RELIABILITY STUDY OF PRINTED ELECTRONICS ON FLEXIBLE SUBSTRATE FOR AUTOMOTIVE LIGHTING APPLICATION

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A report submitted

In fulfilment of the requirements for the degree of

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DECLARATION

I declare that this project report entitled “Reliability Study of Printed Electronics on Flexible Substrate for Automotive Lighting Application” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report 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 : .....

DEDICATION

To my beloved parents;

Hasman bin Mohd, Jumeah bt Awan

ABSTRACT

This research demonstrates the effect of different geometrical parameter on the reliability performance of the printed circuit. The circuit thickness is fixed at 1 mm while the width are varied at 1 mm, 2 mm and 3 mm. The square-shaped circuit pattern is printed on PET substrate by using the screen-printing method. The samples are tested in both functionality and reliability performances. Functionality test result shows that thicker line width contribute to lesser sheet resistivity, which will increase the electrical conductivity. The initial sample's sheet resistance also shows good compliance to the theoretical value provided by the Conductive Ink Technical Data Sheet. The samples are then exposed to twisting test and the overall resistance are recorded. The values are then compared with the preferred resistance value for a standard LED. The resistance comparison before and after application of mechanical load verified that the circuit will experience higher resistance and sheet resistance value. The measured resistance from this research shows exceptionally high reading; exceeding the needed resistance for LED lighting application. Theoretically, the LED, however, will be able to light up but it will contribute to electrical energy wastage since higher current are needed to overcome the high circuit resistance. Thus, it can be concluded that the printed circuit board in this research are only sufficient to act as the benchmark design for further improvement to serve industrial or market purpose.

ABSTRAK

Kajian ini mengenalpasti kesan dari perbezaan parameter pada ketahanan litar bercetak. Ketebalan litar ditetapkan pada 1 mm manakala kelebarannya terbahagi kepada 3 bacaan iaitu 1 mm, 2 mm dan 3 mm. Litar yang berbentuk petak tersebut dicetak diatas substrat PET dengan menggunakan kaedah percetakan skrin. Sampel tersebut diuji dengan dua cara iaitu dari segi fungsi dan juga ketahanan. Keputusan dari ujian fungsi menunjukkan litar yang mempunyai kelebaran yang tinggi menyumbang kepada pengurangan dari nilai rintangan lembaran, dan ini meningkatkan nilai kekonduksian elektrik. Nilai awal bagi rintangan lembaran untuk sampel juga selaras dengan nilai teori seperti yang dinyatakan di Conductive Ink Technical Data Sheet. Sampel kemudiannya didedahkan kepada daya pusingan berulang dan nilai rintangan dicatatkan. Kemudian, nilai tersebut dibandingkan dengan nilai rintangan yang sesuai bagi penggunaan LED. Perbezaan antara kedua bacaan (sebelum dan selepas dikenakan daya) membuktikan bahawa litar akan mengalami nilai rintangan yang lebih setelah dikenakan daya pusingan, melebihi nilai yang dikehendaki oleh LED. Secara teorinya, LED akan dapat dinyalakan tanpa masalah, namun ianya akan mengakibatkan pembaziran tenaga elektrik kerana nilai arus yang tinggi diperlukan bagi mengatasi nilai rintangan litar yang tinggi. Secara konklusinya, litar yang dihasilkan dari kajian ini hanya mampu dijadikan tanda aras bagi pembaharuan rekaan yang akan mempunyai fungsi di pasaran

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LIST OF ABBREVIATION

FPCB	- Flexible Printed Circuit Board
FPC	- Flexible Printed Circuit
OLED	- Organic Light Emitting Diode
PET	- Polyethylene terephthalate
PEN	- Polyethylene naphthalate
LCD	- Liquid crystal display
LED	- Light Emitting Diode
PDMS	- Polydimethylsiloxane
RFID	- Radio-frequency identification
CNT	- Carbon Nano Tube
SEM	- Scanning Electron Microscopy

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF RESEARCH

In the uprising demand for downsizing of mobile electronics, flexible electronics have become an important aspect of technology. The evolution of electronic circuitry began with complicated wiring that requires high maintenance and usually end up with bulky design. This has been simplified into a single piece of board which convey the same function but with a minimised and smaller design. The future of electronic board is to have the flexible properties because of the advantageous applications such as in portable or wearable electronics, electric automobiles or even automotive applications. The working principle of a flexible electronic circuit is usually to have a conductive ink, printed onto a flexible substrate, which functions to hold the ink. The usage of ink and the substrate are both to replace the copper layer and circuit board; respectively. The difference being made is the rigid circuit board being substituted with a flexible and bendable material.

