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Comparison of Sn-Ag-Cu Solder Alloy Intermetallic Compound Growth Under Different Thermal Excursions for Fine-Pitch Flip-Chip Assemblies

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The intermetallic compound (IMC) evolution in Cu pad/Sn-Ag-Cu solder interface and Sn-Ag-Cu solder/Ni pad interface was investigated using thermal shock experiments with 100-μm-pitch flip-chip assemblies. The experiments show that low standoff height of solder joints and high thermomechanical stress play a great role in the interfacial IMC microstructure evolution under thermal shock, and strong cross-reaction of pad metallurgies is evident in the intermetallic growth. Furthermore, by comparing the IMC growth during thermal aging and thermal shock, it was found that thermal shock accelerates IMC growth and that kinetic models based on thermal aging experiments underpredict IMC growth in thermal shock experiments. Therefore, new diffusion kinetic parameters were determined for the growth of $(Cu,Ni)_6Sn_5$ using thermal shock experiments, and the Cu diffusion coefficient through the IMC layer was calculated to be 0.2028 $\mu m^2/h$ under thermal shock. Finite-element models also show that the solder stresses are higher under thermal shock, which could explain why the IMC growth is faster and greater under thermal shock cycling as opposed to thermal aging.

Key words: Lead-free solder, intermetallic compound, cross-reaction, thermal shock

INTRODUCTION

Over the past decade, flip-chip packaging has experienced tremendous growth in applications such as microprocessors, cellular telecommunications, and portable electronics.[1,2] To meet these growing market needs for miniaturized electronic products with multifunctional capabilities, flip-chip packages with fine-pitch solder interconnects are increasingly used.[3] With the reduction in interconnect pitch, the diameter and height of solder interconnects also have reduced. This miniaturization trend has a great influence on the microstructure of solder joints, especially for the intermetallic compound (IMC); For example, the lower standoff height will shorten the metal diffusion distance between the two pads, and thus, the metallurgy of both pads will influence the growth of IMC. Furthermore, solder joints with shorter standoff height experience more stress under thermal excursion, which can also influence the IMC growth.[4]

The IMC layer formed during the reflow process is essential for a functional and robust metallurgical bond between pad and solder joint. However, IMC layers are typically brittle, and often crack under thermomechanical loading. Therefore, excessive thickness of the interfacial IMC layer can be detrimental to solder joint reliability.[5,6] Extensive experimental research has been reported for interfacial IMC evolution between Pb-free solders and different metallizations.[7–11] However, there appears to be limited research on the interpad cross-reaction effect on the microstructure evolution of solder

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