

**EFFECT OF TYPE OF SUBSTRATES TO CONDUCTIVE INK UNDER
THERMAL PERFORMANCE**

MUHAMMAD ZAIM BIN AZMI

A report submitted

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DECLARATION

I declare that this project report entitled “Effect of type of substrates to conductive ink under thermal performance” is the result of my own work except as cited in the references

Signature :

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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 with Honours.

Signature :

Supervisor's Name :

Date :

DEDICATION

This report is dedicated to my beloved late father and my beloved mother,

Azmi bin Saad and Zaitun binti Ibrahim

ABSTRACT

This research project were done to investigate the effect of type of substrates to conductive ink under thermal performance. Two type of substrates were use which is Thermoplastic Polyurethanes (TPU) and Polyethylene Terephthalate (PET) were considered to be use in this research project. Carbon conductive ink from company *Bare Conductive* were used to be printed on the substrates using screen printing method. Instead of conventional method of screen printing method which use mesh as ink template, two tape were tape parallel to each other with the gap of 3 mm to create the ink template. The consistency of the ink printed where considered before continue with the resistivity test of the substrate. The conductive ink were printed for both TPU and PET substrates to be use for the resistivity test & surface roughness test. The electrical resistivity were tested using four-point probe from Jandel's RM3000 test unit, with using ASTM F390-98 as guideline. In terms of the substrate's resistivity, it can be conclude that the TPU resistivity is much lower than PET resistivity where TPU at room temperature have 149.2 Ω /sq while PET have 370.8 Ω /sq at room temperature which is twice the amount of TPU. For the resistance against temperature's result, the resistivity of the conductive ink on both substrates will decrease as the temperature applied to the conductive ink increase where at 100°C, TPU resistivity drop till 52.8 Ω /sq while PET resistivity at 100°C is 102.3 Ω /sq. The surface roughness of both of the substrates and the conductive ink will also decrease when the temperature applied increase where for TPU the mean surface roughness are 2.958 μ m at room temperature and drop to 1.17 μ m at 100°C while PET's mean surface roughness for room temperature are 1.921 μ m and drop to 1.332 μ m for 100°C. For the adhesion test, a new batch of TPU and PET samples were made to be conduct for this test. The test were conducted using ASTM D3359 as guideline. For the adhere test, the conductive ink appear to be easily detached from the TPU substrates compare to PET and the same results occurred as the temperature increase. However this result seems to be contradicted to the fact that higher surface roughness give better adhesion. Therefor, it can also be conclude that this conductive ink are not suitable as it is very easily detach from the substrates.

ABSTRAK

Projek penyelidikan ini dilakukan bagi menyiasat kesan jenis-jenis substrat kepada dakwat konduktif dibawah prestasi termal. Dua jenis substrat telah digunakan iaitu Poliuretana Termoplastik (TPU) dan Polietilena Tereftalat (PET) telah dipertimbangkan bagi digunakan didalam projek penyelidikan ini. Dakwat konduktif karbon daripada syarikat Bare Conductive telah digunakan untuk dicetak pada substrat menggunakan kaedah percetakan skrin. Daripada menggunakan kaedah konvensional percetakan skrin iaitu menggunakan jerat sebagai templat dakwat, dua pita di pita selari sesamanya berjurangkan 3 mm untuk dibuat ruang sebagai templat dakwat. Konsistensi dakwat dicetak telah dipertimbangkan sebelum meneruskan ke ujian rintangan kepada substrat. Dakwat konduktif ini telah dicetak pada kedua-dua substrat TPU dan PET untuk kegunaan ujian rintangan dan ujian kekasaran permukaan. Rintangan elektrik telah diuji menggunakan prob empat titik daripada Jandel RM3000 unit ujikaji, dengan menggunakan ASTM F390-98 sebagai garis panduan. Dari segi rintangan substrat, ia boleh dirumuskan bahawa tahap rintangan TPU lebih rendah berbanding tahap rintangan PET dimana di suhu bilik, TPU mempunyai rintangan sebanyak 149.2 Ω/sq dan PET pula 370.8 Ω/sq iaitu dua kali ganda lebih banyak berbanding TPU. Untuk keputusan rintangan terhadap suhu, rintangan dakwat konduktif pada kedua-dua substrat akan berkurangan jika suhu yang dikenakan kepada substrat bertambah dimana di suhu 100°C, rintangan pada TPU menurun ke 52.8 Ω/sq dan PET pul menurun ke 102.3 Ω/sq . Kekasaran permukaan kedua-dua substrat dan dakwat konduktif juga akan berkurang apabila suhu yang dikenakan bertambah dimana untuk TPU purata kekasaran permukaan adalah 2.958 μm untuk suhu bilik dan menurun ke 1.17 μm pada suhu 100°C manakala purata kekasaran permukaan bagi PET di suhu bilik adalah 1.921 μm dan menurun ke 1.332 μm ke 100°C. Untuk ujian kelekatan, kumpulan sampel TPU dan PET yang baru telah dihasilkan untuk digunakan di ujian ini. Ujian ini telah dijalankan menggunakan ASTM D3359 sebagai garis panduan. Untuk ujian kelekatan, dakwat konduktif didapati mudah untuk tercabut daripada substrat TPU berbanding substrat PET dan hasil yang sama juga berlaku apabila suhu ditambah. Namun keputusan ini kelihatan bercanggah dengan fakta dimana kekasaran permukaan yang tinggi mampu memberikan kelikatan yang lebih baik. Oleh itu ianya boleh dikonklusikan bahawa dakwat konduktif ini adalah tidak bersesuaian untuk kegunaan kerana ianya mudah untuk tercabut daripada substrat.

