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

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MEMS (MicroElectroMechanical Systems) 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™ (Electrochemical FABrication), 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 microelectrodeposition technique in that it has characteristics that are different from those of traditional plating and through-mask plating:

- Sealed micro plating cell
- Microbatch 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 be 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.

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References