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**(54) TITLE OF THE INVENTION**

# Lead-Free Solder

**(57) ABSTRACT**

**PURPOSE:** To provide a lead-free solder that allows the melting point to be lower and thus provides good wettability and mechanical properties.

**CONSTITUENT ELEMENTS:** A lead-free solder, the composition of which consists of:

Ag 1.0 to 3.0 wt%;

Cu 0.5 to 2.0 wt%;

Bi 1.0 to 10.0 wt%; and

Sn constituting all or the majority of the remaining portion.

**WHAT IS CLAIMED IS:**

**CLAIM 1**

A lead-free solder, the composition of which consists of:

Ag 1.0 to 3.0 wt%;

Cu 0.5 to 2.0 wt%;

Bi 1.0 to 10.0 wt%; and

Sn constituting all or the majority of the remaining portion.

**DETAILED DESCRIPTION OF THE INVENTION**

[0001]

**FIELD OF INDUSTRIAL APPLICATION**

The present invention pertains to a lead-free solder primarily used to accurately mount small chip components and semiconductor components on a circuit board of an electronic device or electrical equipment.

[0002]

**CONVENTIONAL TECHNOLOGY**

Conventional solders contain large amounts of lead. When a substrate that uses such a solder is discarded and thus left unattended without the proper treatment of the highly toxic lead, it leads to environmental issues. Accordingly, there has been an urgent need to develop a lead-free solder without the use of lead, doing so while maintaining characteristics equivalent to those of lead-containing solders.

[0003]

Examples of conventional lead-free solders include those having the compositions listed in Table 1, i.e., a solder based on an Sn-Ag alloy (conventional example 1), a solder based on an Sn-Zn alloy (conventional example 2), and a solder based on an Sn-Sb alloy (conventional example 3).

[0004]

**[Table 1]**

| Conventional Example | Percent composition (wt%) | | | | Melting point (°C) (eutectic line) | Wettability |
|---|---|---|---|---|---|---|
| | Sn | Ag | Sb | Zn | | |
| 1 | Rest | 3.5 | -- | -- | 221 | □ |
| 2 | Rest | -- | -- | 9.0 | 199 | X |
| 3 | Rest | -- | 5.0 | -- | 240 | △ |

[0005]

**PROBLEM TO BE RESOLVED BY THE INVENTION**

However, in the case of the conventional example 1 (Sn-Ag alloy system), the melting point is as high as 221°C, which may lead to damage to the soldered component parts or the printed circuit board. Also, in the case of the conventional example 2 (Sn-Zn alloy system), Zn is susceptible to oxidation, thus posing a problem when [such a solder] is used for a soldering task performed in the open air, whereby the wettability is extremely poor. Furthermore, in the case of the conventional example 3 (Sn-Sb alloy system) there are still problems that have remained unresolved. For example, the melting point is as high as 240°C, the wettability is not good, and Sb is slightly toxic.

[0006]

As is commonly known, while the aforementioned alloys have high ductility, they also have disadvantages in that they do not have sufficient creep resistance for use in applications that require higher levels of stability and the like. Accordingly, there has been a demand for a modified product in which the aforementioned disadvantages are ameliorated.

[0007]

**MEANS FOR RESOLVING THE OBJECTIVE**

In order to resolve the aforementioned objective, the lead-free solder according to the present invention is characterized by the composition consisting of:

Ag 1.0 to 3.0 wt%;

Cu 0.5 to 2.0 wt%;

Bi 1.0 to 10.0 wt%; and

Sn constituting all or the majority of the remaining portion.

[0008]

**OPERATIONAL ADVANTAGE**

Because the present invention has the above-mentioned composition, it provides the following operational advantages:

[0009]

The addition of Ag to the primary component Sn is effective in lowering the melting point and improving the mechanical properties. However, such effects are insufficient when the additive amount of Ag is 1.0 wt% or less, whereas the addition of 3.0 wt% or more will be minimally effective without notable enhancement and is therefore unfavorable because it will only lead to high cost and a higher liquidus temperature.

