Actinic Characterization of EUV Bump-Type Phase Defects

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Despite tremendous progress and learning with EUV lithography, quantitative experimental information about the severity of point-like phase defects remains in short supply. We present a study of measured, EUV aerial images from a series of well-characterized, open-field, bump-type programmed phase defects, created on a substrate before multilayer deposition.

Researchers in EUV lithography have been aware of the challenges associated with buried, *phase defects* since the earliest days of this technology. Phase defects elicit such great concern because they place enormous demands on even the most advanced mask-inspection tools. Defect sizes that cause significant disruptions of the EUV aerial image may be below 1.5-nm in height and tens-of-nm wide.

Through modeling and the results of numerous experiments, disruptions in the aerial image caused by bump and pit-type substrate defects have been predicted and observed. Yet it is difficult to replicate the operating conditions of lithography tools, or to accurately model the detailed multilayer distortion that results from buried defects. Measurements from EUV microscopes can provide critical insight to bridge the gaps in our understanding.

We present a series of aerial image measurements from programmed, buried, bump-type defects, performed with the SEMATECH Berkeley Actinic Inspection Tool (AIT). The AIT is an EUV zoneplate microscope, operating at a numerical aperture equivalent to 0.35 NA (4×), and a partial coherence σ value below 0.2. The defects range in size from 1.0 to 1.6-nm high, and 43 to 120-nm full-width at half-maximum (FWHM), measured at the top surface. Measurements were performed through-focus to improve characterization. Defects were observable down to 1.0-nm height, and 43-nm FWHM, although at that small size, they are difficult to differentiate from the effects of multilayer phase roughness.

Calculations show that a simple, fully coherent, single-surface model of the defect phase, based solely on the measured top-surface profile, greatly over-predicts the observed aerial image intensity change as compared with AIT measurements. We provide measurements and various simulations for comparison.

Keywords: EUV, actinic, mask imaging, phase defects, aerial image

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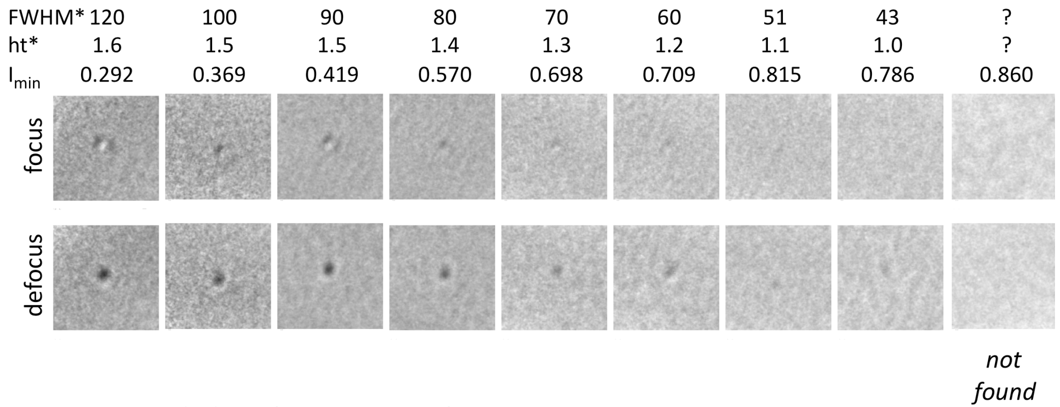

Data recorded on the AIT, November 16–17
0.35 NA (4x). Image details are 1.36-µm square.
* defect sizes are based on AFM

Figure 1. A selection of defect aerial images, both in focus and slightly out of focus where the strongest intensity change is measured. The top-surface height and FWHM are given for each defect. The minimum, normalized, measured intensity level (I_{min}) is also given. Here the average reflectivity of the mask is normalized to 1.0.