# Corrosion Rate of Black Chromium Coating Result of Electroplating on Copper

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***Abstract* - The problem faced is that the white chromium coating has a low selling value or aesthetic value than the black chromium layer which is more in demand, especially by the younger generation who prioritizes aesthetics. The purpose of the corrosion test was to determine the corrosion resistance ability of the black chromium coating resulting from the electroplating process on the relationship between the solution temperature and the immersion time of copper in a corrosive solution. Corrosion test methods include literature studies, field observations, weighing specimens, immersing specimens in corrosive solutions, weighing specimens, calculating corrosion rates, and data analyzing. Corrosion test results show that the higher the temperature of the solution and the longer the immersion time, the smaller the corrosion rate for the lowest conditions at 30ºC and a duration of 5 minutes with a corrosion rate of 0.2004 mm/year and the highest conditions at a temperature of 50ºC and a duration of 9 minutes at a rate of corrosion of 0.0108 mm/year.**

*Keywords:* ***electroplating, temperature,; immersion time, corrosion rate, copper.***

## I. Introduction

The resistance of the black chromium layer resulting from electroplating on copper was measured by corrosive treatment on the resulting coating in the form of a corrosion rate.

Previous studies have examined the effect of the associated parameters on the coating on the electroplating of various coating materials on various specimen materials under various conditions.

Black coatings on metal have been widely used for decorative coatings, solar panels, or optical instruments [1]. Immersion of copper specimens in NaCl solution at a concentration of 36.05 g/l for 336 hours from the results of electroplating at 10, 20, 30, 40, and 50 minutes respectively, obtained a corrosion rate of 0.029, 0.013, 0.017, 0.022, and 0.012 mm/year, whereas uncoated copper has a corrosion rate of 0.308 mm/year which means that copper metal coated with nickel-chromium is most effective at resisting corrosion with electroplating time at 50 minutes [2]. Black chromium plating on copper with various trivalent electrolyte solutions and hexavalent electrolytes are good results at 10 ºC electrolyte temperature, current density 55 A/dm$^2$ [3]. The corrosion resistance of copper-tin alloys depends on the thickness of the Chromium plating and the duration of the test in the corrosion chamber [4]. Electrochemical impedance spectroscopy (EIS) shows that chromium coated A588 steel has better corrosion resistance ($E_{corr}$= - 1.742 V; $I_{corr}$= - 0.334 mA) than Cu, Ni, Zn layers [5]. Chromium electroplating at a duration of 35, 45, and 65 minutes resulted in an average corrosion rate of 0.0236, 0.0607, and 0.0135 mpy (mil/year) respectively, which means that the average corrosion rate tends to decrease with the length of coating time [6]. Chromium electroplating at 6, 9, 12 V respectively, has a corrosion rate of 0.5781, 0.2683, 0.0173 mm/year, and for the uncoated specimens, the corrosion rate reached 3.5052 mm/year [7]. Electroplating of ST 37 with Nickel and Chromium at the lowest duration of 10 minutes obtained a precipitate of 0.1095 g and the highest duration was 50 minutes, a precipitate of 0.5475 g was obtained, the lowest electric current was 0.24 A, the precipitate was 0.1748 g and the highest electric current was 1.20 A, a precipitate of 0.8592 g is obtained, which means that the longer the duration and the higher the current, the heavier the precipitate is obtained [8]. Electroplating of ST 40 with Nickel and Chromium at a solution temperature of 40, 45, 50, 55 and 60ºC indicates that the increase of the liquid temperature, the thickness and hardness increase, but at 60 ºC the thickness and hardness decrease due to the Chromium ions attached on the surface of the specimen has saturation properties, so it can damage the bond layer of the specimen which

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reduces the surface hardness [9].The thickness of the Cu layer resulting from electroplating on low carbon steel is influenced by the duration of the process and the current with a value in the current range of 0.1 ÷ 0.5 A/cm$^2$ and the duration of the process at 5 minutes, the thickness of Cu 0.119 ÷ 0.521 µm, 10 minutes, the thickness of Cu 0.247 ÷ 0.931 µm, 15 minutes, the thickness of Cu 0.250 ÷ 1.751 µm, and 20 minutes, the thickness of Cu 1.001 ÷ 2.355 µm [10].

