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Effect of annealing and damaging by heavy ions of W-Cr-Y alloy on deuterium retention and structure change

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Safety of fusion reactor is one of key issues. In the case of loss-of-coolant accident (LOCA) with simultaneous air ingress, W-10wt%Cr-0.5wt%Y alloy was developed as a plasma-facing material with an increased resistance to oxidation [1]. To study the effect of structure on the deuterium retention and improve the properties of this alloy to neutron irradiation, the annealing of the W-Cr-Y alloy at 1273 and 1473 K for 3 hours has been performed. After annealing at 1273 K, (aCr) phase was formed. However, the formation of this phase was not observed after annealing at 1473 K. Both annealing at 1273 and 1473 K resulted in a decrease in the mean size of grains and yttria particles. An increased D retention in both initial and annealed W-Cr-Y alloys compared to pure W was measured. The correlation between the structure of the alloy and D retention was established. It was found that increasing of both grains and yttria particles leads to increasing the D retention.

Irradiation of the promising alloys W-Cr-Y before and after annealing and pure W has been performed with 5.6 MeV Fe ions at 500C to the dose peak of 12 dpa. Atom probe tomography (APT) and transmission electron microscopy (TEM) methods have been used for study the chemical compositions at the atomic scale in the alloy before and after irradiation. The formation of nanoscale clusters enriched with Cr (78 at.%) of the mean size of (1.8± 0.4) nm with a density of (3-6.3)x1024m-3 and in the case of initial W-Cr-Y alloy and the alloy annealed at 1273 K, respectively, were measured in the damage region. Beyond the damage region, Cr clusters were not observed.

Significant increase in the D retention in pure W and small increase in the D retention in as-received W-Cr-Y alloy after pre-irradiation with heavy ions simulating n-irradiation was found. Moreover, the D retention at radiation-induced defects in W-Cr-Y alloy is lower than that in W. It was found that D is trapped at defects formed by radiation-induced Cr clusters in W-Cr-Y alloy (dislocation loops were not observed by TEM) as observed by APT. While D is trapped at radiation-induced vacancy-type of defects in W (as well as in dislocation loops). Tritium removal from damaged W requires higher temperature than from as received damaged W-Cr-Y alloy. A new radiation resistance two phase W-Cr-Y alloy produced by annealing of the as-received alloy at 1273 K for 3 hours was developed. Further work is required to study alloy properties after annealing at elevated temperatures and irradiation with heavy ions at various elevated temperatures

References:
[1] A. Calvo et al., Self-passivating tungsten alloys of the system W-Cr-Y for high temperature applications, Int. J. Refract. Met. H. 73 (2018) 29–37, https://doi.org/10.1016/j.ijrmhm.2018.01.018

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