# Resistivity and morphological analysis of silver-argentum-copper material with different loading of MWCNT

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**Keywords**: SAC305; four-point probe; electrical properties

**ABSTRACT** – The formation of Intermetallic compounds (IMCs) and the resistivity at the solder-substrate interface is essential in the manufacturing of solder joints. In this study, the formation of the IMCs and relationship between resistivity and size of the grain boundary were investigated. The results from the four-point probe showed that the resistivity of SAC305 added with the 0.04% MWCNT were higher than those of SAC305 added with 0.03%, 0.02%, 0.01% and without added MWCNT. The resistivity value is resulted from the size of the grain boundary that appeared at the solder surface.

## 1. INTRODUCTION

In recent years, the researcher has focused to produce the lead-free solder after the lead (Sn) has be claimed as hazardous substances and be banned from being used in the solder [1]. The tertiary solder which is Sn-Ag-Cu is claimed as the most solder that has similar properties with the tin-lead(SnPb) solder [2]. The SnPb solder has been a benchmark for the lead-free solder because of it have good mechanical properties and electrical properties. Besides that, the SnPb solder also has low melting point.

Recently, the interest in adding the nanoparticle in solder to enhance the mechanical properties and electrical properties of the lead-free solder has becoming huge concern in the research area. The carbon nanotube (CNT) has been stated will give the excellent mechanical properties, lowering the melting point of the composite solder and improved the wettability of the solder [3]. However, the effect of the CNT in the solder towards the electrical properties is still lacking.

Therefore, this paper will explain the effect of the CNT in solder and effect of CNT to resistivity of the solder.

## 2. RESEARCH METHODOLOGY

### 2.1 Samples preparation

There are two separate process to prepare the sample in this paper. For the first is to prepare the copper(Cu) substrate and the second is to prepare the 96.5Sn-3.0Ag-0.5Cu (SAC305) filled with the MWCNT. Firstly, the accublack paper with printed Cu substrate design will be placed on top of the positive board. Then they will undergo ultraviolet (UV) curing process about 120 second. The design of the Cu board will be appeared in green color after the positive board were soak in the printed circuit board (PCB) developer machine. The chemical used to soak the board is sodium carbonate. Then, the board with the green circuit will place in stripping machine to strip the unwanted copper. Lastly, the green circuit on the board will be washed out with photoresist stripper chemical and turn it to copper lining. Figure 2.1 shows the condition of the positive board before and after process of PCB develop.

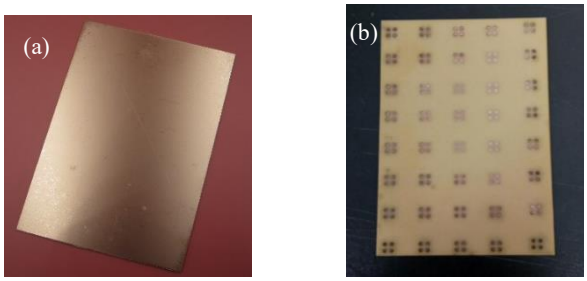


Figure 2.1 Positive board (a) before process (b) after process

For molten solder SAC305, the different loading of the MWCNT will be added in the SAC305. The different loading use for MWCNT are 0, 0.01, 0.02, 0.03 and 0.04. The process to mix these two materials was manufacture by RedRing Solder (M) Sdn. Bhd.

### 2.2 Soldering process

The molten solder without adding with WMCNT will refers as control sample and will be naming as sample 1. The SAC305 adding with 0.01, 0.02, 0.03 and 0.04 will be referring to sample 2, sample 3, sample 4 and sample 5. All the sample will be manually printed by using syringe on the cu substrate. The ready sample will then will be undergoes the reflow process.

### 2.2 Resistivity measurement

The resistivity of the SAC305 were measured with four-point probe. Before the sample being indent with the four-point probe, the surface of solder ball will first be grinding to get the flat surface. The four-point probe also will be calibrating first before being tested on the solder sample.

