# Characterization and Processing of Electroplated Materials for LIGA Micromachining

R. P. Janek[A], T. E. Buchheit[B], S. V. Prasad[B], C. Vanecek[C]

**Sandia National Laboratories** Microsystems Processing Department[A] Livermore CA 94551

**Sandia National Laboratories** Mechanical Reliability Department[B] , Surety Mechanisms and Integration Department[C] Albuquerque NM 87185

Sandia National Laboratories operates an active LIGA prototyping facility with synchrotron beam lines at the Lawrence Berkeley National Laboratory Advanced Light Source and at the Stanford Synchrotron Radiation Laboratory.[1] These resources are used to generate thick high aspect ratio molds that are electroplated to produce precision microcomponents. The implementation of LIGA mechanisms in high reliability systems requires a complete assessment of the strength and aging properties of the electrodeposited material. We seek to expand the scope of LIGA-fabricated devices by characterizing the fundamental material issues associated with electroplated microparts and by developing processes to create tailored electrodeposited materials. Specifically, we report here on the characterization and processing of Ni alloys, Co alloys and Ni metal matrix composites. The electrodeposition process for each of these material classes can be manipulated and optimized by considering three physico-chemical regimes: 1. chemical and electrochemical reduction reactions of the metal cations and organic constituents of the electrodeposition medium, 2. the electric field of the anode/cathode system and 3. the mass transfer of reactants to the cathode surface by forced convection or diffusion. Metal test structures and components are used to evaluate properties of the electrodeposited materials and permit an iterative process optimization within the fundametal framework described above.

Sample Results

The fine grain, highly textured microstructures created by electrodeposition[3] yield materials that differ appreciably from the properties of castings, forgings, or rolled sheet.[4] These differences arise from the influence of the electric current and interfacial electron transfer reactions that form the deposit and from the interaction between the adsorbed metal atoms and reactants present in the aqueous electrolyte. This study first considers the behavior of electrodeposited Ni-Fe alloys fabricated with a nickel sulfate / iron sulfate based process using dc galvanostatic conditions at 30 mA $cm^{-2}$. Ni-Fe alloys are favored in MEMS because of their superior soft magnetic properites and high strength. However, they are somewhat difficult to electrodeposit to thicknesses greater than ~50µm because of residual stress present in the growing film. In this process, stress reduction is achieved by including saccharin in the electrolyte. Initial characterization and process optimization is performed using copper rotating disk electrodes. In addition to compositional analysis, disk electrode studies provide materials for tribological investigation. The wear scar and friction coefficient are measured on the disk surface using a pin-on-disk tribometer. The disk samples can also serve as a convenient means to test any coating methods used to control wear. Results from these experiments will be presented.

Small scale tension testing was performed using a tabletop servohydraulic load frame designed to evaluate LIGA materials. The as-deposited Ni-Fe alloy was found to have an elastic modulus of approximately 140 GPa, an ultimate test strength of 2.1 GPa and elongation to 0.09 before unstable deformation began to occur in the specimen. However, rapid degradation of properties was noted when the samples were treated with 1 hr. thermal exposures at modest temperature. Electron microprobe analysis of the 80Ni-20Fe sample after a 1 hr. exposure at 700 $^{o}$C is illustrated in Figure 1 indicating the presence of sulfur accumulation at grain boundary triple points. This result demonstrated that sulfur migration is responsible for embrittlement after the thermal exposures. With this information we were able to make changes in process conditions to prevent sulfur contamination in Ni-Fe components by developing electrodeposition techniques that do not use saccharin or whose process conditions reduce the incidence of saccharin reduction products, i.e. sulfur, from becoming incorporated in the metal. Examples of other processing-properties studies on LIGA materials will be discussed during the presentation.

To further investigate the properties of LIGA components a test platform has been designed and fabricated and is shown in Figure 2. This structure is driven by a precision motor and incorporates many features to allow complete mechanical and tribological characterization of actual electrodeposited and planarized LIGA substrates. Characterization of LIGA fabricated Ni, Ni-Fe, Ni-Co, Ni-P, Ni-W, Co-W, and Ni composites using this new tool will be reported.

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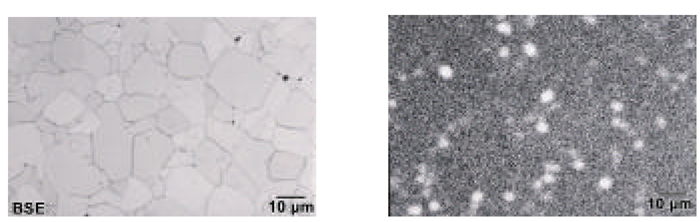


Figure 1. Ni-Fe microprobe sulfur analysis

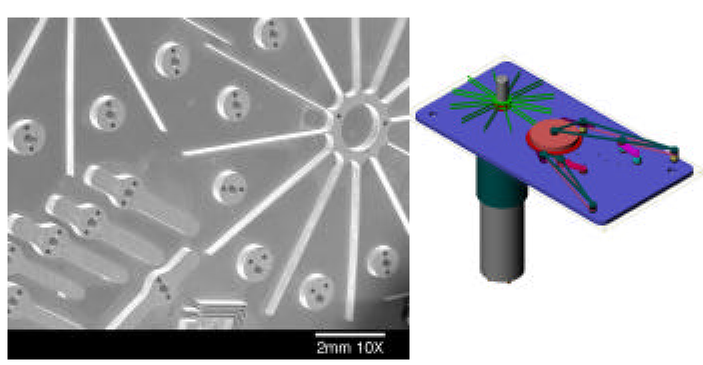


Figure 2. Ni-Fe LIGA test component

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