Silicon-Dioxide as a Resist

We have rebuilt the carbon-enhanced vapor etching facility to provide better control over etch rates and uniformity. This has substantially improved the system. We have exposed SiO₂ in the electron-beam lithography facility in a process that provides carbon contamination of the sample. It is found that an exposure dose of 100 µC/cm² (roughly one-half that needed for PMMA) provides sufficient carbon to provide a 23:1 differential in the etch rate of the SiO₂. We are proceeding now to ascertain the resolution limits that can be obtained (previous work by one of the investigators, D. Allee, showed that direct e-beam damage of SiO₂ could achieve 8 nm resolution).

Arsenic-Sulfide as a Resist

We have developed improved techniques of deposition of As-S thin films, which provide for improved uniformity. In this case, the resist is activated by Ag to provide differential etch rates in a CF₄ plasma. A thin film of Ag is deposited on the As-S resist and then driven into the resist by an electron beam or by optical exposure. During the coming year, we will investigate this resist material.

STM/SFM Lithography

Three new types of scanning tunneling and force lithography have been developed. Nanometer scale patterns have been fabricated on a Langmuir-Blodgett deposited monolayer film of stearic acid using a scanning tunneling microscope in air. Carbon deposits build up underneath the tip for tip voltages with absolute value greater than 4 V. Using an atomic force microscope to image, lines 25 nm wide on a 60 nm period have been written. As confirmed with Auger electron spectroscopy, the unexposed film can be removed with a chloroform soak without affecting the existing carbon patterns, and no additional patterns could then be written because of the removal of the monolayer film.

The use of a scanning force microscope with a metallized tip to do selective area oxidation of silicon was demonstrated. Sub-100 nm lines have been achieved.
resolution may be improved even further by using a sharper SFM tip. Removal of the oxide lines with buffered hydrofluoric acid reveals trenches in the silicon consistent with silicon consumption in SiO₂ formation. The process is thought to be similar to plasma anodization.

A scanning tunneling microscope tip and a metallized scanning force tip have been used to selectively write oxidation patterns on a thin Si₃N₄ film on p⁺-silicon. After etching the patterns in hydrofluoric acid, trenches are observed consistent with silicon consumption in the oxidation process. The patterns in the nitride film could be transferred to the underlying silicon with an ammonium fluoride etch. 250 nm resolution has been achieved.

In addition to various infrastructure projects and collaborations, our efforts are focused on using the first of these techniques to fabricate a gate electrode in a working field effect transistor. To our knowledge, this would be the first transistor partially patterned with scanning tunneling lithography.

**Electron-Beam Lithography and Pattern Transfer**

We have been preparing substrates, in which thin films of Si₃N₄ will be used to support PMMA for studies of ultimate resolution. The scanning Auger microprobe has been installed and characterized. We have been studying its use for identifying fragments of long-chain PMMA that are produced by the electron-beam. We have also rebuilt a special RIE system to provide slow etching of thin layers. Etch rates of 5 nm/minute have been achieved at low power in a CF₄ plasma.

**Publications During the Period:**


**Personnel:**

*Co-Investigators:*

Dr. David K. Ferry, Regents' Professor of Electrical Engineering
Dr. Michael N. Kozicki, Associate Professor of Electrical Engineering
Dr. David R. Allee, Assistant Professor of Electrical Engineering
Graduate Students Supported by ARPA:

H. C. Day, doctoral student
J. Allgaier, masters student
M. Khoury, masters student

Other Students Associated with the Program:

Mary Jo Rack, NSF MEADE* Fellow, doctoral student
H. Upadhyay, masters student
Susan Kersey, NSF MEADE* Fellow, masters student

*Graduate Engineering Education Program for Women, Minorities, and/or Disabled Persons; Dr. D. K. Ferry, Co-Principal Investigator.