HYDROGEN ISOTOPE RETENTION BEHAVIOR IN WTAVCR HIGH-ENTROPY ALLOY FOR FUSION APPLICATIONS

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Plasma-facing materials (PFMs) in fusion reactors endure extreme environments, including high thermal loads, neutron irradiation, and plasma exposure. While tungsten (W) is the primary PFM candidate, it is susceptible to irradiation damage and recrystallization, leading to irradiation embrittlement and high-temperature mechanical degradation. In contrast, high-entropy alloys (HEAs) exhibit superior properties, such as enhanced irradiation resistance and high-temperature mechanical stability [1][2], making them promising alternatives. However, hydrogen isotope retention in PFMs remains a critical issue for steady-state plasma control, fuel cycling, and radiation safety. Despite the potential of HEAs, their hydrogen retention behavior, particularly after high-energy particle irradiation that induces phase segregation [3], has not been fully characterized. This study systematically investigates hydrogen isotope retention in a WTaVCr quaternary HEA, focusing on phase-dependent retention characteristics following irradiation-induced phase segregation.

A three-phase WTaVCr multi-component alloy, consisting of a WTaVCr HEA phase and two Cr-rich phases (Fig. 1), was selected to investigate phase-dependent hydrogen isotope retention. Deuterium (D) charging was performed at 900°C for 10 hours in a quartz tube under a 10^5 Pa D_2 atmosphere. After charging, specimens were analyzed using X-ray diffraction (XRD), followed by thermal desorption spectroscopy (TDS). Both D charging and TDS measurements were conducted using the gas-driven permeation/retention system at the University of Science and Technology of China.

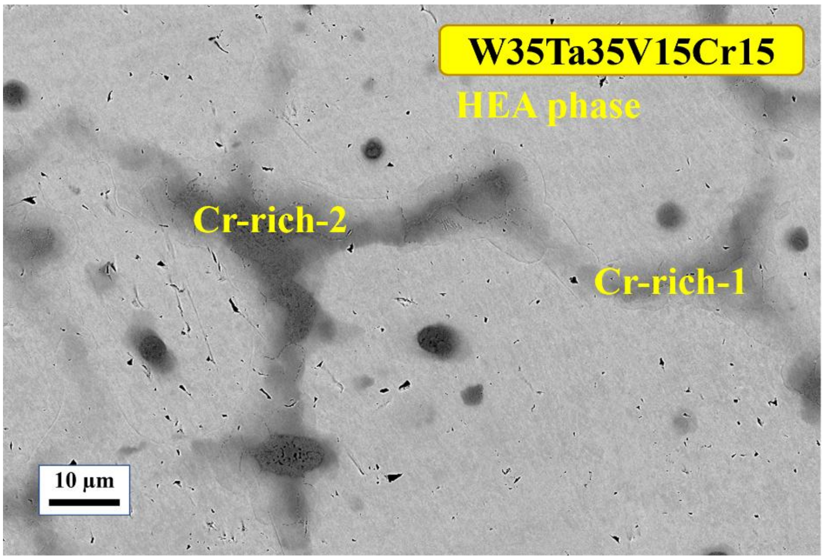

Figure 1 Microstructure of WTaVCr multi-component alloy

XRD analysis demonstrated phase-dependent differences in D retention, with lattice expansion observed in all phases post-D charging. The WTaVCr HEA phase exhibited the most pronounced lattice expansion. In contrast, the Cr-rich phase showed the least (Fig. 2a), confirming a strong correlation between hydrogen retention and phase composition. A lattice distortion-concentration correlation model[4] enabled quantitative analysis of hydrogen isotope uptake in individual phases and volume changes induced per hydrogen atom. TDS analysis further revealed significantly higher deuterium retention in WTaVCr multi-component alloy compared to W [4] (Fig. 2b). These findings provide crucial insights into phase-dependent hydrogen retention in HEAs, advancing the understanding of their potential as plasma-facing materials in fusion reactors.

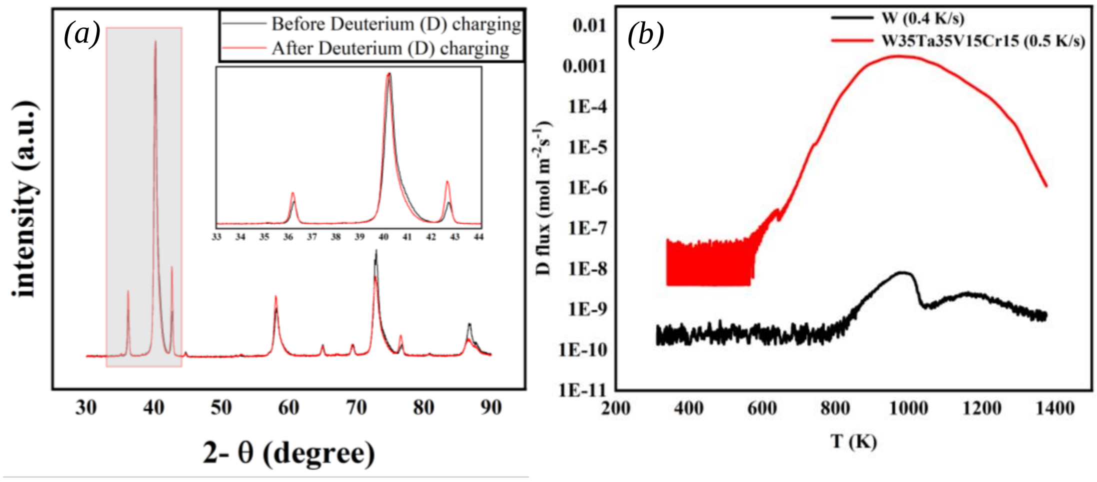

Figure 2 (a) XRD patterns of WTaVCr multi-component alloy before and after deuterium charging; (b) TDS analysis of WTaVCr multi-component alloy and W deuterium retention[4]

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