



**UNIVERSITI PUTRA MALAYSIA**

**RADIATION AND TEMPERATURE EFFECTS ON CONDUCTIVITY AND  
DIELECTRIC PROPERTIES OF POLY (VINYL ALCOHOL)-POTASSIUM  
HYDROXIDE-PROPYLENE CARBONATE**

**MOHD ASRI BIN MAT TERIDI**

**FPSK(M) 2005 5**

**RADIATION AND TEMPERATURE EFFECTS ON CONDUCTIVITY AND  
DIELECTRIC PROPERTIES OF POLY (VINYL ALCOHOL)-POTASSIUM  
HYDROXIDE-PROPYLENE CARBONATE**

**MOHD ASRI BIN MAT TERIDI**

**MASTER OF SCIENCE  
UNIVERSITI PUTRA MALAYSIA**

**2005**



**RADIATION AND TEMPERATURE EFFECTS ON CONDUCTIVITY AND  
DIELECTRIC PROPERTIES OF POLY (VINYL ALCOHOL)-POTASSIUM  
HYDROXIDE-PROPYLENE CARBONATE**

**By**

**MOHD ASRI BIN MAT TERIDI**

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

**March 2005**



## **Dedication**

**To my Mom and Dad.**



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

**RADIATION AND TEMPERATURE EFFECTS ON CONDUCTIVITY AND DIELECTRIC PROPERTIES OF POLY (VINYL ALCOHOL)-POTASSIUM HYDROXIDE-PROPYLENE CARBONATE**

By

**MOHD ASRI BIN MAT TERIDI**

**March 2005**

**Chairman: Associate Professor Elias Bin Saion, PhD**

**Faculty: Science**

The physical and chemical properties of polymeric materials can be modified by treatment with ionizing radiation. This radiation processing technique has been used to modify the structural and electrical properties of polymer composites for use as electrical devices. Alkaline composite polymer electrolytes (ACPEs) are materials that have attracted great attention for their vast application in the development of solid-state ionic devices. The materials have their chemical and electrical properties change with radiation dose allowing modification of the electrolytes in the solid state form. One serious problem of the ACPEs is low ionic conductivity at room temperature because they have a tendency to crystallize. In this study radiation-processing technique was chosen to increase the ionic conductivity at room temperature. The ACPE consists of poly(vinyl alcohol) (PVA) as the host polymer, potassium hydroxide (KOH) as an ionic blend and propylene carbonate (PC) as a plastisizer. The compositions of KOH and PC were varied from 40 to 70%. The electrolytes were prepared by chemical method and the finished films were obtained by solvent-casting technique. The films were irradiated with 1.25 MeV gamma rays with dose from 0 to 200 kGy at room temperature. The sample of irradiated and unirradiated films of different compositions was placed



between two parallel-plate metal electrodes and the conductivity and dielectric properties were measured using an impedance analyzer at different frequencies ranging from 20 Hz to 1 MHz. For the unirradiated samples, the conductivity and dielectric properties were also measured at different temperatures of narrow range from room temperature to 343 K. The X-ray diffraction (XRD) measurements were performed to characterize the change of molecular structure of the electrolytes with radiation dose and compositions of the blend and plasticizer.

The results show that the ACPE sample of PVA-KOH (40 wt.%) - PC (60 wt.%) irradiated with dose 200 kGy exhibits the highest ionic conductivity of  $2.7 \times 10^{-3} \text{ Scm}^{-1}$  at room temperature. For ACPE sample with PVA-KOH (40 wt.%) - PC (60 wt.%) the highest ionic conductivity value is  $7.8 \times 10^{-3} \text{ Scm}^{-1}$  at 343 K. The results show that the frequency dependent conductivity and dielectric constant of the ACPEs depend on radiation dose, temperature and composition of the blends and plasticizer. From the XRD analysis, the molecular structure of the electrolytes change from semi-crystalline to amorphous when the composition of PC increased to 60% and the radiation dose increased to 200 kGy. Finally, we have demonstrated that radiation processing can be used to modify ACPEs to increase their ionic conductivity for the development of solid-state ionic devices.



