Hydrogen permeability in pure Fe metal and FeC alloy

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ABSTRACT

Samples of pure Fe metal and FeC alloy with controlled chemical alloying element contents and microstructure, supplied by the European Fusion Development Agreement (EFDA), were experimentally analysed in the facilities located at the University of the Basque Country (UPV/EHU) in collaboration with CIEMAT.

In this work, the hydrogen transport parameter of permeability was experimentally measured in pure Fe metal and FeC alloy by means of the gas evolution permeation technique. The experimental temperature range explored was from 423 K to 823 K and the high purity hydrogen loading pressures from 10^4 Pa to 1.510^5 Pa. We observed that the permeability obtained for the two materials in this temperature range follows an Arrhenius law. The resulting diffusive permeability for pure Fe metal and FeC alloy were found to be \( \Phi_{Fe} = 3.88 \times 10^{-5} \exp(-35.9 (kJmol^{-1})/RT) \) and \( \Phi_{FeC} = 9.10 \times 10^{-3} \exp(-37.4 (kJmol^{-1})/RT) \), respectively. The resulting activation energies turn to be very close, whereas the permeation prefactor increases for the FeC alloy, in comparison to pure Fe. These results are in good agreement with values found in the literature for pure Fe metal and for low carbon content FeC alloys. According to the results, the influence of the metallurgical composition of C in FeC alloys in the diffusion of hydrogen is discussed.

EXPERIMENT

PERMEATION FACILITY - A single run of the experiment consists of holding one surface of a thin membrane of the material at a certain high H pressure level, forcing the H permeation through the specimen to a low pressure region (Figures 1 and 2 and Photograph). Two capacitance manometers (P1 and P2) record the pressure increase in the low pressure region (Figures 1 and 2 and Photograph). The permeation steady-state flux is measured by QMS. The pressure in the high pressure region is controlled by a combination of stainless steel flanges and Gold O-rings (Figure 1).

MATERIAL PREPARATION - Rods provided by EFDA with controlled chemical alloying element contents and microstructure: pure Fe and FeC alloy. Initially, samples were cut to a thickness of about 1.3 mm. After that, the specimens were prepared with a fixed grinding sequence using progressively finer abrasive grits. Then, samples were polished with diamond paste and heating at 353 K before cleaning them in different ultrasonic baths and drying of the specimen in hot air. Finally, samples were heated under UHV conditions up to 823 K inside the permeation facility before the first experimental run.

RESULTS

Permeability was calculated for both samples at different temperatures, following in both cases an Arrhenius law (Figure 4): \( \Phi_{Fe} = 3.88 \times 10^{-5} \exp(-35.9 (kJmol^{-1})/RT) \) and \( \Phi_{FeC} = 9.10 \times 10^{-3} \exp(-37.4 (kJmol^{-1})/RT) \). In both cases the diffusive regime has turned out to be prevailing, with variation of the flow with loading pressures (J vs. p_P) following a potential relation with powers close to 0.5 for every temperature (Figure 5).

CONCLUSIONS

The gas permeation technique has been used with samples of pure Fe and FeC alloy in a broad range of temperatures (423 K to 823 K) to obtain its hydrogen permeability values. The analysis of steady-state permeation fluxes at each experimental temperature and different loading pressures has agreed on a diffusion-limited regime. The resulting activation energies for both samples are similar with an increase of the permeation prefactor for the FeC.

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