

Novel Scanning Immersion Lithography for 3D Microfabrication

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The gap between the mask/resist was minimized for reducing diffraction error. To avoid sticking, the uniformity of the resist thickness and precision of the stage are highly demanded. This will become very critical when performing large-area scanning.

For immersion lithography, a liquid was applied between the lens/resist for refractive-index (n) matching to increase the numerical aperture (NA) and the lithography resolution. In this study, we propose the first time combining the merit of scanning and immersion lithography to fabricate 3D microstructure. With the n -matching liquid to reduce the diffraction error, the gap between the mask/resist becomes more tolerable. In addition, the liquid also act as a lubricant for achieving smooth scanning. These advantages might make the proposed scanning immersion lithography (SIL) a promising technique to fabricate high-precision, large-area 3D microstructure.

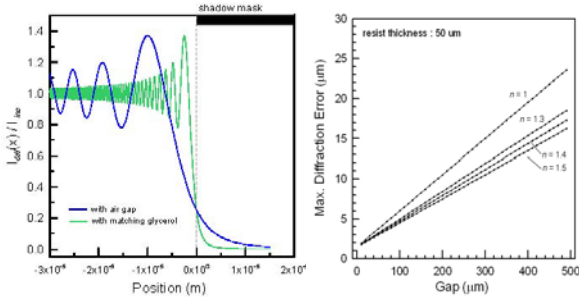


Fig. 1: Simulated intensity distribution under a semi-infinite straight opaque with a 300 μm gap of air and glycerol.

The Intensity distribution of semi-infinite straight opaque for a 300 μm gap with air and glycerol medium is simulated and present in Fig. 2. As shown, the approximated intensity distribution with glycerol layer is much more close to the ideal case, which will result in a better lithography resolution.

AFM measurements indicate the average surface roughness (R_a) of the as-lithographed resist is well below 10 nm; however, its R_{MAX} (peak to valley distance) is as high as about 100 nm. That will causes severe scattering in optical applications. A post-exposure baking is then attempted to decrease the surface roughness via thermal diffusion. As depicted in Fig. 2, the R_{MAX} can be effectively reduced even the baking process is conducted at 70 $^{\circ}\text{C}$ for only 2 minutes. Meanwhile, the resist can sustain its thickness (geometry) without evident reflowing.

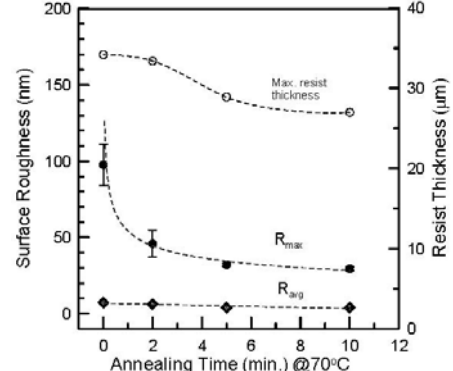
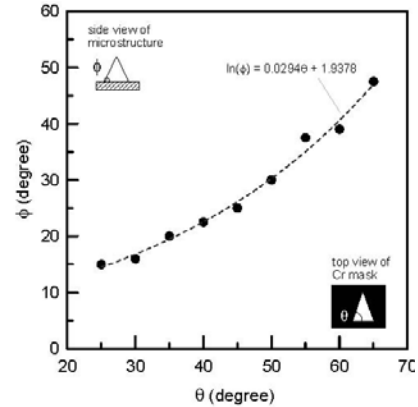


Fig. 2: Surface roughness and max. resist thickness with various annealing times at 70 $^{\circ}\text{C}$.



The measurement results (Fig. 3) also reveal that there is an exponential relationship between the angle θ (@mask) and ϕ (@resist):

Consequently, the mask geometry can be determined if a specific triangle microstructure is required.

$$\ln(\phi) = 0.0294\theta + 1.9378 \quad (1)$$

The structured 3D resist were then deposited with a metal film for reflection measurement. For the sample structured with matching glycerol, a sharp reflection peak

was detected at an angle ϕ close to the angle ϕ (as

defined in Fig. 3) of the triangle microstructure. In contrast, the laser light is seriously dispersed for the resist lithographed with air gap. Based on the experimental results, the presented SIL technique should be a promising way to fabricate precise and large-area 3D microstructure with simple equipment.