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SEMINAIRE

energie atomique • energies alternatives

Service de Recherches de Métallurgie Physique

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Salle de réunion du SRMP – Bâtiment 520 – Pièce 109

Effect of boron on carbide coarsening at 600°C in 9-12% Cr steels

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Martensitic 9-12% Cr steel alloys are today widely used for components in fossil-fired steam power plants with steam temperatures up to 600° C, where excellent creep properties and sound oxidation protection are required. Their strength and long-term creep resistance rely strongly on a fine-grained martensitic microstructure, Cr-rich $M_{23}C_6$ (M = Cr, Fe, Mo, W) carbides, and dispersion strengthening by densely distributed M(C,N) (M = V, Nb, Ta) precipitates, which together effectively restrict migration of dislocations and subgrain boundaries under service.

During the last decades, one of the most important metallurgical experiences has been that the addition of modest amounts of boron (20-100 ppm) improves the creep strength of the steel alloys. This beneficial impact has been suggested to be connected to an observed reduced coarsening rate of the primary $M_{23}C_6$ carbides due to boron incorporation into these precipitates. However, the exact mechanism for this reduction has remained undetermined due to difficulties to accurately detect and probe the boron atoms in the alloys.

In the present talk, the nature of boron solution and migration mechanism in pure α-Fe, and the boron interaction with the alloying elements in the steels, have been studied with first-principles DFT calculations in order to understand the increased coarsening stability of the $M_{23}C_6$ carbides. We have demonstrated that the boron atoms under equilibrium conditions will form a mixed substitutional-interstitial solution, and that their diffusion process will be dominated by the interstitial mechanism. Our findings have then been combined with a multicomponent coarsening model to estimate the effect from the boron diffusion on the coarsening constant. The outcome of the model showed that the fast interstitial diffusion constant was too high to explain the enhanced stability of the precipitates, whereas a non-equilibrium substitutional mechanism, favored by vacancy generation during dissolution of $M_{23}C_6$, was concluded to be a plausible rate-limiting effect for the coarsening process.

Lundi 11 avril 2011 à 10h30

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