Table-top Microscope for the Actinic Aerial Imaging Inspection of Extreme Ultraviolet Lithography Masks

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Extreme ultraviolet lithography (EUVL) has been selected to print a new generation of semiconductor chips at the 22 nm half-pitch node and beyond. This technology has been demonstrated at laboratory and beta-tool scales. There are however, several technological issues, including the fabrication of defect-free masks, that remain a challenge for high volume manufacturing (HVM). The successful implementation of EUVL for HVM imposes pressing demands to develop actinic metrology tools capable of detecting printable defects on masks and mask-blanks.

Demonstrations of high resolution actinic aerial microscopes have until now been conducted at synchrotron facilities where 13.5 nm wavelength radiation from bending magnets provides illumination at the wavelength where the Mo/Si multilayer EUVL masks have the highest reflectivity. [1] Transitioning EUV inspection microscopes into compact devices to inspect EUVL masks on-site is possible but requires table-top light sources with high brightness and sufficient flux near 13.5 nm as found in recently developed EUV full field microscopes. [2]

We have implemented a reflection microscope for actinic aerial imaging of EUVL masks using a table-top, plasma-based, collisional 13.2 nm wavelength EUV laser in combination with specialized Fresnel Zone Plates (FZP). [3, 4] In this full field reflection microscope the EUVL mask is imaged under the same illumination conditions as in a 4X EUVL stepper. (Fig. 1) The microscope has the capability to resolve absorption patterns with critical dimensions as small as 55 nm. [5] This resolution exceeds the specifications set for the 22 nm technology half-pitch node. The microscope provides high quality images of EUVL masks necessary for quantifying the printability of patterns and defects prior to wafer printing. (Fig. 1)

We acknowledge the contribution of Dr. Georgiy Vaschenko and the support of the Engineering Research Centers Program of the National Science Foundation under NSF Award Number EEC-0310717.

1. K.A. Goldberg, A. Barty, Y.W. Liu, P. Kearney, Y. Tezuka, T. Terasawa, J.S. Taylor, H.S. Han, and O.R. Wood, *Actinic inspection of extreme ultraviolet programed multilayer defects and cross-comparison measurements.* Journal of Vacuum Science & Technology B, 2006. **24** (6): p. 2824-2828.
2. G. Vaschenko, C. Brewer, F. Brizuela, Y. Wang, M.A. Larotonda, B.M. Luther, M.C. Marconi, J.J. Rocca, and C.S. Menoni, *Sub-38 nm resolution tabletop microscopy with 13 nm wavelength laser light.* Optics Letters, 2006. **31**(9): p. 1214-1216.
3. J.J. Rocca, Y. Wang, M.A. Larotonda, B.M. Luther, M. Berrill, and D. Alessi, *Saturated 13.2 nm high-repetition-rate laser in nickellike cadmium (vol 30, pg 2581, 2005).* Optics Letters, 2006. **31**(1): p. 129-129.
4. E.H. Anderson, *Specialized electron beam nanolithography for EUV and X-ray diffractive optics.* Ieee Journal Of Quantum Electronics, 2006. **42**(1-2): p. 27-35.
5. F. Brizuela, Y. Wang, C.A. Brewer, F. Pedaci, W. Chao, E.H. Anderson, Y. Liu, K.A. Goldberg, P. Naulleau, P. Wachulak, M.C. Marconi, D.T. Attwood, J.J. Rocca, and C.S. Menoni, *Microscopy of extreme ultraviolet lithography masks with 13.2 nm tabletop laser illumination.* Optics Letters, 2009. **34**(3): p. 271-273.

