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## METHOD FOR JOINING METALS AND DEVICE PRODUCED THEREBY

The present invention relates to a method for joining metals selected from among aluminum, an aluminum alloy, copper and a copper alloy. More particularly, the invention relates to a method for joining the metals by use of solder paste which contains Zn and Sn, as well as to the solder paste used in the method, flux used in the solder paste, a joined product obtained by the method, and electronic equipment into which the joined product is incorporated.

There has heretofore been unavailable a desirable technique for directly joining a copper heat sink and an aluminum-based copper-clad substrate. For this reason, the sink and substrate have been joined together by use of screws while interposing a heat dissipation sheet or a heat dissipation grease (resin adhesive) therebetween so as to lower thermal resistance arising therebetween.

Needless to say, soldering or the like is the most preferable method for joining metals together, in consideration of low thermal resistance at the joined portions and simplicity of a joining process. However, there has not been established a soldering technique capable of appropriately joining together metals containing an aluminum alloy in particular.

A method for joining such metals through brazing using alloys of Sn-Zn as a brazing material is available.

However, since brazing involves a large thermal strain in an article subjected to brazing or thermal deterioration in any peripheral electronic component due to use of a high brazing temperature of 400°C to 600°C, brazing has been hardly applicable to electronic materials and electronic equipment. Furthermore, since brazing encounters difficulty in joining portions of large area, brazing has been limited to, for example, joining of end faces of metallic pieces. Also, since an activator used in brazing contains a fluoride or a chloride in a predominant amount, joined members have suffered corrosion.

An object of the present invention is to solve the above-mentioned problems, thereby providing a method for joining metals selected from among aluminum, an aluminum alloy, copper, and a copper alloy at low temperature in a simple process; a joined product featuring no susceptibility of the joined portion with low thermal resistance to corrosion; a heat sink, power module substrate, microprocessor unit (MPU), central processing unit (CPU), or the like to which enhanced heat-dissipation properties are imparted through use of the joined product; and high-performance electronic equipment into which the heat sink, power module substrate, MPU, CPU, or the like is incorporated.

The present inventors carried out extensive studies in an attempt to solve the above problems. As a result, they found that when solder paste containing Sn and Zn was

used, metals selected from among aluminum, an aluminum alloy, copper, and a copper alloy could be joined together at a low temperature of about 250°C, with the joined portion exhibiting low thermal resistance. They also found that solder paste containing Bi in addition to Sn and Zn enabled joining of the metals at a lower temperature.

They additionally found that solder paste containing, as flux components, an organic halogen compound and an organic acid component selected from among organic acid esters and ester decomposition catalysts enhances reflow properties of a solder metal, can further lower thermal resistance at the joined portion, and prevents corrosion of the joined portion. They further found that through incorporation of the thus formed joined product into a heat sink, power module substrate, MPU, CPU, or the like, high-performance electronic equipment of enhanced heat dissipation properties can be provided in a simple process. Thus, the present invention has been accomplished.

Accordingly, the present invention provides a method for joining metals together, that comprises the steps of applying solder paste containing Sn and Zn to a portion-to-be-joined of two or more metals selected from among aluminum, an aluminum alloy, copper, and a copper alloy; and causing the applied solder paste to reflow.

The solder paste can contain Bi.

When one of the metals to be joined is aluminum or an aluminum alloy, another metal can be copper or a copper

alloy.

The solder paste can contain, as a flux, at least one component selected from among organic acid esters and ester decomposition catalysts, and an organic halogen compound.

The ester decomposition catalyst can be an organic base hydrohalogenated acid salt.

The organic halogen compound includes a brominated benzyl compound which contains a substituent having an alkyl chain with 10 or more carbon atoms, a polybrominated fatty acid compound with 10 or more carbon atoms that contains four or more bromine atoms in one molecule thereof, or a polybrominated alicyclic compound with 10 or more carbon atoms that contains four or more bromine atoms in one molecule thereof.

The flux can contain the component(s) selected from among organic acid esters and ester decomposition catalysts in a total amount of 0.01-20% by mass, and the organic halogen compound in an amount of 0.02-20% by mass.

The present invention further provides a method for joining metals, that comprises the steps of applying solder paste to a surface of a metal to be joined; placing another metal on the surface coated with the solder paste; and causing the applied solder paste to reflow;

The present invention further provides a metal-to-metal joined product obtained by the methods described above.

