EFFECT OF STRETCHABLE CONDUCTIVE INK DIMENSIONS ON ELECTRICAL CONDUCTIVITY

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DECLARATION

I hereby declare that Final Year Project Report submitted to the Universiti Teknikal Malaysia Melaka (UTeM) is a record of an original work done and this report submitted in the part of the fulfillment of the requirements for the award of the degree of Bachelor Mechanical Engineering Hons. If any discrepancy is found regarding the originality of this project I may be held responsible. I have not copied from any report submitted earlier this or any other university. This is purely original and authentic work.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Mechanical Engineering with Honours.

Signature :

Supervisor Name : DR. NOR AZMMI BIN MASRIPAN

Date :

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I would like to dedicate my thesis to my beloved parents and my supervisor who gave me never ending affection, love, encouragement and pray of day and night throughout this Final Year Project.

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ABSTRACT

This project is about the study of effect of dimension on stretchable conductive ink electrical conductivity. The parameter use in this project is the different length, different width and different thickness. This paper presents the result on the different dimension effect on the electrical conductivity and the analysis of the microstructure surface. The ink was printed on the TPU substrate which is the substrate can be stretch. After print the ink on the TPU the stretchable conductive ink was cure in an oven at 120℃ with different time of curing, 15 minutes, 30 minutes and 45 minutes. The lower resistance for the length is 40 mm at 45 minutes curing time, the resistance is 1019.79 (R/sq). The result for the width is 7 mm at 45 minutes of curing time, the resistance is 679.86 (R/sq). The lower resistances for the thickness is 0.6 mm at 45 minutes of the curing time, the resistance is 566.55 (R/sq). The effect on the dimension that can be concluding the longer the length of the conductive ink, the higher the resistance it will give. For the thickness, the thicker the conductive ink, the lower the resistance it will show. Lastly, the wider the width of the conductive ink, the lower the resistance of the conductive ink. The curing time also effect the resistance of the conductive ink, the longer the curing time, the lower the resistance, this is due to the decreasing of the gap between the particles on the ink.

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ABSTRAK

Projek ini adalah mengenai kajian kesan dimensi pada konduktif elektrik dakwat konduktif yang boleh diperbaharui. Parameter yang digunakan dalam projek ini adalah panjang yang berbeza, lebar yang berlainan dan ketebalan yang berlainan. Makalah ini membentangkan hasilnya pada kesan dimensi yang berbeza pada kekonduksian elektrik dan analisis permukaan mikrostruktur. Dakwat dicetak pada substrat TPU yang substrat boleh meregangkan. Selepas mencetak dakwat pada TPU, dakwat konduktif yang disegangkan adalah menyembuhkan dalam ketuhar pada 120 ℃ dengan masa pengawetan yang berlainan, 15 minit, 30 minit dan 45 minit. Rintangan yang lebih rendah untuk panjang ialah 40 mm pada masa pengawetan 45 minit, rintangan ialah 1019.79 (R / persegi). Hasilnya untuk lebar ialah 7 mm pada masa pengawetan 45 minit, rintangan ialah 679.86 (R / persegi). Rintangan yang lebih rendah untuk ketebalan ialah 0.6 mm pada 45 minit masa pengawetan, rintangan ialah 566.55 (R / persegi). Kesan pada dimensi yang boleh menyimpulkan panjang dakwat konduktif, semakin tinggi rintangan yang akan diberikannya. Untuk ketebalan, tebal dakwat konduktif, semakin rendah rintangan itu akan ditunjukkan. Terakhir, lebar lebar dakwat konduktif, semakin rendah rintangan dakwat konduktif. Waktu pengawetan juga memberi kesan terhadap ketahanan dakwat konduktif, semakin lama masa pengawetan, semakin rendah rintangan, ini disebabkan oleh penurunan jurang antara zarah pada tinta.

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I would like to thank to all those who have helped me to finish this project. First, I would like to thank very much to my beloved supervisor Dr. Nor Azmmi Bin Masripan for guidance and giving brilliant advice to me as well as provision of the valuable time management. There are no other words that would able to express my feeling of gratitude toward you except thanks for kindness and helpfulness. His willingness to spend his time so generously whenever I confront problems is much appreciated. Deepest sense of gratitude to my beloved parents for never endless support and encouragement. They gave me a lot of persistence in not giving up completing my final year project. I bring my beloved parents spirit to finish the final year project.

