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The Effect of Geopolymer Ceramic Additions to The Wettability and Shear strength of Sn-Ag-Cu (SAC) Solder: A Preliminary Study

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Abstract. The effect of geopolymer ceramics addition into Sn-3.0Ag-0.5Cu (SAC305) lead free solder was successfully investigated. The lead-free solder SAC305 with the addition of geopolymer ceramics was fabricated by using powder metallurgy microwave-sintering method in order to form a composite solder. The composite solder was analyzed based on wettability and shear strength. The wettability of SAC 305 solder was greatly enhanced with the decreasing in its contact angle. Then, the geopolymer ceramic addition enhanced the shear strength of SAC 305 solder.

1. Introduction

Solder interconnects are absolutely necessary parts in electronic devices which play vital roles in providing an electrical connection and mechanical support. Tin-lead (Sn-Pb) solders are widely used in electronic packaging industries back then since it gives outstanding reliability and solderability. However, the consumption of lead in the solders were banned by legal laws and regulations owing to the toxic nature of lead to human health and environments. Thus, the development of solders that are free from lead usage has been made by many researchers.

Among all the lead-free solders developed, the most promising and economically affordable approach is by introducing a composite solder. A composite solder is form when the reinforcing particles are introduced into the lead-free solder alloys [1]. The reinforcing particles can be in micrometer or nanometer size. Example of reinforcing material that have been used by previous researchers is ceramic particles. The ceramic particles can be in the form of oxide or non-oxide particles such as Silicon Nitride (Si_3N_4) [2-4], Silicon Carbide (SiC) [5, 6], Titanium oxide (TiO_2) [7-9], Aluminium Oxide (Al_2O_3) [10] and Zirconium dioxide (ZrO_2) [11, 12]. The addition of the reinforcement particles into lead free solder alloys are greatly improved and enhanced the solder performances. According to Mohd Salleh et.al., [1], he reported that the additions of TiO_2 into Sn-0.7Cu suppressed the growth of interfacial layer during soldering. Besides that, the addition of Si_3N_4 into Sn-0.7Cu as reported by Mohd Salleh et.al., [4] had improved the wettability of the solder by lowering the contact angle. A.K.Gain et.al., [11] studied the shear strength of Sn-Ag-Cu solder with the addition of nano-particles ZrO_2. He found that, the addition of ZrO_2 increase the shear strength of the solder due to the nano-particles (second phase) dispersion strengthening. Thus, it is believed that the addition of ceramic particles that acts as reinforcement materials in lead free solder alloys give positive effects to the solder performances.

In this study, Sn-3.0Ag-0.5Cu (SAC 305) solder will be reinforced with the geopolymer ceramic particles. To the best of author knowledge, there is no research on the effect of this type of ceramic to lead free solder alloys reported elsewhere. Therefore, in this research attempt has been made by incorporate geopolymer ceramic particles with 0.5 wt% into SAC 305 lead free solder.

2. Methodology

In this research, Sn-3.0Ag-0.5Cu (SAC305) lead free solder powders supplied by Sigma Aldrich with a size range of 25-45um was used as a base matrix. The micron size of geopolymer ceramics was fabricated and used as reinforcement materials in this study.

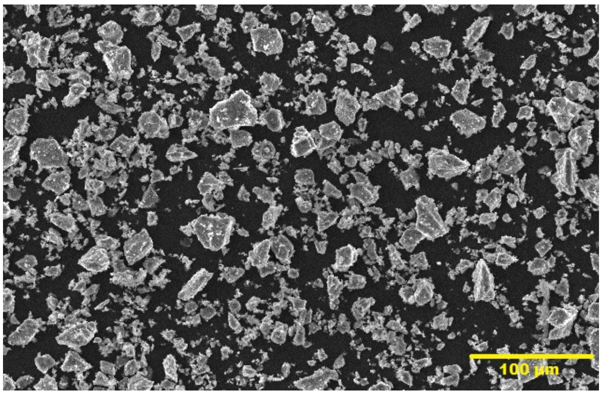

Fig. 1. Microstructure of geopolymer ceramics particles by using SEM

The fabrication of composite solder was carried out by using powder metallurgy (PM) microwave sintering method. The base material, SAC 305 lead free solder was mixed with 0.5 weight percentages (wt%) of geopolymer ceramics powder. The lead-free solder SAC 305 and geopolymer ceramics were pre weighted on a balance weight and homogeneously mixed in an airtight container by using a planetary mill. The rotation speed used was 200 rpm for one hour. The monolithic SAC305 was fabricated by using the same method. Then, each of the solder mixtures were pressed by using a Specac 15-ton Manual Hydraulic Press and uniaxially compacted in a 12 mm diameter mold at a pressure of 4.5 tonnes. The compacted cylinder pellets with about 1 mm thickness were sintered by using a microwave sintering method at a temperature of 185 $^{\circ}$C under ambient conditions in an 800 W, 50 Hz Panasonic microwave oven.

