Indonesian Journal of Science and Education
Volume 4, Nomor 2, 2020, pp: 99 ~110
ISSN: : 2598-5213, e-ISSN: 2598-5205, DOI: 10.31002/ijose.v4i2.2758
e-mail: ijose@untidar.ac.id, website: jurnal.untidar.ac.id/index.php/ijose

Experimental Design in Constructing Low Temperature Sensor Based on Resistance Temperature Detector (RTD)

Suwito Singgih[1a)], Moh. Toifur[2b)], Suryandari[3c)]
[1]Program Studi Pendidikan IPA Universitas Tidar, Jalan Kapten Suparman 39 Magelang
[2]Program Pasca Sarjana Pendidikan Fisika, Universitas Ahmad Dahlan, Jl. Pramuka 42 Yogyakarta
[3]Program Studi Tadris Fisika, UIN Antasari Banjarmasin, Jalan A. Yani KM. 4.5 Banjarmasin
e-mail: [a)]suwitosinggih@untidar.ac.id, [b)] mtoifur@yahoo.com, [c)] suryandari@uin-antasari.ac.id

Received: July, 16th 2020 Revised: September, 02nd 2020 Accepted: September, 15th 2020

ABSTRACT

Thin film copper-based RTD still has a low TCR. Hence, plating a Cu-based RTD with nickel will develop a higher TCR. TCR is the sensitivity of RTD's value in response to temperature change. The experimental design in constructing Cu/Ni thin film by using the electroplating method with a concentration of solution and electrode spacing's variation has been done. Electroplating is performed with a concentration of solution and electrode spacing's variations. Electroplating processed by limiting DC voltage to 6 volts. Electrolyte solutions composition were NiSO4, Ni2Cl2, H3BO3 and aquades. Concentrations of solutions can be varied by changing NiSO4 and Ni2Cl2 masses. Based on these concentrations of solutes and electrode's spacing, this research used 15 samples. Thickness, thin-film resistance, and temperature sensor test are performed to each sample. The purpose of thickness test is to measure nickel plates which were formed from the electroplating process. Thin-film resistance test performed to measure sample resistance changing to the electroplating process, and the temperature sensor test was performed to measures the sample's sensitivity in responding to temperature changes. This research's result shows the greater the concentrations of solutes used for copper electroplating, the thicker nickel plates will form. This condition makes its resistance's value decreasing.

Keywords: thin layer resistance, concentration of the solution, electrode distance, electroplating, thin layers of Cu / Ni, RTD, modules

INTRODUCTION

Resistance Temperature Detector (RTD) is a sensor used to measure temperature by utilizing the Temperature Coefficient of Resistance (TCR). TCR is a temperature-resistance coefficient, which states the level of RTD sensitivity in responding to changes in temperature. The higher the TCR coefficient value of an RTD material, the greater the sensitivity to temperature changes. By increasing the TCR value of a material, it will also increase the level of sensitivity of the material to changes in temperature. Increasing the temperature can increase the resistance value of RTD, and vice versa, if the temperature decreases, the RTD resistance value will decrease (Chowdhury, 2010).

RTD is made from various types of metals or alloys including platinum (Maher, 2014), copper (Imran, 2006), nickel (Nusse, 2008) and nickel copper alloys. Of the various metals used, in making RTD, platinum is the most widely used because platinum has the highest TCR (S.K. Sen, 2011).

RTD that exist today can be a winding wire or thin plate. RTD in the form of plates or thin layers has an advantage when compared to RTD in the form of a coil of wire. These advantages include, lower prices, fast response, smaller size and resistance to impact.

To measure very low temperatures, the copper can be used as it has a good linear characteristics in response to relatively small changes in temperature. Copper has a lower TCR coefficient compared to platinum (Riswanto, 2014). Therefore, efforts should be made to increase the TCR coefficient of copper so that it approaches the platinum TCR.

There are many ways that can be used to increase the value of material resistance, one of which is to contaminate or add layers to other metals. Besides by adding impurities to the material, forming into plates or thin layers is a way that can be used to increase the value of material resistance (Sudjatmoko, 2005).

The metal that can be used as a copper impurity is nickel. Nickel is a metal that can be easily found because of its abundant presence, also has a relatively low or inexpensive economic value. As is nature that can reduce the purity of copper, nickel is a good enough material as impurity on copper.

There are several methods or ways to add impurities or layers to a metal such as hot dopping, electroplating, spraying, cementation, and diffusion. Electroplating is the most widely used method, because it is relatively easier and cheaper (Sukarelawan, 2015).

The process of adding nickel impurity to copper by the electroplating method is done by dipping copper and nickel in an electrolyte solution and connecting it to a voltage source. The electroplating process is one of Faraday's experimental applications. To get the best results, there are several things that must be considered in the electroplating process, including the concentration of electrolyte solution (Sukarelawan, 2015), and the distance of the electrode.

In the application of RTD to measure temperature, RTD circuits can be connected with 2-WCB, 3-WCB and 4-WCB transducers. Transducer used in the form of wheatstone bridge which aims to obtain accuracy measurement of resistance which has a relatively small value. 2-WCB and 3-WCB transducers still produce excessive self heating compared to 4-WCB transducers.

