EUV Mask Challenges, Status, and Closing the Remaining Technology Gaps

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The ability of optical lithography to steadily produce images at increasingly smaller dimension while maintaining pattern fidelity of devices with greater complexity has enabled the success of Moore's Law. Although 193nm immersion and double patterning techniques have recently proven successful in extending optical lithography, the strategies proposed for further extension are considerably costly. As a result, extreme ultraviolet lithography (EUVL) has emerged as the most likely candidate to succeed optical projection lithography as the mainstream imaging solution for future technology nodes. While similar to conventional optical lithography there are unique challenges to EUVL, one of which is the change from transmission masks to the reflective masks required for EUVL. The use of reflective reticles greatly increases complexity of EUV reticle structure when compared to the binary masks used with optical lithography. To maximize the reflectance a EUV mask requires the use of a multilayer Bragg reflector deposited on a finely polished substrate with a thin absorber film on top used to define the device pattern. Although similar in form to the substrates used in optical lithography, the tolerances on figure, surface finish, and defects are significantly more stringent for EUV substrates. Control of aberrations and maintaining pattern fidelity places tight constraints on the flatness and roughness of the EUV substrate, while imperfections and particles can results in printable defects. The Bragg reflector of the EUV mask consists of 40 to 50 Si/Mo bi-layers deposited using an ion beam deposition tool. This film stack must be deposited to meet the reflectivity and uniformity requirements of the exposure tool and must be completely free of defects. The absorber film is typically a tantalum based nitride layer selected for its ability to absorb EUV radiation and maintain thermal stability. The thickness and morphology of this film must be tightly controlled to enable use as the patterning film for the device. In addition to the increase in complexity of the mask, introduction of EUVL requires infrastructure development of new substrate, mask blank, and finished reticle inspection tools and techniques for handling and storage of a mask without a pellicle. This paper discusses the ability of EUV masks and mask blanks to meet the near term exposure pilot line requirements and review the existing technology gaps which must be closed to extend the current capability to meet HVM specifications. A special focus will be put on blank and mask defectivity but the other challenges concerning substrate, mask blank and mask requirements will also be addressed.