



**UNIVERSITI PUTRA MALAYSIA**

**EFFECTS OF IONIZING RADIATION ON THE ELECTRICAL AND  
OPTICAL PROPERTIES OF POLYVINYL ALCOHOL/ ANILINE  
HYDROCHLORIDE BLEND FILMS**

**AZIAN BINTI OTHMAN**

**FS 2007 6**



EFFECTS OF IONIZING RADIATION ON THE ELECTRICAL AND  
OPTICAL PROPERTIES OF POLYVINYL ALCOHOL/ ANILINE  
HYDROCHLORIDE BLEND FILMS

AZIAN BINTI OTHMAN

MASTER OF SCIENCE

2007

AZIAN BINTI OTHMAN

MASTER OF SCIENCE  
UNIVERSITY PUTRA MALAYSIA  
2007



**EFFECTS OF IONIZING RADIATION ON THE ELECTRICAL AND  
OPTICAL PROPERTIES OF POLYVINYL ALCOHOL/ ANILINE  
HYDROCHLORIDE BLEND FILMS**

**By**

**AZIAN BINTI OTHMAN**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
Malaysia, in Fulfilment of the Requirement for the Degree of Master of  
Science**

**January 2007**



## DEDICATION

*To my parents, Othman Saki and Azizah Hamzah, my family  
last but not least to all of my friends.  
Thank you very much.*



Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**EFFECTS OF IONIZING RADIATION ON THE ELECTRICAL AND OPTICAL PROPERTIES OF POLYVINYL ALCOHOL/ANILINE HYDROCHLORIDE BLEND FILMS**

By

**AZIAN BINTI OTHMAN**

**January 2007**

**Chairman : Professor Elias Saion, PhD**

**Faculty : Faculty of Science**

An attempt was made to produce polyvinyl alcohol (PVA)/polyaniline (PANI) conducting polymer composites from PVA/Aniline hydrochloride (AniHCl) blends via radiation induction. Films of PVA/AniHCl blends at various AniHCl compositions were initially prepared by solvent casting method. The films were then irradiated with Co-60 gamma rays to doses up to 20 kGy. The optical properties were measured by using a UV-Visible spectrophotometer in the wavelength range of 200-800 nm. The formation of PANI was observed when the films changed colour from colourless to light green at 20 kGy. However the amount of PANI formed was limited as the green colour did not reveal significantly in the absorption spectra, but instead the main absorption band was peaking at 315 nm corresponding to the formation hydrochloric acid by radiation. The absorbance data at 315 nm were fitted to an exponential law and



found to have a relationship between dose sensitivity  $D_{0.01}$  and AniHCl composition  $C$  as  $D_{0.01} = 0.3133C + 3.18$ . The radiation caused bond scission of covalent bonds of AniHCl and hydrolysis of water to produce  $\text{Cl}^-$ ,  $\text{OH}^-$ , and  $\text{H}^+$  ions in the blends and as well as PANI that lead to the changes in optical properties and conductivity of irradiated PVA/AniHCl blends.

The absorption spectra of irradiated PVA/AniHCl films were analyzed further for absorption edge, activation energy, and band gap energy. From the plot of absorption coefficient  $\alpha$  versus photon energy  $h\nu$ , the absorption edge for 9% AniHCl decreases from 4.76 to 4.66 eV when the dose increases from 0 kGy to 20 kGy and that for 29% AniHCl the value decreases from 4.52 to 4.40 eV. From the slope of  $\ln \alpha$  versus  $h\nu$ , we found the optical activation energy  $\Delta E$  decreases from 1.08 to 0.87 eV for 9% AniHCl and from 0.33 eV to 0.25 eV for 23% AniHCl. The optical band gap for the direct allowed transition was determined from the intercepts of the extrapolated linear part of the plot of  $(\alpha h\nu)^2$  against  $h\nu$ . The band gap energy decreases from 2.60 to 2.38 eV for 9% AniHCl and that for 29% AniHCl the value decreases from 2.46 to 2.14 eV .

