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Short Communication

Effect of Sb addition on the tensile deformation behavior of lead-free Sn–3.5Ag solder alloy

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ABSTRACT

Tensile deformation behavior of Sn–3.5Ag and Sn–3.5Ag–1.5Sb alloys was investigated at temperatures ranging from 298 to 400 K, and strain rates ranging from 5×10^{-4} to 1×10^{-2} s^{-1}. After melting and casting, the samples were rolled to sheets, from which tensile specimens were punched and pulled to fracture in uniaxial tension tests. Scanning electron microscopy (SEM) was used to study the microstructure and fracture surface of the samples. Addition of 1.5% Sb into the binary alloy resulted in an increase in both ultimate tensile strength (UTS) and ductility. The enhanced strength was attributed to the solid solution hardening effects of Sb in the Sn matrix. The improved ductility was, however, caused by the structural refinement which results in the higher strain rate hardening of the Sb-containing alloy. This was manifested by the higher strain rate sensitivity (SRS) indices (m) of 0.14–0.27, as compared to 0.11–0.20 found for the Sn–3.5Ag alloy.

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1. Introduction

Lead–tin solders have been used in electronic packages and assemblies for the last four decades, due to their unique combination of properties such as; low melting point, good wettability and desirable mechanical characteristics [1]. However, concerns about environmental problems caused by the toxicity of lead, have resulted in serious restrictions on the use of these lead-containing solders [2–4]. Accordingly, many lead-free Sn-based alloy systems with different alloying elements such as Ag, In, Cu, Zn, Bi, Ni and Sb have been developed and their microstructures, mechanical properties and wettability have been reported. Among the developed lead-free solders, those based on the eutectic Sn–3.5Ag alloy are of interest. Although the high melting temperature (494 K) of Sn–Ag adversely affects the wettability and reflow process, it has good mechanical strength, ductility and thermal resistance [5]. The improved strength of Sn–Ag alloys has been attributed to the presence of the Ag_3Sn compound uniformly distributed in the β-Sn matrix [6]. It has been reported that addition of elements such as Sb can improve the mechanical properties, mainly due to the solid solution hardening effects of Sb [7], formation of the SnSb particles [8,9], and the presence of Ag_3Sn intermetallics [10] in the Sn matrix. It has also been shown that adding Sb can suppress the coarsening the of β-Sn, refine the Ag_3Sn precipitate, and thus, improve the mechanical properties and thermal resistance of the Sn–Ag–Sb solders [6,7].

There are a few studies on the influence of Sb additions on the mechanical properties of the Sn–3.5Ag solder joints. Lee et al. [6] have studied the effect of adding Sb on the microstructure and adhesive strength of Sn–Ag solder joints. They showed that Sb decomposes the microstructure of Sn–3.5Ag and causes solid–solution hardening. Adding Sb refines the rod-like Ag_3Sn compounds and improves hardness, adhesive strength, and thermal resistance of Sn–3.5Ag solder joints. Effects of 0–10 wt.% Sb addition on the shear strength and fracture behavior of Sn–3.5Ag solder have been also considered [11]. It has been shown that although the strength of the solder increases as the amount of added Sb increases, high amounts of Sb can decrease the volume fraction of Ag_3Sn in the solder and effectively ease the Ag_3Sn coarsening effect during isothermal storage.

Since many electronic components undergo wide ranges of temperature with different stresses, it is important to evaluate the mechanical behavior of the used solders at various strain rates over different temperature ranges. Thus, the aim of this study is to investigate the influence of 1.5 wt.% Sb addition on the microstructure and deformation behavior of a Sn–3.5Ag alloy. The test conditions cover the temperatures and the strain rates, which are important for the assessment of solder joint reliability.

2. Experimental procedure

2.1. Materials and processing

The materials used were Sn–3.5 wt.% Ag and Sn–3.5 wt.% Ag–1.5 wt.% Sb. They were prepared from high purity (99.9%) tin, silver

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