LIGA – <u>Li</u>thographie, <u>G</u>alvanoformung, <u>A</u>bformung (Lithography, Electroplating, Moulding) – and its potential application to High Power Laser Science.

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Introduction

LIGA (German acronym for **<u>Li</u>**thographie, **<u>G</u>**alvanoformung, **<u>A</u>**bformung – lithography, electroplating and moulding) is the ultimate lithography technique for making high aspect-ratio microstructures. A synchrotron x-ray source is used for exposure, and resist walls with the ultimate in wall straightness and smoothness are obtained. Exposures in resist with thickness of more than 1 millimetre and aspect ratios up to 100:1 are possible. The resulting structure is used as a mould for subsequent electroplating to form a metallic structure which can either be used "as is" or can be used as the master for mass production by injection moulding.

This paper describes the basic LIGA process and some early-stage research and development being carried out by Scitech Precision in collaboration with Diamond Light Source with the objective of producing high aspect-ratio pinholes in gold.

The LIGA process consists of six basic steps, as shown in Figure 1.

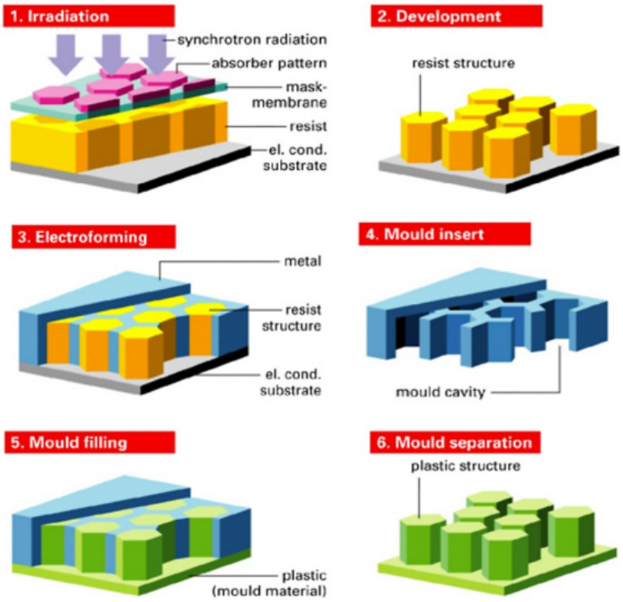


Figure 1. Six basic steps of the LIGA process.

X-ray lithography and electrodeposition were combined at IBM as early as 1975[1], devising the "LIG" part of LIGA (i.e. without the moulding step). This final step was realised at the Karlsruhe Nuclear Research Centre in 1982[2]. LIGA processing was carried out in the UK by STFC in the 1990s and utilised the SRS at Daresbury Laboratory. A schematic of the set-up used by STFC is shown in Figure 2. The deep x-ray beam at the beamline on SRS is approximately 10mm x 100mm and by translating the mask/substrate pair up and down many times, uniform exposure over a 4-inch wafer was achieved.

A simulation of how the x-rays pass through the various components is shown in Figure 3. Using PMMA, the optimum exposure dose is ~4500J/cm^3 at the bottom of the resist, which ideally should not be less than one-quarter of the dose at the top. Some examples of the possible structures are shown in Figure 4 below.

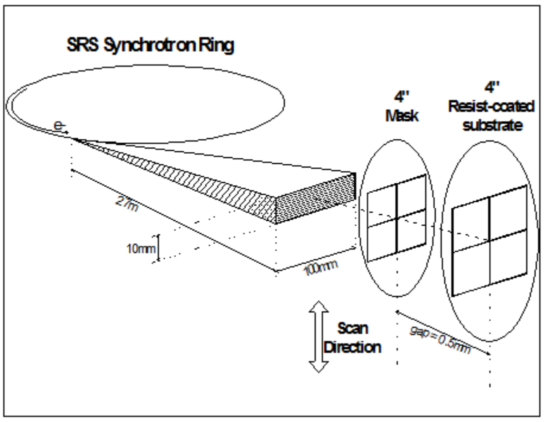


Figure 2. Schematic of synchrotron and radiation emitted by a bending magnet on SRS. Substrate and mask are scanned to produce uniform dose.

