Department of Systems Science and Industrial Engineering

EVOLUTION OF INTERMETALLIC MORPHOLOGY AND VOID FORMATION IN MICROJOINTS OF Ni/Sn/Ni

THESIS DEFENSE

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ABSTRACT

In microelectronics industries, the interfacial reaction is increasingly becoming an important concern, because of its wafer bonding applications in 2.5/3D integrated circuits. In small solder joint as pad/joints diameters are reduced, the concerns with respect to electromigration and thermomigration increases. Notably, it is not practical to control the orientations of the extremely anisotropic Sn grains, so at least a few percent of single Sn grain joints invariably end up with a vastly inferior resistance. Ni pad soldering results in a formation of intermetallic compounds at the interface of tin (Sn)/solder and the pad. As solder thicknesses are reduced below 30-40μm the combined properties of these and the remaining solder keeps changing at rates that vary strongly with details of design, process and subsequent thermomechanical history, posing general challenges in terms of prediction and control. In addition, electromigration concerns grow as joint dimensions are reduced. One alternative is to use a Sn cap/thin solder on Ni, optimizing processes to limit stresses on dielectrics during initial bonding, and then react it completely to form an intermetallic (IMC) joint. However, the collision of the intermetallic layers has been shown to be accompanied by tin (Sn) entrapment, leading to microscopic voids, which is a reliability concern. An ongoing research effort addresses effects of design and process parameters and their interactions on the associated risk. Results of this study are also

relevant to applications where reaction is left to continue during processing and long-term use.

A relationship between the morphology of the Ni_3Sn_4 and the formation of voids would seem credible as this IMC grows by diffusion of Sn through it to the Ni surface. This study is focused on the morphology of colliding IMC layers at the time when they meet and aims to uncover the effects of parameters affecting the intermetallic growth and morphology, notably the combination of solder composition, Sn/solder thickness, Ni purity, reflows, and aging temperature.

The initial morphology of the IMC layer right after reflow was, not surprisingly, found to depend on the solder thickness, the reflow profile and the alloy. All of these and the Ni properties also had clear effects on the subsequent IMC growth rate when annealed at a given temperature. Of course the growth rate varied with annealing temperature. However, in all cases the initial morphology differences were eliminated at a rate that varied with the growth rate so that the morphology of an IMC layer of any given thickness of practical interest ended up being independent of how fast that thickness was reached. The morphology of the IMC layers when they impinge on each other, and thus the entrapment of voids, was found to be independent of all the factors considered.