Development of low cost stencil printer for silver nanoparticles filled conductive ink

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ABSTRACT – This paper presents development of stencil printer and comparison result measurement of sheet resistivity of silver nanoparticles-filled conductive ink printed by using manual deposition method and stencil printer. The study was conducted by using product design specification (PDS), Pugh concept selection method and four-point probe. After printing, the conductive ink was tested by four-point probe. The function of four-point probe is to measure the resistivity of samples. The lower the value of resistivity, the higher the conductivity of conductive ink.

1. INTRODUCTION

This study proposes to develop low cost stencil printer for conductive ink. Stencil printer is a printer to depositing solder paste on the printed surface mount printed circuit board (PCB) by using a stencil and squeegee to establish electrical connections [1-3]. Solder paste consists of solder metal and flux. It used to connect surface mount components to pads on the printed circuit boards. During component placement and reflow solder, paste will act as sticker, it is then heated in oven to produce solder joints. The solder has melted well, flowed and moistens the lead form the mechanical connection as well as the electrical connection is a good solder joint. Various variables influence stencil printing. Design of stencil, composition for solder paste, speed and pressure of squeegee, and other environmental conditions are the variables that influence the printing. In this study, these variables should be studied in depth to improve the stencil printer [4-6].

The objective of this study is to develop low cost stencil printer and compare result measurement of sheet resistivity of silver nanoparticles-filled epoxy conductive ink printed by using manual deposition method and test rig stencil printer [3-5]. The reason for using silver nanoparticles as filler because it is the most commonly in formulation of conductive ink despite of its high cost. Even being oxidized, silver still electrically conductive which is make it's the best filler. Silver is widely used and is being investigated for printing electronic application due to these unique features. Silver can easily be formulated with binder and it demonstrates adhesion to different substrates is better than copper and nickel (Gilleo, 1996).

2. RESEARCH METHODOLOGY

2.1 Samples preparation

Silver nanoparticles filled epoxy conductive ink was formulated. Silver nanoparticles had been used as filler, epoxy as binder and hardener as the solvent. Composition of the material were weighed based on Table 2.1. Then all the material was mixed in a beaker and stirred until silver was completely dissolved for about 10 minutes.

Table 2.1 Composition of Ink Loading

Filler		Binder		Hardener (30%from binder) (g)	Total (g)
(%)	(g)	(%)	(g)		
60	1.2	40	0.8	0.24	2

After the stirring process, manual deposition method had been used as printing method. Next, the samples were heated in an oven with at 160 °C for 60 minutes. In previous research, silver nanoparticles conductive ink was heated at curing temperature over 150 ˚C (Perelaer, 2010). After 60 minutes, the sample was put aside until it fully dried.

2.2 Product design specification (pds)

Product design specification is the design aspects that fulfil the customer's needs and requirement shown in Table 2.2.

Table 2.2 Product Design Specification

Priority	Requirement	Metric	Target
4	Cost	RM	Below RM200
4	Weight	kg	Below 30kg
5	Ease of use	Yes/No	Yes
5	Ease of assemble	Yes/No	Yes
5	Availability of parts	Yes/No	Yes

In designing a product, the designer must know the basic product features and requirement that are demanded by the user and customer so that the product can be made

useful and satisfy the user and customer. Failure to cooperate with the demands may result the product to be failure to be market. The feature that will be applied in our project is affordable, ease of use and lightweight.

2.3 Pugh concept selection method.

Pugh concept selection method is applied to evaluate concepts. It is a method compares each concept relative to a reference or datum concept to determine the best concept as design product. There are five criteria included in reference or datum. These criterions are low cost, ease of manufacturing, ease of assembly, light weight, simplicity of design. There are three concepts for the design of our stencil printer. The three concepts are shown in Table 2.3 and the Pugh selection method in Table 2.4, respectively.

Table 2.3 Three concepts for Pugh method

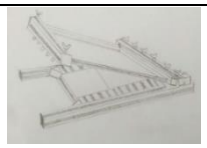
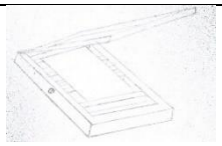
Concept	Drawing
A	
C	
D	

Table 2.4 Pugh selection method for concept A, B, C and D

Criteria	Sign	Concept			
		A	B	C	B
Cost		+	DATUM	+	+
Ease of Manufacturing		-		-	-
Ease of Assembly		-		+	+
Weight		+		+	+
Simplicity of Design		-		+	-
	Pluses	2		4	3
	Minuses	3		1	2

(+ means higher, - means lower, = means equal)

Based on the Pugh Concept Selection method, concept C has the highest rating compare to others. Hence, concept C had been chosen as product concept and will undergo further discussions for this concept.

2.4 Sheet resistivity measurement

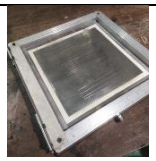
The resistivity measurement was tested by using Four-Point probe after the ink was fully dried. Data readings were taken 3 times at different spot and then the average value of data had been calculated to get accurate value.

3. RESULTS AND DISCUSSION

3.1 Final product

The final product is shown in Table 3.1. Operation of product is very simple. Put substrates on the positioning table of stencil printer, where it's should secure substrates by using scotch tape against moving. Then close the frame with stencil and accurate harmonizing stencil with surfaces on substrates by using of two screws. Now it is prepared for paste application. It is possible set height of desk and frame height above the desk. Be careful during sprinting and do not deform stencil

Table 3.1 Final product

View	Design
Back	
Top	
3-D	

3.2 Results of sheet resistivity

In order to test the functionality of the stencil printer, the square resistance of the conductive ink was measured after the samples were printed and cured in the oven. The values obtained are shown in Table 3.2.

