A New Method for TEM *in situ* Tensile Testing of Ion Irradiated Alloys

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The objective of this work is to demonstrate a novel method for transmission electron microscopic (TEM) *in situ* tensile testing of near-surface ion irradiated layers in metallic alloys. Depth-sensing TEM *in situ* mechanical testing offers unprecedented advantages for understanding fundamental deformation mechanisms in materials because nanoscopic, electron-transparent material volumes can be tested. This approach is especially attractive for testing irradiated materials, because it allows one to create a mechanical test specimen contained entirely within the nanoscale ion irradiation damage layer. TEM *in situ* tensile testing configurations have been widely utilized for nanowires and nanotubes, because of the uniaxial loading, stress uniformity, and ability to evaluate ductility and elongation. However, producing TEM *in situ* tensile test specimens from irradiated alloys is a considerable challenge, because of the complex and extensive focused ion beam (FIB) machining and micromanipulation required.

In this work, we will present a simplified FIB lift-out method, requiring no micromanipulation, enabling site-specific fabrication of push-to-pull (p2p) TEM *in situ* tensile beams. We will demonstrate the method on 5 MeV Fe^{2+} irradiated binary Fe-*x* (*x* = P, N, Mn, Cr, or Mo) alloys. Regions of interest are identified by electron backscatter diffraction (EBSD), or can be selected randomly. Conventional FIB trenching and lift-out are used to extract lamellae approximately 8 um x 2.5 um x 2 um, and the Pt deposits are removed by milling. The lamellae are laid across the gap of a Si p2p device, with the 8 um dimension spanning the p2p gap and the 2.5 um dimension oriented to the eventual TEM electron beam. The p2p-mounted lamella is thinned to electron transparency, then shaped to the desired width. Specimens are tested within a Hysitron PI-95 Picoindenter using a 100 μm flat punch to apply load to the p2p device. TEM resolution videos reveal dislocation slip activity during loading, and a real-time stress-strain curve is generated during the tensile testing. The effects of irradiation on tensile bar performance will also be discussed.