# LIGA Prototyping at Sandia National Laboratories

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**Abstract**

A complete LIGA capability for prototyping metal microparts has been established at Sandia National Laboratories in Livermore, California. The processing equipment, facilities and methodologies, as well as examples of LIGA prototypes fabricated by Sandia are presented here.

## Introduction

Sandia National Laboratories has developed a complete capability to fabricate metal LIGA microparts. These metal microparts are primarily prototypes for Sandia's U.S. national defense mission needs and include accelerometers, motors, and locking mechanisms. In addition, Sandia fabricates LIGA microparts for additional customers at Sandia and at other national laboratories, universities, and industry. Examples of LIGA parts being fabricated include miniature gas chromotography columns, microfluidic channels, miniature klystrons, wave guides, and electrodischarge machining tools.

## Facilities

All the LIGA processing steps are completed in-house at Sandia in Livermore, California with the exception of the synchrotron exposures and generation of the chrome mask. The primary facilities consist of three laboratories: a clean room, a chemistry laboratory, and an electroplating laboratory.

*Mask Generation:*
The electronic design of the mask is completed at Sandia, and the artwork is sent to a commercial chrome mask supplier, usually PhotoSciences, for fabrication. Once the chrome mask is received at Sandia, a LIGA mask is fabricated. The standard x-ray mask used by Sandia is gold patterned on a 100 micron silicon substrate. The gold thickness ranges from about 8 to 30 microns, depending on the desired lateral feature sizes and tolerance control [1]. The metallized silicon wafer is patterned using one or two layers of SJR 5740 photoresist and a Karl Suss MA6 mask aligner. Gold is electroplated in the SJR 5740 pattern using a gold sulfide bath. This mask has proven to be cost-effective, robust, and provide excellent results when used at the high-energy light sources mentioned above.

*Synchrotron Beamlines and Exposures:*
Our synchrotron exposures are performed at one of three U.S. Department of Energy -owned-and –operated synchrotrons: (1) the Advanced Light Source (ALS) Beam Line 3.3.2 at Lawrence Berkeley National Laboratory operated by Sandia, Lawrence Berkeley National Laboratory, and the NASA Jet Propulsion Laboratory (JPL); (2) the Stanford Synchrotron Radiation Laboratory (SSRL) Beam Line 3.1 at the Stanford Linear Accelerator Center operated by Sandia and JPL; and (3) the National Synchrotron Light Source Beam Line X27B at Brookhaven National Laboratory operated by Brookhaven. Due both to the characteristics of the beams and the proximity of the synchrotrons to Sandia, our exposures are conducted primarily at the SSRL and ALS beam lines.

The ALS beamline is currently operated using a scanner with an eight-sample position turret that employs a counter-weighted belt drive system. The entire instrument operates in a non-hutch, closed-box, x-ray safety enclosure using an interlocked door for sample placement. When a LIGA exposure is underway, the three inch diameter mask and PMMA substrate are scanned vertically through a beam approximately 1 cm high and 10 cm wide. The substrate is water-cooled and the entire instrument is purged with nitrogen with prevent the buildup of ozone that degrades the electrical system.

At the present time, the Sandia LIGA team is using SSRL as an individual investigator. In parallel, we are completing construction of a dedicated beamline. For use at the new beamline, Sandia designed and had fabricated, a scanner with the capability to accommodate scans as large as 5.5 inches in width and 8.5 inches in length. The scanner has multiple mask and substrate mounts, and is capable of five degrees of freedom. This allows the mask to be rotated, scanned vertically, and scanned horizontally. This scanner accepts four-inch diameter masks, accomodates water cooling on the substrate, and is continuously purged with helium. The new scanner, shown in Figure 1, was procured for about $80K and a control and data acquisition program has been written by Sandia. We expect to be operational at the new beamline before October, 1999.

The x-ray photoresist used by Sandia is CQ-grade PMMA supplied by Goodfellow. This sheet PMMA is typically adhered to a metallized 600 micron silicon wafer, and then fly cut to a thickness about 50 microns greater than the final desired thickness of the microparts. Oxidized copper is used as a substrate when the micropart(s) are not to be released from the substrate.

