

# **FABRICATION OF THIN FILM AND METAL-ORGANIC-METAL (MOM) DIODE USING PTAA-TIPS-PENTACENE**

**HOH HANG TAK**



**FACULTY OF ENGINEERING  
UNIVERSITI MALAYSIA SABAH**

**2018**

**FABRICATION OF THIN FILM AND METAL-  
ORGANIC-METAL (MOM) DIODE USING PTAA-  
TIPS-PENTACENE**

**HOH HANG TAK**

**THESIS SUBMITTED IN FULFILLMENT FOR THE  
DEGREE OF MASTER OF ENGINEERING**

PERPUSTAKAAN  
UNIVERSITI MALAYSIA SABAH

**FACULTY OF ENGINEERING  
UNIVERSITI MALAYSIA SABAH**

**2018**

# UNIVERSITI MALAYSIA SABAH

## BORANG PENGESAHAN STATUS TESIS

JUDUL: **FABRICATION OF THIN FILM AND METAL-ORGANIC-METAL(MOM) DIODE USING PTAA-TIPS-PENTACENE**  
IJAZAH: **MASTER OF ENGINEERING (ELECTRICAL AND ELECTRONIC ENGINEERING)**

Saya **HOH HANG TAK**, Sesi **2014-2018**, mengaku membenarkan tesis Sarjana in disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis ini adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/):

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

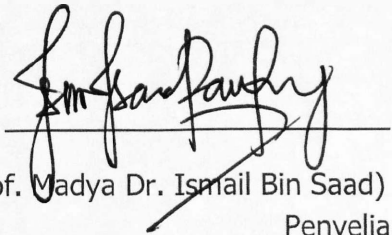
TIDAK TERHAD



HOH HANG TAK  
MK1411012T

Disahkan Oleh,

  
NURULAIN BINTI ISMAIL  
PUSTAKAWAN  
UNIVERSITI MALAYSIA SABAH  
(Tandatangan Pustakawan)

  
(Prof. Madya Dr. Ismail Bin Saad)  
Penyelia

Tarikh : 07 September 2018

## DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equation, summaries and references, which have been duly acknowledged.

15 November 2017



---

Hoh Hang Tak

MK1411012T



UMS  
UNIVERSITI MALAYSIA SABAH

# CERTIFICATION

NAME : HOH HANG TAK  
MATRIC NUM. : MK1411012T  
TITLE : FABRICATION OF THIN FILM AND METAL-ORGANIC-METAL(MOM) DIODE USING PTAA-TIPS-PENTACENE  
DEGREE : MASTER OF ENGINEERING  
(ELECTRICAL AND ELECTRONIC ENGINEERING)  
VIVA DATE : 27 April 2018



CERTIFIED BY

UMS  
UNIVERSITI MALAYSIA SARAWAK

**1. MAIN SUPERVISOR**

Prof. Madya Dr. Ismail Bin Saad

SIGNATURE

**2. CO-SUPERVISOR**

Ir. Pungut Bin Ibrahim

SIGNATURE

COMMITTEE MEMBER

Dr. Khairul Anuar Mohamad

# CERTIFICATION

NAME : **HOH HANG TAK**

MATRIC NUM. : **MK1411012T**

TITLE : **FABRICATION OF THIN FILM AND METAL-ORGANIC-METAL(MOM) DIODE USING PTAA-TIPS-PENTACENE**

DEGREE : **MASTER OF ENGINEERING**  
**(ELECTRICAL AND ELECTRONIC ENGINEERING)**

VIVA DATE : **27 April 2018**



**CERTIFIED BY**

**UMMS**  
UNIVERSITI MALAYSIA SARAWAK

**1. MAIN SUPERVISOR**

Prof. Madya Dr. Ismail Bin Saad

**SIGNATURE**

**2. CO-SUPERVISOR**

Ir. Pungut Bin Ibrahim

**SIGNATURE**

COMMITTEE MEMBER

Dr. Khairul Anuar Mohamad

## ACKNOWLEDGEMENT

Firstly I would like to express my deepest gratitude and appreciation to my supervisors, Prof. Madya Dr. Ismail Bin Saad, Ir. Pungut Bin Ibrahim, and Dr. Khairul Anuar Mohamad of the Faculty of Engineering at University Malaysia Sabah who have shared their time and effort in guiding me towards the success of this work. Lot of moral supports and appreciation done from my supervisors who given me there constructive comments and suggestions to complete this research and help make this project finish smoothly. There is so much I have learned especially in semiconductors field. If I were to involve in academic field in the future, I hope I can be a good advisor to my students such as my three supervisors.

