

UNIVERSAL LEAD-FREE SOLDERING MATERIAL

FIELD OF THE INVENTION

The present invention relates to a universal lead-free soldering material for use in soldering electronic components, and particularly relates to an Sn-Ag-Bi lead-free soldering material.

DESCRIPTION OF THE PRIOR ART

Generally, each of soldering materials has unique properties so as for it to be suitable for the application field. In the usual soldering materials, the melting temperature and solidification temperature ranges are important.

That is, a soldering material which is selected for a special purpose has to have a low melting temperature to the extent that damages should not be caused to the adjacent temperature-sensitive parts. Further, after the completion of the soldering, the soldered material has to have a high melting temperature range, so that the joined state would be thermally stable.

Further, soldering materials are generally composed of composition systems in which eutectic reactions occur. Therefore, if a soldering material has a special composition other than the relevant eutectic composition, a liquidus line at which the solidification begins after

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the soldering is crossed to make the liquid phase and the solid phase exist together, and then, a solidus line at which the solidification is completed is reached, this being the solidification temperature range of the special composition. If the solidification temperature range is large, the solidification time is lengthened, and a shrinking phenomenon may occur. Therefore, it is important that the soldering composition should have a small solidification temperature range as far as possible. A soldering material having a small solidification temperature range is advantageous for a stepwise soldering during a continuous soldering.

One of the conventional soldering materials having the above described properties is the Sn-Pb series alloy. This soldering alloy is superior in the various mechanical and physical properties, and therefore, it is widely used in structures such as plumbings and heat exchangers, and in the general electronic components.

However, lead is a non-decomposed metal, and if lead is once ingested by a human body, it is not discharged but accumulated in the human body. For example, the Center for Disease Control of the United States reports that, if the lead concentration in the blood exceeds 10 $\mu\text{g}/\text{dl}$, it becomes fatal. Particularly, the lead accumulation causes a deterioration of intelligence in children, and that the lead waste



contaminates the soil.

Particularly, the traditional soldering materials such as 50Sn-50Pb and 70Sn-30Pb can be used in a wide temperature range, constitute strong mechanical connecting portions, and are useful to soldering copper pipes. However, it was found that lead is dissolved into the water to adversely affect the human health in the long run. Therefore, the use of lead in soldering the pipes which carry the drinking water began to be regulated.

As examples of the regulation of the use of lead and lead-containing composition, the use of lead in the consumer paint was totally prohibited in 1978 in the United States, and the U.S. Environmental Protection Agency (EPA) published a regulation in the Toxic Substance Control Act (TSCA) that there will be a duty of recovering lead-containing materials. Further, the House of Representatives of the United States proposed that a tax of 100-200% be levied for forming a Pb-cleanup fund (HR2479).

Further, the Senate formulated the Lead Exposure Act (S-729) proposing a total regulation for the use of industrial lead. Further the U.S. Occupation Security and Health Agency (OSHA) decided the lead standard for regulating the lead concentration which is tolerant in the air and in jobs. This regulation states that the exposure of employees to lead should be minimum under a high lead concentration atmosphere. Thus, in the United States,



the use of lead, particularly the use of 50Sn-50Pb was prohibited to the pipe line joining, and the use of leading containing soldering materials was prohibited in the field related to the drinking water. Further, the use of lead containing soldering material for purposes other than the joining of pipe lines was prohibited. This trend is similar in the domestic field.

With the appearance of such regulations against the use of the soldering lead, lead-free soldering materials began to be developed. U.S Patent 1,778,733 proposes a lead-free soldering material composed of Sn-Ag(0.05-3%)-Cu(0.7-6%). Further, U.S. Patent 4,929,423 proposes a lead-free soldering material composed of a mixture of Sn-Bi(0.08-20%)-Ag(0.01-1.5%)-Cu(0.02-1.5%)-P(0.01%)-rare earth elements.

Besides U.S. Patent 499,452 A1 proposes a lead-free soldering material composed of: 87-97% of Sn, 0.1-3% of Ag, and 3-7% of Bi. Further, Japanese Patent Laid-open No. Hei-5-228685 proposes a lead-free soldering material containing: 92-95.8% of Sn, 3-5% of Ag, and 1.2-3% of Bi. However, the above mentioned lead-free soldering materials are high melting temperature soldering materials, and therefore, they cannot be used for soldering electronic components, but are intended to be used for special purposes.



SUMMARY OF THE INVENTION

In order to solve the above described disadvantages of the conventional techniques, the present inventors carried out repeated experiments and studies, and came to propose the present invention based on the experiments and studies.

