Beamline 13: Lithography

Potential Research Fields

Life sciences

- Biotechnology and bio-sensors

Physical sciences

- Advanced materials
  - nanomaterials and composites
  - micro-electronic and magnetic materials
- Engineering
- Chemical reactions and catalysts
- Agricultural and food technologies

Advanced manufacturing

- Production of micro-devices

Introduction

Lithography stands alone in synchrotron applications as the only technique that creates artefacts, i.e. parts and devices.

Lithography is the process of making mechanical parts and structures by photographically exposing light-sensitive material (usually a resist) to create patterns that may be used either directly or as shields to allow selective etching of lower layers, or as moulds to fill with metals, ceramics, polymers, glasses or even bio and nano-engineered materials.

Lithography more generally, as opposed to x-ray lithography, is the cornerstone of the semiconductor industry where the world's top ten manufacturers have combined sales in excess of $US400 billion annually. The great competitive advantage of lithography over other machining methods is that the costs of devices are determined by the batch process costs rather than the costs to machine individual parts. Hence we no longer consider buying transistors one at a time, but use transistors in their millions as they are lithographically patterned into integrated circuits. This naturally leads to miniaturisation and integration, since by so doing, only the pattern in the photographic image is made more complex (the batch processing steps are no more complex) and the productivity and profit margins of the manufacturer increase as a result of producing more parts per batch. Hence in lithography making things smaller often makes them cheaper to produce (measured on a per part basis). Now we are able to apply this efficiency to fabricating integrated, three-dimensional mechanical systems.

Advantages of a Synchrotron Source

Lithography using synchrotron radiation sits at the top of the list of other lithography techniques in terms of resolution, aspect ratio and tolerance. The other techniques include excimer laser micromachining, UV lithography, electrodischarge machining and electrochemical machining. Collectively these techniques are applied to the creation of high aspect ratio micro systems (HARMST). In comparison to other techniques LIGA provides the following unique features:

- aspect ratios (depth : width) >100, essential for power transfer in micro devices
- optically smooth side walls, vital for telecommunication applications
- almost perpendicular walls, a consequence of the collimation of the synchrotron x-rays.

User Community

At the recent HARMST 2003 conference held in Monterey, USA, more than 300 researchers gathered from more than 16 countries to discuss the science, technology and commercialisation of HARMST, and in particular LIGA.

It is intended to set up this beamline so that it is capable of high volume production. It will incorporate an advanced design of scanner and will work in tandem with the nearby MiniFAB facility. As such, it is expected to attract substantial international user interest.

Already there are several industrial users interested in exploring the product development potential of LIGA. These include Masterfoods, Varian, Micromachines Ltd and AMCOR. All of these are pursuing their interests through MiniFAB Pty Ltd, a private venture that has expressed early support for the industrial application of

LIGA, and which operates supporting infrastructure, for example clean rooms, mask aligner, laser ablation, deposition and moulding.

The CRC for MicroTechnology has been developing an industrial capability in LIGA, assisted by the ASRP. Industrial users require that the LIGA process be specification driven, that is that it is able to provide a reliable, guaranteed service. Such a service can only be provided if it is underpinned by a sound understanding of the fundamentals of LIGA, and can only remain globally competitive if supported by a strong scientific R&D program.

International partnering

Preliminary discussions with the LIGA representatives of the new Canadian Light Source and the UK Diamond facility indicate that they would partner in this development, with the aim of building three scanners for installation at each of the new synchrotrons.

Research Applications

This beamline will provide opportunities to support basic research in nanoscience as well as manufacture of complex, deeply structured micro-devices. In basic science, it will be useful for the preparation of substrates for nano devices, photonic crystals, and fuel cell studies.

New applications in the production of micro-devices being researched internationally include:

- fuel cell development
- deposition nozzles
- cochlear implant moulds
- accelerometer sensors
- micro-relays
- x-ray lens fabrication
- micro gas bearings
- ink jet printers
- micro spectrometer development
- micro-optic fabrication
- micro medical devices (forceps, tweezers, micro-needle arrays, etc)
- direct synchrotron machining of polytetrafluoroethylene resin (Teflon®)
- variable reluctance stepping motors.

There is substantial effort and debate in the local and international LIGA community concerning developments in modelling of the full process (including electroforming and moulding), metrology, characterisation, resist development, and the development of infrastructure. Theoretical models for the exposure have only been developed for polymethylmethacrylate, and the complexities of secondary electron emission, scattering processes, top-to-bottom dose ratios, thermal effects and others remain important in gaining a fundamental understanding of the x-ray interaction with resists.

