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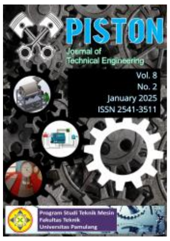

The Influence of Chloride Ion Concentration and Short Immersion Time on the Corrosion Behavior of C11000 Copper Alloy

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Abstract: The effect of various chloride ion concentration (0 %, 1 %, 2 %, 3%, 4% and 5 % NaCl solution) on the corrosion behavior of the C1100 copper alloy was investigated with the immersion test (weight loss method). The effect of various immersion periods was also examined up to 14 days. After conducting immersion test, metal surfaces were observed with an optical microscope and the SEM analysis. The product of corroded copper was characterized using Energy Dispersive Analysis of X-rays (EDAX). On the basis of results, the magnitude of corrosion rate is higher in increasing the chloride concentration and immersion period, respectively. The increase of chloride concentration causes the copper oxide layer to become porous and cracked compared to without chloride addition. The reduction in the integrity of the copper protective layer took place due the presence of chloride ion.

Keywords: Corrosion; Copper; Weight Loss Method; NaCl Solution; Corroded Material.

Abstrak: *Pengaruh berbagai konsentrasi ion klorida (larutan NaCl 0%, 1%, 2%, 3%, 4% dan 5%) terhadap perilaku korosi paduan tembaga C1100 diselidiki dengan uji perendaman (metode kehilangan berat). Pengaruh berbagai periode perendaman juga diperiksa hingga 14 hari. Setelah melakukan uji perendaman, permukaan logam diamati dengan mikroskop optik dan analisis SEM. Produk tembaga yang terkorosi dikarakterisasi menggunakan Analisis Dispersi Energi Sinar-X (EDAX). Berdasarkan hasil, besarnya laju korosi lebih tinggi dengan meningkatkan konsentrasi klorida dan periode perendaman, masing-masing. Peningkatan konsentrasi klorida menyebabkan lapisan oksida tembaga menjadi berpori dan retak dibandingkan tanpa penambahan klorida. Pengurangan integritas lapisan pelindung tembaga terjadi karena adanya ion klorida.*

Kata kunci: *Korosi; Tembaga; Metode Penurunan Berat; Larutan NaCl; Bahan yang Terkorosi*.

INTRODUCTION

Since copper has outstanding mechanical workability and excellent electrical and thermal conductivity, it is a metal that is utilized extensively in many industrial applications [1]. However, its corrosion resistance tends to decrease when in an expose with aggressive solutions. In addition, the presence ion nitrate, sulphate and chloride ions contribute to lead passive film breakdown which cause corrosion [2]–[4].

The presence of Cl ions induces corrosive effect for copper, depending on the concentration of chloride [5]. The aggressiveness of chloride ions also leads to promote localized destruction such pitting corrosion on the surface of copper alloy [6]. The reaction of chloride ions with copper produces cupric chloride compound [7] where that compounds has an good solubility in water [8]. The presence of cupric chloride compounds indicate the corrosion attack take place due to the electrochemical process on copper alloy [9].

Furthermore, the immersion time of metals and alloy is an essential factor to determine of the magnitude of corrosion rate [10]. Commonly, with an increase in immersion time, the corrosion rates of metal increases significantly [11]. Because of the extended contact with the corrosive medium, a less protective layer forms the longer the immersion period [12]. Copper alloys has a primary failure of localized corrosion attack such pitting corrosion [13] as well as aluminium alloy [14] and stainless steel [15].

There is more extensive investigation of corrosion study on copper alloy in neutral chloride environment. However, there is no or little study about the effect of immersion time in short duration in various chloride concentration. Therefore, the objective of this study is to elucidate the corrosion behavior of C1100 copper alloy in different short immersion time in various chloride concentration. The other objective is to observe and characterize the corroded surface of copper after short exposure in neutral chloride environment.

METHODS

Materials Preparation

C1100 copper specimens with dimensions of 50 mm in length, 20 mm in width and 1 mm in thickness were prepared. The pickling procedure, in accordance with ASTM G1-81, was used to remove corrosion products from the metal specimens prior to the experiment. The pickled specimens were cleaned and washed using distilled water and afterwards acetone, and then stored in vacuum desiccators. Initial weight was determined by weighing them. Sodium chloride solution was used as corrosive media in various concentrations (1 %,2%,3%,4% and 5%) where that solution prepared from analytical grade.