The metal-to-metal joined product can contain at least one component selected from among a heat sink, power

module substrate, MPU, and CPU.

The present invention further provides a solder paste for use in the methods described above.

The present invention further provides flux for use in the solder paste described above.

The present invention further provides electronic equipment incorporating the joined product described above.

The above and other objects, characteristic features, advantages of the present invention will become apparent from the description of the invention made with reference to the accompanying drawings.

FIG. 1. is a side view showing a copper plate and an aluminum heat sink to be joined by the joining method of Example 10.

FIG. 2 is a side view showing an aluminum substrate on which electronic components are mounted, a copper plate, and an aluminum heat sink to be joined by the joining method of Example 11.

The method for joining metals of the present invention is characterized in that solder paste contains Sn and Zn. Generally, solder paste is used in the electronics industry for surface mounting of electronic components and prepared by mixing solder powder with rosin or a synthetic resin component, an organic halogen compound serving as an activator, a solvent, a thixotropic agent, an antioxidant, and the like.

According to one characteristic feature of the

present invention, solder paste is applied to a portion-to-be-joined of a metal and the applied solder paste is caused to reflow through application of heat so as to effect metal-to-metal joining. Particularly, metals can be joined in a simple process by the steps of applying a solder paste to the relevant surface of one of the metals, placing another metal on the surface coated with the solder paste, and causing a solder alloy to reflow by heating the solder paste to its melting point or higher. If the metals to be joined are bonded making use of adhesiveness of the applied solder paste, the solder paste is caused to reflow, thereby facilitating the joining work.

Since solder powder used to prepare solder paste of the present invention contains Sn and Zn, it is possible to provide a method for joining metals, featuring low reflow temperature, good joining performance, and a simple process.

Examples of compositions of solder powder containing Sn and Zn include Sn-Zn, Sn-Ag-Zn, Sn-Bi-Sb-Zn, Sn-Bi-Cu-Zn, Sn-Ag-Sb-Zn, Sn-Ag-Cu-Zn, and Sn-Zn-Bi.

The compositions include 91% by mass of Sn and 9% by mass of Zn (shown as 91Sn/9Zn, and hereinafter shown in the same manner), 95.5Sn/3.5Ag/1Zn, 51Sn/45Bi/3Sb/1Zn, 84Sn/10Bi/5Sb/1Zn, 88.2Sn/10Bi/0.8Cu/1Zn, 88Sn/4Ag/7Sb/1Zn, 97Sn/1Ag/1Sb/1Zn, 91.2Sn/2Ag/0.8Cu/6Zn, 89Sn/8Zn/3Bi, 86Sn/8Zn/6Bi, and 89.1Sn/2Ag/0.9Cu/8Zn. Solder powder used in the present invention may be a mixture of two or more of the solder powders of different compositions.

Among the above solder powders, those which contain Bi are preferable, since they can be caused to reflow at lower temperatures to reduce the degree of thermal strain and thermal deterioration of a joined product.

The method of present invention is applied to join metals of two species selected from among aluminum, an aluminum alloy, copper, and a copper alloy. These metals exhibit high thermal conductivity and are frequently used as base metals for heat sinks, power module substrates, MPUs, and CPUs. Therefore, joined products manufactured by the method of this invention exhibit a high thermal conductivity.

The aluminum alloy includes Al-Si, Al-Mg, Al-Mg-Si and Al-Mn, including those exhibiting ductility. The copper includes pure copper, oxygen-free copper and tough pitch copper. The copper alloy includes brass, bronze and phosphor bronze.

Conventionally, joining different kinds of metals has been difficult to perform when one metal is aluminum or an aluminum alloy, while the other metal is copper or a copper alloy. However, even in joining metals of this combination, the joining method of the present invention can provide a joined product which involves lower thermal resistance than a joined product provided by a conventional joining method.

Preferably, the solder paste of the present invention contains as flux components at least one organic acid component selected from among organic acid esters and ester decomposition catalysts, and an organic halogen compound.

The organic halogen compound is used to remove an oxide from the surface of a solder metal during reflow so as to attain good joining. When the organic halogen compound includes a brominated benzyl compound which contains a substituent having an alkyl chain with 10 or more carbon atoms, a polybrominated fatty acid compound with 10 or more carbon atoms that contains four or more bromine atoms in one molecule thereof, or a brominated alicyclic compound with 10 or more carbon atoms that contains four or more bromine atoms in one molecule thereof, the effect of removing an oxide from the surface of a solder metal is enhanced.

