Sub-Micron High Aspect Ratio Direct E-Beam Patterning of SU-8 Epoxy Resist

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Hard X-ray Zernike phase contrast imaging at transmission X-ray microscopes (TXM) [1] is a useful technique for imaging inside objects with low absorption contrast. The method requires precise alignment of at least three optics: the condenser, objective, and phase ring where best alignment maximizes phase contrast in the image. We found that imaging a known phase test object is a straightforward way to perform the precise alignment without resorting to an additional optic. One material suitable for low absorption and high phase contrast is SU-8 epoxy resist. The resist is usually lithographically patterned by optical lithography or X-ray lithography for LIGA processes, but it has been shown to work using electron beam lithography.

For the test object, a thickness >1 μm was needed for enough phase shift at 8 keV imaging X-ray energy, while sub-micron features were desired for use as an image standard. We have developed a way to pattern high aspect ratio SU-8 structures using e-beam lithography resulting in the pattern shown in Figure 1. The inner spokes of the Siemens star were 200 nm wide with 200 nm space, and the structure is 1.8 μm thick measured by a profilometer. SU-8 2002 (MicroChem) solution was spun and patterned with exposure dose <40 $\mu C/cm^2$, though a range of 20-40 $\mu C/cm^2$ was acceptable for the pattern. The sample was taken to the TXM at Sector 32 of the Advanced Photon Source[2] and used as a phase object. Figure 2 shows a SEM image, an aligned Zernike phase image, and a misaligned image. Of note, the aligned image appears blurry but a gain in contrast away from the noise floor is seen compared with the misaligned image especially at the smallest features. Though we applied the fabrication method for a phase test pattern, direct patterning of SU-8 can be useful for a multitude of other applications requiring high aspect ratio structures including electronics and microfluidics.

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[1] Neuhausler, U., *et al.,* J. Phys. D: Appl. Phys. **36**, A79 (2003).
[2] Normile, S.J., *et al.,* Mat. Today Energy **9,** 187 (2018).

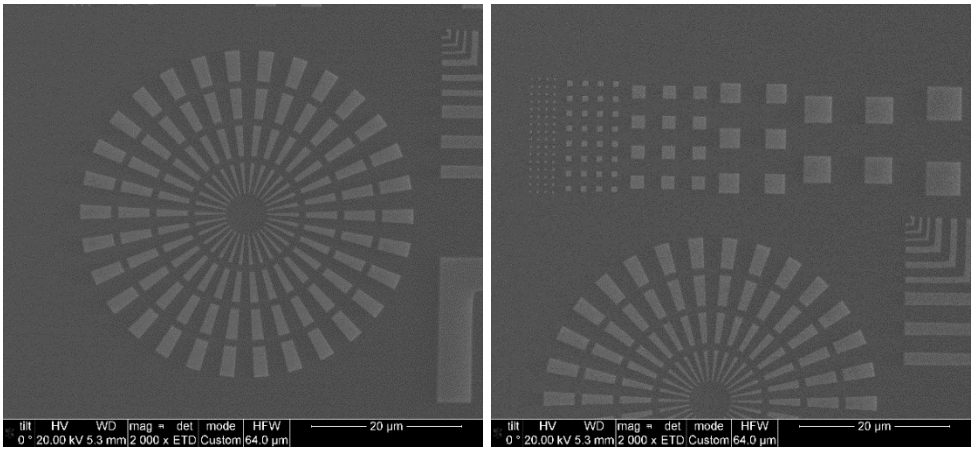

Figure 1: SEM image of the test pattern with 200 nm smallest features inner spokes of the Siemens star and smallest square pattern array.

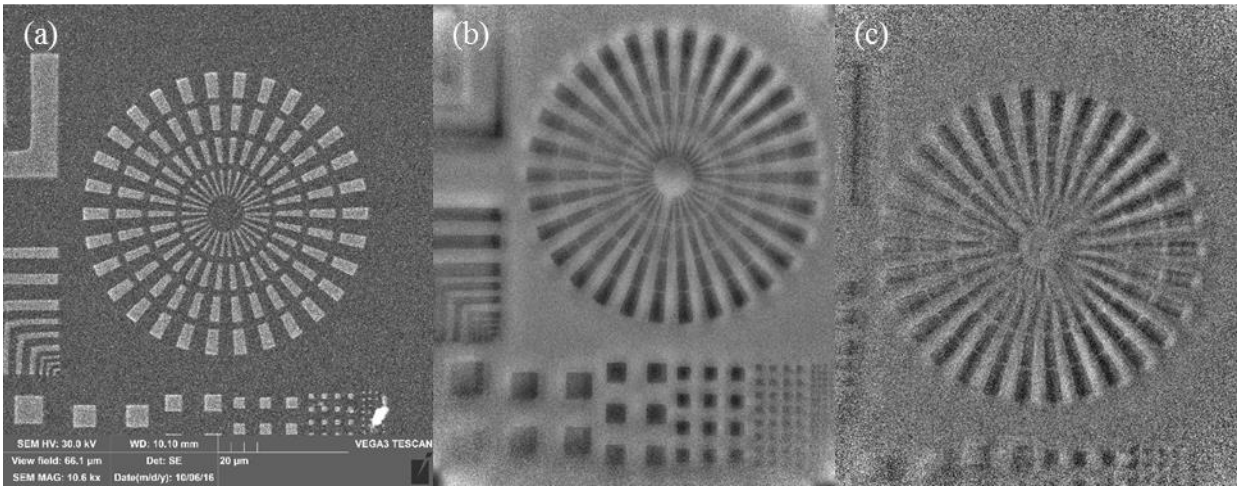

Figure 2: Images of the same Siemen star pattern taken with (a) SEM and TXM with (b) Zernike phase enhanced and (c) misaligned Zernike contrast modes. Beam damage to the inner spokes of the Siemens star is visible in the TXM images.