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MECHANICAL PROPERTIES OF HIGHLY DEFORMED SN-3.0AG-0.5CU SOLDER WIRE

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ABSTRACT

In this study, mechanical properties of highly deformed Sn-3.0Ag-0.5Cu (SAC305) lead-free solder wire were investigated. The SAC305 solder wire underwent tensile test with 0.1 mms^{-1} strain rate at room temperature, and 25°C and at 120°C chamber conditions. The mechanical properties of the deformed solder wires were evaluated from a stress strain curve by tensile test followed by nanoindentation test. Micromechanical behavior of deformed solder wires was determined using nanoindentation multicycle method. Results showed that the deformed SAC305 solder wire at room temperature have a high yield stress compared to SAC305 solder wire at 120°C temperature. The hardness values of the deformed SAC305 solder wire at room temperature were higher than the hardness values of SAC305 solder wire at 120°C temperature. The decreasing of hardness values in the SAC305 solder wire at 120°C was due to existence of additional heat. In addition, thermal induced the softening behaviour of deformed SAC305 solder wire.

Keywords: SAC305 solder wire; tensile test; mechanical properties; nanoindentation; hardness

INTRODUCTION

Since the use of plumbum (Pb) is prohibited because of its toxicity, lead-free solder has become a popular candidate to replace Pb-based solder. Sn-Ag-Cu is one of the most demanding lead-free solders used today. Sn-Ag-Cu has good wettability and mechanical properties compared to other Sn-based lead-free solders [1]. Sn-Ag-Cu can be found in various forms of solder such as in paste, wire, and ball. In electronic packaging, solder is used as a joint between the die and substrate [2]. Solder joint plays a significant part in ensuring that electronic devices are working. The rapid growth of the miniaturisation trend in electronic packaging triggers great interest in research of the solder joint. Size reduction induces higher heat densities within the solder joint [3]. Exposure of the solder joint to heat may degrade the properties of the joining. The generated heat may alter the microstructures that result in detrimental mechanical properties of the solder joint [4].
Many studies have been conducted on the mechanical properties of thermally induced by solder such as aging condition and heat treatment. Gain and Zhang [5] conducted a study

on the effect of temperature and humidity on the microstructure and mechanical properties Sn-Ag-Cu solder. Exposure to heat treatment induced the coarsening of Sn-Ag-Cu microstructure and degraded the mechanical properties of the solder. A study on thermal cycling aging effects towards the tensile properties and behaviour of Sn-3.0Ag-0.5Cu solder alloy was carried out by Yao and Yu [6]. A new material damage parameter was proposed to consider the effect of temperature during treatment, which was incorporated into the developed model to describe the mechanical behavior of Sn-3.0Ag-0.5Cu.

There are a few methods that can be used to evaluate the mechanical properties of solder such as tensile test, pull test, and nanoindentation test [7]. Nanoindentation is one of the easy-to-use methods for analysing small scale mechanical properties. Nanoindentation may provide the qualitative and quantitative mechanical properties of materials. Qualitative observation can be determined from the loading and unloading profile. Quantitatively, the analysis of mechanical properties is based on extracted indented data [8]. In this study, the mechanical properties of deformed SAC305 solder wire induced by tensile test were analysed using nanoindentation test.

MATERIALS AND METHODS

The deformed solder wires were prepared from Sn-3.0Ag-0.5Cu (SAC305) solder wire provided by Red Ring Solder (M) Sdn. Bhd. Selected SAC305 solder wires with 2 mm diameter were cut into 50 mm length. These solder wires were then attached to the epoxy resin to ease the samples gripped during the tensile test. Figure 1 shows the representative of sample prior to the tensile test. The tensile test was performed according to the standard ASTM E8/E8M-13 [9]. The test was carried out at about 0.1 mms^{-1} strain rate at room temperature (25°C) and 120°C chamber temperature. Tensile machine brand Bruker was used in this testing. After the tensile test, the deformed solder wire went through a metallography technique to provide a flat and smooth surface before undergoing nanoindentation test. Selected regions of the deformed SAC305 solder wire were then cut and mounted. Then, the mounted samples were grounded with 600, 800, and 1200 SiC grit before polished by using a 1µm diamond solution. Then the flat and smooth surface samples were indented using the multicycle nanoindentation test method. For the multicycle nanoindentation test, the applied load was up to 10 mN for 10 cycles of indentation. Figure 2 shows the example of the loading-unloading graph of the multicycle indentation test. In this study, 10 cycles were performed for each sample and repeated three times for each test. The hardness properties of the SAC305 solder wires were extracted from the indented data using Oliver and Pharr method [10].

