#505 The interaction of hydrogen with microstructural defects studied by internal friction

Liese Vandewalle[1], Milan J. Konstantinović[2], Tom Depover[1], Kim Verbeken[1]

[1]*Ghent University, Department of Materials, Textiles and Chemical Engineering, Sustainable Materials Science, Tech Lane Ghent Science park 46, B-9052 Zwijnaarde, Belgium, Liese.Vandewalle@UGent.be*

[2]*Belgian Nuclear Research Centre, Boeretang 200, B-2400 Mol, Belgium*

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Abstract Understanding of the interactions of hydrogen with microstructural defects is of major importance for the mitigation of hydrogen embrittlement. Several current mechanisms for hydrogen embrittlement identify the hydrogen-dislocation interaction as the detrimental one. However, recently interest has also been raised towards the action of vacancies and their interactions with hydrogen. Moreover, other interstitials present in steel, such as carbon, are known to interact with these defects as well. Consequently, the carbon distribution might strongly influence the hydrogen defect-interactions.

Therefore, in this work an ultra-low carbon steel is subjected to various thermo-mechanical treatments, resulting in specific defect concentrations and carbon distributions. These microstructural conditions are characterized in detail via positron annhiliation spectroscopy (PAS) measurements, transmission electron microscopy (TEM) and internal friction (IF) experiments. A full overview of the hydrogen-material interactions is obtained by thermal desorption spectroscopy (TDS) as well as IF measurements on electrochemically hydrogen charged samples. Information on the dislocation structure and density in the samples is obtained by TEM. While the presence of all open volume defects, both vacancy clusters and dislocations, is evaluated by PAS. The IF technique characterizes the carbon distribution in the material as well as to evaluate the interstitial-dislocation interactions. Moreover, the IF spectra of hydrogen-charged samples provide additional in-depth information on the hydrogen-defect interactions, which could be linked to the TDS spectra.

Hydrogen trapping in the cold rolled steel is dominated by dislocations. Moreover, the hydrogen-dislocation interaction results in an additional relaxation peak in the IF spectrum. Recovery annealing results in a strong decrease of the trapping contribution of the dislocations in the TDS spectrum as well as the annihilation of the relaxation peak, despite the dislocation densities being similar. This could be attributed to the dissolution of meta-stable kink pairs and small carbon-vacancy clusters. Dissolution of these clusters causes additional carbon segregated at the dislocations, consequently reducing the hydrogen trapping capacity. Further investigation of the influence of the carbon distribution was obtained via redeformation (tensile or torsional) of recovered and recrystallized samples. Interestingly, the relaxation peak could only be reintroduced under specific conditions. Hence carbon is considered to play an important role in the generation of defects, and as such influences the hydrogen ingeractions in the material. The large vacancy clusters produced during the cold rolling were able to act as strong trapping sites. Hydrogen release from these vacancy clusters, resulting in a small higher temperature peak in the TDS spectrum, is related to dissolution of the clusters rather than unbinding.