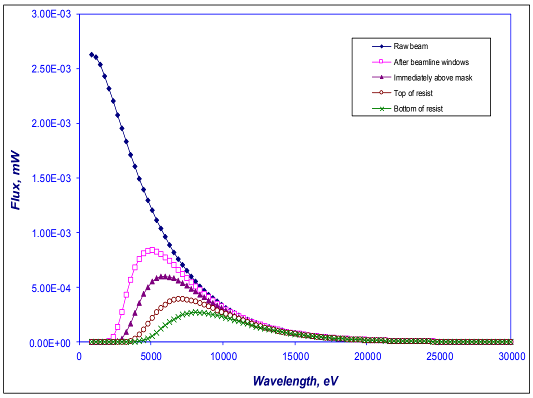
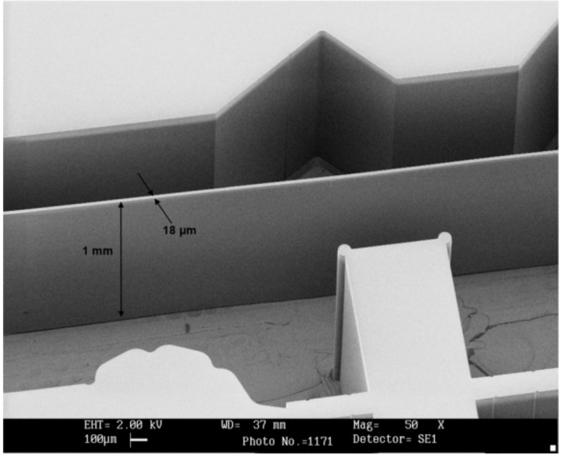
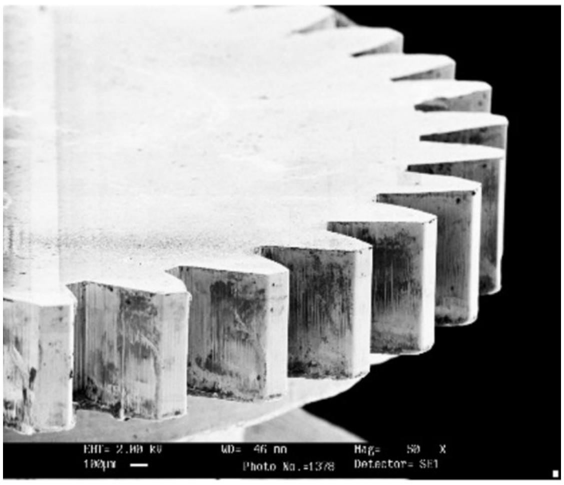


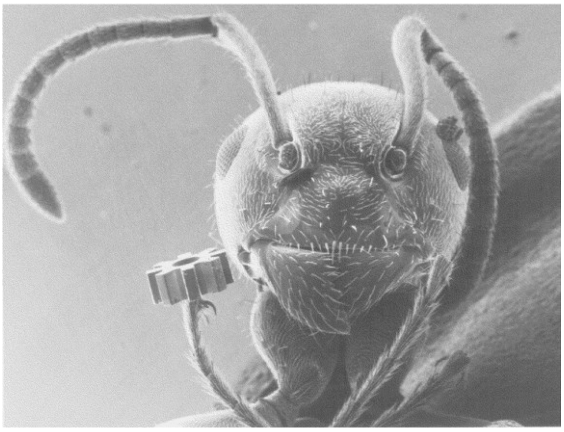
Figure 3. Simulation of the radiation at SRS as it passes through the various component layers. Top and bottom of resist curves are needed for dose calculation.



a.



b.



c.

Figure 4. (a) is a 1mm thick resist structure; (b) is a nickel gearwheel electrodeposited into a thick PMMA layer. Both (a) and (b) were created at STFC using SRS; (c) is LIGA-made gearwheel held by an ant which made the cover of *Scientific American* and shows the resolution possible. (G. Stix, *Scientific American* 267, 5 (1992)).

Application to High Power Laser science.

Researchers using high power lasers (or synchrotron radiation) have requirements for devices such as pinholes which are compatible with high energy x-rays. The early-stage research reported here has the objective of creating 25um diameter pinholes through 1mm of gold (A/R = 40:1) and, like [1], will utilise the "LIG" steps of the full LIGA process.

A 3-inch wafer set-up has been used. In addition, the x-ray spectrum required the gold "blocker" on the x-ray mask to be 25um thick instead of 10um as used on SRS. This mask is made using a combination of optical lithography and gold electrodeposition into a 30um optical resist film. The finished mask is shown in Figure 5 and the exposure set-up on beamline B16 is shown in Figure 6.