The conductivity of irradiated PVA/AniHCl films was measured at room temperature and in the frequency range from 20 Hz to 1 MHz by means of an impedance analyzer. The conductivity at 20 Hz for 9% AniHCl increases from  $9.41 \times 10^{-7} \text{ Sm}^{-1}$  at 0 kGy to  $5.01 \times 10^{-6} \text{ Sm}^{-1}$  at 20 kGy. The conductivity for 23%



AniHCl increases from  $1.85 \times 10^{-5} \text{ Sm}^{-1}$  at 0 kGy to  $5.78 \times 10^{-5} \text{ Sm}^{-1}$  at 20 kGy. The frequency exponent values of  $s_1$  and  $s_2$  were determined from the gradients of the linear plots of  $\log \sigma(\omega)$  versus  $\log \omega$ . The value of  $s$  decreases with the increase of dose and AniHCl composition. The  $s_1$  value varies from 0.04 to 0.20 and that of  $s_2$  its value varies from 0.30 to 0.90. The dc conductivity extracted from the Cole-Cole plots of the complex impedance  $Z''$  vs.  $Z'$ , shows the dc conductivity increases with dose by an exponential law. The slope of the linear regressions from  $\ln \sigma_{dc}(\omega)$  versus  $D$  plot was used to determine the value of dose sensitivity  $D_0$ , for conductivity. The  $D_0$  and  $\sigma_0$  values obtained are AniHCl dependent given by  $D_0 = 0.3226C + 10.904$  and  $\sigma_0 = 1.0 \times 10^{-6} \text{ C} - 4.0 \times 10^{-6}$  where C is AniHCl composition.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**KESAN SINARAN MENGION KEATAS SIFAT ELEKTRIK DAN OPTIKAL  
BAGI ADUNAN FILEM POLYVINYL ALCOHOL/ ANILINE  
HYDROCHLORIDE**

Oleh

**AZIAN BINTI OTHMAN**

**Januari 2007**

**Pengerusi : Profesor Elias Saion, PhD**

**Fakulti : Sains**

Satu percubaan telah dibuat untuk menghasilkan komposit alkohol polivinal (PVA)/polianilin (PANI) polimer konduktor daripada adunan polivinal alkohol /aniline hidroklorida (AniHCl) secara aruhan sinaran mengion. Filem campuran PVA/AniHCl pada komposisi AniHCl berbeza telah disediakan dengan menggunakan kaedah acuan pelarut. Filem kemudian disinarkan dengan sinar gama Co-60 dengan dos berbagai sehingga 20 kGy. Ciri-ciri optik adunan ini diukur dengan menggunakan meterspektrum UV-sinar tampak dalam julat panjang gelombang 200-800 nm. Pembentukan PANI telah diperhatikan apabila filem berubah warna daripada tidak berwarna kepada warna hijau pada 20 kGy. Bagaimanapun kandungan terbentuknya PANI adalah terhad ini kerana warna hijau tidak jelas kelihatan dalam spectra penyerapan. Sebaliknya julat penyerapan terbentuk pada 315 nm bersesuaian





dengan spectrum pembentukan asid hidroklorida oleh sinaran. Data penyerapan pada 315 nm dipadankan dengan hukum eksponen dan didapati satu hubungan antara kepekaan dos,  $D_{0''}$  dan komposisi AniHCl,  $C$  sebagai  $D_{0''} = 0.3133C + 3.18$ . Sinaran menyebabkan terputusnya ikatan kovalen AniHCl dan hidrolisis air menghasilkan ion-ion  $Cl^-$ ,  $OH^-$ , and  $H^+$  daripada adunan itu dan juga menghasilkan polaron daripada PANI menyebabkan perubahan kepada ciri-ciri optik dan kekonduksian adunan PVA/AniHCl yang didedahkan dengan sinaran.

Spektra penyerapan filem PVA/AniHCl telah dianalisis berkenaan penyerapan pinggir, tenaga pengaktifan dan jurang jalur tenaga. Daripada lakaran pekali penyerapan  $\alpha$  lawan tenaga foton  $h\nu$ , tenaga penyerapan pinggir untuk 9% AniHCl berkurangan daripada 4.76 kepada 4.66 eV apabila dos ditambahkan daripada 0 kGy kepada 20 kGy dan untuk 29% AniHCl nilainya berkurangan daripada 4.52 kepada 4.40 eV. Daripada kecerunan  $\ln \alpha$  lawan  $h\nu$ , didapati tenaga keaktifan optik  $\Delta E$  berkurangan daripada 1.08 kepada 0.87 eV untuk 9% AniHCl dan daripada 0.33 eV kepada 0.25 eV untuk 23% AniHCl. Jurang jalur tenaga peralihan terus yang dibenarkan telah ditentukan daripada pintasan garis linear graf  $(\alpha h\nu)^2$  lawan  $h\nu$ . Jurang jalur tenaga berkurangan daripada 2.60 kepada 2.38 eV untuk 9% AniHCl dan daripada 2.46 kepada 2.14 eV untuk 29% AniHCl.

