THE PRINTABILITY OF THE CONDUCTIVE POLYMER EPOXY ONTO THE PET FLEXIBLE SUBSTRATE

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SUPERVISOR'S DECLARATION

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

Signature	:………………………..
Supervisor's name	:………………………..
Date	:………………………..

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A report submitted
in fulfilment of the requirements for
the degree of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this project entitled "The Printability of The Conductive Polymer Epoxy onto The PET Substrate" is the result of my own work except as cited in the references.

Signature	**:……………………….**
name	**:……………………….**
Date	**:……………………….**

DEDECATION

To my beloved mother and father

ABSTRACT

The applications of the flexible electronic circuit have increase significantly in the recent years. In order to fabricate a good flexible electronic, there are two important components need to be chosen carefully which are conductive polymer epoxy and substrate. Thus, this project will study about the printability of the conductive polymer epoxy onto the PET substrate. In this study, the conductivity of the conductive polymer epoxy will be measured by using four point probe after printed on the PET substrate with different percentage of filler. The sheet resistance value of the sample in ohms-per-square, the resistivity volume in ohms-cm and the sample thickness can be measured using a four-point probe. After that, morphological analysis will be carried out to observe the surface integrity of the conductive epoxy polymer on the PET substrate. By observing the microstructure of the conductive ink can let to know the quality of the of the conductive ink on the substrate. In addition, the gap of the filler particles can also be observed by microscope, this provided the information about the conductivity of sample with different filler loading. After that, correlate the conductivity vs adhesion property of the conductive polymer epoxy after print on the PET substrate is also one part in the study. This study determines the conductivity of the conductive ink will remain the same or change when the substrate is under bending condition. Due to the flexible electronics have to tolerance bending, vibration and stretching so the study of conductivity under these conditions are very important. Through this study, the printability of the conductive polymer epoxy onto the PET substrate can be determined. The conductivity will decrease with increase of filler percentage and the resistivity will maintain under bending test.

ABSTRAK

Aplikasi litar elektronik fleksibel telah meningkat dengan ketara pada tahun-tahun kebelakangan ini. Untuk menghasilkan elektronik fleksibel yang baik, terdapat dua komponen penting yang perlu dipilih dengan teliti yang epoksi dan substrat polimer konduktif. Oleh itu, projek ini akan mengkaji tentang cetakan epoksi polimer konduktif ke substrat PET. Dalam kajian ini, kekonduksian epoksi polimer konduktif akan diukur dengan menggunakan empat titik probe selepas dicetak pada substrat PET dengan peratusan pengisi yang berlainan. Nilai rintangan lembaran sampel dalam ohm-per-persegi, kelantangan resistiviti dalam ohm-cm dan ketebalan sampel boleh diukur dengan menggunakan kuar empat titik. Selepas itu, analisis morfologi akan dijalankan untuk memerhatikan integriti permukaan polimer epoksi konduktif pada substrat PET. Dengan memerhati struktur mikro dakwat konduktif boleh membezakan kualiti dakwat konduktif pada substrat. Di samping itu, jurang zarah pengisi juga boleh dilihat oleh mikroskop, ini memberikan maklumat tentang kekonduksian sampel dengan pemuatan pengisi yang berlainan. Selepas itu, kaitkan sifat konduktiviti vs sifat lekatan epoksi polimer konduktif selepas cetakan pada substrat PET juga merupakan satu bahagian dalam kajian ini. Kajian ini menentukan kekonduksian dakwat konduktif akan tetap sama atau berubah apabila substrat berada di bawah keadaan lenturan. Oleh kerana elektronik yang fleksibel harus toleransi lenturan, getaran dan regangan supaya kajian kekonduksian di bawah syarat-syarat ini sangat penting. Melalui kajian ini, cetakan epoksi polimer konduktif ke substrat PET boleh ditentukan. Kekonduksian akan berkurangan dengan peningkatan peratusan pengisi dan resistiviti akan mengekalkan ujian lenturan.

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LIST OF ABBREVIATIONS

Ag	-	Silver
Cu	-	Copper
C	-	Carbon
Nps	-	Nanoparticles
PET	-	Polyethylene terephthalate
TPU	-	Thermoplastic polyurethane
PC	-	polycarbonate
PI	-	polyimide
Dod	-	Drop-on-demand

LIST OF SYMBOLS

ρ	-	Resistivity
σ	-	Conductivity
A	-	Cross-sectional area of the ink
L	-	Length of sample trace from end to end
R	-	Resistance
l	-	Length of line in mm
W	-	Width in mm
R_{SH}	-	Resistivity of the sheet in *Ohm/sq*, Ω */sq*
V	-	Voltage across the inner pins
I	-	Current between the outer pins
T_m	-	Melting point
E	-	Estimation of error
Ra	-	Average of roughness

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In recent years, the applications of flexible electronic circuit have increase significantly. This is because the flexible electronic can be applied in many fields such as flexible flat-panel display, smart wearable, medical image sensors, photovoltaics, cell phones, electronic paper and etc (Meena *et al.*, 2010). These electronic devices can hardly meet flexible electronics requirements, and these electronics are considered to be the future trend in the development of electronic devices of next generation. (Wang *et al.*, 2014). In addition, the advantages of the flexible electronic are low cost, ruggedness, light weight, easy to manufacture and so on. All of these advantages of flexible electronic are just some of the important advantages over the rigid electronic circuit.