Any brominated benzyl compound having an alkyl chain with 10 or more carbon atoms can be used, so long as it is a bromine compound in which the bond between the alkyl chain and benzyl halogenide is chemically stable.

Specific examples of the benzyl bromide compound include 4-stearoyloxybenzyl bromide, 4-stearyloxybenzyl bromide, 4-stearylbenzyl bromide, 4-bromomethylbenzyl stearate, 4-stearoylaminobenzyl bromide, and 2,4-bisbromomethylbenzyl stearate. Moreover, 4-palmitoyloxybenzyl bromide, 4-myristoyloxybenzyl bromide, 4-lauroyloxybenzyl bromide, and 4-undecanoyloxybenzyl bromide can be cited.

The polybromine compound may have a chemically stable functional group such as a carboxyl group, an ester group, an alcohol group, an ether group and a ketone group. The polybromine is a compound where four or more bromine atoms are bonded.

Specific examples of these compounds include 9,10,12,13,15,16-hexabromostearic acid, methyl 9,10,12,13,15,16-hexabromostearate, ethyl 9,10,12,13,15,16-hexabromostearate, 9,10,12,13-tetrabromostearic acid, methyl 9,10,12,13-tetrabromostearate, ethyl 9,10,12,13-tetrabromostearate, 9,10,12,13,15,16-hexabromostearyl alcohol, 9,10,12,13-tetrabromostearyl alcohol, and 1,2,5,6,9,10-hexabromocyclododecane. Among these compounds, hexabromostearic acid and hexabromocyclododecane are preferable.

Other examples include bromides such as 1-bromo-2-butanol, 1-bromo-2-propanol, 3-bromo-1-propanol, 3-bromo-1,2-propanediol, 1,4-dibromo-2-butanol, 1,3-dibromo-2-propanol, 2,3-dibromo-1-propanol, 1,4-dibromo-2,3-butanediol, 2,3-dibromo-2-butene-1,4-diol, 1-bromo-3-methyl-1-butene, 1,4-dibromobutene, 1-bromo-1-propene, 2,3-dibromopropene, ethyl bromoacetate, ethyl  $\alpha$ -bromocaprylate, ethyl  $\alpha$ -bromopropionate, ethyl  $\beta$ -bromopropionate, ethyl  $\alpha$ -bromoacetate, 2,3-dibromosuccinic acid, 2-bromosuccinic acid, 2,2-bromo-adipic acid, 2,4-dibromoacetophenone, 1,1-dibromotetrachloroethane, 1,2-dibromo-1-phenylethane and 1,2-dibromostyrene. However, the present invention is by no means limited to these examples. Also, corresponding organic halogenated compounds containing chlorine or iodine instead of bromine may be usable.

The organic acid component according to the present invention is preferably an organic acid ester, which generates organic acid when the ester reaches its reflow temperature. Examples of such ester include various

aliphatic carboxylic acid esters, aromatic carboxylic acid esters, aliphatic sulfonic acid esters and aromatic sulfonic acid esters. Specific examples thereof include n-propyl paratoluenesulfonate, isopropyl paratoluenesulfonate, isobutyl paratoluenesulfonate, n-butyl paratoluenesulfonate, n-propyl benzenesulfonate, isopropyl benzenesulfonate, isobutyl benzenesulfonate, n-propyl salicylate, isopropyl salicylate, isobutyl salicylate, n-butyl salicylate, isopropyl 4-nitrobenzoate, tert-butyl 4-nitrobenzoate, tert-butyl methacrylate, tert-butyl acrylate, tert-butyl malonate and tert-butyl bromoacetate. The amount of the organic acid component to be added is from 0.01 to 20% by mass, preferably from 0.05 to 5% by mass, based on the total amount of flux.

The above-mentioned organic acid ester exhibits low decomposability even at its reflow temperature when it is present singly. Addition of a small amount of an ester decomposition catalyst effectively accelerates decomposition of the organic acid ester. Any ester decomposition catalyst can be used so long as it accelerates decomposition of a decomposable organic acid ester at its reflow temperature with resultant acceleration of acid generation. Among such catalysts, a hydrohalogenated acid salt of an organic base is effective.

Specific examples of a hydrohalogenated acid salt of an organic base include hydrohalogenated acid amine salts, such as isopropylamine hydrobromide, butylamine

hydrochloride and cyclohexylamine hydrobromide, and 1,3-diphenylguanidine hydrobromide.

