Characterizing the latent image in block copolymer resists with x-ray diffraction

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Block copolymer self-assembly offers a simple route to pattern highly uniform nanoscale features over large areas, which is attractive for critical dimension control in integrated circuit manufacturing.[1,2] Incorporating these systems into production is potentially simple: Top-down lithography can be used to generate an epitaxial template that directs the placement of each block copolymer domain with respect to the substrate.[3] The self-assembly is speculated to heal errors in the epitaxial template, such as line width variations and line-edge roughness.[4] However, it is unclear if the shape of the block copolymer domains is deformed by the epitaxy process, or if the intrinsic roughness of these systems is too large to be manufacturable.[1,5] This paper uses x-ray diffraction measurements to characterize the structure of lamellar block copolymer resists assembled by epitaxy. The data are analyzed with a simple model that incorporates the domain shape, size, interface structure/roughness, and periodic lattice displacements. We find that the domain shapes are deformed when the dimensions of the epitaxial template are slightly incommensurate with the equilibrium block copolymer line width, producing sloped sidewalls ($\sim 2^\circ$ for 5-7% mismatch). The interface structure reflects high frequency roughness associated with single molecule displacements, and low frequency roughness (10-100 μm^{-1}) due to thermal fluctuations. The results suggest an intrinsic line-edge roughness of $3\sigma \simeq 3.5$ nm for the system investigated. We also determine that periodic displacements in the epitaxial lattice are replicated in the block copolymer resist. These lattice displacements are a consequence of noise during the top-down exposure (electron beam lithography) used to generate the epitaxial template. The amplitude and frequency of the displacement wave can be calculated from the diffraction data without any modeling, providing a fast and easy method to characterize a source of overlay errors with nanometer accuracy.

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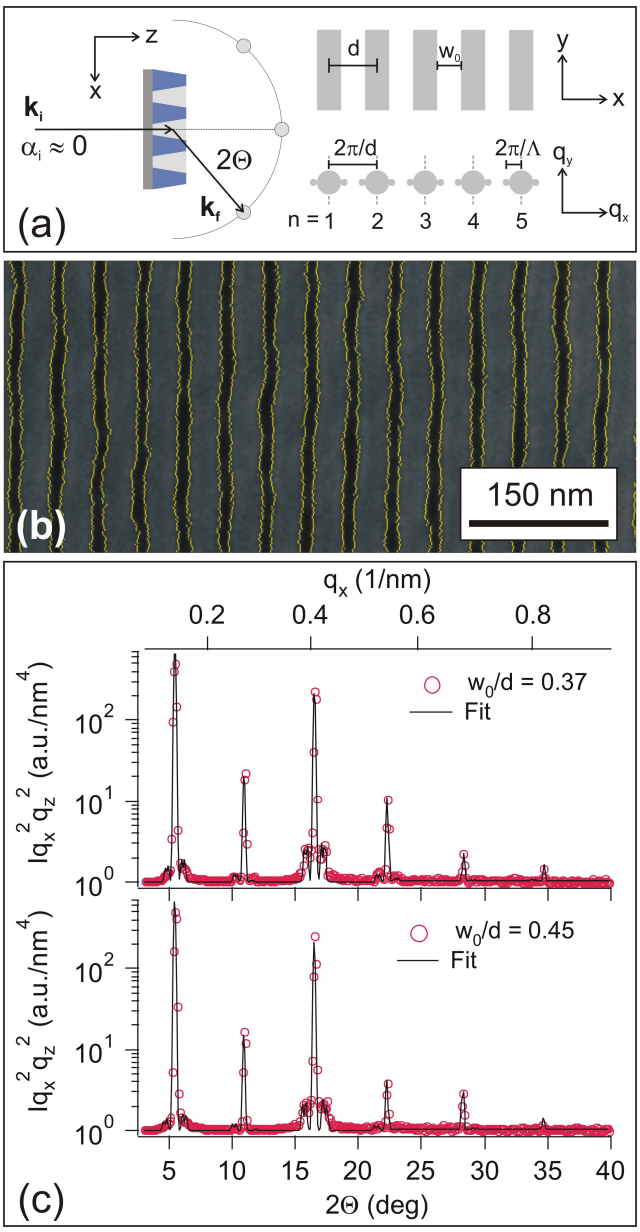

Fig. 1: (a) Illustration of diffraction geometry, and dimensions of the epitaxial template/block copolymer resist. (b) Scanning electron microscopy measurement of the lamellar block copolymer resist. Edge positions are highlighted in yellow. (c) Diffraction data from block copolymer resists assembled on epitaxial templates with duty cycles $w_0/d \simeq 0.37$ and 0.45. Solid lines are the best-fit results.