*Development:*
After the exposure, development of the PMMA is done in a custom designed development system that includes three tanks – a GG developer tank, an intermediate rinse tank, and a water rinse tank. All the tanks are continuously filtered with 0.2 micron filters. Both the GG developer tank and the intermediate rinse tank contain megasonic agitation units. This development system is shown in Figure 2a.

*Plating:*
A dedicated LIGA plating line has been designed and installed at Sandia. The LIGA plating line, shown in Figure 2b, consists of sixteen tanks, each equipped with a 5 micron filter and power supply capable of accurately controlling low currents. The plating line is instrumented with a computer-based diagnostic and control system that allows specialty waveform generation and control for electrical input, and also provides continuous monitoring and off-normal alarms. We have successfully plated nickel, nickel iron, copper, and gold in LIGA molds. Research activities include specialty alloys, dispersion-strengthened plating, and compositionally modulated multilayers.

*Planarization:*
The final step in producing metal microparts is lapping to the final thickness and polishing. This is accomplished at Sandia using diamond slurries and ENGIS lapping equipment. The LIGA wafers are held in a modified vacuum fixture. Thickness tolerance is currently plus or minus five microns, and surface finish one micron rms.

**Prototype Microparts**

Examples of LIGA prototypes produced at Sandia include parts for complex assemblies (e.g. motors) and also precision piece parts for a variety of applications. Specific accomplishments include an electromagnetically-powered linear drive millimotor, an electromagnetically-powered eight millimeter rotary drive motor, an environmental sensing device [3], mesh electrodes for use as plunge EDM tools, wave guides (with JPL), mass spectrometers (with JPL), and more. As examples of dimensions obtained by Sandia, extended lateral features of six microns were produced for the environmental sensing device, and three millimeter thick mass spectrometers have been plated by Sandia. The linear drive millimotor assembly consisted of 30 unique LIGA parts, with over 400 total LIGA parts delivered to the customer [2]. The rotary drive motor consists of 12 unique LIGA parts with a total of 20 LIGA parts per motor. A photograph of the LIGA gear system for the rotary motor is shown in Figure 3 [2]. A precision wave guide, designed and x-ray exposed by JPL, and developed, plated, and planarized by Sandia is shown in Figure 4. The wave guide was designed for 640 GHz operation and is scheduled for an upcoming NASA flight.

**Summary**

The LIGA capabilities at Sandia and examples of prototypes fabricated have been briefly described. The use of dedicated LIGA beam lines at three U.S. synchrotrons, along with established in-house capabilities allows us to routinely produce LIGA prototypes. We have produced parts for complex assemblies and precision piece parts for a wide variety of applications and customers.

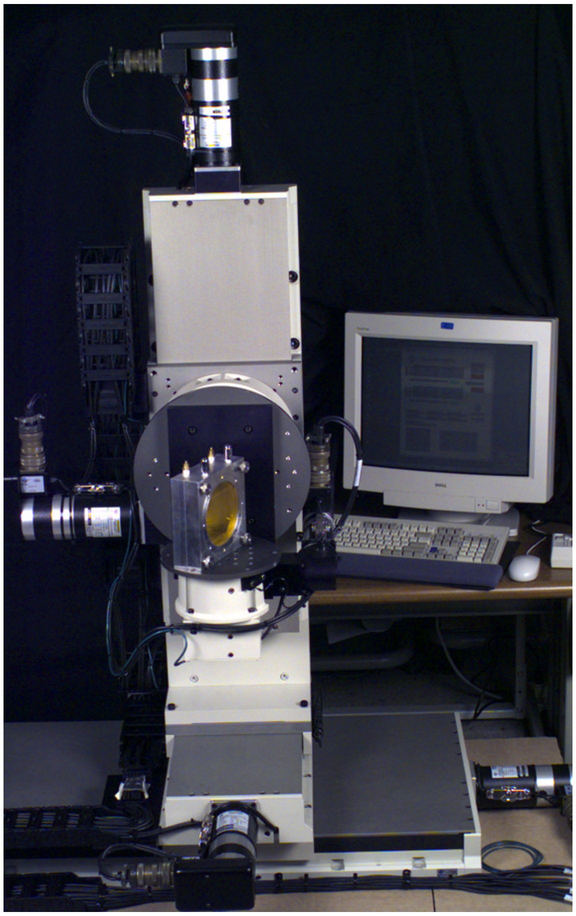

Figure 1. X-Ray Scanner for use at SSRL. The scanner measures about four feet high, scans areas up to 5.5 inches wide and 8.5 inches long, can rotate the mask and substrate horizontally and vertically relative to the beam, and operates using Sandia-developed control and data collection software.

