

SILVER-PLATED MATERIAL FOR LEAD FRAMES,**EXCELLENT IN SOLDER-WETTABILITY** ✓

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BACKGROUND OF THE INVENTION

The present invention relates to a silver-plated material for lead frames which is excellent in solder-wettability, and more specifically to a silver-plated copper alloy material for lead frames for die-bonding Si chips by soldering.

Transistors and ICs mounted on electronic equipment are composed of an electronic circuit made of a Si chip for processing logical equations, a lead frame for transmitting signals from the Si chip outwards, and an epoxy resin type package for protecting the Si chip. In many cases, copper alloys excellent in electrical conductivity and heat radiating ability are used for the lead frame. This lead frame is obtained by plating a copper alloy strip partially with silver and stamping the silver-plated strip.

The assembly process for assembling transistors and ICs comprises the steps of die-bonding a Si chip to a lead frame, wire-bonding the Si chip and inner leads of the lead frame, and packaging the Si chip and the inner leads with a resin.

In the case of transistors and ICs, melting joint with the use of solder balls, wires, or ribbons is frequently utilized for the die bonding of the Si chip. The joint with solder results

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in not only fixation of the Si chip onto the lead frame but also an advantage that heat from the Si chip is efficiently radiated to the lead frame. As the solder ball, a solder such as a Pb-Sn-Ag solder is used. The die bonding of the Si chip is performed as follows. The lead frame plated with silver is heated in the atmosphere of nitrogen or the reduction atmosphere of hydrogen, and then solder balls are put on the silver-plated portion. After the solder is molten and spreads sufficiently, the Si chip is die-bonded to the lead frame.

Conventional silver-plating is poor in solder-wettability, so that solder may not spread sufficiently. If the solder does not spread sufficiently, the joint area of a Si chip and a lead frame becomes small. In this case, the joint power of the Si chip and the lead frame is lowered. That is, reliability of the resultant product becomes remarkably low.

Moreover, because of poor solder-wettability of the conventional silver-plating, much time is required for spreading solder. Therefore, much time is also required for the die bonding of a Si chip. In this way, the step for the die bonding is prolonged to result in a problem that costs for the resultant product rise.

As a method for improving solder-wettability of silver-plating, there is known a method of controlling the size of crystal grains of a silver-plating to improve solder-



wettability, as disclosed in Japanese Patent Application Laid-Open No. 63-130793. In this method, however, the solder-wettability varies greatly dependently on the distribution of the grain size and the shape of the crystal even if the average grain size of the crystal is within the defined range. Thus, the improvement in the solder-wettability is insufficient from the standpoint of reliability. Besides, it is necessary for measurement of the size of the crystal grains, which are very fine, to observe the grains with an SEM. As a result, it is impossible to produce a silver-plated material while measuring and controlling the size of the crystal grains continuously.

SUMMARY OF THE INVENTION

In the light of the above-mentioned situation, an object of the present invention is to provide a silver-plated material for lead frames which is excellent in solder-wettability and makes it possible to perform silver plating continuously while checking the solder-wettability in the process of producing the present material.

To overcome the above-mentioned problems, the inventors have made eager investigations and found that there is a strong correlation between the solder-wettability of a silver plating and the color tone of the surface of the silver plating, that



is, the sum of the a^* value and the b^* value, each of which is a chromaticness index in the $L^*a^*b^*$ colorimetric system defined in JIS Z 8729.

The present invention has been made on the basis of the above-mentioned finding. The color tone of the surface of a silver plating is controlled in such a manner that the (a^* value + b^* value) in the $L^*a^*b^*$ colorimetric system is in the range of 1.5 to 7.

According to the present invention, it is possible to obtain a silver-plated material, for lead frames of transistors, ICs or the like, which has excellent and stable solder-wettability. Since the (a^* value + b^* value) can easily be measured, it is possible to perform silver plating while checking solder-wettability continuously.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing the relationship between the (a^* value + b^* value) of the surface of a silver plating and solder-wettability.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in Fig. 1, about which details will be described later, silver-plated copper alloy materials have better solder-wettability as their (a^* value + b^* value) is higher.



When the (a^* value + b^* value) is less than 1.5, sufficient solder-wettability cannot be obtained. When the (a^* value + b^* value) is more than 7, the solder-wettability is sufficient. However, the external appearance of the silver-plating turns from white to yellow so that a lead frame having the silver-plating is judged as an abnormal product by examination with eyes. The commercial value of the lead frame is lost. Accordingly, if the silver-plated copper alloy material has an (a^* value + b^* value) within the range of 1.5 to 7, the material is excellent in solder-wettability and external appearance.

The (a^* value + b^* value) of the surface of a silver-plating can be controlled by silver-plating conditions, for example, by selecting current density at the time of performing silver-plating treatment, the thickness of the silver-plating, the composition of a silver-plating solution, and the like.