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LIST OF ABBREVIATION

CNT	Carbon Nanotubes
PET	Polyethylene Terephthalate
TPU	Thermoplastic polyurethanes
UTeM	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.0 PROJECT BACKGROUND

Nowadays, the conductive ink has a high demand among the industry. Conductive ink is a type of colloid formed by diffusion of the conductive phase in a solvent that can be form in electronic devices. Thus, the classic technology only used in printing technique and lead to many unique advantages such as being low-cost, eco-friendly and energy efficiency. Furthermore, the conductive ink has many potential for other application such as solar cells, thin film transistor and adjustable electronic devices. (Liu et al., 2018)

Electric Paint is a nontoxic, water based, water soluble, electrically conductive paint. It can be used in circuits as a painted resistor element, a capacitive electrode or can function as a conductor in designs that can tolerate high resistivity. It is intended for applications with circuits using low Direct Current (DC) voltages at low currents. Electric Paint adheres to a wide variety of substrates and can be applied using screening printing equipment. Its major benefits include low cost, solubility in water and good screen life. It is black in color and can be over-painted with any material compatible with a water-based paint. (Bare Conductive Ltd, 2016)

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Polyethylene terephthalate (PET) was use in this project as a film for the stretchable conductive ink. The PET nowdays broadly used as a electronic equipment, packaging materials and automotive products. Moreover, the Polyethylene terephthalate had a good properties and therefore it suitable for the stretchable conductive ink.

Furthermore, the Polyethylene terephthalate are good in tensile, impact strength and clarity. So that, the stretchable conductive ink can stretch widely and can use for flexible ectronic product. The PET is a non-biodegradable plastic but its are easily to recycle. (Zander et.al., 2018)

1.1 PROBLEM STATEMENT

The effectiveness of the conductivity of the conductive ink is the bigger issue that the electronic industries have to face. The dimension of the conductive ink effect the effectiveness of the conductive ink. So that, the different thickness, length and the width will affect the conductivity of the stretchable conductive ink.

1.2 OBJECTIVE

The objectives of this project as follow:

1. To fabricate the stretchable conductive ink on the TPU substrate
2. To evaluate the effect of stretchable conductive ink in length, thickness and the width on electrical conductivity.

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1.3 SCOPE

The scopes of this project are as follow:

1. Fabricate the stretchable conductive ink on the TPU substrate, print the ink using bare conductive ink on the thermoplastic urethane, which is the TPU is a flexible substrate.
2. Measure the conductivity of the conductive ink on three parameter the length, thickness and width using the four-point probe
3. Analyze the surface microstructure of the conductive ink using the microscope.

1.4 GENERAL METHODOLOGY

The details methodology was discuss to complete and to achieve the objective of this project. The step of the general methodology is shown below.

