Characterisation of the hierarchical microstructure in a modern high strength low alloy steel

Ledermüller, C.[1] and Primig, S.[2]

[1] UNSW Sydney, Australia, [2] UNSW Sydney, Australia

Modern high strength low alloy steels are frequently used in construction and automotive industries due to their exceptional cost-performance ratio. Developing such steels with higher specific strength allows to design parts with thinner cross-sections which leads to significant weight savings and, hence, to a reduction in CO_2 emissions. Being able to control the microstructural features of such steels over different length scales, namely from μm-scale down to the atomic scale, allows to engineer steels with superior properties such as increased strength and ductility. Advanced thermo-mechanical processing enables to control the microstructure by choosing optimised processing parameters such as temperature, strain and strain rate and number of deformation passes. In our approach, grain refinement in the submicron range via warm-deformation of a martensitic starting materials is combined with strain-induced precipitation of nano-meter sized Nb(C,N). The multi-scale hierarchy is completed by solute segregation to grain boundaries, dislocation networks and intragranular solute atom clustering during a direct aging step after deformation which leads to increased strength, work hardening capacity and toughness.

In this research, we use correlative characterisation techniques in order to study such hierarchical steel microstructures. Electron backscatter diffraction reveals the grain size achieved as well as the grain boundary character. Fragmentation of the initial martensitic starting microstructure by the formation of subgrain boundaries which eventually convert into high angle grain boundaries can be imaged. Transmission electron microscopy is used to investigate precipitates as well as dislocation networks. Two populations of precipitates are observed, whereby the larger, μm-scale precipitates can be found on grain boundaries and the smaller, nano-scale ones nucleate on dislocations and subgrain boundaries. At the atomic scale, it is possible to determine the detailed chemical composition of precipitates and to image solute segregation at grain boundaries and atom clustering in the matrix using atom probe microscopy.