Notes of the fourth workshop on alloying elements on the growth of ferrite from austenite, December 4-5, KTH, Stockholm

About 20 participants were present (Appendix A).

As intended, the workshop was quite informal, and much of the time was used for wide-ranging discussion. Several points of consensus emerged from the meeting:

- The workshops, while remaining informal, should be more widely publicized, and the scope of the workshops broadened to include "ALloying element Effects on Migrating phase Interfaces"; ALEMI. The topics to be addressed (as proposed by Mats Hillert) are listed in Appendix B.
- The next workshop has been tentatively scheduled for May 8 and 9, 2006, in Grenoble.
- In order to keep participants better informed of developments in this field, workshop participants are invited to send titles, journal references, and a two-sentence summary of any recent relevant publications to the workshop list. It is possible that an ALEMI website could be created and maintained at Graz by Ernst Kozeschnik, so that papers could be posted and downloaded. (Ernst has agreed to undertake this task.)
- Using the same list, information about alloys available for sharing among interested researchers will be made available.
- Chris Hutchinson (Monash) has volunteered to act as archivist for experimental alloys. Anyone offering material should first contact Chris, with a description of the material, chemical analysis, preparation method, and amount available.

Presentations on recent research were made by:

- Hui Guo and Masato Enomoto: [Modeling of ferrite growth in Fe-C-Mn-Si alloy]
- Annika Borgenstam: [Threshold for Widmanst≅tten ferrite formation in Fe-C]
- Philippe Thibaux: [Diffusion of carbon in austenite at lower temperatures]
- Ernst Gamsj≅ger, F. D. Fischer, J. Svoboda and C. M. Chimani: [Austenite-to-ferrite phase transformation in steels with low amounts of interstitial and substitutional components]
- From the De Cooman group, a presentation on martensite in TRIP steels.

In addition, several participants briefly described current research and/or plans for research. These included:

- Gerhard Inden [Described experiments to determine solubilities of refractory metals in Fe-C-based systems.]
- Helio Goldenstein [Maintains an interest in Fe-C-Cr alloys, especially eutectoid reactions that lead to alloy carbide formation.]
- Gary Purdy: [Will soon undertake further study of grain boundary allotriomorphs and Widmanst≅tten needles in α/β brass.]
- Chris Hutchinson [Plans to study precipitation in a non-ferrous analogue system, perhaps Ti-Cr; and is also considering the use of the Mossbauer effect. Chris, Hatem Zurob and Yves Br∋chet, have now begun decarburization experiments on Fe-C-Si and Fe-C-Mn ternary alloys and are currently preparing an Fe-C-Mn-Si alloy. They have also designed an Fe-N-Mo (2N-0.5Mo) alloy that will allow decarburization experiments down to 650^{o}C.]

In discussion of facilities for experimentation, Mats Hillert noted that they would soon lose access to an electron microprobe, and wondered about the possibility of determining local carbon concentrations. Other methods were mentioned, including energy dispersive detectors on scanning microscopes, and SIMS, but they were each considered to have their own problems. Hub Aaronson described an optimal heat treatment facility, as currently maintained by George Spanos at the US Naval Research Laboratory.

In the final session, "Where do we go from here", the five points of consensus noted above were summarized.

Hub Aaronson then highlighted several areas in which more research is indicated:

1) The most difficult and at the same time the most important of these is identifying and characterizing the atomic structure and chemistry of kinks on the risers of growth ledges. The recently developed technique of tomographic-TEM may now make such studies feasible in an alloy where sufficient volumes of austenite can be retained.
2) At lower levels of resolution, TEM studies are needed of growth ledges on the broad faces of ferrite plates. Ledge height, structure of ledge risers (especially in ledge-on-ledge situations) and spacing between risers are all important. For some clues as to what to expect, both qualitatively and quantitatively, see (Met. Trans., 6A, 303 (1975)). Hot-stage TEM is clearly necessary in order to examine ledge formation and growth in situ, as a major supplement to TEM performed on specimens quenched to room temperature. However, Purdy has shown that sideplates do not form in thin foils (Acta Metall., 26, 477, 487 (1978)), presumably because the usual foil thicknesses correspond to very small austenite grain sizes. This problem might be circumvented by partial transformation in bulk specimens in an alloy reacted at a transformation temperature and time that will permit extensive formation of retained austenite during quenching to room temperature. Following thin foil preparation, the transformation could then be continued in a hot-stage TEM.
3) At the present time, data and/or observations on TTT-curves, nucleation kinetics, growth kinetics, ferrite morphology and also carbide morphology when developed in association with ferrite are available in high-purity Fe-C-X alloys as a function of carbon concentration and X concentration mainly when X = Mo (Metall. Mater. Trans.-A, 35A, 1187 (2004)). Helio Goldenstein (University of Sao Paulo) and Bill Reynolds (Virginia Tech) are undertaking to extend the considerably smaller "data base" presently vailable for Fe-C-Cr alloys. Far less systematic information of this type is available when X = Mn, Si, Ni and the other common alloying elements. Building such a base for a given X could be readily divided into a number of smaller, thesis-sized packets to be tackled individually at widely distributed university, industrial and government laboratories. Provided that suitable heat treatment equipment is available, optical microscopy and SEM would suffice as long as a laboratory with a good TEM facility is included in the collaborative effort.

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Appendix A:

Workshop participants

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Appendix B:

Scope of workshop on ALloying Element effects on Migrating phase Interfaces: "ALEMI"

I. Theoretical treatments of:

1) Dissipation in the interface
2) Applications to non-homogeneous interfaces
3) Coupling to bulk diffusion
4) Overall effects on phase transformations
5) Numerical methods

II. Experimental

1) Observations of segregation and spike
2) Measurements of compositions and kinetics
3) Search for rate-controlling mechanisms, including transitions
4) Experimental techniques