number of stereo microscopes, compound microscopes and interferometric microscopes

- Micro balances
- Laser hole drilling apparatus
- Micro assembly work stations

The addition of a new target fabrication facility designed specifically to accomodate the specialized activities associated with inertial fusion target production is currently in the preliminary design phase.

3.B Zone Plate Fabrication

The production of significant fluxes of suprathermal electrons is evidenced in laser fusion experiments by the generation of suprathermal x-ray radiation. This results from bremsstrahlung produced by radiative interactions between these electrons and thermal ions. Since this emission is Z dependent, it can be utilized to identify regions of the target in which significant suprathermal electron deposition occurs. Zone plate coded imaging[1] offers distinct advantages over alternate imaging techniques such as pinhole photography and grazing incidence microscopy, both from the point of view of spectral resolution and light gathering power. However, spatial imaging of the target in the hard x-ray region, typical of short pulse, high intensity exploding-pusher type experiments, requires coded aperture zone plates of thickness sufficient to resolve x-ray emission in excess of 10 KeV[2]. The intent of the present work was the production of zone plates thick enough to image x-rays in the 30 KeV range. This requires zone plates of Au with thicknesses in excess of 25 μm.

Zone plate fabrication begins by making a free standing negative mold, which is filled with gold by electroplating. Previous efforts[3,4] have used standard photolithographic pattern delineation methods. However, this approach encounters considerable problems in its application to the fabrication of thick zone plates having high aspect ratios. Ciarlo and Ceglio[4] have succeeded in delineating patterns in photoresist as thick as 40 μm, but many problems occur in this thickness regime. For example, cracks and bubbles can occur during UV exposure, and resist layers can exhibit thickness nonuniformities. In principle, these problems can be overcome with proper care in processing. A more fundamental problem is zone tapering, which is due to diffractive spreading of the exposure illumination by the fine details in the photomask. The maximum aspect ratio (thickness:linewidth ratio) achieved by the standard technique is about four, while zone plates with aspect ratios as high as ten would prove useful for imaging experiments.

Because of the problems inherent in thick photoresist processing, we have taken a different approach to ultrathick pattern delineation,

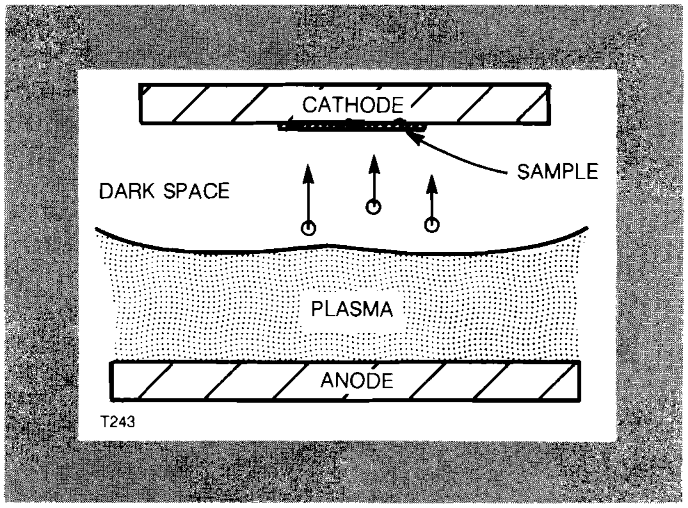


Fig. 20
Schematic representation of the reactive sputter etching apparatus. Positive ions are accelerated toward the cathode, where they react chemically with the sample to form volatile products.

which uses reactive sputter etching (RSE).[5] Figure 20 is a schematic of the RSE apparatus. A radio frequency discharge is employed to sustain a plasma in a gas which is being pumped through a chamber at low pressure. The specimen to be etched is placed on the cathodic electrode. The gas is chosen such that it will chemically react with the specimen, creating volatile reaction products which are pumped away by the vacuum system. Organic media can be reactively etched by oxygen at rates approachng 250 nm/min.[6] RSE is just one of a family of so-called dry etching methods. The exact mechanisms in the RSE process are not completely understood, but RSE is known to be somewhat material specific (due to its chemical nature) and highly directional (presumably due to the acceleration of "reactive ions" in the discharge) as well. These properties make it possible to vertically etch high aspect ratio structures into polymers.

Crucial to this method of pattern delineation is the choice of the polymer and mask material such that the RSE step will etch only the polymer. This polymer must also be capable of being deposited in thick uniform layers and able to withstand the processing steps which follow pattern delineation, including gold plating and wet-chemical etching (to remove metals). In addition, since an integral mask is required, it must be possible to deposit a metal film which does not etch, such as aluminum, with excellent adhesion to the polymer.

