UNIVERSITY OF BIRMINGHAM
School of Metallurgy and Materials

PhD studentship in Refractory Metal Bcc Superalloys for Aerospace Gas Turbines

A funded 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 will link to Rolls-Royce and TIMET as industrial partners.

The research group investigates new alloys for extreme environments in aerospace gas turbines as well as nuclear fusion/fission reactors. 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.

The fuel efficiency of aerospace gas turbines is strongly linked to their operating temperature. However, increasing the operating temperature puts increased demand on the materials employed, namely nickel-based superalloys, potentially leading to catastrophic failure if not done carefully. Over 50 years of this development nickel-based superalloys have become highly sophisticated, but further improvements are increasing hard to realise and are approaching a ceiling [1].

One possibility for increased high temperature capability is to change the base element to one with a higher melting point than Ni (T_m=1455°C), for example Mo (T_m=2623°C) or Nb (T_m=2469°C). However, this results in a change in the matrix crystal structure from γ face-centred-cubic (fcc) to β body-centred-cubic (bcc) necessitating a change from the γ' Ni_3Al precipitates used for Ni. A larger number of ordered-bcc β' intermetallics exist but only few are compatible with Mo or Nb, which typically include rare or expensive element such as Pt or Ru [2], or rely on a matrix of Cr (T_m=1907°C) [3] or Fe (T_m=1538°C) [4]. Recent work has demonstrated for β Ti (T_m=1668°C) alloys that β' TiFe can be used as a reinforcing precipitate and that this has compatibility with β Mo and Nb [5].

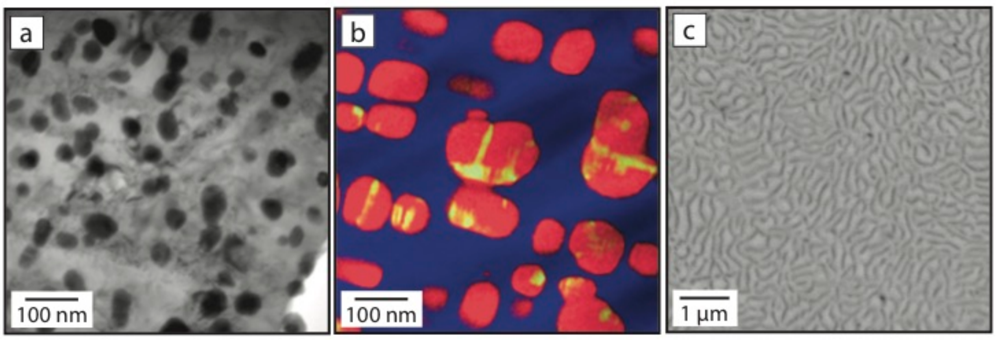
Whilst recently demonstrated as being possible, the capability of Mo or Nb based 'bcc superalloys' using β-β' TiFe remains unknown, with further work needed to bring the concept to a commercial product. This project would produce new Mo and Nb 'bcc superalloys', characterise the microstructures produce and evaluation their mechanical properties and 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



β-β' 'bcc superalloys' based on Nb [2], Fe [4] and Ti [5] that this project seeks to extend to Nb and Mo based alloys.
(a) Nb with β' Pd_2HfAl precipitates
(b) Fe with β' Ni_2AlTi and NiAl precipitates
(c) Ti with β' TiFe precipitates

[1] The Superalloys: Fundamentals and Applications, R.C. Reed, Cambridge University Press (2006).

[2] Integrated design of Nb-based superalloys: Ab initio calculations, computational thermodynamics and kinetics, and experimental results, G. Ghosh, G.B. Olson, Acta Materialia 55 (2007) 3281–3303.

[3] Coherent precipitation in a high-temperature Cr–Ni–Al–Ti Alloy, O. Dogan, X. Song, D. Palacio, M. Gao, J. Mat Science 49 (2014) 805–810.

[4] A hierarchical microstructure due to chemical ordering in the bcc lattice: Early stages of formation in a ferritic Fe–Al–Cr–Ni–Ti alloy, C.H. Liebscher, V.R. Radmilovic, U. Dahmen, N.Q. Vo, D.C. Dunand, M. Asta and G. Ghosh, Acta Materialia 92 (2015) 220–232.

[5] 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