The thickness of the silver-plating preferably ranges from 0.5 to 10 μm . If this thickness is less than 0.5 μm , it is difficult to control the (a^* value + b^* value) of the surface of the silver-plating to 1.5 or more. If this thickness is more than 10 μm , its manufacturing costs increase though the solder-wettability of silver-plating is good. For practical use, the thickness of the silver-plating is most preferably from 1.0 to 5.0 μm .

The silver-plated copper alloy material according to the

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present invention may be a material obtained by plating the entire surface of a copper alloy material with silver or by plating the surface of a copper alloy material partially.

Desirably, the copper or copper alloy strip and the silver-plating layer have a nickel-plating layer therebetween. The wording "nickel-plating" also means nickel alloy-plating. The nickel-plating layer has an effect of suppressing the diffusion of Cu into the silver-plating at the time of thermal treatment of the assembly process. If Cu is diffused into the silver-plating to produce a copper oxide on the surface of silver, the solder-wettability of the silver-plating is undesirably lowered. Therefore, it is desired that the copper alloy strip and the silver-plating layer have the nickel-plating layer therebetween. The thickness of the nickel-plating layer preferably ranges from 0.2 to 10 μm . If the thickness is less than 0.2 μm , the above-mentioned effect becomes insufficient. If the thickness is more than 10 μm , workability becomes poor. This is not preferable from the viewpoint of costs. The nickel-plating layer as a diffusion layer may be a plating layer made of pure nickel, or a nickel alloy-plating layer containing at least one selected from cobalt, phosphorus, manganese, iron and the like. The nickel-plating layer and the silver-plating layer may have a copper strike plating layer therebetween. The copper strike plating layer preferably has a thickness of 0.05



to 1 μm .

The copper alloy strip used in the present invention may be composed of any kind of copper alloy. Concerning the silver-plated copper alloy material for lead frames of transistors or ICs, however, strength and electrical conductivity are required; therefore, it is preferred that the tensile strength of the copper alloy as a base material is 30 kgf/mm² or more and the conductivity thereof is 30% IACS or more.

The (a* value + b* value) of the surface of the silver-plating can be measured with a portable color tone meter. Thus, the (a* value + b* value) can be continuously measured while the silver-plated material is produced. For this reason, the production of the silver-plated material and control of solder-wettability can be attained while the (a* value + b* value) is measured. Thus, it is possible to produce stably the silver-plated material having excellent solder-wettability.

Examples

Specific examples of the present invention will be described, hereinafter.

Example I:

Cu-0.1wt%Fe-0.03wt%P alloys (C19210) plated with nickel of 1 μm in thickness were subjected to copper strike plating, so as to have a thickness of 0.2 μm . The resultants were plated

with silver under the conditions shown in Table 1. At this time, the distance between the anode and cathode was 50 mm, and the area ratio of the cathode to the anode was 1 to 1. The time for the silver-plating was changed and the current density for it was changed from 4 to 14 A/dm² to produce test pieces having different (a* value + b* value)s. Subsequently, the resultant test pieces were subjected to a solder-wettability test.

In the solder-wettability test, as shown in Table 2, the test pieces were heated with a plate of 380 °C in the atmosphere of N₂ for 60 seconds, and then solder balls were put on the test pieces. The test pieces were kept at the above-mentioned temperature without flux nor stirring for 10 seconds, and then cooled to measure the area of the spread solder (solder-spread area). The results are shown in Fig. 1. As shown in Fig. 1, the silver-plated copper alloy materials have better solder-wettability as their (a* value + b* value) is higher. If the (a* value + b* value) is less than 1.5, the solder-spread area is less than 60 mm². That is, sufficient solder-wettability cannot be obtained.

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Table 1

Composition	KAg(CN) ₂ : 170 g/L KCN: 90 g/L
Plating conditions	pH: 12 Bath temperature: 30 °C

Table 2

Solder	Composition: Pb-3%Sn-1.5%Ag Shape: Sphere having a diameter of 1.4 mm
Soldering conditions	Heating condition: 380 °C for 10 seconds Atmosphere: N ₂

Example II:

Cu-0.1wt%Fe-0.03wt%P alloys (C19210) plated with nickel of 1 μ m in thickness were subjected to copper strike plating, so as to have a thickness of 0.2 μ m. The resultants were plated with silver under the conditions shown in Table 1, so as to have a thickness of 4 μ m. At this time, the distance between the anode and cathode was 50 mm, and the area ratio of the cathode to the anode was 1 to 1. The current density for the silver-plating was changed from 4 to 14 A/dm² to produce test pieces having different (a* value + b* value)s. Subsequently, the resultant test pieces were subjected to an external appearance test and a solder-wettability test.

In the external appearance test, the surfaces of the silver-plated copper alloys were observed with eyes and a microscope. The test pieces having an abnormality, such as a turn to yellow, were judged as rejected products. In the

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solder-wettability test, the solder-spread area was measured in the same way as in Example I. The test pieces having a solder-spread area of 60 mm² or more were judged as passed products while the test pieces having a solder-spread area of less than 60 mm² were judged as rejected products.

