Fundamental Study of EUV Resist Line Edge Roughness: Characterization, Experiment and Modeling

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The origin and consequences of the roughness of developed resist features (line edge roughness or LER) has been the subject of many studies over the past several years. As feature sizes shrink the impact of LER on resist features worsens and today it is one of the biggest problems facing EUV resist implementation.[1] At present there is no clear solution to this problem. In this report we describe studies on the origins of LER in model EUV resists. Polymeric resists based on both acrylic and PHOST based chemistry as well as a molecular glass resists were evaluated. In order to understand the evolution of resist roughness we employed interrupted development to halt the dissolution process at different times during the development process. This was accomplished by using a system with timed immersion development or by using a specially designed flow cell to control the contact time of the developer. Characterization of the LER of partially and fully developed resist features was done with standard SEM as well as sidewall AFM using previously described techniques.[2,3] We will report results for both aqueous and organic solvent development of these model polymers. As part of this systematic study of LER, we have used a combination of analytic theory and computational modeling to explore the effect of material properties on LER. IBM's Blue Gene massively parallel supercomputer systems enabled us to simulate detailed models of resist materials and their development on the length scales (>1 µm) relevant for LER. For simple dissolution, LER is expected to be weakly dependent on molecular size. A simple model of resist dissolution as a surface-limited process with a finite reaction zone is showing promise as an explanation why the characteristic wavelengths of LER (typically 50- 100 nm) are larger than resist molecular dimensions (1-10 nm).

References: (1) Patrick P. Naulleau, et al.,, Proc. SPIE 7972, 797202 (2011) (2) Dario L. Goldfarb et al., J. Vac. Sci. Technol. B 22 (2), 647 (2004) (3) Yueming Hua et al., Proc. SPIE, 7971 797118-1 (2011)

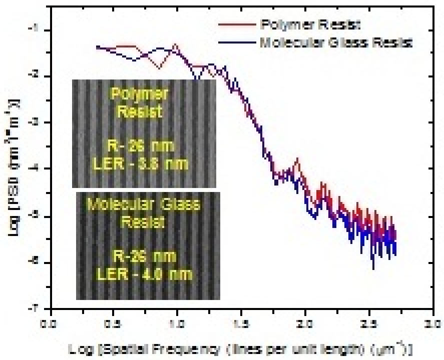

Figure 1. Power spectral density curves as well as top-down SEM images of 26 nm L/S patterns exposed with EUV Lithography

Figure 2. Resist A developed by Aqueous Developer (left) and Organic developer (right). Resist Patterning was performed at KrF

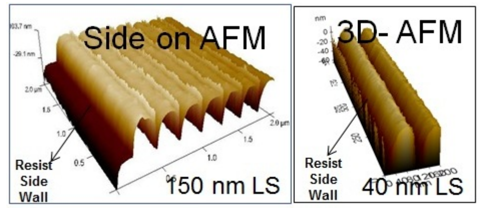

Figure 3. AFM images of resist side wall measured by side on AFM (left) and 3D-AFM (right) techniques

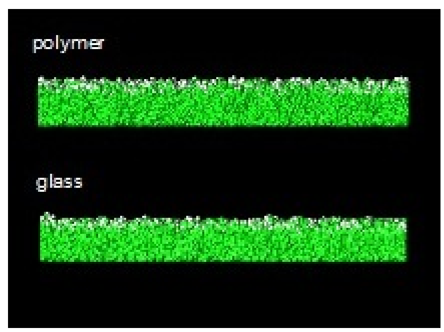

Figure 4. Resist sidewalls from simulated dissolution of mesoscale models of polymer (top, LER 2.1 nm) and molecular glass (bottom, LER 2.1 nm) resists