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Short Communication

The effect of cooling rate on the dendritic spacing and morphology of Ag_3Sn intermetallic particles of a SnAg solder alloy

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ABSTRACT

The size and morphology of intermetallic compounds of Sn–Ag solder alloys can have a significant influence on the mechanical strength of solder joints. The aim of the present study is to characterize the as-cast microstructure of a Sn–2 wt.% Ag solder alloy, and to correlate the resulting scale of the dendritic matrix and the morphology of the Ag_3Sn intermetallic compound (IMC) with the corresponding solidification cooling rate. Pre-heated low-carbon steel molds and a water-cooled solidification apparatus were used permitting a significant range of solidification cooling rates to be experimentally examined. It is shown that under very slow cooling conditions (0.02 °C/s) the microstructure of the sample is formed by a coarse dendritic matrix and a mixture of fiber and plate-like Ag_3Sn IMC in the interdendritic region with the fibers located along the board line separating the matrix. For cooling rates from 0.15 to 1.15 °C/s a mixture of spheroid and fiber-like IMC and secondary dendrite arm spacings between 15 and 40 μm, with the spheroids located in the center of the interdendritic region. At higher cooling rates, of about 8 °C/s only Ag_3Sn spheroids (of about 0.5 μm in diameter) prevail in the eutectic mixture.

1. Introduction

The increasingly environmental concern over the toxicity of Pb combined with strict regulations, are gradually banning the application of Pb-based solders. Sn–Ag solder alloys are among the promising candidates to replace the traditional Sn–Pb solder [1,2]. Typical hypoeutectic Sn–Ag alloys have as-cast microstructure formed by a Sn-rich dendritic matrix and a eutectic mixture of a Sn-rich phase and intermetallic Ag_3Sn particles located in the interdendritic regions. SnAgCu alloys (SAC) present additionally the Cu_6Sn_5 intermetallic which is also located in the interdendritic region, as previously reported in a number of studies [3–9]. Three types of intermetallic Ag_3Sn particles formed during solidification under different cooling rates are reported in the literature: spheroids, needle-like and plate-like Ag_3Sn particles [3–17]. Song et al. [3] have recently reported that the Ag_3Sn particles of the eutectic mixture of rapidly solidified samples (at a cooling rate of about 17 °C/s) have a spherical geometry (having diameters which are less than 1 mm) and when low cooling rates were applied, the resulting Ag_3Sn particles had a needle-like appearance. These morphological observations are also consistent with a number of previous investigations [4–14].

The microstructural morphological array of Sn–Ag solder alloys, including the scale of the dendritic Sn-rich matrix and the size, morphology and distribution of the Ag_3Sn particles in the interdendritic region has an important role on the resulting mechanical behavior of solder joints. For instance, brittle Ag_3Sn particles may lead to serious problems under stressed conditions at service for printed wiring boards [12,13,16]. It has also been reported that large Ag_3Sn platelets can exhibit a mixture of both ductile and brittle fractures while fine platelets would strengthen the solder matrix [7,15–18]. The resulting Sn–Ag microstructure has also great effect upon other properties, such as physical, electrical and oxidation and electrochemical behavior of the solder joint. In this sense, it would be interesting to accurately characterize the intermetallic Ag_3Sn particles and the Sn-rich matrix as a function of the influent parameters during cooling in order to attain guidelines with a view to predetermining a desired performance in terms of the required final properties of the solder joint. The microstructure control in soldering processes can be accomplished by manipulating solidification processing parameters such as the cooling rate and the growth rate, since the resulting morphological microstructure depends on these heat transfer parameters imposed by solidification. It is well-known that the metallurgical and micromechanical aspects of the factors controlling microstructure, unsoundness, strength and other properties of solder alloys are complex. However, the mentioned thermal processing variables are of high order of importance, as previously reported [17–20]. The aim of

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