IN SITU MICROMECHANICS DURING HYDROGEN CHARGING: CASE STUDY OF DIFFUSIBLE HYDROGEN IN BCC IRON ALLOYS

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A strong challenge on the implementation of hydrogen technologies is related to material degradation known as hydrogen embrittlement. To mitigate the negative effects of hydrogen and propose new strategies to protect structural materials it is necessary to understand which embrittlement mechanism is dominant and its origin. This can be reached by studying individual hydrogen-microstructure interactions, thereby targeting analyses at the nano-/microscale during hydrogen exposure. Here, we will present our novel electrochemical cell design developed for this purpose. In this "back-side" charging approach [1], the analyzed front surface is never in contact with the solution, avoiding unwanted corrosion, and the observed effects are only related to hydrogen. Hydrogen diffusion from the charged back-side towards the testing surface is quantified by permeation tests. This unique method allows differentiating between the effects of trapped and mobile hydrogen, and performing well controlled measurements with different hydrogen levels monitored over time to consider hydrogen absorption, diffusion and release through the metal. These particular aspects will be presented with examples of nanoindentation, micropillar compression and nanoscratching tests during hydrogen charging. First, the influence of diffusible hydrogen in Fe-Cr alloys with different Cr content was evaluated through nanoindentation and pillar compression tests. Our measurements show an enhanced dislocation nucleation, consistent with the defactant theory, and a hardening effect while increasing the Cr content and the hydrogen entry, see Figure 1. Secondly, the nanoindentation profiles as a function of time at the first charging step were modeled to quantify the hydrogen diffusion coefficient, using then the changes on the mechanical response as a hydrogen probe.

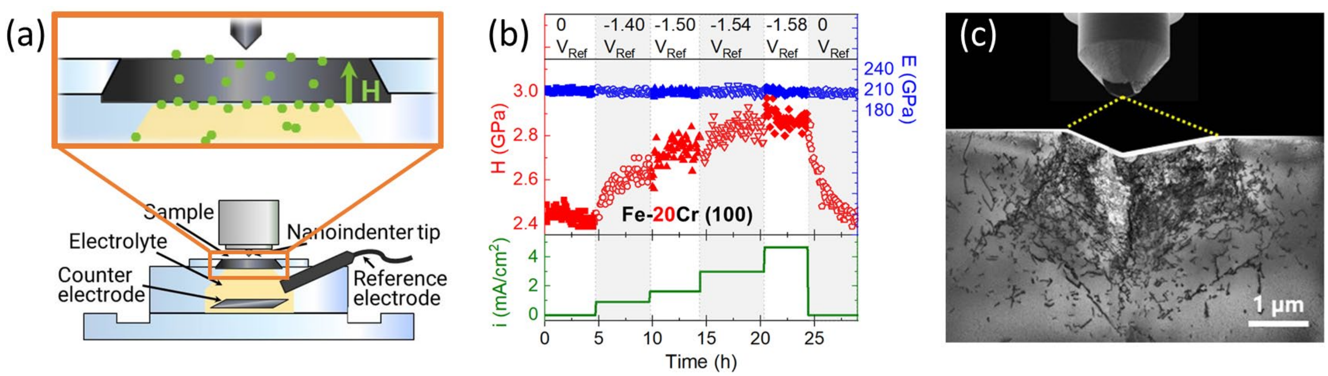

Figure 1 – (a) Schematic of the setup for nanoindentation during back-side hydrogen charging. (b) Time dependent hardness and Young modulus for increasing hydrogen supply. (c) TEM imaging of the dislocation structure after nanoindentation during hydrogen charging.

[1] Duarte M.J., Fang X., Rao J., Krieger W., Brinckmann S., Dehm G., "In situ nanoindentation during electrochemical hydrogen charging: a comparison between front-side and a novel back-side charging approach", Journal of Materials Science, 56, 8732-8744 (2021).