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

**KESAN RADIASI DAN SUHU KE ATAS KEKONDUKSIAN DAN SIFAT DIELEKTRIK KE ATAS POLI (VINIL ALCOHOL)-KALIUM HIDROKSIDA-PROPILENA KARBONAT**

Oleh

**MOHD ASRI BIN MAT TERIDI**

Mac 2005

**Pengerusi: Profesor Madya Elias Bin Saion, PhD**

**Fakulti: Sains**

Ciri-ciri fizik dan kimia bahan polimer boleh diubah sifatnya dengan menggunakan rawatan sinaran mengion. Teknik pemprosesan dengan sinaran ini telah digunakan untuk mengubah ciri-ciri struktur dan elektrik komposit polimer untuk digunakan dalam rekabentuk elektrik. Komposit beralkali polimer elektrolit (ACPEs), merupakan bahan menarik yang diberi keutamaan kerana mempunyai aplikasi yang meluas dalam memajukan rekabentuk ionik keadaan pepejal. Bahan ini mempunyai ciri-ciri kimia dan elektrik yang berubah terhadap dos sinaran yang memudahkan pengubahsuaian sifat elektrolit dalam keadaan pepejal. Satu masalah besar dihadapi ialah kekonduksian ion ACPEs yang rendah pada suhu bilik kerana ia berkecenderungan untuk menghablur. Dalam kajian ini, teknik pemprosesan sinaran telah dipilih untuk meningkatkan kekonduksian ionnya pada suhu bilik. ACPEs mengandungi poli(vinil) alcohol (PVA) digunakan sebagai polimer asas, kalium hidroksida (KOH) sebagai pencampur ion dan propilena karbonat (PC) sebagai agen pemplastik. Komposisi KOH dan PC diubah daripada 40 hingga 70%. Elektrolit ini disediakan dengan kaedah kimia dan hasilnya dalam bentuk filem didapati dengan kaedah acuan-pelarut. Filem-filem disinarkan dengan sinar gama dengan tenaga 1.25 MeV pada dos 0 hingga 200 kGy dalam suhu

bilik. Setiap sampel yang telah dan belum dirawat dengan sinaran diletakkan diantara dua elektrod logam plat selari dan ciri-ciri kekonduksian dan dielektrik diukur dengan menggunakan kaedah analisis impedans pada frekuensi daripada 20 Hz kepada 1 MHz. Untuk sampel yang tidak dirawat dengan sinaran, dan ciri-ciri kekonduksian dan dielektrik juga diukur terhadap suhu berbeza daripada suhu bilik hingga 343K. Pengukuran XRD juga dilakukan untuk pencirian perubahan struktur elektrolit terhadap dos dan komposisi pencampur ion dan agen pemplastik.

Hasil kajian menunjukkan bahawa sampel ACPE PVA-KOH (40 wt.%) - PC (60 wt.%) yang dirawat dengan sinaran sehingga 200 kGy mempamerkan kekonduksian ion tertinggi pada suhu bilik  $2.7 \times 10^{-3} \text{ Scm}^{-1}$ . Bagi sampel ACPE PVA-KOH (40 wt.%) - PC (60 wt.%) pada 343K kekonduksian ion tertinggi ialah  $7.8 \times 10^{-3} \text{ Scm}^{-1}$ . Hasil kajian mendapati bahawa kebergantungan frekuensi bagi kekonduksian ion dan pemalar dielektrik ACPEs adalah bergantung kepada dos sinaran, suhu dan komposisi pencampur ion dan agen pemplastik. Analisis XRD menunjukkan bahawa struktur elektrolit berubah daripada semi-hablur kepada amorfus apabila komposisi PC bertambah kepada 60% dan dos sinaran bertambah kepada 200 kGy. Akhir sekali, kami telah menunjukkan bahawa pemprosesan sinaran boleh digunakan untuk mengubah sifat ACPEs dalam menambahkan kekonduksian ionnya untuk pembangunan rekabentuk ionic keadaan pepejal.



## ACKNOWLEDGEMENTS

First of all I must mention my supervisor, Assoc. Prof. Dr. Elias Saion who carefully and analytically has guided me along the scientific path. I would not have come this far without his help. Secondly, my co-supervisors Prof. Dr. Abd Halim Shaari, Assoc. Prof. Dr. Mohd Zaki Abd Rahman and En. Taiman Kadni must be recognized for all the discussion about science and how to write scientifically.

