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Void Distributions in Sn-3.0Ag-0.5Cu (SAC305) Composite Lead Free Solder Subjected to Thermal Ageing Using Acoustic Micro Imaging Technique

N S M Zaimi^{1*}, M A A M Salleh¹, M M A B Abdullah¹, M Mostapha¹,
M S Baltatu² and R Ahmad³

¹Centre of Excellence Geopolymer and Green Technology, School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Taman Muhibbah 02600, Jejawi, Arau, Perlis, Malaysia.

²Gheorghe Asachi Technical University, Faculty of Materials Science and Engineering, Department of Physics, 67 Prof. Dimitrie Mangeron Blvd., 700050, Iasi, Romania.

³Faculty of Engineering Technology, Unicity Alam Campus, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.

*E-mail: syahirahzaimi25@gmail.com

Abstract. The formations of the voids in SAC305 lead free solder and SAC305 with additions of kaolin geopolymer ceramics were studied. The composite solders were fabricated by using powder metallurgy with microwave sintering method. The samples were sandwiched between two copper substrates and reflowed in a reflow oven and aged at 125°C for 0 and 7 days. The acoustic micro imaging was used to analyse the distributions of voids in the solder joints of SAC305 and SAC305 with additions of kaolin geopolymer ceramics. Results shows that, the void in SAC305 are larger in size and numbers as compared to SAC305 with additions of kaolin geopolymer ceramics for both reflowed and aged conditions.

1. Introduction

Nowadays, the trend in electronic products towards higher speed, lightweight, multifunctional and continual miniaturization has led to the urgent need for a development of very reliable solder material. Solder play a very important role in electronic packaging where it mechanically and electronically connects the electronic components to the printed circuit board (PCB). For more than 50 years ago, tin-lead solder alloy was successfully and widely used in the electronic industry as the main solder materials due to the outstanding properties served by this alloy [1]. However, the toxicity of lead towards environments and peoples, causes the usage of lead is strictly banned by Restriction of Hazardous Substance (RoHS) and the European Waste Electrical and Electronic Equipment (WEEE) directives. Therefore, many researches have been done in order to replace the conventional lead-based solder which could perform same or better than tin-lead solder alloy. Several lead-free solder alloy have been developed including tin-silver-copper (Sn-Ag-Cu) solder alloy. Sn-Ag-Cu solder alloy has been proposed to be the most promising solder alloy to replace lead-based solder especially in surface mount technology (SMT) due to good properties such as better solderability and well compatibility with the current electronic components [2]. Even so, Sn-Ag-Cu solder alloy need to further improved in the reliability as to fulfil the current demand of higher performance solder alloy. To date,



development of composite solder has took placed among many researchers as to increase the reliability of lead free solder alloy [3-5]. Incorporation of reinforcements either metallic or non-metallic particles believed could give better results in terms of the microstructure formation, solderability and strength of the solder joints [6-8].

In this study, Sn-3.0Ag-0.5Cu (SAC305) lead free solder will be incorporated with kaolin geopolymer ceramics particles that are expected to suppressed the formation of IMCs and improve the performance of existing SAC305 lead free solder. Apart from that, the formations of voids in solder could not be avoided. Thus, in this study an acoustic micro imaging will be used as one of a technique in analysing void distributions in the developed composite solders. The acoustic micro imaging is one of non-destructive technique that widely used to inspect the defects such as cracks, voids and delamination in the electronic components and assemblies [9]. Besides that, acoustic micro imaging utilises acoustic microscope that is equipped with transducers. The transducers emits high frequency of ultrasound in the range of 5MHz to more than 400MHz and when the ultrasound waves penetrates the samples it may scattered, reflected or absorbed by the internal features of the material itself [9,10]. The acoustic images were generated as the ultrasound wave is reflected from an internal part of the sample which had been travelled through the entire thickness of the samples itself. Besides that, Zhang et.al. [11], in his study had used acoustic micro imaging in analysing the micro cracks propagation in the microelectronic packages. Semmens et al. [12], also utilised acoustic micro imaging to determine the failure modes of the flip chip interconnections. Therefore, in this research an attempt was made by using acoustic micro imaging as one of the techniques in analysing the void distributions in SAC305 lead free solder incorporated with kaolin geopolymer ceramics which are also subjected to thermal ageing process.

2. Methodology

In this study, the samples of Sn-3.0Ag-0.5Cu (SAC305) with the addition of 1.0 wt.% kaolin geopolymer ceramic was fabricated by using a technique of powder metallurgy microwave sintering. The base material which is SAC305 lead free solder with the particle size in the range of 25-45 μ m. Firstly, SAC305 powders with 1.0 wt.% kaolin geopolymer ceramic were mixed by using a planetary mill machine at a rotating speed of 200 rpm for an hour in an airtight container. Then, the mixture of SAC305 powders with kaolin geopolymer ceramics were uniaxially compacted by using a Specac 15-ton Manual Hydraulic Press at a pressure of 4.5 tonnes. The compacted pellets were then microwave sintered for about 3 minutes at a temperature of 185 $^{\circ}$ C under ambient conditions by using a 800 W, 50 Hz domestic microwave oven.

