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Table-top Extreme Ultraviolet Laser Aerial Imaging of Lithographic Masks

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Table-top Extreme Ultraviolet Laser Aerial Imaging of Lithographic Masks

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Abstract: We report the first at-wavelength line edge roughness measurements of patterned EUV lithography masks realized using a table-top aerial imaging system based on a table-top λ=13.2 laser.

OCIS codes: (110.7440) X-ray imaging, (140.7240) UV, EUV and X-ray lasers, (180.7460) X-ray microscopy

As the expected date for insertion of Extreme Ultraviolet Lithography (EUVL) for high volume manufacturing approaches, metrology tools able to fully characterize patterns and defects on EUVL masks are in critical need. Current microscope systems capable of obtaining at-wavelength, full-field images of EUVL masks use synchrotron radiation illumination [1, 2]. With the goal of enabling the characterization of EUVL masks on-site at mask shops and printing facilities, have developed a table-top, full-field microscope based on a 13.2 nm wavelength laser [3]. We have used this microscope to characterize line patterns on EUVL masks for the first time using a table top EUV imaging tool. The good uniformity of the illumination has allowed the acquisition of extremely high quality images and the measurement of line-edge- roughness.

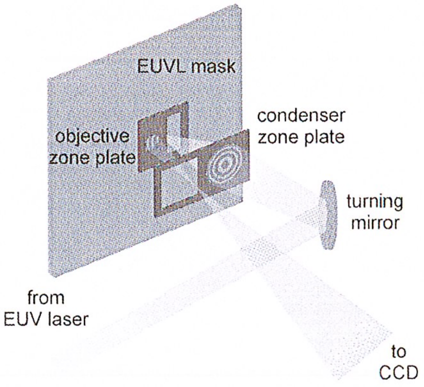

Fig. 1. Schematic of the EUV microscope for aerial imaging of lithographic masks (distances between components are not to scale).

The setup of the EUV reflection microscope is shown in Figure 1. It was designed to mimic the illumination conditions of a 4×-demagnification, 0.25 NA, EUVL stepper. The microscope makes use of a 5 mm diameter, 0.06 NA zone plate to condense the light from an EUV laser onto the mask at an angle of 6 degrees. A 0.0625 NA, 1 mm focal distance, off-axis zone plate projects a magnified image of the reflected light onto a CCD detector. The off-axis design allows for near-normal incidence imaging of the mask surface while providing a mechanism for 0th order light elimination. The illumination source is a table-top, plasma based collisional 13.2 nm wavelength laser that produces highly monochromatic pulses with μW average power [4, 5].

Two lithographic masks consist of Mo-Si multilayer mirrors with absorption patterns on top. Images of the masks were produced with the reflection microscope using exposure times ranging from 5s to 90 s. Figure 2 shows a 180 nm half-pitch absorber elbow pattern in a bright field. The image shows uniform illumination of the field of view which is required for image analysis. The image was obtained with an exposure time of 90 seconds operating the laser at 1 Hz repetition rate. During acquisition the condenser was slightly displaced from shot to shot to improve the uniformity of the illumination.

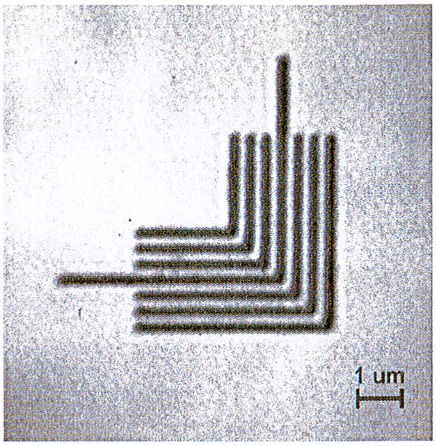

Fig. 2. Bright-field EUV image of a 180 nm half-pitch elbow structure. The image shows excellent illumination uniformity.

Figure 3 shows an image of a 175 nm half-pitch grating in a dark field from a lithographic mask provided by AMD (with 4x-demagnification such grating prints as 43.75 nm lines). This and other similar images were used to measure line edge roughness (LER). The LER of the lines was analyzed as shown in Fig. 3b and 3c. The lines are considered to print without errors if three times the standard deviation, σ, of the line position is within 10% of the critical dimension (CD) - thickness value of the lines. Otherwise the lines are considered defective, which can result in device malfunction. As indicated in Fig. 3c, a LER value below 10% CD was measured for the 175 nm lines.

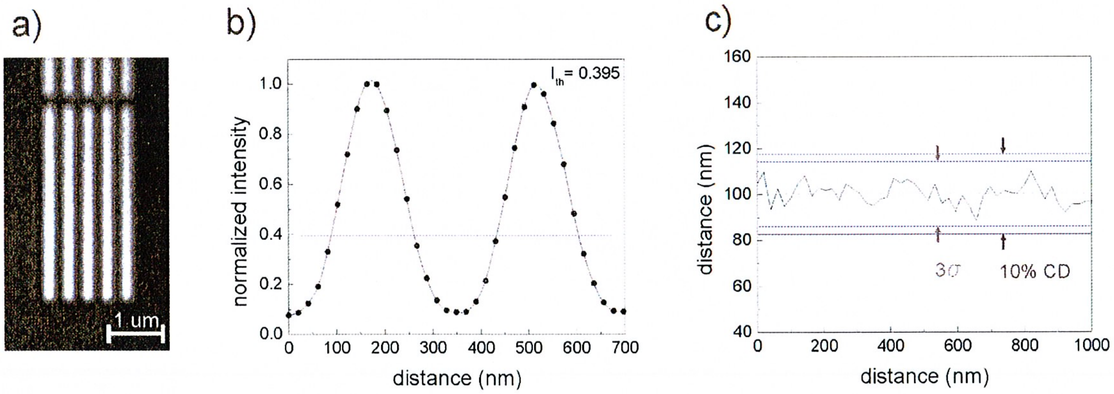

Fig. 3. a) EUV image of a 175 nm half-pitch grating. b) integrated intensity and threshold for which the structure is 1:1. c) Line-edge roughness.

In conclusion we have used a table-top actinic microscope based on a 13.2 nm laser to obtain images of EUVL masks with the high illumination uniformity required for the characterization of line-edge roughness. Due to the high average brightness of the source, the images can be obtained with relatively short exposure times, comparable to synchrotron-based systems.

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DISCLAIMER

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