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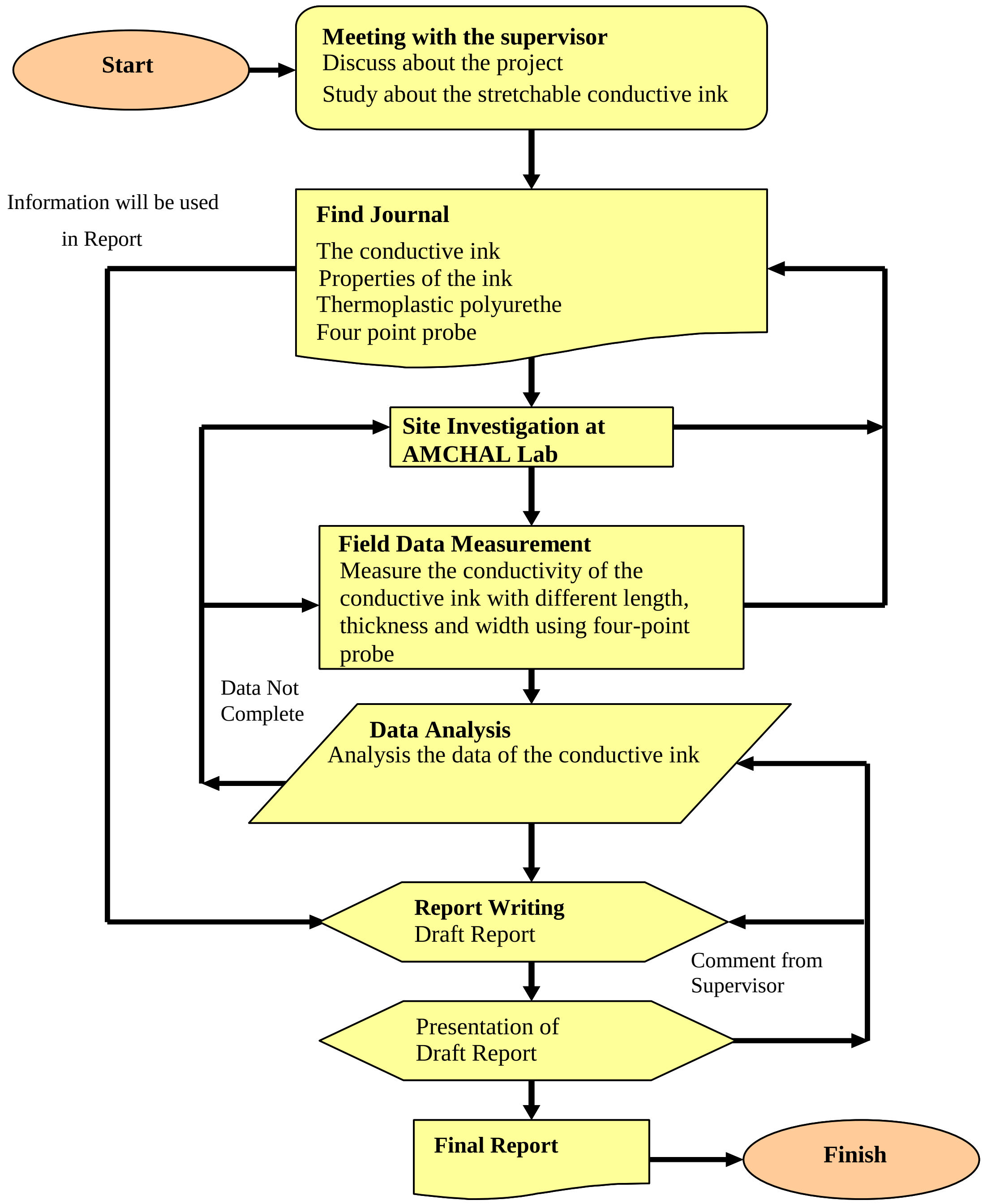

Figure 1.1: Flow Chart for the Project

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Conductive inks, which are a type of colloid formed by dispersion of the conductive phase in a solvent, may be printed directly on substrates to form conductive circuits or electronic devices. (Liu et.al., 2018) Graphene inks have recently enabled the dramatic improvement of printed flexible electronics due to their low cost, ease of processability, higher conductivity and flexibility. (Tran et.al., 2018)The ability to control the dispersion of silver particles and concomitantly formulate conductive inks with controlled surface tension, contact angle, and viscosity are critically important. (Yeop & Lewis, 2014)

Carbon nanotubes (CNTs) suitable use for replacing many existing materials, such as, electrical properties, superior thermal and mechanicals .The advantages of this materials was improves the fracture interfacial rigidity and can stop micro-cracks evolution. (L. Guadagnoet.al., 2018)

CNT is the composites where can be change to others material cause of the thermal, mechanical and electronic properties. Then, the diffusion of a small amount of CNTs in polymer composites changes the structure stiffness. In addition, the growth of polymer polymer-based composites with specific functionalities and performance to fulfill industrial requirements still presents several critical issues. Thus, CNT commonly tend to form collection and reduce performance in normal properties. (Guadagno et. al., 2018)

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The adhesively bonded joint has given the solutions for other mechanical joints in load-bearing structures such as automotive or other engineering application. Then, it can give many advantages such as low cost and lower weight making the structures able the aviation environmental impact. A significant progress in the field of structural joints is the replacement of traditional rivets with structural epoxy conductive adhesives. (Vertuccio et. al, 2017)

2.2 CONDUCTIVE INK

The stretchable printed circuit well known in conductive ink. The conductive can be define as the electrical view in the ability of the material substances to conduct electricity. The high conductivity of the materials such as metal, the electric current will able to flow easily when voltage is exerted. It also has stated that the material with lower resistance will conduct electricity more efficiently compared to material that has higher resistances. (Banfield, 2000)

