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Effects of Y_2O_3 Nanoparticles on Growth Behaviors of Cu_6Sn_5 Grains in Soldering Reaction

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The effects of Y_2O_3 nanoparticles doped in Sn-3Ag-0.5Cu solder on the growth behaviors of Cu_6Sn_5 grains in the soldering reaction with copper were investigated. It is found that the growth rate of Cu_6Sn_5 grains was markedly decreased due to the addition of Y_2O_3 nanoparticles. The statistical size distribution results indicated that Cu_6Sn_5 grains with radius less than the average value account for a high percentage. These results confirm that the nanoparticles can effectively suppress the diffusion behaviors of Cu atoms in the wetting reaction.

Key words: Lead-free solder, intermetallic compounds, interfacial reaction, grain growth

INTRODUCTION

Solder joints between the lead frame of chips and the circuit board, providing not only mechanical connections but also current paths in service, are crucial to electronic packaging. Traditionally, tin-lead alloy has been widely used as a solder material. However, many electronic manufacturers have stepped up their search for new lead-free solders to substitute tin-lead alloys due to health and environmental concerns.[1] The reliability of new lead-free solder has become an interesting research focus.[2–7] To enhance the reliability of solder joints, numerous investigations have been performed, such as adding rare-earth elements, nanoparticles, and other metallic elements into solder materials.[8–10] Although there have been some studies on lead-free solder doped with nanoparticles recently, they focused mainly on isothermal aging or the mechanical properties of the doped solder itself.[11–13] Few reports to date have considered the mechanism of interfacial reaction or the properties of the interfaces between nanoparticle-doped solder and the substrate.

During the reflow soldering process, intermetallic compounds are formed between the solder and the substrate. Generally, the intermetallic compound layer between lead-free solder and Cu substrate is dominantly composed of Cu_6Sn_5 compound.[14] In addition, Cu_3Sn intermetallic compound can be detected, but only when the reflow temperature is very high or the aging time is long enough.[15] The size, morphology, and thickness of the Cu_6Sn_5 intermetallic compound have a notable influence on the reliability of solder joints, since fracture always occurs near intermetallic compounds at interfaces.[16–19] Cu_6Sn_5 grains of large size, which normally endure higher stress in comparison with those of small size, are more apt to fracture prior to the solder.[20] Therefore, it is necessary to understand the growth kinetics mechanism and control the growth of intermetallic compounds between solder and substrate.

On the other hand, the classical theory of conservative ripening of precipitates by Lifshitz and Slyozov[21] and Wagner[22] (LSW theory) is not suitable for nonconservative ripening of Cu_6Sn_5 grains in the wetting reaction.[21,22] In 2002, Gusak and Tu[23] proposed a new flux-driven ripening (FDR)

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