Challenges and progress in extreme ultraviolet mask development

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Despite significant progress in the commercialization of extreme ultraviolet (EUV) lithography, significant challenges remain. Although availability of a reliable high power source is arguably the most daunting of these challenges, important mask and resist issues are also of major concern. In this presentation, we provide an overview of the mask challenges and discuss recent progress.

Of particular concern is the EUV-specific problem of multilayer phase roughness. Reflective in nature, EUV masks are particularly susceptible to surface roughness, since such roughness geometrically couples to phase. The random phase induced in the reflected field then couples to line-edge roughness (LER) in the image plane after propagation through a band-limited system. Illuminated at a wavelength of only 13.5 nm, sub-angstrom roughness is required to meet LER specifications for the 22-nm half-pitch node. In addition having implications on the lithography, EUV mask roughness also negatively impacts mask inspection tools.

Another major concern for EUV masks is contamination. High EUV power loads, combined with imperfect vacuum environments, leads to carbon contamination of the mask. Reasonable mask lifetimes will require masks to undergo numerous cleaning cycles. Cleaning methods must be developed that can remove carbon without significant damage to the multilayer or absorber structure. Extensive print-based tests have been used to demonstrated the feasibility of multiple cleaning.

Finally, the impact of resist performance on mask requirements will be addressed. Since EUV is arguably a resist-resolution-limited lithography process, the resist plays a dominant role in such effects as mask error enhancement. Therefore, the resist has significant impact on mask-induced wafer critical dimension uniformity, defect printability, and to a less extent LER.