I also want to express my heart-felt gratitude to my lovely family especially to my parents, Hoh Wui Lang and Chan Kuan Chung because always give moral, concern, and financial support during my studies. Without them, I probably will have very difficult time in surviving as a student.

Last but not least, not forgetting my friends and colleagues that teach me how to run an experiment and how to analysis data and always give ideas to improve my research. They help and supports make me focus on my project. I will treasure their friendship forever.

Hoh Hang Tak  
15 November 2017



UMS  
UNIVERSITI MALAYSIA SABAH

## ABSTRACT

The organic semiconductors potentially offer attractive characteristics, such as low-temperature fabrication, flexibility deposition technique, low-cost processing, and light-weight, which can be used as an active component in a wide range of electronic applications. Recently, organic semiconductors have gained the attention to facilitate formation of thin film by using solution-processed deposition techniques. The solution-processable organic material such as poly(triarylamine) (PTAA) and 6,13-bis(triisopropylsilylethynyl)-pentacene (TIPS-pentacene) have been reported to exhibit low mobilities, which far comparable to that of vacuum-deposited organic semiconductors mainly due to the morphology of thin films. To achieve device performance to a higher level, morphology design and control by varying spin-coating condition such as spin speed is crucial. The MOM diode was designed by forming a PTAA-TIPS-pentacene layer based on the concentration of TIPS-pentacene, i.e. 0 %, 5 %, 10 %, 15 %, and 20 % in PTAA, between the indium tin oxide (ITO) electrode layer and the counter aluminium (Al) metal layer. X-ray diffraction (XRD) patterns revealed that with the intensity of diffraction peak for PTAA was increased by increasing the pentacene molecules in PTAA. This indicated that there is a binder effect between PTAA and TIPS-pentacene enhance the molecule ordering. Furthermore, the current-voltage (I-V) characteristics were measured using Keithley 2400 source meter unit from -10 to +10 V. Meanwhile, the frequency dependent electrical characteristics were measured using a precision LCR meter in the frequency up to 100 kHz. The turn-on voltage varies from 2.16 to 2.48 V depending on the concentration of TIPS-pentacene in PTAA semiconductors, respectively. The frequency dependence of the electrical responses is attributed to the distribution density of interface states that could follow the alternating current (AC) signal. Investigation exposed that conductance was strongly dependent on the frequency and bias voltage. The capacitance and series resistance were dependent up to constant value at the low frequency region ( $< 1$  kHz), but the capacitance and series resistance were independent at high frequencies ( $< 100$  kHz). The MOM diode showed the positive clamping circuit, where the diode discharges when input voltage in the negative side and charging when input voltage is positive side. In conclusion, blending small molecule organic semiconductors into semiconducting polymer have shown the improvement in electrical properties due to the influence of polymer binding on thin film uniformity and operational stability.



