EUV pattern defect detection sensitivity based on aerial image linewidth measurements

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Extreme ultraviolet (EUV) lithography reticles are complex optical systems, sensitive to the materials properties and thicknesses, and vulnerable to several types of defects. EUV-wavelength aerial image microscopy is currently an extremely useful tool for EUV mask development. Without the constraints of photoresist, continuous-tone EUV mask images provide detailed feedback on aerial image quality, line intensity profiles, roughness, and relative reflectivity with resolutions that can match or exceed the current generation of printing tools. Such measurements are particularly important for answering basic questions about defect printability, and for qualifying simulation tools, through comparison with experimental data.

Operating at EUV wavelengths, the SEMATECH Berkeley Actinic Inspection Tool (AIT) is a synchrotron-based zoneplate microscope that now provides high quality aerial image measurements of EUV reticles.[1] The AIT operates with interchangeable objective lenses, with different resolutions, that project EUV light directly onto an EUV CCD camera with high magnification.

Recently, the AIT has been used to measure a mask with buried substrate “phase” defect arrays positioned below overlapping dense and isolated-line absorber patterns. These measurements are being used to assess defect printability versus size and relative position.[2]

In this paper, we will present statistical analyses of EUV image data to understand the measurement sensitivity and its limits. Factors such as inherent mask pattern roughness, local reflectivity variations, optical aberrations (in the microscope), shot noise, and vibration stability, among others, all contribute to the resultant images. In the pattern regions between the known defect positions (see Fig. 1), we investigate the image properties to understand the limitations of the AIT’s measurements. Looking forward, we discuss how these current measurements influence the requirements of future, commercial reticle inspection tools that EUV lithography needs for defect inspection and repair.

Keywords: EUV, actinic, mask inspection, reticle, EUV, zoneplate, aerial image

[1] Goldberg, Mochi, Naulleau, Han, Huh, SPIE **7122**, (2008), *in press.*
[2] C. Clifford, T. Liang, *et al.*, SPIE **7271**, *to be published.*

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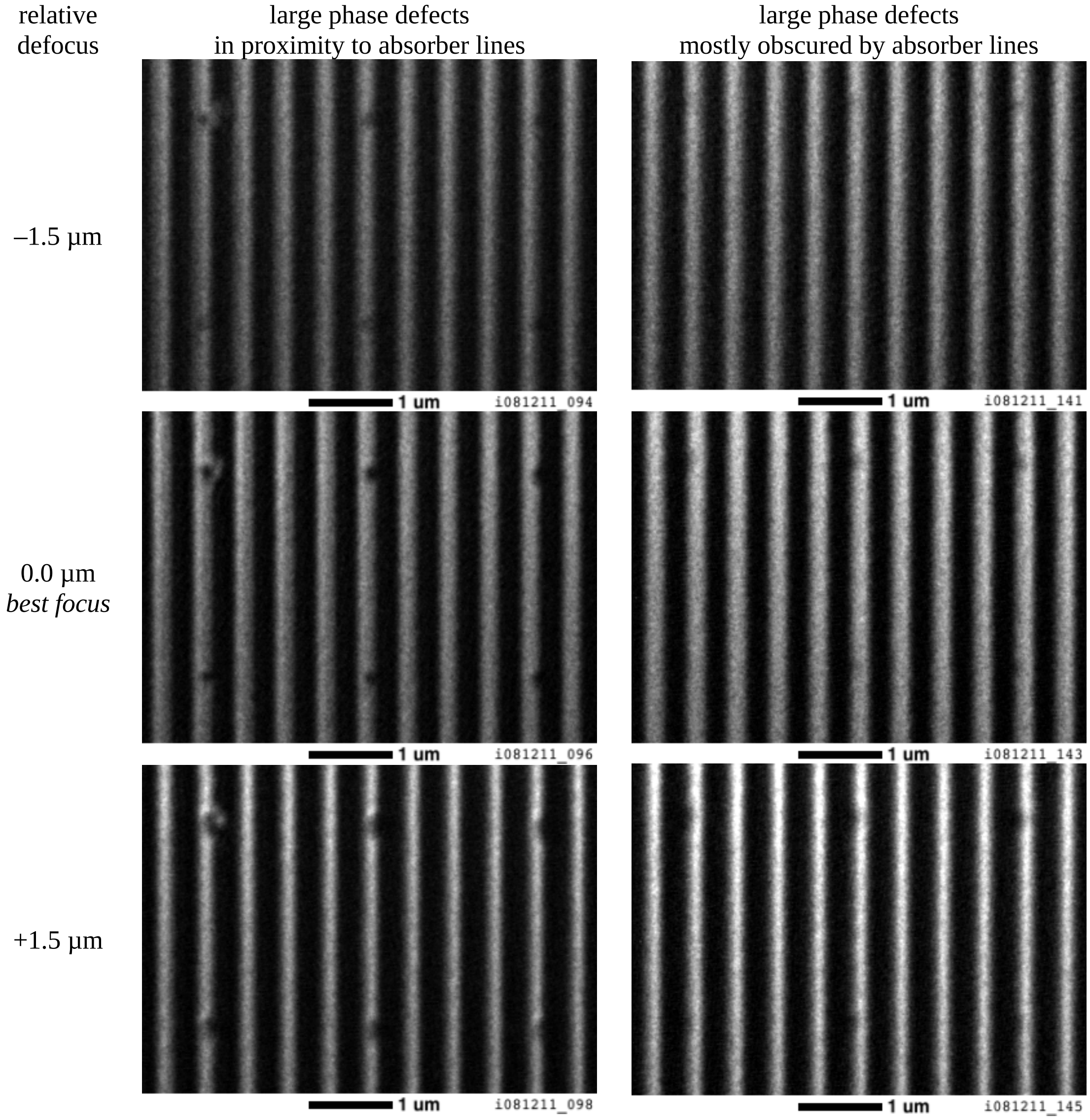

Fig 1. Characteristic EUV aerial images recorded at two positions within a large array of phase defects buried below a 250-nm half-pitch (mask size) dense line pattern. A 0.35-NA, 4×-equivalent zoneplate lens was used (mask-side NA value is 0.0875). From the through-focus series, three focal positions are shown, 1.5 µm (mask) longitudinal step size, apart. (i.e. 92 nm in a 4× system).

While some defects, in close proximity to the absorber line edges, make obvious changes in the line patterns, others are more difficult to detect—especially when they are mostly covered by the dark lines. In the regions between the pattern defects, the measured statistical variation in the line widths, due to noise and the optical characteristics of the microscope, can be used to assess the detection sensitivity.