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Arduino Based Conductive Silver Lamination Device

Fitria Hidayanti[1], Kiki Rezki Lestari[2], Risad Anwar[3]
[1]Engineering Physics Department, Universitas Nasional, Jakarta 12520 Indonesia, fitriahidayanti@gmail.com
[2]Engineering Physics Department, Universitas Nasional, Jakarta 12520 Indonesia
[3]Engineering Physics Department, Universitas Nasional, Jakarta 12520 Indonesia

ABSTRACT

This study has designed laminated devices for Arduino-based conductive silver ink patterns on flexible materials. The resistance of the conductive pattern of silver ink in a flexible Printed Circuit Board (PCB) applications is still quite high and reduces electrical conductivity. Resistance can be reduced by hot lamination of flexible materials with specific optimum temperatures in the material. Research methods carried out by conductive pattern of silver ink heat lamination on flexible materials. The lamination device consists of a heating lamination controlled by an Arduino microcontroller. The measured resistance before lamination as 2.8 ohms and after lamination with the lowest value as 0.1 ohms. The results of the conductive pattern lamination are tested with LED and battery circuits. The conductive pattern testing with LED circuits ensures that the Arduino-based conductive silver ink lamination device can function well.

Key words : Lamination, Conductive Pattern, Silver Ink, Flexible PCB.

1. INTRODUCTION

Technology developments and electronic needs were underlying to research the conductive patterns of silver ink for PCB (Printed Circuit Board). The conductive pattern yield a print of conductive ink on the PCB material layer. Conductive ink can be printed on flexible material for PCB applications as a conductive pattern connecting thin or flexible electronic components. Conductive ink is specific and unique applications to sustain new technologies in the future [1, 2].

Future technological advancements in electronic goods require conductive line boards. The printed conductive line board application is applied in almost all electronics [3, 4]. Conductive pattern technology such as flexible electronics can be printed on PCB substrate HVS paper and thin mica film materials are the major area of application of conductive ink [5-8]. Silver ink remains the top choice for conductive patterns because it has the highest characteristics in conductivity. Besides, silver ink has the lowest material resistance than other metals and better adhesion for the application of conductive patterns in electronic goods [9]. One obstacle of conductive ink printing results is that the resistance is still high at 1.5 Ωcm to 36 Ωcm depending on the treatment of the material [10].

Lamination is the process of coating materials using temperature changes [11]. This research aims to develop an Arduino-based heat lamination device with temperature arrangement for HVS paper and mica film conductive pattern material. The conductive pattern is printed on a flexible PCB substrate on the screen by the screen printing technique [12]. The screen for printing silver ink is cut according to a conductive pattern. The conductive pattern produced after the heating process is measured its resistance value using a multimeter [13].

The chosen research area is designing a hot lamination device with Arduino as a microcontroller. The lamination device is designed so that the heat generated does not damage the flexible PCB substrate, i.e. HVS paper and mica film. The research aims the lamination device can reduce the resistance of the conductive pattern of the flexible PCB and the temperature of the lamination can be adjusted according to the characteristics of the laminated material.

Barv [13] researched the manufacturing of Ultra High Frequency (UHF) of Radio Frequency Identification (RFID) antennas for smart cards with conductive silver ink. UHF antenna printing with single-layer printing by conductive paths. The study was conducted by designing, simulating and testing antennas which were applied to RFID smart cards. The test was carried out with three different conductive silver inks as well as the measured antenna range and the strength of the smart card. RFID card signal strength is also discussed in the research conducted. The results of the study are RFID smart cards that followed a hot lamination process.

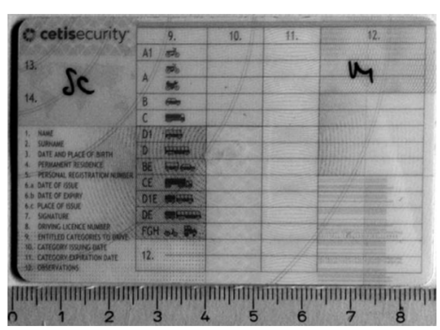

Figure 1: Conductive Silver Ink RFID Card [13]

2. MATERIALS AND METHOD

Lamination Device Design

Arduino-based lamination device design with overall lamination device planning. Following is the design of the lamination system.