## **ABSTRAK**

*Semikonduktor organik menawarkan ciri-ciri yang menarik dan berpotensi, seperti fabrikasi pada suhu rendah, fleksibiliti dalam teknik pemendapan, pemrosesan pada kos rendah, serta ringan, yang boleh digunakan sebagai komponen aktif dalam pelbagai aplikasi elektronik. Pada masa kini semikonduktor organik telah mendapat banyak perhatian untuk memudahkan penghasilan filem nipis dengan menggunakan teknik pemendapan daripada larutan. Semikonduktor organik secara pemrosesan larutan seperti poly(triarylamine) (PTAA) dan 6,13-bis(triisopropylsilylethynyl)-pentacene (TIPS-pentacene) mempunyai nilai mobiliti rendah berbanding dengan semikonduktor organik menggunakan teknik pemendapan vakum disebabkan oleh morfologi filem nipis. Untuk mencapai prestasi peranti ke tahap yang lebih tinggi, rekabentuk dan kawalan morphology berdasarkan teknik pemendapan seperti kelajuan putaran amatlah penting. Diode MOM direka dengan membentuk lapisan PTAA-TIPS-pentacene berdasarkan kepekatan TIPS-pentacene iaitu 0%, 5%, 10%, 15% dan 20% dalam PTAA, di antara oksid tin indium (ITO) elektrod dan logam aluminium (Al) elektrod. Corak difraksi sinar-X (XRD) mendedahkan bahawa intensiti puncak difraksi untuk PTAA telah bertambah dengan peningkatan molekul pentacene dalam PTAA. Ini menunjukkan bahawa terdapat kesan pengikat antara PTAA dan TIPS-pentacene telah meningkatkan susunan molekul. Selain itu, ciri-ciri arus-voltan (I-V) telah diukur menggunakan Keithley 2400 unit sumber meter dari -10 V hingga +10 V. Frekuensi bersandar kepada ciri elektrik tergantung telah diukur dengan menggunakan meter LCR berfrekuensi sehingga 100 kHz. Voltan hidupan berbeza-beza dari 2.16 ke 2.48 V bergantung kepada campuran TIPS-pentacene dalam PTAA. apabila kepekatan TIPS-pentacene meningkat 0 %, 5 %, 10 %, 15 %, dan 20% ke dalam PTAA semikonduktor. Frekuensi bersandar kepada sambutan elektrik adalah disebabkan oleh ketumpatan agihan keadaan antara muka yang boleh mengikut isyarat arus ulang alik. Penyelidikan mendedahkan bahawa kealiran adalah amat bergantung kepada frekuensi dan voltan pincang. Kemuatan dan rintangan siri adalah bergantung ke satu nilai tetap di frekuensi rendah (< 1 kHz) tetapi kemuatan dan rintangan siri adalah tidak bersandar pada frekuensi tinggi (< 100 kHz). Diod MOM menunjukkan litar penjepit positif, di mana diod menyahcas apabila voltan input di sisi negatif dan mengecap apabila voltan masukan di sisi positif. Sebagai kesimpulan, pengadunan molekul kecil semikonduktor organik ke dalam polimer semikonduktor telah menunjukkan peningkatan dalam sifat-sifat elektrik disebabkan oleh pengaruh polimer pengikatan supaya keseragaman filem nipis dan kestabilan operasi terhasil.*

## LIST OF CONTENTS

	Page
<b>TITLE</b>	i
<b>DECLARATION</b>	ii
<b>CERTIFICATION</b>	iii
<b>ACKNOWLEDGEMENT</b>	iv
<b>ABSTRACT</b>	v
<b><i>ABSTRAK</i></b>	vi
<b>LIST OF CONTENTS</b>	vii
<b>LIST OF TABLES</b>	x
<b>LIST OF FIGURES</b>	xi
<b>LIST OF ABBREVIATIONS</b>	xiv
<b>LIST OF SYMBOLS</b>	xv
<b>CHAPTER 1 INTRODUCTION</b>	
1.1 Background Study	1
1.2 Problem Statement	3
1.3 Research Objectives	4
1.4 Research Scope	4
1.5 Thesis Outline	5
<b>CHAPTER 2 LITERATURE REVIEW</b>	
2.1 Overview	6
2.2 Material Classification	6
2.2.1 Conductors	6
2.2.2 Insulators	8
2.2.3 Semiconductors	9
2.3 Classification of Semiconductor	10
2.3.1 Intrinsic Semiconductor	10
2.3.2 Extrinsic Semiconductor	12
2.3.2.1 N-type Semiconductor	12
2.3.2.2 P-type Semiconductor	14
2.4 Organic Semiconductor	15

2.4.1	Small molecule organic semiconductor	17
2.4.2	Polymer organic semiconductor	18
2.4.3	Blended Organic Semiconductor	19
2.5	Organic Semiconductor Devices	20
2.5.1	Organic Device Structure	20
2.5.2	Soluble-Processed Deposition Method for Organic Device	24
2.5.3	Electrical Characterization and Analysis of Organic Diode	26
2.5.3.1	DC characteristics and AC characteristics	26
2.5.3.2	Electrical Characteristics and Performance	26
2.6	Thin Film Deposition Method	29
2.6.1	Spin Coating	29
2.6.2	Drop Casting	30
2.6.3	Gravure Printing	30
2.7	Summary	31

