Abstract

The synergy of hydrogen embrittlement mechanisms in metals: The unified HELP+HEDE model

The unified HELP+HEDE model is a comprehensive concept that explains the coexistence of hydrogen embrittlement (HE) mechanisms in metallic materials [1,2]. This model involves the interplay and competence between two groups of HE mechanisms: HELP and/or other plasticity-mediated HE mechanisms, and the HEDE mechanism [1-3]. The confirmed competition and transition in dominance between hydrogen provoked localized plasticity, i.e., hydrogen-induced dislocation activity (HIDA), HE mechanisms (HELP and others), and HEDE, depending on the global/local hydrogen (H) concentration and distribution, microstructural characteristics, and stress state, are of utmost importance to achieve a unified model for HE. The HELP+HEDE model defined that the previous HELP, or other HIDA mechanisms activity, is not always necessary for the activation and the complete predominance of the HEDE mechanism (non-HELP mediated decohesion) at high local/global hydrogen concentrations. The recently updated unified HELP+HEDE model [3] introduced the "local HEDE micro-incidents" concept as the appearance of discrete micro-scale, i.e., hydrogen-induced crack initiation (HICI) incidents, at a high local H concentration above the critical one, particularly at HEDE-prone H traps in microstructure. These incidents happen even in the case of HIDA (HELP) predominance, i.e., plasticity-mediated HE mechanisms dominance, on the global level [1-6]. For the shift from HELP to HEDE macroscopic predominance, followed by a sharp drop in ductility and other mechanical properties, the necessary prerequisite is the macro-volume appearance of "local HEDE micro-incidents" [3]. This means an accumulation of a high enough number of such HEDE micro HICI incidents throughout the volume of a hydrogenated sample. In that case, the degree of activity of the HELP mechanism and other plasticity-mediated (HIDA types) HE mechanisms can become minor and negligible [1-6]. This talk presents new insights about the unified HELP+HEDE model, validated through experiments [2,4] and modeling studies [5], i.e., the "local HEDE micro-incidents" concept, conditions for particular HE mechanism dominance, and HEDE-prone H traps, highlighting its significance in the fundamental understanding of HE phenomena.

References

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