**In-situ micro-pillar compression of electrodeposited Co/Sn multilater coatings**

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Gradient multilayer Co-Sn coatings were successfully deposited on a copper substrate with the help of double-bath electrodeposition technique. The coating microstructure was nanostructured in nature as confirmed by XRD and S/TEM investigation. Gradient coating shows higher average hardness than that of sole Sn or Co electrodeposited coating due to the presence of intermetallic phases. In this present study, we have investigated micro-mechanical properties of the gradient Co-Sn coating with micro-pillar compression. Micro-pillars with Ø 3 m and length to diameter ratio of 3:1 were fabricated by focused ion beam (FIB) milling and subsequently characterized by in-situ compression using a flat-punch Hysitron nanoindentor (PI 88 Picoindentor). Such in-situ compression analysis shows real time deformation of material and helps to correlate materials' response with corresponding stress-strain curves as shown in Fig. 1.

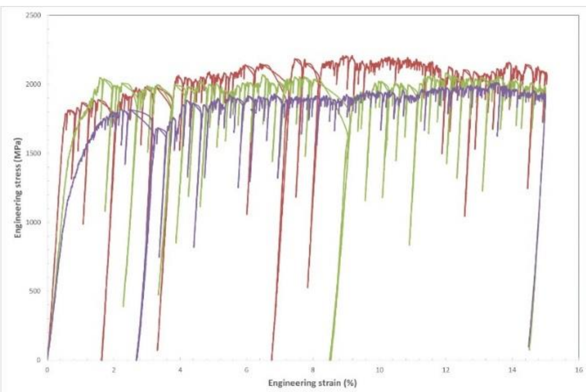


Fig.1: Engineering stress-strain curves of micro-pillars subjected to in-situ compression tests (three different tests were carried out on micro-pillars of similar dimension to ensure reproducibility).

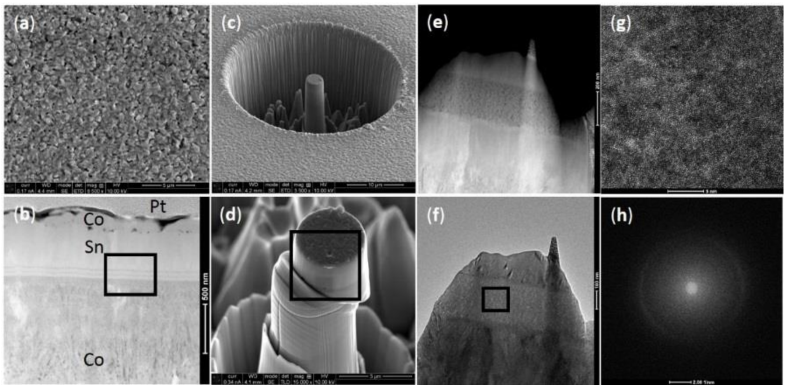


Fig. 2: (a) Top-view SEM micrograph of the coating, (b) cross-sectional STEM image of the coating shows well-defined Co/Sn multilayers (marked area), (c) Ø 3 m micro-pillar was fabricated in the middle of Ø 30 m crater for compression, (d) deformed micro-pillar after compression with slip bands on substrate materials, (e) cross-sectional STEM image of deformed micro-pillar (as marked in Fig. 2d) confirm complete intermixing of gradient multilayers, (f) cross-sectional TEM image of deformed micro-pillar (as marked in Fig. 2d) with intermixing zone, (g) HRTEM images of intermixed layer (as marked in Fig. 2f) and (h) fast-furrier transformation (FFT) of Fig.2f confirming polycrystalline nature of the layer.

Strain hardening behaviour of the coating was evident (Fig. 1) and shows extraordinarily high yield strength (1.7-1.9 GPa), which is about 3-3.5 times higher than that of a sole Co or sole Sn coating. Cross-sectional S/TEM investigation of deformed micro-pillar confirm intermixing of gradient multi-layers and form a deformed zone of polycrystalline layer (Fig. 2). This type of intermixing of multi-layers under compression is unique in nature, as most of the reported studies in literature emphasize on phenomenological ways of deformation that involve scaling laws such as Hall - Petch model based on dislocation pile-up, confined layer slip (CLS) model that involves single dislocation loops that glide through isolated layers and interface barrier strength (IBS) model based on dislocation movement across the interfaces. Unlike those earlier described models in the present case, complete intermixing of gradient multi-layers occurred to accommodate extrinsic loading under compression and thus minimise system energy together with formation of mechanical twinning and staking faults.

**Key words:** Micro-pillar, Gradient coatings, Electrodeposition, Microstructure, Compression.

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