Furthermore, the electrical resistivity has a specific electrical resistance is a parameter to measure how potentially conductors to resists the flow of electric current. Then, the conductivity is inversely proportional to the resistivity where the high conductivity of material results of a lower resistivity. (Merilampi et. al., 2009)

In addition, the conductive ink that has printed on the substrate which give a functional of conduction that the ability of the electrical charge carries electrons. Usually, the conductive elements used in electronic applications to provide stable electrical connection. The conductive ink layer has been built up or has been printed on a polymer of the substrate to form the flexible printed circuit. (Liu et. al., 2018)

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Thus, polymer substrates is one of the polymer-based electrically conductive inks and widely in electrical industries. (Banfield, 2000). It is used to make the conductive paths on the substrate. There are several types of substrate that are able to be used as polymer-based electrically such as Thermoplastic Polyurethane (TPU), which has mentioned details in the subtopic below.

There are several parameters that can affected the performance of sheet resistance, Rs (Ω/sq) of the film which includes of forces applied (tension) and temperature applied to the film. The temperature has applied will influence the particle radius of the conductive filler more precise and will affect the electrical conductivity of the conductive ink. Furthermore, the percentage of tension applied to the conductive ink also will affected the sheet resistances due there will be changes on the gap between particles in the conductive filler. Lastly, the sheet resistances is measured by using Four-Point Probe. (Tran et. al., 2018)

2.2.1 Preparation of Conductive Ink

In combination, 5 g of $CuSO_4$ and 1 g of sodium oleate were broken down in 50 mL of deionized water. Accordingly, 100 mL of xylene was filled the above arrangement, and the blend experienced unconstrained partition into two layers, the upper of which was xylene. In mixing, the blend was converted into a consistently conveyed homogenous stage, into which 15 mL of hydrazine hydrate was quickly infused. Ten minutes later, the response framework turned ruddy darker. The blend was permitted to remain until the point that it layered with the Cu NPs in the upper xylene layer. (Liu et.al., 2018)

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Graphene can be obtained using two distinct strategies, the bottom-up and the top-down. the top-down approaches involve the production of graphene from existing bulk carbon sources, by either exfoliation of graphite towards graphene, reduction of graphene oxide or carbonization of other materials. These methods are widely used for its numerous advantages in term of high yield, low cost, and solution processability, however the quality of graphene produced is of concern. (Tran et.al., 2018)

2.3 PROPERTIES OF FILLER

In the developing countries, it is important to produce product with higher efficiency, high sustainability and affordable. Thus, important features need to be considered in order to enhance the properties of the product. For this study, it is related to the stretchable printed circuit. There are several important features must be review in order to the stretchable printed circuit. The features includes the low manufacturing costs, high durability and high efficiency. In order to meet the requirement of the features, it is necessary to choose high quality of the materials. High quality of material is strongly related to the several properties for example mechanical and electrical properties. Mechanical properties includes of elasticity and tensile strength while electrical properties can be known as sheet resistances and thermal conductivity. Conductive filler is one of the main components in the stretchable printed circuit. Conductive filler provide electrical conductivity to the circuits and form of conductive ink when it combining with the binder and solvent. (Merilampi et. al., 2009)

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2.3.1 Carbon Black

Carbon black is popular carbon based filler and has been widely used and it can be present as the conductive filler which has good in electrical properties and light in weight (Han & Fina, 2011) Then, carbon black is not only good in electrical properties because of it has low resistivity (55 Ω/sq) which has stated at the figure 2.1 below. Then, it became popular in electronic manufacturer due to the carbon black has low cost materials. The electrical conductivity has been improved day by day. (Pu et. al., 2014)

Table 2.1: Properties of Carbon Black

TEST	PROPERTIES
Sheet Resistance at 50 micron film thickness (Ω/sq)	55
Density (g/ml)	1.16
Viscoscity	Thixotropic
Thinner	Water

(Bare Conductive, 2016)

Furthermore, the good electrical conductivity can be formed if the carbon black has produced high conductivity and having a very high surface area. (Nanda, 2008) Then, the electrical conductivity of the Carbon Black is 55 Ω/sq. (Bare Conductive Ltd, 2016) For example, the carbon nanotubes produces higher temperature when it apply to carbon. Thus, it will give lower sheet resistivity value since the gap between particle in the conductive ink decrease. (Hasnanoui et. al., 2017) In a certain condition when heat has applied to the carbon black, the particle of conductive filler expand and reduce the gap between fillers. Thus, the electron will flow easily due to the conductive filler has more contact area between others. Besides, it has increase the conductivity of conductive ink. (Banfield, 2000).

