Growth and Printability of Multilayer Phase Defects on EUV Mask Blank

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The ability to fabricate defect-free Mo-Si multilayer (ML) blanks is a well-recognized challenge in enabling extreme ultraviolet lithography (EUVL) for semiconductor manufacturing. Both the specification and reduction of defects necessitate the understanding of their printability and how they are generated and grow during ML deposition. While the printability of amplitude defects such as those on the absorber patterns has been shown to follow the general scaling trend as in 193nm optical lithography, the comprehension of phase defects, which originate from disturbances to the ML reflective stack, is very complex. The printability of a phase defect is not only sensitive to the size and shape of the defect, but also to the exposure conditions.

This paper describes our recent study of ML phase defects using resist printability data from exposures on a programmed defect mask (PDM). The ML blank was made with a carefully tuned deposition process that produced phase bumps with a full range of surface heights (peak height from 0 to 10nm) and widths (FWHM from 10nm to 70nm). In addition, the lateral shape of the phase bumps was also varied (aspect ratio of 1:1, 1:2, 1:3 and 1:5) to represent point and line defects. Using this blank, a mask was fabricated with line and contact patterns of various CDs (from 25nm to 90nm, 1x) and pitches (1:1, 1:3 and 1:5). For defects in the same size and shape group, placements were offset with varying proximity to the absorber patterns in 10nm (1X) incremental steps. The mask was exposed on the EUV micro-exposure tool (MET). With a currently available EUV resist, we were able to print ≥40nm dense lines on the resist wafer and measure the CD changes caused by the phase defects described above. These are valuable data in understanding the complexity of ML phase defects.

We present this paper in four parts: 1) The fabrication processes for the ML blank and the full mask with pattern overlay to the phase defects; 2) The results characterizing the defect and final mask; 3) The resist data showing the printability of different phase bumps to dense line patterns of various widths, and key findings from these data; 4) Comparison between resist data and aerial image simulations and our explanation of the observed differences. In conclusion, we will assess the methods and the requirements for ML defect specification.