INVESTIGATING THE EFFECT OF SOLUBLE HYDROGEN ON PLASTICITY IN LOW-SYMMETRY a-URANIUM

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Hydrogen embrittlement is a long-standing metallurgical challenge observed in numerous metallic systems, including uranium, when exposed to hydrogen-containing environments. Unlike more common engineering alloys (e.g. steel, aluminum) that exhibit several concurrent deformation mechanisms, alpha-uranium has a low symmetry (orthorhombic) crystal structure that accommodates strain by mechanisms limited by crystallography or temperature. This attribute makes uranium advantageous for studying fundamental mechanisms of hydrogen degradation from a different point of view than is offered by traditional cubic structural metals.
To examine the effect of hydrogen on plasticity in orthorhombic alpha uranium, compression specimens were machined with the loading axis parallel either to the through thickness (TT) direction or within the rolling plane (RP), which exhibit different crystallographic textures as shown in Figure 1. All samples were exposed to a 3-hour heat treatment at 630 °C, where H-charged samples were exposed to vacuum at temperature for 2 hours, followed by introduction of 99% argon 1% hydrogen gas, and finished with a water quench. Uncharged samples remained in vacuum the entirety of the 3 hours followed by a water quench. Compression testing has yielded intriguing macroscale results, shown in Figure 1. Specifically, pre-charging with 1.8 wppm hydrogen did not significantly alter the macroscopic stress-strain response of samples with RP texture but did increase strength of samples with TT texture. Characterization by electron backscatter diffraction (EBSD) has also revealed a significant reduction in twin fraction in samples charged with 1.8 wppm hydrogen. Further, analysis of stress relaxation tests along the through thickness direction suggest hydrogen-induced changes in deformation substructure and subsequent resistance to defect motion.

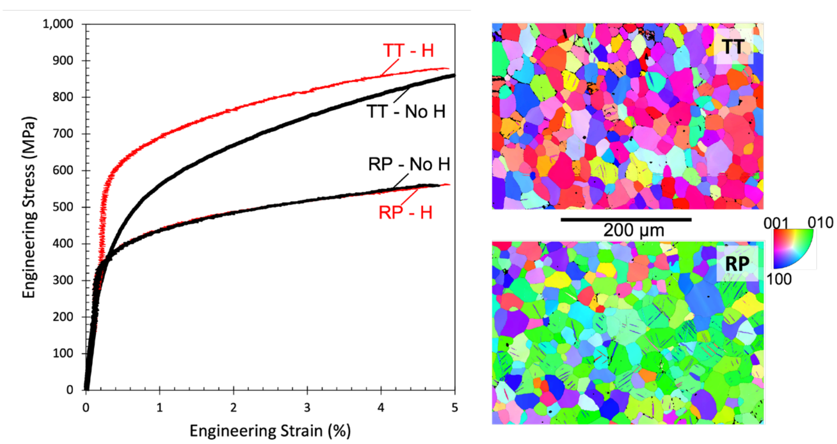

Figure 1 (left) Engineering stress strain curves for TT and RP samples with 1.8 ppm hydrogen and without hydrogen. (right) EBSD Inverse pole figure maps from the TT (top) and RP (bottom).

Advanced characterization, coupled with plasticity modeling feasibility studies, are currently underway to characterize the observed reduction in twins due to hydrogen charging. The parallel modelling effort is assessing if current model frameworks can effectively complement existing experimental data. The fundamental mechanistic understanding acquired with unalloyed uranium can be extended to interpreting experiments in more common engineering metals. Elucidating fundamental mechanisms by which hydrogen affects deformation is critical for predicting and controlling material degradation during extended lifecycles in harsh environments.