Weight Loss Measurement

The specimens were weighed for initial weight using an analytical scale prior to being cleaned with the pickling solution, which included the corrosion layer was pickled with HCl (15%) and isopropanol with 5mg/L of hexamethylenetetramine [16]. The specimens were immersed in various concentration of NaCl solution in static mode for 1, 3, 5, 7 and 14 days at room temperature. Over the course of the certain exposure time experiment, samples were taken from each specimen. Before weighing, the specimens were cleansed with distilled water and soaked in pickling solution to eliminate the corrosion product. To get the final weight, the specimens were cleaned with distilled water, dried, and weighed.

In general, uniform corrosion attacks copper alloy when they are used in corrosive environment [17]. As a result, the corrosion rate was calculated under the assumption that all of the specimens' surfaces would corrode equally. One method to determine the rate of corrosion in unit of mg/day.cm^2 is to use weight loss, which is represented as follows in Eq. (1).

$$Corrosion\ rate\ = \frac{Wo - Wi}{A.t}$$

Where; W_i = weight of the specimen after the immersion test and pickling process (mg), W_o = weight prior to immersion test (mg), A = total surface area exposed to the solution (cm^2), t = immersion time (day).

Chemical and Surface Analysis

Energy Dispersive Spectroscopy (EDS) in conjunction with a Scanning Electron Microscope (SEM) was used to examine the morphology and chemical substance of the corrosion products. The analyses were conducted using a 15 kV accelerating voltage.

In the experiment section, all materials and methods that have been used in the research should be stated clearly.

RESULT AND DISCUSSION

Weight Loss Analysis

The C1100 copper alloy was immersed in various chloride concentration had varying the magnitude of weight losses, as seen in Figure 2. Overall, Figure 2 reveals that the values of weight loss tend to increases with increase in solution concentration. At fourteen days of exposure, the value of weight loss significantly increases where the weight loss at the time of exposure increased by 17 to 200 times.

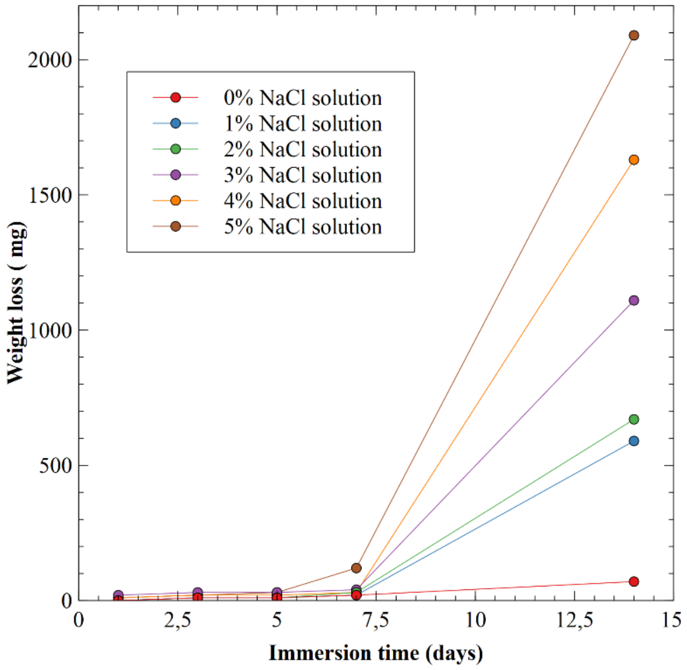


Figure 1. The weight loss of copper alloy against time (days) for variations of concentrations of chloride concentration