## II. Research Methodology

The independent variables were solution temperature and duration of the electroplating process of black chromium, and the dependent variable was the corrosion rate, while the controlled variables were pH of the solution, the area of contact of the specimen in immersion, and electric voltage.

The flow diagram of the electroplating process of black chromium is shown in Figure 1.

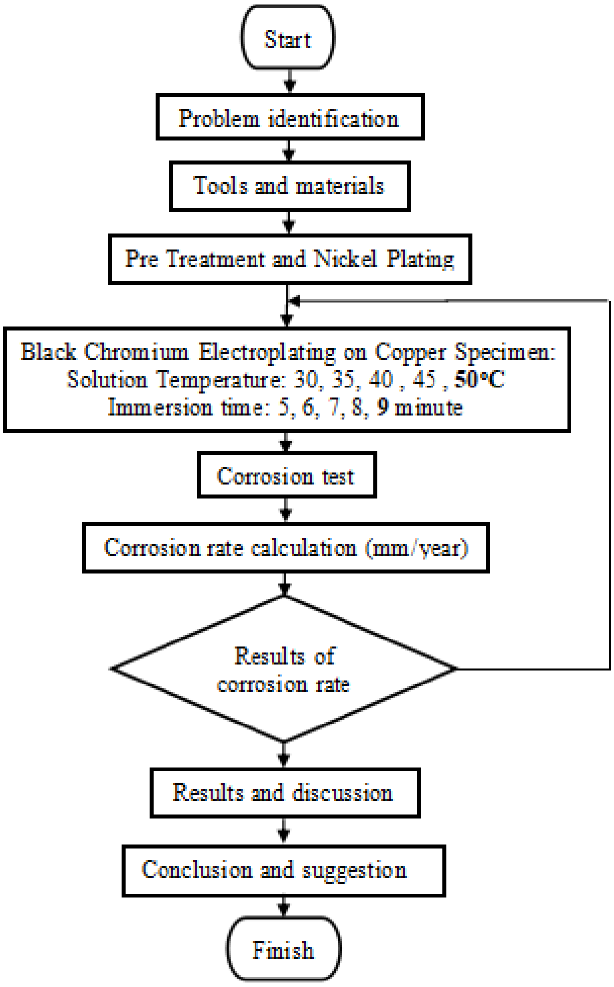


Figure 1. Flow diagram of the electroplating process of black chromium

Copper specimens with dimensions of 50 x 20 x 3 mm are made of 3 mm hanger holes that surface is flattened and polished using a sponge grinder [10] is shown in Figure 2.

Figure 2. Copper specimen

All specimens were subjected to a treatment process to be cleaned the surface with a metal cleaner and then immersed in an activation solution containing HCl and aquadest with a ratio of 1:1 for 3 minutes at a temperature of 50°C is shown in Figure 3.

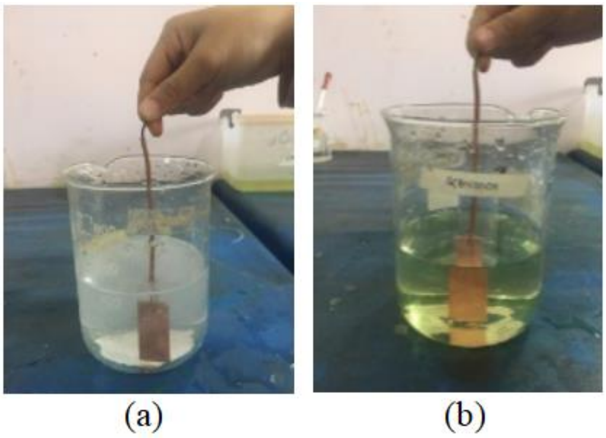


Figure3. Pretreatment in a solution of (a) metal cleaner, and (b) activation

The electroplating process is divided into 2, namely Nickel plating as the base for gloss color at 40°C for 20 minutes and black chromium plating at 50°C for 9 minutes is shown in Figure 4.

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Figure 4. Electroplating (a) Nickel, and (b) Black Chromium

The best results of electroplating on copper with black chromium are at a temperature of 50ºC and an immersion time of 9 minutes is shown in Figure 5.

