Transmission electron microscopy of the Fe-Al-Ti-B alloys with additions of Mo

Jenko, D.[1,2] and Palm, M.[3]

[1] Institute of Metals and Technology, Slovenia, [2] Max-Planck-Institute für Eisenforschung GmbH, Düsseldorf, Germany, Slovenia, [3] Max-Planck-Institut für Eisenforschung GmbH, Germany

Iron aluminides are of considerable technological interest in many applications, such as elevated-temperature structural alloys, surgical implants and hydrogen storage, due to their excellent oxidation and sulfidation resistance especially at elevated temperatures in hostile environments, in combination with their relatively low density and cost. However, the drawbacks of iron aluminides for their practical use are their insufficient strength, creep resistance and ductility. Different mechanisms for strengthening Fe-Al-based alloys at high temperatures were proposed and considered, such as solid solution hardening, strengthening by coherent or incoherent precipitates and increasing the long-range order. In this respect, the Fe-Al-Ti-B alloy with addition of Mo seems to be very interesting since alloying with Mo increases the wet corrosion resistance of the alloys because it has the strongest passivation effect in acidic conditions, and also increases the critical temperature T_c of $D0_3$ to B2 transition. Stabilization of $D0_3$-order combined with notable solid solution hardening increases the strength of the Fe-Al based alloys.

Two alloys were investigated in this work, prepared from high purity Fe (99.98 wt%), Al (99.99 wt%), Mo (99.99 wt%), W (99.99 wt%), B (99.99 wt%) and Ti (99.99 wt%) by vacuum induction melting under argon. Nominal composition of the first alloy was Fe 70.5 at%, Al 26 at%, Mo 2 at%, Ti 0.5 at% and B 1 at%, and the second alloy was Fe 68.5 at%, Al 26 at%, Mo 1 at%, Ti 0.5 at% and B 1 at%. A cold copper mold with ∅18 mm was used for casting. Alloys were annealed at 1000 °C for 100 h and slowly cooled under argon in the furnace. Samples for TEM were cut in thin slices from both alloys by electrical discharge machining (EDM), grinded using SiC papers up to 4000 grit (5 μm) and polished with 3 μm and 1 μm diamond spray and oxide polishing suspension (OP-S). One series of samples was further prepared for transmission electron microscopy (TEM) by focused ion beam (FIB) using Helios NanoLab 650 DualBeam System (FEI, USA), and another series by electro polishing using Tenupol 5 (Struers, Denmark). Thin foils were observed and investigated in TEM at 200 kV acceleration voltage using JEM-2200FS (JEOL, Japan). Chemical composition of individual phases was determined by energy-dispersive X-ray spectroscopy (EDS) with 30 mm^2 silicon drift detector (SDD) (JEOL, Japan). Conventional TEM (CTEM) and high-resolution TEM (HR TEM) was used for imaging of matrix phase and precipitates along the grain boundaries, selected area electron diffraction (SAED) was used for characterization of crystal structures of the phases, and scanning TEM (STEM) was used for elemental mapping. After annealing at 1000 °C for 100 h the eutectics coarsened and complex boride precipitates were distributed inhomogeneously along the grain boundaries. Our interest in this work was to determine the crystal structure of the complex boride phase since it is not known, and to establish if there is any relationship between the boride and the matrix phase.

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