Synchrotron x-ray topography evaluation of mechanical stresses in Si substrates due to electroless nickel under bump metallization

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As a result of European Union and other legislation lead/tin (Pb/Sn) solder bumps are being phased out of integrated circuit and high density/power semiconductor device production. One possible replacement is the use of nickel bumps with an electroless nickel under bump metallization (UBM) layer built on a silicon substrate. In this study Ni(P) based films are used as a UBM layer, and SiO₂ films and an Al bond pad provide the adhesive strength and electrical connections between the bump and the substrate (see Fig. 1). Synchrotron X-ray Topography [1] has been used to confirm that the stress induced in the underlying silicon by nickel bumps varies for different UBM layer thicknesses and different bump diameters. The Large Area Back Reflection Topograph (LA-BRT) geometry was used to generate topographs which could image the strain induced in the silicon substrate due to the bumps and the enhancement of this strain near the bump peripheries. It was found that bumps with the thinnest UBM experienced the most severe silicon misorientation and induced strain. The UBM layer appears to act as a buffer region between the bump and the silicon (see Fig. 2). The Back Reflection Section Topography (BRST) geometry was used to examine the extent of induced strain fields within the Si substrates (see Fig. 3). BRST also confirmed that, as the bump diameter increased, the magnitude of misorientation of the underlying Si substrate increased proportionally.

Reference

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Figure 1 Schematic illustration of the electroless Ni(P) bump sample composition. Not drawn to scale.

Figure 2 (a) 1\textsuperscript{st} 6 LA-BRT image of 600\textmu m diameter bump on thin 2.9\textmu m) UBM; (b) 1\textsuperscript{st} 6 LA-BRT image of 600\textmu m diameter bump on thicker (4.8\textmu m) UBM.

Figure 3 (a) 1\textsuperscript{st} 6 BSRT image of the Si underlying a 400\textmu m diameter bump (UBM thickness = 3.4 \textmu m); (b) 1\textsuperscript{st} 5 BRST image of the same region; (c) 104 BSRT image of the same region.