	Alloy powder J (55 wt% Sn - 43 wt% Pb - 2 wt% Ag)	35.0
	Liquidus temp. 199°C, Solidus temp. 178°C, Size 22 - 45 µm	

Date 30 DEC 1996

- 10 -

	Alloy powder K (70 wt% Sn - 28 wt% Pb - 2 wt% Ag)	35.0
	Liquidus temp. 200°C, Solidus temp. 178°C,	
	Size 22 - 45 μ m	
	Alloy powder L (62wt% Sn - 36 wt% Pb - 2wt% Ag)	20.0
5	Eutectic temp. 178°C, Size 22 - 45 μ m	
	Hydrogenated rosin	6.0
	Diethylene glycol monobutyl ether	2.9
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
10	Caprylic acid	0.5

Comparative Example 1

		Parts by weight
	Alloy powder F (63 wt% Sn - 37 wt% Pb)	90.0
	Hydrogenated rosin	6.0
15	α -terpineol	2.9
	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
	Succinic acid	0.5

Comparative Example 2

20		Parts by weight
	Alloy powder L (62 wt% Sn - 36 wt% Pb - 2 wt% Ag)	90.0
	Polymerized rosin	2.0
	Disproportionated rosin	4.0
	Diethylene glycol monohexyl ether	2.9
25	Hydrogenated castor oil	0.5
	Cyclohexylamine HBr	0.1
	Adipic acid	0.5

As seen from the above explanation, high-quality bumps for ball grid array can be formed with high yield by the use of solder paste produced by kneading of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of the alloy powder having liquidus temperature below reflow temperature, at least one of the alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powder being 58 - 65% by weight of tin and 35 - 42% by weight of lead,

REPLACEMENT SHEET

Date : 30 DEC 1996

- 11 -

or 60 - 65% by weight of tin, 34 - 38% by weight of lead,
and 1 - 3% by weight of silver.

REPLACEMENT SHEET

Date 30 DEC 1996

- 12 -

CLAIMS

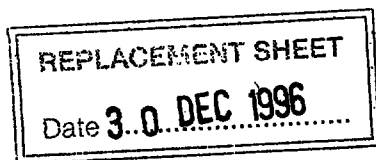
1. A bump-forming solder paste for a ball grid array comprising a mixture of flux and alloy powders comprising two or more kinds of alloy powders with
5 different compositions, wherein said mixture of alloy powders is comprised of one or more alloy powders containing 50 - 60% by weight of tin and 40 - 50% by weight of lead and one or more alloy powders containing 70 - 85% by weight of tin and 15 - 30% by weight of lead,
10 each of said alloy powders having liquidus temperature below a reflow temperature, at least one of said alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powders being 58 - 65% by weight of tin and
15 35 - 42% by weight of lead.

2. The bump-forming solder paste for a ball grid array according to Claim 1 wherein said reflow temperature is in a range of 210°C to 240°C.

3. The bump-forming solder paste for a ball grid
20 array according to Claim 2 wherein said reflow temperature is about 230°C.

4. The bump-forming solder paste for a ball grid array according to Claim 1, 2 or 3, wherein at least one of said alloy powders has a difference of 20°C or more
25 between liquidus and solidus.

5. A bump-forming solder paste for a ball grid array, comprising a mixture of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of said alloy powders having
30 liquidus temperature below reflow temperature, at least one of said alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powder being 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by
35 weight of silver.



- 13 -

SOLDER PASTE FOR BALL GRID ARRAY

5

ABSTRACT OF THE DISCLOSURE

High-quality bumps for a ball grid array can be formed with high yield by the use of solder paste produced by kneading of flux and alloy powders comprising two or more kinds of alloy powders with different compositions, each of the alloy powder having liquidus temperature below reflow temperature, at least one of the alloy powders having a difference of 10°C or more between liquidus and solidus, the average composition of the entire alloy powder being 58 - 65% by weight of tin and 35 - 42% by weight of lead, or 60 - 65% by weight of tin, 34 - 38% by weight of lead, and 1 - 3% by weight of silver.