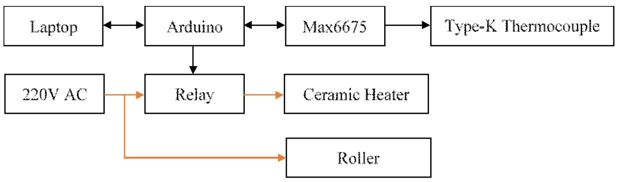

Figure 2: Block Diagram of Lamination Device

In Figure 2, the lamination device system for a conductive pattern using a ceramic heating element to heat the conductive pattern. Temperature controlled by Arduino with a relay module connected to ceramic heaters. Temperature is read by thermocouple with max6675 driver as a converter for Arduino. Flexible PCB towing roller and ceramic heater using AC power source.

Hardware Design

The design of the lamination device is divided into two parts. The first part for hot lamination and the second part for Arduino microcontrollers.

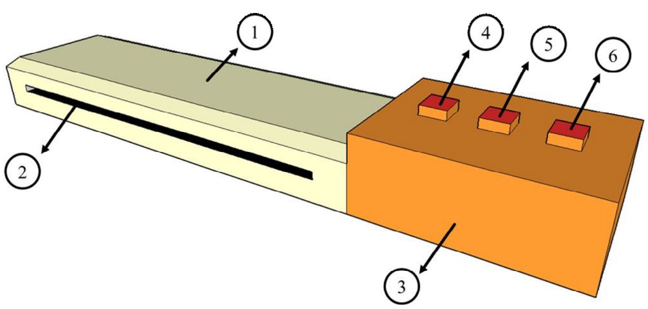

Figure 3: Design of Lamination Device

Figure 3 showed the design Arduino-based lamination device. The design of the lamination device is the basis for designing the components of the lamination device, i.e.:

1. Lamination heating box
2. Flexible PCB towing roller
3. Arduino microcontroller box
4. Lamination button of HVS paper
5. Lamination button of Mica film
6. On / Off switch

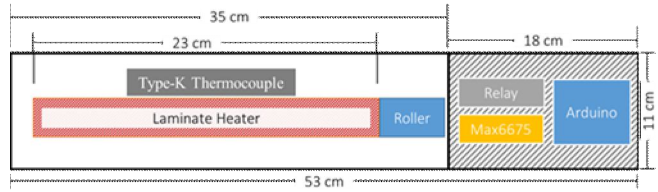

Figure 4: Lamination Device Dimensions (Top)

In Figure 4. dimensions of the lamination device have length and width as 53 cm x 11 cm. The dimensions of the lamination heater box are 35 cm x 11 cm and the flexible PCB lamination heater is 23 cm. In the lamination box, there are ceramic heater, roller and k-type thermocouple sensor. Arduino microcontroller box has a relay and max6675 dimension as 18 cm x 11 cm.

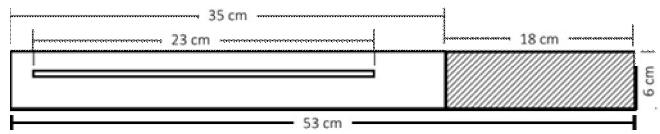

Figure 5: Dimensions of the Lamination Device (Front)

In Figure 5, the height of the lamination device is 6 cm. Dimensions of the flexible PCB lamination towing roller is 23 mm x 0.5 cm.

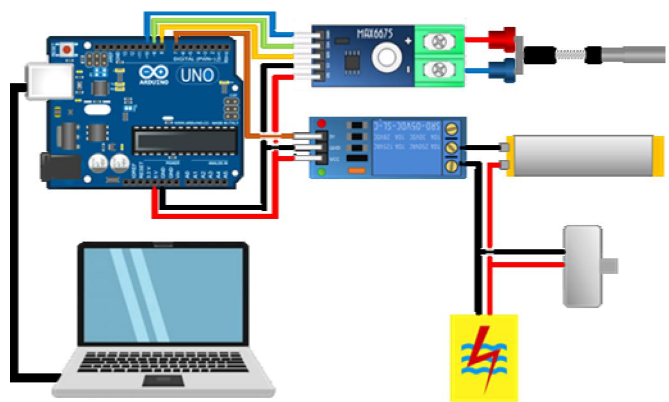

Figure 6: Device Component Diagram

Figure 6 showed a diagram of the components of the lamination device used for flexible PCB lamination. In the lamination, the components used are ceramic heaters and AC motors for roller drive. Arduino sets the max6675 driver as a converter for k-type thermocouple sensors. The temperature of the heating element is controlled by Arduino to set the relay for on /off 220V AC voltage sources. AC motor drive roller uses 220V AC voltage. Arduino will also send measurement data of heating element temperature to the laptop. The following block diagram of the temperature control system of the Arduino-based lamination device.