[0010]

By further adding Cu to the mixture of the primary components Sn and Ag, it becomes possible to achieve a finer metallographic structure, thereby making it possible to further improve the mechanical strength. Cu is minimally effective when it is added in an amount less than 0.5 wt%. However, it causes an abrupt increase of the liquidus temperature when it is added in an amount that exceeds 2.0 wt%, thereby causing thermal damage to the component parts or the printed circuit board.

[0011]

By further adding Bi to the mixture of the primary components Sn, Ag and Cu, it becomes possible to lower the melting point and thereby prevent thermal damage to the component parts or the printed circuit board. Bi is minimally effective when it is added in a smaller amount than 1.0 wt%. However, it leads to the formation of large, coarse crystals when it is added in an amount of 10.0 wt% or more, thereby leading to a fragile [structure] and consequently less mechanical strength.

[0012]

The present invention can provide a lead-free solder, doing so by setting [the amounts of] Sn, Ag, Cu and Bi within the above-mentioned ranges so as to thereby achieve a melting point that is as close as that of an Sn-Pb eutectic solder (183$^{o}$C) while providing superior wettability and mechanical properties.

[0013]

**WORKING EXAMPLES**

Lead-free solders having the compositions listed in Table 2 were produced as the working examples 1 through 3. Subsequently, evaluation was conducted for the melting points and wettability.

[0014]

**[Table 2]**

| Working Example | Percent composition (wt%) | | | | Melting point (°C) | | Wettability |
|---|---|---|---|---|---|---|---|
| | Sn | Bi | Ag | Cu | Solidus line | Liquidus line | |
| 1 | Rest | 7.5 | 2.0 | 0.5 | 117 | 209 | ○ |
| 2 | Rest | 2.0 | 1.5 | 1.0 | 178 | 221 | ○ |
| 3 | Rest | 10 | 3.0 | 2.0 | 178 | 206 | ○ |

[0015]

For the wettability evaluation, each solder composition was used to make a resin flux cored solder JIS B-grade (wire diameter = 1.6 mm) containing 3 % w/w of flux. And, the resin flux cored solder was cut into ring-shaped pieces so that the weight of the resin flux cored solder would be 300 mg [each], and [the cut pieces] were then used as the test pieces. [Each] test piece was placed on an oxidized copper plate (30 x 30 x 0.3 mm), which was then placed on a hot plate with the liquidus temperature of +50°C for 30 seconds, whereupon [the wettability] was evaluated based on the expansion rate in accordance with JIS-Z-3197, 6.10. Those with the expansion rate of 90% or more were evaluated as ○; those with rates of 89% to 80% were evaluated as □; those with expansion rates of 79% to 70% were evaluated as △; and those with expansion rates of 69% or less were evaluated as ×.

[0016]

As is evident based on Table 2, the working examples 1 through 3 all indicated good wettability, and the melting points were substantially lower than those of the conventional examples. Moreover, the addition of Cu and Ag contributed to the improvement of the mechanical properties, although such an effect is not explicitly indicated in the results of the experiment.

[0017]

The lead-free solder according to the present invention is molded and thus used in various forms, such as a rod, wire, ribbon, preform, powder, etc. Additionally, while each composition of the working examples 1 through 3 consisted only of four components of Sn, Bi, Ag and Cu, a minute amount of Fe or the like may be added in addition to said [four components] in order to produce a lead-free solder.

[0018]

**EFFECT OF THE INVENTION**

The present invention can provide a lead-free solder that allows the melting point to be lower and thus provides good wettability and mechanical properties.

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## Certification

This is to certify that the foregoing translation of the patent publication **H08-132277** was made from Japanese to English from the source document by a competent translator well acquainted with both languages, and that, to the best of our knowledge and belief, it is a true and complete rendering into English of the selected text.

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