# IN-SITU TEM STUDY OF THE EFFECT OF HYDROGEN ON CRACK PROPAGATION IN STEEL

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Identifying the atomic scale mechanisms for hydrogen embrittlement in steels remains a much discussed yet elusive goal. On the one hand, microscopy investigations show that hydrogen enhances dislocation motion, while on the other, the quasi-cleavage morphology of the fracture surfaces and early fracture confirm the embrittling role of hydrogen. Taking advantage of an in-situ fracture testing method in an environmental transmission electron microscope, we attempt to reconcile these apparently contradictory trends using dynamic studies of crack tip propagation in Cr-Mo low alloy steel lamellae. The first stage of crack propagation in the lamellae involves extensive plasticity and thinning ahead of the crack tip, whether hydrogen gas is present or not in the microscope chamber [1]. However, subsequent stages are strongly changed by pressures as low as 2 mbar of $H_2$. In the absence of hydrogen gas, extensive plasticity continues, leading to crack tip blunting, void nucleation, crack bridging and necking [1]. In contrast, the crack tip in hydrogen gas remains sharp and propagates by the formation and linking up of {100} facetted staircase micro-cracks, without much associated plasticity. We propose an explanation for this behavior, which is based on the effect of H segregation on dislocation formation and mobility energies, and provides a consistent understanding of the observations of hydrogen embrittlement in steel.

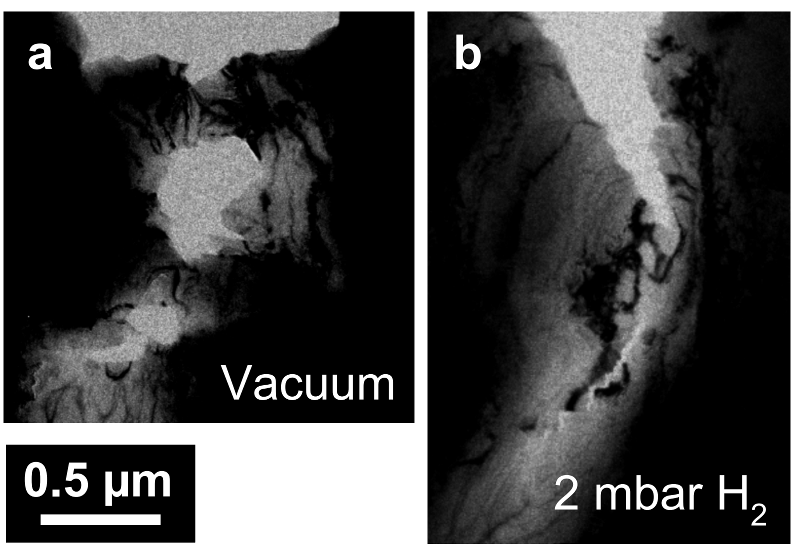


*Figure 1 – Stills from in-situ TEM videos of crack propagation in a Cr-Mo steel during fracture testing (a) in vacuum [1], and (b) in 2 mbar $H_2$ gas reveal clear evidence of hydrogen embrittlement and enhanced local plasticity.*

[1] L. Tian, C. Borchers, M. Kubota, P. Sofronis, R. Kirchheim, C.A. Volkert, Acta Materialia 223 (2022) 117474.