Modules on thin layer resistance and electroplating in the RTD concept tend to be scarce, whereas in the conduct of this experiment, researchers need modules on thin layer resistance and electroplating on RTD. With this condition, it is expected to produce a module about thin layer resistance and electroplating in the RTD concept.

Temperature Sensor

The sensor is defined as a device that functions to receive and respond to signals in the form of physical or chemical quantities to be converted into electrical quantities using electronic circuits. The amount of electricity must be able to be channeled, strengthened and modified by electric circuits (Fraden, 2004).

Temperature sensors detect physical parameters such as resistance or output voltage according to temperature changes (Wilson, 2005). There are various types of temperature sensors, namely thermocouple, thermistor (thermal resistor or thermal sensitive resistor), and RTD (Resistance Temperature Detector).

Thin Layer RTD

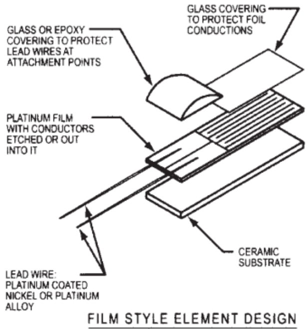

Figure 1. Thin layer RTD (source: Wilson, 2005)

RTD in the form of thin layers with platinum or alloy RTD material is made with snake-like lithography to ensure the length or width of the ratio is quite large (Fraden. 2010). RTD is characterized by positive linear changes in material resistance to temperature changes.

The RTD is then connected to a series of wheat stone bridges that function as a change in the resistance of the material used as the manufacture of RTD to the voltage as an output. Wheatstone bridges that are connected to RTD are usually 2-WCB, 3-WCB and 4-WCB wheat stone bridges.

RTD with 4-WCB wheatstone bridge transducer

The RTD that is connected with the 4-WCB wheatstone bridge is a series of low temperature sensors with the best level of accuracy when compared with RTD type 2-WCB and type 3-WCB. The addition of two connecting cables as an extension cable that transmits heat (self heating) into an output voltage.

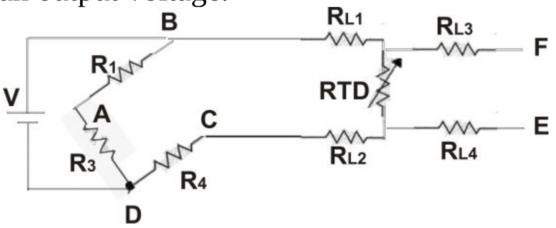

Figure 2. RTD circuit with 4-WCB transducer

The output voltage of the RTD with the 4-WCB wheatstone bridge can be written in the following equation:

$$V_{FE} = V_{FD} - V_{ED}, \quad (1)$$

$$V_{FD} = \left(\frac{R_{L2} + R_{TD} + R_4}{R_{L1} + R_{TD} + R_{L2} + R_4}\right)V, \quad (2)$$

$$V_{ED} = \left(\frac{R_{L2} + R_4}{R_{L1} + R_{TD} + R_{L2} + R_4}\right)V, \quad (3)$$

by substituting equations (2) and (3) in equation (1), is obtained

$$V_{FE} = \left[\begin{matrix} \left(\frac{R_{L2} + R_{TD} + R_4}{R_{L1} + R_{TD} + R_{L2} + R_4}\right) \\ -\left(\frac{R_{L2} + R_4}{R_{L1} + R_{TD} + R_{L2} + R_4}\right) \end{matrix}\right]V, \quad (4)$$

$$V_{FE} = \left(\frac{R_{TD}}{R_{L1} + R_{TD} + R_{L2} + R_4}\right)V \quad (5)$$

If value $R_{L1} = R_{L2} = R_L$, then equation (5) becomes the following equation:

$$V_{FE} = \left(\frac{R_{TD}}{2R_L + R_{TD} + R_4}\right)V \quad (6)$$

The RTD value can be obtained by modifying equation (6) to:

$$R_{TD} = \left(\frac{1}{\frac{V}{V_{FE}} - 1}\right)(2R_L + R_4) \quad (7)$$

Material Resistivity

The resistivity or resistance of a material is the tendency of a material to inhibit the flow of electric current, which is useful for determining the ohmic and non-ohmic properties of a material. The material's ohmic properties are the properties of materials that can conduct electricity, and the non-ohmic properties are the properties of materials that cannot conduct electricity (Safitri, et al. 2014).

The amount of material resistivity is influenced by thermal vibrations, impurities and plastic deformations, which can be expressed in the equation (Sukarelawan, 2015):

$$\rho_{total} = \rho_t + \rho_i + \rho_d, \quad (8)$$

where t = thermal vibrations, i = impurity and d = deformation.

Resistance is expressed as the value of the electrical resistance of a material that is electrified from a voltage source.

Mathematically, the value of material resistance is obtained by the equation:

$$R = \frac{\partial V}{l}, \qquad (9)$$

where R = material resistance, i = strong current and δv = voltage.

By dividing the quantity r by the length l and the surface area of material A, the material resistivity value is obtained in the equation:

$$R = \rho \frac{l}{A}, \qquad (10)$$

where ρ = material resistivity.