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TABLE OF CONTENTS

	PAGE
DECLARATION	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	xii
LIST OF ABBREVIATIONS	xiii
LIST OF SYMBOLS	xv
CHAPTER	
I INTRODUCTION	1
1.1 Background	1
1.2 Problem statement	3
1.3 Objectives	4
1.4 Scope of project	4
1.5 Planning and execution	5
II LITERATURE REVIEW	8

2.1	Introduction	8
2.2	Flexible electric circuit	8
2.3	Conductive ink	13
2.4	Carbon ink	15
2.5	Screen printing	16
2.6	Ink curing	17
2.7	Conductivity	18
2.8	Printed pattern	20
2.9	Substrate material	22
2.10	Thermalplastic Polyurethanes (TPU)	24
2.11	Polyethylene Terephthalate (PET)	28
2.12	Surface roughness	33
III	METHODOLOGY	36
3.1	Overview of research	36
3.2	Sample preparation	38
3.3	Curing	41
3.4	Sample labeling	42
3.5	Resistivity Against Temperature experiment setup	43
3.5.1	Room temperature against resistivity	44
3.5.2	Designed temperature against resistivity	45
3.6	Surface roughness test setup	47
3.7	Adhesion test setup	48
3.7.1	Room temperature	50
3.7.2	Designed temperature	53

IV	RESULT AND DISCUSSIONS	54
4.1	Overview of research	54
4.2	Physical observation of conductive ink and substrates	54
4.2.1	Conductive ink	55
4.2.2	Thermoplastic polyurethane (TPU) and polyethelene terephthalate (PET)	55
4.3	Resistivity against temperature	57
4.4	Surface roughness test result	59
4.5	Adhesion test result	63
4.6	Surface roughness against resistivity and temperature	68
4.6.1	Surface roughness agaisnt resistivity	69
4.6.2	Surface roughness against temperature	69
4.6.3	Resistivity against temperature	69
4.6.4	Overall result	69
4.7	Research findings	70
4.7.1	Stencil	70
4.7.2	Ink dimension	72
4.7.3	Ink adhesion	73
V	CONCLUSION & RECOMMENDATION	74
5.1	Conclusion	74
5.2	Recommendation for future works	75
	REFERENCES	76

LIST OF TABLES

TABLE	TITLE	PAGE
1.1	PSM 1 planned schedule	6
1.2	PSM 2 planned schedule	7
2.1	Max stress of TPU with different hard and soft TPU segment	25
2.2	Root mean square (RMS) and mean (RA) roughness of TPU and SP-TPU	27
2.3	Formulation of content for PET and Huntite ratio (Kahraman, 2015)	30
2.4	Thermal properties of composite for PET and Huntite (Kahraman, 2015)	31
2.5	Summarized of different characteristic of substrates	32
2.6	Effect of surface roughness on conductivity (Laura et al., 2005)	33
4.1	Conductive ink properties after heated	55
4.2	TPU substrate properties after heated	56
4.3	PET substrate properties after heated	56

