Replication of High Aspect Ratio Microstructures in Plastics, Metals, and Ceramics

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Successful commercialization of high aspect ratio microstructures requires economical, high throughput replication technologies without repetitive synchrotron and development steps. In addition, these replication technologies should produce microstructures from a large suite of materials to enable microsystems designers to choose the best material for their applications. Sandia National Laboratories, California, is actively pursuing new replication technologies that combine different microfabrication and materials processing techniques to produce quality microparts from plastics, metals, and ceramics.

We are investigating plastic replication through hot embossing and injection-compression molding that employ LIGA fabricated mold inserts (Fig. 1). Hot embossing is simple and allows the rapid screening of various thermoplastics. Injection-compression molding provides greater control over the resin flow and allows faster replication rates. We have successfully replicated high aspect ratio plastic microstructures in PMMA, polyolefins, and other polymers or blends (Fig. 2). Plastic microstructures are desirable as economic microfluidic components for portable analytical and medical instrumentation.

Plastic replicates are also used as sacrificial molds for the production of ceramic microstructures via cold pressing, debinding, and sintering of nanoparticles. We have successfully produced alumina and zirconia microstructures and are currently extending this technique to other ceramics (Fig. 3a). The incorporation of ceramics into microstructures will allow the exploitation of materials properties such as high temperature inertness, photochromism, chemical and biological compatibility, piezoelectricity, and magnetism. We are currently developing micromolding and surface chemistry techniques for metal nanoparticles. This will allow the fabrication of microparts from engineering metals not available through aqueous electroforming such as stainless steel, aluminum, titanium, and brass (Fig. 3b).

We have developed a novel technique for replicating plastic electroplating micromolds using a LIGA fabricated master tool. Micro-perforated metal screens allow the rapid production of micromolds with a conducting base and insulating sidewalls (Fig. 4a). Plating and lapping of the replicated mold produce solid metal microstructures which can then be released from the screen (Fig. 4b). This process is suitable for the replication of both contiguous and non-contiguous metal parts.

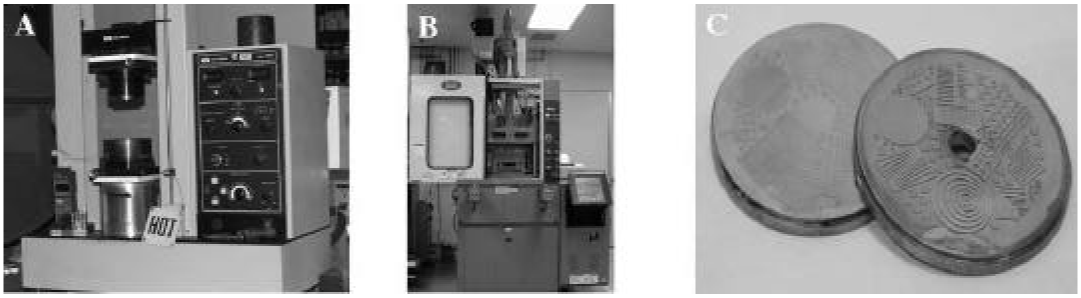

Figure 1. a) Standard test frame modified with a vacuum die and heating platens for use as a hot embosser. b) Nissei vertical injection-compression molding machine. c) Interchangeable, LIGA fabricated mold inserts.

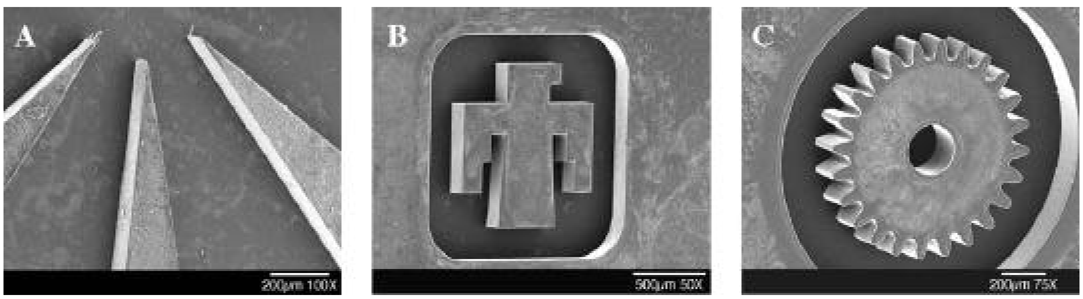

Figure 2. Hot embossed plastic microparts. a) 95 micron thick HDPE microwedges. b) 170 micron thick PMMA microthunderbird. c) 170 micron thick PMMA microgear.

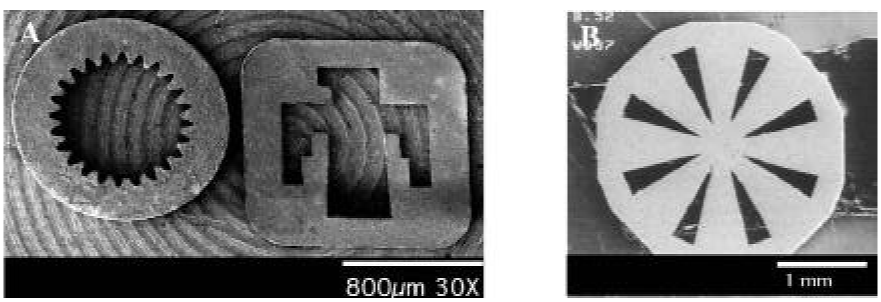

Figure 3: a) Sintered alumina microparts. Densities higher that 98 % theoretical density have been obtained. b) Sintered 316 stainless steel micropart.

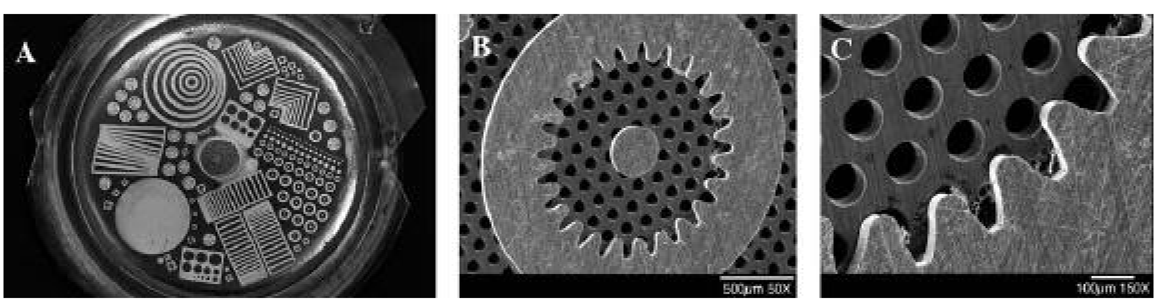

Figure 4: a) PMMA/microscreen plating mold. b) 90 micron thick electroplated nickel internal gear. c) Higher magnification view of electroplated nickel internal gear.