Determining the current profile along the anode-cathode line in Cu/Ni electrolyte by logger pro

M I Aminudin, M Toifur, D Sulisworo
Physics Education Department, Ahmad Dahlan University, Indonesia

mihya150007029@webmail.uad.ac.id

Abstract. In electroplating, the broad role of cathode and anode is often neglected. This study aims to simultaneously prove the electric current in the three pairs of probes in the cathode-anode direction. It also describes the effect of variations in the anode-cathode area ratio. This result proves that the greater the ratio, the greater the current density in all pairs of probes. Data retrieval used a current sensor current probe DCP-BTA Vernier displayed on a computer screen with the help of Logger Pro software. The results in the study show that the current at every point in the measurement has a less identical graph. In electroplating, nickel (Ni)-1 has a relatively constant amplitude than nickel (Ni)-2. The variation of the anode area ratio at the first nickel (Ni) is 1: 0.821. The ratio of the anode area to the second nickel (Ni) is 1: 0.343. From the analysis results, the first nickel (Ni) has a relatively constant amplitude compared to the second nickel (Ni).

1. Introduction
In electroplating, the broad role of the cathode and anode is often neglected. At the same time, the amount of electric current used in electroplating is current density (J), which is the ratio between current (I) and surface area (A). Therefore, the difference in cross-sectional area of the anode-cathode determines the current density. If the cathode cross-sectional area is not the same as the cathode cross-sectional area, the current density in each region along the anode-cathode path is not the same. If the anode area is greater than the cathode, the current density near the cathode is greater than the current density near the anode.

Setywati and Iriani conducted a study on the effect of current density on the thickness and crystal structure of the nickel layer on copper. The results showed that the thickness of the nickel layer increased with increasing current density [1,2].

In this research, an electric current measuring instrument was designed to measure electric current in several locations in line with the anode-cathode direction in the electrolyte solution simultaneously. The probe consisted of 3 pairs made of copper with a distance between the pins of 2.3 mm. This research examined two factors, namely proving: first, the electric current in the three pairs of probes in the cathode-anode direction at the same time, in varying the anode-cathode area ratio to verify that the larger the ratio, the greater the current density in all pairs of probes and, more specifically, the probe closest to the cathode. For data retrieval, a Vernier current sensor was displayed on a computer screen with the help of Logger Pro software.
2. Theoretical Background

2.1. Electroplating

Electroplating is one of the processes to coat metal using the principle of electric current and the help of chemical compounds to produce coating particles that cover the material [3–5].

![Electroplating process](image)

Figure 1. Electroplating process

The electroplating process consists of a positive electrode (anode), a negative electrode (cathode), and an electrolyte solution containing metal ions [1,6,7]. During electroplating, ions move from the anode to the cathode. These ions carry nickel particles towards the copper so that the copper becomes coated.

2.2. Flow Meeting

Electric current density is a quantity that states the amount of electric current flowing per unit area of the electrode surface [9]. Current density is divided into two types, namely, anode current density and cathode current density. In the electroplating process, the current density is the cathode current density, the amount of electric current required to obtain metal atoms in each unit surface area of the coated workpiece. For this electroplating process, the cathode current density plays a critical role. It will affect the efficiency of the coating, the oxidation-reduction reaction, and the diffusion of the coating on the surface of the coated object.

The principle of the electroplating process is based on Faraday’s Law of electrolysis. There is a difference between the mass of the sample after and before electroplating. The thickness of the nickel layer formed can be calculated using the Lowenheim equation [7]

\[
\delta = \frac{W}{\rho A}
\]

with,

- \(\delta\) = thickness of the formed layer (cm)
- \(\rho\) = coating density (g/cm\(^3\))
- \(W\) = \(m_2-m_1\) = the mass of the layer formed (g)
- \(A\) = layer surface area (cm\(^2\))

2.3. Electric current

Electric current is the flow of electrons from an atom to the atom that occurs in a conductor at a certain speed at a particular time. The cause of the emergence of the electric current is the potential difference at both ends of the conductor. It gets the power to push the electrons to move places [8,9].

Current is a characteristic of a conductor [10]. A microscopic quantity associated with current is the current density given the symbol J [11,12]. The current density is a vector and is a feature of a point in the conductor. It is not a characteristic of the conductor as a whole. If the current is distributed uniformly in a conductor whose cross-sectional area is A, then the current density for all points is
\[ J = \frac{I}{A} \] \quad \text{...(2)}

2.4. Logger Pro

Logger Pro is software that has the privilege of presenting quantitative data and graphs simultaneously from natural physical phenomena and providing a bridge between direct observations and abstract representations of various physical phenomena, both conceptually and analytically [13]. The Logger Pro program can be presented together with the occurrence of electric current measurements, namely the relationship between the electric current (A) measured on the Vernier DCP-BTA current probe current sensor as a function of time (t). This software also allows observers to predict and compare the results obtained theoretically with the observed behaviour objectively [14].