The ester decomposition catalyst is added in an amount of 0.01-20% by mass to the total amount of flux, preferably 0.05-5% by mass to the total amount of flux.

A known resin that has conventionally been blended in flux may be blended in the solder paste of the present invention. Examples of such a resin include a natural rosin, a disproportionated rosin, a polymerized rosin, a modified rosin, a hydrogenated rosin, a rosin ester and a synthetic resin, such as polyester, polyurethane and an acrylic resin.

The present invention may use any of the solvents used in conventional fluxes and solder pastes, specifically, alcohols, ethers and aromatic solvents. Examples of such solvents include benzyl alcohol, butanol, ethyl cellosolve, butyl cellosolve, butyl carbitol, diethylene glycol hexylether, propylene glycol monophenylether, dioctyl phthalate and xylene. These solvents may be used singly or in combination.

A thixotropic agent to be added so as to improve spreadability in application to metal subjected to joining may be an inorganic substance, such as fine silica particles and kaolin particles, or an organic substance, such as hydrogenated castor oil and an amide compound.

Flux for use in the solder paste of the present invention comprises 20-60% by mass of a resin component, 0.04-20% by mass of a thixotropic agent, 0.01-20% by mass of

an organic acid component, 0.02-20% by mass of an organic halogen compound, all to the total amount of flux, and a balance of solvent reducing agent. The thus prepared flux (14 to 8% by mass to the total amount of solder paste) is mixed with solder powder (86 to 92% by mass), thereby yielding the solder paste of the present invention. Mixing is performed by use of a known apparatus, such as a planetary mixer.

The pH of the solder paste is adjusted preferably to a predetermined range of 4 to 9, more preferably 6 to 8, so as to suppress the reaction of the solder powder and the flux. A preferred pH-adjusting agent is any of amine compounds, such as alkanolamines, aliphatic primary through tertiary amines, aliphatic unsaturated amines, alicyclic amines, and aromatic amines.

Specific examples of the amine compound include ethanolamine, butylamine, aminopropanol, polyoxyethylene oleylamine, polyoxyethylene laurylamine, polyoxyethylene stearylamine, diethylamine, triethylamine, methoxypropylamine, dimethylaminopropylamine, dibutylaminopropylamine, ethylhexylamine, ethoxypropylamine, ethylhexyloxypropylamine, bispropylamine, isopropylamine and diisopropylamine.

An amine compound is added preferably in an amount of 0.05-20% by mass to the total amount of flux contained in the solder paste. When the amount is less than 0.05% by mass, the amine compound fails to sufficiently serve as a pH-adjusting agent. When the amount is in excess of 20% by

mass, the pH of the solder paste usually exceeds 9; i.e., the pH shifts to the alkali side. As a result, the solder paste tends to become hygroscopic.

In order to effect rust prevention for a joined product, any of azoles may be added to the flux. Examples of such azoles include benzotriazole, benzimidazole and tolyltriazole. The rust preventive is added preferably in an amount of 0.05-20% by mass to the total amount of flux.

According to the method for joining metals of the present invention, solder paste, for example, is applied to the surface of one of the metals subjected to joining. Next, another metal is placed on the surface coated with the solder paste such that the surface thereof subjected to joining is brought into contact with the coated surface. The applied solder paste is caused to reflow through application of heat from a reflow heat source, thereby joining the metals. Examples of such a reflow heat source include a hot blast furnace, an infrared furnace, a vapor-deposition soldering apparatus and a light-beam soldering apparatus. As compared with a conventional method that uses a brazing material, the joining method of the invention features a simpler process and higher productivity.

The reflow process of the present invention varies depending on the composition of a solder alloy. In the case of solder alloys of Sn-Zn and Sn-Zn-Bi, such as 91Sn/9Zn, 89Sn/8Zn/3Bi and 86Sn/8Zn/6Bi, reflow is performed preferably in two steps, namely, preheating and reflow. The

preheating temperature is 130-180°C, preferably 130-150°C. The preheating time is 60-120 sec, preferably 60-90 sec. The reflow temperature is 210-230°C, preferably 210-220°C. The reflow time is 1-60 sec, preferably 1-40 sec. In the case of solder alloys other than the above, the reflow temperature is the melting point of a solder alloy to be used plus 20-50°C, preferably the melting point plus 20-30°C, whereas the preheating temperature, the preheating time and the reflow time may fall within the above-mentioned corresponding ranges.

