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Micro-electrochemical investigation of hydrogen absorption around MnS inclusion in carbon steel

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The hydrogen absorption of steels would be closely associated with the corrosion reaction around MnS inclusions, because MnS is known as a preferential corrosion site, and hydrogen absorption occurs as a result of the cathodic reaction of corrosion. Microscopic electrochemical measurements are suitable to investigate the influence of the inclusions on hydrogen absorption. The objectives of this study are to fabricate a small hydrogen permeation cell and to analyze the hydrogen absorption behavior around MnS inclusions in carbon steel. Resulferised carbon steel was used in this study (0.052%S, AISI type 1145). Large MnS inclusions were formed in the steel, and the typical size of the inclusions was around 25 μm long. The steel surface was polished with a 1 μm diamond paste.

Figure 1 shows the schematic of the hydrogen permeation cell fabricated in this study. The hydrogen entry side is a micro-electrochemical cell composed of a single glass tube with a silicone rubber seal. The electrode area of the microcell was 1.3×10^{-8} m^2 (approximate 130 μm in diameter). The hydrogen exit side was made with an acrylic plate and a poly-etherether ketone (PEEK) fitting. The inner diameter of the exit-side-cell was 3 mm. A deaerated 0.1 M NaOH solution was filled, and the exit side of the steel surface was polarized at -0.1 V (vs. SHE). To suppress the residual current in hydrogen permeation measurements, a Palladium layer was electro-plated on the specimen surface of the exit side. A battery-powered low current potentiostat was used to measure hydrogen permeation currents. All measurements were carried out at 298 K.

At first, hydrogen permeation in acidic environments was measured (Fig. 2). The micro-electrochemical cell was filled with a 0.1 M NaCl (pH 1, adjusted with H_2SO_4) solution and touched to the entry side of the steel surface at 6.5 ks, as shown in Fig. 2. At this moment, the current of the exit side suddenly increased. After that, the micro-electrochemical cell was released from the steel surface at 12 ks. As a result, the current of the exit side decreased sharply. It was confirmed that the hydrogen absorption in the small area was detected by the small hydrogen permeation cell fabricated in this study.

To analyze the hydrogen absorption behavior of the steel around the MnS inclusions hydrogen, permeation currents were measured in a boric-borate buffer solution at pH 5.5. Figure 3 shows the effect of the MnS inclusions on the hydrogen absorption of the steel. In the case of the small electrode area with the MnS inclusion, the decrease in the corrosion potential for the entry side of the steel was observed after the electrolyte was placed on the electrode surface of the entry side. The hydrogen permeation current slightly increased with time, suggesting that hydrogen absorption occurs in the small area with the MnS inclusion. On the other hand, no increase in the permeation current was detected on the steel surface without the MnS inclusions, although the electrode potential of the entry side decreased with time, which was similar to that observed in the area with the MnS inclusion. From the above results, the dissolution products of the MnS inclusions were thought to promote the hydrogen absorption around the MnS inclusions. It is known that H_2S or HS^- promotes hydrogen absorption. These species prevent the recombination reaction of adsorbed hydrogen atoms. This is why hydrogen absorption was promoted in the area with MnS inclusions.

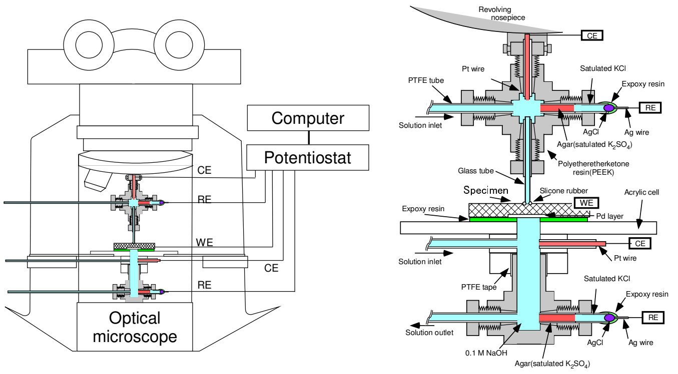

Fig. 1 Schematic of hydrogen permeation measurement system

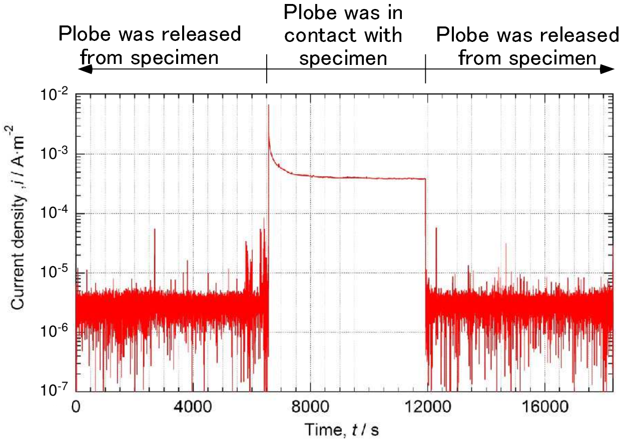

Fig. 2 Hydrogen permeation in 0.1 M NaCl (pH 2.0).

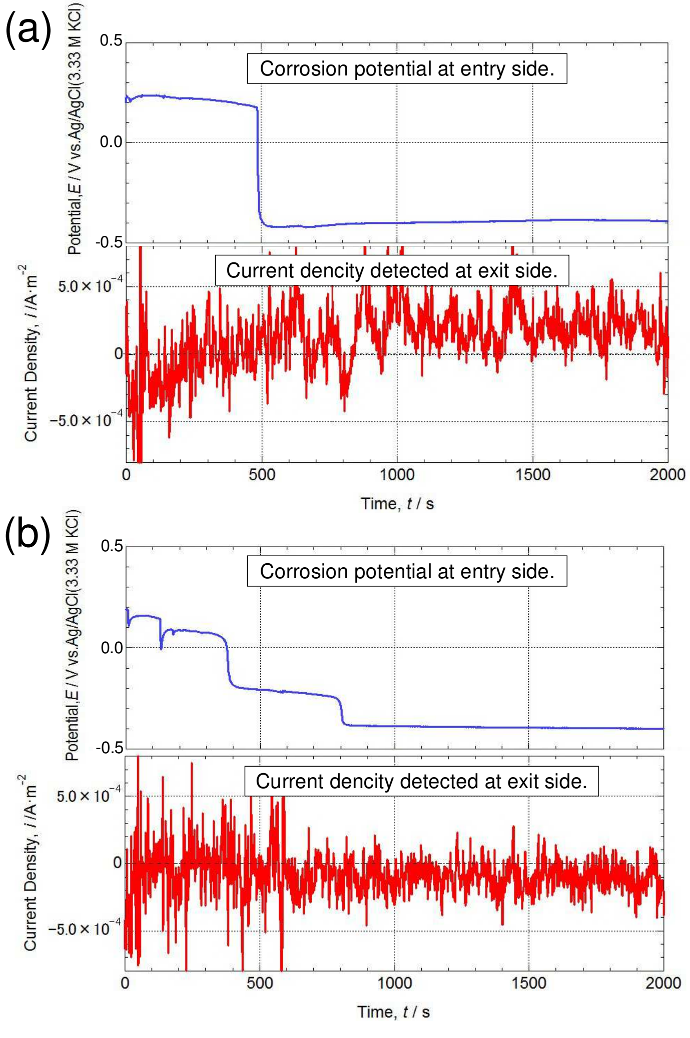

Fig. 3 Corrosion potential and hydrogen permeation current density in boric-borate buffer solution of pH5.5. (a) Area with MnS and (b) without MnS inclusion.