Contribution ID: **512** Type: **Oral**

Precipitation of transmutant elements in neutron irradiated tungsten

Tuesday 6 June 2017 12:00 (20 minutes)

As the leading plasma facing material in fusion reactors, tungsten is confronted with extremely hostile environment, characterized by high temperature, and high fluxes of heat and particles (i.e., D, T, He, and neutrons). One of the primary concerns is the generation of transmutation elements (i.e., Re, Os) and the subsequent radiation-induced segregation and precipitation, and the resulting thermomechanical property degradation induced by the 14 MeV-peak neutron irradiation. In this study, we have used advanced electron microscope methods to explore the response of tungsten to high dose neutron irradiation in the High Flux Isotope Reactor, focusing on the detailed characterization of irradiation-induced W-Re-Os precipitates in polycrystalline tungsten through TEM, X-ray mapping in STEM, multivariate statistical analysis data-mining of the X-ray data and transmission Kikuchi diffraction. The association of voids and precipitates, the chemical compositions, crystal structures and phases of precipitates along the grain boundary and within the grains were identified. The results showed that the intragranular precipitates are sigma-phase while the precipitates along the grain boundaries are chi-phase. The kinetics process of transmutant elements and radiation defects were briefly discussed to reveal the formation process of the observed precipitates.

In addition, we also investigated the hardening contribution of W-Re-Os precipitates. A dispersed barrier hardening model informed by the available microstructure data was used to predict the hardness. The results indicated that the formation of intermetallic second phase precipitate dominant the radiation-induced strengthening with a relatively modest dose (>0.6 dpa). The hardening strength factor of the transmutation-induced precipitates was also determined to be 0.6.

The work presented in this paper was partially supported by Laboratory Directed R&D funds at ORNL. The research was also sponsored by the US Department of Energy Office of Fusion Energy Science under grants DE-AC05-00OR22725 with UT-Battelle LLC and by the US-Japan PHENIX project under contract NFE-13-04478, with UT-Battelle LLC.

Eligible for student paper award?

No

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Session Classification: T.OA2: Divertors and PFCs: Tungsten

Track Classification: Plasma facing components