Kekonduksian elektrik filem PVA/AniHCl telah diukur pada suhu bilik pada julat frekuensi daripada 20 Hz kepada 1 MHz. Kekonduksian pada 20 Hz untuk 9% AniHCl bertambah daripada  $9.41 \times 10^{-7} \text{ Sm}^{-1}$  pada 0kGy kepada  $5.01 \times 10^{-6} \text{ Sm}^{-1}$  pada 20kGy. Kekonduksian pada 23% AniHCl bertambah daripada  $1.85 \times 10^{-5} \text{ Sm}^{-1}$  pada 0 kGy kepada  $5.78 \times 10^{-5} \text{ Sm}^{-1}$  pada 20 kGy. Nilai kuasa frekuensi eksponen  $s_1$  dan  $s_2$  telah ditentukan daripada kecerunan graf linear log  $\sigma(\omega)$  lawan log  $\omega$ . Nilai  $s$  berkurang dengan bertambahnya dos dan komposisi AniHCl. Nilai  $s_1$  berubah daripada 0.04 kepada 0.20 dan nilai  $s_2$  berubah daripada 0.30 kepada 0.90. Kekonduksian arus terus ditentukan daripada lakaran graf Cole-Cole bagi impedans kompleks  $Z''$  vs.  $Z'$ , dimana ia menunjukkan kekonduksian arus terus bertambah dengan dos menurut hukum eksponen. Kecerunan garis linear regresi  $\ln \sigma_{dc}(\omega)$  lawan  $D$  telah digunakan untuk menentukan dos sensitiviti,  $D_0$ , bagi kekonduksian. Nilai  $D_0$ , dan  $\sigma_0$  didapati bergantung kepada komposisi AniHCl dan masing-masing dinyatakan sebagai  $D_0 = 0.3226C + 10.904$  dan  $\sigma_0 = 1.0 \times 10^{-6} C - 4.0 \times 10^{-6}$  di mana  $C$  adalah komposisi AniHCl.

## ACKNOWLEDGEMENTS

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

Alhamdulillah, with Allah's blessing, this thesis entitle "*Effects of ionizing radiation on the electrical and optical properties of polyvinyl alcohol/ aniline hydrochloride blend films*" completed. I am grateful to all those who has extended their cooperation and guidance towards the completing of this thesis. I would like to express my sincere gratitude to my supervisor, Professor Dr. Elias Saion for his guidance, patience, advice, contributions, support and understanding throughout the undertaking of this thesis. My grateful appreciations are also due to my supervisor committee members, Dr. Jumiah Hassan, Associate Professor Dr. Zaki Ab. Rahman and Dr. Dahlan Hj. Mohamad for their countless invaluable comments and suggestions to improve this research.

Thanks are also due to Mr Zain from biophysic laboratories, Faculty of Science, UPM foe assistance and providing facilities during laboratories work. Deep thanks and appreciation are extend to all my seniors and friends; Mrs. Susilawati Hambali, Mr. Aris Doyan, Mrs. Azlina baha, Mrs. Nuraihan Harun, Ms. Azimah Yusof, Ms. Noor Haslinda Daud, Mr. Iskandar Shahrim Mustafa, Mr. Asri Tridi, Mr. Ajis Lepit, Mr. Hamzah Harun, Mr. Mohammad Ahmed and Mr. Yusoff Mohammed, for their unfailing friendship and unselfish support. Last but not least, I wish to express my deep thanks to my beloved parents for their moral support, undying love, and prayers.



I certify that an Examination Committee has met on 10 January 2007 to conduct the final examination of Azian Binti Othman on her Master of Science thesis entitled “Effects of Ionizing Radiation on the Electrical and Optical Properties of Polyvinyl alcohol/Aniline Hydrochloride Blend Films” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Zainal Abidin Sulaiman, PhD**

Associate Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Chairman)

**Abdul Halim Shaari, PhD**

Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Internal Examiner)

**Mohd Maarof H. A Moxsin, PhD**

Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Internal Examiner)

**Ibrahim Talib, PhD**

Professor  
Faculty of Science  
Universiti Kebangsaan Malaysia  
(External Examiner)

---

**HASANAH MOHD. GHAZALI, PhD**  
Professor/ Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 15 FEBRUARY 2007



This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

**Elias Saion, PhD**

Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Chairman)

