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Linkages Between Microstructure and Mechanical Properties of Ultrafine Interconnects

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Microstructures within ultrafine electronic interconnections, which change rapidly during the formation of such joints and evolve continuously thereafter under service conditions, are an important factor to be considered in order to accurately evaluate the reliability of electronic packages that contain such interconnects. By combining phase-field and finite-element mechanical modeling techniques, this work explicitly considers both the size and geometry of the joints to understand their effects on microstructural evolution and subsequent mechanical properties. The simulation results indicate that the degree of inhomogeneity of the stress distribution increases as the size of the joints is reduced when microstructure is considered. The calculated maximum stresses present in hourglass-shaped joints when considering microstructure are approximately 10 MPa larger than those present in the corresponding joints when neglecting microstructure. The geometries of such interconnects also have a significant effect on their mechanical properties. Hourglass-shaped joints exhibit the lowest maximum von Mises stresses in comparison with the other shapes considered. In addition, the included microstructural features can introduce local stress concentrations within the microjoints, which may deteriorate the reliability and performance of the electronic packages. It is therefore recommended that the microstructure as well as the size and geometry of joints be considered among the design and fabrication parameters to enable reliable ultrafine interconnects.

Key words: Microstructure, size and geometry effects, mechanical properties, phase-field method, ultrafine interconnects

INTRODUCTION

Microstructure within interconnects has been observed to change rapidly during manufacturing and evolve continuously in service.[1–4] The mechanical properties of interconnects, as a result, can vary with microstructure, and reliability issues may be induced by the formation of some microstructural features; For example, large Ag_3Sn plates in Sn-Ag-Cu solder joints can have adverse effects on the plastic deformation properties of the solder.[5,6] The microstructural effects can be even more important for three-dimensional (3D) electronic packaging technologies due to the continuous miniaturization of such interconnects; i.e., the size of the interconnects has shrunk to such small scales that the size of the interconnects and the microstructural features are comparable, as exemplified in the case of through-silicon vias,[7] and therefore microstructure should be taken into consideration in designing for reliable ultrafine interconnects.

The sizes and geometries of interconnects have been demonstrated to have an effect on microstructural evolution and the resultant mechanical properties;[8–11] For instance, Huang et al.[8] studied

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