### **CHAPTER 3 METHODOLOGY**

3.1	Chapter Overview	32
3.2	Research Methodology Flow	32
3.3	Thin Film Deposition and Fabrication Steps	34
3.3.1	Substrate Preparation	34
3.3.2	Film Deposition Using Spin Coating	35
3.3.3	Design and Fabrication of Transparent MOM Diode	38
3.3.3.1	Design MOM Diode	38
3.3.3.2	Metal Deposition	39
3.3.3.3	MOM Diode Fabrication	40
3.4	Thin Film and Device Characterization Methods	42
3.4.1	Structural Properties Characterization	42
3.4.1.1	X-Ray Diffraction	42
3.4.1.2	Surface Morphology	44
3.4.2	Electrical Response Characterization	45
3.4.2.1	Direct Current (DC) Measurement and Analysis	45
3.4.2.2	Alternating Current (AC) Measurement and Analysis	47
3.4.2.3	Rectification Measurement and Analysis	49
3.5	Summary	50

## **CHAPTER 4 RESULTS AND DISCUSSION**

4.1	Chapter Overview	52
4.2	Characterization and Analysis of Thin Films	52
4.2.1	Surface Roughness	52
4.2.2	Thin Film Thickness	56
4.2.3	Thin Film Structure	57
4.3	DC Characterization and Analysis	59
4.3.1	Current-Voltage (I-V) Characteristics	60
4.4	AC Characterization and Analysis	66
4.4.1	Capacitance Characteristic	66
4.4.2	Conductance Characteristic	69
4.4.3	Series Resistance	72
4.5	Rectification Behavior and Analysis	75

## **CHAPTER 5 CONCLUSION**

5.1	Conclusion	76
5.2	Future Work	77

## **REFERENCES**

79

## **APPENDIX**

86



**UMS**  
UNIVERSITI MALAYSIA SABAH

## LIST OF TABLES

	Page
Table 2.1: Different structure device with own performance	23
Table 2.2: Organic semiconductor device with various deposition methods	25
Table 2.3: DC and AC characteristic of organic devices	28
Table 3.1: Blended organic thin films deposition parameter	37
Table 3.2: Metal deposition parameter	40
Table 4.1: Surface roughness thickness of cross section area	56
Table 4.2: XRD results of soluble organic thin film	58
Table 4.3: Barrier Heights for carrier injection	64
Table 4.4: I-V characteristic of the PTAA with different percentage of TIPS-pentacene MOM diodes	65



UMS  
UNIVERSITI MALAYSIA SABAH

## LIST OF FIGURES

	Page
Figure 2.1: (a) a narrow bangap and (b) overlapping band of a conductor material	7
Figure 2.2: Band diagram of insulator material	8
Figure 2.3: Band diagram of semiconductor material.	10
Figure 2.4: Silicon atoms bonding to form a crystalline.	11
Figure 2.5: Intrinsic silicon lattices at $T > 0K$ .	11
Figure 2.6: Semiconductor doped with pentavalent atoms.	13
Figure 2.7: Semiconductor doped with trivalent atoms.	14
Figure 2.8: Ethylene molecule with $\sigma$ and $\pi$ bonds.	16
Figure 2.9: History of the organic semiconductor.	16
Figure 2.10: 6, 13 - bis(triisopropylsilylethynyl) - pentacene (TIPS-pentacene).	17
Figure 2.11: Poly(triaryl amine) (PTAA).	18
Figure 2.12: Schematic diagram of organic device: (a) metal-organic-metal (MOM), (b) metal-insulator-semiconductor (MIS), (c) metal-polymer-semiconductor (MPS).	22
Figure 3.1: Flowchart of Research Approach.	33
Figure 3.2: Sample dimensions label (a) glass and (b) ITO coated glass.	34
Figure 3.3: Stepwise representation of glass cleaning: (a) Glass substrate was soaked overnight in Decon 90, (b) glass substrate was cleaned in the ultrasonic bath, (c) Ethanol, acetone, and distilled water were used while glass substrate cleaned in the ultrasonic bath, (d) glass substrate was soaked in distilled water after cleaning, (e) glass substrate blow dried by using nitrogen gas and sealed in the petri dish.	35
Figure 3.4: Image of the spin coating process.	36
Figure 3.5: Stepwise representation of organic layer deposition: (a) solution was dropped on the substrate, (b) thin film was spin coated with different spin speed, (c) thin film	37

was annealed in the oven, (d) Blended organic was left on the substrate.

