THE EFFECT OF SOLUTE DISTRIBUTION ON THE STRAIN RATE SENSITIVITY OF SOLID SOLUTIONS

by

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ABSTRACT

Several aspects of the physics of the interaction of mobile solute atoms and dislocations in dilute solid solution alloys are studied in this thesis. Solute is added to pure metals in order to improve their strength. Alloying also leads to a number of other effects, some of which are undesirable. For example, it leads to reduced ductility and may cause plastic instabilities. Both of these limit material formability. Here, understanding is added regarding the physical basis of these phenomena.

Reduced formability is associated with the occurrence of plastic instabilities which are caused either by low strain hardening or by low (negative) strain rate sensitivity (SRS). The current study is focused on the second effect. The strain rate sensitivity has an instantaneous component (always positive), which is associated with the thermally activated motion of dislocations, and a transient component (which may be either positive or negative), which is associated with the correlated motion of dislocations and solute. Negative SRS results when the transient component is sufficiently negative and is presumably due to clustering of solute at dislocations.

The study has a multiscale nature. On the nanoscale, the formation of solute clusters at stationary dislocation cores is studied using Monte Carlo simulations and EAM potentials in an Al-Mg alloy. The size of the thermodynamically stable cluster and the binding energy of the dislocation to its cluster are evaluated as a function of the average solute concentration and temperature. Such data enter all existing constitutive models of DSA. On the mesoscale, we investigate how solute structures (concentration fluctuations) defined on longer length scales affect dislocation motion and hence the strain rate sensitivity of the material. This investigation is performed using 2D dislocation dynamics simulations. On the macroscopic scale, parametric constitutive modeling is used to investigate the effect of mesoscopic solute structures on strain rate sensitivity. The thesis will discuss these efforts and will put them in perspective relative to existing experimental data.