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Spreading Behavior and Evolution of IMCs During Reactive Wetting of SAC Solders on Smooth and Rough Copper Substrates

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The effect of surface roughness of copper substrate on the reactive wetting of Sn-Ag-Cu solder alloys and morphology of intermetallic compounds (IMCs) was investigated. The spreading behavior of solder alloys on smooth and rough Cu substrates was categorized into capillary, diffusion/reaction, and contact angle stabilization zones. The increase in substrate surface roughness improved the wetting of solder alloys, being attributed to the presence of thick Cu_3Sn IMC at the interface. The morphology of IMCs transformed from long needle shaped to short protruded type with an increase in the substrate surface roughness for the Sn-0.3Ag-0.7Cu and Sn-3Ag-0.5Cu solder alloys. However, for the Sn-2.5Ag-0.5Cu solder alloy the needle-shaped IMCs transformed to the completely scallop type with increase in the substrate surface roughness. The effect of Ag content on wetting behavior was not significant.

Key words: Reactive wetting, lead-free solders, contact angle, IMC

INTRODUCTION

Eutectic Sn-Pb solder alloy is the most common solder material used in the electronics industry. However, the Pb present in the solder material is highly toxic and considered to be hazardous to the environment. Hence, research into the development of lead-free solders is becoming increasingly important as legislations restrict use of Pb in solder alloys.[1] Among the new lead-free solders [Sn-Cu, Sn-Ag, Sn-In, Sn-Ag-Bi, and Sn-Ag-Cu (SAC)], ternary SAC alloys are considered to be attractive and reliable Pb-free solder alloys, due to their good wetting and mechanical properties as compared with Sn-Pb solder alloys.[1–3] Research investigations are mainly focused on high-silver-bearing (≥3 wt.% Ag) SAC solder alloys.[3–6] The price of silver has increased dramatically over the last several years, and it was reported that SAC alloys with high Ag content, especially Sn-4Ag-0.5Cu and Sn-3Ag-0.5Cu, exhibited poor reliability.[7,8] The National Electronics Manufacturing Initiative (NEMI) noted that Sn-3.9Ag-0.6Cu solder alloy also showed poor performance in reliability tests of electronic packages.[9] Hence, current research is focused towards lower-silver solders. Among the low-Ag-bearing SAC solders, Sn-0.3Ag-0.7Cu solder alloy has gained a lot of attention. Moreover, at higher temperature, the tensile strength of Sn-0.3Ag-0.7Cu solder alloy is comparable to that of Sn-37Pb solder.[10] According to Cheng et al.,[10] Sn-0.3Ag-0.7Cu and Sn-1Ag-0.5Cu solder alloys have been considered as second-generation lead-free solder alloys. However, literature available on Sn-0.3Ag-0.7Cu solder alloys is scant.[10–15] Sn-2.5Ag-0.5Cu is also one of the new low-Ag SAC solder alloys, and its ultimate tensile strength is better than those of Sn-Pb solder alloys. It has better corrosion resistance with respect to Sn-Bi-Zn solders.[16] Lee et al.[17] reported that the wetting properties of Sn-2.5 Ag-0.5Cu solder are comparable to those of Sn-4.0Ag-0.5Cu and Sn-3.0Ag-0.5Cu solder alloys. Most of the researchers have focused mainly on the interfacial microstructures and mechanical properties of high-Ag SAC lead-free solder alloys.[2,6,7] However, studies on the wetting behavior of low-Ag SAC solder alloys are inadequate. It is known that

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