Effects of carbon black to electrical properties on stretchable printed circuit

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ABSTRACT – This paper seeks to analyze the effect of type of conductive ink to stretchable printed circuit. For this study, carbon black or also can be known as CB is used as the conductive ink. This study is focus on the measurement of sheet resistance. Four-point probing system is used to measure the sheet resistance, Rs of the conductive ink. The sheet of the carbon black is measured under room temperature without any external heat or load applied. A proper printing technique must be considered to get the consistent and accurate data. The surface roughness of the different sample is determined by using 3D non-contact profilometer measuring instrument. Results shows that higher value of the surface roughness will improve the conductivity of the carbon black ink.

1. INTRODUCTION

Stretchable printed circuit (SPC) is a pattern of conductive traces bonded of stretchable substrates. Due to its capabilities and reliability, stretchable printed circuit has a valuable position compared to traditional printed circuit in worldwide printed circuits market. Since the stretchable printed circuit have many specialities for example high flexibility and can be fold without affecting signal transfer function, hence it has been applied in various fields such as biomedical to detect the hydration of athlete's body during training session.

In this study, carbon black is used as conductive ink and thermoplastic polyurethane (TPU) is used as the substrate. The combination of both materials will form the stretchable printed circuit. Conductive ink can conduct electricity and compatible with substrates while SPC is pattern of conductive traces bonded on a flexible substrate.

Sheet resistance, Rs of the conductive ink can be affected by the printing technique. Different printing technique will create different surface roughness, thickness and width of the samples. For this study, the effect of different surface roughness to the sheet resistance has been considered by using carbon black conductive ink. Sheet resistance is measured by using four-point probe system and the surface roughness of the sample is determined by using 3D non-contact profilometer instrument. Next, optical microscope is also used in this study to examine the microstructure of the samples. The objective if this study is to investigate the effects of carbon black to stretchable printed circuit at room temperature.

2. RESEARCH METHODOLOGY

2.1 Samples Preparation

There are a few materials involved to prepare the samples; carbon black conductive ink, thermoplastic polyurethanes, isopropyl alcohol and cellophane tape. Two samples are prepared and followed the dimension as in Table 2.1 below:

Table 2.1 Dimension of samples

(1) Conductive ink	
(a)width (mm)	3
(d)thickness (mm)	0.08
(2) Substrate	
(b)width (mm)	20
(c)length (mm)	30

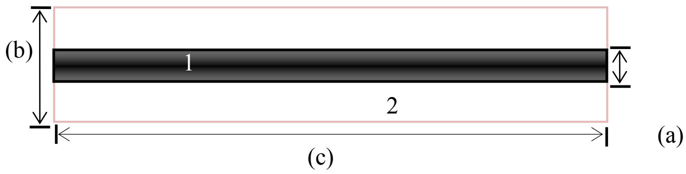

Figure 2.1 Sample's top view

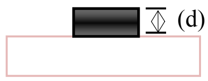

Figure 2.2 Sample's side view

The samples are printed with dimension of 3 mm width, 0.08 mm thickness and 30 mm length of conductive ink on the 20 mm width of thermoplastic polyurethane substrate as shown above. Next, the samples must be cured or dry at room temperature for 5–15 minutes. After the samples are completely cured, for accurate data purpose, the samples were divided and marked into five points and at each point, three times readings are taken. By doing this step, the data obtain is more accurate since it is considering the average data. The samples are marked as shown in Figure 2.3 below:

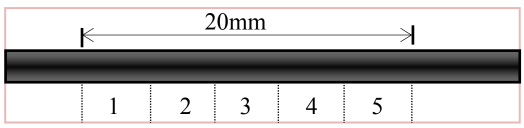

Figure 2.3 Samples divided into five points

2.2 Experimental

For this study, the sheet resistance is calculated by using four-point probe technique. Figure 2.4 below shows the schematic diagram for four-point probe measuring the sheet resistance of the samples.

