LIGA Micromachining and Microdevices Using Deep Etch X-ray Lithography at Beamline 3.3.2

Dale R. Boehme[1] and Dean V. Wiberg[2]
[1]Sandia National Laboratory,
Livermore, California 94550, USA
[2]Jet Propulsion Laboratory,
Pasadena, California 91109-8099, USA

INTRODUCTION

A dedicated LIGA end station was commissioned at the Advanced Light Source (ALS) Beamline 3.3.2 in July, 1998 for exploring the science and technology of high aspect ratio microfabrication. The capabilities at BL3.3.2 have been developed by a Participating Research Team (PRT), named the West Coast LIGA Group, and consisting of Sandia National Laboratories (SNL), the Jet Propulsion Laboratory (JPL), and the Lawrence Berkeley National Laboratory (LBNL). LIGA, an acronym for the German words for lithography, electroforming, and molding is a micromachining technology that uses high energy x-rays from a synchrotron to create high aspect-ratio microdevices having micron to millimeter features [1,2,3].

At the ALS, the LIGA process begins with deep etch x-ray lithography (DXRL) of thick, low stress, photoresists, typically polymethylmethacrylate (PMMA). This is accomplished with the use of a mask patterned with high Z (atomic number) absorbers that prevent penetration of x-rays. The x-ray mask substrate must be made of a material that minimizes the loss of x-rays through absorption, which suggests low Z materials such as silicon and beryllium. The mask absorber material is, conversely, a high Z material corresponding to a high x-ray absorption coefficient material, such as gold or tungsten. In the open areas of the patterned mask radiation passes through the mask substrate and exposes the PMMA resist, which is then chemically developed. The exposed cavities replicate the mask and are used as molds for electroplating. The electroplating step can be the final step in the process or the electroplated part can be used as a mold for replication from another material such as a plastic or ceramic.

ACCOMPLISHMENTS

All three PRT members have used BL3.3.2 extensively since its commissioning in July. Following are summaries of accomplishments in the laboratories individual research areas.

<u>Sandia National Laboratory:</u>

Two major projects were emphasized at the ALS using BL3.3.2 to perform x-ray exposures for the LIGA process. These have included components for a mechanical milliengine design and electrodes for use in electrodischarge machining (EDM). The milliengine consists of a variable reluctance device (Figure 1). Magnetomotive force is created in coils mounted on horseshoe-shaped ferrite pieces attached below the engine substrate. The reluctance in the air gaps dominates the circuit. One air gap varies with position (hence the term variable reluctance device) and the other is constant. All components for this milliengine design were fabricated using LIGA except for the motor coils that were machined from Hiperco. Five different x-ray masks (3 inch Si-wafers with patterned gold) were used to mold thirty different parts including stators, actuators, drive arms, gears and associated connectors. These components have thicknesses ranging from 200 μm to 500 μm and were electroplated from nickel, copper, and permalloy (nickel-iron). The magnetic circuit includes the coil, horseshoe ferrite, the shuttle, the stator, and to air gaps.

The electrode project consisted of components for an AGIE micro sinker electro discharge machine (EDM) used at Sandia, New Mexico. The coupling of the precision of the LIGA technique to the final part and materials that cannot be electroplated, such as Kovar and stainless steel, resulted in the fabrication of copper electrodes for use in the EMD production of a neutron tube screen presently manufactured using chemical milling. 1mm thick PMMA resist was exposed using the pattern of the electrode design to produce molds that were electroplated with Cu-metal (Figures 2 & 3).

