Mn as an Additive in Ni Electrodeposition for High Performance Microsystem Applications

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Electrodeposition through thick photoresist (such as SU8 or polymethylmethacrylate) has enabled the fabrication of high aspect ratio (*i.e.* large height to width ratio) metallic microstructures (HARMST) for various applications.[1-2] The electrodeposited metal of choice is nickel, typically deposited from a sulfamate bath. For some applications, the strength of the as-plated Ni is insufficient. As the cross-sectional areas of microfabricated components decrease (to save space and weight, for example), the stresses experienced in load-bearing members (e.g. actuators, springs, flexures, etc.) rise, necessitating materials having high yield strengths.

The use of organic additives and metal alloying elements to achieve fine-grained, high strength Ni will be discussed. In some cases, the use of S-bearing additives (such as saccharin), though convenient, is precluded due to possible grain boundary embrittlement.[3] Alloying elements such as Co or Fe may be employed to produce fine-grained, sulfur-free Ni alloys. During electrodeposition into deep HARMST features (using practical plating parameters), NiCo and NiFe deposits typically exhibit unacceptable compositional nonuniformities due to these systems' high mass transport sensitivities.[4] Systems less influenced by local mass transport conditions, such as NiMn, do not exhibit this sensitivity and are more readily adapted to throughmask electrodeposition of HARMST.

Figure 1 shows stress-strain curves of a tensile test specimen deposited from a Ni sulfamate electrolyte with 5 g/L Mn as an additive at 28 °C. The alloy contains approximately 1 weight % Mn. A second curve shows the stress-strain behavior after a 1 hour anneal at 600 °C. Ductility is improved, with little loss in yield strength. A reference curve of pure Ni from a sulfamate bath without Mn is shown for comparison. Upon heat treating, the pure Ni loses most of its strength. The strength retention of the NiMn alloy is comparable to that of some wrought superalloys, as has been reported previously.[5] The NiMn material's strength is presumably derived from its small grains, shown in cross section by focused ion beam microscopy in Figure 2, along with that of pure Ni for reference. A method for nanostructuring the material to reduce the high reported film stresses[5] will be discussed. Deposits > 1mm in thickness are possible, allowing for high strength, compositionally uniform HARMST devices.

REFERENCES

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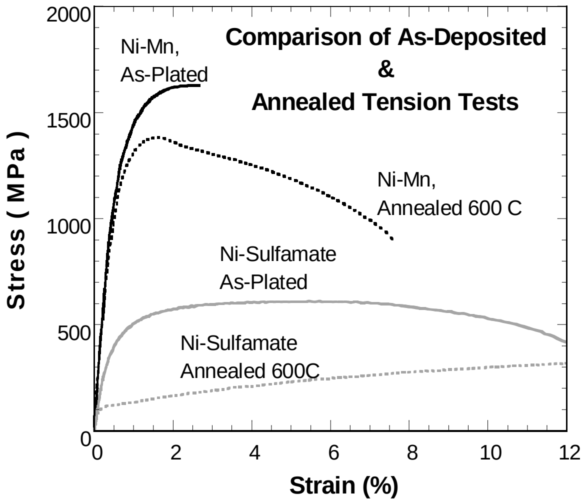

Figure 1. Tensile properties of as-plated electrodeposited NiMn alloy (at room temperature). Heat treating at 600 °C for one hour results in minimal loss in yield strength while greatly improving ductility. Tensile curves for as-plated and annealed pure Ni from a sulfamate bath are shown for comparison.

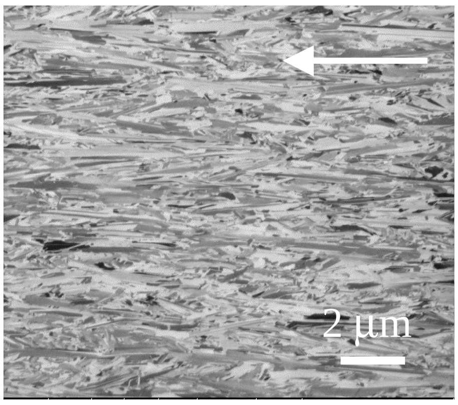

Figure 2a. Focused ion beam cross sectional image of a NiMn film deposited from a Ni sulfamate electrolyte with 5 g/L Mn as an additive at 28°C. Arrow shows film growth direction.

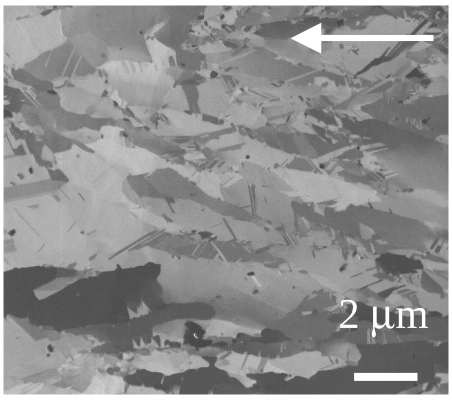

Figure 2b. Focused ion beam cross sectional image of a Ni film deposited from a pure Ni sulfamate electrolyte at 28°C. Arrow shows film growth direction.