Figure 5. Specimen from the electroplating process of black chromium at 50ºC for 9 minutes

Corrosion testing of specimens coated with Black Chromium was carried out by immersing them in a NaCl solution with a concentration close to the NaCl concentration in seawater at 36.05 g/l by immersion for 336 hours (2 weeks) which the condition of the solution is the same as that of Dewi and Ahmadi [2] is shown in Figure 6.

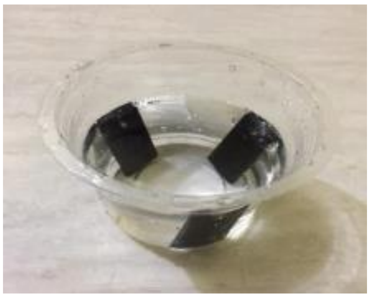

Figure 6. Specimens under corrosion test

The data from the corrosion rate test in the form of the difference in specimen weight before and after corroding which is used by Digital Analytical Scales with an accuracy of one ten thousand grams is shown in Figure 7.

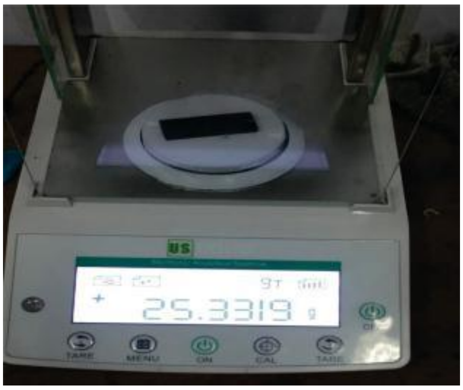


Figure 7.Digital Analytical Scales

One of the methods for determining the corrosion rate is by calculating the weight per unit time or the depth per unit penetration time. The rate of reaction can be expressed in inches per year (ipy), mils per year (mpy), millimetres per year (mmpy), or micrometers per year (μm / y) [7].

The difference in specimen weight is determined by equation (1).

$$\Delta W = \Delta V \times \rho \quad (1)$$

Where:
ΔW: Difference in specimen weight (g)
ΔV: Difference in specimen volume ($mm^3$)
ρ: Density of specimen ($g/cm^3$)

The depth of penetration on the metal surface is determined by equation (2).

$$t = \Delta V / A \quad (2)$$

where:
t: penetration depth (mm)
ΔV: difference in specimen volume ($mm^3$)
A: Surface area ($mm^2$)

The corrosion rate that occurs is determined by equation (3).

$$r = t / T \quad (3)$$

where:
r: Corrosion rate (mm / year)
t: Depth of penetration (mm)
T: Time (years)

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## III. Result and Discussion

The results of calculating the corrosion rate for various solution temperatures and the duration of immersion of the black chromium electroplating specimens in the solution are shown in Table 1 and Figure 8 [11].

Table 1. The corrosion rate of black chromium coating on copper

| Temperature (°C) | Duration of immersion process (Minute) | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| 30 | 0.1811 | 0.1354 | 0.1318 | 0.1259 | 0.1059 |
| 35 | 0.1420 | 0.1184 | 0.1048 | 0.0926 | 0.0812 |
| 40 | 0.1240 | 0.0858 | 0.0676 | 0.0532 | 0.0485 |
| 45 | 0.0881 | 0.0622 | 0.0485 | 0.0403 | 0.0384 |
| 50 | 0.0653 | 0.0404 | 0.0337 | 0.0159 | 0.0100 |

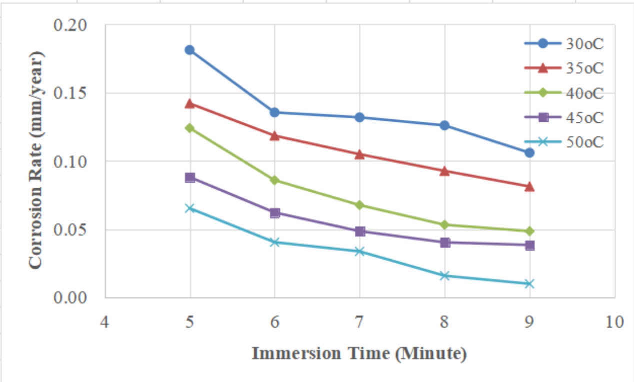


Figure 8. Corrosion rate for various solution temperatures and the duration of immersion of the black chromium electroplating specimens in the NaCl solution [11]

Figure 8 shows that the higher the temperature of the solution, the lower the corrosion rate of the specimens resulting from black chromium electroplating immersed in NaCl solution. Likewise, the longer the specimen immersion in NaCl solution shows a lower corrosion rate, which indicates that the black chromium layer which is longer electroplated has better corrosion resistance.

