# Predicting the mechanical behaviour of tungsten in a fusion environment

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Tungsten is the leading candidate material for plasma facing components in future fusion devices. In this environment tungsten will be exposed to high neutron fluxes (up to 14 MeV energies) that will cause both chemical changes through transmutation and displacement damage. This will lead to hardening and potentially embrittlement, limiting the lifetime of tungsten in a reactor. Neutron irradiation of single crystal tungsten to 1.7 dpa has been carried out in the Petten test reactor with a thermal neutron spectrum. Transmutation of tungsten to rhenium was also measured using energy dispersive x-ray spectroscopy. This was found to match the levels predicted by modelling, using inventory code FISPACT, at 1.4 wt% Re. This is similar to the levels of transmutation expected in a fusion neutron spectrum after ~18 months [1].

Self-ion irradiation has been carried out on tungsten and a tungsten rhenium alloy to 1.6 dpa to simulate the neutron irradiation, but without activation of the samples. The presence of rhenium was shown to increase irradiation hardening from 2 GPa to 10 GPa. This accounts for some previous discrepancies in the literature for irradiation hardening following ion and neutron irradiation [2-5].

The mechanical behaviour following ion irradiation has also been analysed using in-situ micro-pillar compression, carried out using a Hysitron PI 85 Picoindenter at UC Berkeley. Unirradiated tungsten and tungsten rhenium, and irradiated tungsten, all showed the same behaviour and similar yield stresses, however the irradiated tungsten rhenium again showed a significant increase in yield stress, and showed a shift to more localised deformation. This shows the presence of rhenium must be considered when studying radiation damage in tungsten for fusion applications.

Transmission electron microscopy with energy dispersive x-ray spectroscopy has been carried out on the samples to examine the differences in microstructure following neutron and ion irradiation, and to examine the effect of rhenium on defect formation and growth. This has shown the suppression of loop growth due to the presence of rhenium, with some evidence of sub grain formation after ion irradiation conditions.

[1] M. Gilbert and J.C. Sublet, 2011 *Nuclear Fusion* Vol 51 Issue 4
[2] R. Abernethy 2017 *Materials Science and Technology* Vol 33 Issue 4
[3] T. Tanno et al. Mater. Trans., 2007, 48, (9), 2399–2402
[4] J. He et al. Nucl. Fusion, Nov. 2006, 46, 877–883
[5] D.E.J. Armstrong et al. J. Nucl. Mater., Jan. 2013, 432, 428–436.

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