Hydrogen isotope retention in W-based high entropy alloys

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Abstract
Refractory high entropy alloys are a new class of materials that exhibit favorable mechanical properties at high temperatures over standard alloys. In this study, the hydrogen isotope retention properties of Tungsten (W) based high entropy alloys were studied with the purpose of evaluating their suitability as possible plasma facing materials in future fusion reactors.

Keywords: Tungsten, High Entropy Alloy, Hydrogen retention

1. Introduction

Refractory high entropy alloys (HEA) or multi-component alloys exhibit enhanced mechanical strength at high temperatures with improved wear and oxidation resistance, fatigue and high-temperature fracture resistance, good thermal stability and toughness [1]. Such properties make them attractive plasma facing materials (PFM) from the viewpoint of power handling in the divertor region of fusion reactors. However, PFMs must meet the additional constraint of low tritium inventory. To date, Tungsten (W)- based high entropy alloys are composed of elements that are exothermic (Ta, Ti, V) absorbers of hydrogen in comparison to the endothermic properties of W. This raises the possibility of enhanced hydrogen retention in such W-based HEAs. In this study, we clarify the hydrogen retention properties of two types of W-based HEAs (WTaVCr, WTaVCrTi) and the effect hydrogen retention has on the mechanical properties of such alloys.

2. Experiments

Two types of HEAs were irradiated with 1 keV Deuterium (D) ion beam up to a fluence of 10^{24} D/m^2 over temperature range 500-800 K. For comparison purposes, pure elements of W, Ta, V, Cr, Ti were also irradiated under identical conditions. Deuterium retention was measured by thermal desorption spectroscopy (TDS). Mechanical property changes following D-irradiation were examined by nano-indentation.

3. Results and Conclusion

Deuterium retention in W-based HEAs is 3 to 4 order of magnitude higher than pure-W. After D irradiation at T < 600 K, WTaVCrTi and WTaVCr alloys retain nearly 100% and 10% of the implanted D, respectively. TDS data reveals one broad release peak centered at ~800 K. After D irradiation at 800 K, the retention amount decreases to 10% and 1% of the implanted D, respectively. HEAs containing Ti show additional hydrogen release extending up to ~1200 K – similar to the behavior observed in pure Ti. However, despite the large increase in hydrogen retention in W-based HEAs, the changes to Young's modulus or hardness are limited (~20%). In conclusion, W-based HEAs have the potential of enhanced mechanical properties in comparison to pure-W materials, but it comes at a cost in increased hydrogen retention due to the exothermic properties of the alloying principal elements. Use of W-based HEAs as PFMs would likely require alloying exclusively with endothermic principal elements.

References

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