Initially an attempt was made to find a polymer which could be deposited on a gold substrate, but to date all of the materials we have tried have failed to meet at least one of the requirements discussed above. Consequently, we have adopted the somewhat different procedure outlined in Fig. 21. Since we were interested in zone plates approximately 50 μm thick, we began with a piece of standard 2 mil Mylar™. Both sides of the Mylar™ were then coated with approximately 0.2 μm of Al. One surface was then coated with approximately 0.2 μm of Au. The gold surface was epoxied to a glass cover slip, which offered the support necessary

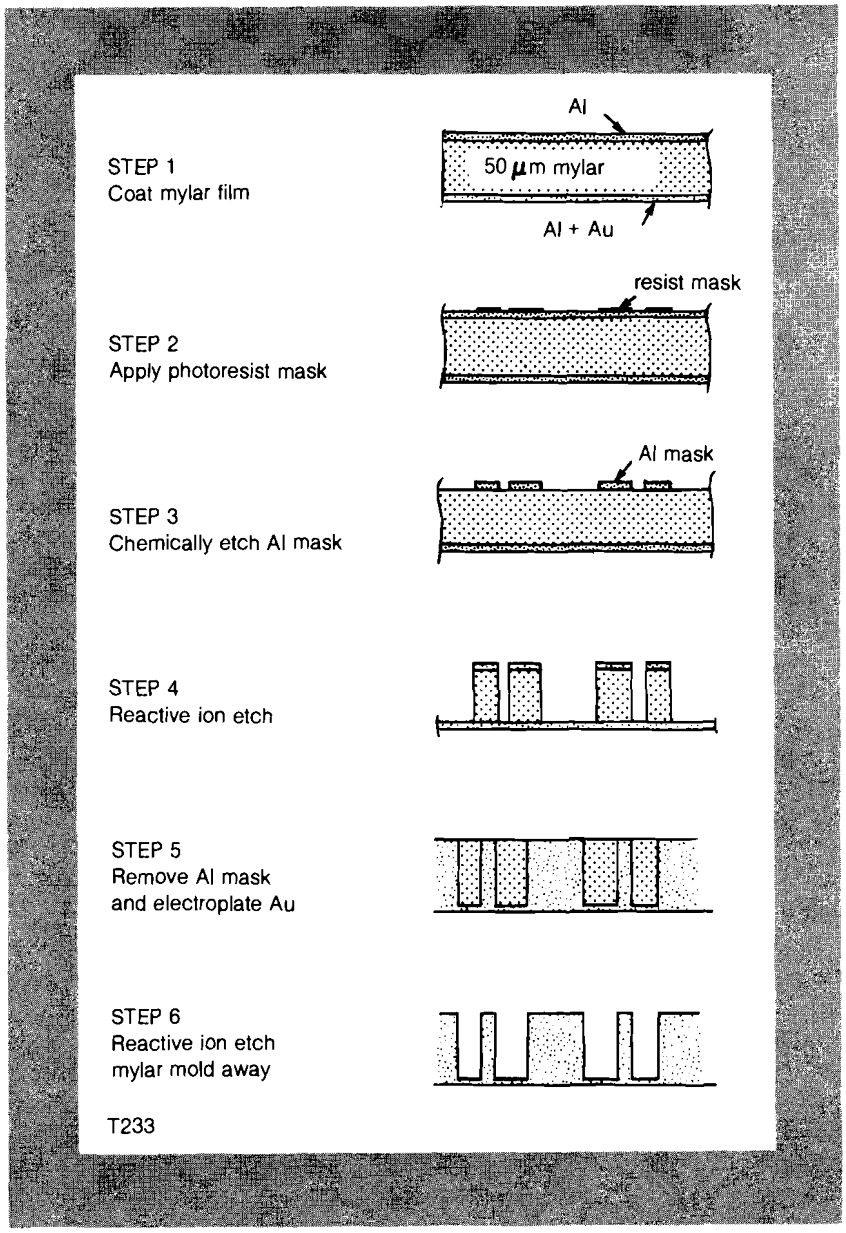
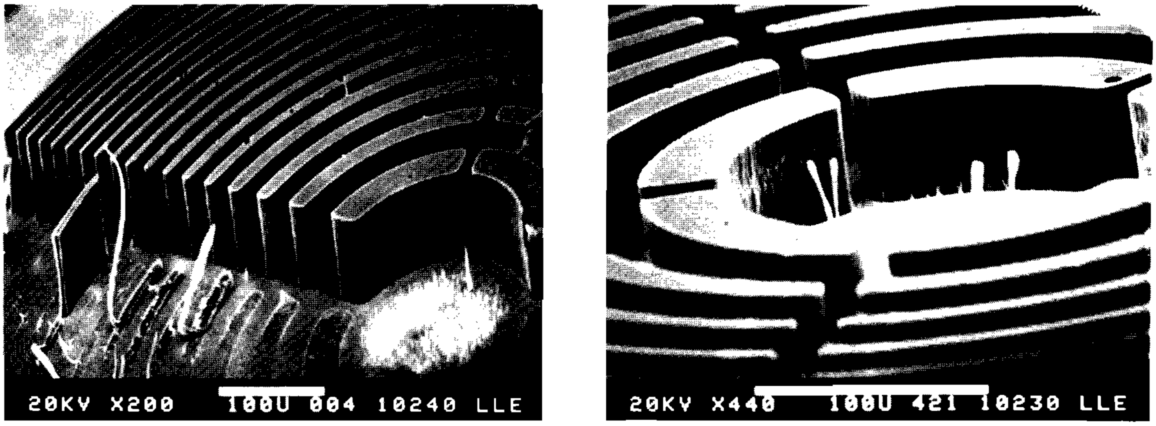


