

SEMINAR SERIES

FERRITE GROWTH IN THE MULTICOMPONENT STEELS - SOLUTE DRAG, COUPLED SOLUTE DRAG AND TRANSFORMATION STASIS

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Professor Christopher Hutchinson is a physical metallurgist in the Department of Materials Science and Engineering at Monash University in Melbourne, Australia. He received his PhD from the University of Virginia, USA for work on the thermodynamics and kinetics of the pearlite transformation in alloyed steels, before undertaking post-doctoral work in Grenoble, France on modelling microstructural evolution in metallic materials.

His research includes activities on Steels and Stainless steels, Aluminium alloys, Copper and Brasses, Titanium alloys and Magnesium alloys. Approximately half of his research is conducted in collaboration with Industry (automotive, aerospace, rail, manufacturing, oil and gas) and half funded by fundamental research agencies such as the Australian Research Council (ARC). Christopher's work combines, in roughly equal parts, advanced experimentation and characterisation (including electron microscopy, synchrotron x-ray radiation and neutron diffraction) and theory and computer modelling of the response of alloy structures to changes in materials processing and deformation.

It is now well established in physical metallurgy that solute in solution may have a drastically retarding effect on the migration of solid state interfaces. The effect is most obvious during grain growth, but is also important during recrystallization and phase transformations. This effect is known as 'solute drag', or sometimes 'diffusional dissipation of free energy', and models have been proposed to quantitatively describe the effect as a function of solute content, temperature and interface velocity. The models due to Cahn (the force approach) and Hillert (the dissipation approach) have come to dominate the literature and under certain conditions the two models reduce to the same result.

Solute drag is frequently invoked as a reason for ferrite formation kinetics from austenite in alloyed steels being slower than expected based on diffusional growth theory. This is most evident in alloys containing Mo, transformed in the bainitic temperature range where complete transformation stasis is sometimes observed. This kinetics has important industrial processing, and alloy design, implications, and consequently there has been a dedicated effort to understand the interaction of solutes with the migrating phase boundaries.

For fundamental studies of the kinetics of ferrite formation from austenite, specially designed ternary Fe-C-X (X = Mn, Si, Cr, Mo, etc) systems are often used. Using growth kinetic data collected at a range of temperatures (and sometimes compositions) unknown parameters in solute-drag models or interface mobility expressions can be calibrated to fit experiment and theory. However, real steels are multicomponent and it is not very satisfactory to have to perform 'calibration' studies for every different alloy composition.

A question is: how far can we go in describing the kinetics of ferrite growth in quaternary and higher order systems, based on models calibrated on ternary systems?

In a recent study focused on the Fe-C-Mn-Si system, the solute drag effect in the quaternary system was shown to be significantly overestimated if the solute drag parameters tuned on the respective Fe-C-Mn and Fe-C-Si ternary systems were used. A number of possible reasons for the apparent 'anti-coupled solute drag effect' were proposed.

In this presentation, a series of Fe-C-Mn-Mo alloys are used to demonstrate that ferrite growth kinetics can indeed be predicted based on parameters tuned from the respective Fe-C-Mn and Fe-C-Mo ternary systems. The reasons for the differences in predictive ability between Fe-C-Mn-Mo and Fe-C-Mn-Si are discussed.

Using this model for ferrite growth, a new explanation for transformation stasis in steels is presented.



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