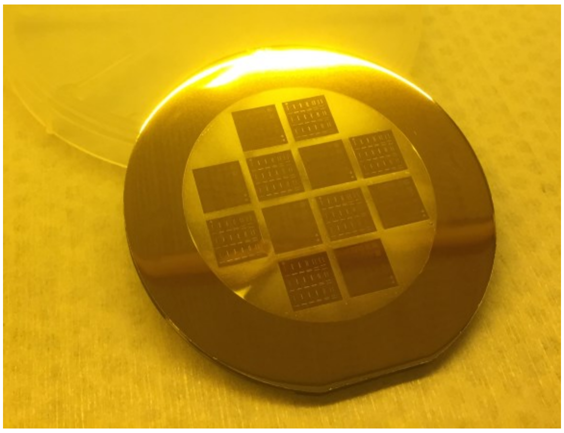


Figure 5. X-ray mask consisting of a steel ring with a Kapton membrane. A gold seedlayer is applied prior to the optical lithography which results in the 25um thick Au pattern.

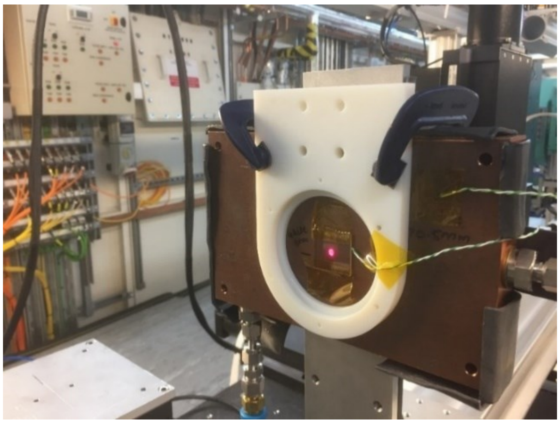


Figure 6. The x-ray exposure station on DLS beamline B16. The wires are a thermocouple to measure heating caused by the 3mm x75mm x-ray beam which is centered on the red laser spot.

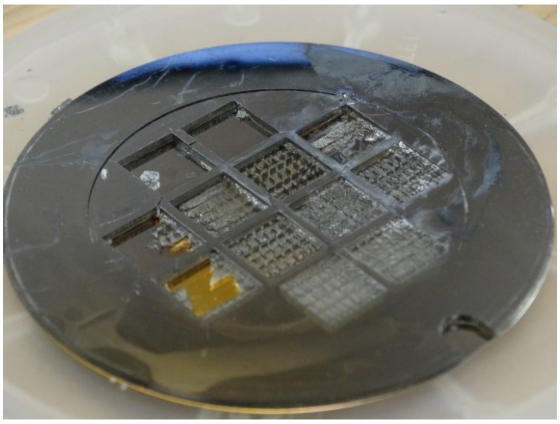


Figure 7. First x-ray exposure and development run. The sample has been flash-coated with Pt for later SEM inspection.

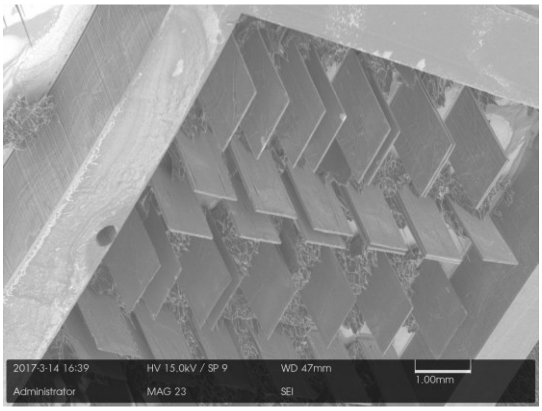


Figure 8. SEM close-up of structures in Figure 7. High aspect ratio structures are clearly seen although some optimization of the process is still required.

Results and Conclusions.

Figure 7 shows a PMMA/Si wafer substrate after x-ray exposure, development and Pt flash-coating for SEM examination. Each $1cm^2$ block has had a different exposure dose in order to find the optimum. Figure 8 shows an SEM close-up of one block showing the high aspect ratio structures.

The early results show that these high aspect ratio structures can be created with a relatively modest set-up. Additional beamtime would allow further optimization of the exposure and development stages prior to electrodeposition of the 1mm thick gold layer giving finished pinholes (and other structures).

Acknowledgements.

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References.

1. 1. E. Spiller, R. Feder, J. Topalian, E. Castellani, L. Romankiw and M. Heritage, “X-ray Lithography for Bubble Devices,” *Solid State Technol*., April 1976, pp. 62-68.

2. 2. E.W. Becker, W. Ehrfeld, D. Munchmeyer, H. Betz, A. Heuberger, S. Pongratz, W. Glashauser, H.J. Michel and V.R. Siemens, “Production of Separate Nozzle Systems for Uranium Enrichment by a Combination of X-ray Lithography and Galvanoplastics,” *Naturwissenschaften*, vol. 69, 1982, pp. 520-523.