京都大学 構造材料元素戦略研究拠点セミナー

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5 階材料工学セミナー室（527 室）

講演者：　**Prof. Easo P. George**
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講演題目: **Recent developments in our understanding of high-entropy alloys**

Abstract :

In general, the greater the number of alloying elements in an alloy, the higher the probability that second phases will precipitate out. Recently, however, a few alloys containing multiple constituent elements in roughly equiatomic concentrations have been discovered that crystallize as solid solutions with simple (FCC or BCC) crystal structures. What is striking about some of these alloys is that they are comprised of elements with very different crystal structures, which contradicts our traditional notions of solid solubility based on empirical rules such as Hume-Rothery. As a possible explanation for these observations, it has been hypothesized that their remarkable solid solubility is the result of high configurational entropies, which, it has been argued, can overcome enthalpies of compound formation and phase separation, thereby stabilizing the solid-solution state relative to the various possible multiphase states in such highly alloyed materials. This high-entropy concept, if generally valid, provides a new way to rationalize alloy phase stability.

In this talk I will first show that this hypothesis is not true in the vast majority of the so-called high-entropy alloys and that it is the rare multi-element alloy that is in fact a solid solution. Thermodynamic analyses of the various binary pairs comprising the alloys investigated show that enthalpy and non- configurational entropy have greater contributions to free energy than configurational entropy. The rest of my talk will then focus on a couple of model FCC-structured high- and medium-entropy alloys (containing 5 and 4 elements, respectively) that are true solid solutions. These alloys were arc melted, cast, homogenized, deformation processed, and recrystallized to obtain equiaxed polycrystalline microstructures. Their mechanical behavior was studied over a range of temperatures, strain rates, and grain sizes.

A strong temperature dependence of strength was observed unlike in pure FCC metals where no such dependence is typically seen. Interestingly, ductility increased hand in hand with strength as the temperature decreased from room temperature to liquid nitrogen temperature—to elongations in excess of 60% as the yield strength practically doubled. In addition to the yield strength and ductility increasing with decreasing temperature, the degree of work hardening also increased dramatically. This increased work hardening postpones the onset of necking to higher strains (Considere criterion) and is the reason for the increased ductility at cryogenic temperatures. Transmission electron microscopy showed that there is strain-induced nano-twinning at liquid nitrogen temperature, which progressively fragments the grains, and decreases the mean free path of dislocations, thereby increasing the work hardening rate. These nanotwins, along with the numerous (coarser) annealing twins seen in the recrystallized grains, suggest that the stacking fault energies are low in these alloys. Consistent with this, both undissociated ½{111}<110> dislocations, as well as dislocations dissociated into partials with stacking faults in between, were observed in the TEM micrographs. The talk will end with a summary of our current understanding of deformation and fracture in concentrated (equiatomic) solid solutions, which is rudimentary compared to our understanding of dilute solid solution alloys.

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