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INTERACTION OF BIAG11 SOLDER WITH CU, AG AND NI SUBSTRATES

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Abstract: *The aim of this contribution is to look at the interactions between BiAg11 solder and Cu, Ag and Ni substrates in detail. A degree of interaction was determined on the basis of wetting angles. The best wetting angle of 18° was measured in the case of Ag substrate with the application of flux. Unsatisfactory wetting angle of 146° was attained in case of Ni substrate with the application of flux. The sizes of wavy interfaces were determined by the EDX microanalysis and this experiment was aimed at finding in which cases the application of substrates resulted in the formation of intermetallic compounds and when only a eutectic reaction occurred. The intermetallic compound was created only during the application of Ni substrate. The results showed that shorter endurance and addition of flux resulted in better interaction between BiAg11 solder and Cu or Ag substrates. On the contrary, longer time of endurance without the application of flux caused better interaction between Ni substrate and the solder used.*
Key words: *solder, wetting, transitional area, flux*

1. INTRODUCTION

Sn-Pb based alloy was the most commonly used solder alloy for electronic industry. The harmful effects of lead are generally well known, and therefore, all soldering materials are being substituted for lead-free ones. However, PbSn5 and PbSn10 solders with high lead content are still utilized in the applications where higher temperature is required because no existing substitutes have been developed. Nevertheless, there are alternative solders whose qualities are similar to lead-containing solders (Zhao at al., 2004). These include precious metals such as gold (AuSn20, AuGe12) and silver (BiAg11, SnAg25Sb10). BiAg11 solder was chosen for the experiment due to more affordable price than Au based solders and higher melting point in comparison to SnAg25Sb10 solder.

2. EXPERIMENT

Cu, Ag and Ni substrates as well as the solder consisting of 89 % of Bi and 11 % of Ag were chosen for the experiment. Not only the melting point had to be in the range from 260 °C to 450 °C but also solder had to have satisfactory tensile strength and reasonable price. Vacuum casting was performed in order to ensure the 99.99 % purity of the solder alloy (Song at al., 2006). The sizes of samples were 40 x 40 x 2 mm. A production procedure of the first three samples began with putting 1 gram of BiAg11 solder to the centre of clean and degreased surface of each sample. Samples were soldered in an air furnace at the temperature of 380 °C for 30 minutes. A production procedure of other three samples was similar with the difference that in final stage to this 1 gram of BiAg11 solder we added flux. Samples were soldered in an air furnace at the temperature of 380 °C as well. The endurance at this temperature differed, however, it was only 10 seconds. The aim of the experiment was to learn about the interactions between BiAg11 solder and Cu, Ag and Ni substrates and also determine the influence of flux and its effects. The level of interaction was determined on the basis of wetting angles. Tests of wettability of BiAg11 solder were conducted with the help of goniometric method. The lower the angle; the better interaction can be expected. Flux can help the interaction but it depends also on the type of the substrate. Samples were prepared metalographically with the aim to determine the contact wetting angles and perform observations of the solder-substrate interface. Since the samples were in corroded state the results proved the presence of phases and visible wavy interfaces. The EDX analysis was utilized to monitor the change in the concentration of elements on the determined line through the defined area of phase interface. These areas included the areas of dark phases, matrix and the areas of phase interface.

3. RESULTS

First, the samples with Cu substrates were measured. The sample without the application of flux had the wetting angle of 91° which means unsatisfactory wettability (Fig. 1 a). Negative effects included the formation of visible hollows. On the contrary, in the sample with the application of flux the wetting angle was 25° which means good wettability (Fig. 1 d).

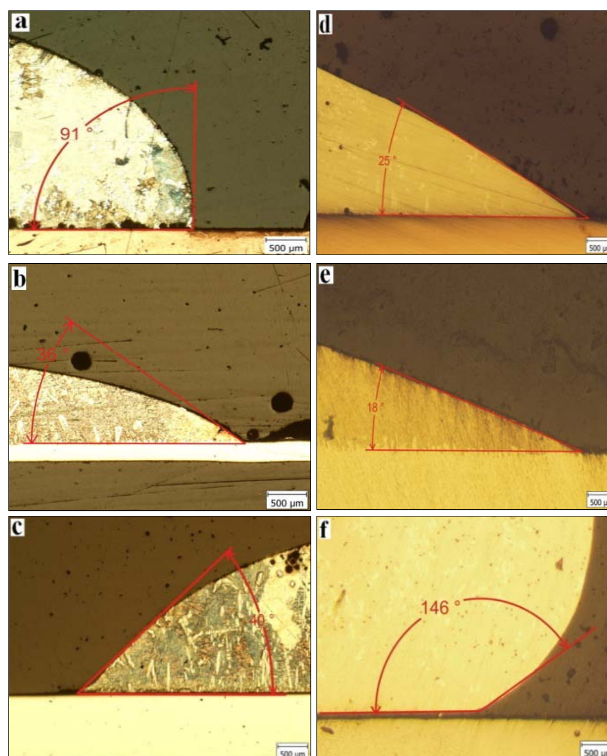

Fig. 1. Angles of wettability on Cu (a), Ag (b) and Ni (c) substrate without flux and Cu (d), Ag (e) and Ni (f) with flux

Satisfactory results were recorded in both cases when samples with Ag substrates were utilized. The sample without the application of flux had the wetting angle of 36° which means good wettability (Fig 1 b) and the sample with the application of flux had very good wettability of 18° (Fig. 1 e). The results of samples regarding wetting angles with Ni substrates were as follows. In case of the sample without the application of flux the angle was 40° which still means good wettability (Fig. 1 c). Unsatisfactory value of 146° was recorded in the sample with the application of flux (Fig. 1 f). Visible gap between BiAg11 solder and Ni substrate proves that there were unwetted areas.