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Wearable Market Share Revenue for 2014 and Forecast Revenue for 2018 (Suikkola, 2015)	10
2.2	(a) absolute and (b) normalized initial resistances of the studied populations as a function of trace width (Happonen et al., 2015)	11
2.3	Factors affecting fatigue life (Happonen, 2016)	12
2.4	Various factors governing the properties of a conductive ink (Bhore, 2013)	14
2.5	Fundamental principle of screen printing (Suikkola, 2015)	16
2.6	Conductive ink reaction to UV radiation in curing process (Bhore, 2013)	17
2.7	Surface-resistivity spectrum (Don, 2011)	19
2.8	Schematics of the various circuit design: (a) single line, (b) rectangular shape, (c) horseshoe/serpentine, (d) zigzag, and (e) the stretch capability of the Ag-MWNT circuits with different mixture ratio (Kim et al., 2013)	20
2.9	a) simulated of elastic stretchability for horseshoe/serpentine patterns with different arc angle, and (b) experimental and FEM analysis of sympatric buckling behavior of the	22

	horseshoe/serpentine pattern with strain from 0% to 80% (Yu et al., 2017)	
2.10	Processes of producing plastic and its example (Klein, 2012)	23
2.11	TPU Structure (2011, p.5)	24
2.12	Stress-strain behaviors of TPUs when under a large strain compression acting on (a) overall TPU, (b)TPUa , ©TPUb , and (d)TPUc (Cho et al., 2017)	26
2.13	AFM topographical images of the (a) TPU and (b) SP-TPU surfaces	27
2.14	PET structure (Miranda et al., 2017)	28
2.15	Surface potential amplitude relationship over the decay time of thermal aged sample	29
2.16	A dielectric barrier discharge plasma sketch with (a) typical discharge image of plasma system. (b) the schematic picture of the surface modified different areas (Gao et al., 2017)	31
2.17	Image of water droplet on top of the PET film surfaces (Gao et al., 2017)	31
2.18	Effect of surface roughness with the resistivity on printed line (Eshkeiti, 2015)	32
2.19	Schematic adhesion between conductive ink and substrate (Ryan & Lewis, 2012)	34
2.20	Mean average roughness, Ra (2001, p.1)	35

3.1	General flowchart of methodology	37
3.2	Image of (a) scrapper, (b) TPU roll, (c) Bare Conductor conductive ink, and (d) 0.04mm tape	38
3.3	TPU (Clear) and TPU cover (pink)	39
3.4	Taped TPU substrates for making a sample	40
3.5	Sample dimension	40
3.6	Example sample	41
3.7	Sample labelling	42
3.8	Example sample labelled	42
3.9	Jandel's Four-point probe model RM3000 Test Unit	43
3.10	Data taking process for resistivity against room temperature	44
3.11	Heating experiment setup	45
3.12	Image of (a) hair dryer, and (b) thermal imaging camera	46
3.13	Surface roughness test setup	47
3.14	Data taking process for surface roughness sample	48
3.15	Magic's scotch tape used for adhesion test	49
3.16	Adhesion sample dimension	50
3.17	12 slit cut for adhesion test samples	51
3.18	Taped sample	52
3.19	Pulling process of adhesion test	53
4.1	TPU and PET sheet resistivity, Ω/sq vs temperature, $^{\circ}\text{C}$	58

4.2	TPU and PET mean surface roughness, Ra vs Temperature, °C	60
4.3	Graphical image of TPU sample surface roughness	61
4.4	Graphical image of PET sample surface roughness	61
4.5	Comparison of conductive ink surface roughness on a) TPU substrate and b) PET substrate	62
4.6	Example damage on the conductive ink surface	63
4.7	Schematic diagram of TPU at room temperature adhesion test	64
4.8	Image of TPU sample after tape pulling process for room temperature	64
4.9	Schematic diagram of TPU at 100°C adhesion test	65
4.10	Image of TPU sample after tape pulling process for 100°C	65
4.11	Schematic diagram of PET at room temperature adhesion test	66
4.12	Schematic diagram of PET at 100°C adhesion test	66
4.13	Image of PET sample after tape pulling process for 100°C	67
4.14	Stencil used for print screening process	70
4.15	Image of test sample of (a) stencils, (b) 1mm tape and (c) 2mm tape	71
4.16	Conductive ink detach from the substrate	72

