Design and Development of Radiated Heater with Temperature Control Program for Surface Plasmon Resonance Experiment

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Abstract. This research aims to design and to develop of radiated heater with temperature control program to be used in surface plasmon resonance experiments (SPR). The heater is made of NiCr solenoid with a value of 1 ohm resistance and 5 volt DC of voltage source. The control device in this experiment used the Arduino microcontroller which was connected to the LabVIEW software with an interface. The result that heating control program has been functioning in good condition with a deviation value at 3% from setpoint value at a distance of 0.8 cm, 1.0 cm and 1.2 cm from the heater surface.

1. Introduction

Heat energy can be transferred from an object that has a high temperature (heat source) to another object which has a low temperature. Thermal energy is required in surface plasmon resonance experiments with controlled processes. The design of the devices of surface plasmon resonance has been made by assessing the effect of temperature on the detection of materials such as volatile organic compound [1]. Another research has been finished to study about temperature effect and refraction index in surface plasmon resonance [2].

Furthermore, the research about an application in surface plasmon resonance experiment has been been done concerning sensitivity and light intensity in an electrochemical process [3]. Further and even more importantly, though, the research about study of thickness gold and silver sample has been completed in surface plasmon resonance experiment [4]. It is also interesting to note that the application in biosensor has been worked on food characteristic of a chemical compound by surface plasmon resonance experiment [5]. Equally interestingly, surface plasmon resonance experiment in medical research has been done for initial study of avian influenza virus subtype H6 characterization [6]. Because of that, it is important to know application about surface plasmon resonance experiment that used of the temperature effect.

Generally, the heater is made from solenoid with AC voltage source [7]. In this research, the heater is made from solenoid with DC source voltage. The designed plant is a low cost application with components easy to access. This heater design is made to fulfill of surface plasmon resonance experiment that needs temperature effect to study such as biomolecules [8]. The heater is designed by specification with small area 1 x 1.5 cm\textsuperscript{2} and the position is near from the experiment sample with range...
of mm. Therefore, in this research aims to design and to develop of radiated heater which has ability to control temperature value in surface plasmon resonance experiment.

2. Theory
The assumption in this study is based on the law of energy conservation that the power radiated from the core solenoid to the surface solenoid with $r_s$ distance that is described by red line. This solenoid heating with a certain distance $r_x$ that is described by blue line. The assumption of wave front is solid cylinder as shown in Figure 1.

Based on the heat transfer scheme can be determined intensity of the heat radiation on the surface in heat source of heater as shown in equation 1.

$$I_s = \frac{e\sigma T_s^4}{2\pi r_s l}$$

(1)

$I_s$ is the intensity of the radiation on the surface of solenoid, $r_s$ is the distance from the core of solenoid to the surface of solenoid and $T_s$ is the surface of solenoid temperature. Then, the determination of temperature at a distance from the core of solenoid can be determined by equation 2.

$$I_s = \frac{e\sigma T_x^4}{2\pi r_x l}$$

(2)

$I_x$ is the intensity of radiation at a distance of $r_x$ from the core of solenoid and $T_x$ is the temperature at a distance of $r_x$ from the core of solenoid. Assuming that the power radiated from the core solenoid is same, then the equation 1 and equation 2 is the same, so that the intensity of the heat radiation only depends on the distance from the core solenoid as shown in equation 3.

$$T_x = T_s \left(\frac{r_s}{r_x}\right)$$

(3)

3. Experiment Method
The design of heater in this study is made of NiCr solenoid wire with 53 coils, the length is 0.469 m, the diameter is $2.5 \times 10^{-4}$ m, the mass is $2.5 \times 10^{-4}$ kg and the area is $3.68 \times 10^{-4}$ m$^2$. This solenoid has a resistance value of 1 ohm. This is connected by power supply 5V DC, relay SSR 25-DA, microcontroller Arduino UNO R3, and a temperature sensor used is the LM35 sensor. The method used in this study is an experiment with including the heaters design, microcontroller program design and LabVIEW...
software program design and test tools with a heating control program. In this testing phase to vary the distance from the heat source (solenoid) in one dimension at the distance of 0.8 cm, 1.0 cm, and 1.2 cm.