The modern automobile has a broad electronic circuit consisting of electric, electromechanical and electronic loads that are vital to either vehicle operation, safety or comfort. In order for a vehicle to function smoothly and safely, it takes more than the engine operation. It also needs other contributing factors such as the air conditioning system for comfort and automotive lighting for safety and illuminating purposes. Example of automotive lighting includes headlights, signal lights and internal lights. The car headlight

has a significant influence on traffic safety, the same goes with the signal and internal lights. Nevertheless, it is proven that the main goal of vehicle lighting is to enable the driver to see and for them to be seen. Thus, researchers must progressively develop the lighting systems to make driving safer. (Mou et al., 2018).

This research tested the reliability of flexible, printed electronic circuit for the automotive lighting application. This study will be focused on prototyping of a flexible circuit and to test its function under cyclic twisting and the effect on electricity flow through the measurement of resistivity

1.2 PROBLEM STATEMENT

As said by Lim et al. (2013), the desire of flexibility, compact, lightweight and low cost in current electronic device increases the application of flexible printed circuit board (FPCB). Flexible electronics are not a new thing in industrial applications, but there are always room for improvement and development of the technology. According to Chu et al. (2017), with the popularity of intelligent terminals, flexible electronic products present a huge market prospect. Various experiments are done for the sake of futuristic and sleek application of either devices or machinery. Since the circuit is made up of flexible substrate, it is expected to operate for a supple application with small failure possibilities. Several researches have reported on the reliability performance of FPCB under various mechanical loading by using different type of substrates such as paper, PET, TPU etc and different type of conductive ink such as silver ink, copper etc. However, there is no reported results so far on the reliability performance of FPCB under cyclic twisting load by using PET substrate and carbon-based conductive ink at varying square patterned circuit width. In this research,

the performance of the flexible circuit before and after the cyclic twisting test was measured. The performance of the FPCB were assessed in terms of the effect of the cyclic twisting load on the change of sheet resistivity.

1.3 RESEARCH QUESTION

The questions related to this research:

i) What are the effects of cyclic twisting test on the FPCB performance at varying circuit width?
ii) Is this geometrical parameter suits with the LED lighting application?

1.4 OBJECTIVE

The objectives of this research are as listed below:

i) To develop printed electronic sample on flexible substrate using carbon black-based conductive paste
ii) To study the effect of square-patterned connection on sheet resistivity at varying line width
iii) To evaluate the sample reliability when subjected to cyclic twisting load

1.5 RESEARCH SCOPE

1.5.1 Scope of research

The scopes for this research are as follows:

i) Usage of Polyethylene Terephthalate (PET) as the substrate and carbon-black based conductive ink as the circuit
ii) Printing of square-patterned conductive ink on flexible substrate by using screen printing method
iii) Resistance measurement on flexible printed circuit by using a multi-meter
iv) Testing of samples on cyclic twisting load
v) Data collection and analysis

1.5.2 Limitation of study

This limitation of this study are as follows:

Table 1. 1 Limitation of study

Material of substrate	Polyethylene terephthalate
Ink type	Carbon-based
Printing method	Screen printing method
Reliability test	Measurement of the sheet resistivity
Mechanical test	Twisting test

1.6 PLANNING AND EXECUTION

The research activity and PSM progress is being shown as in the Figure 1.1 and 1.2 below.

Activities/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Research title review	■														
Literature review					■	■	■	■	■	■	■	■	■	■	■
Design of experiment		■	■	■	■	■	■	■	■	■	■	■	■	■	
Sample fabrication											■	■	■	■	
Testing/Data collection											■	■	■	■	
Data analysis											■	■	■	■	
Report writing		■	■	■	■	■	■	■	■	■	■	■	■	■	
Report submission														■	■
PSM presentation															■

Figure 1. 1 Planning for PSM 1

Activities/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Literature review															
Design of experiment															
Torsion test on samples															
Data collection															
Data analysis															
Report writing															
Report submission															
PSM presentation															

Figure 1. 2 Planning for PSM 2

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focus on explaining on the materials and testing process for the study. Discussion will include description on polyethylene terephthalate as the substrate, conductive ink, printing method and experimental method such as measurement of bulk resistivity, surface roughness, hardness, optical microscope and adhesion peel test.

2.2 Flexible electronics

Development of the latest technology, gadget and invention has further advanced with the innovation of flexible and durable device; illustration shown in Figure 2.1 below. Electronic printing has been available since the 1950s (Suganuma, 2014) in which some of the requirements are mechanical stability, flexibility and electrical conductivity (Bao et al., 2016; Yang et al., 2018).