Modeling of Pulse-Plating in High Aspect Ratio Recesses for MEMS

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Introduction

Electrodeposition in deep recessed geometries is one of the most important steps in the manufacturing of micro-electro-mechanical systems (MEMS). Although traditionally single metals and particularly elemental nickel have been used for microstructure applications, pulse-plating of alloys could achieve better properties, such as corrosion resistance and hardness, thus providing better fabrication materials.

In pulse plating a current waveform (pulse plating followed by an off and/or a reverse period) may be applied to the cathode. Depending of the waveform a greater control of the bath concentrations can be obtained leading to a desired deposit composition.

In this work a mathematical model is presented to predict the deposit composition during pulse plating of alloys in recessed geometries with high aspect ratio taking into account the transient character of the phenomena involved at time scales less than the diffusion time. The model addresses the complete transport balance in transient electrochemical systems involving moving boundaries. Study of pulse and pulse-reverse plating including various waveforms was possible. The influence of the plating parameters, such as pulse time, duty factor and applied current density, and the role of the geometry type and solution composition were investigated.

Mathematical Model

The continuum model of the electrochemical systems of interest consists of coupling the associated species balances with electroneutrality for the solution potential. The transient transport equation includes diffusion, migration and convection. Appropriate initial and boundary conditions complete the mathematical formulation including adsorbance / desorbance mechanisms for intermediate formed species. The duty cycle of the process determines plating, no-plating and reverse plating (where applicable) intervals during the pulse period.

FIDIPIDDIS, a finite difference method (based on general curvilinear coordinates) for transient deposition and dissolution processes in micro- features such as recessed geometries and vias, was used for solving the continuum equations. The code incorporates a multi-block adaptive grid generation technique for the discretization of the physical domain, adaptive meshing capabilities for the simulation of the moving boundary and a backward Euler implicit scheme for the time integration.

Results

FIDIPIDDIS was applied to the problem of alloy pulse (and pulse-reverse) plating inside deep recessed geometries. The resulting deposit composition depends on bulk composition and pulse waveform parameters. The model can then be used to tune the processing conditions for achieving the desired deposit properties.