IMAGING HYDROGEN INTERACTIONS WITH MATERIALS AT THE NANOSCALE: SIMS-BASED CORRELATIVE MICROSCOPY

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Hydrogen embrittlement degrades the mechanical properties of steel and other alloys impacting their durability and occasionally resulting in catastrophic consequences [1]. Clear understanding of the local hydrogen-metal interaction mechanisms will help to identify the most effective strategies to mitigate or eliminate the degradation of mechanical properties. While high-resolution electron microscopy is suitable for imaging materials even at the atomic scale, direct imaging of hydrogen in solid materials with nanoscale lateral resolution is a challenge for the typical analytical techniques available on an electron microscope. Secondary Ion Mass Spectrometry (SIMS) is capable of detecting all elements (and isotopes) of the periodic table including hydrogen, but the lateral resolution of SIMS imaging is fundamentally limited to ~ 10 nm by the ion-solid interaction volume. In practice, the lateral resolution of SIMS imaging is often poorer than the fundamental limit because of insufficient ionization efficiencies of the sputtered species and/or too low concentrations of the elements imaged for a given voxel size. In the context of combating hydrogen embrittlement, nanoscale precipitates may be dispersed within the matrix to act as hydrogen traps, making it essential to correlate nanoscale structures (e.g., precipitates) with hydrogen maps. To overcome this challenge, we use a correlative microscopy approach combining electron microscopy and high-resolution dynamic SIMS imaging [2, 3]. As the hydrogen in steels and other metallic alloys is highly mobile, advanced experimental protocols are needed to obtain accurate hydrogen maps in steels. Hence, we started with relatively easier cases where hydrogen is bound to the sample such as in passivating layers in solar cells [4] and hydrogen storage materials [5] in order to optimize the SIMS image acquisition protocols. We then proceeded to investigate the correlation between microstructure and hydrogen trap sites in a TWinning Induced Plasticity (TWIP) steel in both the as-received and annealed states. With these case studies, we will present the challenges and opportunities in SIMS based correlative microscopy to directly visualize hydrogen-metal interactions with nanoscale lateral resolution.

References:

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