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Measurement of the Buried Structure of Sub-30 nm Block Copolymer Lithography Patterns Using Resonant X-ray Scattering

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The semiconductor industry is pushing the limits of conventional optical lithography. According to the ITRS roadmap, new lithographic methods will be required to economically produce the smaller patterned features of future processing generations. Technologies being evaluated to produce these finer feature sizes include extreme ultraviolet lithography, multiple-beam electron beam lithography, multiple exposures, and directed self-assembly (DSA) of block copolymers (BCPs). One of the critical questions remaining for BCP lithography is the buried structure and potential 3D defects not visible with surface characterization methods such as scanning electron microscopy and atomic force microscopy. We have combined resonant soft x-ray scattering with critical-dimension small-angle x-ray scattering (CD-SAXS) to determine the buried structure of the two blocks, the interfacial roughness, and the pitch uniformity in native BCP films with sub-12 nm features with programmed changes in the template. We found samples that had similar top surface structure often had substantial variations in their buried structure. We also found that lamella on a neutral surface were almost always different from the neighboring lamella on a preferential surface. We will discuss how these insights into the 3D structure of the block copolymer interface correspond to computational simulations of the directed self-assembly process of line-space pattern gratings.