Section 3
DEVELOPMENTS IN MICROFABRICATION

3.A Zone Plate Fabrication Developments

A new microfabrication method has been developed for making micro-Fresnel zone plates used in the coded imaging of x-rays and α-particles from laser fusion experiments. Previous work has concentrated on developing individual 25-40 μm thick zone plates.[1,2] However, since each α-particle image requires a new zone plate wihch is approximately 5 μm thick, the present work has concentrated on producing many zone plates from a single master-pattern, thereby eliminating the delicate and time consuming photolithographic steps previously required for each zone plate.

In the new process zone plates are formed by electroplating gold into epoxy molds. The epoxy molds are made by a series of intermediate steps from a single Mylar master-pattern. The process is divided into two phases; fabrication of the master-pattern, and creation of the epoxy replicas from this pattern. The zone plate microfabrication process has many features similar to those developed here at LLE for microhemispherical shell fabrication.[3]

Figure 26 illustrates the five fabrication steps used in constructing a zone plate master-pattern. The sequence begins with a piece of standard 2 mil Mylar. 200 nm of aluminum is evaporated onto one side of the Mylar, which is then spin coated with 1.5 μm of positive photoresist. The zone plate pattern is delineated photolithographically in the photoresist. The exposed aluminum is removed

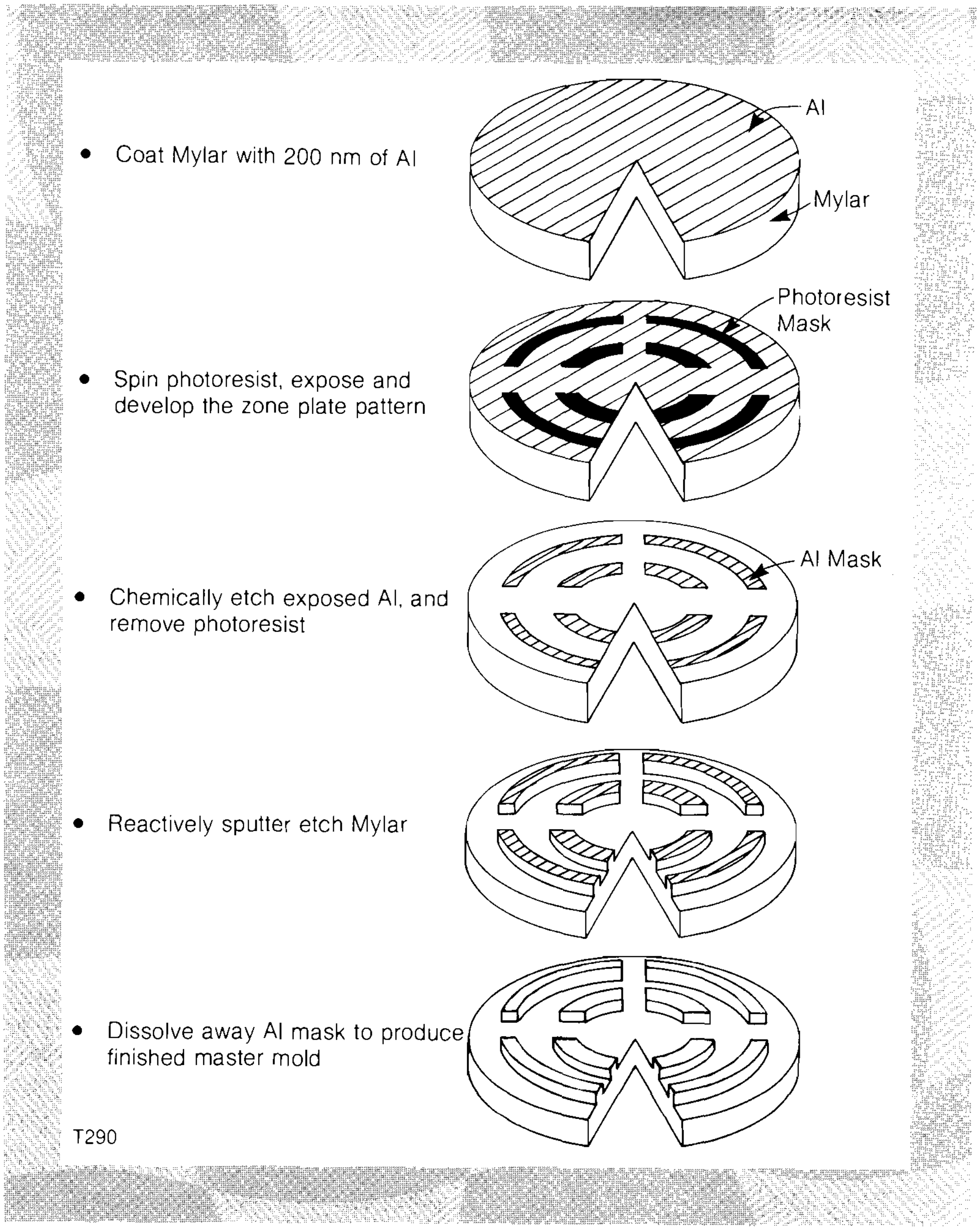
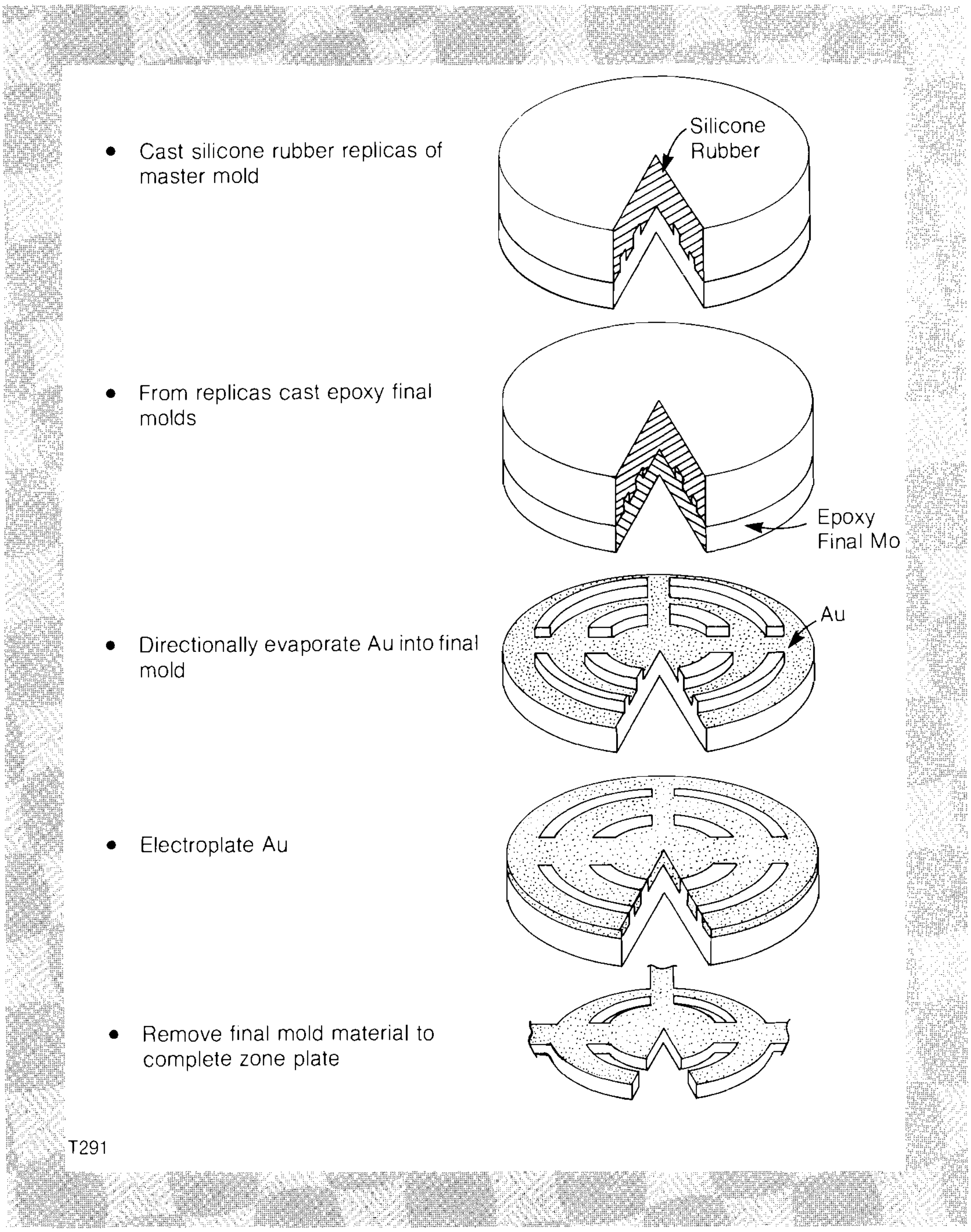


Fig. 26
The fabrication sequence for master-pattern production. Using photolithography and reactive ion etching a three-dimensional Mylar mold is made.

by chemical etching leaving an integral aluminum mask on th Mylar. This masked Mylar is placed in a reactive sputter etcher[2] and etched with O_2 to a 10 μm depth. The aluminum is finally chemically removed leaving a completed Mylar master-pattern.

