3. Focused Ion Beam Fabrication

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3.1 Focused Ion Beam System

Joint Services Electronics Program (Contract DAAG29-83-K-0003)

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A focused ion beam system has been purchased by M.I.T. from Ion Beam Technologies, Inc. as part of the Microsystems Program. The system is specified to focus a beam of ions of 0.1 μm diameter on to a sample, at a current density of 1A/cm^2, and at accelerating voltages between 30 and 150 keV. The ion species available now are Ga^+, Si^{++}, B^+, Pt^+, and Au^+. Soon to become available are Be^{++}, As^+, Sb^+, and others. The beam can be positioned over a sample of 12 cm diameter with $\pm$ 0.1 μm precision. The system will remain at the manufacturers plant until the construction of the Microsystems Technologies Laboratories is complete but is available for research use by M.I.T. personnel.

The focused ion beam is a versatile microfabrication tool which will have a serious impact in a number of areas. The following applications have so far been demonstrated in various laboratories: maskless, resistless implantation of dopants in semiconductors; ion milling with submicron resolution; ion beam assisted deposition; lithography (exposure of resists); microanalysis (ultra-high resolution SIMS); and ion microscopy. The focused ion beam program is just beginning at M.I.T. Support has been received for circuit restructuring research and for mask repair. Support for direct implantation into devices is pending.

3.2 Connections Through Focused Ion Beam Milled Vias

Joint Services Electronics Program (Contract DAAG29-83-K-0003)
Charles Stark Draper Laboratory (Contract DL-H-225270)

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One of the possible applications of focused ion beams is in integrated circuit restructuring or circuit repair. With the focused ion beam one can "see" a circuit in the scanning mode much as in an SEM, and one can address and, say, mill away parts of a circuit with submicron resolution. Thus breaking connections is straightforward, but making connections is not. This work investigates a method of shorting together two metal (Al) layers separated by a SiO_2 film and covered by SiO_2. The surface is first covered by nitrocellulose, a self-developing resist. The focused ion beam is then used to mill vias down to the lower level of metalization. Aluminum is then evaporated, and the nitrocellulose is dissolved to achieve liftoff. Thus the aluminum remains only in the vias. All nine milled vias in the initial test showed short circuits. In the course of this work the ability to expose (and simultaneously develop) nitrocellulose with vertical sidewalls was demonstrated using a focused ion beam (Ga^+ at 65 keV with a 0.1 to 0.2 μm beam size). Lines 0.4 μm wide were produced in 2.3 μm thick nitrocellulose using an exposure of 1 msec/pixel at 0.1 μm pixel spacing. Undercut resist profiles were produced by exposing a bi-level structure consisting of 2.3 μm of nitrocellulose covered by 0.17 μm of PMMA. Special test structures have now been fabricated with contact pads and many aluminum cross-overs. Ion milling will be used to produce shorts at the cross-overs.

3.3 Mask Repair and Ion Assisted Deposition

Joint Services Electronics Program (Contract DAAG29-83-K-0003)
International Business Machines, Inc. (Contract 3260)
Henri J. Lezec, Edwin Kellog[10], John Melngailis

One of the most immediate practical applications of focused ion beams is in photomask or x-ray mask repair. The ion beam can easily mill away unwanted metal from a defect in a mask. How to repair a clear defect is, however, less obvious. In photomasks a diffracting or scattering structure can be milled into the surface to achieve an opaque region. However, x-ray masks need a substantial thickness of high-Z material. Our research program is aimed at measuring the milling rates of some of the commonly used materials in order to achieve better control over the process, and to develop methods of repairing clear defects. Focused ion beams can be used to deposit material, if a gas such as $Al(CH_3)_3$ at say 30 μm pressure surrounds the specimen. Workers at Osaka University have demonstrated this using a special pumped cell surrounding the sample.

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We have demonstrated that ion assisted deposition can be obtained using a simpler (to be patented) fixture. With this fixture the focused ion beams system can be rapidly cycled from deposition to milling. In preliminary experiments we found that with a flood beam of 750 eV argon ions (instead of a focused ion beam) incident over the entire surface deposition occurs. Using WF_6 gas we deposited tungsten ~1000 Å thick. This was verified by Auger analysis. A deposit, presumably carbon, was also obtained using CH_4.