

Palladium-Hydrogen System (Pd-H) : Expected and Unexpected Behavior Following H Loading at Room Temperature and Explanation

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The objective of this presentation is to report new fundamental aspects regarding the Palladium-Hydrogen system (Pd-H) and other Face-Centered-Cubic, such as Ni-H. A substantial literature scan has been made, resulting in three review papers [1-3]. This research has allowed us to find out various relevant and new aspects. The main purpose of these reviews, gathering experimental results, is to complete a Chapter of the so-called series of “H in Metals” 1978 [4].

The reported aspects only deal with macroscopic asymmetric samples (foil, plate, rod, wire, bar, disk) hydrogenated via gaseous H₂ or electrolytically, preliminary annealed (stress released) or not (as drawn, i.e. oriented grains).

(i) We will recall that a Pd sample, when cycled (hydrogenated/dehydrogenated) at Room Temperature (RT), shrinks after each cycle and gradually tends to form a sphere as cycles are made. This behavior, regarding ductile metals such as Pd, is known for a long time but no mechanism has been proposed to account for it*.

(ii) Then, we will highlight another behavior which is widely ignored and unexpected. While absorbing H at RT, a macroscopic Pd sample does not expand isotropically. The smallest dimensions expand much more than the longest one (e.g. with a Pd wire at H/Pd = 0.6 : + 1 % in length and + 9 % in diameter). On the other hand, during H desorption, the Pd sample volume decreases isotropically – as it should also be expected during absorption.

Thereafter, it is shown that these two phenomena (i,ii) do not occur when samples are loaded above the critical temperature of the Pd-H system (293°C) [5].

These anomalies originate from the difference in mechanism of formation and decomposition of the hydride (beta phase in Pd-H). The way beta penetrates Pd during absorption at RT creates a considerable stress/strain field that generates a displacement of material in the opposite direction of the H diffusion – which does not occur during desorption. Other consequences of this mechanism will be mentioned. Some few tips will be shared in order to avoid these “problems”, which modify substantially the sample and therefore can result in a lack of reproducibility.

References

- [1] : Expansion of the Palladium lattice vs Hydrogen concentration : is the change of slope at 0.75 real ?
- [2] : Anisotropic expansion behaviour of Palladium bulk samples during Hydrogen absorption at room temperature.
- [3] : Volumic expansion of Palladium due to Hydrogen absorption : a critical review of dimensional measurements.
- [4] : H. Peisl, Lattice strains due to hydrogen in metals, in : G. Alefeld, J. Völkl (Eds), Hydrogen in metals I - Basic properties, Topics in applied physics, **Vol. 28**, Springer-Verlag, Berlin, 1978, pp. 53-74.
- [5] : F.D. Manchester, A. San-Martin, J.M. Pitre, The H-Pd (hydrogen-palladium) system, Journal of Phase Equilibria, **Vol. 15**, 1 (1994) 62-83 (see Table 2 and text pp 64-65).

* : no explanation has been found in the key reference papers of the field « Metal-Hydrogen Systems », as well as with those focused on Pd-H. These papers (articles, reviews, chapters and PhD theses) will be shared simply on demand.