Notes of Second Workshop on "The Effects of Alloying Elements on the Austenite to Ferrite Transformation in Steels"

Mercure Hotel, Metz, France.
August 23, 2001

Hosted by IRSID-USINOR

AGENDA:

9:00 Welcome and Introduction

9:15 Mats Hillert:
Nature of Local Equilibrium at the Interface in the Growth of Ferrite from Austenite.

9:45 Hub Aaronson and Bill Reynolds Jr.
The Roles of Sympathetic Nucleation During Ferrite Formation in Fe-C-X Alloys

10:15 Discussion and Coffee

10:45 John Xgren
Preliminary Results from a New Program for the Simulation of Solute Drag in Fe-C-M Systems

11:15 Matthias Militzer
Incorporation of Solute Drag into a Mixed-Mode Model for Austenite Decomposition

11:45 Sybrand van der Zwaag
Effect of N Concentration on Average Interface Mobility in an Fe-Si Alloy

12:15 Discussion and lunch

13:15 Philippe Cugy, Gerhard Inden and Matthieu Kandel
Multi-Scale Experiments on Ferrite Precipitation from Austenite in Fe-C-Mn Steel During Continuous Cooling

13:45 David Quidort, and D. Deschere
On the Influence of Alloying Elements on Growth Kinetics of Bainite

14:15 Pascal Jacques
Bainite Formation in Fine-Grained C-Mn-Si Steels

14:45 Sybrand van der Zwaag
In-situ TEM Observation of Austenite-Ferrite Interfaces in Fe-0.36%C

15:00 Gerhard Inden and Gary Purdy
Discussion of Paraequilibrium as a boundary condition for ferrite growth

15:30 General Discussion: Brief summaries of current research, plans for the immediate future, and collaborative initiatives.

Gary Purdy opened the meeting with a word of welcome, and, on behalf of the participants, expressed thanks to David Quidort and his colleagues at IRSID for their efforts in organizing and acting as hosts for the workshop. He stressed that the workshop was intended to be informal, and to generate discussion and ideas for collaboration. A list of attendees is attached as Appendix 1.

Mats Hillert then presented a review and elucidation of concepts of alloying element effects on the motion of ferrite-austenite interfaces in simple iron-based systems. He focused on the nature of predicted transitions in kinetic behaviour of growth interfaces and emphasized the importance of exploring them experimentally. In response to a question from Yves Br9chet, Mats distributed a draft manuscript based on his presentation. Among other issues, he discussed the limiting cases of paraequilibrium growth and growth under conditions of full local equilibrium, and possible intermediate kinetic states.

In a presentation co-authored with Bill Reynolds, Hub Aaronson discussed the phenomenon of sympathetic nucleation SN of ferrite and the effects of alloying element upon it. The morphological effects of alloying elements on proeutectoid ferrite were documented, and the drastic effect of bay-forming alloying elements was ascribed to the "coupled solute drag effect", C-SDE. The likely contributions of SN and C-SDE to the formation of morphologically degenerate microstructures and to the incomplete transformation of ferrite were discussed. Hub also mentioned recent results showing a wide range of Mo accumulations found at different at austenite-ferrite boundaries (Scripta Metall., 45, 2001, 561). It appears from these results that the extent of solute accumulation strongly depends on the fine structure of the interface.

John Xgren presented the preliminary results of a DICTRA-based program to simulate the results of solute drag in Fe-C-M alloys. His approach included terms for the diffusion of C and M within the interface and for interfacial friction. The solute drag force and the interfacial friction force are then functions of interface velocity. One of the more unexpected results was the prediction of cessation of growth when a critical situation is realized. John also made an apparent distinction between solute drag and dissipation of Gibbs energy.

Matthias Militzer reported on recent advances in the semi-empirical modeling of diffusional transformation kinetics in alloy steels: a more fundamental description of solute drag effects has been combined with a mixed-mode model for ferrite growth. The model as currently constituted is capable of the reasonable prediction of overall transformation kinetics during the thermal processing of steel.

Sybrand van der Zwaag spoke on the possible effects of nitrogen concentration of the average interface mobility in a series of binary iron-based alloys. For all alloys considered (Fe-Co, Fe-Cu, Fe-Mn, Fe-Cr and Fe-Al, at the 1 or 2% solute level), the mobility vs 1/T data appeared to fall on a single line. The alloys had low nitrogen contents, but it was suggested that nitrogen, even at these low levels, might be controlling the mobility. Another possibility was that the segregation energies of the solutes are not very different.

Philippe Cugy, Gerhard Inden and Matthieu Kandel described a series of experiments on ferrite precipitation from Fe-C-Mn austenite. These included dilatometric studies of continuous cooling kinetics, metallographic studies of interrupted cooling specimens, and 3D atom-probe studies of ferrite/martensite interfaces (presented by F. Danoix). No Mn spike was found at the interface in a specimen continuously cooled at 0.5°C/s from 850 to 730°C, then water quenched. However, the width of the expected spike is very thin in these specimen. Moreover, carbon distribution was probably influenced by quenching artifacts (room temperature segregation). These experiments are continuing with a new specimen (same treatment + holding 10min at 730°C) in which the expected Mn spike should be much wider.

David Quidort (with D. Deschere) described experiments on the kinetics of bainite growth (plate lengthening) by carbon diffusion. It was demonstrated that cementite precipitation had the effect of accelerating growth (or that the absence of carbide precipitation in Si-containing alloys causes a slowing of the steady state rate of growth). The effects of substitutional alloying elements are only partially accounted by a mixed-mode model in which only thermodynamic effects are included.

Pascal Jacques presented his work on the formation of ferrite and bainite in dual phase steels. The effective austenite grain size is of the order of several microns, and the carbon level in austenite is strongly influenced by prior treatment in the two-phase austenite + ferrite field.

Sybrand van der Zwaag then showed a video of some in-situ TEM studies of the motion of ferrite/austenite interfaces. The motion of growth ledges was observed, as was the existence of other linear features (probably interfacial dislocations).

In shorter presentations:

> Masato Enomoto described in some detail his progress on a computational scheme to predict the effects of solute drag during continuous cooling of an alloy steel.
> Gerhard Inden spoke of some preliminary work on the computation of free energy changes attending ferrite formation under paraequilibrium conditions.
> Gary Purdy noted that the decarburization of alloy steels offers new opportunities for defining interfacial carbon concentrations during ferrite growth from austenite.

In a general discussion session, it was proposed that the next meeting should take place in North America, probably in conjunction with the Fall 2002 TMS meeting. The need for a supply of alloys was also raised, and representatives of IRSID volunteered to help in this regard. Preparation of Fe-2, 5, 9% Ni and Fe-2, 4, 7.8% Cr binary alloys (15-20 kg ingots for each composition) is scheduled for the 1st quarter of 2002.

List of attendees :

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