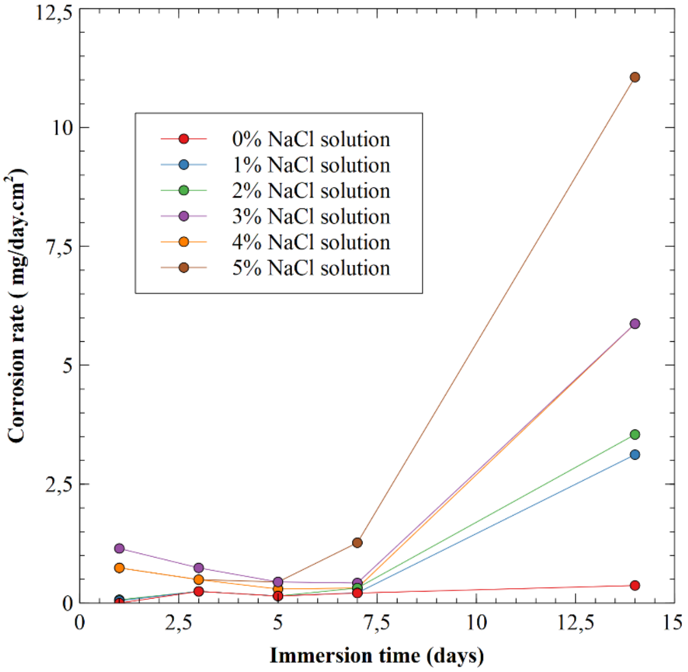


Figure 2. The corrosion rates of copper alloy against time (days) for variations of concentrations of chloride concentration

Figure 2 shows the changes in corrosion rate of the copper alloy obtained from immersion in various chloride concentration in room temperature. That figure shows the immersion time dependence of the corrosion rate for the copper alloy in the various concentration of chloride. The increase of both the chloride concentration and immersion time tends to increase the magnitude of corrosion rates on copper alloy. Due to the role of oxygen and chloride in electrochemical processes, the magnitude of corrosion rate is increased [18].

After 3 days of exposure, the initial phase, known as the initiation phase, exhibits arise in corrosion rate. After the initial phase, the rate of corrosion declined until 5 days of exposure. The decrease in corrosion rate can be corresponded to the presence of a passive layer on the surface of the metal, which acts as a protective layer against further corrosion [19]. After initial phase, the corrosion rate increased significantly to 14 days of exposure. It presumed that chloride ions lead predominantly in passive film breakdown in copper [20]. Generally, it was summarized that the corrosion resistance of copper alloy tends to decrease with the increase of immersion time up to 14 days of short exposure in each certain chloride concentration.

Surface Morphology of Corroded Copper Alloy

Figure 3 shows corrosion morphology of C1100 copper alloy in various concentration of NaCl solution at 14-day exposure. The adherent oxide layer of copper alloy is formed homogeneously as seen in Figure 3(a) without the addition of chloride ion. The porous and grain layer structure were formed on the surface of corroded copper (Figure 3(b)) in 3% NaCl solution. The increase of chloride concentration up to 5% NaCl lead the breakdown of corroded layer on copper alloy (Figure 3(c)).