### 2.3 Morphological study

The soldered sample will be place in the rubber mold and were cold mount before proceeding with the cross-section process. The cold-mounting is a mixing between resin and hardener with ration 3:1. The sample

that has been putting with the mixing will left until the sample has been fully harden. Figure 2.2 shows the example of the sample that has been cold-mounted.

Figure 2.2 Sample that has been cold-mounted

The harden solder sample will then be cross-sectioned perpendicular to the solder-copper interface. The sample will be ground by using silicon carbide paper with sequence of 180, 320, 600 and 1500 grit sizes. The sample will be cooling with flowing water during the process. Next, the sample will be polished with 6µm DIAMAT™ Polycrystalline Diamond suspension followed by 3µm DIAMAT™ Polycrystalline Diamond suspension, 1µm DIAMAT™ Polycrystalline Diamond suspension and 0.05 µm NANOPOLISH Alumina.

After the cross section, the sample will be chemically etched in a mixture of 2% HCL, 5%$HNO_3$, and 93% methanol for a few second to get the clear view of morphological for each sample. The morphological of the sample were investigate via Image Analyser.

## 3. RESULTS AND DISCUSSION

### 3.1 Metallographic observation

Figure 3.2 has shown the morphological structure for sample 1, sample 2, sample 3, sample 4 and sample 5. The formation of the needle like has appeared at the surface of the sample one. This needle shape is presuming as Ag3Sn [4]. Most of the Ag3Sn has been observed precipitated near to the intermetallic compound (IMC) layers. The Ag particles are prone to react with Sn particles to form the $Ag_3Sn$ compound during their first reaction. Then, during the cooling state, the $Ag_3Sn$ will attracted by the IMC. This explained the Figure 3.2 (a), where there are many needle shapes placed at the IMC layer.

However, for sample 2, the IMC shape is different from the sample 1. The scallop shape is form at the IMC and the thickness of the IMC is thick and in uniform. The thickness of the IMC started to decrease for sample 3, sample 4 and sample 5. This situation indicated that, by increase the percentage of the MWCNT in the molten solder will reduce the thickness of the IMC. The MWCNT has taken part to limit the growth of the IMC which result increase the strength of the solder joint. It is because, the IMC is the most brittle part in solder joint, therefore to thick IMC will make the solder joint easily broken.

