Method for Extracting True Strain & Stress from TEM in situ Compression Testing

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The purpose of this study is to demonstrate an automated method for determining the true stress-strain relationship and strain hardening coefficient from transmission electron microscopic (TEM) in situ compression pillar tests. TEM in situ compression tests have been increasingly used to investigate plastic behavior of irradiated materials. The technique is capable of measuring yield strength and elastic modulus of an electron-transparent specimen, while offering the distinct advantage of concurrent real-time observation of plastic phenomena. Many reports in the literature have studied the effect of barreling and sample taper on the true stress-true strain, yet it remains difficult to implement these considerations into analysis of TEM in situ compression testing results because of the need for real-time pillar geometry measurements. TEM test output is typically comprised of the load and displacement at each time step. To simplify this task, we design a two-part analytical tool in Matlab™ for post-processing the compression videos. First, an edge tracking tool measures the average distances between multiple pairs of points on both edges of a compression pillar, in each frame of the video. Next, the tool combines the real-time pillar widths with the pillar height and thickness and the load-displacement data measured during the compression test, to determine the true strain and true stress. The strain hardening coefficient is subsequently found by fitting to the plastic portion of the true stress-strain. This presentation will demonstrate these analytical tools on compression pillars of an Fe-9%Cr oxide dispersion strengthened (ODS) alloy irradiated with Fe2+ ions to 3 and 100 dpa (displacements per atom) at 500°C, and nanocrystalline Cu-10Ta (an immiscible model ODS system) irradiated with protons to 1 dpa at 500°C. The strain hardening coefficients range from -0.17 to 0.35, based on the degree of barreling observed in each pillar.