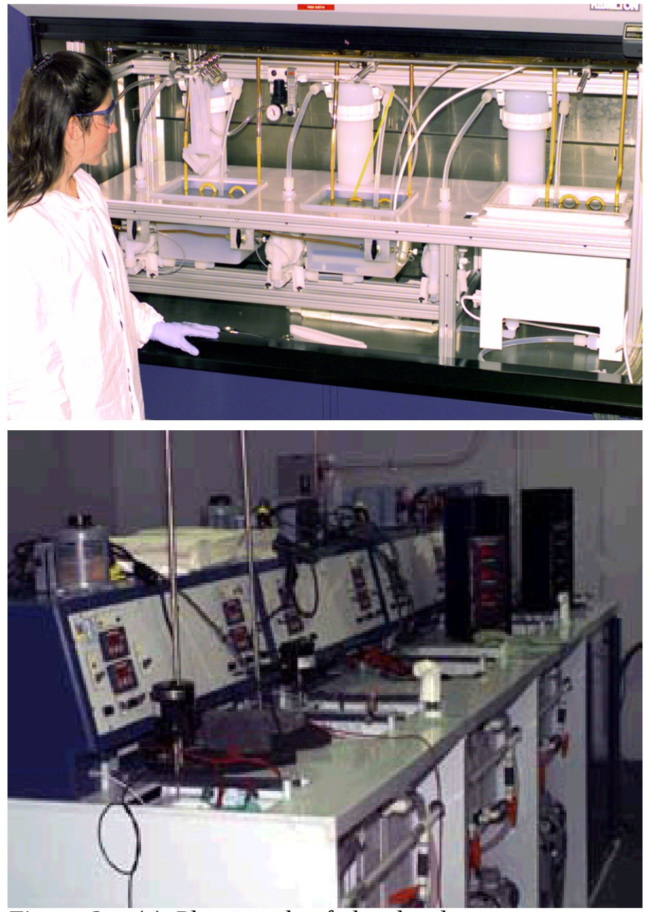

Figure 2. (a) Photograph of the development system at Sandia. The tank on the right is the GG developer tank, the center tank contains the intermediate rinse solution, and the left tank is water. (b) Photograph of dedicated LIGA plating line at Sandia. The sixteen tanks are filtered with five mircon filters and are used for a variety of materials including nickel, nickel iron, copper, and gold.

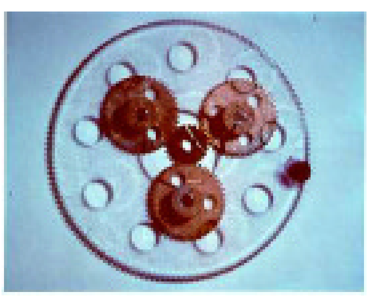

Figure 3. Top view of LIGA-fabricated planetary, sun, and output (PMMA) gears for an 8 mm rotary drive motor.

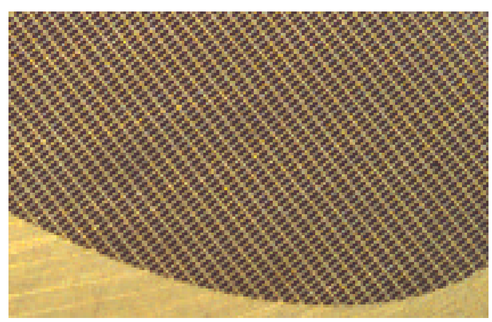

Figure 4. JPL designed 640 GHz wave guide, developed and plated at Sandia. The slats are 40 microns wide and the openings 320 by 144 microns edge to edge.

References:


1. S. K. Griffiths, J. M. Hruby, and A. Ting, "The Influence of Feature Sidewall Tolerance on Minimum Absorber Thickness for LIGA X-ray Masks," Proceedings of Micromachining and Microfabrication, SPIE, Paris, 1999.

2. The linear drive millimotor and 8 mm motor were designed by Ernest J. Garcia and assembled and tested by Ernest J. Garcia and Andrew Jojolo, Sandia National Laboratories.
3. The environmental sensing device was designed by Marc Polosky, Sandia National Laboratories.