If the material is a thin layer (figure 3), then the material resistance equation can be obtained:

$$R = \frac{\rho}{t}, \qquad (11)$$

If the t value is very small, then the material resistance equation is known as the sheet resistance.

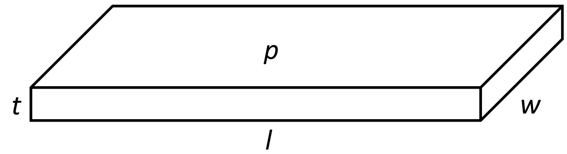

Figure 3. Thin layer in 3 dimensions

It has been said that the resistivity value of the material is affected by thermal resistivity, the more the temperature increases, the resistivity of the material will increase. As seen the resistivity value of the material is directly proportional to the resistance of the material, it can be concluded that an increase in temperature can trigger an increase in material resistance. The relationship between the amount of resistance and temperature can be written in the equation:

$$R_T = R_0 + (1 + \alpha T - \beta T^2), \qquad (12)$$

where rt = temperature at t in ohms (ω), r0 = resistance at 0oC in ohms (Ω), α and β = standard constants and t = large increase in temperature in ºC.

Four-Point Probe

Four-point probe is a tool that can be used to measure the value of resistance or resistance to s of electrical material, in the form of metals or semiconductors in the form of thin layers (thin layers) used in the manufacture of electronic devices (Haryadi, 2014).

The four-point probe tool scheme and the thin surface current distribution model in the use of the four-point probe are presented in Figure 4 and Figure 5.

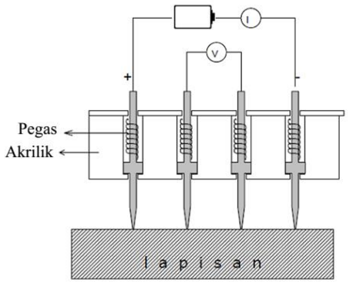

Figure 4. The four-point probe tool scheme (Toifur, 2015).

In accordance with Figure 4, the four-point probe consists of 2 probes that function to flow electric current on the surface of the thin and 2 probes that serve as a point of measuring the voltage when the probe is touched on the thin.

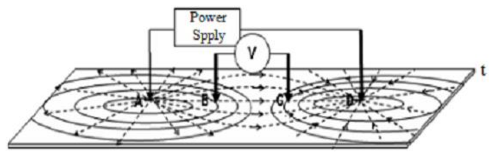

Figure 5. Current distribution models on the surface of thin layers using a four-point probe (Toifur, 2015).

In figure 5, if the distance between the probes is equal, s, then the potential difference between points B and C from the positive current source A can be determined using the equation:

$$V_{BC+} = -\rho I \int_{s}^{2s} \frac{dr}{2\pi t}$$

$$= \frac{-\rho I}{2\pi t}[\ln 2s - \ln s] \qquad (13)$$

While the potential difference between points B and C from the negative current source D can be determined by the following equation:

$$V_{BC-} = -\rho(-I)\int_{2s}^{s}\frac{dr}{2\pi t}$$

$$= \frac{\rho I}{2\pi t}[\ln s - \ln 2s] \qquad (14)$$

By summing equations (13) and (14) a total potential difference can be obtained between points B and C.

$$VBC = \frac{-\rho I}{2\pi t}[\ln 2s - \ln s] + \frac{\rho I}{2\pi t}[\ln s - \ln 2s]$$

$$= \frac{2\rho I}{2\pi t}[\ln s - \ln 2s]$$

$$= \frac{\rho I}{\pi t}\ln 2 \qquad (15)$$

By substituting equality (15) in equation (11), the resistivity of the pieces is presented in equation (16).

$$R_S = \frac{\pi}{\ln 2} \times \frac{V}{I} \qquad (16)$$

Elektroplating

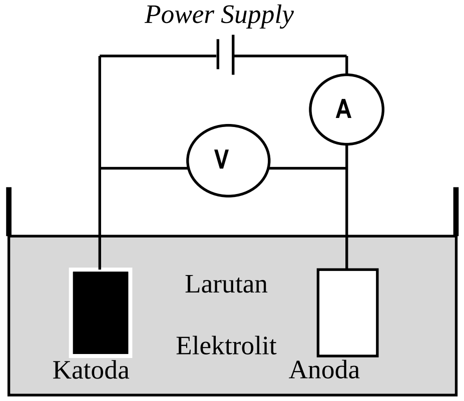

Figure 6. Electroplating tools scheme

Electroplating is the process of settling the desired metal ions (anodes) above the other metal (cathode) by electrolysis. During the deposition process, chemical reactions occur at the electrodes (cathode and anode) and the electrolyte in a particular direction (Basmal. 2012). In electroplating required direct current (DC) and a constant voltage

Important elements in the electroplating process are as follows:

a. Electrical circuits (circuits) outside. The external circuit is composed of a DC current source, and the necessary equipment such as a voltmeter, ammeters, thermometers, and voltage and current regulating devices.
b. Cathode. The cathode is a negative electrode which is the object to be coated. To note, the cathode used is a metal that has a collection of bound atoms and electrons can move freely so that the electroplating process can provide the best results.
c. Anode. Anode is a positive electrode used to coat the cathode.
d. Electrolyte solution. Electrolyte solution is a solution that functions as a medium to transfer ions from the anode to the cathode.

