Fabrication and Characterization of Ultrahigh Strength Ni-TiO_2 Composite Coatings Electroplated with Supercritical Carbon Dioxide Emulsified Electrolyte

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Metal matrix composites (MMCs) are composite materials of which the physical and chemical properties are reinforced by allowing dispersion of nanoparticles into the metal matrix [1, 2]. Electroplating was proved as a reliable process for incorporating nanoparticles into matrix and enhanced the mechanical strength of metal matrix in microelectromechanical systems (MEMS) [3]. However, in electroplating with nanoparticles, uneven distribution of the nanoparticles in the metal matrix caused by aggregation of nanoparticles in the electrolyte would lead to an unevenly local enhancement of the desired property. Therefore, in co-electrodeposition of MMCs, controlling the dispersity, such as the size and space distribution, of the particles in the metal matrix is a research topic of interest. Supercritical carbon dioxide (SC-CO_2) is a state of CO_2 when the temperature and pressure are above its critical point. SC-CO_2 has low surface tension and low viscosity, which are advantageous in co-electrodeposition of MMCs. Dispersed phases in the SC-CO_2 emulsified electrolyte would improve transfer of materials in the electrolyte and expect to influence incorporation amount and distribution of suspension particles in the electrolyte then eventually affect the dispersity in the electroplated metal matrix.

In this work, Ni-TiO_2 composite films were electroplated on Cu plates using Ni Watts bath-based electrolyte containing 30 g/L TiO_2 nanoparticles. A constant current of 3 ASD was applied to the Cu electrode for 40 min with the assistance of SC-CO_2 at 15MPa and 50°C. The amount of TiO_2 in Ni-TiO_2 composite films were evaluated by energy dispersive X-ray spectroscopy and the uniformity of TiO_2 in the Ni matrix was quantified by coefficient of variation of Ti amount per unit area in the elemental mapping region of heatmap. The Vickers hardness of SC-CO_2 assisted Ni-TiO_2 was improved to 1167HV from that of conventional Ni-TiO_2 (360HV). Micro-pillars in dimensions of 10 μm × 10 μm × 20 μm were fabricated from Ni-TiO_2 with and without assistance of SC-CO_2 for examining the mechanical properties of Ni-TiO_2 composite films in micrometer-scale. Yield strength of the pillar fabricated from SC-CO_2 assisted Ni-TiO_2 was 3.37 GPa, which was proper for high strength applications in MEMS devices.

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