Hydrogen entry into iron through porous sol-gel coatings

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Abstract

PhD thesis concerns one of the most important issues of hydrogen corrosion of metals, namely, preventing this undesired phenomenon by modifying the metal surface. The research was based on the interaction of hydrogen with ZrO₂ coated iron membranes, to clarify the role of the coating on the hydrogen evolution reaction and, consequently, on the entry of hydrogen into and its absorption within the metal.

In order to achieve these goals, one (entry) side of iron membranes were coated with two and five layers of ZrO₂ by the sol-gel method. The chemical composition, structure and thickness of ZrO₂ coatings were examined using SEM, XPS and AFM techniques. Electrochemical examinations by the potentiodynamic polarization curves and the impedance spectroscopy (EIS) confirmed that the produced coatings were not completely tight. Then, the essential electrochemical studies of hydrogen permeation and desorption, based on the electrochemical detection of hydrogen, were carried out. During the permeation measurements, the membrane entry side was subjected to galvanostatic cathodic charging, i.e. at constant current density referred to the geometric area.

The results of hydrogen permeation measurements revealed that the ZrO₂ coating plays a positive role - the rate of hydrogen entry significantly decreased. In the light of the proposed model of blocking the iron surface by ZrO₂, the effective coating coverage was determined by comparison of the fluxes of diffusible hydrogen, permeating the coated and uncoated membranes.

In turn, the results of hydrogen desorption measurements revealed the indirect influence of ZrO₂ on hydrogen absorption inside the metal. It was found that in the presence of ZrO₂ coating, the amount of absorbed hydrogen admittedly decreased, but not as much as the hydrogen permeation rate. This effect was caused by the increased concentration of the diffusible hydrogen and, hence, by the increased trapping of hydrogen in the iron substrate beneath the ZrO₂-free sites.

The proposed analysis of the results of permeation and desorption measurements can serve as a model for resolving similar issues for other hydrogen-coated metal systems.