LMS Seminar

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From thermodynamics to strengthening mechanisms: high entropy alloys invite us to re-discover metallurgy

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ABSTRACT

Since the discovery of the single-phased CoCrFeMnNi alloy and the proposition of the concept of high entropy alloys (HEA) in 2004, the understanding of the behavior and properties of those materials has tremendously improved. We can now say that, against all expectations, HEA are just like other alloys. Well, almost. In other words, those alloys follow the classical laws of thermodynamics, diffusion, mechanics ... in short the laws of physics and chemistry, but not always the approximations that are commonly done for conventional alloys. We will illustrate it, especially for configurational entropy and X-ray absorption. Thus, it appears that the interest of HEA does not lie in their specificity but rather in the opportunity and the challenge that they raise to explore wide domains of composition. First, a challenge. We will show it through a complete thermodynamic description of the Co-Cr-Fe-Mn-Ni, which requires massive data calculations, new plotting methods and experimental validation (1). The study of solid solution strengthening relies on a similar approach, which will also be presented (2). Second, opportunities. Indeed, promising HEA compositions were identified for various applications and will be presented (3). Finally, high entropy alloys have inspired a new strengthening mechanism, by chemical architecturation. It consists in multi-scale microstructure, in which two phases are separated by a 3D network of composition fluctuations. We will expose the processing and microstructure characterization with a focus on the composition fluctuations, named interphase (4, 5). To identify the main strengthening mechanism, finite element modelling was performed with various approaches (two-phase and three-phase models, strain gradient plasticity, addition of a new chemical gradient effect) (6). Finally, a strategy to optimize and extend strengthening by composition fluctuations will be exposed.

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