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This Week's Citation Classic

Oriani R A. The diffusion and trapping of hydrogen in steel. *Acta Metall.* **18:**147-57, 1970. [E. C. Bain Lab. Fundamental Res., US Steel Corp. Research Center, Monroeville, PA]

The mobility of dissolved hydrogen in an iron lattice having a number of attractive interaction sites for hydrogen is analyzed assuming local equilibrium between the mobile and the trapped populations of hydrogen. Values for trap number and depth are obtained by applying the relevant equations to selected data on a variety of steels with and without cold work. [The *SCI*® indicates that this paper has been cited over 120 times since 1970.]

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"My effort was inspired by the pioneering work of Darken and Smith.[1] They found that the amount of hydrogen absorbed by a corroding specimen of steel increased with increasing amount of cold work priorly applied to the steel. They also clearly enunciated the concept that attractive interactions between chemical or physical singularities in the metallic lattice and the dissolved hydrogen would not only increase the apparent solubility of hydrogen but also decrease the kinetics of permeation. Much data had accumulated at that time on the diffusivity of hydrogen in iron and b.c.c. steels and the data below about 200°C displayed a disconcertingly large distribution of values achieving about three orders of magnitude at room temperature.

"I decided to see how far the concept of a local equilibrium between a diffusing population of lattice-dissolved hydrogen and a population of hydrogen interacting ('trapped') at one kind of attractive singularity would take one in rationalizing the disparate diffusion data. Local equilibrium seemed a satisfactory initial postulate because it was known that the extraction of the dissolved hydrogen was for the greater part possible, albeit with a time delay. My effort was nearly aborted when shortly afterward I became aware of an excellent paper by McNabb and Foster[2] who solved with a generality that I would have been incapable of approaching the problem of permeation of a solute subject to trapping and untrapping with each process separately specifiable kinetically. However, the difficulty of applying this analysis to extract meaningful physical parameters prompted me to proceed with my simpler approach. In addition, little had as yet been done to make sense of the great variation in the apparent diffusivity of hydrogen in steels.

"The simple analysis was successful in deriving similar trap depths from the excess solubilities and from the diminished diffusivities produced by cold working steels and by yielding magnitudes of trap depths and their number densities that were consistent with internal friction results and with the observed dislocation densities. The paper was useful because it provided a sense of the information that could be extracted from what formerly were simply phenomenological numbers, and hence stimulated much experimental work. However, it was in no sense the last work, nor was it ever so regarded, and indeed that is probably the main reason for the large number of citations since the directions in which improvements should be attempted were immediately obvious. It was clear that the assumption of only one type of attractive singularity produced by a process as complicated as cold work in a material as complex as steel cannot be more than the grossest simplification. In addition, the idea of local equilibrium cannot be correct for all kinds of possible interactions. Contemporary work on permeation transients is revealing inconsistencies among the interpretations of a variety of experiments where formerly consistency seemed to reign. Nevertheless, I am gratified that my effort stimulated much experimental and theoretical work."

1. **Darken L S & Smith R P.** Behavior of hydrogen in steel during and after immersion in acid. *Corrosion* **5**:1-16, 1949.
2. **McNabb A & Foster P K.** A new analysis of the diffusion of hydrogen in iron and ferritic steels. *Trans. Metall. Soc. AIME* **227**:618-27, 1963.