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The Effect of Magnetic Field on Corrosion Inhibitor of Copper in 0.5M NaCl Solution

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ABSTRACT

The effect of magnetic field on corrosion of metals had been studied by many studies, but so far not many researches had been done on the effect on corrosion inhibitor. In this paper, we studied the effect of magnetic field on the inhibition efficiency of imidazole when it's added to copper in 0.5M NaCl. Based on weight loss test and electrochemical analysis, we found that imidazole inhibition efficiency had decreased when a 13mT magnetic field was applied perpendicular to the working surface of copper samples. It is suggested that magnetic field may have disturbed the adsorption of imidazole via magnetohydradynamic effect.

Keywords: Copper; Corrosion; Imidazole; Magnetic Field

INTRODUCTION

There is an increasing effort to study the interaction of magnetic field with the corrosion mechanism of metals. As magnetic field can interact with charged particles via Lorentz force, many studies had been done to discover a novel method for corrosion control. So far, it is known that magnetic field can influence the corrosion behavior of metals where the kinetic is largely governed by mass transport, but the exact mechanism for many metals are still unknown [1]. In the case of heterogeneous electron transfer kinetics, the findings are more controversial, where it is demonstrated that no effect is observed for several redox systems [2,3]. Several studies had been done on the effect of magnetic field on the corrosion of copper [4,5]. During anodic dissolution of copper, turbulence induced by magnetohydradynamic effect had been observed via the usage of holography technique [6]. Magnetic field gradient also contribute significantly to the corrosion behaviors of ferromagnetic materials. It may enhance or retard corrosion rate depends on the magnetic flux density gradient on the working surface [7].

In the field of corrosion inhibition, there is an active research to find green corrosion inhibitor for many common metals such as steel and copper. Benzotriazole, for instance, is one of the commonly used inhibitors for copper-based materials due to its high corrosion efficiency, but its toxicity and difficulty to remove from effluence during wastewater treatment have make it a less desirable choice [8]. One of the more promising alternatives is imidazole and its derivatives. Imidazole is a planar, nontoxic aromatic heterocycle and is a member of

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the azole group, where inhibition mechanism involves adsorption onto the copper surface. For imidazole, the π-electron within the aromatic ring and the N atom with lone sp2 pair provide sites for adsorption to occur. Although imidazole has good corrosion inhibition efficiency, it is not as good as benzotriazole, and currently studies had been done to further improve the inhibition efficiency [9].

Although many studies had been done on the corrosion of metals within an applied magnetic field, the interaction between magnetic field and corrosion inhibitors has not been studied extensively. In this study, we use imidazole as corrosion inhibitor of copper, and observe the effect of magnetic field on the inhibition efficiency of imidazole when it is added to copper in 0,5M NaCl solution. Weight lost test and electrochemical test were used, where magnetic field is generated using a pair of neodymium permanent magnet.

Materials and Methods

2.1 Materials:

Copper of 99.99% purity were used throughout the experiments. 0.5M NaCl with 60 ppm and 100 ppm imidazole were used throughout this study. All solutions were prepared using chemicals of reagent grade or better. A pair of neodymium magnets was used to generate the magnetic field with strength up to 13mT at the working surface of the copper coupons. Magnetic field strength was determined using a teslameter with Hall Effect probe (Linkjoint LZ-610H).

2.2 Weight loss test:

Experimental setup for weight loss test is shown in Figure 1. Copper coupons with 16.3 mm diameter and 3 mm thickness were grinded using silicate sand paper up to #800 grit. The coupons were cleaned using distilled water and acetone before they were immersed into the solutions. The coupons were then immersed for one week.

2.3 Electrochemical Test:

Gamry PC4/750 potentiostat with CMS105 Direct Current Analysis software suite (embedded within Gamry Framework v3.2) was used for polarization analysis. Copper electrode with surface diameter of 16 mm and enclosed within an epoxy mold were grinded using silicate sand paper up to #1200 grit and then polished using 1 micron diamond abrasives. Copper electrode was then immersed in the test solution for 30 minutes before running the electrochemical analysis. Standard caramel electrode (SCE) was used as reference electrode, while carbon electrode was used as counter electrode. Voltage range of ±150 mV from open circuit potential and scan rate of 1mV/s were used.

3. Results:

3.1 Weight loss test:

Figure 2 shows the corrosion rate of copper after it had immersed in test solution, with or without magnetic field, for a week, while Table 1 shows the inhibition efficiency of imidazole based on the result of the weight loss test. The inhibition efficiency of imidazole is calculated using the following equation:

$$IE = \frac{CR_f - CR_0}{CR_0} \times 100\%$$

where IE is inhibition efficiency, CR_0 and CR_f are the corrosion rate of untreated and treated coupons respectively. Test results show that the inhibition efficiency of imidazole had decreased when 13mT magnetic field is applied to the copper coupons. The deterioration of inhibition efficiency is very noticeable in the case of 60 ppm imidazole, where the corrosion rate is as high as copper in pure 0.5M NaCl. Corrosion rate in 100 ppm imidazole also increased when under the applied magnetic field, although the effect is not as severe as in 60 ppm imidazole. Previous studies had demonstrated that magnetic field does not affect the corrosion rate of copper in 0.5M NaCl [10]. Therefore there is no synergetic effect between NaCl and imidazole and the effect of magnetic field is only on the imidazole itself.

