Direct observation of trapped hydrogen and boron segregation at austenite grain boundaries in steels by atom probe tomography

Jun Takahashi, Kawakami Kazuto, Yukiko Kobayashi, Kyohhei Ishikawa
: Nippon Steel & Sumitomo Metal Corporation

The hydrogen embrittlement becomes more serious in higher-strength steels. Hydrogen penetrated from the surface diffuses in the matrix of steel and accumulates in the strain regions and the defects. Hydrogen generates vacancy-type defects, helps the movement of dislocation, and/or weakens the bond of grain boundaries, which causes fracture. To increase the resistance of hydrogen embitterment in high-tensile steels, dispersion of fine carbide precipitates such as titanium carbide (TiC) and vanadium carbide (VC) were proposed because a high number density of precipitates increases tensile strength by the particle-strengthening mechanism and simultaneously produces a number of trapping sites for hydrogen. However, hydrogen trapping sites associated with the fine carbide precipitates have remained still unclear. The lack of spatial resolution in conventional analysis methods for hydrogen made it difficult to determine hydrogen trapping sites associated with nano-sized precipitates. We accomplished direct observation of hydrogen trapping site in steel using atom probe tomography (APT) for the first time, by developing “deuterium charge cell” which enables deuterium charging to the specimen tip and quenching within the equipment of the atom probe. Fig.1 shows the APT analysis result of deuterium (D)-charged specimen tips of the TiC precipitated steel, where Ti and D atomic positions are represented. In the figure, concentrated titanium atoms correspond to nano-sized TiC. The two sets of figures show front and side views of each TiC platelet in selected cubic boxes of 10nm. D atoms are homogeneously distributed on both broad (001) surfaces of the platelet, and not at the edge region. No deuterium atoms were observed around very small TiC. Therefore, we concluded that the origin of the trapping site is misfit dislocation core or surface C vacancy of the TiC platelet.

We will also report the direct observation of boron (B) segregation at prior austenite grain boundaries. Although the segregation at austenite grain boundaries influences the hardenability of steels, it has been remained unclear because of difficulty on direct observation. We clarified the behavior of B and Mo segregations in Mo-B combined addition steels by our developed technique of the APT specimen tip fabrication.

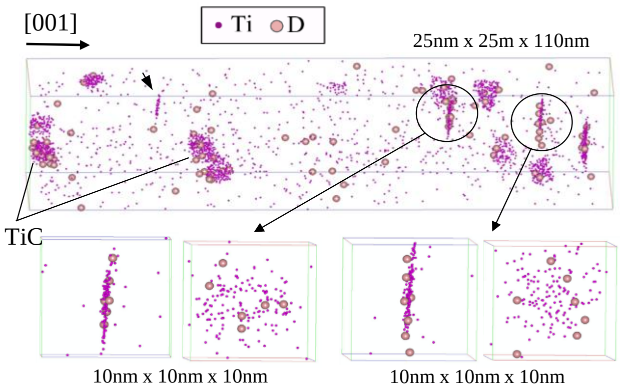

Fig.1 3D elemental maps of a deuterium-charged specimen tip of the TiC precipitated steel [1].

Bibliography

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