Figure 3.6:	(a) Sputtering machines, (b) shadow mask for contact electrode.	39
Figure 3.7:	(a) ITO glass substrate, (b) ITO glass substrate with blended organic semiconductor layer, (c) shadow mask's cover, (d) Metal-Organic-Metal (MOM) diodes were fabricated.	41
Figure 3.8:	X-ray diffraction of atom in crystal plane.	43
Figure 3.9:	Stylus tips moving along uneven surface of thin film.	44
Figure 3.10:	Circuit diagram of DC response measurement for metal-organic-metal diode.	46
Figure 3.11:	Circuit diagram of AC response measurement for metal-organic-metal diode.	49
Figure 3.12:	Circuit diagram of half wave rectifier.	50
Figure 4.1:	Image of PTAA with 0% of TIPS-pentacene thin film.	54
Figure 4.2:	Image of PTAA with 15% of TIPS-pentacene thin film.	54
Figure 4.3:	Surface roughness of the organic thin film with different speed: (a) 1000rpm, (b) 2000rpm, (c) 3000rpm, (d) 4000rpm.	55
Figure 4.4:	Thickness versus speed of spin coating.	57
Figure 4.5:	XRD pattern for pure PTAA thin film.	57
Figure 4.6:	Top view of PTAA/TIPS-pentacene based on metal-organic-metal (MOM) diode.	59
Figure 4.7:	Cross section view of PTAA/TIPS-pentacene based on metal-organic-metal (MOM) diode structure.	60
Figure 4.8:	I-V characteristic of blend PTAA/TIPS-pentacene-based diode from -10 to +10 V range.	60
Figure 4.9:	Forward region of I-V characteristic from 0 to 4 V range.	61
Figure 4.10:	reverse region of I-V characteristic from 0 to -10 V range.	61
Figure 4.11:	Turn on-voltage of PTAA with 0 %, 5 %, 10 %, 15 %, and 20 % of TIPS-pentacene MOM diode.	62
Figure 4.12:	Breakdown voltage of PTAA with 0 %, 5 %, 10 %, 15 %, and 20 % of TIPS-pentacene MOM diode.	62

Figure 4.13:	The corresponding band diagrams of PTAA/TIPS-pentacene diode.	63
Figure 4.14:	Semilog plot of PTAA/TIPS-pentacene diode.	65
Figure 4.15:	Capacitance characteristic as a function of frequency (C-f) with various bias voltages of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	67
Figure 4.16:	Capacitance characteristic as a function of bias voltage (C-V) with various frequency of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	68
Figure 4.17:	Conductance characteristic as a function of frequency (G-f) with various bias voltages of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	70
Figure 4.18:	Conductance characteristic as a function of bias voltage (G-V) with various frequency of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	71
Figure 4.19:	Series resistance as a function of frequency ( $R_s$ -f) with various bias voltages of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	73
Figure 4.20:	Series resistance as a function of bias voltage ( $R_s$ -V) with various frequency of the PTAA with (a) 0 %, (b) 5 %, (c) 10 %, (d) 15 %, and (e) 20 % of TIPS-pentacene MOM diode.	74
Figure 4.21:	Rectifier input and output signals.	75



## LIST OF ABBREVIATIONS

RFID	Radio Frequency Identification
IoT	Internet-of-Thing
AC	Alternating Current
DC	Direct Current
BJT	Bipolar Junction Transistor
FET	Field-Effect Transistor
$I_{BE}$	base-emitter current
$I_{CE}$	collector-emitter current
$V_{GS}$	gate-source voltage
$I_{DS}$	drain-source current
$V_{in}$	input voltage
$V_{out}$	output voltage
$E_v$	valence band
$E_c$	conduction band
$E_g$	Energy band gap
MOM	Metal-Organic-Metal
MIS	Metal-Insulator-Semiconductor
MPS	Metal-Polymer-Semiconductor
HOMO	Highest Occupied Molecular Orbital
LUMO	Lowest Un-occupied Molecular Orbital
SCLC	Space Charge Limited Current
ILC	Injection Limited Current
FWHM	Full Width Half Maximum
sccm	Standard Cubic Centimetre Per Minute
eV	electron volt
°C	Celsius
K	Kelvin
cm	Centimetre
V	Volt
s	Second
$\Omega$	Ohm
Hz	Hertz