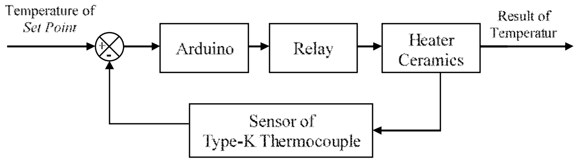

Figure 7: Block Diagram of a Control System of Lamination Device Temperature

Software Design

The design of the software aims to control the performance of the device as desired. Arduino is programmed to regulate the temperature of the lamination device. The reference temperature used is 60 °C and 70 °C for flexible PCB applications of HVS paper and mica film materials. Following is the flow diagram of the lamination device program in Arduino.

Data was collected by measuring the resistance of the conductive pattern of flexible PCB HVS paper and mica film material. Resistance measurements are carried out using an ohmmeter. Conductive patterns are made by screen printing on a flexible PCB [14].

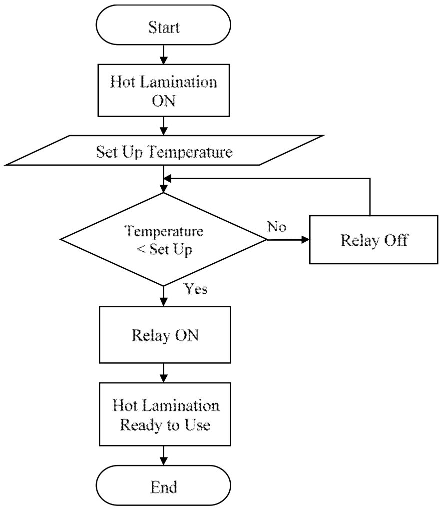

Figure 8: Flow Chart of the Lamination Device Program

Then, a dry flexible PCB measured resistance using an ohmmeter. The flexible PCB laminated in accordance with the material used. The results of the lamination device are resistance measured and then tested for the LED circuit and battery.

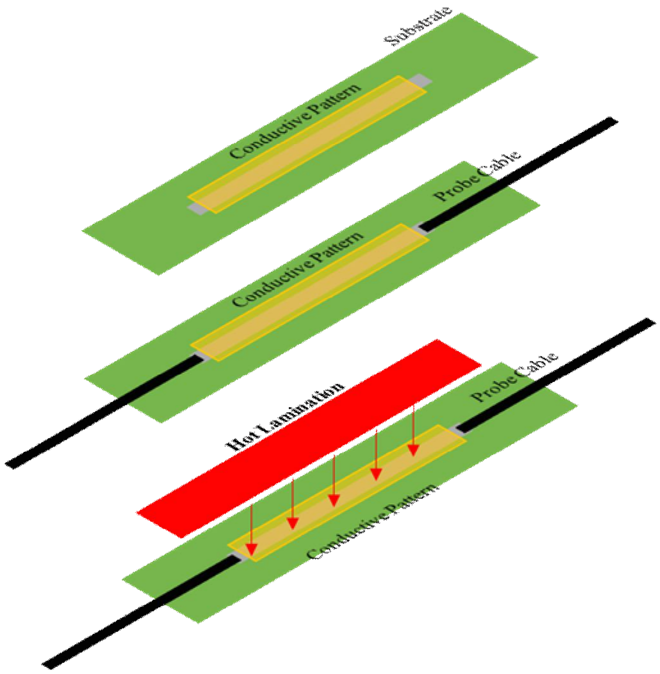

Figure 9: Conductive Pattern Lamination Method

The conductive pattern lamination process for flexible PCBs as shown in Figure 9. A good conductive pattern path has an unbroken conductive path and is measured using a multimeter. Measurements for the resistance of the conductive pattern are shown in Figure 10 was measured before lamination. The lamination process is carried out using a lamination device that has been designed. The result of the lamination process is a conductive pattern flexible PCB. Lamination is carried out on HVS paper and mica film materials.