Then, the solder wettability was determined by measuring its contact angle between solder and substrate as shown in Figure 2. The samples were placed on copper substrates and reflowed it in a reflow oven. About 10 samples of each composition were prepared to measure the contact angle in order to ensure the accuracy of the results. The contact angle was measured by using Optical Microscope and J-Image software. Besides that, a single-lap shear test was conducted by using Universal Testing Machine (UTM) INSTRON in order to determine the strength of the solder that are bonded with a copper substrate. Approximately 1.0 g compacted pellets were sandwiched between the copper substrates and were subsequently reflowed it. The test was done according to the ASTM D1002 standard with copper substrate specifications of 101.6mm x 25.4mm x 1.5 mm.

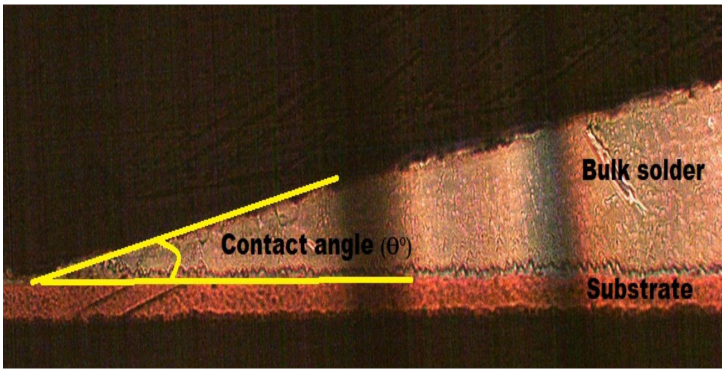

Fig. 2. Contact angle measurement

3. Result and Discussion

3.1 Wettability

Wetting is one of important part in soldering since it determines the good metallic bonding between the solder and the substrate. The wettability of the solder can be described through its contact angle (Θ°) between the solder materials and the substrate. The smaller the contact angle give a better wettability results and it is desired in the process of soldering. This was owing to the fact that; the molten solder materials are able to spread out on the substrate in order to form a perfect solder joint and reliable solder bonding. As the contact angle value is less than 45°, it is considered to be accepted [8].

Based on the results in Figure 3, it is observed that the addition of 0.5wt% of geopolymer ceramics into SAC 305 lead free solder decreased the contact angle value. The contact angle for pure SAC 305 solder was 24.3°. Addition of 0.5 wt% geopolymer ceramics results in contact angle about 23.5°. The decreasing trend of contact angle in composite solder showing that the addition of geopolymer ceramics into lead free solder can improved the wettability of the solder. In addition, the lower contact angle of lead-free solder on substrate is favorable for a good solder bonding.

The possible reasons behind the improvement in wettability of SAC 305 composite solder is caused by the appropriate amount of geopolymer ceramics addition that acts as an agent in reducing the surface tension in a solder. As the geopolymer ceramics were added into SAC 305 solder, it tends to accumulate at the flux and molten solder interface during reflow soldering. Thus, the interfacial surface energy decreased and caused the interfacial tension between flux and solder to be lowered. As a result, a smaller contact angle formed.

Mohd Salleh et.al., [4] , discovered a similar phenomenon of the decrease in the wettability of composite solder. He reported that, the contact angle of Sn-0.7Cu/ Si_3N_4 was improved and the optimum contact angle achieved as 1.0 wt% of Si_3N_4 was added.