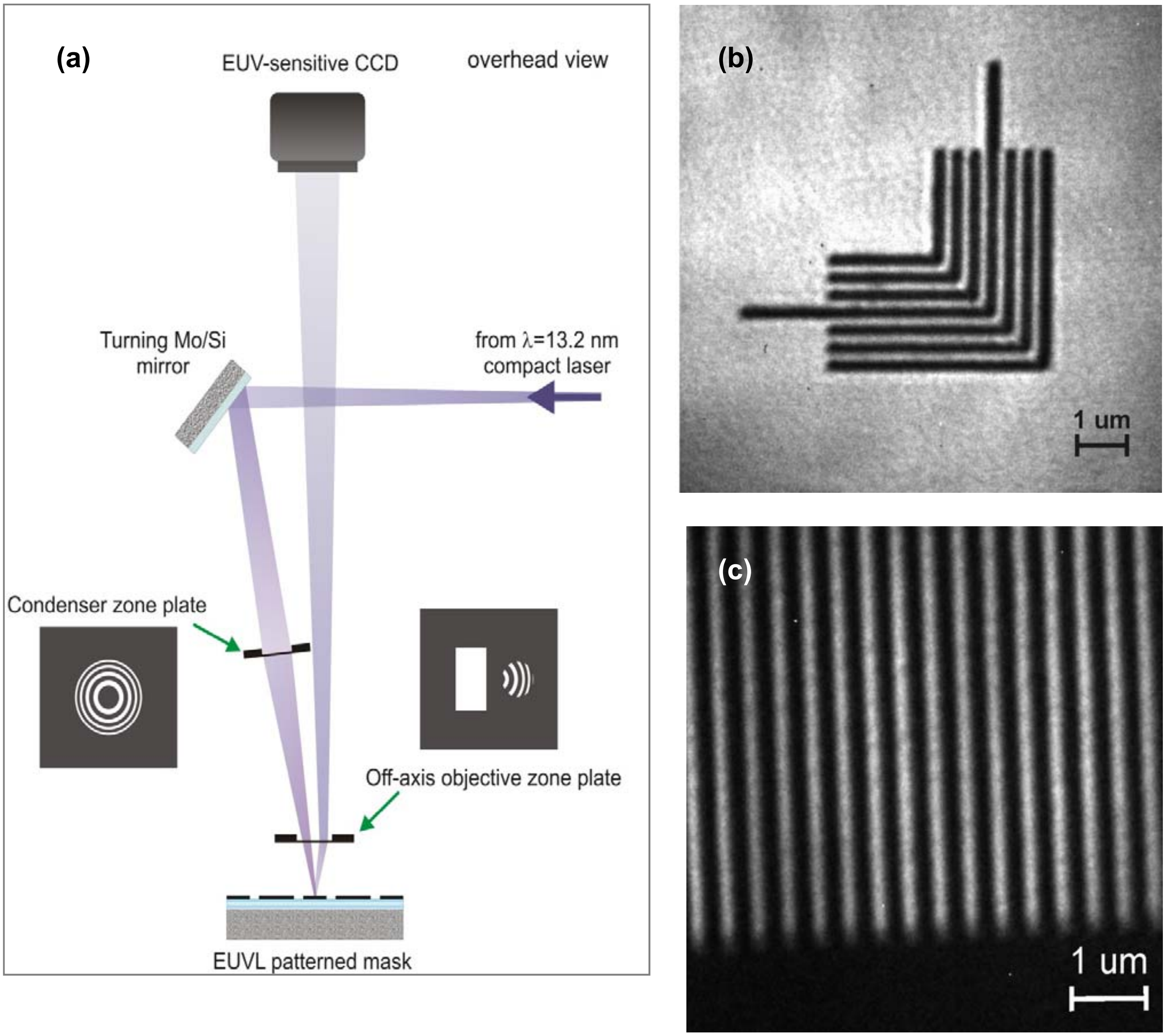

Figure 1. (a) Schematics of the layout of the table-top λ=13.2 nm actinic microscope for aerial actinic EUVL mask inspection. The EUVL mask is illuminated at an angle of six degrees using a zone plate condenser with numerical aperture NA=0.06. The first order diffraction from the off-axis objective with NA=0.06, forms the image on a charged coupled array detector (CCD). (b) High quality bright field EUV image of a dense elbow pattern with critical dimensions of 180 nm. (c) Dark field EUV image of periodic lines with CD=200 nm patterned in a EUVL mask. Both of these images were obtained with 90 seconds exposure.