Therefore it is the object of the present invention to provide a universal lead-free soldering material suitable for soldering electronic components, in which the composition of the Sn-Ag-Bi lead-free soldering material is properly controlled, so that the mechanical strength would be superior over the conventional Sn-40Pb soldering material.

In achieving the above object, the universal lead-free soldering material has a composition including: 3.1-7% of Ag, 6-30% of Bi and a balance of Sn.

BRIEF DESCRIPTION OF THE DRAWINGS

The above object and other advantages of the present invention will become more apparent by describing in detail the preferred embodiment of the present invention with reference to the attached drawings in which:

FIG. 1 is a graphical illustration showing the solderability of the universal lead-free soldering material according to the present invention; and

FIG. 2 is a graphical illustration showing the



mechanical properties of the conventional soldering materials and the soldering material according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

First, the content of Ag in the universal lead-free soldering material may be maintained at 3% by considering the low melting temperature of the soldering material, but actually Ag is added in the amount of 3.1% or more to improve the thermal fatigue characteristics.

However, if the content of Ag is excessive, the melting temperature of the soldering material is raised, and therefore, it should be preferable to limit the content of Ag to 7% or less.

When the ingredient Bi is added into an Sn-Ag alloy system, e.g., into an Sn-3%Ag alloy system (melting temperature: 221°C), the ingredient Bi lowers the melting temperature and improves the wettability. However, if Bi is added by less than 6%, the effect is insufficient. If it is added by 30% or more, the melting temperature is lowered, and the wettability is improved, but the soldering material itself becomes brittle, and the melting temperature range is widened.

The universal lead-free soldering material of the present invention constituted as described above may be manufactured in the air by weighing the raw metallic



materials, by melting them in a pot or crucible, and by agitating them in the usual method. Under this condition, if the melting is carried out in the air, the impurities, non-metallic materials and alloy melt may react with the air to form soluble gases such as soluble nitrogen or soluble oxygen in the soldering alloy. Consequently, the wetability relative to the base material is lowered so as to lower the solderability or so as to form voids in the solder-joint. As a result, the thermal conductivity, the thermal fatigue and the product reliability may be aggravated. Therefore, in order to minimize the impurities or the non-metallic materials and the soluble gases which are formed during the melting in the air, and in order to improve the solderability, the thermal fatigue and the product reliability, the raw metallic materials are melted in vacuum or in an inert gas atmosphere, so that, among the raw metallic materials, particularly the oxidation of Bi would be inhibited to minimize the formation of dross.

The universal lead-free soldering material of the present invention which is manufactured in the above described manner can have various shapes such as ingot, rectangular, circular and the like. Further, a powder of spherical particles of various sizes can also be manufactured. In the case of powder, a suitable flux may be mixed with the powder to form a solder paste.



The universal lead-free soldering material of the present invention thus manufactured not only has a melting temperature suitable for wiring general electronic components, but also has a narrow solidification range so as to be advantageous for stepwise automatic soldering. Further, it has improved mechanical strengths compared with the conventional Sn-Pb soldering material.

Now the present invention will be described based on actual examples, but the scope of the present invention will not be limited by the specific examples.

Example 1

<Inventive example 1>

The metallic ingredients Sn, Ag and Bi were weighed to the composition shown in Table 1 below. The casting was carried out by melting the composition in a vacuum of over 10^{-3} torr by using a vacuum induction furnace. For the alloy thus manufactured, the solidus line temperature and the liquidus line temperature of the solidification procedure were measured, and the measured results are shown in Table 1 below.



<Table 1>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
90%	3.9%	6.1%	200°C	220°C

As shown in Table 1, for the inventive material 1, the liquidus line temperature was 220°C, and the solidus line temperature was 200°C, while the solidification range was 20°C. Thus it is apparent that the material is suitable as a universal lead-free soldering material.

<Inventive example 2>

The raw metallic materials having a composition as shown in Table 2 below were melted in the air by using a induction furnace, and casting was carried out. For the cast alloy after the casting, the solidus line temperature, the liquidus line temperature and the solidification temperature range were measured, and the measured results are shown in Table 2 below.



<Table 2>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
90%	3.1%	6.9%	195°C	218°C

As shown in Table 2 above, The inventive material 2 had characteristics such that the liquidus line temperature was 218°C, the solidus line temperature was 195°C, and the solidification temperature range was 23°C. Therefore, the material was very much suitable as a universal lead-free soldering material.