The EDX analysis was performed only on those samples which recorded the best values of wetting angles (Figs. 1 c,d,e).

Based on the images from the EDX analysis it is visible that Cu does not dissolve either in Bi or Ag. Independently on the fact whether flux was applied or not, there was no intermetallic compound between Bi and Cu elements, and only a eutectic reaction occurred with expected weak interaction between solder and the Cu surface at the temperature of 270 °C. The size of wavy interface reached 1 µm and was insignificant (fig. 2). Eutectic reaction was not significant as well.

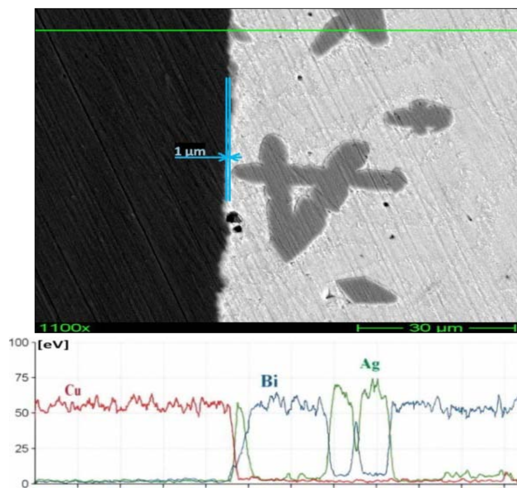

Fig. 2. EDX analysis of BiAg11 solder- Cu substrate fabricated with the use of flux and line profiles of elements present.

During soldering Ag substrates with BiAg11 solder, a eutectic reaction with more significant interaction between solder and surface occured. There was higher probability that primary material would be wetted. The more significant eutectic reaction occurs, the bigger is the waving effect. The size of wavy interface of 3.5 µm is depicted on the fig. 3.

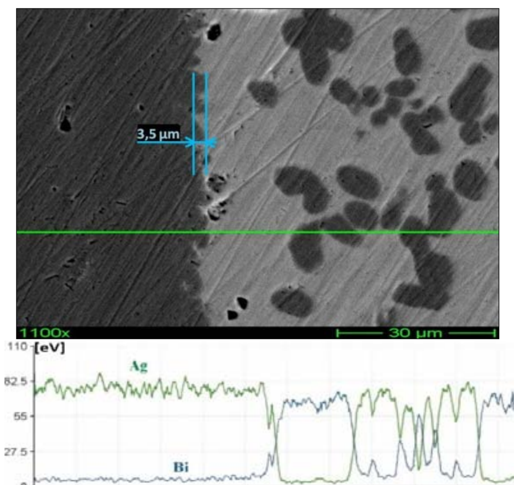

Fig. 3. EDX analysis of BiAg11 solder- Ag substrate fabricated with the use of flux and line profiles of elements present

The complexity of this process was determined by low solubility of Ag in Bi in the liquid state (Liang, 2007).

During the interaction of BiAg11 solder with Ni substrate, the formation of inter-layer of chemical compound was expected. According to Ni-Bi binary diagram, the formation of $NiBi_3$ intermetallic compound was the most probable at the temperature of 271°C. Then Ni dissolved to $NiBi_3$. The width of formed $NiBi_3$ intermetallic compound was 20 µm (Fig. 4).

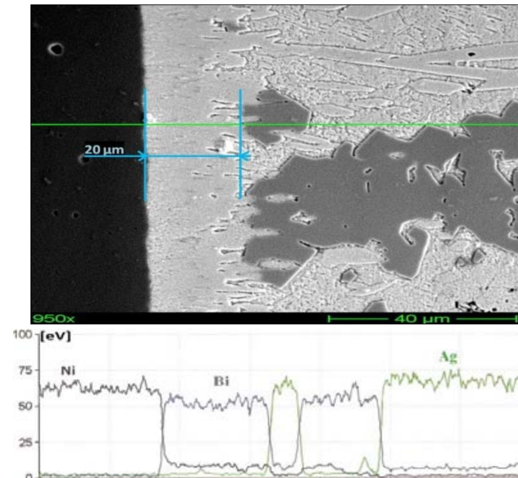

Fig. 4. EDX analysis of BiAg11 solder- Ni substrate fabricated without the use of flux and line profiles of elements present

4. CONCLUSION

Better results were recorded with Cu and Ag substrates when flux of the Soldaflux type was applied. The results of wetting angles were 25° for Cu substrate and 18° for Ag substrate which means that both materials are suitable for BiAg11 solder and for its potential application in practice.

In case of Ni substrate it is better not to apply flux. The results of wetting angles are only then satisfactory. In the nearest future, BiAg11 solder has a good perspective to be used in electrical engineering in soldering printed circuit boards directly on a conductive surface (Lee, 2007). It is the first economically advantageous lead-free solder which can be used to solder printed circuit boards and which is able to withstand the temperature of 260 °C during the reflow soldering (Rahn, 2006).

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