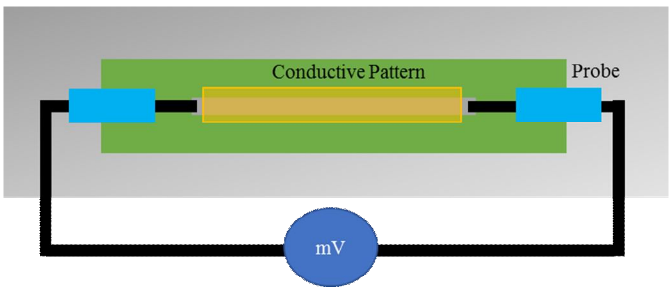

Figure 10: Conductive Pattern Measurement Method

3. RESULTS AND DISCUSSION

Thermocouple Sensor Testing

The results of the thermocouple sensor testing based on comparative measurements with a digital thermometer are shown in Table 1.

Table 1: Sensor Testing of Type K Thermocouple

No	Temperature of Termometer (°C)	Temperature of Thermocouple (°C)	Error (%)
1	10.0	10.75	5.83
		10.50	
		10.50	
2	20.0	20.75	5.00
		21.00	
		21.25	
3	30.0	30.50	4.44
		31.75	
		31.75	
4	40.0	39.50	3.13
		41.50	
		42.75	
5	50.0	52.25	2.83
		51.75	
		50.25	
6	60.0	61.50	2.36
		62.00	
		60.75	
7	70.0	72.75	2.38
		71.00	
		71.25	
8	80.0	81.00	2.29
		81.25	
		83.25	
9	90.0	91.75	2.50
		92.25	
		92.75	
10	100.0	102.25	3.83
		104.75	
		104.50	

From the test results and calculation, the highest thermocouple sensor error occurred at a temperature of 10 °C with a temperature difference of 0.58 °C and an error of 5.83 %. The lowest error from the calculation is 2.29%. The average error from the calculation is 3.46%. The results of the tests and calculations in Table 1. K-type thermocouple is feasible to be used in this study because the error is still below 10%.

Ohmmeter Testing

Ohmmeter test results based on a comparison of six resistors with different resistance are shown in Table 2. The test results and calculations in Table 2 for the ohmmeter is done with a resistor variation of 1 Ω to 4.7 Ω. The resistor used has an accuracy of 1%. In the measurement of resistor 1 Ω the average difference calculation is 0.03 Ω with the highest error of 3.33%. The average error calculation from the ohmmeter is 1.92%. The results of ohmmeter testing and calculations are feasible to be used in this study because the error is still below 10 %.

Table 2: Ohmmeter Testing

No	Resistance Variations of Resistor (Ω)	Measurement of Resistor (Ω)	Error (%)
1	1.0	1.0	3.33
		1.1	
		1.0	
2	1.8	1.9	1.85
		1.8	
		1.8	
3	2.2	2.2	3.03
		2.3	
		2.3	
4	3.3	3.2	1.01
		3.3	
		3.3	
5	3.9	4.0	0.85
		3.9	
		3.9	
6	4.7	4.8	1.42
		4.8	
		4.7	

Lamination Heat Testing

The test carried out for 3 minutes on the heat of the lamination device achieved was 130 °C. Tests carried out by connecting the lamination with an electric current.

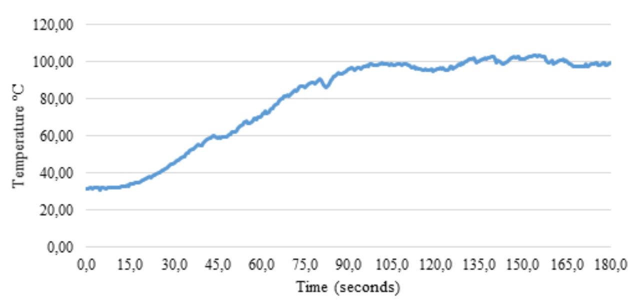

Figure 11: Heat Testing of Lamination Equipment

Figure 11 showed the heat testing graph of the lamination device. The blue line shows the performance increase in temperature of the lamination device can function well. A lamination can reach a maximum temperature of 130 °C for 180 seconds. The temperature used for flexible PCB HVS paper and mica film materials between 60 °C and 70 °C. The time needed to reach this temperature is 50 seconds to 70 seconds.

