Ultrasmall-angle X-ray Scattering (USAXS) Imaging of Materials

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Discussion

USAXS imaging is a new class of x-ray imaging technique that is remarkably sensitive to the microstructures within a scattering volume. The imaging technique is derived from the scattering experiment, which makes use of a collimator crystal pair before the sample and an analyzer crystal pair after the sample to measure scattered x-rays. For imaging purposes, the analyzer is rotated to a specific angle, and the selected x-rays are used to form an angle-filtered image of the sample. Since the *only* x-rays that contribute to the image are those produced by small-angle scattering, the image is a direct map of where the USAXS is originating from within the sample. When data are acquired at several values of q, it becomes possible to extract shape and size information, even when the imaged objects are smaller than the spatial resolution of the imaging process, although determination of their location is still resolution limited. Since the image contrast does not change during sample rotations about the scattering vector (which is the vertical axis in the laboratory), combining images from two such rotations has been used to produce stereo USAXS images. In principle, a full 3-D tomographic reconstruction should also be feasible. USAXS imaging is proving useful both as an independent imaging technique and as an important adjunct to small-angle x-ray scattering generally. To date, USAXS imaging has been used successfully to investigate materials problems in metal, ceramic, polymer, and biological systems. The example shown in Fig. 1 is taken from a USAXS imaging study of a copper crack.

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FIG. 1. Image of a crack in copper metal, taken at $q = 0.0005$ Å^{-1} with 0.9-µm resolution. The incident photon energy was 8.94 keV. The microstructures near and far from the crack are the same in quality but differ greatly in quantity.