**Mohd Zaki Abdul Rahman, PhD**

Associate Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Member)

**Jumiah Hassan, PhD**

Lecturer  
Faculty of Science  
Universiti Putra Malaysia  
(Member)

**Dahlan Haji Mohd, PhD**

Secondary Standard Dosimetry Laboratory  
Malaysian Institute for Nuclear Technology Research (MINT)  
(Member)

---

**AINI IDERIS, PhD**

Professor/ Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 8 MARCH 2007



## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions

---

**AZIAN BINTI OTHMAN**

Date: 12 FEBRUARY 2007



## TABLE OF CONTENTS

	<b>Page</b>
<b>DEDICATION</b>	ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	vi
<b>ACKNOWLEDGEMENTS</b>	ix
<b>APPROVAL</b>	x
<b>DECLARATION</b>	xii
<b>LIST OF TABLES</b>	xv
<b>LIST OF FIGURES</b>	xvi
<b>LIST OF ABBREVIATIONS</b>	xx
 <b>CHAPTER</b>	
 <b>1 INTRODUCTION</b>	
Conducting polymer composite	3
Significant of the study	4
Problem statement	5
Scope of the study	5
Objective of the study	6
Outline of the thesis	7
 <b>2 LITERATURE REVIEW</b>	
Introduction	8
Ionic exchange polymer composites	9
Conducting polymer composite	11
Applications of conducting polymer composite	15
Radiation induced modification of ICP composites	17
Electrical properties of ICP composites	20
Optical properties of ICP composites	22
 <b>3 THEORETICAL</b>	
Introduction	24
Ionizing radiations	25
Direct ionizing radiation	26
Indirect ionizing radiation	27
Gamma radiation	27
Interaction of radiation with matter	27
Rayleigh scattering	28
Photoelectric effect	29
Compton scattering	30
Pair production	31



Absorption of gamma rays	32
Electrochemical conducting polymers	34
Conducting polymers	36
Ultraviolet and visible absorption spectroscopy	41
Lambert- beer law	42
Absorption	43
Optical properties of polymer composite	44
Conductivity of polymer composite	45
<b>4 MATERIALS AND METHODS</b>	
Preparation of PVA/ AniHCl blends films	49
Poly (Vinyl alcohol)	49
Aniline hydrochloride	50
PVA/ AniHCl blend films	51
Irradiation	53
Conductivity Measurements	56
Optical absorption measurements	58
<b>5 RESULTS AND DISCUSSION</b>	
Radiation interactions with PVA/ AniHCl blends	62
Optical properties of irradiated PVA/ AniHCl blends	65
Introduction	65
Optical absorption spectra	65
Dose response and dose sensitivity	70
Absorption edge	72
Optical activation energy	77
Band gap energy	82
Electrical conductivity of irradiated PVA/ AniHCl blends	87
Introduction	87
Dose -dependence conductivity	87
Blend concentration - dependence conductivity	92
AC conductivity component and frequency exponent	96
Hopping frequency	104
Complex impedance	112
DC conductivity	122
<b>6 CONCLUSIONS AND FUTURE WORKS</b>	
Conclusions	125
Suggestions for future works	127
<b>REFERENCES</b>	128
<b>BIODATA OF THE AUTHOR</b>	137
<b>LIST OF PUBLICATIONS</b>	138





## LIST OF TABLES

<b>Table</b>		<b>Page</b>
3.1	Interaction radiation with matter	28
4.1	Concentration of PVA/AniHCl blends	52
4.2	Thickness (in mm) of PVA/AniHCl blends	52
5.1	The value of hopping frequency, $\omega_p$ at different doses and AniHCl composition for $s_2$	105
5.2	The value of hopping frequency, $\omega_p$ at different doses and AniHCl composition for $S_1$	109



## LIST OF FIGURES

Figure		Page
3.1	Schematic of Photoelectric Effect	30
3.2	Schematic of Compton Effect	31
3.3	Schematic of Pair Production	32
3.4	Diagram of range of conductivity from insulators to metallic conductors	34
3.5	Examples of conjugated polymer	35
3.6	The repeat unit for the emeraldine base	40
3.7	Schematic diagram showing the principles of band theory as described in the text.	47
4.1	Structure of poly(vinyl alcohol)	50
4.2	Structures for Aniline Hydrochloride	51
4.3	The J.L. Shepherd <sup>60</sup> Co radiation source facility with the time controller shown at the next side	54
4.4	Schematic diagram of J.L. Shepherd <sup>60</sup> Co radiation source	55
4.5	The 17% PVA/HCl films before and after irradiation	56
4.6	HP4284A precision LCR Meter	57
4.7	Schematic of a double-beam UV-Vis Spectrophotometer	59
4.8	Schematic of band gap in material	60
4.9	Absorbance HCl at 315 nm	60
4.10	Camspec M350 Uv/Vis Spectrophotometer	61
4.11	Flow chart of the project	61