A special word of thanks to Dr. Jumiah Hasan and Dr. Ahmad Azmin Mohamad for excellent and friendly supervision throughout this work and also for their financial support

All my colleagues at the Biophysics laboratory are always remembered and especially my roommate Abdul Rashid Yusof, housemates Najib and Ismail, my lab-mates Iskandar Shahrin and Hamzah, and fellow friends, namely Peja, Mizan, Bux, and Tay.

Finally, I want to thank my family and especially to my Mum and Dad.



## TABLE OF CONTENTS

	<b>Page</b>
<b>DEDICATION</b>	ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	v
<b>ACKNOWLEDGEMENTS</b>	vii
<b>APPROVAL</b>	viii
<b>DECLARATION</b>	x
<b>LIST OF TABLES</b>	xiv
<b>LIST OF FIGURES</b>	xv
<b>LIST OF ABBREVIATIONS/ SYMBOLS</b>	xxiv
<b>LIST OF GLOSSARY OF TERMS</b>	xxvi
<b>CHAPTER</b>	
<b>I INTRODUCTION</b>	1
General Introduction	1
Solid Composite Polymer Electrolytes	2
Significance of the Study	4
Problem Statement	6
Scope of the Present Study	7
Objective of the Study	7
Scope of the Thesis	8
<b>II LITERATURE REVIEW</b>	9
History of Composites Polymer Electrolytes	9
Solid Composites Polymer Electrolytes and Applications	11
Classification of Solid Composites Polymer Electrolytes	11
Poly(vinyl alcohol) (PVA)	12
Properties of PVA	14
Alkaline Composite Polymer Electrolyte	15
SCPE – Plasticizer System	18
Radiation Treatment on SCPE	19
<b>III THEORETICAL WORK</b>	21
Introduction	21
Interaction of Ionizing Radiation with Matter	22
Ionizing Radiations	23
Gamma Ray Interactions with Matter	23
Gamma Ray Interaction Process	25
Radiation effects on polymer blends	32
Grafting	32
Chain Scission	33
Free Radicals	33



X-Ray Diffraction (XRD)	34
Electrical Conductivity	36
Theory of Polarization	36
Electronic Polarization	37
Orientation Polarization	38
Atomic or Ionic Polarization	39
Interfacial Polarization	39
Dielectric Relaxation	40
Types of Dielectric Relaxation	41
Dipolar Relaxation	42
Ionic Relaxation	43
Electronic Dispersion (Resonance)	43
Relaxation Mechanisms	44
Theory of Dielectric Permittivity and Loss	45
Conductivity	50
<b>IV SAMPLE PREPARATION AND CHARACTERIZATION</b>	<b>53</b>
Introduction	53
Preparation of ACPE Samples	54
Weighing of Materials	54
Chemical Mixing	57
Sample Casting	57
Sample Storing	58
Sample Irradiation	58
Irradiation Source	59
Irradiation Procedure	59
Characterization of ACPE Samples	60
X-Ray Diffraction (XRD)	60
Conductivity Measurements	61
Dielectric Measurements	62
Data Processing	63
Calculation of Impedance	64
<b>V EFFECTS OF RADIATION DOSE ON MICROSTRUCTURE AND AC CONDUCTIVITY</b>	<b>66</b>
Introduction	66
XRD Analysis for Pure PVA System	67
XRD Analysis for PVA-KOH Composites	69
XRD Analysis for PVA-PC Composites	74
XRD Analysis for PVA-KOH-PC Composites	77
Conductivity of Pure PVA	81
Impedance of Pure PVA	83
Dielectric Permittivity of Pure PVA	85
Dielectric Modulus of Pure PVA	87
Conductivity of PVA-KOH System	89
Impedance of PVA-KOH System	94