Then, the sintered samples were cold rolled by using a rolling machine. The solder sheets obtained from the rolling process were then sandwiched between two copper substrates as in Figure 1 and then reflowed by using a F4N reflow oven with the aid of rosin mildly activated flux (RMA). The reflowed samples were then undergo thermal ageing at a temperature of 100 $^{\circ}$ C for 7 days.

Acoustic micro imaging technique was used to analyse the internal features of the thermal aged samples and it was carried out at Liverpool John Mores University, United Kingdom. The acoustic microscope of the Sonoscan Gen6TM with the 100Mhz 0.5inch transducer was used in this study.

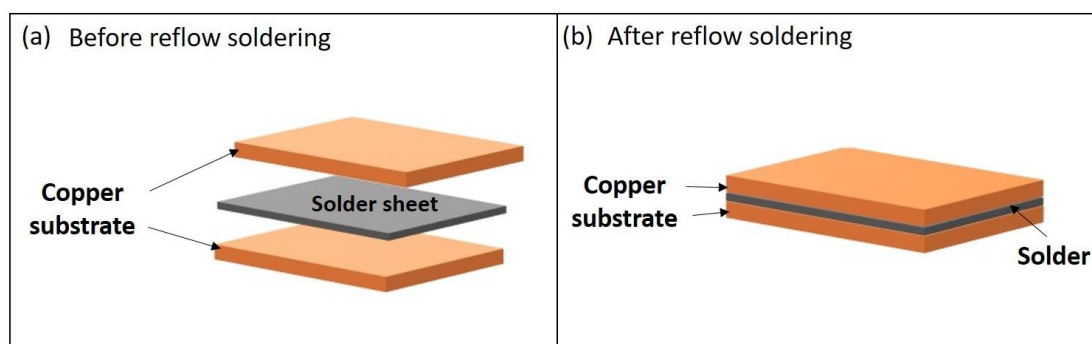


Figure 1. Sample preparation for the reflow soldering of sandwiched samples.

3. Results and Discussions

Figure 2 shows the result of scanning from acoustic micro imaging for the samples of SAC305 and SAC305 with additions of kaolin geopolymer ceramics, subjected to thermal ageing at 125 °C for 0 and 7 days. Based on Figure 2, the brighter circle regions of lower density corresponds to the solder voids. While, the darker regions represents higher density of solder.

The size of the voids in the pure SAC305 were bigger and with larger numbers than the sample of SAC305 with additions of kaolin geopolymer ceramics as revealed in Figure 2(a), 2(b) and Figure 3. It shows that the numbers of solder voids were lesser in the SAC305 with additions of kaolin geopolymer ceramics in as-reflowed and aged samples.

The formation of the voids in the solder was due to the outgassing flux that were entrapped in the solder during soldering. The sources of outgassing flux was due to the evaporation and thermal decomposition of flux constituents that were entrapped in the solder joint. Moreover, the formation of the voids in the solder joint could affect the reliability and the performance of the solder joints. Size of the voids will influence the robustness of solder joint in where larger size of voids increases the tendency of solder joint cracks compared to smaller voids [13, 14]. Besides that, IPC-7095 standard had specified the maximum allowable of void area [14, 15].