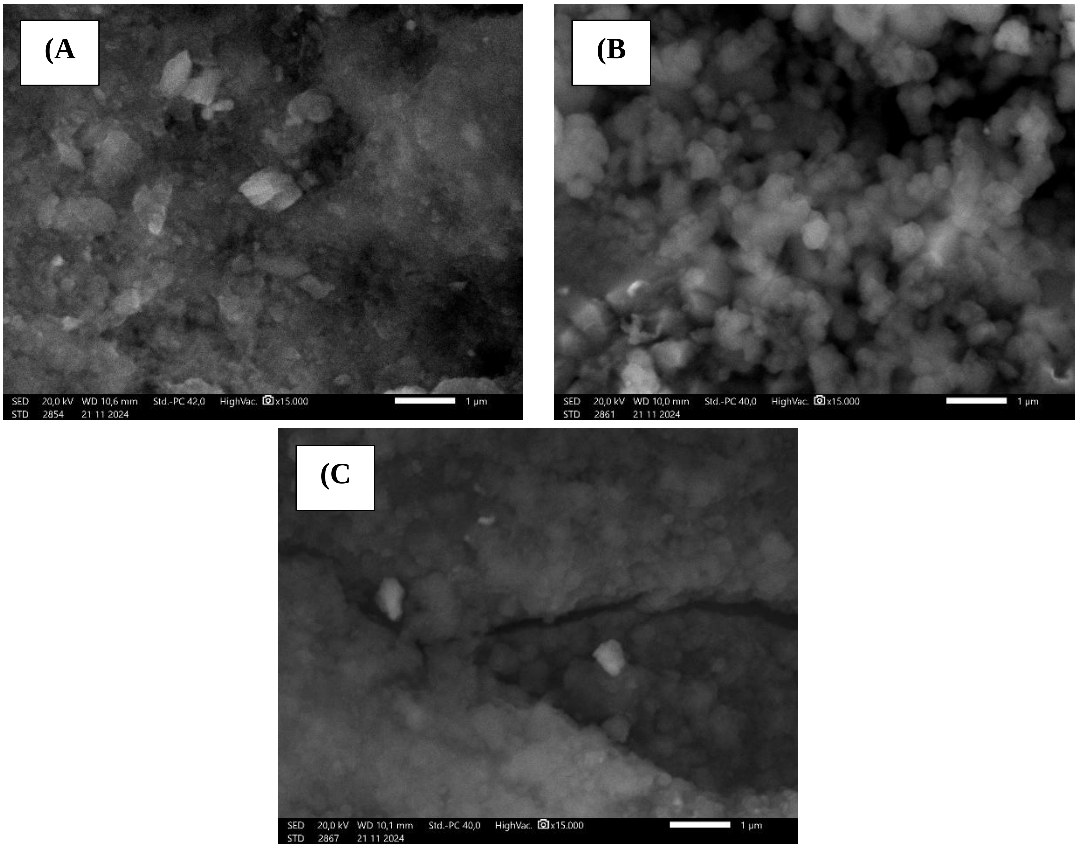
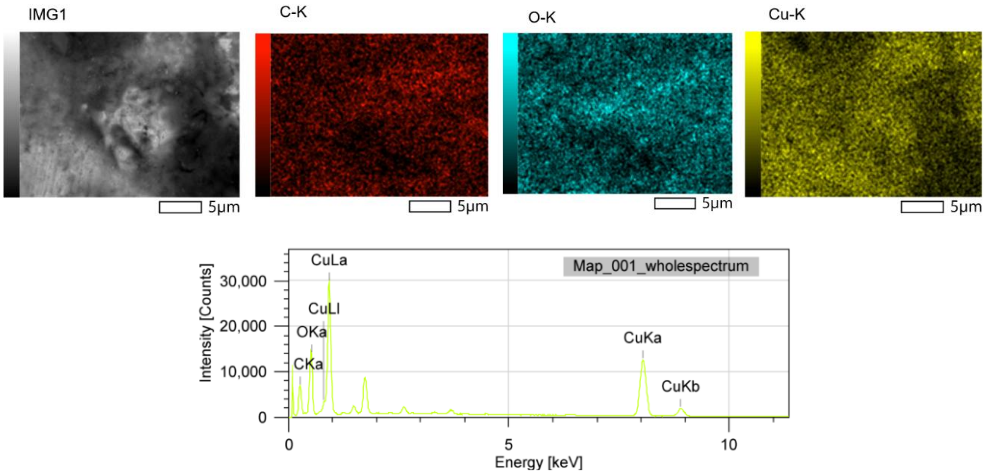


Figure 3. Corrosion morphology of C1100 copper alloy in (A) 0 % NaCl solution; (B) 3% NaCl solution and (C) 5% NaCl solution at 14-day exposure

Because the copper oxides are porous and spatially heterogeneous rather than having a uniform surface, they can hold onto the ingress of chloride ions [21] as well as the present study. Figure 4 shows scanning electron microscopy (SEM) images, energy dispersive X-ray spectroscopy (EDS) spectra and elemental mapping of C, Cu, O, and Cl of copper alloy in different chloride concentration at ambient temperature. The spectra indicated that there were elements of C, O, Cl and Cu after immersion in chloride solution as shown Figure 4(b) and (c). There is no chloride content on the control sample (Figure 4(a)).

(a)



