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On the Physics of the Apparent Solubility and Diffusivity of Hydrogen in Metals and Alloys, Relevance for Revealing the Hydrogen-Assisted Damage Micromechanisms

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1. Introduction

As has been formulated in Report [1] of the Basic Energy Sciences Workshop of the U.S. Department of Energy on Hydrogen Production, Storage and Use, in chapter Safety in Hydrogen Economy, corrosion and hydrogen embrittlement of materials are closely connected to details of their microstructure, and, in particular, to the segregation and diffusion processes that occur at internal interfaces and associated defects, such as dislocations. Micromechanisms of such processes are not well understood.

As has been also noted [1] in Potential Impacts, fundamental knowledge of hydrogen embrittlement of metals and welded joints would enable the setting of standards for the materials used in building a hydrogen infrastructure.

As has been noted [1] in chapter Basic Research Challenges for Hydrogen Storage (in item Safety), fundamental research will be needed to understand materials' hydrogen degradation and failure processes to allow design of improved materials for hydrogen storage. Hence, Research Directions have been formulated by the U.S. DoE as: Understanding of the Basic Physics of Hydrogen Transport in Metals and Hydrogen-assisted Damage Mechanisms.

2. Discussion - analytical results

In the present contribution, some related fundamental problems [2-4] of revealing micromechanisms of hydrogen plastification, superplasticity, embrittlement, cracking, blistering and delayed fracture of some technologically important industrial metallic materials are formulated. Their solution [2-4] contributes to optimizing technological processes and materials, particularly in the hydrogen and gas-petroleum industries, some aircraft, aerospace and automobile systems.

The results [2-4] are related to the safety and standardization problems [1] of metallic materials in the hydrogen and gas-petroleum industries, and also, - in some aircraft, aerospace and automobile systems.

Specific phase diagrams [5-7] are discussed for "hydrogen – the near-dislocation (or grain boundary) lattice nanoregions" of the hydride-like composition and structure, in comparison with the generally used conventional "H – Metal" phase diagrams.

The influence of the hydride-like nanosegregation [5-7] at dislocations (or grain boundaries) on hydrogen apparent solubility, apparent diffusivity and some other properties and processes in metallic materials is also discussed, including the processes of the thermal-hydrogen treatment, the hydrogen-induced transformation hardening, the embrittlement and the hydrogen-induced superplasticity.

It's relevant to emphasize the importance of such a non-conventional analysis [2-7] of the related experimental, theoretical and technological data for revealing the micromechanisms and optimizing the technological processes and/or materials.

Such analysis and interpretation can also be used for other systems and diffusion-assisted processes, for instance, with respect to numerous experimental data on the diffusion anomalies of transition element impurities (Fe, Mn, Cr, Ti, V, Zr, Sc) in alu, the data on the anomalous diffusion of carbon and nitrogen impurities in cold-rolled iron and steels, and the data on the diffusion mass-transport anomalies during internal oxidation, nitridation and precipitate coarsening (or shrinking) in metals [8-12].

3. Conclusion

The fundamental problems of the specific phase diagrams for “hydrogen (and/or other interstitial or substitutional impurities)– the near-dislocation (or grain boundary) lattice nanoregions” of the hydride-like or compound-like composition and the influence of such compound-like nanosegregation at dislocations (or grain boundaries) on diffusion-assisted processes in metallic materials are still “open” questions [2-12], and further studies are necessary, particularly, with respect to novel metallic nanomaterials.

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