WETTABILITY OF BiAg11 SOLDER DURING FLUX APPLICATION

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Abstract

Recently does not exist any adequate substitute for high lead content PbSn5 solder. Therefore, new alternative solder alloys, such as BiAg11 are developed. The aim of this contribution is to identify wettability and interactions between alternative BiAg11 solder and base materials Cu, Ag and Ni using the flux and reflow soldering (temperature 380 °C) without shielding gas. Holding time at the temperature was 10 seconds. Wettability measurement on the specimens was performed. Measured wettability angles for the BiAg11 and Cu base material solder joints was 25° (very good wettability), BiAg11 - Ag base material reached the value of 18° (perfect wettability) and BiAg11 - Ni base material was approximately 98° (unsufficient wettability). Optical microscopy and EDX analysis were used for the observation of specimen cross sections. Values of wavy interface were measured in the case of all samples. BiAg11 solder - Cu interface was thick only 1 µm, BiAg11 solder - Ag interface 3.5 µm and the last BiAg11 solder - Ni interface was about 5 µm. As follows from reached results, Ag and Cu base materials are the most suitable materials for the BiAg11 solder. The application of Ni as the base material is inappropriate, because of the formation of brittle intermetallic compounds. In the case of Ag and Cu base materials, only a weak eutectic reaction occurred.

Key words: wettability, BiAg, 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 has been developed. But there are alternative solders whose qualities are similar to lead-containing solders \cite{1, 2, 3}. These include precious metals such as gold (AuSn20, AuGe12) and silver (BiAg11, SnAg25Sb10). BiAg11 solder was chosen for the experiment, because of more affordable price than Au based solders and higher melting point in comparison to SnAg25Sb10 solder \cite{2}.

Many contributions focused on BiAg11 solder properties. The interaction among BiAg11 solder with metallic substrates were studied at Tsingua university in Beijing. Institute of Multidisciplinary research for advanced materials at Tohoku university deals with thermodynamic properties and evaluations of lead – free solders for higher working temperatures. Tensile strength and ductility of BiAg11 solder was tested \cite{2, 4, 5}.

2. EXPERIMENT

Cu, Ag and Ni substrates as well as solder consisting of 89 % of Bi and 11 % of Ag were chosen for the experiment. Not only the melting point must have been in the range between 260 °C and 450 °C but also solder must have had satisfactory tensile strength and be at reasonable price. Vacuum casting was
performed in order to ensure the 99.99 % purity of the solder alloy [3]. The sizes of samples were 40 x 40 x 2 mm. A production procedure of the samples began with putting 1 gram of BiAg11 solder to the centre of clean and degreased surface of each sample. Than we added 1 gram flux of the Soldaflux type 7000 (3.1.1.A). Samples were soldered in an air furnace at the temperature of 380 °C and during 10 seconds at this temperature.

The aim of the experiment was to learn about the interactions between BiAg11 solder and Cu, Ag and Ni substrates and also to determine the influence of flux and its effects. The level of interaction was determined on the basis of wetting angles [10]. Tests of wettability of BiAg11 solder were conducted with the help of goniometric method. The lower is the angle, the better interaction can be expected. Flux can help the interaction but it depends also on the type of substrate [1, 2].

Samples were prepared metallographically with the aim to determine the contact wetting angles and perform observations at the solder - substrate interface. Because of the fact that 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 concentration of elements on determined line through defined area of phase interface. These areas included the areas of dark phases, matrix and the areas of phase interface [6, 7, 8].

3. RESULTS

3.1 Optical microanalysis

Areas of phase boundaries and the microstructure, which are obtained by optical microscopy are clearly visible in following figures. Various precipitated particles of the second phase rich in Ag, can be observed in the Bi rich primary phase (fig. 1 a, b, c) [11, 12].

![Fig. 1 Cu (a), Ag (b) and Ni (c) substrate - solder phase interface](image1)

3.2 Measurement of wettability angles

First, the sample with Cu substrate were measured and wetting angle was 25° which means good wettability (fig. 2 a).
Satisfactory results were recorded in case when sample with Ag substrate were utilized. The sample had the wetting angle of $18^\circ$ which means good wettability (fig. 2 b).

The result of sample regarding wetting angle with Ni substrate were as follows. The angle was $146^\circ$ which means unsatisfactory wettability (fig. 2 c). Visible gap between BiAg11 solder and Ni substrate proves that there are unwetted areas. Negative effects also included the formation of visible hollows [7, 9, 10].

### 3.3 EDX analysis

Based on the images from the EDX analysis it is visible that Cu does not dissolve neither in Bi nor Ag. Independently on the fact whether flux has been 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 270.4 °C. The size of wavy interface reached 1 µm and was insignificant (fig. 3). Eutectic reaction was not significant as well. [13, 15, 16].
During soldering Ag substrates with BiAg11 solder, a eutectic reaction with more significant interaction between solder and surface occurs. There is a higher probability that primary material will 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. 4). The complexity of this process is determined by low solubility of Ag in Bi in the liquid state [12, 14, 17].

During the interaction of BiAg11 solder with Ni substrate, the formation of inter-layer of chemical compound is expected. According to Ni - Bi binary diagram, the formation of NiBi₃ intermetallic compound is the most
probable at the temperature of 271 °C [18, 19]. Then Ni dissolves to NiBi$_3$. The width of formed NiBi$_3$ intermetallic compound was about 20 µm (fig. 5). [19].

![Image]

**Fig. 5** EDX analysis of BiAg11 solder on Ni substrate and line profiles of elements present

4. CONCLUSION

Better results were recorded with Cu and Ag substrates. 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 the practice. In case of Ni substrate is better not to use it for application to practice [4]. The results of wetting angles are only then satisfactory. In the near future, BiAg11 solder has a good perspective to be used in electrical engineering in soldering printed circuit boards directly on conductive surface [3, 12]. 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 reflow soldering [16].

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REFERENCES