Figure 1: flexible Electronic

In addition, they need to be highly stable during bending, folding, compressing, and even stretching in certain specific applications, such as wearable devices. In order to understand the electrical behavior and mechanism of flexible electronic devices under mechanical deformation, many studies have been conducted in the last decade. Polymers that are mechanically flexible due to their unique structures were mostly explored for the manufacture of flexible electronic devices among the investigated materials. They are especially promising for flexible fiber-shaped electronic devices with unique and promising advantages compared to the planar structure.(Chen *et al.*, 2012).

The main components of the printed circuits are conductive ink and a flexible PET substrate. The flexible substrates like paper and polyethylene terephthalate (PET) are low price materials so they are enable the wide use of low cost (Zhang *et al.*, 2011). Furthermore, there are many advantages of flexible substrates other than low cost, which are high transparency, exceptionally bright surface, excellent stability, high pressure resistance, light weight and good barrier properties. Thus, the flexible substrates like paper and polyethylene terephthalate (PET) are very suitable to produce flexible electronic.

Conductive ink print on substrate to conduct electricity have been in some talk over the last few years for their applications in Flexible Electronics (FE) and Printed Electronics (PE) as the circuits able to print on paper or some flexible substrate through different kind of printing technology. Some improvements have been made in the electronics sector due to the arise of conductive ink, thus enable the flexible electronics to develop in real world. Some factors such as environmental-wise (due to non-etching manufacturing procedures) good production performances, followed by reductions of material cost as well as lead to the alternative yet efficient way of using conductive inks through PE and FE for end-use applications.

Material selection is one of critical success to fabricate a good quality conductive ink. Basically, there are there main components consist in conductive ink; filler(usually silver), polymer epoxy and hardener (Merilampi *et al* , 2009). When the mixture of all three components is printed to the substrate, it will dry and the random connections of bridge-creating nanoparticles will be established.

1.2 PROBLEM STATEMENT

There are many imperfections after the conductive ink print on the substrate such as the thickness of on the conductive ink is not consistence through the layer, defects inside the conductive layer, the gap among the silver nanoparticle are too large and etc. Hence, observation of the surface integrity should take place to ensure the quality of the conductive layer on substrate. In addition, the accuracy of the adhesion and conductive testing result will increase due to the high quality of the printing.

One of the problems by the conductive ink after printed onto the substrate is the strength of the conductivity though the pattern of conductive ink is different at different location of the printed ink. The reason for conductivity is consistence is the concentration of filler at different location are not same. Therefore, electrical testing used to test the conductivity strength of the conductive ink at different point.

Conductivity of the conductive ink after print on the flexible substrate is a very important study for produce a flexible electronic. This is because the conductivity of the ink on the flexible substrate will be various when the substrate is under bending, twisting and stretching. Hence, conductivity of conductive ink after bending, twisting and stretching should be testing in order to know the suitability of the ink for printing on flexible substrate.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. Observe the surface integrity between epoxy and PET by using microscope
2. Evaluate the strength of resistivity of conductive ink on the PET substrate
3. Evaluate the strength of the resistivity of the conductive ink under bending condition

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. There are many types of polymer epoxy but only one of polymer epoxy will be selected to produce conductive ink and print on the PET substrate.
2. The strength of conductivity of the conductive polymer epoxy after print onto the PET substrate will be measure.
3. The strength of the conductivity of the conductive polymer epoxy will be measure under bending test

CHAPTER 2

LITERATURE REVIEW

2.1 METHOD OF PRINTING

There are many printing methods like inkjet printing, doctor-blading, casting coating, gravure printing, screen printing and etc.

2.1.1 Screen printing

screen printing is a printing process that has been used to manufacture printed circuit boards for many years(Riemer, DE 1989). In recent year, screen printing is simpler and faster compared with other printing tool so it is widely used for manufacturing of solar cells, thin film transistors, and sensors(Suganuma K. 2014). The process of screen printing is shown in figure 2.2. The screen on the printing board is lowered down. Ink is added to the screen's top end, and a squeegee is used to pull the ink along the screen's full length. This presses the ink through the stencil's open areas and imprints the design on the product below.(Hyun, WJ 2015). Due to its simplicity, reproducibility and high compatibility with different inks and substrates, screen printing has advantages; making it a cost-effectiveness approach for flexible device mass printing.

