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Microstructure, Thermal and Wetting Properties of Sn-Bi-Zn Lead-Free Solder

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The microstructures, phase transformations, and wettability of Sn-Bi-Zn solder alloys were investigated by scanning electron microscopy, x-ray diffraction, and differential scanning calorimetry (DSC). The results show that the alloys are composed of primary Sn-rich phase or Zn-rich phase, (Sn + Zn) eutectic structure, and (Sn + Bi + Zn) ternary eutectic structure. The microstructural characterization of Sn-*x*Bi-Zn alloys indicates that, with increasing Bi content, more of the eutectic (Sn-Bi-Zn) structures is formed. DSC profiles reveal that the eutectic peak of the samples did not differ very much, but the reaction temperature of the alloys decreases with increased Bi content. The spreading rates of solders increased with the addition of Zn, which affects the interfacial reactions between the solders and copper.

Key words: Lead-free solder, Sn-Bi-Zn, microstructure, melting point, wettability

INTRODUCTION

Sn-Pb solders have been widely used in the microelectronics packaging industry for many decades.[1] However, there are environmental and health issues concerning the toxicity of lead (Pb) present in Sn-Pb solder alloys. In recent years, the European Union and many countries have enacted legislation to prohibit use of tin-lead solders.[2] As a result, development and study of lead-free solders have attracted worldwide attention. There are four main systems of lead-free solders, namely Sn-Ag, Sn-Cu, Sn-Zn, and Sn-Bi alloys. Due to their high melting points, Sn-Ag, Sn-Cu, and Sn-Zn alloys cannot be used in low-temperature soldering. The eutectic temperature of Sn-Bi binary alloy is 139°C, which meets the melting-point requirement for low-temperature soldering, and it can be used especially to prevent heat damage to electronic components. In recent years, much research has been carried out on Sn-Bi alloys, e.g., on their thermal properties[3,4] and wettability.[5,6] Also, investigations on the formation and evolution of intermetallic compounds (IMCs) between the solder alloy and Cu substrate have been carried out.[7,8] However, Bi may cause troublesome tensile embrittlement,[9] and the content of Bi needs to be further reduced. Some researchers have started to focus on element addition to Sn-Bi solder alloys. Dong et al.[10] found that trace amounts of rare-earth elements not only improve the wettability of Sn-Bi-based solder alloys but also refine the microstructure and size of the IMC particles. Since Zn can react with Cu to form Cu-Zn intermetallic compounds,[11] it can be speculated that Zn would affect the interfacial reactions between Sn-Bi solder and copper. In this research, the Bi content was further reduced to 38 wt.% and Zn was added to form ternary alloy solders with application prospects. Low melting point and good wettability are expected for ternary alloy solders.[12] This study aims to research the microstructure and properties of Sn-Bi-Zn ternary alloy and to determine the effect of Bi and Zn addition on promoting the properties of the solder alloys.

EXPERIMENTAL PROCEDURES

Sn-Bi-Zn alloys were prepared from pure Sn (99.99%), Bi (99.99%), and Zn (99.99%) metals by

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