## LIST OF SYMBOLS

$\pi$	pi
$h_f$	final thickness
$k$	mass transfer coefficient
$c_0$	initial solids concentration
$w$	spin speed
$\beta_0$	initial kinematic viscosity
$\rho$	density
$h_0$	blade height
$\Delta P$	slurry pressure head
$\mu$	fluid viscosity
$U$	blade speed
$L$	channel length
$j$	current density
%	percentage
rpm	Revolutions per minute
A	Ampere
W	Watt
N	integer (1, 2, 3,...)
$\lambda$	wavelength
$\theta$	angle
$d$	Spacing between plane
$D$	average grain size
$\beta$	Width of FWHM
$I_0$	prefactor current
$n$	ideality factor
$\phi_b$	barrier height
$E_g$	band gap energy
$\chi_s$	electron affinity of the semiconductor
$Y$	admittance
$Z$	impedance
$G$	conductance
$\omega$	angular frequency

$f$	frequency
$C$	capacitance
$R_s$	series resistance
$^\circ$	degree
$\text{\AA}$	Angstrom
$\sigma$	electrical conductivity



UMS  
UNIVERSITI MALAYSIA SABAH

# CHAPTER 1

## INTRODUCTION

### 1.1 Background Study

Organic semiconductor has received a fast growing interest with the advantages of large area, light weight, low-temperature fabrication, flexibility deposition technique, and potentially low-cost electronics that make the field simultaneously challenging and exciting towards the realization of environmentally sustainable electronic devices. Organic semiconductors have been proposed for several numbers of applications such as flexible display for televisions or smartphones, portable media players, rollable solar cell, wireless devices, and radio frequency identification (RFID) tags (Ye et al, 2015). For example, organic solar cells or photovoltaic devices fabricated on flexible substrates such as plastics or metal foils will create new applications on curved surfaces on building, human body, vehicles and portable electronics. Moreover, the organic semiconductor layer possess advantages such as light weight and easy to attach to any part or surface and thus very useful for wireless devices and sensors for internet-of-thing (IoT) applications.

Electronic components can be divided into two-terminal and three-terminal. A diode is one of the two-terminal electronic devices, which has low resistance to allow the current flow in forward direction, and high resistance in the reverse direction in order block the current flow back. So, the diode has the same function of check valve in electronic version. This type of behavior is called rectification. It used to convert an alternating current (AC) to direct current (DC). By using two or more diodes to form full-wave rectification circuit which converts full AC wave into DC.

Meanwhile, a transistor is a three-terminal electronic component. It is categorized into Bipolar Junction Transistor (BJT) and unipolar transistor such as Field-Effect Transistor (FET). BJT terminals are labeled as base, collector, and emitter. A small base-emitter current ( $I_{BE}$ ) can control and switch the collector-emitter current ( $I_{CE}$ ). FET terminals are gate, source, and drain. The gate-source voltage ( $V_{GS}$ ) can control the drain-source current ( $I_{DS}$ ). There are two common functions for the transistor. Transistor as an electronic switch in the circuit is one of the functions. By increasing the base voltage, the  $I_{CE}$  also increases. The collector voltage decreases and nearly no voltage difference to emitter voltage, the current can flow from collector to emitter freely. When saturated, the transistor is switched on. Another function of transistor is as an amplifier. The common-emitter amplifier is designed with base as input, collector as output, and the emitter as grounded with both. The change in input voltage ( $V_{in}$ ) will decide if the transistor is switched on or off, which decides the flow of supply voltage and creates a large change in output voltage ( $V_{out}$ ).

Organic semiconductor is the material, mainly made up of chains of carbon, hydrogen, nitrogen, sulfur, and oxygen atoms, and shows properties typically associated with semiconductor properties. Most organic materials are less expensive to create than high crystalline inorganic materials. It also might fabricate devices with low-cost fabrication methods. Organic semiconductor is further divided into two categories, which are semiconducting polymers and small molecules which will be further explained in Chapter two (Zaki, 2015). The small molecule organic semiconductor materials are like 6,13-bis(triisopropylsilylethynyl)-pentacene (TIPS-pentacene), Tetracene, and Anthra[2,3-b:6,7-b']dithiophene (ADT). On the other hand, the polymer organic semiconductor materials are like Poly(triarylamine) (PTAA), Poly[[5-(2-ethylhexyl)-5,6-dihydro-4,6-dioxo-4H-thieno[3,4-c]pyrrole-1,3-diyl](4,4'-didodecyl[2,2'-bithiophene]-5,5'-diyl)] (PBTPD), and Poly(3-hexylthiophene-2,5-diyl) (P3HT).