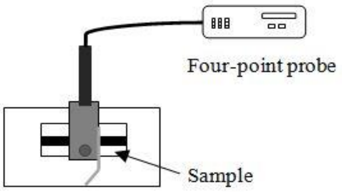

Figure 2.4 Schematic diagram top view of four-point probe measuring sheet resistance of samples setup

3. RESULTS AND DISCUSSION

The average sheet resistance, Rs for Sample 1 and Sample 2 were taken at room temperature condition. Figure 3.1 below shows the total average sheet resistance for Sample 1 and 2.

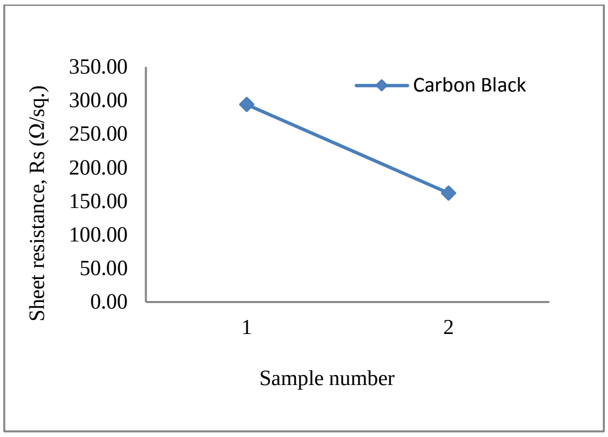

Figure 3.1 Sheet resistance versus sample number

By referring Figure 5, the total average Rs for sample 1 and 2 when exposed in room temperature are 293.90 Ω/sq. and 162.25 Ω/sq., the graph shows quite large different value of sheet resistance between two samples. This is due to the different surface roughness of both samples. In addition, sheet resistance also depends on the internal microstructure of the printed lines. The structure could be affected by several parameters for example printing techniques, surface roughness and curing time [1].

By using 3D non-contact profilometer instrument, it shows that the total average surface roughness of each five points of sample 1 and 2 are 3.05um and 4.59 um as shown in Table 3.1.

As stated by J. Sánchez [2], the surface roughness also improve the contact between particles and will reduce the sheet resistance value and it is shows the electrical conductivity of the carbon black increased. The increasing of surface roughness not only increase the electrical conductivity, it will also will improve the mechanical properties of the conductive ink [3]. Higher surface roughness also means the sample to have more filler.

Table 3.1 Data for total average sheet resistance and surface roughness for Sample 1 and 2

Samples	Surface roughness (um)	Total average sheet resistance, Rs (Ω/sq.)
1	3.05	293.90
2	4.59	162.25

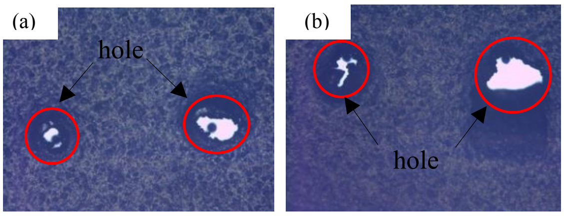

Figure 3.2 Optical microscope image for (a) Sample 1 (b) Sample 2

Figure 3.2 above presents the optical microscope image for both samples. It can be seen that the sample expose substrate (hole) when four-point probe applied to the samples. This is due to the thickness of the samples are not suitable to be measured under four-point probe. By referring the application notes of the carbon black product that has been used in this study, the sheet resistance should be lower than 55 Ω/sq. with suitable thickness printed [4].

4. SUMMARY

In conclusion, this study was conducted to analyze the effects of carbon black to stretchable printed circuit at room temperature. The 3D non-contact profilometer used to study the surface roughness of the sample and optical microscope is used to examine the microstructure of the carbon black. Next, higher surface roughness will give a better conductivity. To obtain a good result and consistent value of sheet resistance, the printing method must be improved and printed in a steady way. To get a better value of sheet resistance as recommended in application notes of the product, the thickness of the printed ink must be increased.

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