Ultra-Small-Angle X-ray Scattering (USAXS) Imaging, Contrast Mechanism and Applications

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Ultra-Small-Angle X-ray Scattering (USAXS) imaging has been proven useful in studies of metallurgical, biological and polymeric materials. This is a size sensitive imaging technique to directly probe the morphology and three-dimensional arrangements of the small-angle scattering objects, where images acquired at different scattering vectors can reveal different microstructural features within the same sample volume. In this study, we offer a general treatment of X-ray imaging contrast for USAXS imaging. It makes use of phase propagation and dynamic diffraction theory to account for the intensity distribution in the detector plane. Simulated results from a model system of micron-sized spherical SiO_2 particles embedded in a polypropylene matrix show good agreement with experimental measurements. Simulations with an alternative geometrical ray-tracing method also account for the features in the USAXS images, and offer a complementary view of the small-angle X-ray scattering contrast mechanism. We will also present a few examples to show the capability of USAXS imaging to identify local scattering length density inhomogeneity and orientational anisotropy.