According to Rieger (Sukarelawan, 2015), the quality of electroplating results is influenced by several factors, namely:

a. Current flow. Current density affects the cross-section structure of the coating metal. Small dense currents cause a cross-shaped crystalline structure of quartz and large current densities cause crystals to tend to grow like trees.
b. Concentration of electrolyte solution. The concentration of electrolyte solution affects the current density.
c. Temperature of the electrolyte solution. The temperature of the electrolyte solution affects the rate of ion transfer from the anode to the cathode. Crystal growth and decreasing of h2 gas potential are affected by the increase in temperature of the electrolyte solution.
d. PH value of the electrolyte solution. The value of the degree of acidity (pH) is affected by the concentration of the solution. Sutomo stated to adjust the pH of the electrolyte solution needs to

be added elements that function as a regulator of pH.

e. Time of coating. Rasyad (2011) states that the coating time will affect the quantity of coating results that will occur on the surface of the product to be coated.

According to Osye Kurneli, et al, the factors that influence the electroplating process are throwing power. Throwing power is the ability of an electrolyte solution to produce an even thickness on the surface of the cathode by varying the distance of the anode and cathode. Throwing power is expressed as a percent (%). According to Parthasarady, the factors that influence throwing power are:

a. Physical: the shape of the electrode geometry and the distance of the electrode.
b. Chemical: composition of the solution, the acidity of the solution, dissolved impurities and addictive substances.
c. Electrical: current density, solution conductivity, solution efficiency.

Derek Pletcher, states that a large percentage of throwing power can be obtained from the field equation:

$$\%(ThrowingPower) = \frac{100(K-B)}{K+B-2} \quad , (17)$$

with:

K = ratio of anode and cathode distance

B = weight ratio of metal deposits

The electroplating process is based on Faraday's legal principles. In Faraday's law the weight of the deposited metal is directly proportional to the time and electric current (Basmal. 2012). The statement can be written mathematically in the following equation:

$$W = \frac{M_a It}{nF} \quad , \qquad (18)$$

with:

W = weight of deposited metal (grams)

Ma = atomic mass (gram / mol)

I = electric current (ampere)

t = time (seconds or seconds)

n = valence electron

F = faraday number (96,500 coloumb)

Lowenheim states the thickness of the formed from the electroplating process in the equation (Basmal, 2012):

$$\delta = \frac{W}{\rho A} \qquad (19)$$

with:

δ = thickness of the formed (cm)

ρ = density of (gr / cm3)

W = weight of formed (gr)

A = surface area of the (cm2)

Characteristics of Copper (Cu) and Nickel (Ni) metals

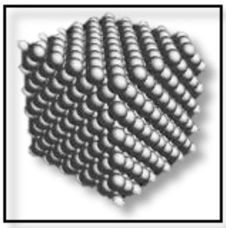

Figure7. Cristal structure of nickel metal

Copper is a chemical element with the symbol Cu and has an atomic number of 29. Copper belongs to the category of non ferrous heavy metals because it does not find Fe and C as its basic elements. Physically, copper is a metal that has a high electrical conductivity and heat. Copper metal configuration [Ar] $3d^{10}$ $4s^{1}$. Copper is the second metal after silver which has a high conductivity value.

Table 1. Characteristics of copper metal (Cu)

Criteria	Specifications
Melting point	1357,77 K
Boiling point	2835 K
Atomic mass	63, 546 gram/mol
Density	8,96 gr/cm^3
Crystal structure	FCC (*face-centered cubic*)
Smelting heat	13 26 kj/mol
Evaporation heat	300,4 kj/mol
Heat capacity	24.440 j/mol.K
Linear expansion coefficient	1,65 µm.m^{-1}. K^{-1} at 25ºC
Electrical resistivity	16,78 nΩ. M at 20ºC
Thermal conductivity	401 w/m.K

Nickel is a chemical element in the periodic table that has the symbol Ni and atomic number 28. The electron configuration of nickel is [Ar] $4s^2$ $3d^8$.

The mechanical properties of nickel include corrosion resistance, oxidation resistance and resistance to high temperatures. Nickel is very strong and has the properties of clay (ductile), is ferromagnetic, very easily combined with other metals. Because of this physical property, nickel is widely used as an alloying material in other metals.

Table 2. Characteristics of nickel metal (Ni)

Criteria	Specifications
Melting point	1455ºC
Boiling point	2913ºC
Atomic mass	58, 6934 gram/mol
Density	8,908 gr/cm^3
crystal structure	Fcc (*face-centered cubic*)
Smelting heat	17, 48 kj/mol
Evaporation heat	377, 5 kj/mol
Thermal conductivity	90,9 w/m. K
The coefficient of linear expansion	13,4 µm.m^{-1}. K^{-1} at 25ºC
Electrical resistivity	69,3 nΩ. M at 20ºC
Heating capacity	26,07 j/mol. K

Figure 8. Nickel metal crystal structure

Nickel as a Coating Material in the Electroplating Process

In the electroplating process with nickel coatings, electrolyte solutions that can be used include nickel sulfate ($NiSO_4$) and nickel chloride ($NiCl_2$). The acidity (pH) level of the electrolyte solution needs to be considered. So that the acidity level can be obtained, it is necessary to add boric acid (H_3BO_3) as a control for the acidity of the electrolyte solution.