DC Conductivity of PVA-KOH System	102
Dielectric Permittivity of PVA-KOH System	104
Dielectric Modulus of PVA-KOH System	113
Conductivity of PVA - PC System	123
Impedance of PVA - PC System	130
Dielectric Permittivity of PVA - PC System	134
Dielectric Modulus of PVA - PC System	143
Conductivity of PVA-KOH-PC System	151
Impedance of PVA-KOH-PC System	156
DC Conductivity of PVA-KOH System	161
Dielectric Permittivity of PVA-KOH-PC System	162
Dielectric Modulus of PVA-KOH-PC System	170
<b>VI EFFECT OF TEMPERATURE ON CONDUCTIVITY AND DIELECTRIC</b>	<b>178</b>
Introduction	178
Conductivity of Pure PVA	178
Impedance of Pure PVA	180
DC Conductivity of Pure PVA	182
Dielectric Permittivity of Pure PVA	183
Dielectric Modulus of Pure PVA	185
Conductivity of PVA-KOH System	187
Impedance of PVA-KOH System	191
DC Conductivity of PVA-KOH System	199
Dielectric Permittivity of PVA-KOH System	200
Dielectric Modulus of PVA-KOH System	208
Conductivity of PVA-PC System	217
Impedance of PVA-PC System	221
DC Conductivity of PVA-PC System	227
Dielectric Permittivity of PVA-PC System	228
Dielectric Modulus of PVA-PC System	236
Conductivity of PVA-KOH-PC System	244
Impedance of PVA-KOH-PC System	248
DC Conductivity of PVA-KOH-PC System	252
Dielectric Permittivity of PVA-KOH-PC System	253
Dielectric Modulus of PVA-KOH-PC System	260
<b>VII CONCLUSION AND SUGGESTIONS FOR FURTHER WORK</b>	<b>268</b>
<b>REFERENCES</b>	<b>273</b>
<b>APPENDICES</b>	<b>284</b>
<b>BIODATA OF THE AUTHOR</b>	<b>285</b>
<b>LIST OF PUBLICATION/SEMINAR/POSTER</b>	<b>286</b>



## LIST OF TABLES

Table		Page
2.1	Historical development of polymer composites starts from beginning to years 1975 (Sheldon, 1982)	10
2.2	Conductivity ( $\sigma$ ) and applications of PVA mixed with different salts.	16
2.3	Conductivity ( $\sigma$ ) and applications of KOH mixed with different polymer	17
2.4	Conductivity ( $\sigma$ ) and applications of polymer and ionic conductor with PC plasticizer	19
2.5	Conductivity ( $\sigma$ ) and applications of composite polymer electrolyte using gamma radiation	20
3.1	Compton scattering at fixed angles (Loveland 2000)	29
4.1	The compositions of PVA and KOH to form PVA-KOH composites	55
4.2	The composition of PVA and PC to form PVA-PC composites	55
4.3	The compositions of PC in PVA- 40 KOH	55
5.1	Parameters of power law fitting to AC conductivity data for pure PVA at various doses	83
5.2	Parameters of power law fitting to AC conductivity data for sample PPC at various doses	130



## LIST OF FIGURES

Figure		Page
2.1	Structure of PVA showing syndiotactic placement of three consecutive hydroxyl groups (Lindemann, 1971).	13
3.1	Shows the absorption coefficient, $\mu$ , for four radiation-matter interactions as a function of radiation energy in MeV with an iron absorber. In the chart, PE = Photoelectric effect; C = Compton Scattering; PP = Pair Production; R = Thomson or Rayleigh scattering. (Loveland 2000)	25
3.2	Schematic diagrams of (top to bottom) photoelectric effect, Compton effect, and pair production	27
3.3	A schematic diagram of Compton scattering	28
3.4	Grafting in polymer blend	32
3.5	General setup for an X-ray diffractometer (Mikael 2000)	35
3.6	Electronic Polarization (Callister, 2000)	38
3.7	Orientation Polarization (Callister, 2000)	38
3.8	Atomic Polarization (Callister, 2000)	39
3.9	Interfacial Polarization (Callister, 2000)	40
3.10	Dependence of $\epsilon'$ and $\epsilon''$ on the logarithm of frequency (Blythe 1979)	42
3.11	The various relaxations and dispersion in materials (Blythe 1979)	44
3.12	Variation of $\tan \delta$ peaks with temperature (Blythe 1979)	45
3.13	AC losses in a dielectric (a) circuit diagram, (b) Argand diagram of complex current-voltage relationship (Blythe 1979)	49
4.1	ACPE preparation and measurements flow-chart	56
4.2	Capacitance with $C_p$ -G circuit mode selection	62
5.1	XRD patterns for pure PVA at various doses	68



