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Thermal Parameters, Microstructure, and Mechanical Properties of Directionally Solidified Sn-0.7 wt.%Cu Solder Alloys Containing 0 ppm to 1000 ppm Ni

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Environmental concerns over the toxicity of Pb are resulting in the progressive ban of Pb-based solders as part of electrical and electronic devices. Sn-Cu alloys are becoming interesting Pb-free solder alternatives. In the case of hypoeutectic Sn-Cu alloys (< 0.7 wt.% Cu), small alloying additions of Ni can prevent the growth of coarse and deleterious Cu_6Sn_5 particles. Solidification thermal parameters such as the growth rate, cooling rate, and interfacial heat transfer coefficient (h_i) determine the morphology and scale of the phases forming the resulting microstructure. In the present study, directional solidification experiments were carried out with Sn-0.7 wt.%Cu, Sn-0.7 wt.% Cu-0.05 wt.%Ni, and Sn-0.7 wt.%Cu-0.1 wt.%Ni alloys and interrelations of solidification thermal parameters, microstructure, and tensile properties have been established. The highest time-dependent h_i profile was found for the Sn-0.7 wt.%Cu-0.1 wt.%Ni alloy, which is an indication that this alloy has the highest fluidity. Constrained dendritic arrangements were observed for all alloys experimentally examined. This morphology has been associated with high cooling rates and growth rates. Cellular regions, characterized by aligned eutectic colonies, were also observed to occur for cooling rates lower than 0.9 K/s and 6.0 K/s for the unmodified Sn-0.7 wt.%Cu alloy and for both Ni-modified Sn-Cu alloys, respectively. Experimental Hall–Petch-type equations correlating the ultimate tensile strength and elongation with cell/dendritic spacings are proposed.

Key words: Solidification, microstructure, thermal parameters, mechanical properties, solder alloys

INTRODUCTION

Soldering technology plays a key role in various levels of electronic packaging, such as solder joints in printed circuit boards (PCB) formed by either surface-mount soldering or plated through-hole (PTH) soldering of components, flip-chip connections, heat sink attachments, etc. The mechanical support in electronic packages depends on the solder joints. These joints serve as electrical interconnections as well. When either of these requirements cannot be met, the solder joint is considered to have failed, which can cause the collapse of the entire electronic system. Lead (Pb)-containing solders, such as 63Sn-37Pb, Pb-10Sn, and Pb-3Sn (all in wt.%), have been used in various microelectronic applications. Strong research and development efforts with a view to replacing Pb-containing solders with Pb-free solders are being

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