According to Sugiaryta (2012), the level of acidity in electrolyte solutions permitted so that the electroplating process can occur properly is in the range of 2-4.5. Meanwhile, according to Rasyad (2011), in nickel electrolyte solution, the permitted pH value is in the range of 1.5-5.2.

Chemical reactions that occur during the electroplating process with nickel as a coating material can be explained as follows (Sukarelawan, 2015):

On the cathode	At the anode
Formation of a nickel coating	Formation of oxygen gas
$Ni_2^+ {}_{(aq)} + 2e^- \rightarrow Ni_{(s)}$	$H_2O_{(l)} \rightarrow 4H^+{}_{(aq)} + O_{2\,(g)} + 4e^-$
Formation of hydrogen gas	Hydrogen gas oxidatio
$2H^+{}_{(aq)} + 2e^- \rightarrow H_{2\,(g)}$	$H_{2\,(g)} \rightarrow 2H^+{}_{(aq)} + 2e^-$
Reduction of dissolved oxygen	
$½ O_{2\,(g)} + 2H^+ \rightarrow H_2O_{(l)}$	

Characteristics With XRD

The series of X-ray diffraction devices, composed of three main components, namely the source of X-ray (x-ray source), the material being tested (specimen) and the X-ray detector (X-ray detector).

X-rays are a form of electromagnetic radiation that has energies between 200 eV to 1 meV with wavelengths ranging from 0.5 to 2.5 amstrong. Because the wavelength is almost the same as the distance of the electron electrons in the crystal, x-rays are widely used as a mineral analysis technique (Suryanarayana and Norton, 1988).

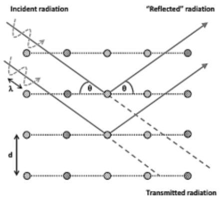

Figure 9. X-ray difraction.

X-ray diffraction is one of the techniques used to identify the crystalline phase in material materials to analyze the structural properties of materials. Bragg's Law states that the difference in the x-ray diffraction path must be a multiple of the wavelength, mathematically it can be written as follows (Suryanarayana and Norton, 1988):

$$n\lambda = 2d\sin\theta \qquad (20)$$

With
n = integers 1, 2, 3, ...
λ = wavelength
d = distance between fields
θ = diffraction angle

The X-ray diffraction beam will be received by the X-ray detector which will then be presented in the form of a graph of the relationship between the intensity of the spectrum and the angle of 2θ. From this graph, it can be seen (1) the estimated

size of the crystal, (2) the relative composition of the mixture, (3) the lattice parameters and (4) the structure of the material.

METHODS

The sample in this study is a thin layer of copper measuring 10 cm x 3 cm, with a width of 2 mm lithographic pathway as many as 15 pieces which will be coated with Ni by the electroplating method.

The electroplating method is done by varying the concentration of the solution and the electrode distance. Next, the sample is tested thickness, resistivity test with a four-point probe and temperature sensor test using liquid nitrogen to obtain a negative temperature.

Before the electroplating process, the sample was cleaned using sandpaper size 3000. Furthermore, the sample was washed using soapy water, rinsed with distilled water, soaked with HCl, rinsed with distilled water, soaked H_2SO_4, rinsed with distilled water, dried and stored with wrapped tissue and then put it in a plastic clip.

Electroplating process to be varied concentration (Table 4) and the electrode spacing of 4 cm, 6 cm and 8 cm. The naming of samples is based on these variations (table 3). The electroplating circuit according to Fig. 6 with the cathode is nickel metal and the anode is a thin layer of copper. The temperature of the electrolyte solution is set at ± 65oC. Electroplating was done in 1 minute.

Table 3. Naming samples

Solution to - Distance	1	2	3	4	5
4 cm	S1	S2	S3	S4	S5
6 cm	S6	S7	S8	S9	S10
8 cm	S11	S12	S13	S14	S15

Table 4. Solution concentration

Solution to -	$NiSO_4$ (gram)	$NiCl_2$ (gram)	H_3BO_3 (gram)	Aquades (ml)
1	200	40	30	1000
2	225	45	30	1000
3	250	50	30	1000
4	275	55	30	1000
5	300	60	30	1000

Before the electroplating process the sample was weighed to determine the mass of the sample before electroplating (m_1) and measured the resistance value before the electroplating process (RS_1) using a four-point probe. The sample is rinsed with distilled water, dry it, weigh the sample to determine the mass of the sample after the electroplating process (m_2) measure the resistance value after the electroplating process using a four-point probe (RS_2) and stored back into a plastic clip.

Sample testing as a low temperature sensor is carried out using a 4-WCB transducer and liquid nitrogen. The sample test is carried out in the range of ± 138ºC to ± 0ºC. The results of the low temperature sensor test are the relationship between temperature changes and changes in output voltage.