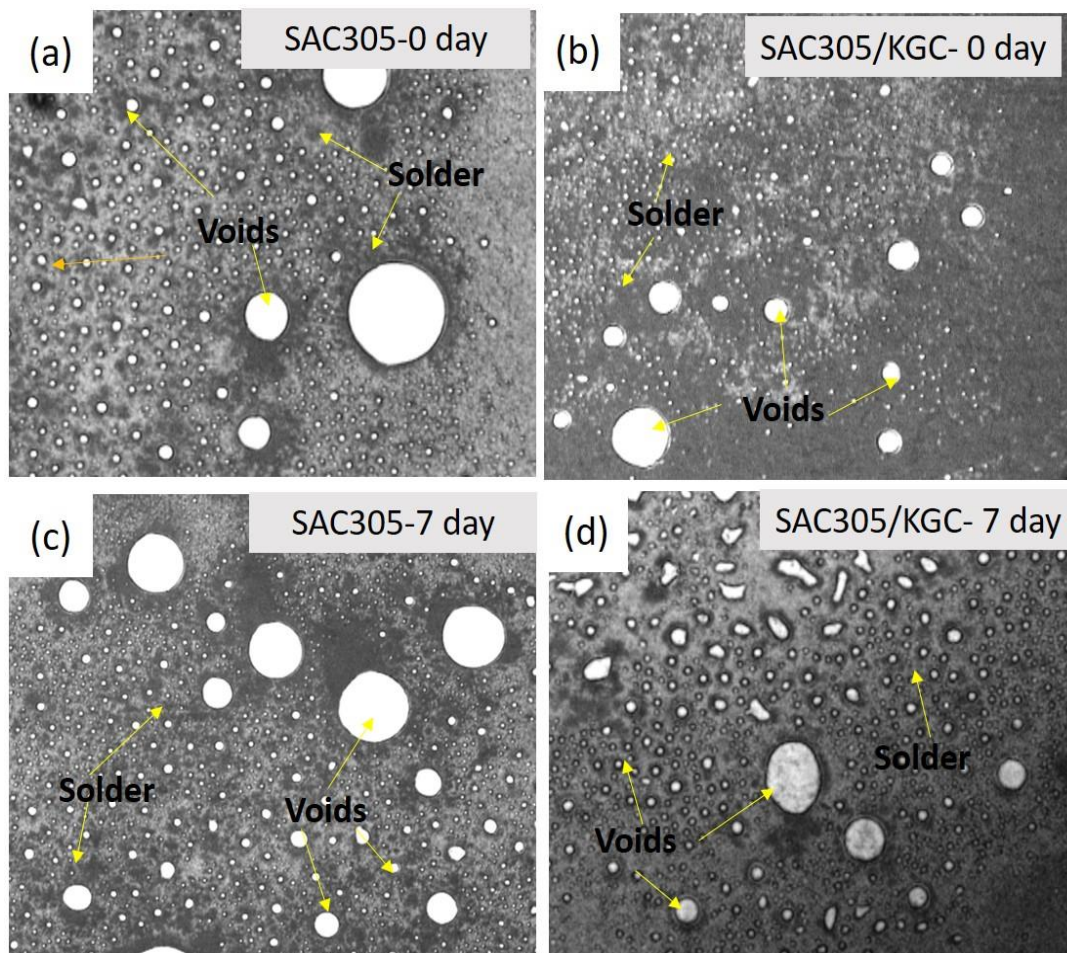


Figure 2. Distribution of voids in SAC305 as a function of thermal ageing temperature at 125°C for (a) 0 day, (c) 7 days and SAC305 with addition of kaolin geopolymer ceramics as a function of thermal ageing temperature at 100°C for (b) 0 day, (d) 7 days.

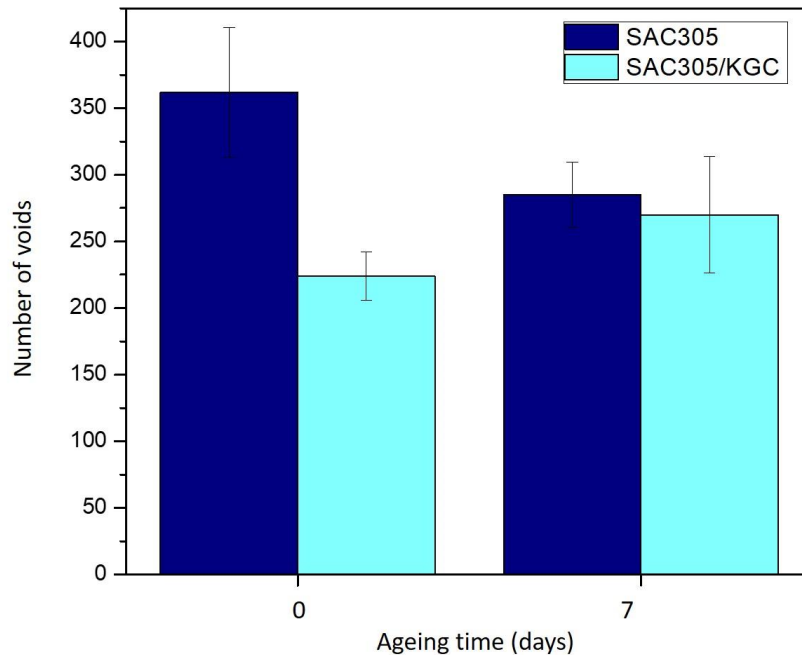


Figure 3. Number of voids as a function of thermal ageing temperature at 125°C for 0 and 7 days in SAC305 and SAC305 with addition of kaolin geopolymer ceramics.

Apart from that, these results also proved that the utilization of acoustic micro imaging in analysing the internal features of solder joint could give new insight in this study area. It was also proved that, the use of high frequency transducer which is 100MHz 0.5inch in this study were able to provide better acoustic image with high resolution since the resulting acoustic image depends on the material itself [9]. However, the results obtained from the acoustic micro imaging could be supported by other characterisation techniques.

4. Summary

A new lead-free composite solder system with the addition of kaolin geopolymer ceramics that are subjected to thermal ageing were successfully fabricated. The acoustic micro imaging technique was used to analyse the distributions of voids in the solder joints. It was clearly observed that the formations of void in SAC305 with additions of kaolin geopolymer ceramics were reduced as compared to pure SAC305 solder joints either on as-reflowed or aged conditions.

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