Phase-enhanced defect sensitivity for EUV mask inspection

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The quality of EUV mask is a key priority for EUV lithography. Among various kinds of defects, phase defects are the biggest challenge to achieving defect free EUV mask. We show that a higher sensitivity and in-focus inspection capability for the phase defects can be achieved based on the Zernike phase contrast method. The signal-to-noise ratio can also be improved by apodization due to the reduction of the low frequency component of the mask roughness power spectral density. Moreover, we demonstrate that both phase and amplitude defects can be simultaneously detected at focus on an EUV mask with optimized phase shift. The undesired trade-off between the signal-to-noise ratio for phase and amplitude defects' can be mitigated by adding apodization and a phase-shift near 45 degrees.

The generalization of the inspection strategy for 11 nm line patterns will also be discussed. Data for the typical worst case scenarios of phase defects centered in the space and amplitude defects placed at the line edge will be shown. Critical defects that showed a 5% linewidth variation were then used to study defect inspection signal-to-noise ratios. Initial results show that with a moderate trade-off, phase-enhancement can be used to detect both phase and amplitude defects simultaneously. Again for patterned masks the phase-enhanced method enables the opportunity to collect information from both types of defect on EUV mask with a single scan at focus.

The phase-enhanced defect inspection method is sufficiently promising that we are exploring experiments in visible light on an optical bench and on the SEMATECH-Berkeley SHARP EUV microscope. For the optical bench experiments, the phase defects are modeled using a holographic phase encoding method and zone-plate lenses are used to easily study a wide range of Zernike phase shifts and apodization levels. A similar set of zoneplates has also been designed for SHARP and will be conducted this summer.