In particular, most organic materials are soluble in solvents that allows for the opportunity for solution processing which can produce many devices at a fraction of the cost. In addition, most devices require an annealing step to reach high performance that is generally at high temperatures at least 500 °C for silicon,

but is much less or not required for organic materials (Zhang et al, 2013.). One of the advantages for deposit organic materials in solution form is the wide range of thin-film coating technologies already applied by existing industries (Sahu et al, 2009). These include inkjet technique and also a screen printing technique for an individual substrate and extend to continuous roll-to-roll manufacture. The existence of mature, low-cost, and large-area manufacturing routes means that scaling-up of organic semiconductor technology is usually expected to be a quite cheap process.

## 1.2 Problem Statement

Now a day, solution-processed deposition techniques used to fabricate organic semiconductor materials thin film have getting more and more interest. However, there are several problems which need to be solved in order to improve the organic semiconductor materials performance in the application. The solution-processable organic semiconducting materials such as poly(triarylamine) (PTAA) and 6,13-bis(triisopropylsilylethynyl)-pentacene (TIPS-pentacene) have been reported to show low mobility (Intaniwet et al, 2011). The morphology of the organic semiconductor layer has an influence on the device performance. To achieve device performance to a higher level, morphology control by varying deposition condition such as spin speed to vary thickness is crucial.

In solid-state physics, the carrier mobility characterizes how fast the carrier moves through the metal or semiconductor when it pulled by an electrical field. By increasing voltage which in DC, the electric field also increases. By analysis the DC electrical response, the mobility of the carriers in the organic materials was investigated. On the other hand, AC describes the flow of charge that changes polarity or direction periodically. By changing the frequency, the investigation of AC conductivity is needed to investigate the real and imaginary parts of the electrical modulus on spin-coated organic semiconductor layers and how the organic materials to orient with the oscillations of an external alternating electric field.

### 1.3 Research Objective

This research aim is to investigate the structural property and electrical response of soluble blended organic semiconductor thin films using spin-coating deposition techniques for MOM diode application. This research work can be completed through the following objectives:

- To design blended organic semiconductor thin film-based diode.
- To fabricate blended organic semiconductor thin film-based diode using metal-organic-metal structure.
- To evaluate the structural property and electrical response of blended soluble organic semiconductor thin film-based diode device on glass substrate.

### 1.4 Research Scope

This research focus on design, fabrication and characterization, which conducted to determine the optimum percentage of TIPS-pentacene blended in the PTAA during deposition that will optimize the DC electrical characteristics and AC frequency-dependent impedance characteristics of the metal-organic-metal (MOM) diode. In the process of diode fabrication, spin coating technique was used as the organic semiconductor material deposition technique to form thin film or layer. The ability of spin coater can quickly and easily form uniform thin films. Thus, spin coating technique requires organic materials which easily to be dissolved in solvent. As a result, the soluble organic semiconductor materials were chosen for this project. Besides that, all experiments to fabricate thin films and MOM diode were conducted in a controlled environment by minimizing the exposure of the fabricated diode with ambient environment. The DC and AC measurement setup is required to conduct electrical and frequency-dependent impedance of MOM diodes.

## 1.5 Thesis Outline

The thesis contains five chapters. Chapter 1 is an introduction that gives a brief explanation of the technology that organic semiconductor, diode, transistor, and what is the limitation in achieving high efficiency organic diode. The research aim, objective scope of this thesis is presented in this chapter.

Chapter 2 is gives a brief explanation about the basic theory behind organic semiconductor. A brief review on previous research is written to show the various materials that are used for the development of organic devices.

Experimental steps are explained in chapter 3. This chapter explains the details on pre- and post-processing procedures and steps in order to form a thin film or layer and fabricate the MOM devices. A physical characterization method of determining thin film properties such as X-Ray diffraction and profilometer is also briefly explained, while experimental setup for the DC and AC measurement using an LCR meter and computer-controlled current-voltage measurement were also explained to determine the electrical properties of MOM devices.

Chapter 4 focusing on the results that obtains from the experiment. The characterization has been selected which is the frequency dependent electrical characteristics and the DC current-voltage (I-V) characteristics of the diode device.

Chapter 5 presenting the summary of the findings, conclusion and also recommendation. All the result of this work is summarized. By the thesis data, a future work regarding the thin film performance is described.