3.2 Electrochemical analysis:

Figure 3 shows the result of polarization test, where Tafel extrapolation technique was used to determine the corrosion current, icorr from the polarization curve. The data obtained from Tafel extrapolation is shown in Table 2. From the polarization curve, the inhibition efficiency of imidazole is calculated using the following equation:

$$IE = \frac{i^0{}_{corr} - i^f{}_{corr}}{i^0{}_{corr}} \times 100\%$$

where IE is inhibition efficiency, i^0_{corr} and i^f_{corr} are the corrosion current of untreated and treated copper electrode respectively. As in the case of the weight loss test, corrosion current increased when it is under magnetic field. The anodic slope, Ba, also increased when under the influence of magnetic field. Although cathodic slope, Bc, decreases under magnetic field, the decrease is not significant enough to overcome the increase of Ba. Therefore it is highly possible that formation of the protective layer had been retarded with the presence of the magnetic field. It is known that imidazole, like most of the azoles compounds, inhibits the corrosion of copper via physisorption [11]. It is possible that the micro-turbulence flows created by magnetic field-induced magnetohydrodynamic effect creates significant resistance for the imidazole to adsorb on the surface of copper. The changes in corrosion potential, Ecorr, under 13mT magnetic field is not significant, which suggests that electrochemical kinetic governed by electron transfer is not affected by magnetic field.

4. Conclusion:

From weight loss test and electrochemical analysis, inhibition efficiency of imidazole as inhibitor of copper in 0.5M NaCl had decreased when it's under 13mT magnetic field. We believe this observation is caused by magnetohydradynamic effect that retards the physisorption of imidazole on the copper surface. Therefore, protective surfaces may not be properly formed to protect the copper from corrosion.

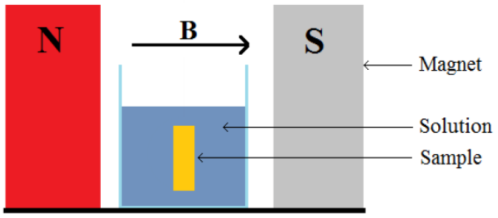

Fig. 1: Schematic diagram of experimental setup.

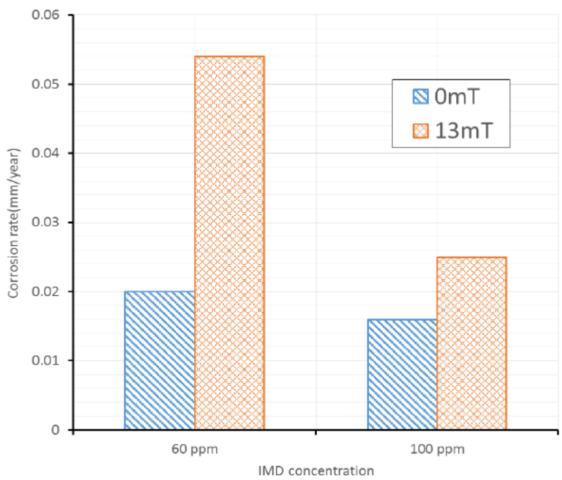

Fig. 2: Corrosion rate of copper in 0.5M NaCl with or without 13mT magnetic field.

Table 1: Result of the weight loss test.

Solution	Corrosion rate (mm/year)	IE/%
0.5M NaCl	0.053	-
0.5M NaCl + 60 ppm IMD (0 mT)	0.020	62.26
0.5M NaCl + 60 ppm IMD (13mT)	0.054	-1.89
0.5M NaCl + 100 ppm IMD (0mT)	0.016	69.81
0.5M NaCl + 100 ppm IMD (13mT)	0.025	52.83

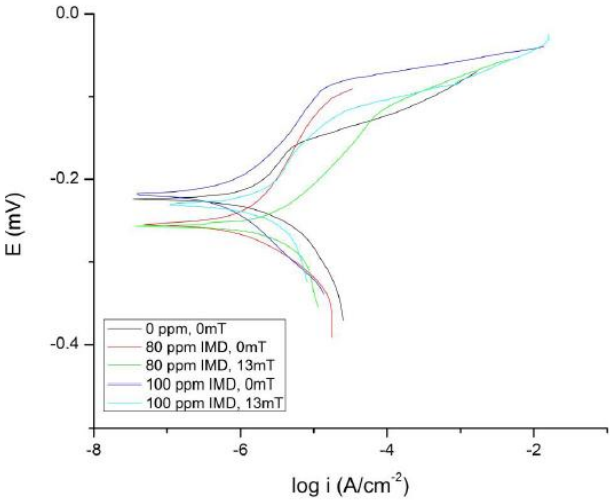

Fig. 3: Polarization result of copper in 0.5M NaCl with or without 13mT magnetic field.

Table 2: Tafel extrapolation result from polarization curve of copper in 0.5M NaCl with or without magnetic field.

Solution	Ecorr/mV	icorr/μA cm^{-2}	Bc/mV $Decade^{-1}$	Ba/mV $Decade^{-1}$	Rp/kΩ cm^2	IE/%
0.5M NaCl	-224.2	4.488	110.8	749.3	9.34	-
0.5M NaCl + 60 ppm IMD (0mT)	-181.1	1.798	192.8	83.4	14.07	59.94
0.5M NaCl + 60 ppm IMD (13mT)	-237.2	2.763	93.7	144.1	8.923	38.44
0.5M NaCl + 100 ppm IMD (0mT)	-218.2	1.146	135.8	119.2	24.05	74.47
0.5M NaCl + 100 ppm IMD (13mT)	-230.2	2.807	97.2	160.2	9.361	37.46

This finding suggested that corrosion prevention strategy had to be reconsidered and modified when magnetic field is to be expected.

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