

MODELING EFFECTS OF BATH STIRRING IN LIGA ELECTRODEPOSITION

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Electrodeposition is a key process in LIGA (Lithographie, Galvanoformung, Abformung — German words for lithography, electroplating and molding) micro-fabrication, which is increasingly demonstrated to be a viable technology for fabricating micro-devices or parts. Electrolyte baths employed in LIGA electrodeposition are normally stirred in order to keep the electrolyte solution well mixed and thus shorten deposition time. Such bath stirring creates forced flow and gives rise to buoyancy-induced natural convection — both of which help transport electrolyte species from the bath into the feature cavities or trenches in which deposition takes place. Consequently, LIGA electrodeposition involves 1) diffusion, migration, and convection of charged species in a centimeter-scale electrolyte-bath region and in micron-scale feature-cavity regions; 2) homogeneous and heterogeneous electrochemical reactions; and 3) moving deposition surfaces on which metal ions (e.g., Ni²⁺) are electrochemically reduced to form a pure metal or an alloy.

In this presentation we report efforts toward developing a predictive multi-dimensional computer model for simulating electrodeposition in LIGA micro-fabrication. We solve the momentum and species-mass conservation equations, a Poisson equation that explicitly describes electrolyte potential (and is derived by utilizing the species mass conservation equations and the electroneutrality constraint), and mesh-motion equations that employ an arbitrary-Lagrangian-Eulerian formulation in a fully coupled fashion using GOMA in parallel computations. The GOMA simulation tool is a multi-physics multi-dimensional finite-element computer code developed and being advanced at Sandia National Laboratories. To handle the dramatic reduction of trench domains, re-meshing is repeatedly performed using Sandia's mesh-generation toolkit, CUBIT, and re-mapping is done with Sandia's utility program, MAPVAR. The process of re-meshing and re-mapping is automated using a Unix script we wrote. In this work, we assume that the homogeneous electrochemical reactions are infinitely fast, and reactions on deposition surfaces are taken to be described by Butler-Volmer kinetics. Results are presented for flow field, electrolyte potential, species concentrations, and position of deposition surfaces for nickel electrodeposition in 2-D trenches on a PMMA mold. Numerical challenges encountered when buoyancy-induced natural convection is appreciable are also highlighted.

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