At-Wavelength EUV Lithography Mask Observation Using a High-Magnification Objective with Three Multilayer Mirrors

M. Toyoda, K. Yamasoe, T. Hatano, M. Yanagihara
Laboratory of Soft X-ray Microscopy, IMRAM, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai, Miyagi 980-8577, Japan
toyoda@tagen.tohoku.ac.jp

A. Tokimasa, T. Harada, T. Watanabe, H. Kinoshita
Laboratory of Advanced Science and Technology for Industry, University of Hyogo, 1-1-2 Kouto, Kamgori, Ako, Hyogo 678-1205, Japan

Motivated by the need for at-wavelength observation of EUV lithography masks, we are developing a full-field EUV microscope based on a multilayer-mirror objective. Recently, we proposed an innovative objective design enhancing a magnification over 1000,[1,2] which is suitable for using an EUV-CCD camera as a detector. Besides, this novel design corrected for off-axis aberrations, i.e., coma, astigmatism, and field curvature, can be configured to have a large field of view in a few hundred micron scale with a diffraction-limited resolution, which allows us a rapid whole mask inspection within a practical observation time.

As shown in Fig.1, the microscope uses synchrotron EUV from the bending magnet beamline BL3 of NewSUBARU at University of Hyogo. The optics was made of seven Mo/Si multilayer mirrors, which were optimized at a wavelength of 13.5 nm. The high-magnification objective was configured as a two-stage imaging system. The Schwarzschild mirror having a numerical aperture of 0.25 projects an image of the illuminated mask with a magnification of 30. The intermediate image is magnified again by the concave mirror M3, to have a high magnification of 1480 on the CCD camera. The mirror M3 also acts as a field flattener,[3] which effectively corrects the off-axis aberration, i.e., field curvature. A numerical raytrace calculation showed that a resolution of 30 nm would be expected in a large area of 160 μm in diameter on the sample plane.

The magnification enhancement was clearly confirmed experimentally by taking EUV images both on the intermediate image plane and the second image plane, as shown in Fig. 2. A spatial resolution of the EUV microscope was also evaluated by observing line and space patterns. As shown in Fig. 3, 88 nm-width patterns were clearly observed with an exposure time of 10 s. In the presentation we will report several at-wavelength images of test patterns and defects that were taken on EUV lithography masks. We will also show results obtained by an interferometric wavefront measurement of the novel objective.

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[1] M. Toyoda, T. Jinno, M. Yanagihara, AIP Conf. Proc. **1365**, 176 (2011).
[2] M. Toyoda, Japan patent no. 2010-79257.
[3] V. N. Mahajan, *Optical Imaging and Aberrations*, (SPIE Press, 1998), Part 1, pp. 314.

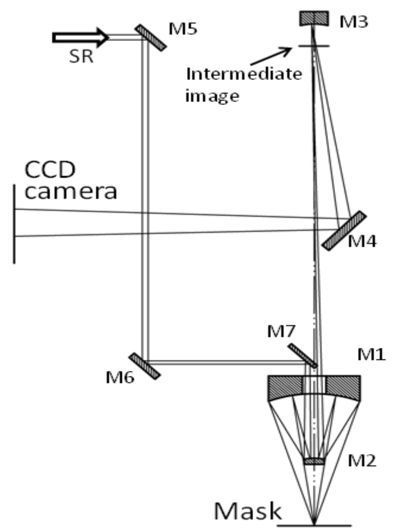
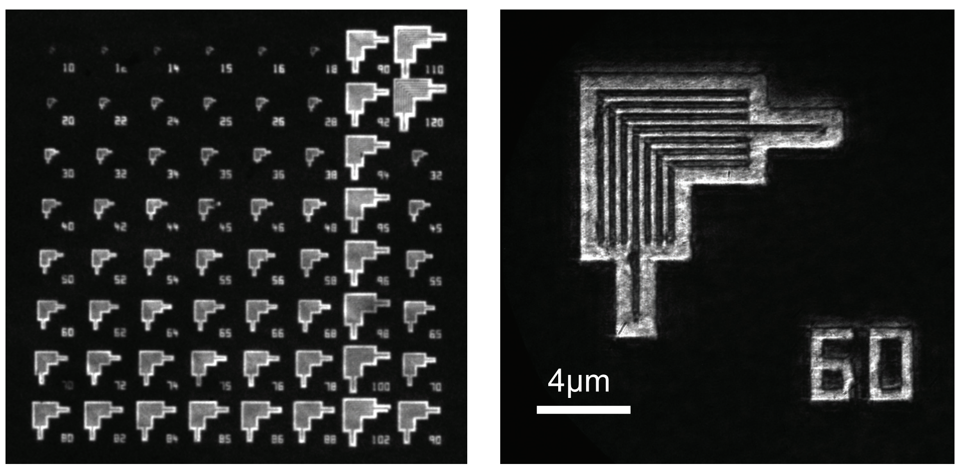


Figure 1: A schematic layout of the EUV microscope: Three mirrors, i.e., M1, M2, and M3, act as a two-stage imaging system with the high magnification.



(a) (b)

Figure 2: Bright field images of elbow patterns: (a) an intermediate image, (b) a secondary magnified image of 240 nm-width elbow patterns.

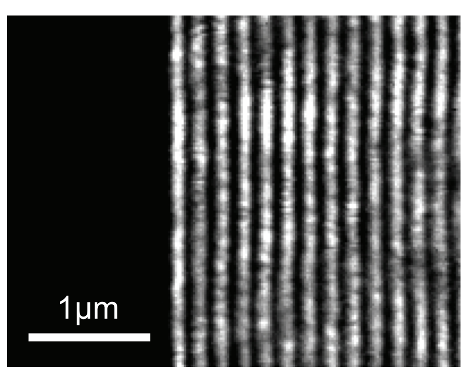


Figure3: A detailed image of 88 nm-width line and space patterns.