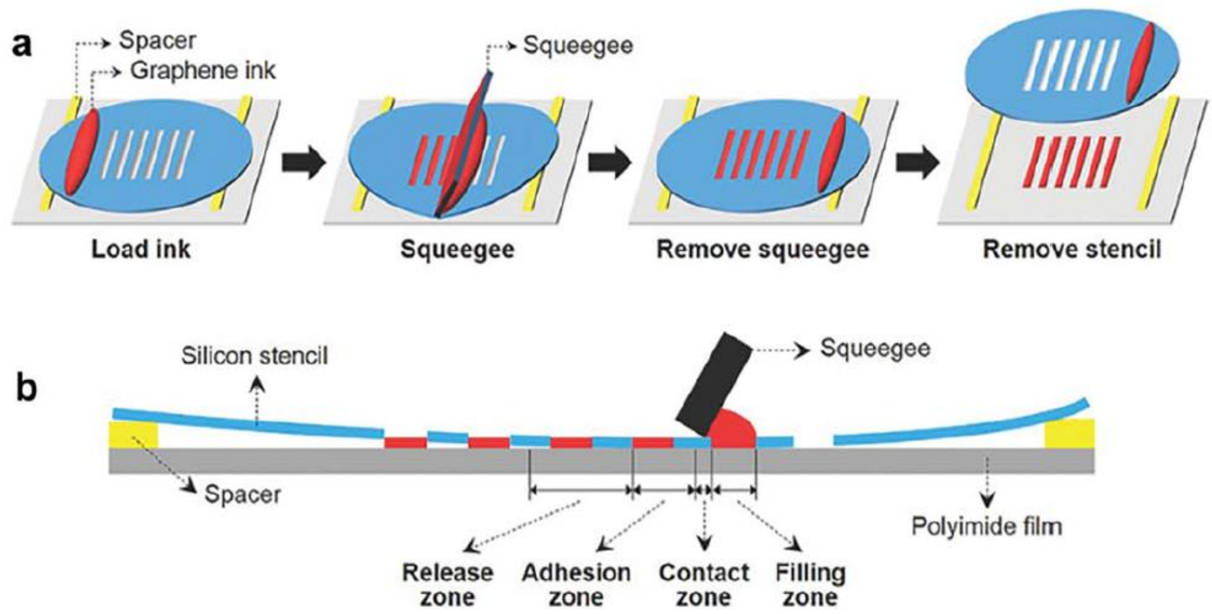

Figure 2.1: (a) Schematic illustration of the screen printing process; (b) Cross-sectional illustration of the screen printing(Hyun *et al.*, 2015b)

2.1.2 Casting coating

In casting method, there is no advanced equipment is required but a well horizontality of surface of substrate is crucial to have. The ink is casted onto the substrate in two forms; liquid portion or isolated drops and then, the ink is being dried at elevated or room temperature. This method is allowed to obtain thick films with nice coating quality, but the accuracy of the film thickness control is what it lacks of (Schwartz, 2010).

2.1.3 Gravure printing

In 2013, Hrehorova, E. et al. represented that gravure printing has four basic elements (Figure 2.2) to each unit of printing; impression roller, doctor blade, ink fountain and an image carrier (engraved cylinder) which the carrier itself is used to deliver the image that will be printed.

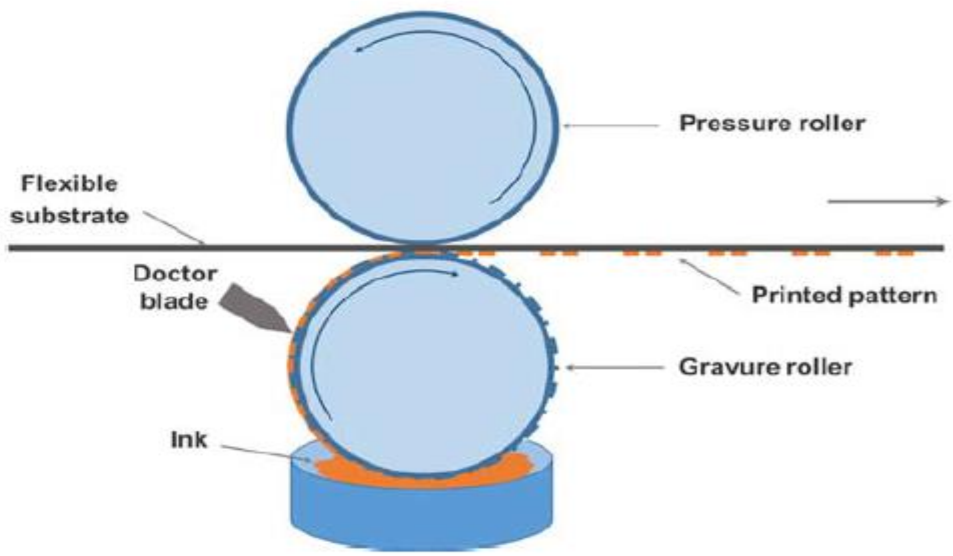

Figure2.2: Schematic illustration of the gravure printing process(Tran, Dutta and Choudhury, 2018)

Some of the benefits that make it an appealing procedure to print the electronic layers consist of its capability to print a wide thickness of ink track and to deposit low viscosity inks; thus, it can be applied for a wide range of ink composition as well as substrates(Hrehorova *et al.*, 2011). In addition, it can produce a printing with great resolution and a long-term stability at increasing printing speeds. It also has the image carrier that comes with the solvent resistance and a special characteristic that other printing methods lack of (Secor *et al.*, 2014).