

RESEARCH ARTICLE | SEPTEMBER 03 2014

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AIP Conf. Proc. 1614, 26–29 (2014)

<https://doi.org/10.1063/1.4895164>



15 April 2024 02:16:14

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The Effect of Magnetic Field on Copper in Various Corrosive Medium

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Abstract. The effect of applied magnetic field on the corrosion behaviour of copper within various corrosive medium is investigated. The copper coupon is immersed in 0.5 M HCl, 0.5 M NaCl and 0.5 M NaOH with or without applying up to 40 mT magnetic fields for 24 hours. The weight loss of copper coupon in HCl increased up to 96.56% with applied magnetic fields. However, in NaOH medium, only 33.33% more weight loss was observed and no difference were observed for coupons in NaCl when magnetic field is applied. This observation indicates that corrosion behaviour in HCl and NaOH is controlled by mass transport that can be influenced by the induced magneto hydrodynamics effect when magnetic field is applied. There was no change in weight loss of copper in NaCl when magnetic field is applied because the corrosion mechanism of copper in NaCl is governed by electron charge transfer.

Keywords: Corrosion, magnetic field, copper

PACS: 81.05.Bx, 82.45.Bb, 41.20.Gz

INTRODUCTION

There is a rise of interest to study magnetochemistry and its application to corrosion inhibition. So far, the result of the findings is still controversial. One of the leading theories suggested that magnetic field affects corrosion during mass transfer via magnetohydrodynamic (MHD) effect generated via Lorentz force, F_L [1]:

$$F_L = q(\mathbf{E} + \mathbf{v} \times \mathbf{B}) \quad (1)$$

where q is the electron charge, \mathbf{E} is the electrical field, \mathbf{v} is velocity vector of the electron and \mathbf{B} is the applied magnetic field strength. Yuan et al. [2] showed the aforementioned MHD effects on the corrosion of copper in NaCl with applied magnetic field using holography method. According to Lu and Yang [3] hydrogen reduction of iron can be affected by magnetic field up to 0.4 T. Magnetic field orientation in respect of the working surfaces is also important in determining the corrosion behaviour of ferrous metals in applied magnetic field. Studies showed that magnetic field gradient caused by the magnetization of the iron electrode can influence mass transfer step even if Lorentz force is reduced to insignificant magnitude via adjustment of magnetic field orientation and the reduction of working surface area [4]. This gradient force, F_B , can be described as:

$$F_B = \chi_m c \frac{B \nabla B}{\mu_0} \quad (2)$$

where χ_m is the molar susceptibility, c is the concentration of bulk solution and μ_0 is the magnetic permeability of vacuum. There are studies that shown positive improvement of organic inhibitors' efficiency when magnetic field is applied, which is attributed to the enhancement of inhibitors' adsorption on surface of metals [5-6]. However, it is shown using electrical impedance spectrometry that magnetic field has no effect on electron charge transfer for redox system [7-8]. Most studies focused on the effect of high \mathbf{B} value ($\mathbf{B} \geq 0.4$ T), and very few studies have been done on lower \mathbf{B} , where more practical applications can be employed by the industry.

The objective of this study is to investigate the effect of 40 mT **B** magnetic field on copper in different corrosive medium. Weight loss test was carried out to archive the objective. For this study, HCl, NaCl and NaOH were chosen as the corrosive medium. Neodymium magnet was used as the source of magnetic field.

METHODOLOGY

FIGURE 1 shows the schematic diagram of experimental setup of the weight loss test. Copper with 99.99% purity were used for this experiment. 50 mL solutions of 0.5 M HCl, 0.5 M NaCl and 0.5 M NaOH were prepared using reagent grade chemical. Copper coupons of diameter 16.3 mm and thickness 3 mm were ground using SiC paper up to 800 grit, then the coupons were rinsed and cleaned using distilled water and acetone before they were suspended within the medium for 24 hours. After weight loss test was conducted, the coupons were cleaned and dried. The weight of the coupons was then taken using electronic weighing scale. The percentage change of the weight loss with and without **B**, Δwt , was calculated using the following equation:

$$\Delta wt = \frac{(wt_B - wt_0)}{wt_0} \times 100 \quad (3)$$

where wt_B and wt_0 is the weight loss with and without **B** respectively. Two neodymium block magnet were used to generate **B** up to 40 mT at the centre of the coupon. The field was parallel with the working surface, which was defined as the circular area of the coupon. These magnets were secured on the side of the beaker using strong adhesive tape. The value of **B** was measured using Hall Effect probe connected to a teslameter (Linkjoin LZ-610H). To avoid the effect of remanent magnetic effect, **B** = 0 experiments were done in locations far from the magnetic sources. Room temperature was used throughout the course of experiment.