5.2	XRD patterns for pure PVA and PVA-KOH systems at various composition of KOH	70
5.3	XRD patterns for (a) 10%, (b) 20%, (c) 30%, (d) 40%, (e) 50% KOH by weight in the PVA at various doses	73
5.4	XRD patterns for pure PVA and various concentrations by weight of the PC in the PVA	74
5.5	XRD patterns for a) 40%, (b) 50%, (c) 60%, (d) 70% PC by weight in the PVA at various doses	77
5.6	XRD patterns for pure PVA, PKOH 40 wt.%, PPC 60 wt.% and various concentration of the PC in the (PVA-KOH) system	78
5.7	XRD patterns for a) 40%, (b) 50%, (c) 60%, (d) 70% PC by weight in the (PVA-KOH) system at various doses	80
5.8	The conductivity (in log scale) of pure PVA vs. frequency at various doses	82
5.9	Power law plots $\log \sigma$ versus $\log \omega$ to determine $s$ for different doses	83
5.10	Complex impedance plot at various temperature of pure PVA	85
5.11	Frequency dependence of real part ( $\epsilon'$ ) of dielectric constant at different doses in pure PVA at room temperature	86
5.12	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric loss at different doses in pure PVA at room temperature	86
5.13	The real part of modulus ( $M'$ ) as a function of frequency for pure PVA at various doses	87
5.14	The imaginary part of modulus ( $M''$ ) as a function of frequency for pure PVA at different doses	88
5.15	Conductivity vs. frequency at various doses for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	92
5.16	Conductivity vs. frequency at various KOH concentrations for (a) 0 kGy and (b) 200 kGy	83
5.17	Frequency dependence of complex impedance at various doses at room temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH	98

	(d) 40% KOH and (e) 50% KOH	
5.18	Frequency dependence of complex impedance at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	102
5.19	Arrhenius type plot: dc conductivity as a function of Dose for irradiated samples	104
5.20	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various doses at room temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	108
5.21	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity for various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	109
5.22	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various doses at room temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	112
5.23	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	113
5.24	The real part of modulus ( $M'$ ) as a function of frequency at various doses at room temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	117
5.25	The real part of modulus ( $M'$ ) as a function of frequency at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	118
5.26	The imaginary part of modulus ( $M''$ ) as a function of frequency at various doses at room temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	122
5.27	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	123
5.28	Logarimatic scale plots of conductivity vs. frequency at various doses for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	132
5.29	Logarimatic scale plots of conductivity vs. frequency at various concentrations for (a) 0 kGy and (b) 200 kGy	133





5.30	Power law plots $\log \sigma$ versus $\log \omega$ to determine $s$ for different doses for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	135
5.31	Frequency dependence of complex impedance at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	139
5.32	Frequency dependence of complex impedance at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	140
5.33	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	143
5.34	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	144
5.35	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	147
5.36	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	148
5.37	The real part of modulus ( $M'$ ) as a function of frequency at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	151
5.38	The real part of modulus ( $M'$ ) as a function of frequency at various concentration at room temperature for (a) 0 kGy and (b) 200 kGy	152
5.39	The imaginary part of modulus ( $M''$ ) as a function of frequency at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	155
5.40	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentration at room temperature for (a) 0 kGy and (b) 200 kGy	156
5.41	Logarimatic scale plots of conductivity vs. frequency at various doses for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	154
5.42	Logarimatic scale plots of conductivity vs. frequency at various	155



	concentrations for (a) 0 kGy and (b) 200 kGy	
5.43	Frequency dependence of complex impedance at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	159
5.44	Frequency dependence of complex impedance at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	160
5.45	Arrhenius type plot: dc conductivity as a function of $D$ for irradiated samples	161
5.46	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	165
5.47	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	166
5.48	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	168
5.49	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	169
5.50	The real part of modulus ( $M'$ ) as a function of frequency at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	172
5.51	The real part of modulus ( $M'$ ) as a function of frequency at various concentrations at room temperature for (a) 0 kGy and (b) 200 kGy	173
5.52	The imaginary part of modulus ( $M''$ ) as a function of frequency at various doses at room temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	176
5.53	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentration at room temperature for (a) 0 kGy and (b) 200 kGy	177
6.1	Logarimatic scale plots of conductivity of pure PVA vs. frequency at various temperatures	180