<Inventive example 3>

A lead-free soldering material having a composition as shown in Table 3 below was melted in an inert gas (N₂) atmosphere by using a vacuum induction furnace, the pressure of the inert gas atmosphere being maintained at 250-300 m bar. Then casting was carried out, and for the cast alloy, the solidus line temperature and the liquidus line temperature were measured, and the measured results are shown in Table 3 below.



<Table 3>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
81.7%	3.3%	15%	180°C	206°C

As shown in Table 3 above, the inventive material 3 had characteristics such that the liquidus line temperature was 206°C, the solidus line temperature was 180°C, and the solidification temperature range was 26°C. Therefore, it was apparent that the material can be used as a universal lead-free soldering material.

<Inventive example 4>

A lead-free soldering material having a composition as shown in Table 4 below was manufactured in the same method as that of the inventive example 3, and the solidification temperature was measured for the manufactured material. The results of the measured solidification temperature are shown in Table 4 below.

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<Table 4>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
63.2%	6.8%	30%	138°C	144°C

As shown in Table 4 above, the inventive material 4 had characteristics such that the liquidus line temperature was 144°C, the solidus line temperature was 138°C, and the solidification temperature range was 6°C.

Therefore, it was apparent that the material can be used as a universal lead-free soldering material.

<Comparative example 1>

A conventional lead-free soldering material having a composition as shown in Table 5 below was manufactured, and then, the solidification temperature for the manufactured alloy was measured. The measured results are shown in Table 5 below.



<Table 5>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
94.5%	3.5%	2%	215°C	220°C

As shown in Table 5 above, the soldering material having a composition as shown in Table 5 had characteristics such that the liquidus line temperature was 220°C, the solidus line temperature was 215°C, and the solidification temperature range was 5°C. Therefore, this material was a high melting temperature lead-free soldering material.

<Comparative example 2>

A lead-free soldering material having a composition as shown in Table 6 below was manufactured in the same method as that of the comparative example 1, and the measured values are shown in Table 6 below.

<Table 6>

Sn	Ag	Bi	Solidus line temp.	Liquidus line temp.
93-93.5%	1.5-2%	5%	211°C	223-236°C



As shown in Table 6 above, the soldering material having a composition as shown in Table 6 had characteristics such that the liquidus line temperature was 223-236°C, the solidus line temperature was 211°C, and the solidification temperature range was 12-25°C. Therefore, this material was a high melting temperature lead-free soldering material.

Example 2

The inventive material 2 which was composed of Sn-3.1%Ag-6.9%Bi, and the comparative material 3 which was composed of Sn-3.5%Ag-4.5%Bi, were melted in the air by using a induction furnace, and then, casting was carried out. For the cast alloys, the wetability was measured, and the measured results are shown in FIG. 1.

As shown in FIG. 1, the inventive material 2 was superior in the wetability over the comparative material 3, thereby showing a superior solderability.

In order to see the mechanical properties for the conventional soldering material and the lead-free soldering material according to the present invention, a conventional soldering material composed of Sn-40Pb and the inventive material 2 were measured as to their mechanical properties. The measured results are shown in FIG. 2.

As shown in FIG. 2, the inventive material 2 was extremely superior in the tensile strength over the



conventional material. This suggests that the final joining strength of the lead-free soldering material of the present invention is superior.

As can be seen in the above described examples, the lead-free soldering material according to the present invention is superior in the mechanical properties over the conventional Sn-Pb soldering material, with the result that the lead-free soldering material of the present invention is superior in the final joining strength. Further, since there is contained no lead, the working environment is improved. Further, the melting temperature is low, and the solidification temperature range is narrow. Therefore, the lead-free soldering material according to the present invention is more suitable for soldering general electronic components compared with the conventional Sn-Ag-Bi high melting temperature lead-free soldering materials.



Claim

1. A universal lead-free soldering material comprising a composition including: 3.1-7% of Ag, 6-30% of Bi and a balance of Sn.

2. The universal lead-free soldering material as claimed in claim 1, wherein the composition includes: 6-7% of Ag, 29-30% of Bi and a balance of Sn.

3. The universal lead-free soldering material as claimed in claim 1, wherein the composition includes: 3.1-4% of Ag, 6-7% of Bi and a balance of Sn.

4. A universal lead-free soldering material, characterized in that:

the material has a solidus line temperature of 138-200°C, and a liquidus line temperature of 144-220°C; and

the material is composed of Ag, Bi and Sn.

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