Superzone blazed phase solid immersion diffractive optics for enhanced near-infrared scanning laser microscopy

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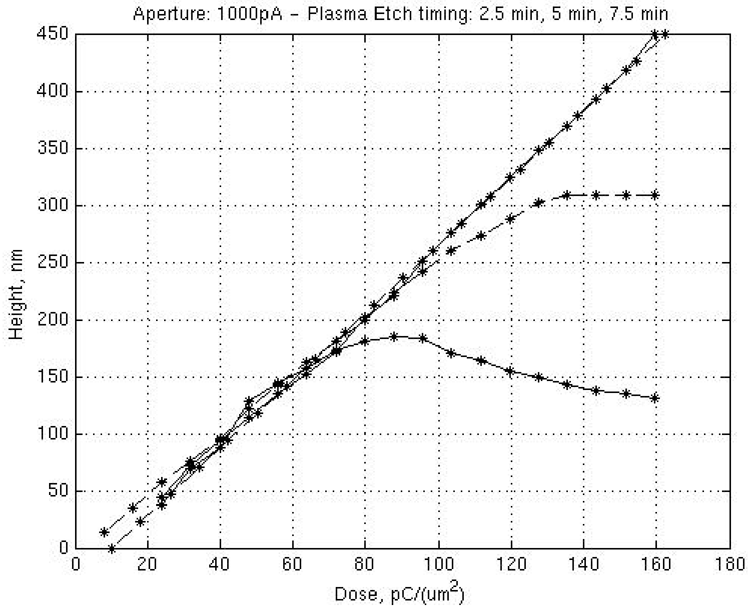
Superzone blazed phase solid immersion diffractive optics have been developed to enhance scanning laser microscopy of integrated circuits through the silicon substrate. The complete technique can design a higher order diffractive optic to generate any user-defined laser pattern with a maximum diffraction efficiency of 87.9% using a single fabrication step. With a first order diffractive optic, lateral resolutions up to 3.5 times better have been achieved and this scales with higher diffraction orders.

To achieve the general mathematical design technique that can accommodate any incident and reconstructed wavefront, the method of computer-generated holography is used. Holographic imaging enables the reconstruction of any wavefront from the interference pattern generated between it and a reproducible reference wavefront. This mathematical process provides a powerful tool for designing the diffractive optics.

To convert the designs into a physical structure, the Focused Ion Beam (FIB) is used to implant gallium atoms in the silicon substrate to form a mask. This is followed by reactive-ion etching using CHF_3 chemistry, where the implanted region resists the plasma etch relative to the exposed silicon. The implant dose determines the end point for the differential plasma etch, and through experimental trials by adjusting the ion current, implant spacing and etch conditions, a single implanted mask can achieve a continuous blazed phase profile with a first order height of 440 nm and a minimum implant separation of 140 nm, Figure 1. This is then multiplied to higher orders by repeating the fabrication process and accumulating the total etch depth.

The imaging capability of the solid immersion blazed phase lens is then compared to a binary phase lens with a diffraction efficiency of 39 %, Figure 2(a). The use of a binary structure has the advantage of being easier to construct, however it is shown that the increased efficiency of the blazed phase design results in a large improvement with the image contrast of integrated circuits.

The technique is then extended to reconstruct multiple focal points and ring patterns, to demonstrate an analysis capability that uses phase contrast to compare the scanning images produced by different focal points from the same diffractive optic, Figure 2(b).



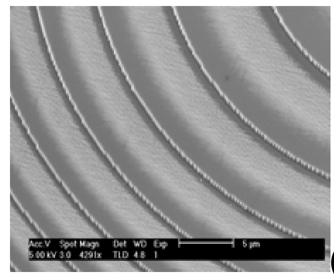
(a)

(b)

Figure (1): Graph (a) shows the etched silicon height as a function of implant dose for plasma etch times of 2.5 minutes, 5 minutes, and 7.5 minutes. The linear profile obtained with the 7.5 minutes CHF_3 plasma etch is used to fabricate the blazed phase design. SEM image (b) shows a blazed phase structure that achieves a diffraction efficiency of 87.9 %.

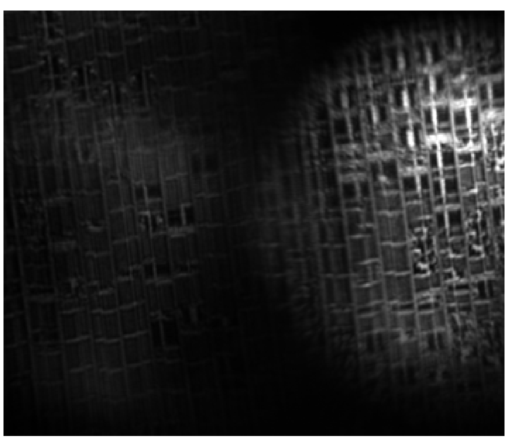
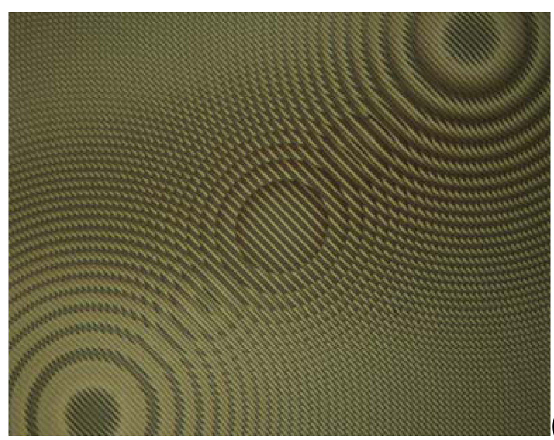

(a)

(b)

Figure (2): Scanning laser image (a) shows a comparison between the images produced by the binary lens (left) and the blazed lens (right). Optical image (b) shows a two focal point blazed phase diffractive optic used to generate a differential pattern between the images from each scanning focal point, using phase contrast.