CCFE
CULHAM CENTRE FOR FUSION ENERGY

UNIVERSITY OF BIRMINGHAM
School of Metallurgy and Materials

PhD studentship in Nanostructured Tungsten Alloys for Nuclear Fusion

A 3-year UK/EU PhD studentship is available in the group of Dr Sandy Knowles within the School of Metallurgy and Materials at the University of Birmingham, with a stipend of £14,777 per year.

This project is supported by Culham Centre for Fusion Energy (CCFE), who will provide both industrial supervision and access to irradiation testing facilities.

The research group investigates new alloys for extreme environments in nuclear fusion/fission reactors as well as aerospace gas turbines. This involves the design of new alloys; production through arc melting, powder metallurgy or additive manufacturing; characterisation using electron microscopy and x-ray diffraction; mechanical testing using macro/micro-mechanical methods and failure investigation.

Nuclear fusion offers the prospect of large-scale low carbon energy with no long-lived radioactive waste. Over 50 years of worldwide research to overcome the significant technological challenges is culminating in the ITER experiment [1], currently under construction in Cadarache, France to be completed by 2025. In this, 50 MW of input heating is anticipated to output 500 MW of fusion power from a 150 million°C plasma sustained for up to 1,000 seconds, which will demonstrate the commercial potential of fusion power.

The materials used to construct such reactors are exposed to extreme conditions in terms of temperature, heat flow and plasma ablation as well as neutron irradiation. This is despite the highly sophisticated magnetic confinement of the fusion plasma used to shield the reactor's physical components and materials. The leading plasma facing material to withstand such temperatures is tungsten, the highest melting point metal. However, tungsten exhibits a brittle to ductile transition temperature (DBTT), and also suffers from irradiation embrittlement.

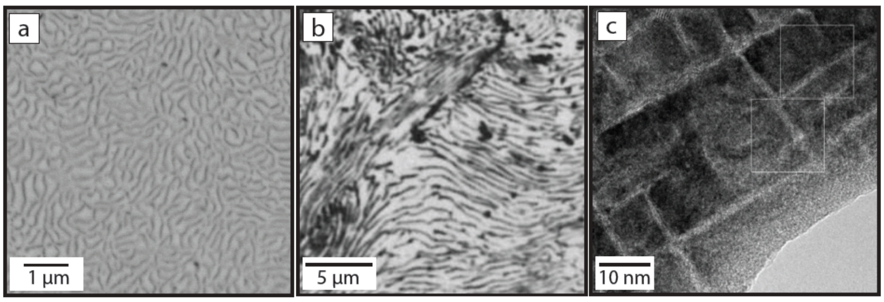
In this project new tungsten alloys with increased performance will be developed following two microstructural design concepts. Firstly, utilising two-phase microstructure to enable nano-scale grain refinement to improve ductility and fracture toughness. Secondly, utilising nano-scale grain boundaries and semi-coherent interfaces to act as sinks for irradiation damage. Such microstructures have been demonstrated within recently developed Ti 'bcc superalloys' using β-β' TiFe (see Figure a) [2], which are suggested to be possible for W within the W-Ti-Fe ternary system [3]. An alternative route is to use a two-phase miscibility gap as in W-Cr (see Figure b) [4] or even within refractory metal 'high entropy alloys' (HEAs) such as TaNbHfZr (see Figure c) [5]. This project would produce new two-phase tungsten 'bcc superalloys', characterise their microstructures and evaluate their mechanical properties as well as underlying deformation mechanisms.

The candidate will have a 1st class Undergraduate or Masters degree (or equivalent) in Materials Science, Mechanical Engineering, Physics or related discipline. A background in microstructural characterisation and/or mechanical testing would be advantageous.

Applications should be made through the university's on-line application system:
https://www.birmingham.ac.uk/postgraduate/courses/research/metallurgy-materials/metallurgy-materials.aspx?OpenSection=HowT

Please provide a cover letter summarising your research interests and suitability for the position, the contact details of two referees and a curriculum vitae. Please send a copy directly to Sandy Knowles.

Any question please contact Sandy Knowles: a.j.knowles@bham.ac.uk



Micrographs of high temperature 'bcc superalloys' based on Ti-Mo [2] Cr-W [4] and TaNbHfZr HEA [5] that this project seeks to extend to tungsten alloys.
(a) Ti with TiFe intermetallic precipitates
(b) Cr with W two-phase
(c) TaNbHfZr two-phase HEA

[1] www.iter.org

[2] A new beta titanium alloy system reinforced with superlattice intermetallic precipitates, A.J. Knowles, T.S. Jun, A. Bhowmik, N.G. Jones,T.B. Britton,F. Giuliani, H.J. Stone, D. Dye, Scripta Materialia 140 (2017) 71-75.

[3] An experimental study and thermodynamic evaluation of the Fe-Ti-W system at 1000°C, C. Qiu, Z.P. Jin, Scripta Metallurgica 28 (1993) 85-90.

[4] The decomposition of tungsten-chromium solid solution, D.E. Porter, Acta Metallurgica 15 (1967) 721-726.

[5] Structural-disorder and its effect on mechanical properties in single-phase TaNbHfZr high-entropy alloy, S. Maiti, W. Steurer, Acta Materialia 106 (2016) 87-97

[6] https://www.birmingham.ac.uk/postgraduate/courses/research/metallurgy-materials/metallurgy-materials.aspx?OpenSection=HowT