Inhibition of Hydrogen Permeation through Pure Iron by Plasma Nitriding

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Hydrogen embrittlement is a serious problem for steels such as high strength steels. In order to prevent the hydrogen embrittlement, the hydrogen entry into steels is one of the important subjects. To improve the hydrogen absorption resistance into steels, a nitriding treatment is thought to be effective because nitrogen is an interstitial element similar to hydrogen. The existence of nitrogen atoms in the steel lattices is possible to work as a high energetic barrier against the hydrogen entry into steels. The objective of this study is to elucidate the effect of plasma nitriding treatment on the hydrogen permeation behavior through pure iron.

Pure iron sheets of 1 mm in thickness were used as the specimens. Prior to the nitriding treatment, the specimen surfaces were polished using the diamond past down to 1 μm. The plasma nitriding treatments were carried out in a nitrogen-hydrogen atmosphere composed of 75 % N_2-25 % H_2 at 600 Pa for 3.6 ks. The supplied DC voltage was controlled so as to keep the temperature of the specimen at 400 ºC. The nitrogen compound layer composed of ε-$Fe_{2-3}N$ and γ'-Fe_4N phases was formed by the plasma nitriding treatment in the nitrogen-hydrogen atmosphere. The thickness of the nitrogen compound layer was ca. 4.0 μm.

To investigate the effect of the nitrided layer on the hydrogen permeation behavior through the specimen, a hydrogen permeation test using a conventional Devanathan-Stachurski cell was carried out. The plasma nitriding was treated only in the hydrogen detection side of the specimen. Pd of 200 nm in thickness was deposited on the nitrided layer by electroplating and physical vapor deposition. The hydrogen detection side was polarized at 0.3 V vs. SHE in 0.1 M NaOH fully deaerated by pure Ar gas. The specimen in the hydrogen entry side was galvanostatically polarized at −10 $mA \cdot cm^{-2}$ in 0.1 M H_2SO_4 to absorb hydrogen into the matrix.

In the case of the untreated specimen, the permeation current drastically increased to ca. 1300 $nA \cdot cm^{-2}$ in the period to 0.1 ks, and achieved a steady state. On the other hand, the increase of the permeation current was hardly seen for the nitrided specimen. Only 10 $nA \cdot cm^{-2}$ of the permeation current was detected. The hydrogen permeation tests revealed that the nitrogen compound layer strongly suppressed the hydrogen permeation through the pure iron. The nitrided layer seems to act as an effective barrier against the hydrogen entry.