RESULTS AND DISCUSSION

The mass data of the sample before (m1) and after (m2) electroplating process were analyzed to determine the thickness of the formed Ni layer. The analysis was performed using equation 19. The results of the analysis are presented in table 5.

Table 5. Data thickness of the formed Ni layer

Sample	Sample Mass (gr)			δ (cm) x10^{-5}
	m_1	m_2	Δm	
S1	2,2101	2,2115	0,0014	1,05
S2	2,39	2,3919	0,0019	1,42
S3	2,2582	2,2605	0,0023	1,72
S4	2,2922	2,2948	0,0026	1,95
S5	2,3954	2,3984	0,003	2,25
S6	2,2508	2,2519	0,0011	0,82
S7	2,2514	2,2531	0,0017	1,27
S8	2,3572	2,3593	0,0021	1,57
S9	2,388	2,3904	0,0024	1,80
S10	2,2277	2,2305	0,0028	2,10
S11	2,2896	2,2906	0,001	0,75
S12	2,4056	2,4072	0,0016	1,20
S13	2,3268	2,3288	0,002	1,50
S14	2,3463	2,3486	0,0023	1,72
S15	2,2683	2,271	0,0027	2,02

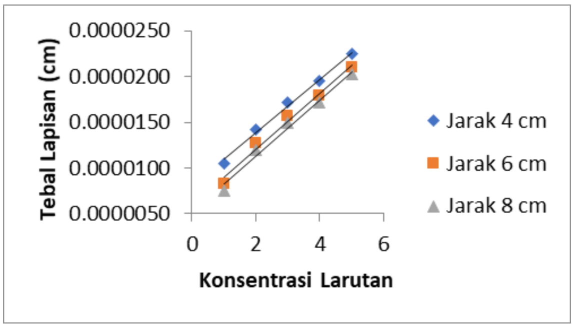

Figure 10. Graph of the relationship of the concentration of solution to the thickness of the Ni layer formed for each electrode distance

Based on the graph in Figure 10, it is shown that the greater the concentration of the electrolyte solution, the thicker the Ni layer is formed. This condition is caused because the concentration of the solution affects the electroplating current density. The greater the concentration of the solution, the greater the current density increases, so that the repositioning process is faster which results in the thicker layer formed.

Table 6. Increase data on sample resistance.

Sample	Resistivity of a sample chip (Ω/sq)		
	R_{S1}	R_{S2}	ΔR_S
S1	0,010217	0,010267	0,00005
S2	0,010032	0,010152	0,00012
S3	0,009785	0,009917	0,00013
S4	0,009743	0,009805	0,00006
S5	0,009733	0,009773	0,00004
S6	0,009361	0,009431	0,00007
S7	0,009353	0,009409	0,00006
S8	0,009299	0,009403	0,00010
S9	0,00901	0,00908	0,00007
S10	0,008873	0,009003	0,00013
S11	0,008407	0,008497	0,00009
S12	0,007924	0,008075	0,00015
S13	0,007789	0,007869	0,00008
S14	0,007098	0,007238	0,00014
S15	0,007095	0,007198	0,00010

Based on data in Table 6, it appears that the electroplating can increase the value of the resistivity of the thin layer of the sample.

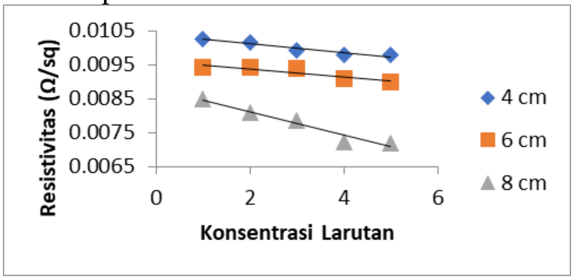

Figure 11. Relationship concentration of the solution to the thin layer of sample resistivity values after electroplating

In figure 11, it appears that the resistivity value of the sample decreases with increasing concentration of the solution. This is due to the increase in the concentration of the solution resulting in a thicker layer of nickel formed so that electrons in the thin layer move more easily.

Temperature sensor test on the sample produces a relationship of temperature changes to changes in output voltage. The output voltage output is converted to RTD resistance by modifying equation 7.

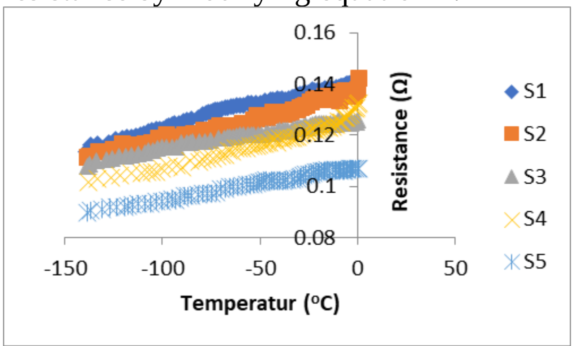

Figure 12. Graph of the relationship of temperature changes to resistance for a 4 cm electrode distance.

