Environmental Degradation and Mechanisms of Multi-Principal Element Metallic Materials

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Abstract

Multi-principal element high-entropy alloys (HEAs) have emerged as promising candidates for next-generation structural materials owing to their unique compositional design and excellent combination of mechanical strength and corrosion resistance. However, their hydrogen embrittlement behavior and underlying mechanisms remain to be fully clarified. In this work, we systematically investigated the mechanical properties and failure behavior of multi-component HEAs in hydrogen-containing environments, based on our group's recent research. By employing in-situ hydrogen charging tensile tests, slow strain rate tests, transmission electron microscopy, and three-dimensional atom probe, we revealed the diffusion, accumulation, and trapping mechanisms of hydrogen in HEAs. Combined with first-principles calculations and molecular dynamics simulations, the effects of alloying composition, lattice distortion, and multiscale defects on hydrogen embrittlement susceptibility were elucidated. The results demonstrate that appropriate multi-element alloying can introduce diverse hydrogen trapping sites, retard crack propagation, and thus effectively improve HE resistance. This study provides both theoretical insights and experimental evidence for the design of high-strength, hydrogen-resistant HEAs.

Keywords: hydrogen embrittlement; high-entropy alloys; microstructure; environmental degradation