In situ high-voltage TEM observation of constrained Cu_6Sn_5 during solid-state thermal cycling

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Cu_6Sn_5 is an intermetallic compound that typically forms in a layer between high-Sn solders and Cu substrates during the soldering process. It is well known that the Cu_6Sn_5 exists as a monoclinic eta'-Cu_6Sn_5 structure below 186°C and transforms to a hexagonal eta-Cu_6Sn_5 structure at higher temperatures. While the polymorphic transformation in Cu_6Sn_5 has been extensively studied, direct observation of the eta- eta' transformation in a real solder joint has been a significant challenge that may hinder advances in solder joint reliability.

We introduce a systematic approach to characterising the polymorphic transformation and structural evolution of a single targeted Cu_6Sn_5 grain constrained between Sn-rich and Cu-Cu_3Sn phases. The technique involved bright-field imaging at controlled zone-axis conditions of a lamella sample of around 0.5 micron in thickness containing Cu/Cu_3Sn/Cu_6Sn_5/Sn-rich solder alloy structure using a high-voltage transmission electron microscope (HVTEM) equipped with an Omega energy filter and a double-tilt heating holder.

Using this technique, the movement of bend contours from the grain boundary in between Cu_6Sn_5 grains, which are believed to arise from strain accumulation and release were observed at around 180°C to 210°C in the Sn-0.7wt.%Cu solder joint. It was confirmed that the monoclinic diffraction pattern observed at room temperature changed to a hexagonal pattern during isothermal holding at 210°C. The method provides a new approach for further understanding and potentially controlling the solid-state transformations in a variety of solder systems in micro-alloyed Pb-free solder joints.