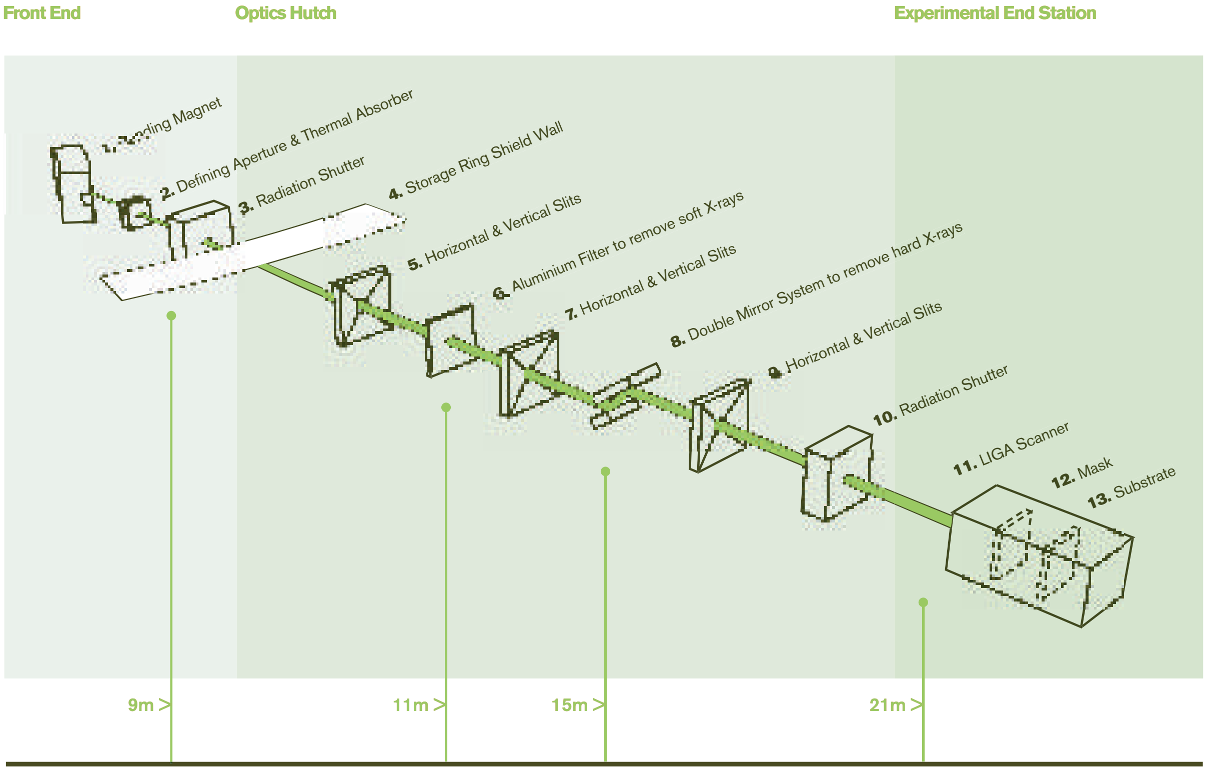

Figure BL 13.1. *Schematic for the lithography beamline.*

Beamline Design

Two LIGA beamlines will be designed to operate from a bending magnet beam and will supply the LIGA scanner with a range of x-ray energies (2–30 keV) to suit the application.

The beamlines will have appropriate mirrors and filters to remove unwanted high energy and low energy x-rays, respectively. The first beamline will be suitable for deep x-ray lithography (DXRL) with resist thicknesses up to 500 microns The second beamline (not budgeted for in this proposal) is planned for ultra deep x-ray lithography (UDXRL) on resist thicknesses up to 2000 microns.

The mirror systems will have the ability to be driven out of the beam to allow the beamline to 'switch' between harder and softer x-ray photon applications.

An advanced technology LIGA scanner will be designed to provide multiple degrees of freedom and hence different exposure strategies. It will be capable of accommodating wafer sizes in the range 100–200 mm, exposed with a range of x-ray energies to suit the application.

It is proposed that two beamlines be installed with the following specifications:

LIGA Line DXRL

Mirror	7500 eV cut-off Ni mirror (single or double)
Windows	500 micron Beryllium
Absorber	15 microns Aluminium
Energy	2–8 keV

LIGA Line UXRL

Mirror	None
Windows	500 micron Beryllium
Absorber	80 microns Aluminium
Energy	5–40 keV

Beamline 13 – Lithography

Source	Bending magnet
Energy range	2–8 keV (DXRL); 5–40 keV (UXRL)
Resolution $\Delta E/E$	10^{-4}
Beam size at sample (horizontal × vertical)	200 × 200 mm
Resist thickness	500 microns (DXRL); 2,000 microns (UXRL)