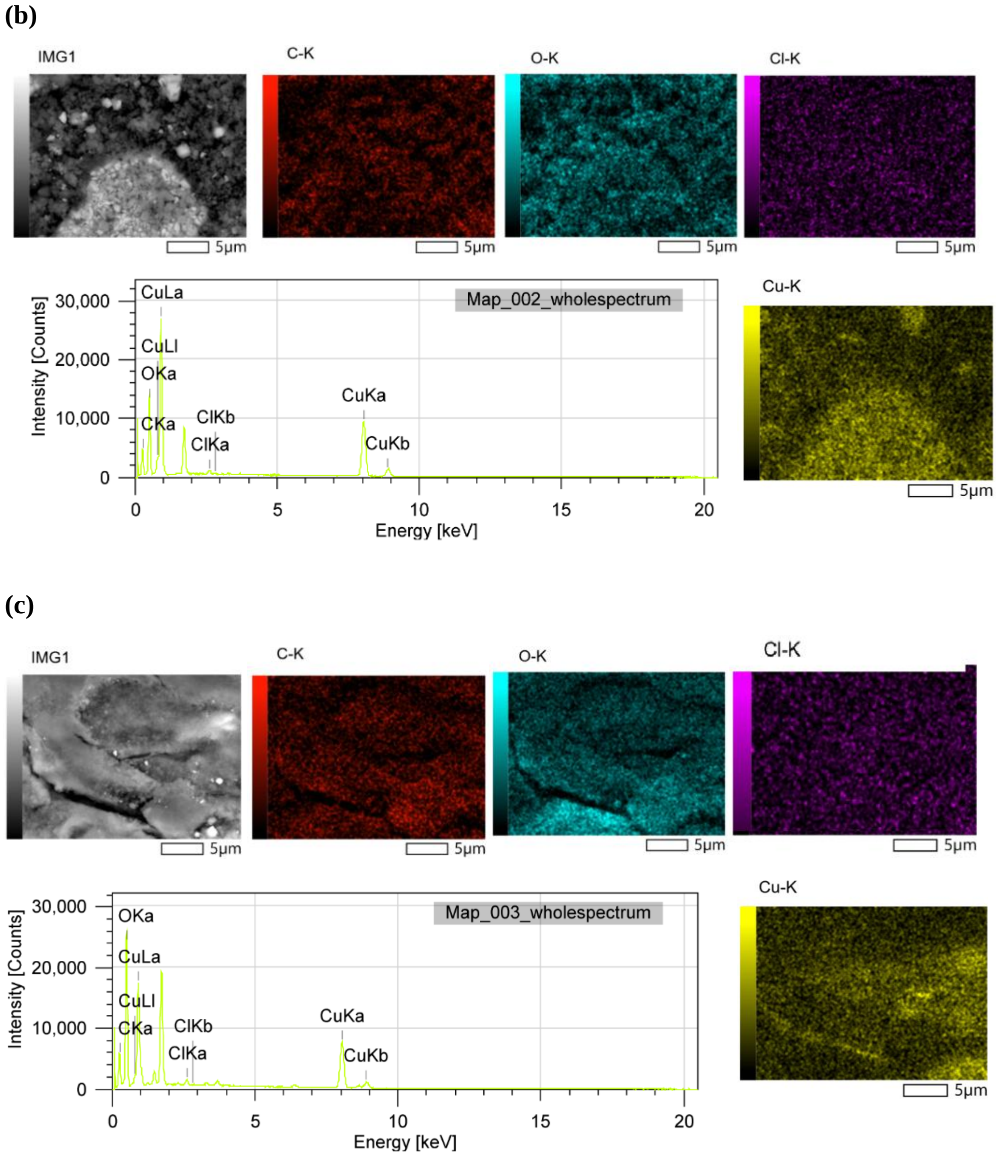


Figure 4. Scanning electron microscopy (SEM) images, energy dispersive X-ray spectroscopy (EDS) spectra and elemental mapping of C, Cu, O, and Cl. The results are copper alloy in (a), 0% NaCl solution (b) 3 % NaCl solution (c) 5 % NaCl solution

In EDS analysis, the peak intensity of an element is proportional to its concentration in the material analyzed as well as the recent study. The increase of chloride concentrations decreases copper concentrations which tends to dissolve copper into the environment. The element of O is evenly distributed on the surface of the copper metal, indicating the presence of dense copper oxide as well as the element of Cu as shown in Figure 4(a). The presence of chloride ions has a negative impact by breaking down copper oxide where the distribution of O and Cu elements is not dense as shown in Figure 4(b) and 4(c). In the current study, a significant increase in both corrosion rate and weight loss indicated the breakdown of copper oxide at 5% NaCl concentration. Both the rupture of copper oxide and the porous morphology provide a pathway for aggressive chloride solutions to enter the active region. The active area as anode experiences an anodic reaction through the dissolution of copper into the environment which is indicated by a decrease in copper concentration and an increase in the corrosion rate.

CONCLUSIONS

The effect of increasing chloride concentration and exposure time increases the corrosion activity of copper metal which is indicated by the increasing value of corrosion rate and weight loss. The morphology of copper surface changes from dense copper oxide to porous copper oxide. The rupture of copper oxide occurs with the increase of chloride ion concentration. The rupture of copper oxide provides a way for aggressive solution to react with copper metal as an anodic active area. The decrease of copper concentration with the increase of chloride ion is indicated by the high corrosion rate of copper.

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