Effect of line thickness cross-sectional geometry to stretchable printed circuit

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ABSTRACT – The effect of thickness of the ink on the resistivity. There are five samples with different thicknesses (2, 4, 6, 8 and 10 layers). The layers was made using cellophane tape and each layer represent 0.04 mm. The printing method used was screen printing method and the samples was measured using four point probe in the unit of Ω/sq. In this paper the conductive ink used is carbon black and the substrate used are glass and thermoplastic-polyurethane (TPU). The result of the study shows that when the thickness of the ink increase, the resistivity will decreased.

1. INTRODUCTION

Stretchable printed circuit board (SPCB) have similar function as printed circuit board (PCB) which is to connecting electrical component together and actually make the device working and functioning correctly. The existence of the SPCB really improve our technologies to another level. The characteristic of the SPCB making it is widely used not only in industry but also in fashion, health and sport [1]. The component of the SPCB can divided into two main components which are the conductive ink and substrate, where the conductive ink replacing the traces that being used in the PCB and the substrate as the medium to place the conductive ink. The function of the traces and the conductive ink is to making the path for the electric to flow in the circuit.

There are several kind of conductive ink such as silver, copper and carbon. Silver ink is widely used because of high conductivity but the cost is high. Meanwhile carbon black is cheaper but less conductivity compared to silver [2].

The objective of this study is to investigate the effect of thickness of the ink against the resistivity. The resistivity will be measured using the four point probe and the graph of sheet resistance against the thickness of the ink will be tabulated.

2. RESEARCH METHODOLOGY

2.1 Samples Preparation

There are 3 main processes to preparing the samples which are preparing the material and apparatus needed for printing process, the printing of the ink to the substrate and the curing of the samples process.

The material and apparatus needed for printing process are the razor blade that is used for spreading the ink paste, the cellophane tape to change the thickness of the ink, the conductive ink and the substrate. In this study the conductive ink used was carbon conductive ink made by Bare Conductive and the substrate used were glass slide and TPU. The printing method used to print the ink to the substrate was screen printing method [1]. Before start printing the ink, the substrate will be tape using cellophane tape where the thickness of the tape is 0.04 mm, in order to create different thickness when the ink printed to the substrate. The tape will be stack together to create layers, the layers used for this study are 2, 4, 6, 8 and 10 layers.

Then the conductive ink will be place on the sample and spread using the razor blade. The method used to print the samples are following the standard of razor straight line printing method referred to standard ASTM D2739 [3]. After the printing process complete, the samples was cured in the room temperature for 15 minutes as mentioned in the technical datasheet of Bare carbon conductive ink [4].

2.2 Experiment Setup

The electrical test will be tested using the four point probe to measure the resistivity of each samples in the unit of Ω/sq. The test conducted in the room temperature.

3. RESULTS AND DISCUSSION

In this section the result of the measurement will be discussed in detail on the effect of thickness on ink resistivity. There will be two result since there are two types of substrate being used which are glass slide and TPU.

3.1 Glass Slide

The glass slide physical characteristic is a rigid body non-flexible and non-stretchable substrate. The purpose printing the conductive ink on the glass slides are to focus the result only on the effect of the different thickness of the conductive ink to the resistivity of the conductive ink measured by the four point probe. So this are the result obtain from five samples of glass slides by the four point probe.

Table 3.1 : Glass slide data.

Sample	Num. Layer	Total Average Rs (Ω/sq)
1	2	494.93
2	4	289.33
3	6	313.35
4	8	350.48
5	10	201.98

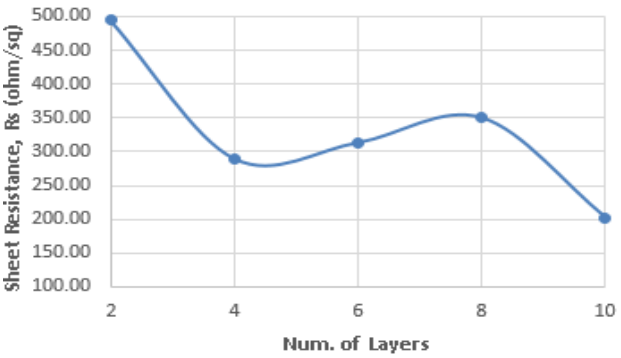

Figure 3.1 : Glass slide data.

As can be seen the lowest and the highest sheet resistance are 201.98 Ω/sq (10 layers) and 494.93 Ω/sq (2 layers) respectively. So basically as the number of the layers or the thickness of the ink increasing, the sheet resistance will be decreasing The result is same as expected and based on other founding [5].

But there are sudden increasing in the graph on sample 3 and 4. This phenomenon can be due to the inexperience of printing technique which the samples are not printed smoothly and unevenly. It also can be due to void on the ink, the probability of the void become higher if the thickness of the ink is too thin which making the electrical flow not smooth and affecting the measurement of the data. The last reason is due to the cellophane tape not perfectly stack together while making the layers which causing the thickness of the ink not consistent after printing.

3.2 Thermoplastic-Polyurethane (TPU)

Thermoplastic-polyurethane physical characteristic is opposite from glass slide because it is stretchable and flexible. The result of the experiment as below.

Table 3.2 : TPU data.

Sample	Num. Layer	Total Average Rs (ohm/sq)
6	2	465.92
7	4	392.94
8	6	297.55
9	8	119.89
10	10	136.47

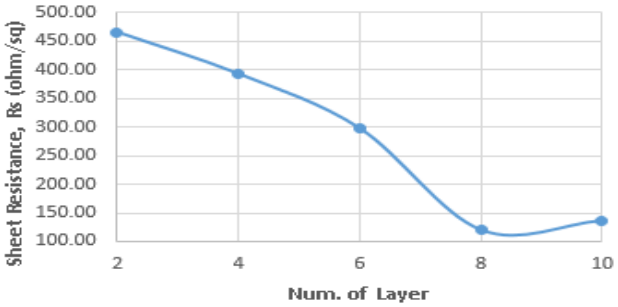

Figure 3.2 : TPU data.

The pattern of the data of TPU is quite similar as glass slide which as the thicker the ink, the lower the resistivity reading. As can be seen the lowest sheet resistance is 119.89 Ω/sq (8 layers) and the highest is 465.92 Ω/sq (2 layers).

The pattern of the graph is constantly decreasing until sample 9 and sudden increasing on sample 10. The increase in resistivity of sample 10 is due to same reason as the problem occur in the glass slide.

4. SUMMARY

The purpose of the study is to investigate the effects of thickness cross-sectional geometry of the ink against the resistivity by measuring the samples using the four point probe. The result from this study can be conclude that when the thickness of the ink increasing will decrease the resistivity of the samples or in other word the conductivity will be increasing.

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