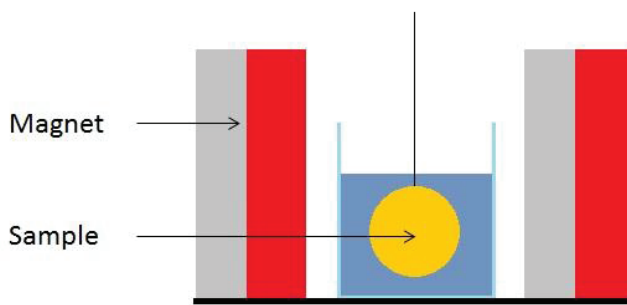


FIGURE 1. Schematic diagram of experimental setup for weight loss test.

RESULT AND DISCUSSION

The result of the weight loss test on copper coupons is shown in FIGURE 2. Weight loss of copper coupons increases under applied magnetic field compared to the coupons without applied magnetic field when coupons were immersed in HCl and NaOH, however no changes were observed for coupons in NaCl. The calculated Δwt of HCl, NaCl and NaOH using Equation 3 is 96.55%, 0% and 33.33% respectively, as shown in TABLE (1). This observation suggested that there is a shift in free corrosion potential in the case of HCl and NaOH, but no shift occurred for the case in NaCl. In the anodic dissolution of copper in acidic or neutral media, three possible cases had been proposed [9].

Case I:



Case II:



Case III:



TABLE (1). Weight loss of copper in HCl, NaCl and NaOH without magnetic field, wt_0 , with magnetic field, wt_B , and the change in weight loss, dwt .

Medium	wt_0/mg	wt_B/mg	$\Delta wt/\%$
HCl	2.90	5.70	96.56
NaCl	0.20	0.20	0
NaOH	0.75	1.00	33.33

Case I is represented by Equation 4, Case II is represented by Equation 5 and 6, while Case III is represented by Equation 7 and 8. The high Δwt value of copper in HCl suggested that dissolution in HCl may obeys either Case I or Case II, where the corrosion is controlled by the mass transport of chloride ions to the copper surfaces. This mass transport can be influenced by the induction of MHD by the magnetic field, as reported by literature [10], and increases the corrosion rate of copper in HCl. The weight loss results of copper coupon in NaCl solution is consistent with the findings by Yuan et al. [2], where Case III is shown to be the most probable case of initial dissolution in NaCl and no influence of magnetic field on Case III dissolution were found. On the other hand, copper corrosion in alkaline corrosion can be described as follow [11-13]:



The slight increases of corrosion rate of copper/NaOH with applied magnetic field may be caused by the same phenomena observed in the case of HCl as explained above, especially the formation of Cu_2O in Equation 9. However, due to the protective nature of CuO , the complete formation of CuO layer by Equation 10 may retard the corrosion rate of copper and prevented the further increase of Δwt , because the formation of protective layer has been established.

CONCLUSION

It is shown that applied magnetic field increases the corrosion rate of copper in HCl and NaOH. However, no changes were observed for NaCl. Higher corrosion rate is observed in the case of HCl. This observation may be explained via the corrosion mechanism of copper in the corrosive medium. In cases where mass transfer is the primary mode of electrochemical corrosion, as in the case of HCl and NaOH, magnetic field can influences the corrosion rate via MHD effects. For NaCl case, the electron charge transfer is the main mode of the electrochemical corrosion. Therefore when magnetic field was applied, no significant effect was observed. Future research need to be investigated on electrochemical analysis on the influence of magnetic field towards corrosion of metals and alloys.

ACKNOWLEDGMENTS

The authors would like to thank Universiti Kebangsaan Malaysia and Department of Higher Education, Ministry of Education Malaysia for the financial support via the Exploratory Research Grant Scheme (ERGS/1/2012/STG05/UKM/01/4) and the Ministry of Education Malaysia for MyMaster scholarship.