The solder paste and flux used in the joining method of the present invention are suited for joining metals and enables joining at lower temperature as compared with a brazing material and flux used in a conventional joining method, thereby realizing smaller thermal strain in the joined portion, lower thermal deterioration of joined components, and lower susceptibility of the joined portion to corrosion.

A joined product obtained by the method for joining metals of the present invention features lower thermal resistance at the joined portion, lower susceptibility of the joined portion to corrosion, smaller thermal strain in the joined portion and lower thermal deterioration of joined components as compared with a joined product obtained by a conventional joining method.

When the joining method of the present invention is applied to components which require enhanced heat

dissipation properties, such as heat sinks, power module substrates, MPUs and CPUs, lower thermal resistance and smaller thermal strain can be realized at the joined portion than in the case of joining by a conventional method. Since the reflow temperature can be lowered below a conventional level, a thermal adverse effect on joined components, peripheral electronic components and the like can be mitigated, and the range of selection of electronic components for application of the present invention thereto is broadened. Thus, the joining method of the present invention can provide electronic equipment that exhibits performance higher than that of conventional electronic equipment. When the joined product of the present invention is applied to mobile equipment, such as mobile communication equipment, notebook computers, camcorders and still cameras, release of heat from a heat-generating portion can be practiced in a more compact manner as compared with conventional practice, thereby enabling reduction in product size.

The present invention will now be described with reference to Examples, but is not limited to these Examples.

(Examples 1-9)

Solder pastes were prepared by use of three kinds of atomized solder powders, i.e., 91Sn/9Zn, 89Sn/8Zn/3Bi and 86Sn/8Zn/6Bi, having a particle size of 20-40  $\mu\text{m}$ . The basic composition of these solder pastes consisted of 89% by mass of solder powder and 11% by mass of flux. The flux

consisted essentially of 20% by mass of disproportionated rosin and 30% by mass of polymerized rosin as resin components, 4% by mass of hydrogenated castor oil as a thixotropic agent, 0.5% by mass of propyl paratoluene-sulfonate as an organic acid, a rust preventive of 0.1% by mass of tolyltriazole and 2% by mass of triethylamine as rust preventives, 0.01% by mass of diphenylguanidine·HBr as an ester decomposition catalyst, 0.34% by mass of an organic halogen compound specified in Table 1 below, all relative to the total amount of flux, and a balance of propylene glycol monophenylether as a solvent. The flux and the solder powder were mixed by use of a planetary mixer, thereby obtaining a solder paste. The thus obtained solder paste exhibited a viscosity of about 200 Pa·s.

The solder paste was applied to a pure aluminum plate measuring 2 mm (thickness) x 25 mm x 25 mm at a central portion measuring 10 mm x 10 mm through printing by use of a printing machine. A pure copper plate measuring 0.5 mm (thickness) x 10 mm x 10 mm was placed on the printed surface. Joining was performed by use of a reflow furnace. Reflow conditions were adjusted to the preheating temperature of 150°C and the reflow temperature (peak temperature) of 220°C, as measured on the surface of the pure copper plate. The belt speed of the reflow furnace was 0.6 m/min, the preheating time was 80 sec, and the reflow time was 3 sec. The reflow atmosphere was a nitrogen atmosphere of an oxygen concentration of 2,000 ppm.

Test samples having undergone joining were cooled and then cleaned by means of ethyl alcohol. Voids of the cleaned test samples were observed by use of soft X-rays and joining strength thereof was measured. Since thermal resistance increases with the amount of voids, the test samples were evaluated according to the three-grade system as being good (O), acceptable ( $\Delta$ ) and not acceptable (X) on the basis of the amount of voids. The joining strength was measured in the following manner. A rivet of pure copper having an end 10 mm in diameter was bonded onto the pure copper plate of each of the test samples by means of adhesive. The tensile strength of the test samples was measured at a tension speed of 10 mm/min by use of a tension tester. Notably, when the test sample had a joining strength of not less than 100 kg/cm<sup>2</sup>, the test sample was bent, disabling measurement. According to the common understanding, thermal resistance at the joined portion decreases with the joining strength. A practically desired joining strength is not less than 30 kg/cm<sup>2</sup>.

