Application of Computer-Aided Design and Manufacturing Concepts to Electrochemical Microfabrication

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Computer-aided design (CAD) and manufacturing (CAM) concepts center around tools and practices that create flexibility within the manufacturing environment. Flexibility, in this context, implies an ability to fabricate any number of different items with modest hardware retooling and with a very short turn-around time. Ideally, only software reconfiguration is required. For the past two decades, numerical simulation has played an important role in the design of electrochemical systems and processes. Despite this, electrochemical microfabrication itself remains, for the most part, beholden to lithography and the need for (inflexible) optical mask sets.

In this presentation, we briefly demonstrate the ever-increasing power of modern simulation packages for computer-aided design of electrochemical systems, and then shift our focus to flexible, software-reconfigurable, methods for electrochemical microfabrication. We highlight two approaches to flexible electrochemical microfabrication: laser-based patterning to generate masks for through mask electrodeposition and etching, and emerging solid freeform fabrication techniques for creating 3-D electrodeposited microstructures.

In our work on laser-based mask generation, a CO_2 laser is used to cut adhesive-backed PVC tape. The laser-cut mask is then peeled from its backing and placed on the cathode to plate. In this manner, a mask can go directly from CAD drawing to plating substrate in minutes, with design revisions requiring no more time than is necessary to redraw the part in AutoCAD. Similar concepts involving laser-based patterning (in this case, of protective oxides) have been demonstrated by Landolt and colleagues for use with Ti-etching.

In the emerging area of electrochemical solid freeform fabrication, Cohen and colleagues have demonstrated a multiple-layer electrodeposition process that involves the use of multiple patterned anodes to direct localized current to certain regions. We have developed a pixelated electrodeposition tool for fabricating complex three-dimensional microstructures via software reconfigurable counter electrode arrays. Each pixel of the tool consists of an independently controlled counter electrode placed within a fluid injector. We have fabricated a working prototype, and have theoretically explored the effects of several design and operating variables on its operation.

In summary, flexible, software reconfigurable methods for electrochemical microfabrication are now being realized, and they have the potential to accelerate the development of new devices and processes.