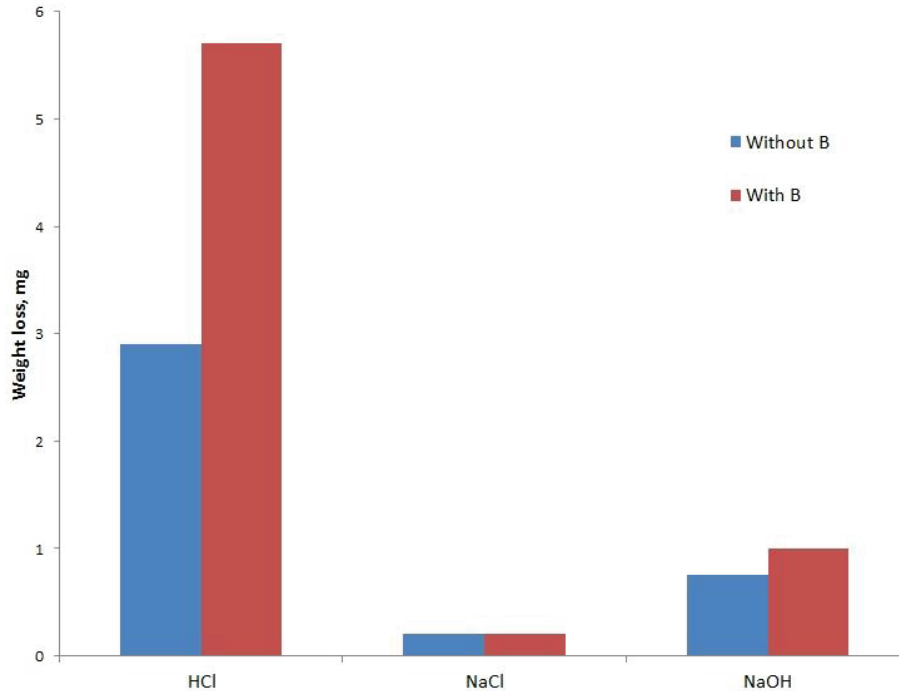


FIGURE 2. Weight loss of copper coupon in 0.5 M HCl, 0.5 M NaCl and 0.5 M NaOH, with and without applied magnetic field.

REFERENCES

1. R. Tacke, and L. Janssen, *Journal of Applied Electrochemistry* **25**, 1–5 (1995).
2. B. Yuan, C. Wang, L. Li, and S. Chen, *Corrosion Science* **58**, 69–78 (2012).
3. Z. Lu, and W. Yang, *Corrosion Science* **50**, 510–522 (2008).
4. R. Sueptitz, K. Tschulik, M. Uhlemann, L. Schultz, and A. Gebert, *Electrochimica Acta* **56**, 5866–5871 (2011).
5. A. A. Rousan, and N. A. F. Al-Rawashdeh, *Corrosion Engineering, Science and Technology* **41**, 235–239 (2006).
6. A. K. Maayta, M. M. Fares, and A. F. Al-Shawabkeh, *International Journal of Corrosion* **2010**, 1–9 (2010).
7. O. Devos, O. Aaboubi, J.-p. Chopart, A. Olivier, C. Gabrielli, and B. Tribollet, *The Journal of Physical Chemistry A* **104**, 1544–1548 (2000).
8. S. Koehler, and A. Bund, *The journal of physical chemistry. B* **110**, 1485–9 (2006).
9. G. Kear, B. Barker, and F. Walsh, *Corrosion Science* **46**, 109–135 (2004).
10. G. Hinds, J. Coey, and M. Lyons, *Electrochemistry Communications* **3**, 215–218 (2001).
11. J. Kunze, V. Maurice, L. H. Klein, H.-H. Strehblow, and P. Marcus, *Corrosion Science* **46**, 245–264 (2004).
12. B. Yu, P. Woo, and U. Erb, *Scripta Materialia* **56**, 353–356 (2007).
13. F. Rosalbino, R. Carlini, F. Soggia, G. Zanicchi, and G. Scavino, *Corrosion Science* **58**, 139–144 (2012).