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Probing the 3-Dimensional Structure of Nanomanufactured Materials using CD-SAXS

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The realization of routine nanofabrication will demand new measurement platforms capable of probing the size, shape, internal morphology, and chemical uniformity of structures ranging from nanometers to 100's of nanometers in size. Traditional microscopies such as scanning electron microscopy and atomic force microscopy are often limited to exposed surfaces and are challenged to probe internal morphologies and structures with complex 3-dimensional shapes. We have developed a platform for non-destructive characterization of repeating nanostructures or nanostructured materials applicable to a wide range of sizes (5 to 500 nm) and materials (polymers, ceramics, and metals). Critical Dimension Small Angle X-ray Scattering (CD-SAXS) utilizes a relatively high energy, collimated x-ray beam to probe the dimensions, shape, and homogeneity of nanostructures fabricated on substrates such as silicon or quartz with sub-nm precision. CD-SAXS is capable of non-destructive measurements in real time during fabrication, providing insight into a wide range of fabrication methods. We demonstrate the wide ranging capabilities of CD-SAXS using recent data from structures created with photolithography, nanoimprint, and self-assembly. Patterns are characterized in terms of their average width, height, sidewall angle, and chemical uniformity. In addition, the distribution in orientation is quantified for self-organized systems, providing insights into the factors controlling defects. Finally, the technique is demonstrated for complex systems involving pattern directed self-assembly, such as in nanoimprinted block copolymers. In these systems, confinement between a mold and substrate prevent conventional imaging during fabrication. Real time data are used to elucidate the evolution of nanometer scale structures within 100 nm scale cavities.