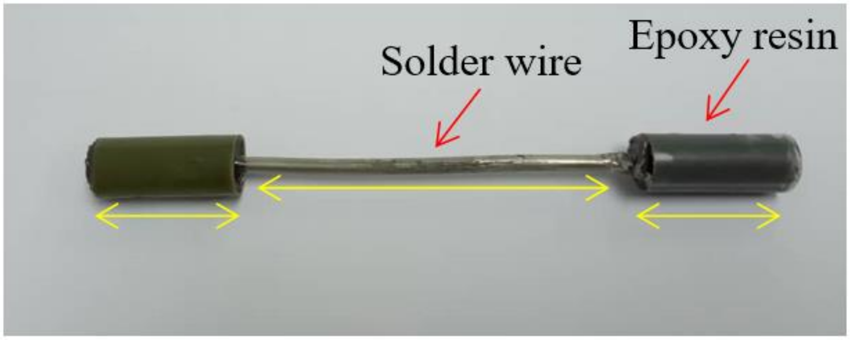

Figure 1: Representative SAC305 solder wire sample for tensile test

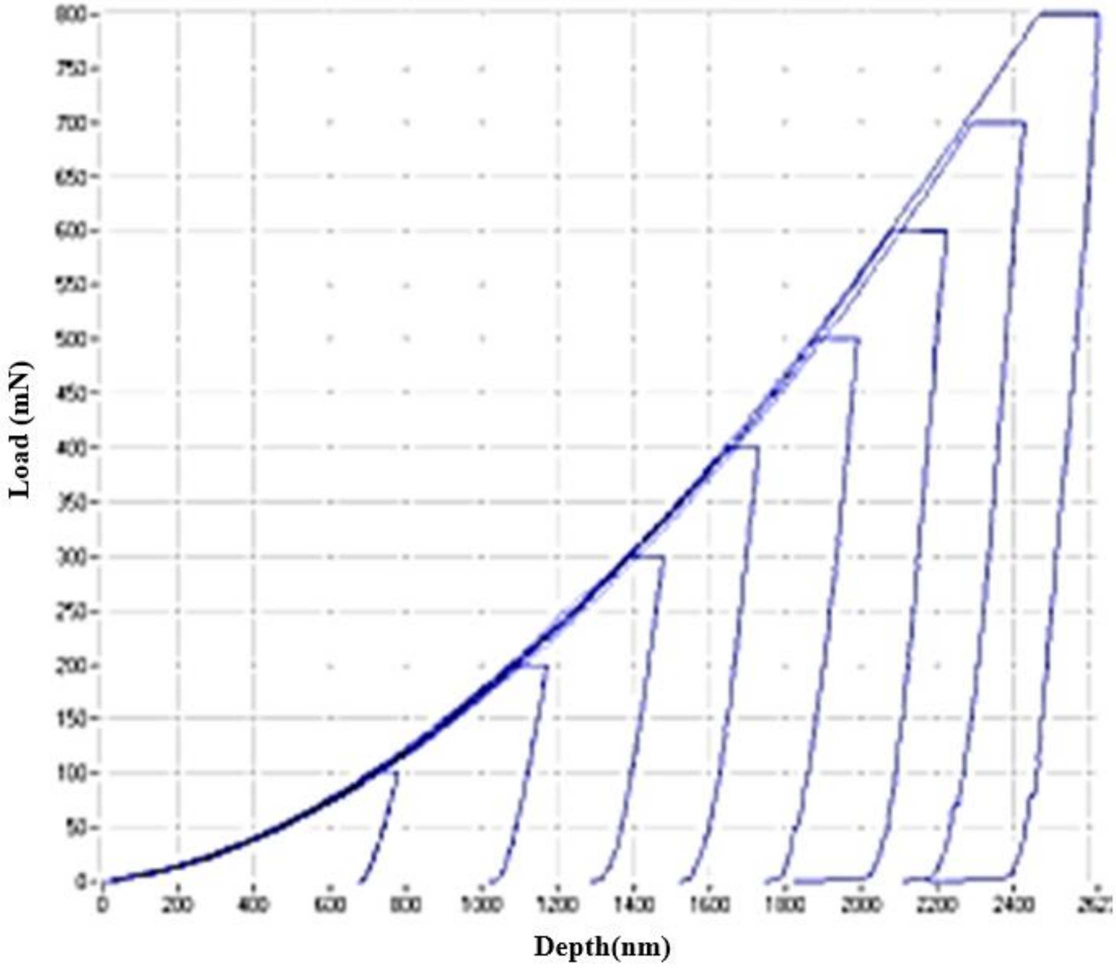

Figure 2: Example of loading and unloading profile of multicycle nanoindention test

