50 nm Resolution Extreme Ultraviolet Imaging With a Desktop-size Laser

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High brightness table-top extreme ultraviolet (EUV) lasers are paving the way for the implementation of novel probing tools for nanoscience and nanotechnology applications that previously were only accessible at large synchrotron facilities. We have developed a microscope based on a desktop-size 46.9 nm capillary discharge laser that can operate in transmission and reflection mode.[1,2] The microscope uses a multilayer-coated Schwarzschild condenser that focuses the laser output onto the object. A free-standing zone plate objective[3] forms an image of the object onto a back-thinned CCD detector. The performance of the microscope was characterized by experimentally determining the modulation transfer functions (MTF) for three objective zone plates from the analysis of single-shot images of transmission gratings of half-periods ranging from 54 nm to 300 nm (Figure 1). A record near-wavelength resolution, 54 nm, was obtained using the zone plate with an outer zone width of 70 nm. Used in transmission mode, we have obtained single-shot images of carbon nanotubes 50 nm in diameter (Figure 2). In reflection mode, we have imaged the surface of a partially processed semiconductor chip (Figure 3). This is to our knowledge the first demonstration of full-field imaging with spatial resolution near the wavelength (46.9 nm) of the illumination in the extreme ultraviolet regime. This work is supported by the Engineering Research Centers Program of the National Science Foundation under NSF Award Number EEC-0310717

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1 C. Brewer et al., *Single-shot Extreme Ultraviolet Laser Imaging of Nanostructures with Wavelength Resolution.,* Opt. Lett., submitted Dec. 2007

2 S. Heimbuck et al., *Demonstration of a Desk-Top Size High Repetition Rate Soft X-Ray Laser*., Opt. Exp. **13**, 4050 (2005).

3 E. H. Anderson, *Specialized Electron Beam Nanolithography for EUV and X-Ray Diffraction Optics*., IEEE JQE **42,** 27 (2006).

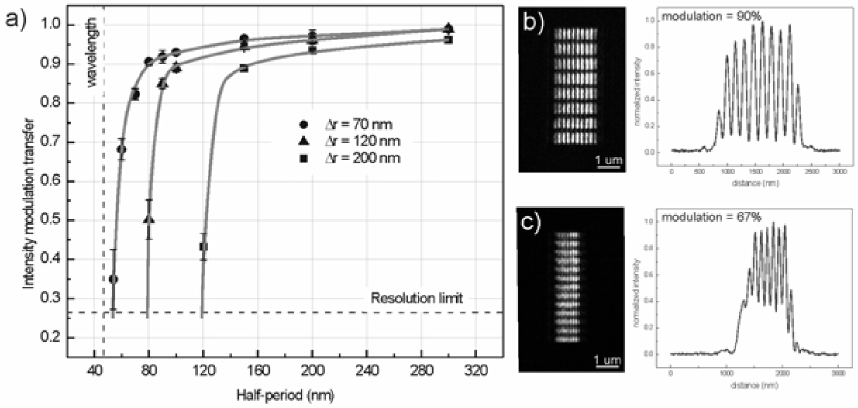

FIG. 1. (a) Modulation transfer functions (MTF) corresponding to Δr = 200 nm, Δr = 120 nm, and Δr = 70 nm objective zone plates. The curve indicates that the spatial resolution of the optical system is 54 nm for the Δr = 70 nm zone plate. Single shot EUV images obtained with the Δr = 70 nm zone plate, and corresponding cross-sections of the (b) 90 nm and (c) 60 nm gratings are also shown.

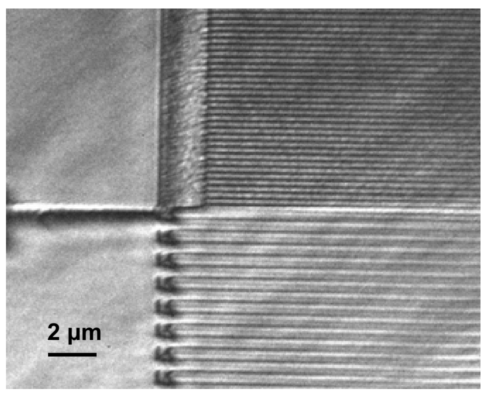

FIG. 2. Reflection mode image of a partially processed semiconductor chip. The images was obtained with a Δr = 200 nm zone plate objective accumulating 60 laser shots. In the top right corner, a 250 nm period grating is fully resolved, and in the lower right, 100 nm lines separated by 800 nm can be seen.

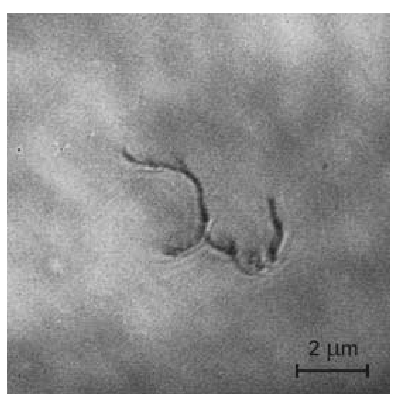

FIG. 3. Transmission mode image of 50 nm diameter carbon nanotubes. The tubes were deposited on a ~ 20% transmissive Si membrane. The images was obtained with a Δr = 70 nm zone plate objective using a single laser shot.