Multiscale 3D characterization with dark-field x-ray microscopy

Dark-field x-ray microscopy is a new way to three-dimensionally map lattice strain and orientation in crystalline matter. It is analogous to dark-field electron microscopy in that an objective lens magnifies diffracting features of the sample; however, the use of high-energy synchrotron x-rays means that these features can be large, deeply embedded, and fully mapped in seconds to minutes. Simple reconfiguration of the x-ray objective lens allows intuitive zooming between different scales down to a spatial and angular resolution of 100 nm and 0.001 degrees, respectively. Three applications of the technique are presented—mapping the evolution of subgrains during the processing of plastically deformed aluminum, mapping domains and strain fields in ferroelectric crystals, and the three-dimensional mapping of strain fields around individual dislocations. This ability to directly characterize complex, multiscale phenomena in situ is a key step toward formulating and validating multiscale models that account for the entire heterogeneity of materials.

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