RESULT AND DISCUSSION

Figure 3 shows the stress-strain graph of SAC305 solder wire at room temperature and

120°C for chamber conditions. From the graph, SAC305 solder wire had the higher stress which was about 380 MPa compared to SAC305 solder wire at 120°C about ~213 MPa. However, SAC305 at 120°C showed higher percentage of elongation compared to SAC305 solder wire under room temperature. It was found that when exposed to heat, SAC305 beaome more ductile [11]. Existence of heat changed the microstructure and automatically changed the properties of the material. Heat played a major role in the softening of metal due to the recovery and recrystallization phenomena. Increase in local heat created during increased strain rates will lengthen the required time to nucleate a crack that created a fracture, thus increasing the ductility of SAC305 solder wire [12].

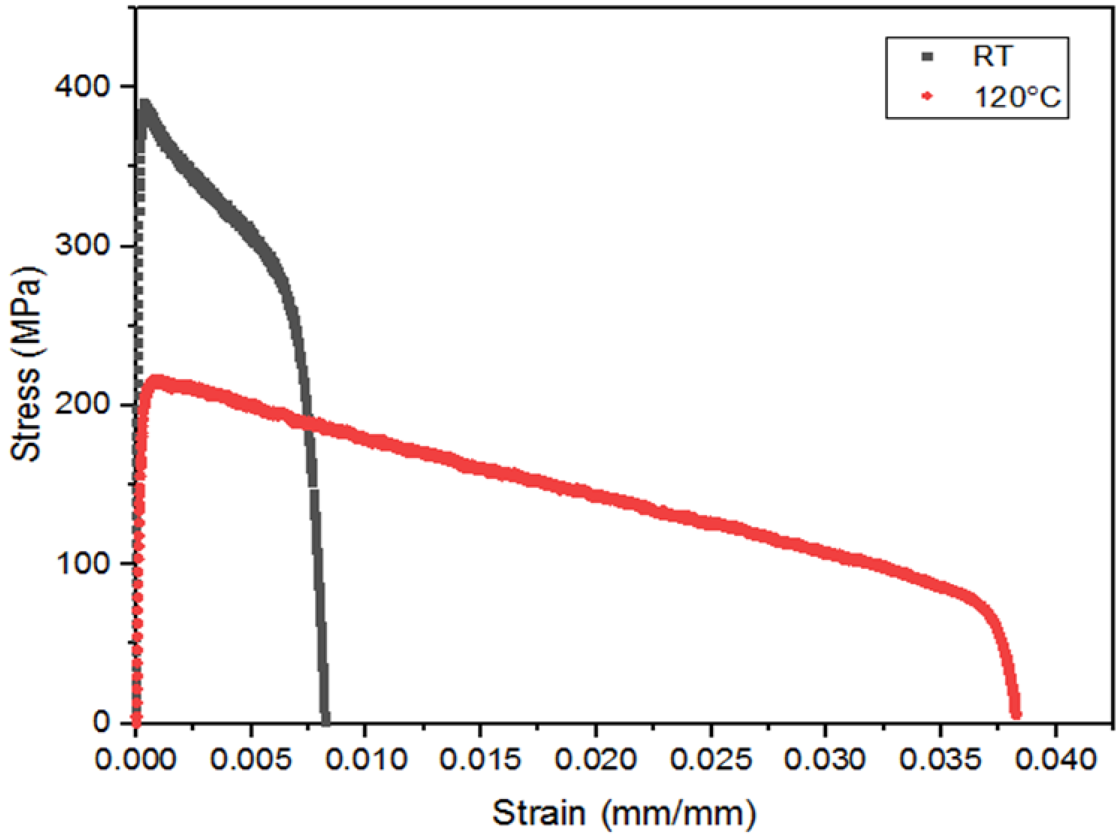

Figure 3: Stress-strain graph of SAC305 solder wire under different temperature condition