4. Experiment Result

4.1. Temperature control display result in LabVIEW
Display result of temperature measurement in this research can be shown in the front panel of LabVIEW as shown in Figure 2. Data retrieval begins when the program is started by clicking the Run button and is finished at a specified time by clicking the stop button in the front panel in LabVIEW software. Data graph is automatically stored on computer drives with format .txt files that it can be analyzed using Microsoft Excel.

![Figure 2. Display of Temperature Control Program in LabVIEW.](image)

4.2. Determination of temperature value at the certain distance
Measurements were taken at the distance 0.8 cm, 1 cm, and 1.2 cm from the surface solenoid heaters. The results of temperature measurements are made during 1000 seconds from the room temperature which is shown in Figure 3.

![Figure 3. Temperature measurements during 1000 seconds based on distance variation.](image)

Based on the measurement results in Figure 3, the line graph reveals increase dramatically rate at the distance 0.8 cm, 1 cm, and 1.2 cm from the surface solenoid heaters, the experiment result shows that the temperatures explain the value at 163 °C, 145 °C, and 129 °C respectively. The measurement data can be further analyzed to determine the relationship between the temperature values against certain distance experimentally by comparing with theory based on equation 3. Based on theory, the
value of $T_s$ used is 422 °C with $r_s$ cm corresponding experimental results and measurements. This equation can determine the relationship between the temperature values against a certain distance as shown in Figure 4.

A glance at the Figure 4 reveals the temperature values slide away at 1000 seconds. Figure 4 describes the temperature measurements against the distance based on theory and experiment. According to the theory, the model can predict at a certain distance which has assumption wave front as solid cylindrical. The heater is radiated heat from the surface solenoid which can be determined by thermal radiation model. At a distance of 0.8 cm from the surface solenoid, the temperature shows 149 °C theoretically, meanwhile, based on experiment at 1000 seconds, the temperature at a distance of 0.8 cm, shows at 163 °C. The difference value also occurs at a distance of 1 cm from the surface of solenoid, the temperature shows 141 °C theoretically. On the other hand, experiment result at a distance of 1 cm at 145 °C for 1000 seconds. At the last measurement at a distance of 1.2 cm from the surface of solenoid, the temperature shows 135 °C theoretically and explains 129 °C experimentally at 1000 seconds. Based on these results, the intensity of the heat radiation only depends on the distance from the heat source (solenoid). Therefore, the relationship of temperature and distance explains inverse relationship between the values of temperature versus distance from the heat source. The result of this analysis can be used as a reference analysis temperature determination of the distance that it needs on surface plasmon resonance experiments.

4.3. Temperature Control Result
The line graph at the Figure 5 describes the temperature rate increase and levelled off at the setpoint value from the room temperature. The experiment has done at a distance of 0.8 cm with setpoint value at 120 °C. This is followed by two measurements at a distance of 1.0 cm and 1.2 cm with setpoint value at 100 °C and 80 °C respectively. The heater temperature control program can control the temperature value in good condition to somewhere in the vicinity of 3 % error from the setpoint value.
Figure 5. Temperature control result at the distance of 0.8 cm, 1.0 cm and 1.2 cm.

Based on the results, temperature control program has been functioning well and can be used to set a certain temperature with a certain distance in accordance with the needs of surface plasmon resonance experiments. But the results of these tests indicate that the heat rate still needs long time to reach setpoint so it needs novelty design with isolator material around the heater to produce transfer heat energy more quickly towards the setpoint. Alternative way, to get the maximum heat energy can be done by setting the smallest possible distance between the heating sources and sample. The reason is that the smallest distance from the heat source, the sample experiment will receive the largest heat intensity based on the law of energy conservation with assumption of the radiated power is constant. Another interesting point, the maximum intensity of heat radiation can also be obtained using a small resistance value (under 1 ohm) in heater which is used to accelerate current on the heating process.

5. Conclusion
The design of heater has been created for surface plasmon resonance experiment which can be controlled at certain temperature value. The heater specification is made of NiCr solenoid with 53 coils, the length is 0.469 m, the diameter is 2.5 x 10^-4 m, the mass is 2.5 x 10^-4 kg and the area is 3.68 x 10^-4 m^2. The result that temperature control program of heater has been functioning in good condition with a deviation value approximately 3% from the setpoint value at a distance of 0.8 cm, 1.0 cm and 1.2 cm.

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7. References
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