Demonstration of below 30-nm half pitch resolution at the SHARP microscope

M. P. Benk, K. A. Goldberg, A. Wojdyla, C. N. Anderson, P. Naulleau
Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, CA 94720
mpbenk@lbl.gov

M. Kocsis
Inpria Corporation, 2001 NW Monroe Ave., Suite 203,Corvallis, OR 97330

The **S**EMATECH **H**igh-NA **A**ctinic **R**eticle review **P**roject (SHARP) is an EUV-wavelength, synchrotron-based microscope dedicated to advanced extreme ultraviolet (EUV) photomask research. We demonstrate real-space imaging resolution below 30-nm half pitch, approaching the design limit for conventional imaging with SHARP's high-numerical aperture (NA) lenses.

SHARP's imaging lenses and flexible illumination emulate EUV lithography printing tools. Using an array of user-selectable Fresnel zone plate lenses, with 4xNA values up to 0.625, and a Fourier Synthesis illuminator capable of illumination angles up to 19° off axis, SHARP's imaging capabilities far exceed current scanners and enable research several generations into the future.

SHARP's Rayleigh resolution is 53 nm for its highest NA lens (0.625 4xNA). While the imaging performance has been studied with its lower-NA lenses (0.25 and 0.33 4xNA), until now a lack of photomasks with sufficiently small features has hindered our ability to test the resolution limits for the higher-NA lenses.

We recently fabricated a test mask with lines and spaces down to 20-nm half pitch. Unlike typical patterned-absorber-on-multilayer masks fabricated with electron beam lithography, here we used a silicon wafer coated with a multilayer and photoresist. We exposed the waver in the SEMATECH Berkeley Microfield Exposure Tool (MET). An EUV lithography test pattern was imaged onto the wafer with 5x demagnification at a wafer-sided NA of 0.3. We selected an experimental photoresist from Inpria based on photocondensed molecular tin oxide. Having four times the absorbance of a standard chemically amplified resist, the developed resist pattern can directly be imaged, eliminating the need for an additional absorber and secondary processing steps. Loose-pitch features on the test mask show an image contrast of 33% in SHARP. The 13-nm resist thickness enabled us to create 17-nm half-pitch line features at a favorable thickness-to-width aspect ratio below 1. (A typical absorber stack of 85 nm TaNO would have an aspect ratio of 5:1 for the same feature size.)

We present image data recorded at mask-side NA values of 0.125 and 0.15625 (i.e. 0.5 and 0.625, 4xNA). The data show diffraction-limited imaging for the 0.125 NA lens and a resolution limit of the tool well below 30 nm.

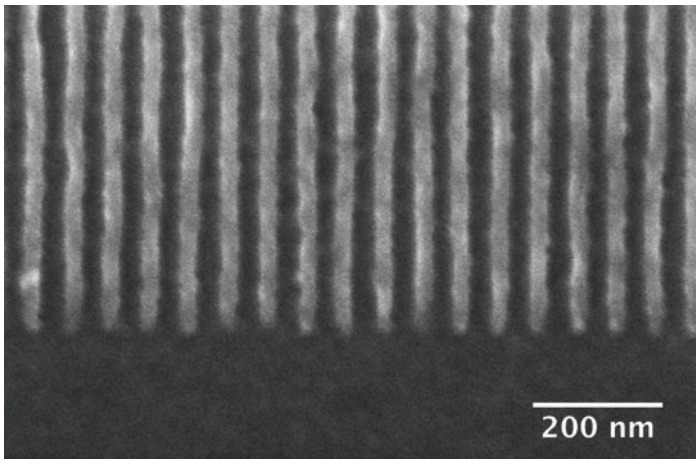

Figure 1: Scanning-electron microscopic image of 30-nm lines and spaces on the test mask.

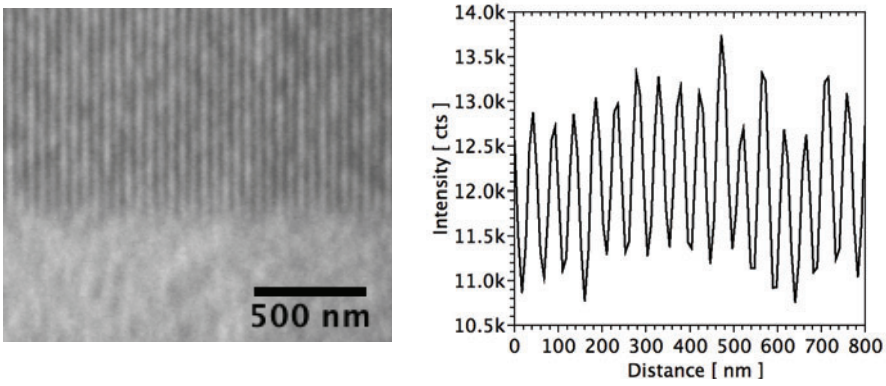

Figure 2:
a) SHARP image of 24-nm lines and spaces, recorded using extreme-dipole illumination.
b) Cross-section plot, vertically averaged over 70 pixels, showing a modulation of approximately 7%.