By referring data on Figure 3.1, there are two samples A and B had been used to be tested their resistivity and the results is shown in graph filler against resistivity using manual deposition method. Total average for all points in sample A is 150.54 Ω/ sq while 369.63 Ω/ sq is the total average for all points in sample B.

Based on Figure 3.2, graph filler against resistivity using stencil printer shows two sample A and B was being tested using four-point probe to check their resistivity. Last point for sample A shows 232.38 Ω/ sq. Total average for all the points in sample A is 148.01 Ω/ sq and

the total average for sample B is 176.89.

Table 3.2 Comparison the value of resistivity between printed by using manual deposition method and stencil printer.

Filler (%)	Sample No.	Total Average resistivity (Ω/ sq)			
		Printed by using manual deposition method		Printed by using Stencil printer	
60	1	108.36	148.33	95.45	108.34
		118.72	141.82	113.65	110.05
		132.59	167.07	102.99	104.29
	AVE	119.89	152.41	104.03	107.56
	2	80.68	301.42	90.33	108.56
		122.19	281.53	106.85	110.98
		75.29	190.22	80.76	99.76
	AVE	92.72	257.72	92.65	106.43
	3	280.88	528.57	165.45	176.43
		312.74	774.82	186.2	162.1
		123.44	792.92	125.9	154.76
	AVE	239.02	698.77	159.18	164.43
	TOTAL AVE	150.54	369.63	118.62	126.14

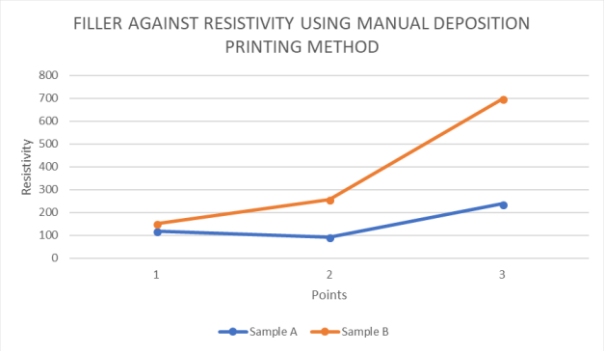


Figure 3.1 Filler against resistivity using manual deposition method.

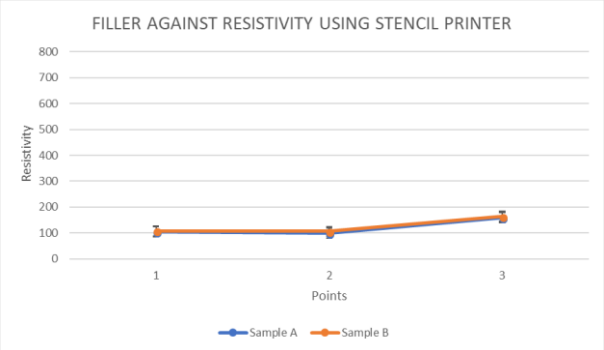


Figure 3.2 Filler against resistivity using stencil printer.

Analysis from the data shows that the result by using manual deposition method is not consistent compared to by using stencil printer. After conductive ink being printed by using stencil printer, the result for resistivity is improve as the value is lower. The lower the value of resistivity, the higher the conductivity of conductive ink.

4. SUMMARY

For the objective which is to develop low cost stencil printer for conductive ink, the first step in the design process is knowing the user's demands on market should be considered. The second step is conceptual design. The next step is detail design. After details design, analysis design had been conducted. The fifth step is estimation costs. Sixth step is fabrication process. Once the design process has been completed, fabrication process had carried out for final design. The last step is testing and analysis. After fabrication process completed, testing the product had been carried out by using four-point probe from Jandel's RM3000 test unit. The result shows the value resistivity is better compared to the value of resistivity when being printed using manual deposition method. Its improving and consistent. The lower the value of resistivity, the higher the conductivity of conductive ink. Hence, the objective in this study were achieved.

REFERENCES

[1] Gilleo, K. (1995). Polymer thick film: today's emerging technology for a clean environment tomorrow. Springer Science & Business Media.

[2] Khader, N., Yoon, S. W., & Li, D. (2017). Stencil Printing Optimization using a Hybrid of Support Vector Regression and Mixed-integer Linear Programming. Procedia Manufacturing, 11, 1809-1817.

[3] Perelaer, J., Smith, P. J., Mager, D., Soltman, D., Volkman, S. K., Subramanian, V., ... & Schubert, U. S. (2010). Printed electronics: the challenges involved in printing devices, interconnects, and contacts based on inorganic materials. Journal of Materials Chemistry, 20(39), 8446-8453.

[4] Rahim, N. A., & Salim, M. A. (2018, April). Investigation of silver nanoparticles ink resistivity on polyethylene terephthalate. In 1st Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER'18) (Vol. 1, p. 10). Penerbit Universiti, Universiti Teknikal Malaysia Melaka.

[5] R. Hamidi., & Salim, M. A. (2018, April). Sheet resistivity and morphological analysis of silver nanoparticles-filled epoxy conductive ink. In 1st Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER'18) (Vol. 1, p. 1). Penerbit Universiti, Universiti Teknikal Malaysia Melaka.

[6] Yusoff, A. N., & Salim, M. A. (2018, April). Modelling and simulation of assembled components of an integrated diffusion method. In 1st Colloquium Paper: Advanced Materials and Mechanical Engineering Research (CAMMER'18) (Vol. 1, p. 8). Penerbit Universiti, Universiti Teknikal Malaysia Melaka.