5.1	Colour of the PVA/AniHCl blend films (a) before irradiation and (b) after irradiated with dose of 20 kGy.	63
5.2	Polymer structure of polyaniline (PANI)	64
5.3	Absorbance spectra for PVA/AniHCl film at different concentration (a) 9%, (b) 17%, (c) 23% and (d) 29% AniHCl composition before and after exposure to the gamma rays.	69
5.4	Dose response curve at 315 nm for different AniHCl concentrations	71
5.5	Dose sensitivity parameter $D_0$ as a function of AniHCl concentration as derived from 315 nm band	71
5.6	Absorption edge for PVA/AniHCl film at different concentration (a) 9%, (b) 17%, (c) 23% and (d) 29% AniHCl composition before and after exposure to the gamma rays	74
5.7	Absorption edge versus dose at different AniHCl concentrations	76
5.8	Absorption edge versus AniHCl concentration at different doses	76
5.9	Activation energy for PVA/AniHCl film at different concentration (a) 9%, (b) 17%, (c) 23% and (d) 29% AniHCl composition before and after exposure to the gamma rays	79
5.10	Optical activation energy $\Delta E$ versus dose for different AniHCl concentrations	81
5.11	Optical activation energy $\Delta E$ versus AniHCl concentration at different doses	81
5.12	Direct allowed transition for PVA/AniHCl film at different concentration (a) 9%, (b) 17%, (c) 23% and (d) 29% AniHCl composition before and after exposure to the gamma rays	84
5.13	Variation of direct energy band gaps versus radiation dose at different AniHCl concentrations	85



5.14	Variation of direct energy band gaps versus AniHCl concentration at different radiation doses	86
5.15	Total conductivity as a function of frequency at different doses with (a) pure PVA, (b) PVA/AniHCl (9%), (c) PVA/AniHCl (17%) and (d) PVA/AniHCl (23%) blend samples	90
5.16	The Total conductivity as a function of frequency at different concentration with (a) before irradiated (b) 5 kGy (c) 10 kGy (d) 15 kGy and (e) 20 kGy.	95
5.17	Variation of $\log \sigma(\omega)$ versus $\log \omega$ at different concentration for PVA/AniHCl blends at (a) before irradiated, (b) 5 kGy, (c) 10 kGy, (d) 15 kGy and (e) 20 kGy for $S_1$ .	99
5.18	Variation of $\log \sigma(\omega)$ versus $\log \omega$ at different concentration for PVA/AniHCl blends at (a) before irradiated, (b) 5 kGy, (c) 10 kGy, (d) 15 kGy and (e) 20 kGy for $S_2$ .	101
5.19	Frequency exponent $s_1$ as a function of dose for ac conductivity of PVA/AniHCl blends	103
5.20	Frequency exponent $s_2$ as a function of dose for ac conductivity of PVA/AniHCl blends	103
5.21	The conductivity master curves at different doses for PVA/AniHCl polymer blends containing (a) 0%, (b) 9%, and (c) 17% and (d) 23 %AniHCl composition using $S_2$ values.	108
5.22	The conductivity master curves at different doses for PVA/AniHCl polymer blends containing (a) 0%, (b) 9%, and (c) 17% and (d) 23% AniHCl composition using $S_1$ value.	111
5.23	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing (a) 0%, (b) 9%, (c) 17% and (d) 23% AniHCl composition	114
5.24	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing PVA, 9%, 17% and 23% AniHCl composition before irradiated to gamma rays.	117



5.25	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing PVA, 9%, 17% and 23% AniHCl composition after irradiated to 5 kGy gamma rays	118
5.26	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing PVA, 9%, 17% and 23% AniHCl composition after irradiated to 10 kGy gamma rays	119
5.27	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing PVA, 9%, 17% and 23% AniHCl composition after irradiated to 15 kGy gamma rays.	120
5.28	The complex impedance in the cole-cole plots at the real part ( $Z'$ ) imaginary part ( $Z''$ ) for PVA/AniHCl polymer blends containing PVA, 9%, 17% and 23% AniHCl composition after irradiated to 20 kGy gamma rays	121
5.29	Variation of $\ln \sigma_{dc}$ as a function of doses at different concentration of aniline hydrochloride	123
5.30	Variation of dose sensitivity as a function of concentration of aniline hydrochloride	123
5.31	Variation of $\sigma_0$ as a function of concentration of aniline hydrochloride	124



