



22<sup>nd</sup> International Conference on  
Diffusion in Solids and Liquids  
22 TO 26 JUNE 2026 | RHODES, GREECE

## ABSTRACT:

### Interstitial Solute Segregation at Interfaces in Martensitic Steels to Improve the Resistance Against Hydrogen Embrittlement

G. Hachet<sup>1,2,\*</sup>, Ali Tehrani<sup>1,3</sup>, Shaolou Wei<sup>1</sup>, Hao Shi, Katja Angenendt, Stefan Zaefferer, Baptiste Gault, Binhan Sun, Dirk Ponge and Dierk Raabe

<sup>1</sup>Max Planck Institute für Eisenforschung, Max-Planck-Strasse, 1, 40237 Düsseldorf, Germany

<sup>2</sup>Groupe de Physique des Matériaux, CNRS UMR 6634, Avenue de l'Université, 76800, Saint-Étienne-du-Rouvray, France

<sup>3</sup>Federal Institute for Materials Research and Testing, Berlin, Germany

<sup>4</sup>Key Laboratory of Pressure Systems and Safety, Ministry of Education, School of Mechanical and Power Engineering, East China University of Science and Technology, Shanghai, China

\*guillaume.hachet@cnrs.fr

Hydrogen is nowadays viewed as a key element in developing low-carbon energy, but it diffuses in metals and alloys and segregates at crystalline defects, reducing the material's ductility. While this phenomenon is well-known and called hydrogen embrittlement (HE), its fundamental impact in metal and alloy remains challenging to understand, given the difficulty in localising hydrogen at atom scale. Nevertheless, different strategies have already been developed to attenuate the negative impact of hydrogen (e.g.: grain boundary refinement, hydrogen trapping at secondary phases, and so on...). For this work, the aim is to reduce the negative impact of hydrogen by favouring solute segregation at interfaces to improve the resistance against hydrogen embrittlement. Among more than 20 elements studied through ab initio calculations, interstitial solutes like carbon and boron (which mostly segregate into prior austenite grain boundaries – PAGBs before the martensitic transformation in steels) are the best candidates against the decohesion driven by hydrogen. This theoretical observation has been verified experimentally by comparing the hydrogen embrittlement resistance of a boron-doped and a boron-free steel. The pronounced segregation of boron naturally improves resistance to HE compared to boron-free steels by avoiding the intergranular fracture at PAGBs. However, HE is still observed when the hydrogen content is increased due to a fracture at martensite boundaries, interfaces where boron is not located. Additional heat treatments have been performed to activate the mobility of boron and carbon, which can segregate in other martensitic interfaces (packets, blocks, and lath boundaries). It results in an improvement of the resistance of boron-doped steels to avoid a cleavage fracture by reducing the hydrogen uptake. The newly developed microstructure is analysed through synchrotron experiments and atom probe tomography, which confirms the segregation of boron at interfaces without any change in the stress states.