Lamination Roller Testing

Table 3: Testing of Lamination Roller

No	Distance (cm)	Time (second)	Speed (cm/second)
1	20.0	15.0	1.3
2	20.0	15.1	1.3
3	20.0	15.2	1.3
4	20.0	15.2	1.3
5	20.0	15.2	1.3
Average		15.14	1.3

Results of tests carried out for rollers of lamination devices using paper with a size of 10 cm x 20 cm. Data of Table 3 obtained to find out the length of rollers to pull the flexible PCB. The time average is needed to pull the paper with a length of 20.0 cm is 15.14 seconds. Calculation of the speed of the laminated roller obtained is 1.3 cm per second. The results of the lamination device roller testing are feasible for use in this study because the speed of the rollers to pull the substrate is stable.

Lamination Relay Testing

Testing of the laminate device relay controlled by Arduino with an initial measurement temperature of 70 °C. Relays set to temperatures exceeding 75 °C will disconnect the electric current for the laminate heater when the temperature is below 70 ° C and the relay will connect the electric current to the laminate heater. The relay test results remain on good status when the temperature is 70 °C to 74 °C. When the lamination temperature reaches 75 °C until it drops to 70 °C the relay stays off with a good status. The results of testing the laminated device relay are feasible to be used in this study because it can open and close the electric current for the lamination device.

Material Lamination Data

The results of research conducted by testing conductive pattern samples with sizes of 50 mm x 2 mm and 50 mm x 4 mm. Silver conductive ink was applied to paper and mica film. Resistance values were obtained based on ohmmeter measurements. From the experimental data, the measurement of the resistance of conductive patterns on flexible PCB has different characteristics. The data is taken based on differences in the length and width of the conductive ink and application media, i.e. HVS paper and mica film. The following results of testing the lamination device and measuring the resistance of the conductive ink pattern are shown in Table 4.

Table 4: Resistance Measurements

Material	Conductive Ink Pattern		The Resistance of Conductive Ink Patterns		Temperature (°C)
	Length (mm)	Width (mm)	Before Lamination (Ω)	After lamination (Ω)	
HVS Paper	50	2	2.8	0.11	70
HVS Paper	50	4	4.2	0.24	
Mica Film	50	2	2.2	0.10	60
Mica Film	50	4	4.4	0.19	

The results of the resistance measurement of conductive ink pattern are displayed in Table 4 with variations of HVS paper and mica film materials. Measurements on HVS paper with a width of 2 mm with resistance before lamination 2.8 Ω and after lamination 0.11 Ω. The resistance of the conductive action pattern of HVS paper material drops by 2.69 Ω of 70 °C. Measurements on mica film with a width of 2 mm with resistance before lamination 2.2 Ω and after lamination 0.10 Ω. The resistance of the conductive action pattern of HVS paper material drops 2.1 Ω with a temperature of 60 °C. The results of the measurement of the conductive ink pattern resistance and testing of lamination equipment are feasible to be used for flexible PCB lamination of HVS paper and mica films materials.

4. CONCLUSSION

In this research has been successfully designed and tested Arduino-based conductive silver ink lamination device. The lamination device can work to reduce the resistance of the conductive silver ink pattern by heating the flexible pattern material of HVS paper and mica film. The lamination works with Arduino to regulate the temperature of the ceramic heater. The temperature is maintained not to damage the conductive pattern of HVS paper and mica film materials. The measured resistance before lamination as 2.8 ohms and after lamination has lowest value as 0.1 ohms. The results of the conductive pattern lamination are tested with LED and battery circuits. The flexible material used is HVS paper and mica film for the LED circuit. Tests conducted a series of conductive patterns can function where the LED can light. From the measurement of the voltage on the LED of 3.3 Volts and current as 0.1 Ampere. Conductive pattern testing with LED circuits ensures that the Arduino-based conductive silver ink lamination device can function well.

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