IM™ Plating: A New Micro-Electrodeposition Method for Manufacturing 3-D MEMS

Gang Zhang, Adam Cohen

MEMGen Corporation
1103 W. Isabel Street, Burbank, CA 91506, USA

MEMS (**M**icro**E**lectro**M**echanical **S**ystems) consist of functional micro-components which perform engineering operations such as sensing and actuation. MEMS designers realize these micro-devices using various microfabrication techniques mainly originating from the microelectronic or IC industry, which are not real 3-D fabrication techniques. Rapid growth of MEMS calls for new fabrication techniques for quickly manufacturing high-aspect-ratio true 3-dimensional (3-D) micro-components. Achieving this goal has been a challenge to the MEMS community.

A new technology, **EFAB™** (**E**lectrochemical **FAB**rication), is emerging as a promising way to meet the challenge [1-2]. The EFAB process combines a key technique– **Instant Mask** (IM™) plating–with other techniques to manufacture arbitrary true 3-D microstructures at high speed using a self-contained, automated machine. In the present EFAB implementation, the EFAB process consists of three steps which are repeated on every layer. The process flow is shown in Fig. 1, where a first material is deposited onto a substrate (cathode) by IM plating to yield a patterned layer (Fig. 1(a-b)). In Fig. 1(c), a second material is blanket-deposited over the first material and the substrate. The entire two-material layer is then planarized to achieve precise thickness and flatness (Fig. 1(d)). After repetition of this process for all layers, the embedded multi-layer structure shown in Fig. 1(e) is etched to yield the desired device in Fig. 1(f).

A simplified model of IM plating is shown in Fig. 2. Patterned layers are fabricated using an Instant Mask, which consists of a patterned insulator layer supported by an anode. IM plating is a new microelectrodepositon technique in that it has characteristics that are different from those of traditional plating and through-mask plating:

- Sealed micro plating cell
- Microbath plating with bath volumes between sub-nanoliter and microliter.
- Thin electrolyte film plating (large area:volume ratio)
- Diffusion-controlled plating with no agitation
- Higher limiting current density due to thinner diffusion layer
- Anode:cathode area ≈ 1:1
- Uniform current distribution
- Interaction between the anode reaction and the cathode reaction
- Degradation of bath quality with plating time

To make the IM plating process reliable so that a uniform deposit with a certain thickness is obtained, some critical issues have to addressed: such as,

- Bath design, selection and formulation
- Optimization of plating parameters
- Deposit uniformity
- IM process monitoring

A patterned copper layer (16 μm thick) using IM plating is shown in Fig. 3. The diameter of the circles is 200 μm. A 12-layer nickel micro-chain fabricated using the EFAB technology is shown in Fig. 4. It has 14 independently-movable links (290 μm wide and 500 μm long) and a total thickness of ~ 100 μm.

EFAB and **Instant Mask** are trademarks of MEMGen Corporation.

Acknowledgements

This research was supported in part by the Defense Sciences Office and the Microsystems Technology Office of the Defense Advanced Research Projects Agency (DARPA) under the Mesoscale Machines program and the MEMS programs, respectively.

References

1. A. Cohen, G. Zhang, F. Tseng, F. Mansfeld, U. Frodis and P. Will, Proc. 12th IEEE Micro Electro Mechanical Systems Workshop, p244, Jan., 1999.

2. G. Zhang, A. Cohen, U. Frodis, F. Tseng, F. Mansfeld, and P. Will, Proc. 2nd International Conference on Integrated MicroNanotechnology for Space Applications, p238, Apr., 1999.

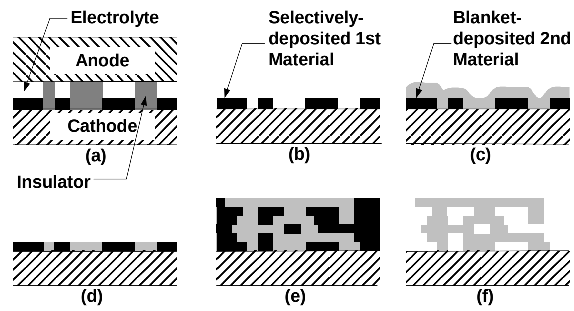

Fig. 1. Steps in the EFAB™ process.

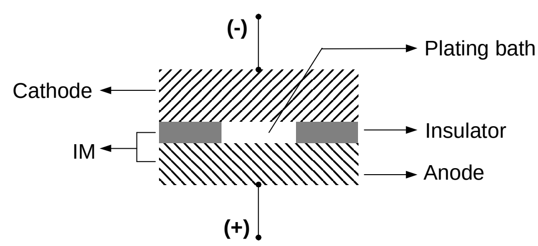

Fig. 2. Simplified model of IM™ plating.

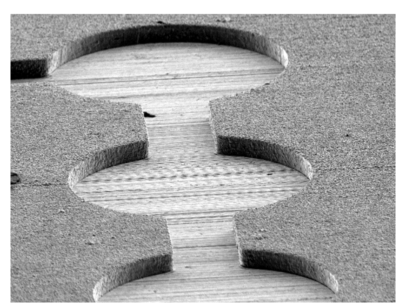

Fig. 3. Patterned copper layer using IM™ plating.

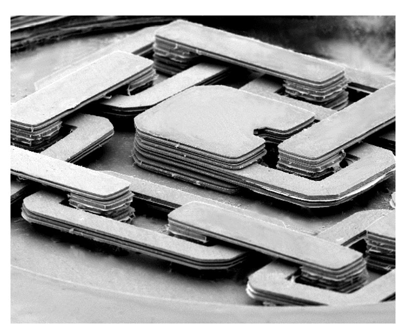

Fig. 4. 12-layer nickel micro-chain.