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Computational Investigation of the Evolution of Intermetallic Compounds Affected by Microvoids During the Solid-State Aging Process in the Cu-Sn System

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In this work, the impact of microvoids on the microstructural evolution of η-Cu_6Sn_5 and ε-Cu_3Sn in the Cu-Sn system is evaluated numerically. Through the use of the multiphase-field method, the systems of interest are allowed to evolve using a solid-state aging temperature of 453 K in conjunction with material parameters and reaction conditions adopted from previous research. The simulation results are then analyzed and compared with previous experiments in terms of the morphological evolution of the intermetallic compounds (IMCs), the IMC layer thicknesses, and the corresponding interfacial roughness. It is shown that the presence of microvoids at the ε/Cu interface interferes with the flow of mass throughout the phases, impeding phase transformations and grain coarsening. This ultimately affects the IMC coarsening rate and overall IMC layer thicknesses. Additionally, it was observed that the presence of microvoids at the ε/Cu interface affects the formation of both IMC layers and their corresponding interfaces, and the changes in roughness for the interfaces are quantitatively provided. Overall, the simulations are found to be within the range of accepted experimental values for the morphology of the IMC grains, the evolution of IMC layer thicknesses, and the evolution of interface roughness.

Key words: Phase-field model, morphology, growth of Cu_6Sn_5 and Cu_3Sn layer, roughness, microvoids

INTRODUCTION

The reliability of solder joints depends on many factors, among which the phase stability, morphological evolution, and growth kinetics of intermetallic compound (IMC) layers are some of the most important. The behavior of solder joints is further complicated by the fact that complex thermodynamic and kinetic phenomena induce the formation of defects (i.e., microvoids) that change the microstructure of IMCs and facilitate the formation of cracks, resulting in degradation of the mechanical and electrical performance of solder interconnects.[1–11]

Recently, there have been many experimental studies on the effects of microvoids—their formation, growth, and migration behavior—on the evolution of IMC layers in many soldering systems such as Cu-Sn,[12–16] Sn-Ag-Cu,[17–22] Sn-Pb,[6,8] and Sn-Ag.[23,24] These works have focused on understanding the causes for the formation of microvoids as well as their growth/evolution during solder joint operation. Among the different causes for the formation of microvoids, the dominant factors seem to be the different interdiffusion rates of constituents in specific IMC phases,[15,16,21,25,26] the different electromigration rates during electroplating

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