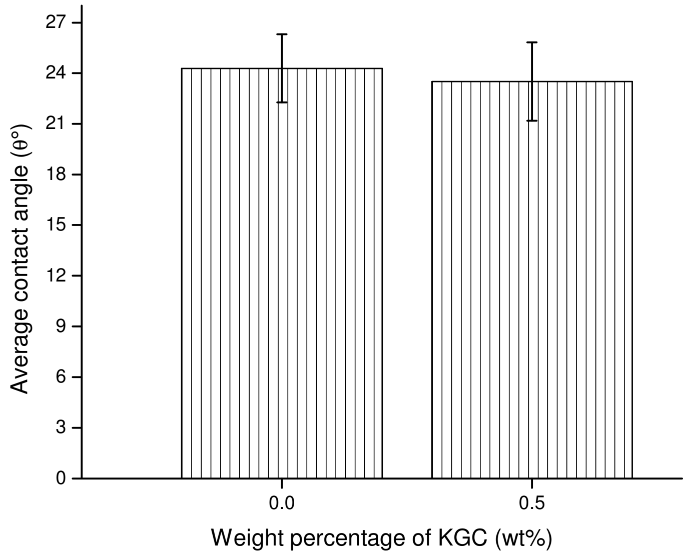

Fig. 3. Bar graph showing the influence of geopolymer ceramics addition to the wetting angle of SAC 305 lead free composite solder

3.2 Shear strength

Shear strength of the solder joint is the most relevant and reliable mechanical properties. It is important in a way that it provide a brief description about performance of new solder composition. In this study, a single-lap shear test was performed in order to mimic the actual solder joints in electronic and microelectronic industry. The results obtained for the single-lap shear test was presented in Figure 4.

Figure 4 shows the shear strength value that is obtained as the geopolymer ceramics added into SAC 305 lead free solder. Pure SAC 305 lead free solder has an average of shear strength of 6.518 MPa. As 0.5 wt% of the geopolymer ceramics added, the average shear strength is 8.098 MPa.

The improvements in the shear strength of the composite solder was attributed to the formation of IMCs that formed between the solder and the substrate [8]. As the geopolymer ceramics were added to the SAC 305 lead free solder, it will alter the IMCs morphology and its thickness and thus, improves the shear strength of the solder joint. Nai et.al., [13] working on 95.8Sn-3.5Ag-0.7Cu with the addition of various wt% of multiwalled carbon nanotube (MWCNTS) particles reported the similar phenomenon. The average shear strength of SAC lead free solder was improved with the addition of MWCNTS. The optimum value of shear strength is achieved when 0.01 wt% of MWCNTS was added to the lead-free solder.

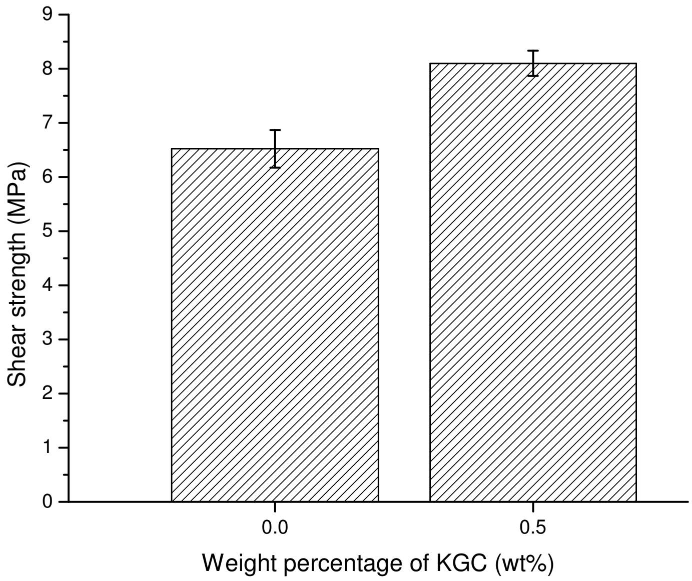

Fig. 4. Average shear strength of SAC 305 composite solder

4. Summary

A new lead-free composite solder reinforced with various wt% of geopolymer ceramics was successfully fabricated by using microwave-sintering powder metallurgy method. The addition of 0.5wt% of geopolymer ceramics improved the wettability of SAC 305 composite solder. Then, the shear strength of the SAC 305 solder also was improved with the addition of geopolymer ceramics. As overall, the addition of geopolymer ceramics gave positive effects to the lead-free solder SAC 305 and thus it can be applied for further analysis in order to elucidate and investigate in terms of its microstructures and IMCs formation.

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