Dewi and Ahmadi [2] obtained a corrosion rate of 0.029 mm/year for the duration of the electroplating process for 10 minutes, whereas in this study the results of the corrosion rate were 0.1059 to 0.01 mm/year for the duration of the process for 9 minutes for a temperature range from 30 to 50°C. From the comparison of the two results, the corrosion rate shows that the value is included in the value range of this study because the results of Dewi and Ahmadi's research do not state the electroplating temperature.

## IV. Conclusion

The conclusions from the discussion are:

1. The higher the solution temperature in black chromium electroplating, the slower the corrosion rate will be because the higher the temperature produces an even and smoother layer on the surface,
2. The longer the duration of the black chromium electroplating, the slower the corrosion rate will be, because the longer the immersion time, the thicker the black chromium layer is, so the corrosion rate will be slower.
3. In future work, it is better if the research parameters are added in addition to the temperature and time of the solution to determine the corrosion rate, especially those that have significant interaction.

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## References


[1] J. Takadoum, "Black coatings: a review," Euro. Phy. J.: App. Phy., EDP Sci., vol. 52, no. 3, pp. 1-15, November 2010.

[2] C. A. Dewi and Ahmadi, "Effect of duration on decorative Chrome electroplating with Copper base metal on corrosion rates," J. of Hydrogen, vol. 1, no. 2, pp. 107-111, 2013.

[3] Sjöberg, J., "Validation and development of an electrodeposition process to deposit a black chromium coating from a trivalent chromium electrolyte," Thesis, Uppsala, Universitet, September 2016.

[4] C. F. Oduoza and S. Hingley, "Electrochemical evaluation of corrosion resistance of chromium plated nickel and copper tin alloys, a comparative study," J. Electrochem. Sci. Eng. 8(3), pp. 227-239. 2018.

[5] J.R. Deepak, V.K.B. Raja, G.S. Kaliaraj, "Mechanical and corrosion behavior of Cu, Cr, Ni and Zn electroplating on corten A588 steel for scope for betterment in ambient construction applications," Results in Phy., vol. 14, pp. 1-10, June 2019.

[6] M. Santoso, "Corrosion rate of Chrome and Nickel plating by electroplating process on low carbon steel on time variation," Final Project, Faculty of Eng., Pancasakti Univ., Tegal, 2020.

[7] H. Alian, "The effect of stress on the electroplating process of steel with Zinc and Chrome coating on its hardness and corrosion rate," 9th Annual National Seminar on Mech. Eng. (SNTTM), Palembang, MIV-245, 13-15 October 2010.

[8] Ahmadi and B. Holil, "Nickel-chrome electroplating study on ST37 type steel for high school chemistry learning," Proc. of the 2011 National Symposium on Learning and Sci Innovation (SNIPS 2011), Bandung, pp. 230-232, 22-23 June 2011.

[9] S. R. Yulianto and E. Widodo, "Analysis of the effect of variations in Chrome Nickel plating process temperature on the quality of thickness and hardness of ST40 type steel," Proc. of the SNFT UMSIDA 2013, pp. 145-149, Sidoarjo, 2013.


DOI : http://dx.doi.org/10.31963/intek.v7i2.2681

[10] S. Hadi, H. P. Buwono, and Subagiyo, "Copper electroplating on low carbon steel," Proc. of the SNTT 2018, State Polytechnic of Malang, vol. 4, pp. 17-24, Malang, 18-19 October 2018.

[11] S. S. M. Valeria, "Effect of temperature and time of electroplating process on corrosion resistance of black Chromium on Copper," Final Project RTP168002, D-IV Mech. Eng. Production and Maintenance Study Program, Department of Mech. Eng., State Polytechnic of Malang, pp. 1-58. 2020.

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