Fluctuation X-ray microscopy: a novel approach for examining medium-range order in non-crystalline systems

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Measuring medium-range order is a challenging and important problem in the structural study of disordered materials. Many x-ray techniques exist to probe long- and short-range order in matter. At present no x-ray technique effectively probes medium-range order. We have developed a technique, which we call fluctuation x-ray microscopy that offers quantitative insight into medium-range correlations in disordered materials at nanometer- and larger-length scales. For FXM setup, a modified scanning transmission soft x-ray microscopy configuration was used. The technique requires coherent x-ray beam and examines spatially resolved fluctuations in the intensity of soft x-ray speckle patterns. The speckle variance depends on higher-order correlations that are more sensitive to medium-range order. Systematically measuring the coherent speckle variance as a function of the scattering vector and the x-ray spot size produces a fluctuation map that contains information about the degree of medium-range order and the correlation length. FXM is better suited for studying materials with nanometer and larger characteristic length scales. It can explore the medium-range order and subtle spatial structural changes in a wide range of disordered materials from soft matter to nanowire arrays and magnetic materials. To demonstrate this new technique at micron-length scales, we studied a model system comprised of polystyrene latex spheres. Using nanofocusing optics, we have further developed fluctuation x-ray microscopy for the study of nanomaterials. The medium-range order correlation of nanostructures self-assembled from two hybrids of PI-b-PEO/ aluminosilicates was quantitatively examined and compared by fluctuation x-ray microscopy.

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