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Hydrogen/ Deuterium Detection in Ferrite-Austenite Dual Phase Steels

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Hydrogen (H), the most abundant element in the Universe, has a great potential to replace the C-based fuels as a more sustainable energy solution. In order to support and implement this transition towards a more sustainable H economy, comprehending the interaction of H with its surrounding infrastructure requires immediate attention. H embrittlement (HE) is a phenomenon that causes abrupt loss in the load bearing capacity of large engineering structures in the presence of H. Its limited understanding poses a hurdle for the transition to a H based economy. High strength steels are particularly prone to HE where even less than 1 part per million by weight (ppmw) H is sufficient to dramatically degrade the mechanical properties [1].

Medium Mn steels consisting of a dual-phase, austenite-ferrite microstructure have been employed for its enhanced transformation induced plasticity (TRIP) effect to achieve an improved strength-ductility combination [2]. However, its multiphase microstructure with difference in H solubilities and diffusivities makes HE studies on this material system challenging. A recent study [3] elucidated to the presence of strong H trapping sites with an activation energy of up to 50 kJ/mol in such steels, hinting towards H trapping at the austenite-ferrite phase boundaries (PBs).

Here we investigate and visualize these deep trapping sites by systematically probing the austenite-ferrite PBs via atom probe tomography (APT). A medium Mn steel (0.2C-10Mn-3Al-1Si) is heat treated to produce a microstructure with a high density of PBs which will enable us to bypass the need for site specific specimen preparation for APT. Two sample conditions are prepared, phase and orientation maps of which are shown in Figure 1. The first sample (namely SCPB) contains PBs which are mostly semi-coherent following a Kurdjumov–Sachs and Nishiyama–Wassermann (KS NW) orientation relationship, while the second sample (namely ICPB) contains both semi-coherent and incoherent PBs. From thermal desorption spectroscopy (TDS), we observe at least 10 times lower intensity of H at the deep trapping sites for the semi-coherent PBs compared to the incoherent PBs. These samples are then prepared into a needle shaped specimen desirable for the APT measurements, electrolytically charged with Deuterium (D) and then transferred to an APT [4]. Figure 2 a) shows an APT reconstruction of a semi coherent austenite-ferrite phase boundary, probable position of which is shown by C iso surface. The time of flight mass spectrum for H^+ and H_2^+ (or D^+) is shown in Figure 2 b). A series of such measurements containing a phase boundary (either semi-coherent or incoherent) within the APT specimen are performed to elucidate the challenges posed by such a technique during the field evaporation experiment and also during data interpretation.

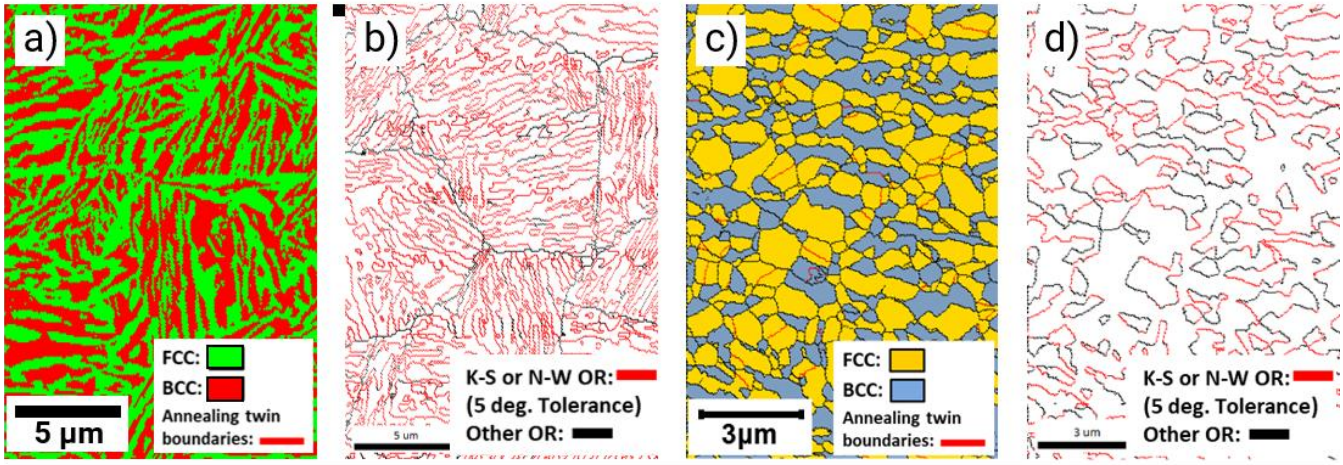

Figure 1 a) and b) shows the phase map and orientation map of the first sample SCPB. c) and d) shows the phase map and orientation map of the second sample ICPB.

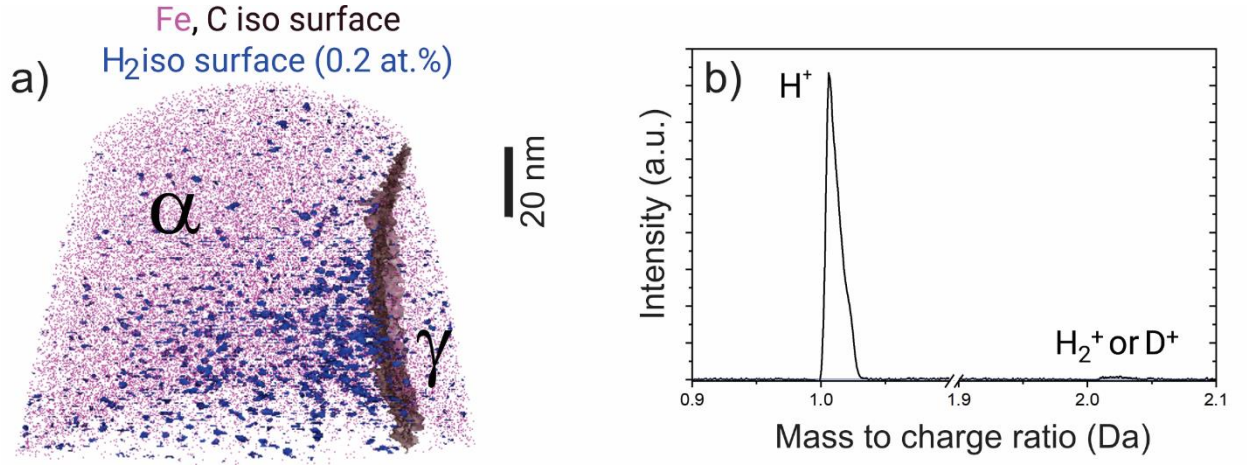

Figure 2 a) Atom probe reconstruction of a D-charged specimen where the austenite-ferrite phase boundary is shown by the C iso-surface. Corresponding time of flight mass spectrum is shown in b).

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