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Effect of Trace Diamond Nanoparticle Addition on the Interfacial, Mechanical, and Damping Properties of Sn-3.0Ag-0.5Cu Solder Alloy

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In the present study, small amounts of nanodiamond particles were added to Sn-3.0Ag-0.5Cu eutectic solder to investigate the growth kinetics of the intermetallic compound (IMC) layer at ball grid array pad/solder interfaces. The IMC growth behavior was found to be comparatively slower than that of plain solder joints due to a change in the diffusivity of the constituent atoms and the thermodynamic parameters of elemental affinity. The solder joints containing nanodiamond particles consistently showed higher hardness and strength than plain Sn-3.0Ag-0.5Cu solder joints, after a number of reflow cycles. The hardness of the doped solder was enhanced due to the homogeneous dispersion of nanoparticles, refining IMC phases which act as reinforcements in the solder matrix and as barriers to movement of dislocations. The fracture surface after shear testing of plain solder exhibited a relatively smooth fracture surface, while doped solder joints showed ductile failures with very rough dimpled surfaces. The damping capacity of the doped solder was better than the plain solder at a wide range of temperatures, and the solder with nanoparticle diamond exhibited lower internal friction.

Key words: Nanomaterials, intermetallics, lead-free soldering, fracture, microstructure, scanning electron microscopy

INTRODUCTION

Sn-Ag-Cu Pb-free solders have been regarded as the most promising candidates to replace conventional Sn-37Pb solder due to their remarkable thermal characteristics, reasonable wetting ability, comparable electrical performance, and good mechanical properties.[1] However, excessive reaction between Sn-3.0Ag-0.5Cu solder and substrates still poses a big threat to the reliability of lead-free solders due to the formation of large brittle intermetallic compounds (IMCs) and short creep lifetime in service.[2] In addition, during prolonged aging, coarsening of the grain structure and formation of large primary Sn dendrites greatly reduce the thermal–mechanical fatigue resistance.[3] Moreover, the advancement of micro/nanodevice technologies and the shrinking size of microelectronic components lead to increased interconnect density. Therefore, conventional solder can no longer pacify the solder joint reliability issues in electronic components due to the high diffusivity and softening nature of the solder.[4] To solve this problem, a potentially viable and economically affordable innovative approach to improve the mechanical properties of conventional solder is addition of nanosized metallic, intermetallic or ceramic particles to the solder matrix.[5–7] In the existing literature, composite solders have shown improved solder joint reliability because the reinforcement particles suppress grain boundary sliding, grain growth, and IMC formation and redistribute the stress uniformly.[8] Lin et al.[9,10] studied the influence of reinforcing with TiO_2 and Cu nanoparticles on the microstructure development and hardness of Sn-37Pb solder, and the measured microhardness revealed that addition of TiO_2 and Cu nanoparticles enhanced the overall

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