Figure 4 indicates the hardness properties of deformed SAC305 solder wires under the different temperatures. Overall, SAC305 at room temperature obtained higher hardness values compared to SAC305 solder wire under 120°C in chamber conditions. It is known that hardness is the resistance of the material to plastic deformation [13]. Thus, exposure of SAC305 solder wire to the thermal conditions decreased the resistance of that material to plastic deformation. Heat induced the coarsening of grain size and intermetallic particles in the solder matrix. In the Sn-Ag-Cu solder, the primary phase formed was the β–Sn phase, followed by the eutectic phase and intermetallic Ag_3Sn and Cu_6Sn. As a result, the coarsening of grain size or subgrain of β–Sn tend to soften and gave lower hardness values [14].

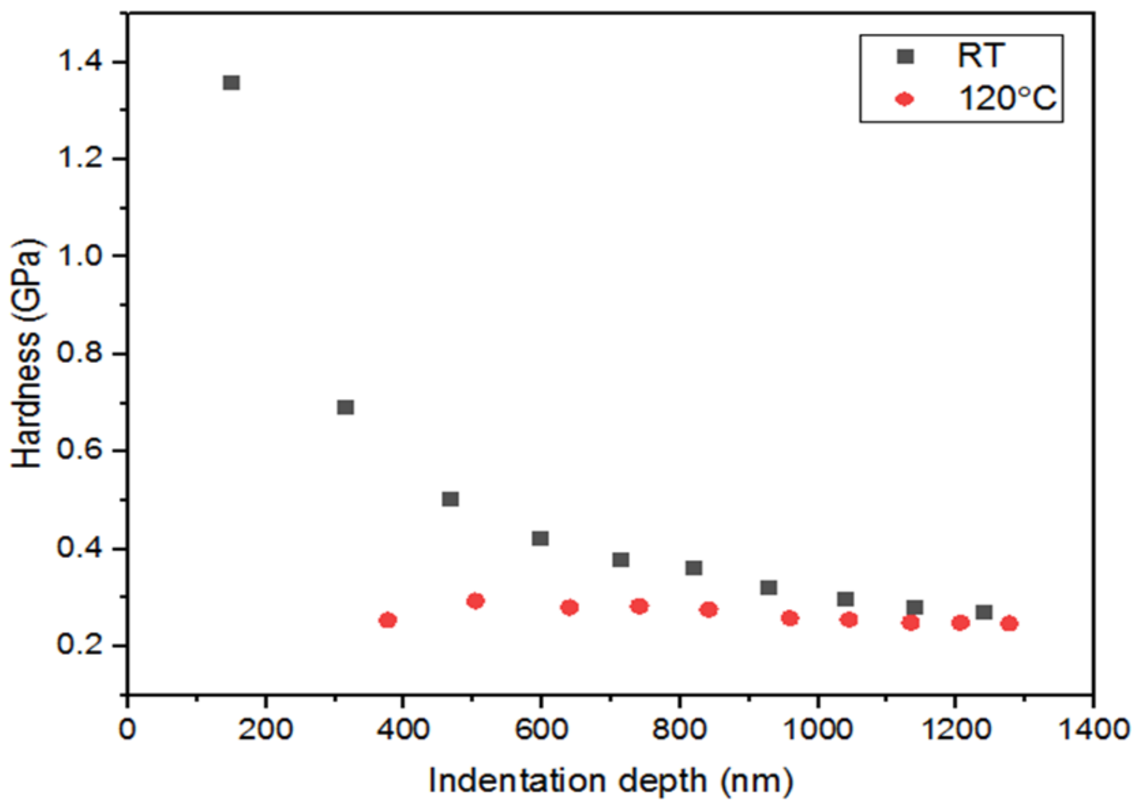

Figure 4: Hardness values of deformed SAC305 solder wire under different temperature

CONCLUSION

From the tensile and nanoindentation test, both mechanical characterisation methods found that the SAC305 solder wire at room temperature showed good mechanical properties in terms of strength and hardness. When subjected to increased thermal condition, the mechanical properties of the investigated solder wire were degraded. This is strongly believed to be due to the changes of microstructure induced by the existence of heat during the tensile test.

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