A corrosiveness test was conducted in the following manner on test samples that were prepared in a manner similar to that mentioned above. The test samples were not cleaned of flux and were allowed to stand at a temperature of 40°C and a humidity of 90% for 72 hours. Subsequently, the test samples were evaluated by use of a microscope as being defective (X) when a trace (spot) of corrosion was observed, acceptable ( $\Delta$ ) when a slight trace of corrosion

was observed and good (○) when no corrosion was observed.  
Test results are shown in Table 1 below.

[Table 1]

| No. | Alloy Composition | Organic Halogen Compound | Joined Materials | Voids | Tensile Strength (kg/cm <sup>2</sup> ) | Corrosiveness |
|-----|-------------------|--------------------------|------------------|-------|----------------------------------------|---------------|
| 1   | Sn-8Zn-3Bi        | isopropylamine·HBr       | Al/Cu            | △     | 33                                     | △             |
| 2   | Sn-8Zn-3Bi        | cyclohexylamine·HBr      | Al/Cu            | △     | 55                                     | △             |
| 3   | Sn-8Zn-3Bi        | butylamine·HBr           | Al/Cu            | △     | 48                                     | △             |
| 4   | Sn-8Zn-3Bi        | hexabromocyclododecane   | Al/Cu            | ○     | 100 or higher                          | ○             |
| 5   | Sn-8Zn-3Bi        | 2,2-dibromoadipic acid   | Al/Cu            | ○     | 100 or higher                          | ○             |
| 6   | Sn-8Zn-3Bi        | hexabromostearic acid    | Al/Cu            | ○     | 100 or higher                          | ○             |
| 7   | Sn-8Zn-3Bi        | hexabromostearic acid    | Al/Al            | ○     | 100 or higher                          | ○             |
| 8   | Sn-8Zn-6Bi        | hexabromostearic acid    | Al/Cu            | ○     | 100 or higher                          | ○             |
| 9   | Sn-9Zn            | hexabromostearic acid    | Al/Cu            | ○     | 100 or higher                          | ○             |

(Example 10)

Through use of the solder paste of the composition of Example 6 (basic composition: 89% by mass of 89Sn/8Zn/3Bi solder powder having a grain size of 20-40  $\mu\text{m}$  and 11% by mass of flux consisting essentially of 20% by mass of disproportionated rosin, 30% by mass of polymerized rosin, 4% by mass of hydrogenated castor oil, 0.05% by mass of propyl paratoluenesulfonate, 0.1% by mass of tolyltriazole, 2% by mass of triethylamine, 0.01% by mass of diphenylguanidine·HBr, 0.34% by mass of hexabromostearic acid, all relative to the total amount of flux, and a balance of propylene glycol monophenylether), a copper plate 1 measuring 2 mm (thickness) x 25 mm x 60 mm and a heat sink 2 of aluminum were joined as shown in FIG. 1. The solder paste was applied to the entire surface of the aluminum heat sink 2 subjected to joining through printing. Next, the copper plate 1 was bonded to the aluminum heat sink 2 through utilization of adhesion of the applied solder paste. Joining was performed by use of the reflow furnace. Reflow conditions were adjusted to the preheating temperature of 150°C and the peak temperature (reflow temperature) of 220°C, as measured on the surface of the copper plate. The belt speed of the reflow furnace was 0.6 m/min, the preheating time was 80 sec, and the reflow time was 3 sec. The oxygen concentration of the reflow atmosphere was 2,000 ppm.

Void observation was conducted on the test sample having undergone joining by use of soft X-rays. However, no

void was observed.

(Example 11)

As shown in FIG. 2, an alumina substrate 3, on one side of which are mounted electronic components 4 and the other side of which is metallized with molybdenum, a copper plate 5, and an aluminum heat sink 6 were joined to thereby fabricate a high power module substrate. A circuit made of copper plate having a thickness of 0.3 mm was formed on the surface of the alumina substrate 3, and the electronic components 4 were mounted on the copper circuit.

The solder paste of Example 6 was applied to the metallized surface of the alumina substrate 3 opposite the surface on which the electronic components 4 were mounted. The copper plate 5 measuring 2 mm (thickness) x 25 mm x 60 mm was bonded to the metallized surface through utilization of adhesion. As shown in FIG. 2, this assembly of the alumina substrate 3 and the copper plate 5 was placed on the surface of the aluminum heat sink 6 subjected to joining to which the solder paste of the composition of Example 6 was applied.