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The Bare Conductive by referring the figure 2.2 has made a research about the relationship between the length and the resistance. The company had been approved that the longer the length of the conductive ink, the higher the resistance. The results has been proved by results in resistance and length has shown in figure 2.2 where the shortest length for 70 mm x 3 mm gives the resistance 473 Ω. Then, the longest length for 130 mm x 3 mm gives the resistance 869 Ω

Generally, the carbon black provide the best electrical conductivity instead and the carbon black also in a low cost. Hence, this is the one of the reasons for choosing these materials as conductive filler in this study.

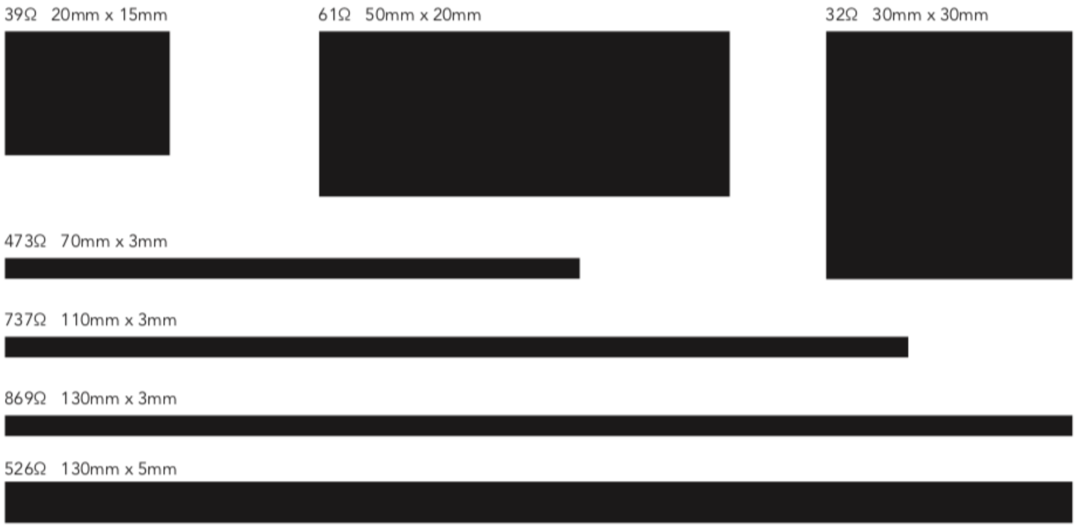

Figure 2.1: The results of the dimension from the Bare conductive LTD
(Bare Conductive, 2016)

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2.3.2 Silver

Recently silver inks have been used in novel applications, for example in RFID tags. Conductive metallic inks are widely used in printed electronics, such as photovoltaics, displays, batteries, sensors, and biomedical devices, while the silver ink or these applications representing over 90% of the materials used in a $1.5B annual market. Hence, the ability to control the dispersion of silver particles and concomitantly formulate conductive inks with controlled surface tension, contact angle, and viscosity are critically important. (Merilampi et.al., 2009) Next, the electrical conductivity of the Silver is 51 Ω/sq. (Logeeswaran et. al., 2008)

2.3.3 Carbon Nanotubes (CNT)

In year 1991, the polymers has been discovered which Carbon Nanotubes. It usually in the formed of the long and thin cylinders of carbon. These are large macromolecules that are unique for their size, shape, and remarkable physical properties. Currently, the physical properties are still being discovered and disputed. Nanotubes have a very large range of electronic, thermal, and structural properties that change depending on the different kinds of nanotube (defined by its diameter, length, and chirality, or twist) (Merlini et. al, 2018)

2.3.3.1 Carbon Nanotubes (CNT) Properties

The size of manufactured nanotubes typically varies widely. For commercial use, nanotube manufacturers will need to make size more consistent. Though nanotubes are very narrow, nanotube matrices typically have quite large (100nm) spacing between tubes. (Merilampi et.al., 2009)

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