Impact of mobile hydrogen on the plasticity of bcc FeCr alloys via in situ micropillar compression

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Abstract

A key challenge in understanding hydrogen-induced mechanical degradation of materials is the role of mobile hydrogen. Currently, most studies rely on post-mortem analysis of ex-situ hydrogen charged probes. These approaches often overlook the behavior of mobile hydrogen, including its desorption, migration and release during mechanical testing. To advance our understanding of the hydrogen interactions with metals, it is essential to investigate its effects at the microstructural scale, where embrittlement initiates, while maintaining a continuous hydrogen supply.

We developed an in-house, *in situ* backside hydrogen charging setup, assembled inside a standard nanoindentation device where the testing sample remains isolated from direct electrolyte contact (1). Using specific hydrogen charging protocols, we investigated the effects of mobile hydrogen on ferritic Fe-20 wt.% Cr alloys with varying dislocation densities. This setup enables time-resolved measurement of nanoindentation-related mechanical properties, shedding light on the hydrogen diffusion behavior through the studied materials (2). For the case of micropillar compression, the presence and spatial distribution of mobile hydrogen on the micropillar surface is verified using scanning Kelvin Probe force microscopy. The hydrogen content in the FeCr alloys is quantitatively assessed through thermal desorption spectroscopy, providing valuable insights into hydrogen uptake and retention characteristics as a function of Cr content, dislocation density and grain size. In addition, microstructure analyses are performed before and after mechanical testing (3).

Our results show that mobile hydrogen induces strain hardening, correlating with an increased dislocation density observed via scanning transmission electron microscopy. In addition, hydrogen promotes the formation of a cellular structure compared to uncharged reference samples, which was observed in micropillars with a (110) grain orientation. The consequences of these findings will be discussed to provide new insights into hydrogen embrittlement mechanisms.

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References

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