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EFFECT OF ISOTHERMAL AGING ON THE INTERFACIAL REACTIONS BETWEEN SN1.5AG0.7CU9.5IN SOLDER AND CU SUBSTRATE

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Abstract: The aim of article is study the effect of isothermal aging on the interfacial reactions between Sn1.5Ag0.7Cu9.5In solder and Cu substrate. Aging of joints made with tin-based alloy Sn1.5Ag0.7Cu9.5In was carried out at various temperatures ranging to 170°C, at various times ranging to 16 days. Samples of solder joints were analyzed by optical microscopy and EDX microanalysis. Microstructure analysis of heat affected joints interface revealed the morphology and thickness change with increase of temperature and time. A significant thickening of the solder structure was observed as well.

Key words: Lead-free solder, Intermetallic compound, Aging, Interfacial reaction

1. INTRODUCTION

The rapid development of electronic packaging and assembly technology has resulted in a demand for advancement in the performance of soldering interconnects (Viňáš, et al., 2009). Reliability of soldering interconnects in electronic packaging and assembly is primarily determined by the microstructure of interconnects, whereas the microstructure of interconnects is dependent on the interfacial reaction during soldering and operation service (Zeng et al. 2010). In this article, the microstructure, especially the interfacial reaction behaviors between lead-free solder Sn-Ag-Cu-In and the Cu substrate in aging process was studied and mechanisms for certain reaction phenomenon were investigated. Currently, from lead-free solders the attention is getting the eutectic SnAg alloy. It has a higher melting point than SnPb alloy and no risk to the environment. Systems of lead-free solders are mainly based on the addition of a small amount of third or fourth addition in binary alloys to improve their properties. Indium is added to the solder alloys in order to decrease melting point and improve the wettability and this make possible to lower soldering temperature (Kanlayasiri, 2009). The addition of indium also advances the oxidation resistance (Šebo et al., 2009; Viňáš et al., 2008).

2. EXPERIMENT

The four component lead-free solder Sn1.5Ag0.7Cu9.5In was created by casting, gradually melted from pure metals and soldering alloys by induction heating in Al_2O_3 crucible. Metals and alloys were used in the form of ingot (Sn 99.99%) and wire (SnAg5.0, SnCu3.0). Individual components were weighed by 0.01g accuracy. Technical copper of purity 99.99 % was used as the basic material. Soldering was provided by using the hot plate method at temperature of 250 C for 4s. The created samples of solder joints Cu-Sn1.5Ag0.7Cu9.5In were subsequently aged at temperatures of 130, 150 and 170°C for 16 days. The samples were gradually taken away from the vacuum furnace at intervals of 2, 4, 8, 12 and 16 days. For microstructural analysis the heat-affected and unaffected joints samples were grinded and polished with diamond paste up to particle size of 0.7 m and then were etched (2% HCl + 5% HNO_3, 93% methanol) for 2-4 s. The microstructure of soldered joints and morphology of intermetallic phase presented in solder structure and on the joints interface was investigated by optical microscopy. To evaluate the chemical composition and identify different phases the EDX microanalysis (JEOL-JXA-840A) was carried out.

3. RESULTS AND DISCUSSION

3.1 Evolution of IMFs at the interface between the solder bulk and Cu substrate during aging

The microstructure of Cu-Sn1.5Ag0.7Cu9.5In solder joints interface after soldering and heat affecting at temperature of 150°C is shown in figure 1.

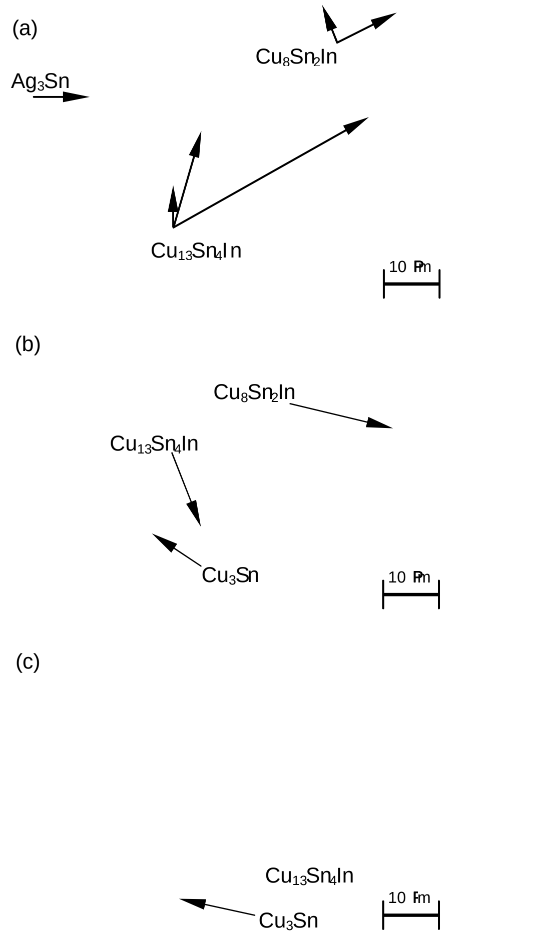

Fig. 1. Microstructural evolution of Cu–Sn1.5Ag0.7Cu9.5In solder joints aged at 150°C for various times; (a) as-soldred, (b) 48 h, (c) 384 h.

