

# NOMATEN SEMINAR

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Nick G. Jones PhD MEng (Department of Materials Science and Metallurgy,  
University of Cambridge, Cambridge, UK)

## Microstructural evolution in Refractory Metal Superalloys

### ABSTRACT:

Materials capable of operating at elevated temperatures are a crucial part of modern infrastructure, particularly in the power generation sector. In many applications, greater efficiency can be achieved by raising the operating temperature of a heat engine, which is accompanied by a reduction in emissions. However, the maximum achievable operating temperature is limited by the capabilities of the materials used in the hottest sections of these engines. Over the last 70 years Ni-based superalloys have been the quintessential materials for such applications but modern design requirements are approaching or exceeding their physical limits, making the need for new options even more critical.

Refractory metal superalloys (RSA) are a recently developed class of materials that aim to fulfil this need by combining the high melting temperatures of the refractory metal elements, with intermetallic reinforcement similar to those of Ni-based superalloys. RSA typically exhibit fine-scale two-phase microstructures comprising small coherent cuboidal precipitates of one phase within a matrix of the other. Whilst these microstructures are visually similar to those of Ni-based superalloys, there are some key differences. First, RSA are based on body centred cubic configurations, unlike the face centred basis found in Ni-base alloys. This variation will have significant implications for a range of material properties, especially mechanical performance. Second, in current RSA, the matrix phase tends to have the ordered B2 structure whilst the precipitates are a disordered *bcc* solid solution phase, the inverse configuration to that found in Ni-based systems. As a result, despite impressive high temperature strengths, there are significant concerns relating to the ductility and toughness of RSA. Consequently, it is critical that an ability to control and tailor the microstructure of these materials is attained. In particular, work is required to understand the microstructural formation pathway, to elucidate the mechanism by which the two phases form, evaluate whether their configuration can be inverted and assess their long term stabilities.

Here, studies of systematically varying alloy series that build in complexity from ternary to senary systems will be presented. These data will be used to discuss how the fine-scale microstructure observed in these alloys arises, identify the role of specific key elements and determine the phase equilibria. Furthermore, critical assessments of the fidelity of current thermodynamic database predictions and the likely microstructural stability of the alloys to in-service type conditions will be made. Finally, the talk will conclude with comments relating to current potential for a commercial viable RSA and some thoughts on the directions of future research.

**BIO:**

Nick is currently a Reader in Metallurgy at the University of Cambridge, a Fellow of Pembroke College and one of the lead academics in the Rolls-Royce University Technology Centre based in the Department of Materials Science and Metallurgy. He gained both his MEng and PhD degrees from Imperial College London, where he specialised in the processing and properties of high strength titanium alloys. Today, his research focusses on designing, developing and optimising alloys for enhanced engineering performance, particularly in the aerospace sector. This work covers a number of different areas including; the identification of new alloy systems with higher temperature capabilities than existing options; the design of materials that are compatible with new fabrication techniques such as additive layer manufacturing; the development of a fundamental understanding of High Entropy Alloys; and the optimisation of transformation behaviour of superelastic and shape memory alloys. Alongside this work, he is also well known for his use of advanced scattering techniques for characterising material behaviour. To date, he has authored over 90 scientific papers, is listed as an inventor on five patents and was the recipient of the 2018 IOM<sup>3</sup> Cooke Ablett Award.