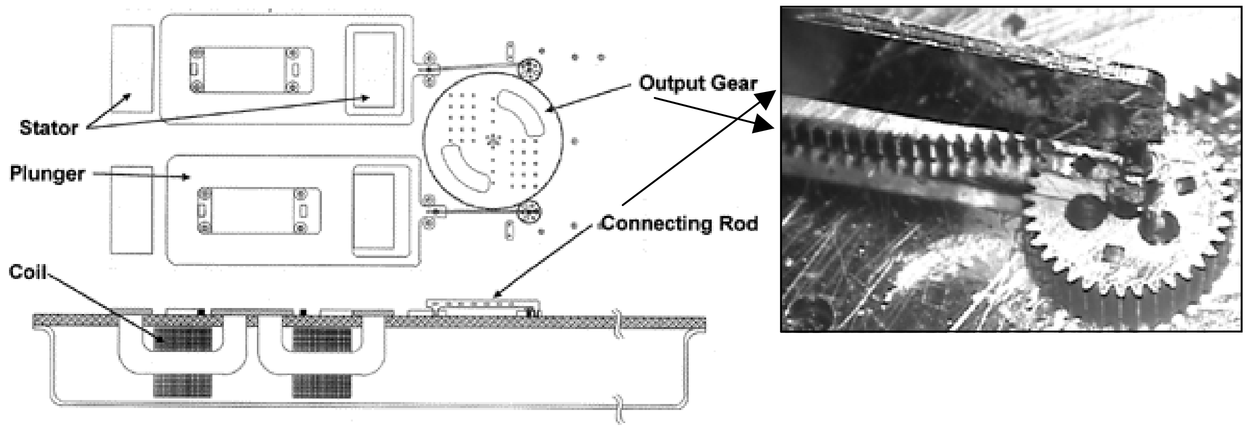


Figure 1. Top view of assembled milliengine. The diameter of the output gear is 12 mm.

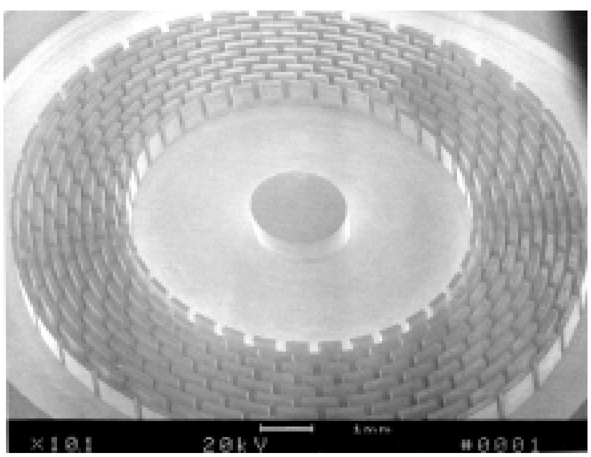


Figure 2. EDM plunge electrode electroplated in copper 1 mm thick X 15 mm diameter. The circular arrangement of pads produces a mesh for the neutron tube design.

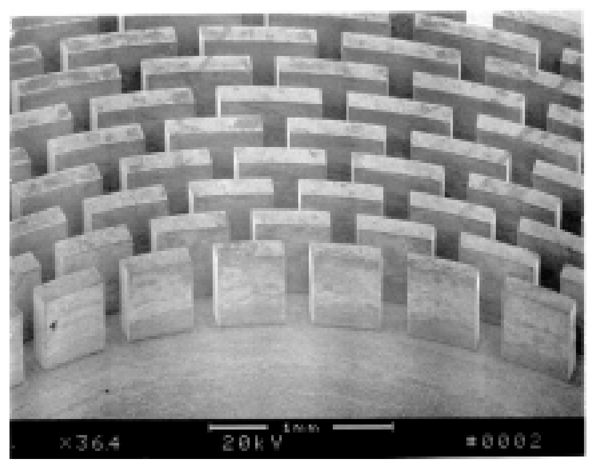


Figure 3. Close-up of the EDM electrode showing individual pads that produce screen openings in Kovar sheet for the neutron tube part.

