

## XIX. MICROSTRUCTURE FABRICATION

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### 1. CREATION OF THE SUBMICROMETER STRUCTURES LABORATORY

National Science Foundation (Grant ENG78-10436)  
M.I.T. Sloan Fund for Basic Research

Henry I. Smith, John Melngailis

The goals of the Submicrometer Structures Laboratory are to develop methods of fabricating surface-relief and doping structures with linewidths ranging from 100 Å to a few micrometers and to use these structures in a variety of research projects.

The administrative structures and funding for the Laboratory were established early in 1978. Laboratory renovations were started in August of 1978 and the main pieces of equipment were installed in December of 1978. The Laboratory was inaugurated on May 8, 1979.

The Submicrometer Structures Laboratory has the following capabilities:

- substrate cleaning and contamination-free handling
- photolithography
- holographic lithography
- x-ray lithography
- ion beam etching
- plasma etching
- reactive ion etching
- advanced optical microscopy
- electron-beam evaporation
- surface profilometry.

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The Laboratory is closely coupled to a similar but larger facility at Lincoln Laboratory which is also directed by H.I. Smith. The Lincoln Laboratory facility has all of the above capabilities as well as electron-beam lithography.

In addition to the research programs described under separate headings below, the Submicrometer Structures Laboratory collaborates in a number of other research projects. The grating in the  $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$  distributed feedback laser in the thesis work of H.H. Hsieh was ion beam-etched in the laboratory. S. Frankel of Harvard and the Peter Bent Brigham Hospital is designing and will build miniature thin-film electrodes to be used to probe electrical signals in individual living cells. S. Asoury has used the ion beam-etching apparatus in a charge-flow transistor project. These are a few examples where the unique capabilities and equipment of the Submicrometer Structures Laboratory have made possible or facilitated other research projects at M.I.T.

### 2. DEVELOPMENT OF MICROSTRUCTURE FABRICATION TECHNIQUES

Joint Services Electronics Program (Contract DAAG29-78-C-0020)

Stephane S. Dana, Andrew M. Hawryluk, Robert F. Kwasnick,  
John Melngailis, Henry I. Smith

The objective of this program is to establish reliable techniques for fabricating artificial microstructures, such as surface-relief structures and doping profiles, having dimensions ranging from 100 Å to a few micrometers. In some cases the effort consists of acquiring technologies developed at M.I.T. Lincoln Laboratory or elsewhere. In other cases the technologies are refined or extended in specialized manners. The following technologies are being established and developed:

conformable photomask lithography

holographic lithography

x-ray lithography

spatial-period division

shadowing

reactive ion etching

plasma etching

ion beam etching.

3. GRAPHOEPIITAXY

U.S. Navy — Office of Naval Research (Contract N00014-79-C-0908)

M.I.T. Cabot Fund

Krikor A. Bezdjian, Stephane S. Dana, John Melngailis, Henry I. Smith

Recently, D.C. Flanders and H.I. Smith at M.I.T. Lincoln Laboratory demonstrated that oriented crystalline overlayers could be obtained on amorphous substrates by first producing an artificial surface-relief structure in the substrate. The technique is called graphoepitaxy. In collaboration with M.W. Geis, graphoepitaxy was demonstrated for Si over SiO<sub>2</sub> in 1979. In the Submicrometer Structures Laboratory graphoepitaxy research is pursued along two avenues: basic studies of nucleation and growth over surface-relief structures; and development of graphoepitaxial approaches to solar cells. Our studies of nucleation and growth have focused on silicon and GaAs deposited by chemical vapor deposition (CVD). Recently, ion beam sputtering of Si has been added. Gratings are fabricated in Si<sub>3</sub>N<sub>4</sub> membranes about 2000 Å thick. Thin films are grown over these gratings and the phenomena of nucleation and island formation are studied by transmission electron microscopy. As expected, the artificial surface-relief structures have a profound effect on film growth.

The research on graphoepitaxy for solar cells is concentrating on crystallizing amorphous Si films over artificial surface gratings in carbon or other conducting substrates.

