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Continuous in situ high-resolution digital image correlation during SEM microtensile testing

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Abstract

Digital Image Correlation (DIC) is a powerful tool to quantify deformation by mapping surface displacement and strain fields. When implemented at high resolution in the scanning electron microscope, termed as HR-DIC, it can reveal how plasticity initiates and localizes at the micro- and nanoscale, through events such as crystallographic slip, grain boundary sliding, and shear banding. However, most SEM-based HR-DIC studies remain quasi in situ (interrupted): maintaining stable, fast, and high-magnification imaging during continuous loading is technically demanding. The required field of views are typically too large for continuous imaging since there is no prior knowledge on where the most interesting deformation events will occur. Here we present a methodology enabling truly continuous HR-DIC during quasi-static microtensile deformation in the SEM. Continuous strain mapping is achieved by combining: (i) optimized electron-beam-induced deposition of high-contrast Pt nanoscale speckle patterns compatible with short exposure times and elevated frame rates, (ii) focused ion beam (FIB) fabrication of micrometer-scale freestanding tensile specimens designed to keep the region of interest within a small SEM field of view throughout loading, and (iii) automated SEM remote-control routines that enables synchronized, stable and flexible high-magnification image acquisition during microtensile loading. We demonstrate the approach on two material classes relevant to nanomechanics. For single-crystal Nb microtensile specimens, the continuous HR-DIC strain fields capture the gradual onset and propagation of slip localization. We apply a recently developed local slip system identification methods (SSLIP) on the deformation fields to provide insights into the evolution and interactions of various slip systems. For multilayer thin-film nano-laminated microtensile specimens, continuous HR-DIC provides robust tracking of elastic and plastic deformation while accounting for evolving cross-section and gauge geometry, enabling a true stress–strain description rather than relying on nominal values. Overall, this workflow improves temporal resolution and quantitative fidelity in SEM microtensile HR-DIC measurements, supporting mechanistic interpretation and more accurate constitutive assessment. The method is broadly applicable to micro-/nanostructured materials where coupling high-resolution experiments with mechanistic or modelling frameworks is essential.

Keywords:

HR-DIC microtensile testing slip system identification digital image correlation strain localization