The electrochemical property of the electrodeposited magnetite electrode with different pH values

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1. Introduction

Flow accelerated corrosion (FAC) causes severe damage to secondary piping systems. An accident from FAC occurred at the Oyster Creek nuclear power plant (NPP) in 1978. Other NPPs such as Surry 2 and Mihama 3 have also experienced an FAC that induced damage to the carbon steel piping [1]. FAC is influenced by many factors such as the water chemistry (temperature, pH, dissolved oxygen (D.O.) in a solution, and etc.), chemical composition of carbon steel, and fluid dynamics [2]. Magnetite is formed at the inner surface of carbon steel, and protects the integrity of pipes from damage. The magnetite has a stable state at each equilibrium condition, so that it can be dissolved into the fluid under conditions that satisfy the equilibrium state. The iron solubility can be calculated by considering the reaction equilibrium constants for prediction of the change in the magnetite layer. On the other hand, it is necessary to measure the experimental solubility to compare the theoretical data and the experimental data. In addition, the solubility of magnetite can be predicted by measuring the electrochemical experiments. However, there are few studies related to the electrochemical property of magnetite owing to the difficulty of the electrode fabrication [3-5].

In the present work, a magnetite electrode was prepared using the electrochemical-assisted precipitation method, and the electrochemical property of the fabricated magnetite electrode was measured in an alkaline solution.

2. Method and Results

2.1 The fabrication of magnetite electrode

The solid magnetite electrode was fabricated by the electrochemical-assisted precipitation method according to the literatures [6-8]. The electrochemical-assisted precipitation reaction follows two step process, and it can be summarized by equation 1 and 2

$$Fe(TEA)^{3+} + e^{-} \rightarrow Fe^{2+} + TEA \qquad (1)$$

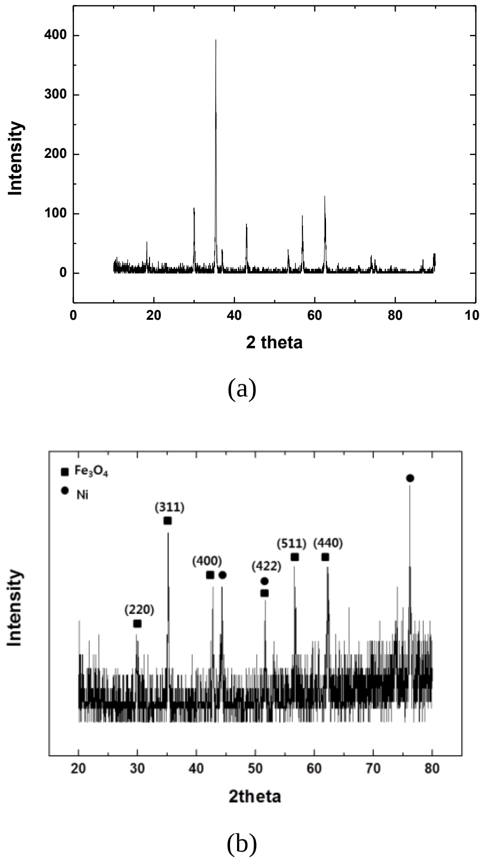
$$Fe^{2+} + 2Fe(TEA)^{3+} + 8OH^{-} \rightarrow Fe_3O_4(s) + 4H_2O + 2TEA \qquad (2)$$

Where TEA is Triethanolamine. The concentrations of the electrodeposition bath were 80g/L NaOH, 20g/L TEA, 60g/L $Fe_2(SO4)_3$. The temperature of the electrolyte was maintained at 60℃. The current density was 5 mA/cm^2 and the electrodeposition time was 120s. The Pt wire anode was used, and the Ni or Pt wire used as the substrate. The fabricated magnetite electrode was characterized by using X-ray Diffraction (XRD). And it was shown in Fig. 1. The observed peaks in the spectrum were characteristic of magnetite, although there are some different peaks from other components, e.g. Ni substrate.

2.2 The electrochemical tests

The caustic solution was used to observe the effect of pH, and the different concentrations of NaCl were used to observe the effect of chloride ion concentration. And the bath temperature was maintained at room temperature. The solution was prepared with deaeration by the purging of N_2 gas, and was not agitated during the electrochemical tests. Each electrode was inserted into a 1 L five neck round flask. The electrodeposited wires were insulated with a Teflon heat shrink tubing.

The electrochemical measurements were carried out on a Solartron 1260 instrument with a three electrode electrochemical cell. The reference electrode was SCE (Standard Calomel Electrode), and the counter electrode was a 1 mm Pt wire. The measured open circuit potential of the magnetite electrode was about -0.5V_{SCE} at 1 M NaOH solution. Cyclic Voltammograms of the magnetite electrode were measured with 100 mV/s scan rate, and the applied potential was from - 1.5 V to + 0.5 V. The cycle voltammetry result of the electrodeposited Fe_3O_4 electrode at the deaerated solution containing 1 M NaOH + 10,000 ppm NaCl, at 25℃ was shown in Fig. 2. In this figure, the reaction peak of Fe_3O_4/Fe was shown at -1.15 V_{SCE}, and that of Fe_3O_4/Fe_2O_3 was shown at -0.74 V_{SCE}.



(a)

(b)

Fig. 1. X-ray diffraction patterns of (a) as-received magnetite powder (b) the electrodeposited Fe_3O_4 electrode.

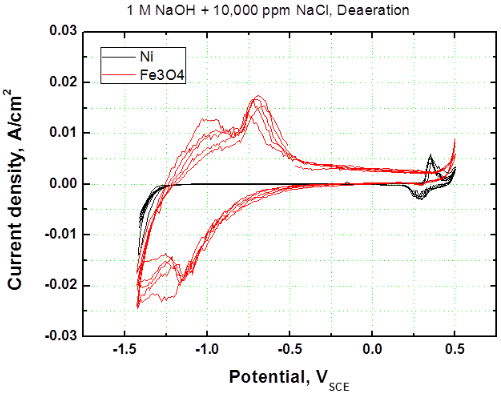


Fig. 2. Cycle voltammetry result of the electrodeposited Fe_3O_4 electrode at the deaerated solution containing 1 M NaOH + 10,000 ppm NaCl, at 25℃.

3. Summary

The magnetite electrode was fabricated by using the electrochemical-assisted precipitation method for the measurement of the solubility of the magnetite. The prepared magnetite electrode showed the characteristic of the magnetite by an XRD spectrum. In addition, the electrochemical test, i.e. cycle voltammetry indicated that the electrodeposited magnetite can be used as the measurement of the electrochemical properties.

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