High Aspect Ratio Zone Plate Fabrication Using A Bilayer Mold

M. J. Wojcik, L. E. Ocola, R. Divan, D. C. Mancini
Center for Nanoscale Materials, Argonne National Laboratory, Argonne, IL 60439
mwojcik@anl.gov

M. Lu
Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY 11973

X-ray zone plates are diffractive optics, similar to a diffraction grating but with changing pitch, where the x-rays are diffracted to a common point with the focal spot size determined by the smallest zone width. For a given x-ray energy, the maximum focusing efficiency is determined by the zone height required for 180 degree phase shift. For hard x-rays, 8-30 KeV, gold phase shifting zones must be greater than a micron high to achieve highest efficiency. Thus, a zone plate with smallest zone width of 100 nm, aspect ratio of greater than 10 is needed. The need to increase aspect ratio is the primary factor limiting fabrication of optics for higher x-ray energies.

Hard x-ray zone plates with 100 nm spatial resolution are usually fabricated by electroforming gold into a lithographically fabricated dielectric mold. The mold is patterned either directly in a resist[1] or by pattern transfer using a suitable mask.[2] Recently, ultrananocrystalline diamond (UNCD) was used as a dielectric mold fabricated by pattern transfer using hydrogen silsesquioxane (HSQ) as a mask.[3] This method was shown to produce a zone plate with an aspect ratio of 10. HSQ can also be directly patterned as a dielectric mold to produce a zone plate with an aspect ratio of 10.[4] Since HSQ can be patterned on UNCD for pattern transfer, it is a simple extension to use a thicker layer of HSQ on the UNCD, the HSQ acts as both a pattern transfer mask and a dielectric mold. The resulting bilayer structure effectively sums the aspect ratios of each layer. Examples of a thick layer of HSQ on UNCD are shown in Figure 1 and Figure 2. Applications of this bilayer mold to zone plate fabrication and future developments will be discussed.

[1] R. Divan *et al.*, Proc. SPIE **4783**, 82-91, (2002).

[2] Y. Feng *et al.*, J. Vac. Sci. Technol. B **25**(6), 2004 (2007).

[3] M. Wojcik *et al.*, J. Vac. Sci. Technol. B **28**(6), C6P30 (2010).

[4] M. Lu *et al.*, Proc. SPIE **7039** 70390V (2008).

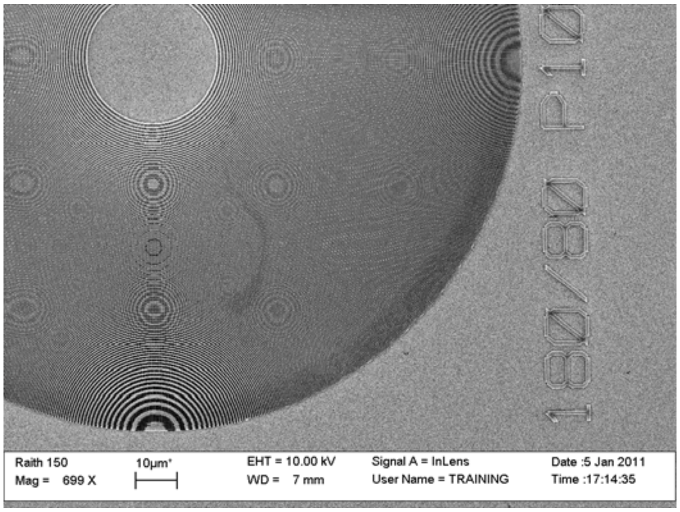
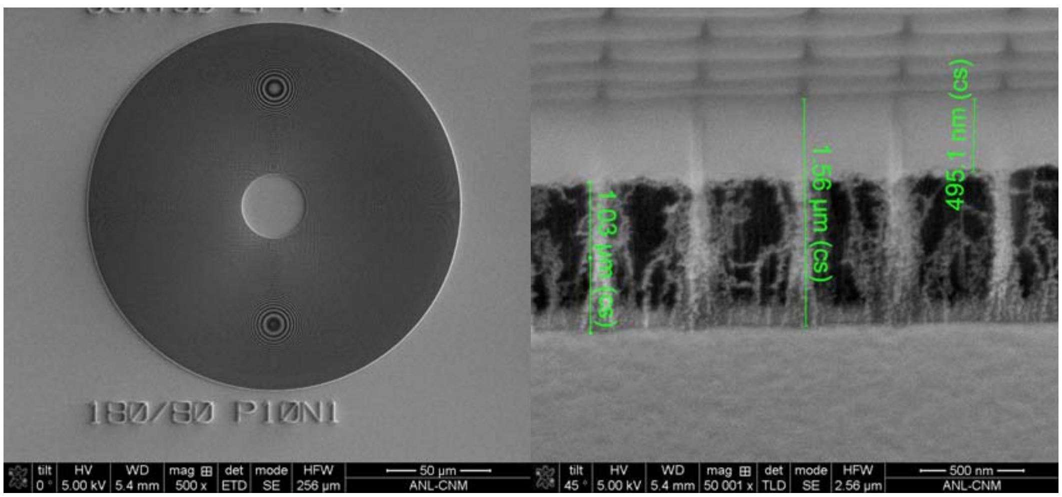


Figure 1: Thick HSQ mold/mask before pattern transfer into UNCD for production of a bilayer mold structure.



(a) (b)

Figure 2: 450 nm of HSQ mold/mask after pattern transfer into 1 micron of UNCD. The zone plate is 180 microns in diameter with a smallest zone width of 80 nm. (a) Low magnification SEM of zone plate, and (b) a high magnification image showing the outer zone thickness of mold.

Use of the Center for Nanoscale Materials was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357