Hydrogen Corrosion of α-Uranium Observed by Transmission Electron Microscopy

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In order to accurately predict the behavior of uranium metal parts at all stages of their life cycle—manufacture, storage, use, and disposal—it is important to have a complete understanding of the corrosion properties of those metal parts. For hydrogen corrosion of uranium in particular, the processes involved are still largely considered stochastic in nature, which simply means (as history shows us) that there is not enough data to fully describe these processes in a predictable way. Indeed, of the many studies investigating this topic to date, the overwhelming majority rely solely on surface information from bulk materials. This surface information is generally in the form of visible-light or scanning-electron micrographs recorded at magnifications far too low to capture the onset of hydride phase interaction with the surface, and by definition excludes any sub-surface information that may be critical to understanding the conditions that favor the nucleation of the hydride phase.

In this work, surface characterization was linked to sub-surface microstructural features of uranium hydride formed in a depleted uranium pellet aged for over nine years in a controlled atmosphere totaling 200 torr, with an initial H_2 partial pressure of 5 torr and the balance He. Hydride formation was in the late stages of the induction period in this sample and intersections of the hydride phase with the sample surface were easily-identifiable. Cross-sections of the hydride structures were prepared using a dual-beam focused ion beam (FIB)/scanning electron microscope (SEM) and examined in greater detail in the (scanning) transmission electron microscope (S/TEM). Electron diffraction revealed that the hydride habit planes coincided exclusively with twin planes in uranium metal. Furthermore, electron energy-loss spectroscopy (EELS) maps generated in STEM mode were used to distinguish the hydride phase from the metal without resolving the hydrogen core loss. Rather, multiple-linear least-squares fitting of the near-edge fine structure of the $O_{4,5}$ uranium edge at 96 eV was sufficient to map the hydride and metal phases. By observing perturbations in the electronic structure of the uranium metal, it is anticipated that direct observation of hydride nucleation events during an in-situ STEM gas-cell experiment is possible.