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Electrodeposition and Characterisation of Novel Ni-NbO$_x$ Composite Coatings from Glycol-based Electrolytes as a Diffusion Barrier for High Temperature Electronics Packaging

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Electronics products are required to operate at high temperatures in various harsh environments, for instance in oil well, geophysical drilling and aerospace applications. Conventional solder interconnects that have been extensively utilised in consumer electronics are no longer adequate primarily due to excessive intermetallic compounds (IMCs) that can be formed and continuously grow during high temperature operation. With an intention of reducing such an excessive IMC growth, the introduction of electrically conducting niobium sub-oxide into the Ni coating which acts as a barrier layer between the solder and substrate may promise the possibility of developing a new solder barrier material with electrical conductivity and chemical resistance as required.

The present study considers a novel electrochemical route to produce Ni-NbO$_x$ composite coatings of good uniformity, smoothness, compactness and purity. The electrolyte is derived from a Type IV eutectic solvent consisting of NbCl$_5$ and propylene glycol (PG). The addition of a small amount of Ni ions (molar ratio: Ni : Nb = 1 : 30) was found to enable the co-deposition of Nb species. The introduction of NaBH$_4$ into the electrolyte has elevated the maximum deposit thickness (above 15 µm), although this led to a reduction in the co-deposited Nb content. The effects of cathodic current density, metal precursor and NaBH$_4$ concentrations on the surface morphology, composition and thickness of the coatings were examined. Scanning transmission electron microscopy (STEM) revealed a nanocrystalline structure resembling that of a simple FCC structure of Ni, with a slightly fluctuating composition across the coating thickness and with Nb uniformly distributed (Fig. 1). From X-ray photoelectron spectroscopy (XPS), a 0.7 eV shift to lower binding energy for the Nb (V) species signifies the partial chemical reduction of Nb$_2$O$_5$ due to possible Ni-Nb bonding. It is thus proposed that a Ni-NbO$_x$ deposit was formed by a two-step mechanism: the simultaneous electrochemical reduction of adherent Ni metal and inadherent niobium oxides on Cu, followed by nickelation of the NbO$_x$. The composite coating’s electrical conductivity, solderability and diffusion barrier characteristics (the latter preventing excessive IMC growth between molten Sn-In solder and Cu substrate) were assessed and showed promising results. From diffusion studies, a Nb-enriched layer was observed at the solder/substrate interface after ageing at 200°C suggesting evident effectiveness of the diffusion barrier characteristics.
Figure 1 - STEM cross sectional image a) of a 95Ni-5Nb coating with corresponding Energy-dispersive X-ray spectroscopy (EDX) maps of b) Ni Kα & c) Nb Lα.