## LIST OF ABBREVIATIONS

PVA	Polyvinyl Alcohol
AniHCl	Aniline Hydrochloride
HCl	Hydrochloric acid
PANI	Polyaniline
UV	Ultraviolet
HOMO	Highly occupied molecular orbital
LUMO	Lowly unoccupied molecular orbital
$\sigma$	Conductivity
Z	Impedance
Z'	Real Part of Impedance
Z''	Imaginary Part of Impedance
Z <sub>0</sub>	Bulk resistance
Ac	Alternating Current
Dc	Direct Current
$\epsilon_0$	Permittivity of vacuum
e	Elementary charge
n	Concentration of charge carriers
$\mu$	Mobility
$\lambda$	Wavelength
D	Dose



$D_0'$	Dose sensitivity of the conductivity
$D_0''$	Dose response of the absorbance
$A$	Absorption
$\alpha$	Absorption coefficient
$s$	Power of Frequency
$\Delta E$	Optical activation energy
$E_g$	Optical band gap energy
$C_p$	Capacitance
$G$	Conductance
$I$	Intensity of transmitted photons
$I_0$	Intensity of incident photons
$T$	Transmittance
$\omega$	Frequency
$\omega_p$	Hopping frequency
$C$	Concentration

## CHAPTER 1

### INTRODUCTION

Since the first solid poly (ethylene oxide) (PEO) based polymer composite produce by Wright and coworkers (1973) an intensive search for ambient temperature solid ionic conducting polymers (ICPs) that suitable for specific applications is continuing. PEO has low conductivity ( $10^{-8} \text{ Scm}^{-1}$ ) at room temperature and is not suitable for use as electrochemical devices. However when it is blended with inorganic salt complexes the composites attract considerable interest as they meet a variety of electrochemical applications: batteries, electrochemical devices, sensors, fuel cell membranes, electronic displays etc. Beside PEO, other polymers have been used as host matrix including poly(vinyl alcohol) (PVA), polyphosphazene (PPA), poly(itaconate) (PIC), poly(vinylidene fluoride) (PVDF), poly(methyl methacrylate) (PMMA), and poly(vinyl pyrrolidone) (PVPR), poly(ethylene-alt-tetrafluoroethylene) (ETFE), poly(tetrafluoro ethylene) (PTFE) etc. Some ICPs have unique polymer structure containing functional groups such as negatively charges  $\text{SO}_3^-$ ,  $\text{CO}_2^-$ , and  $\text{PO}_3^-$  or positively charges  $\text{NH}_3^+$ ,  $\text{NR}_2^+$ , and  $\text{PR}_3^+$  that are acting as a selective barrier membranes, regulating the transport of positive ions such as  $\text{H}^+$  and  $\text{Li}^{2+}$  or negatively ions such as  $\text{Cl}^-$  and  $\text{HSO}_4^-$  to increase the conductivity of polymer composites. The main advantages of ICP composite electrolytes are





their favorable mechanical properties including light weight, flexibility, and simple processibility, and their unique ionic transport properties for electrochemical and electrical devices. Works are continuing to produce ICP composites that are suitable for particular applications.

Since the discovery of electrically conducting polymers (CPs) by the 1953 Nobel prize winners, Alan MacDiarmid, Alan J. Heeger, and Hideki Shirakawa in 1976, research on CP composites has been intensive due to their interesting and useful electronic and optical properties (Heeger, 2002). Organic CP is a new generation of polymers that formed as a result of on unpaired  $\pi$ -electron delocalized along the backbone of conjugated polymers. The conjugated polymers have a framework of alternating single and double carbon-carbon bonds or carbon-nitrogen bonds. The electron delocalization in the conjugated polymers provides the highway for charge mobility along the backbone of the chain polymer. The disordered electronic structures are termed as solitons, polarons, and bipolarons that make the conjugated polymers exhibit the electrical properties of semiconductors. The potential advantages of these conjugated CPs or semiconducting polymers lie in their lightweight and in the ease of their synthesis and fabrication.