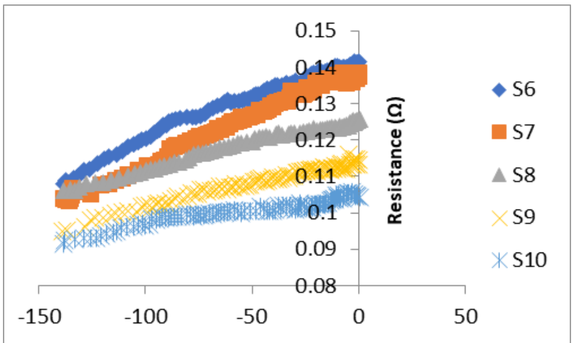

Figure 13. Graph of the relationship of temperature changes to resistance for a 6 cm electrode distance.

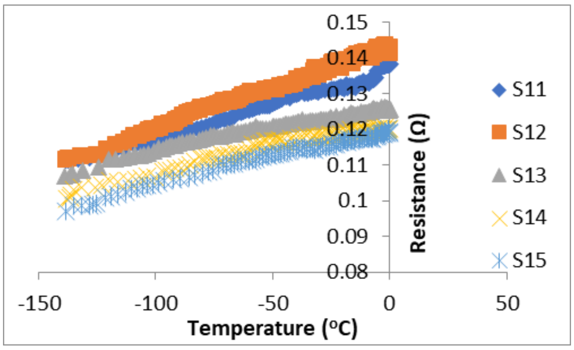

Figure 14. Graph of the relationship of temperature change to resistance for an electrode distance of 8 cm.

Figure 12 and Figure 13 show that the highest resistance value was obtained with a concentration of 1 during electroplating (S1 and S6). In contrast to Figure 14 where the highest resistance was obtained for S12 samples, for which the electroplating process was carried out at concentration 2.

With second order polynomial regression conducted on the data, TCR values of each sample were obtained. The highest TCR was obtained 2311.2 ppm / ºC for the electrode distance of 4 cm (S4), for the 6 cm distance of 1592 ppm / ºC (S7) and for an 8 cm distance of 1474.8 ppm / ºC (S12).

CONCLUSION

1. An experimental design of RTD-based low temperature sensors has been designed with electroplating method on the variation of the concentration of the solution and the electrode distance.
2. The greater the concentration of the solution, the layer formed by the electroplating process gets thicker.
3. Electroplating can increase the value of the resistivity of the thin layer of the sample.

THANK-YOU NOTE

Thank you to the Tidar University Science Education Program and Postgraduate Physics Education Program at Ahmad Dahlan University for providing support so this research can be carried out.

Also thank to all parties who helped both directly and indirectly.

REFERENCES

Adnyani, Ida Ayu Sri dan A A Alit Triadi. 2009. Pengaruh Kuat Dan Distribusi rus Terhadap Ketebalan Dan Kekerasan Lapisan Krom Pada *Stoneware* dan *Earthenware*. *Jurnal.* Jurnal Teknologi Elektro Vol. 8 No.2 Juli - Desember 2009.

Afriany, Reny., Kusmono dan R. Soekrisno. 2012. Pengaruh Konsentrasi Larutan Dan Waktu Pelapisan Nikel Pada Alumunium Terhadap Kekerasan. *Jurnal.* Prosiding Seminar Nasional Aplikasi Sains & Teknologi (SNAST) Periode III. Yogyakarta, 3 November 2012. ISSN: 1979-911X.

Basmal, Bayuseno dan Sri Nugroho. 2012. Pengaruh Suhu dan Waktu Pelapisan Tembaga-Nikel pada Baja Karbon Rendah Secara Elektroplating Terhadap Nilai Ketebalan dan Kekasaran. Jurnal. ROTASI Vol.. 14, No. 2, April 2012 (23-28)

Bevington, R.R dan D.K. Robinson.1992. Data Reduction and Error Analysis for The Physical Sciences. Singapore: McGraw-Hill Book.

Chosim S Widodo dan Jasmadi. 2008. Panduan Menyusun Bahan Ajar Berbasis Kompetensi. Jakarta: PT Alex Media Komputindo.

Chowdhury, Tasnuva dan Haider Bulbul. 2010. Design of a temperature sensitive voltage Regulator for AC Load Using RTD. Jurnal. International Journal of Engineering Science and Technology. Vol. 2 No. 12, p.7896-7903.

Depdiknas. 2008. Pengembangan Bahan Ajar. Sosialisasi KTSP 2008. Jakarta: Depdiknas

Fraden, Jacob. 2004. Handbook of Modern Sensor : Phisics, Designs and Applications.San Diego: Advanced Monitors Cooperation

Fraden, Jacob. 2010. Handbook of Modern Sensor. San Diego: Advanced Monitors Cooperation

Gunawan, Budi dan Citra D. Azhari. Karakterisasi Spektofotometri IR dan Scanning Electron Microscopy (SEM) Sensor Gas dari Bahan Polimer Poly Ethelyn Glycol (PEG). Jurnal. ISSN 1979-6870

Halliday, Resnick. 1993. Fundamentals of Physics.