4. ATTACHMENT AND PROPERTIES OF MOLECULES ON SUBMICROMETER STRUCTURES

U.S. Navy — Office of Naval Research (Contract N00014-79-C-0908)

Dale C. Flanders, Manfred M. Kappes, Ralph H. Staley

Techniques are being developed to provide area-selective covalent attachment of chemicals to artificial microstructures. Research has centered on linking specific classes of compounds to silica surfaces by means of silane reagents. Techniques have been explored which provide uniform thin-film coverages of the order of a monolayer. Complementary work has been pursued in three related areas: (1) chemically blocking

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the attachment-active sites on silica, (2) attachment to an anodized gold surface, and (3) transition metal complexation to surface-attached ligands. Initial applications of these attachment procedures have focused on surface-conductivity measurements across 2 micrometers of chemically modified silica surfaces. By choosing the correct mode of surface derivatization it is possible to prepare sensors in which surface conductivity is modulated as a result of changes in the chemical environment of the attached species.

### 5. ELECTRONIC TRANSPORT IN QUASI-ONE-DIMENSIONAL SUBMICROMETER STRUCTURES IN SILICON INVERSION LAYERS

Joint Services Electronics Program (Contract DAAG29-78-C-0020)

Marc A. Kastner, Robert F. Kwasnick, John Melngailis

There is a great deal of recent interest in the behavior of electrons confined to one dimension. In particular, reduced dimensionality is expected to reveal the strong effects of localization, electron-electron, and electron-phonon interactions. For example, Thouless has argued that all wires are insulators at sufficiently low temperature. The effects of electron-electron and electron-phonon interaction should be dramatic if electrons can be confined to two-dimensional quantum levels but kept free in the third dimension. Inversion layers on the surface of silicon have been used to quantize the energy levels in one dimension, creating a two-dimensional electron gas. We are extending this technique to create a one-dimensional electron gas. Using the facilities of the Submicrometer Structures Laboratory, we are attempting to fabricate a quasi-one-dimensional inversion layer in Si in a field-effect transistor-type structure.

### 6. X-RAY LENSES AND DIFFRACTION GRATINGS

Lawrence Livermore Laboratory (Subcontract 206-92-09)

Marsden P. Griswold, John Melngailis, Henry I. Smith

Under this program, techniques for fabricating x-ray zone plates are developed at M.I.T. Lincoln Laboratory, and techniques for making x-ray diffraction gratings

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are developed in the Submicrometer Structures Laboratory. Testing is done at Lawrence Livermore Laboratory. Zone plates were fabricated with minimum zone widths of  $3000 \text{ \AA}$ , and imaging with 1-micrometer resolution was demonstrated. The next generation of zone plates will involve  $1000 \text{ \AA}$  zone widths.

7. SUBMICROMETER STRUCTURES AND LIQUID-CRYSTAL RESEARCH

U.S. Navy – Office of Naval Research (Contract N00014-79-C-0908)  
National Science Foundation (Grant DMR78-23555)

J. David Litster, John Melngailis, Henry I. Smith, Hans Von Känel

Well-aligned phases of liquid crystals are necessary for studies of their properties by means of scattering spectroscopy. The objective of this program is to use artificial-surface microstructures, such as gratings, to induce uniform alignment of liquid-crystal phases. Various liquid crystals have been aligned on surface-relief gratings of 1-micrometer period etched into fused-silica substrates. Alignment of butoxybenzylidene-p-oktylaniline established in the nematic phase could be retained down to almost one degree below the nematic-to-smectic transition. Farther below this the formation of focal conics could not be prevented but the defects could be removed entirely by heating the sample into the nematic phase. By reducing the spatial period of the gratings, we hope to reduce the number of focal conics in the smectic A phase which should enable us to investigate the smectic A-to-smectic B phase transition.

Publications

Melngailis, J., H.A. Haus, and A. Lattes, "Efficient Conversion of Surface Acoustic Waves in Shallow Gratings to Bulk Plate Modes," Appl. Phys. Lett. 35, 324 (1979).