3. Method

This study uses the following equipment:
- Laptop windows ten pro 64 bit RAM 4 GB is a suggestion to get research data obtained from Logger Pro.
- An electrolyte solution consists of a mixture of 260.00 grams of NiSO₄, 40.00 grams of H₃BO₃, 60.00 grams of NiCl₂, and 1 litre of distilled water.
- Copperplate as cathode with a thickness of 0.5 mm with a surface area of 11.5 cm².
- Two nickels as anodes with a surface area of 14.0 cm² and 33.54 cm².
- Power Supply, used as a voltage source for electroplating.
- Container glass is a container for the electrolyte solution.
- Three Current Probe sensors are parts that play an essential role in research that function as current sensors.
- Logger Pro software is a part that plays an essential role in managing the Current Probe's work.
- LabQuest is a liaison between the current sensor and Logger Pro on the Laptop.
- A series of copper pins, with a distance between pins of 2.3 mm, captures electric current, which the current sensor will read.
- A plating rack was used for placing samples of copper, nickel, and a series of copper pins.
- The connecting cable is a liaison between the current sensor with a series of pins and the power supply with the anode and cathode.

4. Experimental Procedure

4.1. Data How to Retrieve Data

The step is as follow:
- Pour the electrolyte solution that has been made into the electrolyte solution container glass.
- Connect the copper plate on the cathode and first nickel on the anode with the power supply.
- It is placing copper and nickel with a plating rack that has been installed with a series of pins. A row of copper pins is attached using hot glue to a pallet rack that has been perforated and connected with a connecting cable. A series of rivets are used to capture an electric current in an electrolyte solution. A row of pins is placed along with the anodes that are immersed directly in the electrolyte solution.
Figure 2. The series of experimental tools

![Series of experimental tools](image)

Figure 3. Measuring point on the electrolyte solution

![Measuring point on electrolyte solution](image)

- Three pairs of pins are connected to the Vernier Current Probe sensor using a connecting cable. The Vernier Current Probe is used as an electric current reader in a solution.
- Connecting Vernier Current Probe sensor with LabQuest mini as a transducer and LabQuest mini to Laptop
- Prepare the plating process with a voltage on the 5-volt power supply for 18 seconds.
- Open the Logger Pro software and set up a sampling time of 18 seconds and a sampling rate of 10 samples/s.
- After the current is read on the Logger Pro then press the collect button to collect current data.
- After the plating process is complete, copy the current data obtained from the current sensor and transfer the data to Microsoft Office Excel to be analyzed and graphed between current and time.
- Perform the same steps from a to i by replacing the second nickel anode.

4.2. Data analysis

From the data obtained through the three current sensors, a graph is made between current and time. Furthermore, for one type of anode, the electric currents in the three current probes are compared, and for different anodes, the current density in the three pairs of probes is compared.

5. Result and Discussion

The following is an actual series of the data collection process
Figure 4. Data collection process

The results of current measurements at three points in the electrolyte solution are shown in Figure 5.

**Figure 5.** Graph of current versus time on nickel 1

**Figure 6.** Graph of current versus time on nickel 2

Figure 5 and Figure 6 show that the current at each point in the measurement has a graph that is not always identical. However, as in Figure 5 in the first second, the current in each measure looks identical at some points. Especially in the electroplating of the first nickel, which has a relatively constant amplitude compared to the second nickel. This condition is because the area between the anode and cathode in the first nickel has almost the same surface area compared to the second nickel. The distribution of ions from the anode to the cathode will be more parallel. Whereas in the second nickel, which has a larger surface area than copper (cathode), then the distribution of the ions will be narrowed so that the amplitude on the second nickel will be higher than the first nickel. When compared between the current values at each current point at each point along with the anodes in Figure 5. It shows a graph between the first current, second current, and third current in specific seconds, such as in the first second having identical charts. It can show currents at various points in the electrolyte solution having the same current graph. Figure 6 also shows that the first, second, and third current graphs have fewer identical graphs. This condition is because the distribution of current density is not always regular during the measurement process.
6. Conclusion
In this study, the electric currents in the three pairs of probes in the anode-cathode direction have fewer identical graphs. Still, there are almost identical graphs in specific seconds, such as in the first second in Figure 5 and at the second type in Figure 6. This condition is because the distribution of current density is not always regular during the measurement process. The variation of the anode area ratio in the first nickel is 1:0.821, and the anode area ratio in the second nickel is 1: 0.343. The data obtained show that the first nickel has a relatively constant amplitude compared to the second nickel. So the electric current generated from the first nickel cathode is greater than the current generated from the second nickel cathode.

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