Haryadi, Moh. Toifur dan Bagus. 2014. Cow Cement Sensor Based On Coil Resistance Temperature Detector (C-RTD) Coupled With Four Wire Configuration Bridge (4-WCB). Jurnal. 7th International Conference on Physics and Its Applications 2014 (ICOPIA 2014)

Haskia. 2007. Perkembangan Teknologi Sensor dan Aplikasinya untuk Diteksi Radiasi Nuklir. Jurnal. Prosiding PPI - PDIPTN 2007 Pustek Akselerator dan Proses Bahan - BATAN. ISSN: 0216 – 3128. p.9-20

Imran, Muhammad dan Abhijit Bhattacharyya. 2006. Effect of Thin Film Thicknesses and Materials on theResponse of RTDs Ana Microthermocouples. Jurnal. IEEE Sensors Journal, Vol. 6, No. 6, December 2006.

Indratno, Toni Kus dan Moh. Toifur. 2015. Optimasi Diameter Dan Panjang Kawat Koil Sebagai Kandidat Sensor Suhu Semen Sapi Berbasis RTD-C. Jurnal. OMEGA Jurnal Fisika dan Pendidikan Fisika Vol 1, No 2. p. 45-49

Kurneli, Osye, Ahmad A. Sonief, E. Sulistyo. Pengaruh Variasi Jarak antara Anoda dan Katoda Hard Chrome Terhadap Kekerasan pada Baja AISI 1025 Hasil Perlakuan Panas Tempering. Jurnal. Fakultas Teknik. Universitas Brawijaya.

Maher, Anthony., Vijayalakshmi Velusamy, Daniel Riordan and

Joseph Walsh. 2014. Modelling of Temperature Coefficient of Resistance of a Thin Film RTD Towards Exhaust Gas Measurement Applications. Jurnal. Proceedings of the 8th International Conference on Sensing Technology, p.19-22

Nusse, D. , Noetzel, R. and Vdi, 2008. Temperature Sensors in Nickel Thin Film Technology. Jurnal. in Sensoren Und Messsysteme 2008. 2008. p. 891898.

O'Grady, A. 2000. Transducer/Sensor Excitation and Measurement Technique, Analog Dialogue. (34/5)

Rasyad, Abdul dan Budiarto. 2011. Pengaruh Waktu Elektroplating dan *Powdercoating* NiCr Terhadap Sifat Mekanis dan Struktur Mikro pada Baja Karbon SPCC-SD. *Jurnal*. Prosiding Seminar Nasional Pengembangan Nuklir IV. Pusat Pengembangan Energi Nuklir. Badan Tenaga Nuklir Nasional.

Riswanto. 2014. Optimasi Panjang Kawat dan Diameter Kawat Tembaga Sebagai Piranti Sensor Suhu Rendah Berbasis 4 WCB RTD. *Tesis*, Yogyakarta: UAD.

Safitri, Juwita, dkk. 2014. Rancang Bangun Alat Ukur Resistivitas Pada Lapisan Tipis Menggunakan Metode 4 Probe Berbasis ATMega 8535 Dengan Tampilan LCD Berkarakter 2X16. Jurnal Fisika Unand Vol. 3 No. 2 April 2014.

Sen, T.K. Pan, P. Ghosal and S.K. 2011. An Improved Lead Wire Compensation Technique for Conventional Four Wire Resistance Temperature Detectors (RTDs). Jurnal. Departemen of Applied Physics, Vniversity of Calcutta, India.

Serway, Raymond A., dan John W. Jewett. 2004. Physics for Scientist and Engineers.Thomson Brooks.

Soekardjo & L. Permana. 2009. Metodologi Penelitian Pendidikan Kimia. Diktat Kuliah.Yogyakarta: UNY Press

Sudjatmoko. 2005. Kajian Sifat Bahan Lapisan Tipis Feromagnetik NixFe1-X Hasil Deposisi dengan Teknik Evaporasi Hampa. Jurnal. Prosiding PPI-PDIPTN 2005. ISSN 0216–3128. p.111-117.

Sugiyarta, A.P. Bayuseno, Sri Nugroho. 2012. Pengaruh Konsentrasi Larutan dan Kuat Arus Terhadap Ketebalan pada Proses Pelapisan Nikel Untuk Baja Karbon Rendah. Jurnal. ROTASI- Vol. 14. No. 4, Oktober 2012 (23-27).

Sukarelawan, M.Irma 2015. Rancang Bangun Eksperimen Sensor Suhu Rendah Cu/Ni Berbasis Film Tipis RTD (Resistance Temperature Detector) dengan Metode Elektroplating Menggunakan Rangkaian 4-WCB (Four Wire Configuration Bridge). Tesis. Universitas Ahmad Dahlan.

Suryanarayana, C dan M.G. Norton. 1998. X-ray Diffraction, A Practical Approach.

Sutomo, Senen, Rahmat. Pengaruh Arus dan Waktu pada Pelapisan Nikel dengan Elektroplating untuk Bentuk Plat. Jurnal. Fakultas Teknik. Universitas Diponegoro.

Toifur, Moh. 2007. Deposition of Cu/Ag At The Various Deposition Time For Resulting The High Quality Decorative Silver, Proceeding of The International. Jurnal. Seminar on Natural Sciences and Applied Natural Sciences, Yogyakarta 2007, ISBN: 978-979-3812-09-0

Wilson, Jon S. 2005. *Sensor Technology Handbook*.Newnes.