6.2	Complex impedance plot at various temperature of pure PVA for (a) 300 K (b) 313 K, (c) 323 K, 333 K and 343 K	182
6.3	Arrhenius plots: dc conductivity as a function of temperature at irradiated samples	183
6.4	Frequency dependence of real part ( $\epsilon'$ ) of dielectric constant at various temperatures in pure PVA	184
6.5	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric loss at various temperatures in pure PVA	184
6.6	The real part of modulus ( $M'$ ) as a function of frequency for pure PVA at various temperature	185
6.7	The imaginary part of modulus ( $M''$ ) as a function of frequency for pure PVA at various temperatures	186
6.8	Logarimatic scale plots of conductivity vs. frequency at various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	190
6.8	Logarimatic scale plots of conductivity vs. frequency at various concentrations for (a) 300 K and (b) 343 K	191
6.10	Complex impedance plot at various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	196
6.11	Complex impedance at various concentrations for (a) 300 K and (b) 343 K	198
6.12	Arrhenius plot: dc conductivity as a function of $1/T$ for irradiated samples	199
6.13	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	203
6.14	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various concentration for (a) 300 K and (b) 343 K	204
6.15	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity for various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	207
6.16	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric	208

	permittivity for various concentration for (a) 300 K and (b) 343 K	
6.27	The real part of modulus ( $M'$ ) as a function of frequency at various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	211
6.28	The real part of modulus ( $M'$ ) as a function of frequency at various concentration for (a) 300 K and (b) 343 K	212
6.29	The imaginary part of modulus ( $M''$ ) as a function of frequency at various temperature for (a) 10% KOH (b) 20% KOH (c) 30% KOH (d) 40% KOH and (e) 50% KOH	215
6.20	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentration for (a) 300 K and (b) 343 K	216
6.21	Logarimatic Scale plots of conductivity vs. frequency at various temperatures for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	219
6.22	Logarimatic scale plots of conductivity vs. frequency at various concentrations for (a) 300 K and (b) 343 K	220
6.23	Complex impedance plot at various temperatures for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	225
6.24	Complex impedance plot of various concentrations for (a) 300 K and (b) 343 K	227
6.25	Arrhenius plot: dc conductivity as a function of $1/T$ for irradiated samples	228
6.26	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	231
6.27	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various concentration for (a) 300 K and (b) 343 K	232
6.28	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	235
6.29	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various concentration for (a) 300 K and (b) 343 K	236



6.30	The real part of modulus ( $M'$ ) as a function of frequency at various temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	239
6.31	The real part of modulus ( $M'$ ) as a function of frequency at various concentration for (a) 300 K and (b) 343 K	240
6.32	The imaginary part of modulus ( $M''$ ) as a function of frequency at various temperature for (a) 40% PC (b) 50% PC (c) 60% PC and (d) 70% PC	242
6.33	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentration for (a) 300 K and (b) 343 K	243
6.34	Logarimatic scale plots of conductivity vs. frequency at various temperatures for (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC and (d) 70% PKPC	246
6.35	Logarimatic scale plots of conductivity vs. frequency at various concentrations for (a) 300 K and (b) 343 K	247
6.36	Complex impedance plot at various temperatures for (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC and (d) 70% PKPC	250
6.37	Complex impedance plot at various concentrations for (a) 300 K and (b) 343 K	251
6.38	Arrhenius plot: dc conductivity as a function of $1/T$ for irradiated samples	252
6.39	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various temperature for (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC and (d) 70% PKPC	255
6.40	Frequency dependence of real part ( $\epsilon'$ ) of dielectric permittivity at various concentration for (a) 300 K and (b) 343 K	256
6.41	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various temperature for (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC and (d) 70% PKPC	259
6.42	Frequency dependence of imaginary part ( $\epsilon''$ ) of dielectric permittivity at various concentration for (a) 300 K and (b) 343 K	260
6.43	The real part of modulus ( $M'$ ) as a function of frequency at various temperature for (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC and (d) 70% PKPC	263



6.44	The real part of modulus ( $M'$ ) as a function of frequency at various concentration for (a) 300 K and (b) 343 K	264
6.45	The imaginary part of modulus ( $M''$ ) as a function of frequency at various temperature (a) 40% PKPC (b) 50% PKPC (c) 60% PKPC (d) 70% PKPC	266
6.46	The imaginary part of modulus ( $M''$ ) as a function of frequency at various concentration (a) 300 K (b) 343 K	267