Joining was performed by use of the reflow furnace. Reflow conditions were adjusted to the preheating temperature of 150°C and the peak temperature of 220°C, as measured on the surface of the copper plate 5. The belt speed of the reflow furnace was 0.6 m/min, the preheating time was 80 sec, and the reflow time was 3 sec. The oxygen concentration of the reflow atmosphere was 2,000 ppm.

Void observation was conducted on the test sample having undergone joining by use of soft X-rays. However, no void was observed.

A metal-to-metal joined product can be manufactured in a simple process by the manufacturing method of the present invention. This method enables joining at low temperature and can prevent thermal strain in the joined portion and thermal deterioration of joined components. Particularly, inclusion of Bi in a solder paste further lowers the joining temperature, thereby more effectively preventing thermal strain in the joined portion and thermal deterioration of joined components.

The joining method of the present invention enables joining of aluminum, an aluminum alloy, copper and a copper alloy, which has been difficult to perform by a conventional method. Even when one of metals to be joined is aluminum or an aluminum alloy while another metal is copper or a copper alloy, the invented method can join the metals favorably to enable provision of a joined product of low thermal resistance at the joined portion, which cannot be provided by a conventional method.

Flux which is contained in a solder paste used in the joining method of the present invention assumes the aforementioned composition, thereby enabling reduction in voids which arise in a solder alloy during joining, and thus enabling provision of a joined product of low thermal resistance at the joined portion. Also, the potentiality of

corrosion of a joined product caused by residual flux is reduced, thereby enabling provision of a highly reliable joined product.

The manufacturing method of the present invention can join metals in a simple process, thereby enhancing productivity of joined products.

A solder paste and flux used in the joining method of the present invention enable joining at low temperature, thereby enabling provision of a joined product featuring low thermal strain in the joined portion and low thermal deterioration of joined components. Flux of the present invention enables provision of a highly reliable joined product featuring low susceptibility of the joined portion to corrosion.

A joined product obtained by the joining method of the present invention features low thermal resistance at the joined portion, low susceptibility of the joined portion to corrosion, low thermal strain in the joined portion, and low thermal deterioration of joined components, thereby exhibiting high reliability and enhanced heat dissipation properties.

When the joined product of the present invention is applied to components which require enhanced heat dissipation properties, such as heat sinks, power module substrates, MPUs and CPUs, lower thermal resistance can be realized at the joined portion than in the case of a conventional joined product. Since the reflow temperature

can be lowered below a conventional level, the range of selection of electronic components for application of the present invention thereto is expanded, thereby enabling provision of electronic equipment which exhibits performance higher than that of conventional electronic equipment.



Claims:

1. A method for joining two or more metals selected from among aluminum, an aluminum alloy, copper and a copper alloy, characterized by the steps of applying solder paste which contains Sn and Zn to at least one surface of the metals to be joined and causing the applied solder paste to reflow.
2. The method according to claim 1, characterized in that the solder paste further contains Bi.
3. The method according to claim 1 or 2, characterized in that one of the metals to be joined is aluminum or an aluminum alloy, whereas another metal is copper or a copper alloy.
4. The method according to any one of claims 1 through 3, characterized in that the solder paste contains, as flux, at least one component selected from among organic acid esters and ester decomposition catalysts, and an organic halogen compound.
5. The method according to claim 4, characterized in that the ester decomposition catalyst is an organic base hydrohalogenated acid salt.
6. The method according to claim 4 or 5, characterized in that the organic halogen compound includes brominated benzyl compounds containing a substituent that has an alkyl chain with 10 or more carbon atoms, polybrominated compounds including polybrominated fatty acid compounds with 10 or more carbon atoms that contain four or



more bromine atoms in one molecule thereof or polybrominated alicyclic compounds with 10 or more carbon atoms that contain four or more bromine atoms in one molecule thereof.

7. The method according to any one of claims 4 through 6, characterized in that the at least one component amounts to 0.01-20% by mass, and the organic halogen compound amounts to 0.02-20% by mass.

8. The method according to any one of claims 1 through 7, characterized in that the solder paste is applied to a surface of one of the metals, and another metal is placed on the surface of the one metal coated with the solder paste.

9. A metal-to-metal joined product obtained through the method of any one of claims 1 through 8.

10. The metal-to-metal joined product according to claim 9, containing at least one component selected from among a heat sink, power module substrate, microprocessor unit and central processing unit.

11. Solder paste for use in the method of any one of claims 1 through 8.

12. Flux for use in the solder paste of claim 11.

13. Electronic equipment provided with the joined product of claim 9 or 10.