Master-pattern replication and final zone plate construction is completed in the five steps illustrated in Fig. 27. Silicone rubber intermediate molds are made by pouring uncured Dow Corning RTV-E onto the Mylar master-pattern at low pressure (200 mT). After curing, the silicone replica mold is separated from the master-pattern and then filled with epoxy, degassed, and pressed onto a planar substrate. Figure 28 is a scanning electron micrograph of an RTV-E intermediate mold and Fig. 29 of an epoxy cast. Gold is evaporated directionally onto the epoxy cast as a base for plating, as shown in Fig. 27, step 3. Only surfaces normal to the zone plate plane are coated, leaving the tops of the coated cast electrically discontinuous from the bottom which means that no electroplating can occur on the top surfaces. The cast is then electroplated, mounted on a ring, and placed in the reactive sputter etcher to remove the epoxy. This leaves a freestanding 6-10 μm thick gold zone plate. Figure 30 is a scanning electron micrograph of a completed zone plate which has 100 zones and a 5 μm wide outer zone. The diameter of the zone plate is 2 mm.

Fig. 27
Intermediate and final mold production. RTV copies are made of the master-pattern and used to cast the final electroplasting molds in epoxy.



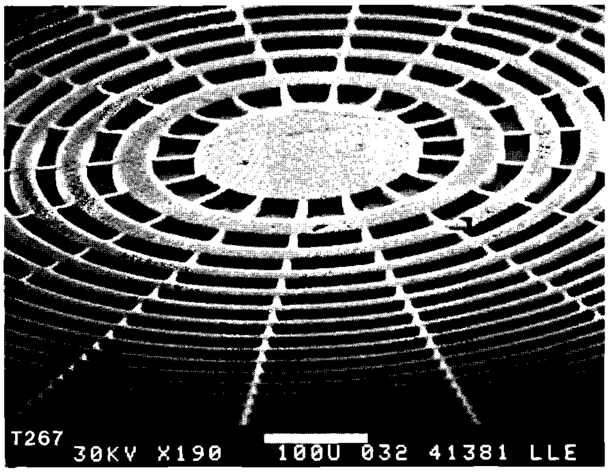


Fig. 28
A scanning electron micrograph of an intermediate RTV mold made from the Mylar master-pattern.

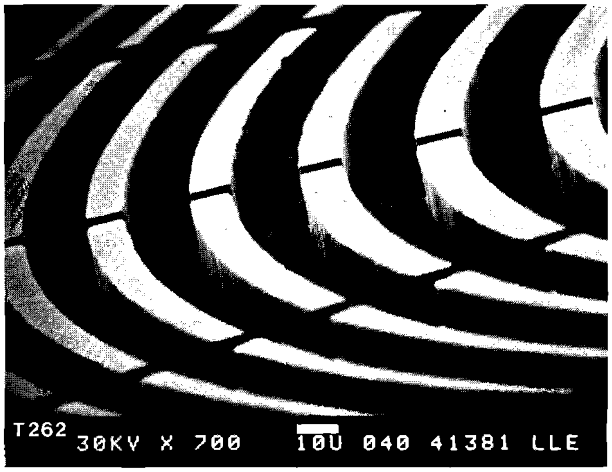


Fig. 29
A scanning electron micrograph of an epoxy final mold prior to gold electroplating.

This new technique for zone plate fabrication greatly reduces the number of critically delicate steps, and thus enables fabrication of 6-10 μm thick zone plates on a production basis. Some features of the process, such as directionally coating the plating base onto the final mold, have application to 40 μm thick zone plate fabrication and other microfabrication techniques.

REFERENCES

1. D. Ciarlo and N. M. Ceglio *Proceedings of SPIE Symposium on Semiconductor Microlithography, San Diego,* March, 1980.
2. F. Kalk and D. Glocker, to be published in *J. Vac. Sci. Tech.*
3. I. S. Goldstein, F. Kalk and J. Trovato, *J. Vac. Sci. Tech.* **18** (2), 1981.

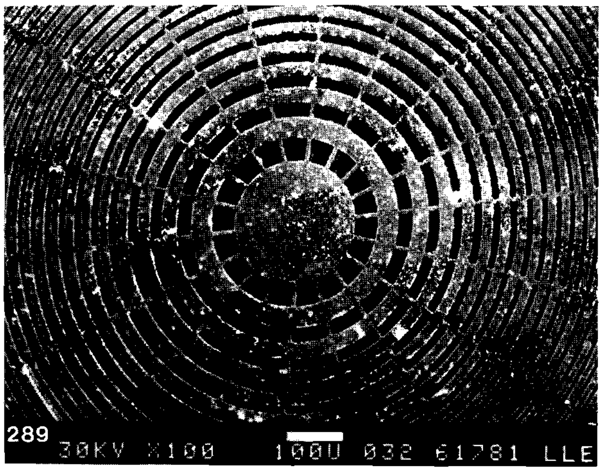


Fig. 30
A completed gold zone plate. The thickness is 5μm, and there are 100 zones with a 5 μm wide outer zone.