Fig. 21
Zone plate fabrication. This sequence uses reactive sputter etching to form the mold.

for the subsequent steps. A thin layer of photoresist was spun on the aluminum surface, and exposed to UV light through the zone plate mask. After developing the resist, the exposed aluminum was chemically etched away, leaving an integral aluminum mask on the Mylar™. The masked Mylar™ was then put in the RSE and etched in oxygen, at a power of 0.28 W/cm^2, down to the Al (aluminum) layer on the back surface. This layer, which served to protect the gold during reactive sputter etching, was then chemically etched away. Gold was then electroplated into the mask, and the gold-Mylar™ combination was mounted on a ring. The final step consisted of placing the zone plate in the RSE and etching away the Mylar™.



T244 a. T245 b.

Fig. 22
Scanning electron micrographs of a mylar zone plate mold made by using reactive sputter etching. Significant improvements in aspect ratio have been obtained with this technique.

Figures 22(a) and 22(b) show scanning electron micrographs of a zone plate made by this method, and Fig. 23(a) and 23(b) show a finished gold micro-Fresnel zone plate. The thickness of this zone plate is 40 μm, and the outer zone width is 15 μm. Further work will probably make it possible to find mold materials that have the needed properties and which can be applied in layers of varying thicknesses. In addition, fabrication of zone plates of similar thickness to that shown in Fig. 21, but with a greater number of zones is now in progress.

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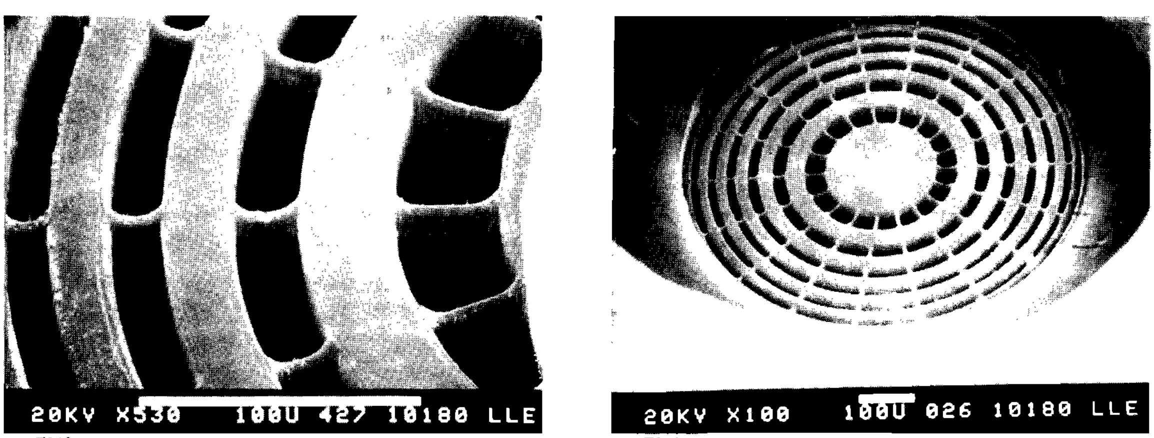
Fig. 23
Scanning electron micrographs of a completed gold micro-Fresnel zone plate. The thickness is 40 μm, and the outer zone width is 15μm.



T246 a. T247 b.