FORMATION AND DEFORMATION OF HYDRIDES IN TITANIUM

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Titanium and its alloys, known for their strength-to-weight ratio and corrosion resistance, are widely used in the aerospace and biomedical industries [1]. Commercially pure alpha-titanium is a desirable material in a wide array of applications due to its resistance to corrosion in various aggressive environments, such as seawater, bodily fluids, etc [2]. However, titanium has a high affinity for hydrogen, making it susceptible to failures from stress corrosion cracking, especially due to the formation of hydrides [3]. A challenge in studying hydride behavior in titanium is the difficulty in preparing hydride-free specimens. This makes it difficult to understand the mechanisms behind hydride formation and deformation. In this research, state-of-the-art were used to uncover some of these mechanisms. Cryogenic sample preparation with focused ion beam and atom probe tomography were used to analyze the segregation and partitioning behavior of hydrogen and trace elements in a commercially pure titanium sample. It was found that the presence of beta-stabilizing elements, such as Fe, can lead to the formation of small beta-phase precipitates which can increase the hydrogen concentration in the alpha phase and cause hydride formation. In this regard iron exhibited promoted the formation of hydrides by indirectly increasing the ingress of hydrogen from the beta precipitates and interaction of H with the alpha phase at the alpha/beta boundaries, Figure 1. Subsequently, high-energy X-ray diffraction was used to investigate the deformation of hydrides in a hydrogen-charged sample. The results showed that hydrides have a platelet morphology with high internal and interphase stresses due to the associated volumetric expansion. During the deformation, the hydrides exhibit a typical high strength but brittle secondary phase behavior, which undertakes more elastic strain than the matrix and is the location where cracks are first generated. Interestingly, the δ-hydrides sustain larger strains than the matrix, especially after the matrix yields.

This study provides insight into the hydride formation and deformation behavior during hydrogen embrittlement of titanium and highlights the importance of cryogenic sample preparation and in situ analysis methods for collecting high-fidelity data as a path toward improving understanding of hydrogen embrittlement. The findings are likely applicable to zirconium and other hydride forming refractory metals as well.

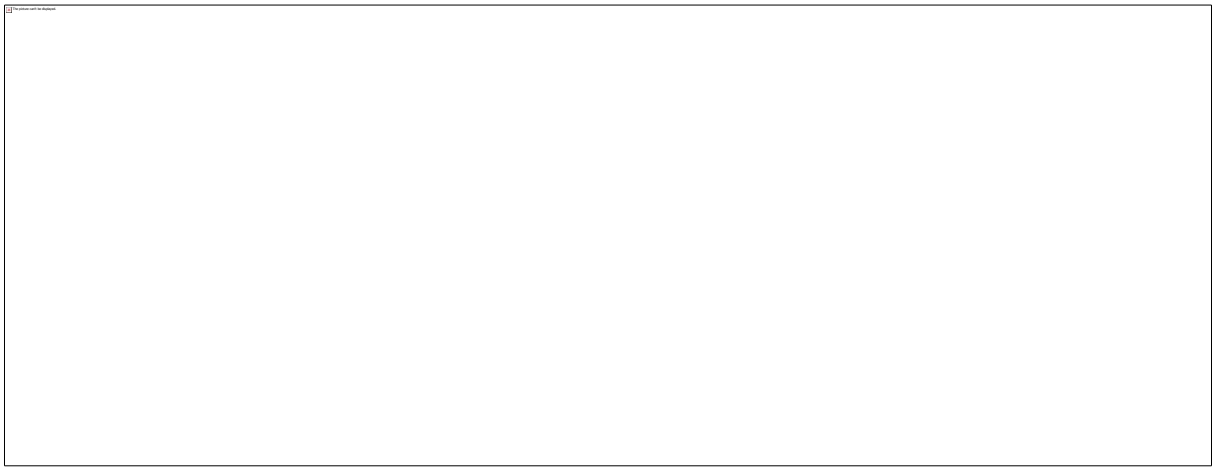

Figure 1. Atom probe analysis of the grain and phase boundary elemental segregation and a proposed mechanism for the ingress of H and subsequent TiH_x formation in Grade 2 CP-Ti.

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[2] I. V. Gorynin, Materials Science and Engineering A 263 (1999), 112–116. doi: 10.1007/978-3-540-73036-1
[3] Y. Chang et al., Scripta Materialia 178 (2020), 39–43. doi: 1 0.1016/j.scriptamat.2019.11.010