Effects of mask absorber structures on the EUV lithography

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ABSTRACT

Extreme ultraviolet lithography (EUVL) using 13.5 nm wavelengths has become a leading next generation lithography technique expected to be used in the sub-32 nm regime. In contrast to conventional lithography using a transmissive and refractive optics system, EUVL employs a reflective mask consisting of Mo/Si multilayer mirrors and absorber stacks. Due to the non-telecentric off-axis illumination on the mask side combined with the three-dimensional mask topography, shadowing effects which distort the printed image on the wafer side is prevalent on the EUVL. The impacts of shadowing normally depend on the height of the absorber stack, incidence angle of EUV light, and CD on the mask side.

In this paper, we present the results of an investigation of the dependence of mask absorber structure on the EUVL to reduce shadowing effects. First, we estimate lithographic performances of the EUVL masks as a function of both absorber height and mask CD through rigorous electromagnetic simulation. We use two commercial simulators, EM-Suite and Solid-EUV, for the calculation of image contrasts, normalized image log slope (NILS), horizontal-vertical (H-V) CD bias, depth of focus (DOF), and process windows (PW), as well as an in-house tool for the reflectivity-phase simulation. Second, we investigate actual mask printability, including image quality, H-V bias, and PW, on the resist coated wafers at 13.5 nm EUV radiation by exposing patterned masks in a small-field micro exposure tool (MET). For this purpose, we fabricate several patterned masks with various absorber thicknesses which made from in-house EUVL mask blanks consisting of Mo/Si multilayers, Ru capping layers, and TaN absorbers on the quartz 6025 substrates. The simulation results also give a hint to design optimum absorber structure in the EUVL masks. Finally, we discuss the implications on the selection of desirable mask structure to minimize shadowing effects with high image qualities by comparing MET printing results with simulations.

Keywords: EUVL, mask, absorber, shadowing effect, H-V bias, phase, MET