

## Chemistry of ferrite/austenite boundaries

In the workshops the influence of alloying element segregation on the migration of ferrite/austenite boundaries was the subject of primary concern and thus, measurements of chemical composition of ferrite/austenite boundaries and correlation with the structure of the boundary in binary Fe-X and ternary Fe-C-X alloys were proposed. Fletcher et al [1], Humphrey et al [2] and Enomoto et al [3] employed a STEM technique all to measure the Mo segregation at ferrite/austenite boundaries in Fe-C-Mo alloys, and the latter two reported an increase in the Mo concentration with transformation time [2, 4]. The enrichment of Mo atoms at ferrite/austenite boundaries was also revealed by atom-probe in an Fe-C-Mo alloy [5]. Hackenberg and Shiflet [6] conducted an EDS microanalysis of the chemistry of the reaction front at the bay in a Fe-C-Mo alloy to observe small amounts of Mo enrichment and diffusion into austenite. They also noted alloy partitioning between ferrite and carbide and proposed that this was responsible for the slow kinetics in the alloy around the bay temperature.

The mechanism for the segregation at moving boundaries was discussed. It can be different from segregation at static boundaries, and is called accumulation [2]. It is thought that the accumulation of impurity or solute atoms several times the bulk concentration can be readily achieved during the migration of the interface.

Guo et al [7] conducted a STEM analysis of Mn segregation at ferrite/austenite boundaries in a low carbon Fe-C-Mn-Si alloy. The height and width of Mn concentration peaks increased with holding time. Coupled with the observed kinetic features of the transformation they concluded that three growth stages existed in this alloy which are characterized by the initial rapid growth involving no partition or interfacial accumulation of Mn and presumably Si also, enrichment of Mn at the ferrite/austenite boundaries and partitioning of Mn between ferrite and austenite. The co-segregation of Si was expected, but was not observed consistently. Both the interfacial segregation and the diffusion pile-up could contribute to the enrichment of alloying element in the boundary region.

It is probable that the segregation of Mo or Mn at ferrite/austenite boundaries is increased by carbon. The effects of substitutional alloying elements which presumably co-segregate with interstitial solute, the diffusion of which primarily is rate-controlling, and enhance the amount of free energy dissipation at the boundaries, are termed coupled-solute drag effects (C-SDE) [8, 9]. Further studies are needed which are concerned with the correlation of alloying element segregation with boundary structure. For example, the segregation at ledge risers would play a crucial role in the boundary migration and morphological development.

A series of experiments of migration of ferrite/austenite boundaries were conducted under

controlled decarburization conditions in ternary Fe-C-X alloys. In this experiment the influence of boundary structure and crystallography on the migration is likely to be minimal. Another advantage of this method is that the boundary migration can be studied at such a high temperature (or low undercooling) that ferrite precipitation is suppressed due to nucleation barrier. In Fe-C-Ni alloys the migration rate tends to follow LE-NP growth at lower temperatures, rather than growth under paraequilibrium [10].

Hutchinson et al [11] employed this method to measure the influence of Mo segregation at moving ferrite/austenite boundaries in an Fe-C-Mo alloy. They chose an alloy composition such that the uncertainty of the local interfacial condition, i.e. paraequilibrium or LE-NP, and the influence of carbide precipitation were eliminated. They observed a significant retardation of boundary migration and attributed it to the interfacial segregation (or accumulation) of Mo at ferrite/austenite boundaries.

In contrast to usual expectation a transition from LE-NP to paraequilibrium kinetics was observed in an Fe-C-Mn alloy as the temperature was raised in the ( $\alpha+\gamma$ ) two-phase region. This was discussed in relation to possible segregation of Mn to the moving interface [12].

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