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Retarding Electromigration in Lead-Free Solder Joints by Alloying and Composite Approaches

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The voids induced by electromigration (EM) can trigger serious failure across the entire cathode interface of solder joints. In this study, alloying and composite approaches showed great potential for inhibiting EM in lead-free solder joints. Microsized Ni, Co, and Sb particles were added to the solder matrix. Cu and Sn particles were added to the melting solder to form *in situ* Cu_6Sn_5, which formed a barrier layer in the underbump metallization of flip-chip solder joints. The polarity effect induced by EM was observed to be significantly inhibited in the alloyed and composite solder joints. This indicates that the Sn-Ni, Sn-Co, Sn-Sb, and Cu_6Sn_5 intermetallic compounds may act as barriers to obstruct the movement of the dominant diffusion species along phase boundaries, which in turn improves the resistance to EM. However, Sb particles could induce crack formation and propagation that might lead to joint fracture.

Key words: Lead-free solder, alloying approach, composite approach, retarding EM

INTRODUCTION

The miniaturization of electrical components, the increase of current density with functional demands, and the nonuniform distribution of current density are seriously endangering the reliability of solder joints.[1] Thus, reliability issues caused by the combined effect of high temperature and high current density have received extensive attention from researchers.[1–4] Electromigration (EM) is a form of mass transportation which results from the combination of thermal and electrical effects during the operation of solder joints. The reliability of electronic products can be degraded by EM through polarity effects, void formation, and crack propagation on the cathode side.[5,6] Structural optimization and materials modification have been proposed to improve the reliability of lead-free solder joints by Tu et al.[7,8] A thick Cu pillar was utilized to relieve the current-crowding effect and reduce the current density to a normal level in the solder bump.[7] The intermetallic compounds (IMCs) formed in solder joints are brittle in nature.[9] Excessive growth of IMCs can degrade the mechanical reliability of the joints. Therefore, materials modification methods are applied to suppress the growth of IMCs as well as the nucleation and propagation of cracks induced by EM. Alloying and use of composites are two popular approaches to incorporate trace elements into Sn-based solder alloys to improve their stability.[10,11] In this study, solder joints reinforced by Sb, Ni, Co, and *in situ* Cu_6Sn_5 were fabricated for EM testing. The objective of this study is to investigate the effect of these reinforcements for retarding EM behaviors in solder joints. The microstructural evolution of the solder joints was observed periodically using optical microscopy (OM) and scanning electron microscopy (SEM).[12–15] The mechanisms of retarding EM in alloyed and composite solder joints are analyzed and discussed.

EXPERIMENTAL PROCEDURES

In this study, commercially available Ni, Co, and Sb powders were added to Sn-3.0Ag-0.5Cu and

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