**Radiation Damage in Tungsten Literature Critique**

**2016 Radiation damage Course work**

Tungsten will almost certainly be used as the plasma facing material in any future fusion device. During operation it will see an intense flux of high energy neutrons as well as lower energy alpha particles. As such the tungsten will be physically altered, by both displacement damage and transmutation.

There is a reasonable amount of work on the effect of ion (heavy, light and proton) irradiation to mimic neutron damage in tungsten, some work on neutron damage from fission reactors in tungsten and much modelling of radiation damage in tungsten. However none of this work (Obviously!) perfect mimics a fusion environment.

Your task is to critically review some of this work. **The aim is to identify weaknesses in the work carried out so far, gaps in the literature and suggest future research directions to allow a better understanding of radiation damage in tungsten as needed for a DEMO style reactor.** This should take the form of a report of between 3000 and 5000 words written in the style of a lit review paper (properly referenced, reproduce figures from papers as required etc)

Any questions email me david.armstrong@materials.ox.ac.uk

The following papers will be a good starting point (but you are free to use any others you find)

* Predicting the performance of tungsten in a fusion environment: a literature review R.G. Abernethy <http://dx.doi.org/10.1080/02670836.2016.1185260>
* Neutron-induced transmutation effects in W and W-alloys in a fusion environment M.R. Gilbert and J.-Ch. Sublet 2011 Nucl. Fusion 51 043005
* Hardening of Self Ion Implanted Tungsten and Tungsten 5-wt% Rhenium DEJ Armstrong, X Yi, EA Marquis, SG Roberts Journal of Nuclear Materials 432 (1-3), 428
* Ion-irradiation induced clustering in W-Re-Ta, W-Re and W-Ta alloys: An atom probe tomography and nanoindentation study A Xu, DEJ Armstrong, C Beck, MP Moody, GDW Smith, PAJ Bagot, Acta Materialia 124, 71-78
* Effect of neutron irradiation on the microstructure of tungsten M Klimenkov, U Jäntsch, M Rieth, HC Schneider, DEJ Armstrong, Nuclear Materials and Energy
* Ion-irradiation-induced clustering in W–Re and W–Re–Os alloys: A comparative study using atom probe tomography and nanoindentation measurements A Xu, C Beck, DEJ Armstrong, K Rajan, GDW Smith, PAJ Bagot, Acta Materialia 87, 121-127
* Neutron irradiation effects on the microstructural development of tungsten and tungsten alloys Journal of Nuclear Materials Hasegawa et al. Volume 471, 1 April 2016, Pages 175–183
* Property change mechanism in tungsten under neutron irradiation in various reactors Akira Hasegawa , Takashi Tanno, Shuhei Nogami, Manabu Satou Journal of Nuclear Materials 417 (2011) 491–494
* High temperature indentation of helium-implanted tungsten JSKL Gibson, SG Roberts, DEJ Armstrong Materials Science and Engineering: A 625, 380-384
* The effect of 800 MeV proton irradiation on the mechanical properties of tungsten at room temperature and at 475 °C S.A. Maloya, M.R. Jamesb, W. Sommer Jr.c, G.J. Willcutt Jr.b, M. Lopezd, T.J. Romerod, M.B. ToloczkoJournal of Nuclear Materials Volume 343, Issues 1–3, 1 August 2005, Pages 219–226
* High-energy collision cascades in tungsten: Dislocation loops structure and clustering scaling laws A. E. Sand, S. L. Dudarev and K. Nordlund EPL (Europhysics Letters), Volume 103, Number 4
* In-situ TEM studies of 150 keV W+ ion irradiated W and W-alloys: Damage production and microstructural evolution X Yi, ML Jenkins, MA Kirk, Z Zhou, SG Roberts Acta Materialia 112, 105-120
* Irradiation hardening of pure tungsten exposed to neutron irradiation, Xunxiang Hu, , , Takaaki Koyanagi, Makoto Fukuda, N.A.P. Kiran Kumar, Lance L. Snead, Brian D. Wirth, d, Yutai Katoh Journal of Nuclear Materials Volume 480, November 2016, Pages 235–243
* Defect evolution in single crystalline tungsten following low temperature and low dose neutron irradiation Xunxiang Hu, , , Takaaki Koyanagi, Makoto Fukud, Yutai Katoh, Lance L. Snead, Brian D. Wirth Journal of Nuclear Materials Volume 470, March 2016, Pages 278–289