The results of the solder-wettability test about the respective test pieces are shown in Table 3. The test pieces of Examples 1-5 having an (a* value + b* value) within the range of 1.5 to 7.0 were passed in both the solder-wettability test and the external appearance test. On the other hand, Comparative Example 1 having an (a* value + b* value) of less than 1.5 was poor in solder-wettability. Comparative Example 2 was good in solder-wettability, but the external appearance of its silver-plating was yellow. Thus, in the external appearance test, it was judged as a rejected product.

Table 3

		a* value + b* value	Solder-spread area (mm ²)		External appearance
Example	1	1.5	60	Passed	Passed
	2	3.0	82	Passed	Passed
	3	4.0	131	Passed	Passed
	4	5.0	133	Passed	Passed
	5	7.0	200	Passed	Passed
Comparative Example	1	0	32	Rejected	Passed
	2	8.0	207	Passed	Rejected

Example III:

Cu-0.1wt%Fe-0.03wt%P alloys (C19210) plated with nickel of 1 μm in thickness were subjected to copper strike plating,

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so as to have a thickness of $0.2 \mu\text{m}$. The resultants were plated with silver under the conditions shown in Table 1. At this time, the distance between the anode and cathode was 50 mm, and the area ratio of the cathode to the anode was 1 to 1. The electric density was made up to 10 A/dm^2 and the time for the silver-plating was changed to produce test pieces having different thicknesses of the silver-plating. In the same manner as in Example II, the resultant test pieces were subjected to an external appearance test and a solder-wettability test.

The results of the solder-wettability about the respective test pieces are shown in Fig. 4. The test pieces of Examples 6-10 having an (a^* value + b^* value) within the range of 1.5 to 7.0 and having a silver-plating thickness within the range of 0.5 to $10.0 \mu\text{m}$ were passed in both the solder-wettability test and the external appearance. On the other hand, Comparative Example 3 having a silver-plating thickness of less than 0.5 had an (a^* value + b^* value) of less than 1.5 and was poor in solder-wettability. Comparative Example 4 having a silver-plating thickness of more than $10 \mu\text{m}$ was good in solder-wettability, but the external appearance of its silver-plating was yellow. Thus, in the external appearance test, it was judged as a rejected product.

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Table 4

		Ag plating thickness (μm)	a* value + b* value	Solder-spread area (mm^2)		External appearance
Example	6	0.5	1.5	65	Passed	Passed
	7	1.0	2.5	97	Passed	Passed
	8	3.0	4.9	130	Passed	Passed
	9	5.0	5.2	105	Passed	Passed
	10	10.0	7.0	205	Passed	Passed
Comparative Example	3	0.2	-3.8	20	Rejected	Passed
	4	15.0	8.1	209	Passed	Rejected

Example IV:

A Cu-0.1wt%Fe-0.03wt%P alloy (C19210) plated with nickel of $1\ \mu\text{m}$ in thickness, the same alloy plated with Ni-5wt%P, and the same alloy which was not plated were subjected to copper strike plating, so as to have a thickness of $0.2\ \mu\text{m}$. The resultants were plated with silver under the conditions shown in Table 1, so as to have a thickness of $1\ \mu\text{m}$. At the thought on heat treatment in the assembly process of transistors or ICs, the test pieces were subjected to heat treatment at $400\ ^\circ\text{C}$ for 5 minutes. In the same manner as in Example I, the resultant test pieces were subjected to a solder-wettability test. In this test, the test pieces having a solder-spread area of $60\ \text{mm}^2$ or more was judged as passed products while the test pieces having a solder-spread area of less than $60\ \text{mm}^2$ were judged as rejected products.

The results of the solder-wettability test about the respective test pieces are shown in Table 5. The test pieces of Examples 11 and 12 subjected to the plating with nickel and

the plating with the Ni-5wt% P, respectively, were good in solder-wettability. On the other hand, Comparative Example 5 not subjected to any plating with nickel was poor in solder-wettability since copper diffused in the silver-plating reached the surface of the silver-plating to produce an oxide.

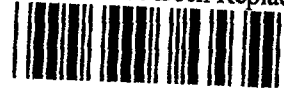
Table 5

		Presence or absence of Ni-plating layer (Component of the Ni plating layer)	Solder-spread area (mm ²) of samples after the treatment at 400 °C for 5 minutes	
Example	11	Presence (Ni)	96	Passed
Example	12	Presence (Ni-5wt%P)	95	Passed
Comparative Example	5	Absence	51	Rejected

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WHAT IS CLAIMED IS:

1. A silver-plated material for lead frames which has excellent solder-wettability, wherein a silver-plating layer having an (a* value + b* value) of the L*a*b* colorimetric system within the range of 1.5 to 7 is made on a copper strip or a copper alloy strip.
2. A silver-plated material for lead frames according to claim 1, wherein the thickness of the silver-plating layer is from 0.5 to 10 μ m.
3. A silver-plated material for lead frames according to claim 1 or 2, wherein the copper strip or the copper alloy strip and the silver-plating layer have a nickel- or nickel alloy-plating layer therebetween.



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