NOMATEN Online Seminar

Location: gotomeeting room - https://meet.goto.com/NCBJmeetings/nomaten-seminar
Seminar date: February 25th, 2025
Time: 1 PM

Speaker name: Prof. Sandy Knowles

Speaker affiliation: University of Birmingham, UK.

Title: Low Neutron Cross Section Materials Gen-IV Fission & Fusion: Novel Zirconium Alloys & High Entropy Alloys

Abstract: Nuclear fusion and generation-IV fission reactor designs aim for operating temperatures in the range 500°C–1000°C. To optimise neutron efficiency, materials with low neutron cross section are sought for the fuel clad, or tritium breeding module. However, conventional zirconium alloys are precluded due to limited oxidation and creep performance at temperatures >400°C. Two approaches have been explored to meet the challenge of high temperature (HT) operation & low neutron cross section: (1) Novel Zirconium Alloys inspired by titanium metallurgy, (2) High entropy alloys.

(1) HT Zirconium alloys, exploiting the similarity in physical metallurgy between titanium and zirconium to make high temperature 500°C–800°C capable Zr alloys. These are based on the Zr-Al-Sn-(Si,Cr,V) system, designed by analogy to near-alpha titanium alloys, e.g. Ti-834. Using advanced microscopy and diffraction, microstructures akin to near-alpha Ti alloys have been demonstrated, specifically a lath grain structure with coherent Zr3Al and incoherent Zr-(Si,Cr,V) based precipitates. A key transformation sequence is described, involving continuous nanoscale precipitation of Zr3Al (D019) in a Zr (HCP) matrix, followed by discontinuous precipitation of Zr3Al (L12). Bending, tensile, and creep tests show greatly improved mechanical performance relative to conventional zirconium alloys. Further work is underway to evaluate the irradiation and environmental resistance of these alloys.

(2) High Entropy Alloys (HEAs) have greatly expanded the compositional design space for alloy design and are promising candidates for advanced nuclear applications due to their exceptional mechanical properties and irradiation damage resistance. This work investigates low density & low neutron cross-section refractory HEAs (RHEAs) for nuclear cladding/structural components. A high throughput computational screening tool, Alloy Search and Predict (ASAP), was used to identify promising RHEA candidates from over 15 million equimolar combinations, such as Zr-Ti-Nb-V type RHEAs. With Thermocalc and first principles modelling then used. Selected compositions were manufactured by arc-melting, thermomechanical deformation, and heat treatments. Techniques including SEM, EBSD, EDX, TEM and diffraction were used to characterise the alloys with a focus on thermal stability and any precipitate evolution, and to link this back to the computational predictions. Mechanical tests, from hardness to creep tests have been performed to evaluate the stability and structural integrity of RHEAs during prolonged reactor operation.

Bio: Sandy Knowles is a Professor in Nuclear Materials and UKRI Future Leaders Fellow 2020-2028 in the School of Metallurgy & Materials, University of Birmingham, UK.

Sandy started his career with a 4-year MEng in Materials Science from the University of Oxford 2011, with masters research on aluminium metal-matrix-composites. He undertook a PhD at the University of Cambridge 2011-2015, on 'Novel refractory metal alloys' linked with Rolls-Royce plc. Then moving to Imperial College London for a postdoc 2015-16 on Ti alloys, before receiving an EPSRC Doctoral Prize Fellowship 2016-17 to develop his 'beta Ti-superalloys'. From 2017-19 he held a EUROfusion Researcher Grant to investigate nanostructured tungsten alloys for fusion, held between Imperial, UoB and UKAEA.

Sandy started at University of Birmingham in 2018 and was awarded both a UKRI Future Leaders Fellowship 2020-28 and Royal Academy of Engineering Research Fellowship 2019-24, to take forward his 'bcc-superalloy' concepts, alongside award of EU H2020 & EPSRC grants. He now leads a 10-person research group, focused on novel nano-structured alloys for Extreme Environments: nuclear fusion, Gen-IV fission, gas turbines and thermal-solar. He has close industrial partnerships with UKAEA, NNL, TIMET and Rolls Royce and a wide international academic network. He is a UKAEA Visiting Fellow, UK Fusion Skills Council & TMS Refractory Metals Committee member, and organiser of 2024 BCC Superalloy Workshop 8-9th Feb, TMS 2025 Advances in Bcc-Superalloys, and Chair for 2026 Beyond Nickel-Based Superalloys V.