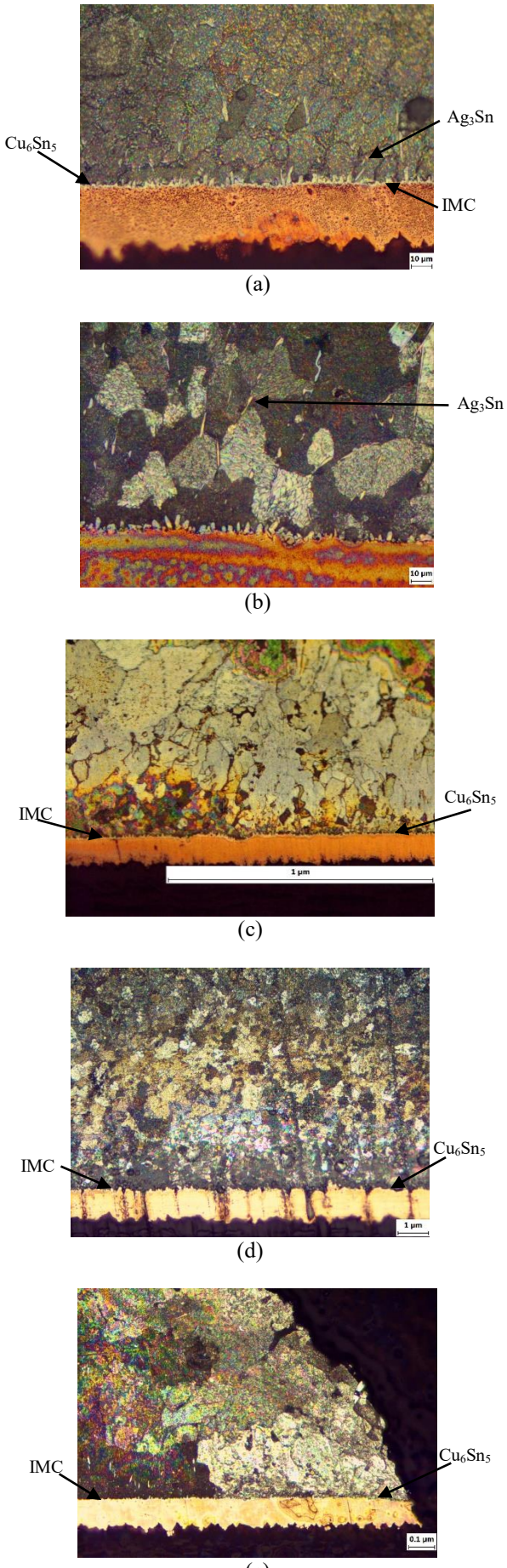


Figure 3.1 The surface morphology for (a) Sample1 (b) Sample2 (c) Sample 3 (d) Sample4 (e) Sample5

### 3.2 Correlation between resistivity and size of grain boundary

The measurement of the sheet resistivity is aiming to get the electrical resistance for the solder before and after adding the MWCNT particle. Figure 3.2 shows graph of resistivity against different percentage of MWCNT. The resistivity of the solder is increase when the percentage of the MWCNT added to the solder SAC305. Sample4 and sample5 has been observed to have the highest resistivity compared to other with 10% higher compared with other. Which means that, the sample4 and sample 5 has indicate lowest conductivity compared to sample 1, sample2 and sample3.

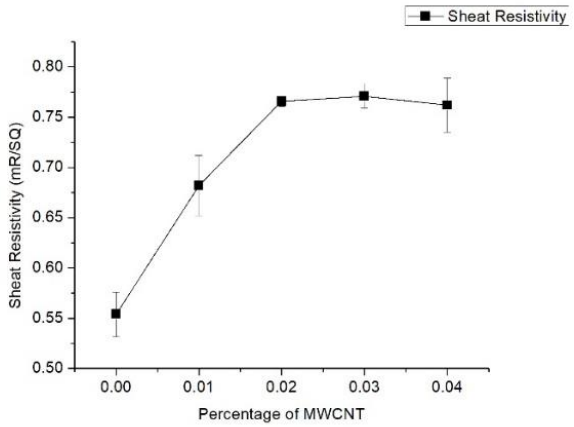


Figure 3.1 Average Resistivity versus percentage of MWCNT

The value of the resistivity of the solder can be relate with the size of the grain boundary. The grain boundaries plays a crucial role to electrical conductivity of the material [5]. Sample 1 is having fine morphological surface with small grain boundary. The grain boundary of the solder surface becoming bigger when the MWCNT added in the molten solder is increasing. The charge carrier mobility will depend on the grain size. When the grain size is increase it will limit the movement of the charge carrier and reduce the conductivity of the material [6].

## 4. SUMMARY

In this study, the MWCNT is using to improve the electrical properties of SAC305 solder. The different percentage of MWCNT (0, 0.01%, 0.02%, 0.03% and 0.04%) are added in the SAC305 solder. The four-point probe is using to find the resistivity of the SAC305 solder before added with MWCNT and after added with different percentage of MWCNT. The surface behaviour of SAC305 also were observe through Image Analyser and the observation result will be relating with resistivity result.

The result can be concluded that, the resistivity of the solder is increase when the weight percentage of the MWCNT increase. Which shows that, the SAC305 added with 0.04% of MWCNT has low conductivity. This case can be explained with the size of the grain boundary for the sample. Therefore, proving that the resistivity of the sample will be affected by the grain boundary of the sample.

Other than that, the advantage of the MWCNT towards SAC305 can be seen with MWCNT can limit the growth of the IMC.

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