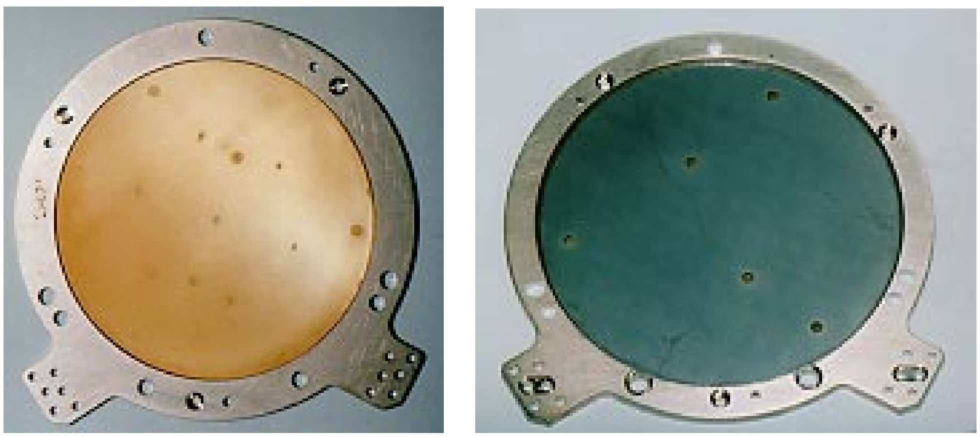
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC0494AL85000.

Jet Propulsion Laboratory:

Wave Guides:

JPL has undertaken the task of fabricating wave guides using the LIGA process for high frequency applications ranging from 640 GHz to 4.5 THz. Each application requires high aspect ratio metal grid structures to be fabricated with active areas ranging from about 0.25 cm^2 to over 4 cm^2 with metalized thickness up to about 0.5 mm. The 640 GHz device will be incorporated into NASA's Earth Observing System-Millimeter Limb Sounder (EOS-MLS) which will perform atmospheric spectroscopy. LIGA has proved to be a superior technique for the fabrication of waveguides as it allows very straight sidewalls with high aspect ratios unavailable using other available techniques such as deep trench reactive ion etching or thick film UV photo lithography.

X-ray Collimating Grids:
JPL is fabricating 34 µm and 58 µm pitch X-ray collimating grids for the High Energy Solar Spectroscopic Imager (HESSI) to be launched in July 2000 (Figure 4). This instrument is designed to perform imaging of the Sun in the range of soft X-rays through Gamma rays with a spatial resolution of 2 to 10 times better than has previously been available. The technology to fabricate these grids was a direct outgrowth of the X-ray mask process developed to fabricate LIGA masks. Using this technology allowed the mission cost to be reduced by nearly an order of magnitude without significant reduction in the science to be performed.



Gold grid side　　　　　Beryllium backing wafer side

Figure 4. 34 µm pitch, 70 µm thick, Gold X-ray collimating grid mounted on Monel ring with 100 µm thick Beryllium backing wafer attached.

ACKNOWLEDGMENTS
Cheryl Hauck of the Advanced Light Source has provided continued support and mentoring of the LIGA end station at BL3.3.2 and serves as an ALS on site contact for the beamline activities.

REFERENCES
1. W. Ehrfeld, et al, Fabrication of microstructures using the LIGA process, in *Proc. IEEE Micro Robots and Teleoperators Workshop*, no:**87**, 1987.
2. W. Ehrfeld and L. Lehr, Deep x-ray lithographie for the production of three dimensional microstructures from metals, polymers, and ceramics, *Radiat. Phys. Chem.*, **45** (3), pp.349-365, 1995.
3. A. Rogner, J. Eichert, D. Munchmeyer, R. P. Perters, and J. Mohr, The LIGA technique-what are the new opportunities, *J. Micromech. Microeng.*, **2**, pp. 133-140, 1992.

Laboratory principal investigator information:

PRT Spokesperson: Jill Hruby, Sandia National Laboratories, Livermore, CA.
Email: jmhruby@sandia.gov. Telephone: 925-294-2596. Fax: 925-294-3410.

Sandia Representative: Dale Boehme, Sandia National Laboratories, Livermore, CA.
Email: drboehm@ca.sandia.gov. Telephone: 925-294-2060. Fax: 925-294-3410.

JPL Representative: Dean Wiberg, Jet Propulsion Laboratory, Pasadena, CA.
Email: dean.v.wiberg@jpl.nasa.gov. Telephone: 818-354-5724.

LBNL Representative: Keith Jackson, Center for X-ray Optics, Berkeley Lab, Berkeley, CA.
Email: khjackson@lbl.gov. Telephone: 510-486-6894. Fax: 510-486-4955.