4D Materials Science:
In Situ X-ray Synchrotron Tomography of Deformation in Metallic Materials

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The field of materials science and engineering (MSE) is based on the fundamental principle that microstructure controls properties. Traditionally, the study of material structure has been limited by two dimensional (2D) imaging techniques. This approach is often inaccurate or inadequate for solving many cutting-edge problems. It is also often laborious and time-consuming. Advances in experimental methods, analytical techniques, and computational approaches, have now enabled the development of three dimensional (3D) analyses. The study of 3D microstructures under an external stimulus (e.g., stress, temperature, environment) as a function of time (4D) is particularly exciting. Examples include an understanding of time-dependent deformation structures, phase transformations, compositional evolution, magnetic domains, etc. Furthermore, advances in 3D and 4D computational tools and methods have enabled the analysis of large experimental data sets, as well as simulation and prediction of material behavior.

X-ray synchrotron tomography provides a wonderful means of characterization damage in materials non-destructively. In this talk, I will describe experiments and simulations that address the critical link between microstructure and deformation behavior, by using a three-dimensional (3D) virtual microstructure obtained by x-ray synchrotron tomography. The approach involves capturing the microstructure by novel and sophisticated *in situ* tensile testing in an x-ray synchrotron, followed by x-ray tomography and image analysis, and 3D reconstruction of the microstructure. Quantitative analysis and incorporation of the microstructure into a powerful finite element modeling code for simulation can also be conducted. Case studies on fundamental deformation phenomena in metal matrix composites and Sn-based alloys will be presented and discussed.