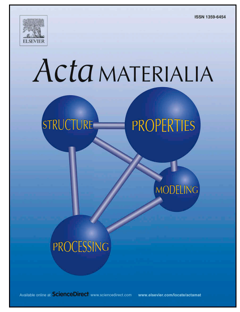

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On the Interfacial Phase Growth and Vacancy Evolution during Accelerated Electromigration in Cu/Sn/Cu Microjoints

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Abstract

In this work, we integrate different computational tools based on multi-phase-field simulations to account for the evolution of morphologies and crystallographic defects of Cu/Sn/Cu sandwich interconnect structures that are widely used in three dimensional integrated circuits (3DICs). Specifically, this work accounts for diffusion-driven formation and disappearance of multiple intermetallic phases during accelerated electromigration and takes into account the non-equilibrium formation of vacancies due to electromigration. The work compares nucleation, growth, and coalescence of intermetallic layers during transient liquid phase bonding and virtual joint structure evolution subjected to accelerated electromigration conditions at different temperatures. The changes in the rate of dissolution of Cu from intermetallics and the differences in the evolution of intermetallic layers depending on whether they act as cathodes or anodes are accounted for and are compared favorably with experiments. The model considers non-equilibrium evolution of vacancies that form due to differences in couplings between diffusing atoms and electron flows. The significance of this work lies in understanding the vacancy transport due to the difference in intrinsic diffusion of elements in different features of the microstructure, and the severe unidirectional convective flux of atoms due to the enforced electron wind that ultimately paves the road to study nucleation of microvoids.

Keywords: Multi-phase-field modeling, Cu/Sn/Cu Solder interconnection, Electromigration, Point defects, Non-equilibrium vacancy evolution

1. Introduction

Currently, there exist five major low-temperature bonding techniques that address the bonding needs in Three Dimensional Integrated Circuit (3DIC) devices: direct, surface activated, eutectic, adhesive, and nano-metal bonding. Each bonding technology uses different approaches and material combinations. Some of these potential technologies are good candidates for mass production applications, and among them, the low temperature hybrid bonding via low volume solder layer seems to have significant advantages due to less damage to the device. Cu-Sn system has become a popular material system for 3D integration. It overcomes the issues related to the eutectic systems (Au-ln, ln-Sn, etc.), where achieving a good performance is highly process-dependent and difficulties such as freezing may occur during reflow, leading to poor wetting and compromised strength. It also overcomes the environmental issues related to the Pb-Sn systems enabling more than Moore system scaling in the 3DICs [1, 2, 3].

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