# Characterization of Small Phase Defect on EUV Mask Using Micro Coherent EUV Scatterometry Microscope

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In extreme-ultraviolet (EUV) lithography, production of defect-free EUV mask is one of the critical issues. Hiding and compensation methods of phase defects by absorber modification require knowledge of the phase defect's size and position. For the phase defect characterization, we have developed micro coherent EUV scatterometry microscope (micro-CSM) at NewSUBARU of a synchrotron radiation facility. Figure 1 shows the micro-CSM system. The micro-CSM is simple system that composed of a Fresnel zone plate (FZP) of off-axis type, an EUV mask, an EUV CCD camera, and coherent EUV light. Coherent EUV light is focused on a defect by the FZP, which illumination size was approximately 200 nm in diameter. The EUV CCD camera records scattering signal from the defect directly. Acceptance angle of the CCD camera is approximately ±16° (NA 0.27). Defect information of size and phase distribution is included in the scattering signal. The target defect size of the micro-CSM system is less than 30 nm in width and 1 nm in height.

We observed the small defects with design widths of 60 nm and 30 nm, which were programmed defect on EUV mask. The design height was 1 nm. Figure 2 shows a relationship of the scattering and reflection signal intensity from each defect. The reflection signal is directly related to the reflectivity decrease on the defect, which cause black spot on a wafer. The scattering signal is strongly related to the defect phase, which indicates phase distribution and size of the defect. The defect signal of reflection and scattering intensities had linear relationship. In fig. 2, the defect with same design had different signal intensity, which indicates the defect had different size. The micro-CSM system directly observes the reflection and scattering intensity that strongly related with the printability. In addition, we observed actual phase defect, which signal was clearly detected. The diffraction signal indicated the actual phase distribution.

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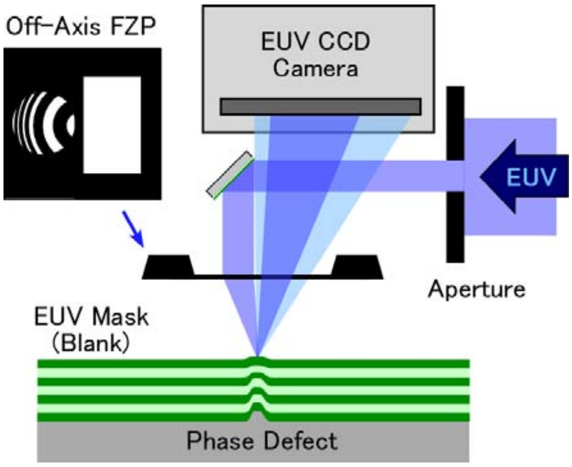


*Figure 1: Schematic view of the micro-CSM system:* The micro-CSM is a characterization tool of phase defects that consists of the focusing optics of the off-axis FZP and the two-dimensional detector of the CCD camera. The focused beam is exposed to a phase defect, where the scattering signal is recorded with the camera. The signal includes the defect information. Focused size was estimated to 200 nm in diameter. The camera records ±16 degree angle from the chief ray.

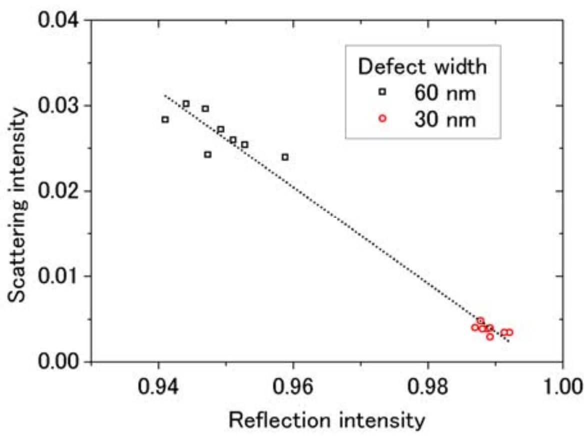


*Figure 2: Relationship of reflection and scattering intensity from small phase defects:* The defect signal of reflection and scattering intensities had linear relationship. The dot line shows linear fitting result. Defect widths of 60 nm and 30 nm are design value. This result shows that actual size of the defect was different, even if the defect had same design.