LIST OF APPENDICES

TABLE	TITLE	PAGE
A	Thermoplastic Polyurethane Elastomers (TPU) Elastollan - Material Properties	80
B	ASTM D3359 - Measuring Adhesion by Tape Test	82
C	Bare Conductive - Electric Paint Technical Data Sheet	87
D	Surface Roughness (JIS B 0601-2001) Technical Information	88
E	ASTM F390-98 - Sheet Resistance of Thin Metallic Films With a Collinear Four-Probe Array	89
F	Bridge Technology - Jandel Four Point Probing System	93

LIST OF ABBREVIATIONS

FEC	Flexible electric circuit
PCB	Flexible electric circuit
TPU	Thermoplastic polyurethanes
PET	Polyethylene terephthalate
IoT	Internet of things
CNT	Carbon nanotubes
SPC	Stretchable printed circuit
EMF	Electromotive force
Ag-MWNT	Silver multi-walled carbon nanotubes
AFM	Atomic force microscope
SP	Nano Silica Particle
RMS	Root mean square roughness
RA	Mean roughness
$(\text{Mg}_3\text{Ca}(\text{CO}_3)_4)$	Huntite/hydromagnesite mineral
TGA	Thermogravimetric analysis
DSC	Differential scanning calorimetry
T _g	Glass transition temperature

DBD Dielectric barrier discharge

ASTM American Society of Testing and Material

LIST OF SYMBOLS

$^{\circ}\text{C}$	=	Celsius
V	=	Volt
A	=	Ampere
Ω/sq	=	Ohm per sheet square
σ	=	Conductivity
ρ	=	Volume resistivity
mm	=	Millimeter
μm	=	Micrometer
ℓ	=	Sample range length

CHAPTER I

INTRODUCTION

1.1 Background

Flexible electric circuit (FEC) or flexible circuit board is an revolutionized technology for printed circuit board (PCB) where its serve the same purpose which is connect electrical and mechanical component into a device. For PCB, it have a solid substrate property while the FEC have a flexible substrate property. This difference is one of the main point of interest in FEC as it can lead to creation of device or machine which is flexible to do a certain task.

The study on the FEC were conduct by many researcher which consist of combination of varies material of substrates, various combination of filler, binder and solvent to create a conductive ink, the thickness of the conductive ink as well as the width of the conductive ink as well. Not only the combination of filler, binder and solvent to create conductive ink will give a various kind of results data, the combination of substrates and conductive ink as well can give different data for its properties and reaction between the combination make it that there are million possibilities for the data to obtain.

In this study, the type of substrates used were compared between Thermoplastic Polyurethane (TPU) into Polyethylene terephthalate (PET). Both type of substrates will undergo the same experiment which is experiment test in room temperature and designed temperature of 40°C, 60°C and 100°C on both substrates and the ink, adhesion test, surface roughness test and the resistivity measuring of the conductive ink.

1.2 Problem statement

In the industry, the PCB were commonly use in making product. However there are a lot of limitation of PCB which searching for new alternative have been the aim of researcher to research for the new method for the electric circuit. Firstly the limitation of the size of the PCB where it is very hard to store. Bigger PCB mean that there are a lot of components can be attach to the board. However, bigger PCB mean bigger board and this will make it hard to transport or store. FEC reduce this problem where FEC can be reshape which it can be fold to reduce the area to store.

FEC usage is also new in the industry. Its combination between various substrates as well as various conductive ink are potential to have thousands of variety. Therefore there are lack of information and data of the usage of the FEC. This research also include the temperature effect on the combination of carbon conductive ink with TPU and PET substrate.

1.3 Objectives

The objectives of the study is to:

- 1) To analyst the resistivity of TPU and PET substrates with carbon conductive ink.
- 2) To compare the resistivity of both TPU and PET sample when different range of temperature applied on the sample.
- 3) To compare the surface condition of the TPU and PET sample before and after the temperature applied on the sample.
- 4) To analyst the adhesion capability of the carbon conductive ink on both TPU and PET sample with and without the temperature applied on the sample.

1.4 Scope of project

The scope of this study are to :

- 1) Make a comparison on the behavior of the substrates and ink when on temperature test of 40°C, 60°C and 100°C.
- 2) Make a study on the TPU and PET sample surface condition before and after the temperature test.
- 3) Make comparison on adhesion test result of the TPU and PET sample with no temperature applied and 100°C temperature applied samples.