The Pitting Behavior of Structural Electrodeposits Used in MEMS Applications

F. D. Wall, M. A. Martinez
Sandia National Laboratories,
Albuquerque, NM, 87185-0888

LIGA is an acronym for the German terms *Lithographie, Galvanoformung, Abformung*, which describe a microfabrication process for high aspect ratio, structural parts based on electrodeposition of a metal into a poly-methyl-methacrylate (PMMA) mold. LIGA-produced parts have very high dimensional tolerances (on the order of a micron) and can vary in size from microns to centimeters. These properties make LIGA parts ideal for incorporation into MEMS devices or for other applications where strict tolerances must be met; however, functionality of the parts can only be maintained if they remain dimensionally stable throughout their lifetime. It follows that any form of corrosion attack (e.g., uniform dissolution, localized pitting, environmental cracking, etc.) cannot be tolerated. This presentation focuses on the pitting behavior of Ni electrodeposits, specifically addressing the influence of the following: grain structure, alloy composition, impurities, plating conditions, post plating processing (including chemical and thermal treatment), galvanic interactions and environment (aqueous vs. atmospheric). A small subset of these results is summarized below.

A typical LIGA part is shown in Figure 1. Due to the small size scale, electrochemical testing was performed using a capillary based test system. Although very small test areas can be probed with this system (e.g., Figure 2), typically capillaries on the order of 80 to 90 µm's were used in the testing. All LIGA parts tested in the as-received condition had better pitting resistance than the high purity wrought Ni material used as a control. In the case of LIGA-Ni and LIGA-Ni-Mn, no detrimental effects were observed due to aging at 700C. Ni-S (approximately 500 ppm S), showed good as-received pitting behavior but decreased pitting resistance with thermal aging. Aged Ni-S showed dramatic increases in grain size (from single µm's to 100's of µm's), and significant segregation of S to the boundaries. The capillary test cell was used to measure pitting potentials at the boundaries and within grains (Figure 3) with the results clearly showing the lowered pit resistance being due to the S-rich boundaries.

It is believed that the process used to release the LIGA parts from the Cu substrate acts as a pickling agent for the LIGA parts, resulting in removal of surface impurities and detrimental alloying additions. EIS data from freshly polished samples exposed to the release bath support this hypothesis; R_P values for all LIGA materials and for wrought Ni, continuously increase during exposure. Mechanical polishing of LIGA parts prior to electrochemical testing consistently resulted in lowering the pitting potentials to a range bounded by Ni 201 and high purityNi. The as-received vs. polished behavior also effects the galvanic interactions with noble metals. When as-produced material is coupled to Au, initially the LIGA material acts as the *cathode*, though eventually the behavior switches such that the LIGA becomes the anode.

Overall, the LIGA produced Ni and Ni alloys examined in this work demonstrated pitting behavior similar to wrought Ni, only showing reduced resistance when specific metallurgical and environmental conditions were met.

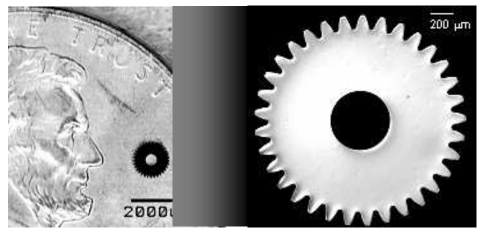

Figure 1. Electrodeposited LIGA Ni gear.
A U.S. penny is shown for scale.

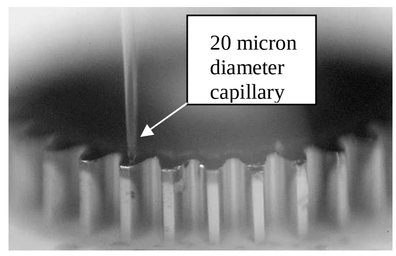

Figure 2. A microcapillary test cell was used to measure local pitting behavior. A 20 µm capillary is shown here in contact with the gear from Fig. 1.

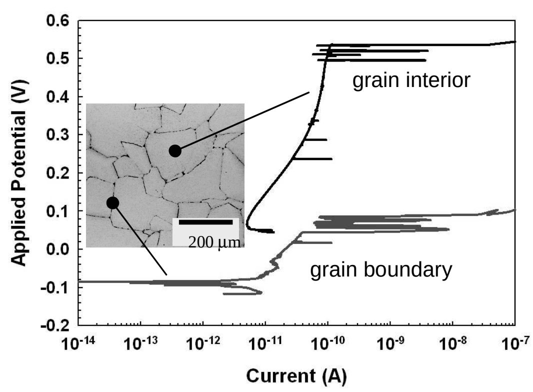

Figure 3. The pitting behavior of the aged Ni-S alloy is determined by the local microstructure. S-rich boundaries show significantly lowered pitting potentials compared to grain interiors.

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