The structure of the solder Sn1.5Ag0.7Cu9.5In after soldering is characterized by heterogeneity. The volume of solder are three phases, the first Ag_3Sn consist of Ag element in the used solder composition, which during influence of heat and time changes its shape and size. The second phase Cu_8Sn_2In which is dispersed in the Sn matrix of solder, and phase $Cu_{13}Sn_4In$, which is located near the interface. Due to the high solubility of In in the Sn at the Cu-Sn1.5Ag0.7Cu9.5In interface after soldering was observed the ternary $Cu_{13}Sn_4In$ intermetallic phase. The presence of this phase was confirmed by EDX microanalysis (58.46 at.% Cu, 33.12 at.% Sn, at 8.41% In). The thickness of IMC layer was about 2 μm. There can be seen the next intermetallic phase Cu_3Sn after aging at Cu - $Cu_{13}Sn_4In$ interface (Fig. 1b). Morphologes of the IMCs at the interface are significantly different each other. IMC $Cu_{13}Sn_4In$ is initially consisted of several sprouts (indent, spicules) differently oriented into the solder, incomparises to Cu_3Sn phase. The indented shape of $Cu_{13}Sn_4In$ phase had changed over time to highly asymmetric one with plenty thick sprouts, being seen especially at the aging temperatures of 150 and 170°C, when the phase grows relatively quickly (Fig. 1c).

The EDX microanalysis of heat affected structure of solder joints Cu-Sn1.5Ag0.7Cu9.5In with created phases can be observed in figure 2. The line analysis confirmed the presence of reaction products at the interface and the presence of phases Ag_3Sn and Cu_8Sn_2In in the solder and on the interface.

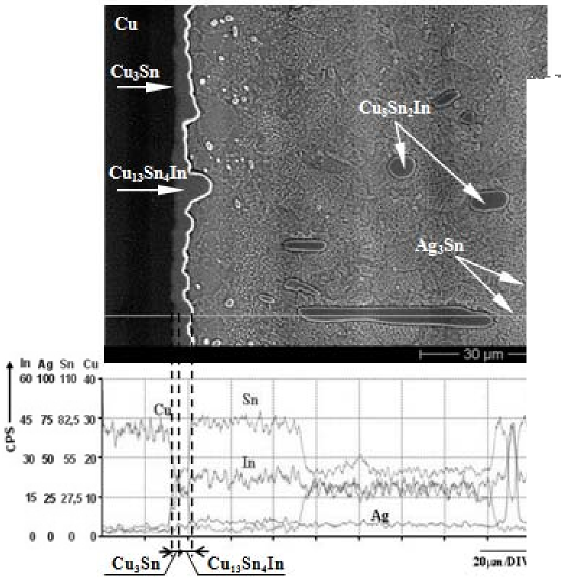

Fig. 2. EDX line profile of Cu–Sn1.5Ag0.7Cu9.5In solder joint interface aged at 150°C for 28 h

3.2 Growth rate of interfacial IMCs during aging

The direction of intermetallic phase's growth, their thickness as dependence on the aging time at different temperatures is documented in figure 3. The results show that temperature increase causes increase of IMC. The most significant increase of layer thickness can be observed at the $Cu_{13}Sn_4In$ phase which is growing faster at all temperatures than Cu_3Sn. At temperatures 130 and 150°C the Cu_3Sn intermetallic phase has the linear kinetics of growth with slower growth compared at the temperature 170°C. Intermetallic phase thickness growth as time dependence seems to be linear at the beginning, but after eight days at 170°C this linear character disappears.

4. CONCLUSION

In this article, the microstructure, especially the interfacial reaction behavior between lead-free solder Sn1.5Ag0.7Cu9.5In and the Cu substrate in aging process was studied. Under the impact of the thermal action it is possible to observe two intermetallic layers darker Cu_3Sn and lighter $Cu_{13}Sn_4In$. Non-continuous grouping of Cu_8Sn_2In IMC can be observed, too.

Fig. 3. Graph of the average thickness of the intermetallic layer Cu_3Sn and $Cu_{13}Sn_4In$ at the Cu/Sn1.5Ag0.7Cu9.5In interface in dependence of aging time.

The thickness of the $Cu_{13}Sn_4In$ layer shows almost linear dependence of the time at beginning. The growth rate of the Cu_3Sn layer reveals the character corresponding to the diffusion process. The average thickness of both IMC layers reached the value of 42.6 μm at 150°C. Intermetallic compounds had physical and mechanical properties different from the solder bulk and substrates, so an excess of IMC would be of considerably affect the fatigue strength and fracture strength of the interconnects. Future research activities assessing the influence of thickness IMC on thermomechanical fatigue of solder joints.

5. ACKNOWLEDGEMENTS

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