UNIVERSITI PUTRA MALAYSIA

SYNTHESIS AND CHARACTERIZATION OF POLYVINYL ALCOHOL/POLYANILINE/FUNCTIONALIZED MULTIWALLED CARBON NANOTUBE NANOCOMPOSITE FILM BY GAMMA- RADIATION METHOD

NORFAZLINAYATI BINTI HAJI OTHMAN

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By

NORFAZLINAYATI BINTI HAJI OTHMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

December 2018

This thesis is dedicated to my beloved husband Mohd. Hamzah Harun and my lovely children Uswatun Hasanah, Muhammad Nasrullah and Muhammad Hidayatullah, my amazing parent, Haji Othman and Puan Nabishah, my wonderful parent in-law, my precious lecturer Prof. Dr. Zainal Abidin Talib, my dearest siblings and good friends who gave me strength and faith to find my dreams.

Lots of love.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Polyaniline/multiwalled carbon nanotubes (PANI/MWCNT) nanocomposite is one type of materials that has properties that are unique and improved as compared to the nature of the individual original materials. However, the fabrication process to apply the nanocomposite to the industry is quite complicated especially in producing a versatile free standing film. The hindrances that are encountered included inhomogeneous composite film, high cost, unclean procedure, difficult to dispose chemical residues and limitation to scale up for mass commercialization. These are among the main factors that scientists and researchers need to resolve before the material can be used commercially. After evaluating different synthesizing techniques, it was decided that gamma-radiation method has the potential to be a promising eco-friendly technique where no oxidizing agent or any surfactant agent was needed and the purity of products is maintained.

In this research project, a free standing film of polyaniline (PANI) and polyaniline/functionalized-multiwalled carbon nanotubes (PANI/f-MWCNTs) with different f-MWCNT composition were synthesized in the PVA matrix by γ-radiation method. All films were exposed to gamma-rays from 10 to 50 kGy. The structural, morphological, chemical composition, chemical bonding, electronic transition, optical energy band gap, degree of disorder of band tail and thermal properties of PVA/PANI composite film and PVA/PANI/f-MWCNT nanocomposite films before and after irradiated by gamma-radiation were characterized by X-Ray Diffraction (XRD), Field Emission Scanning

Electron Microscopy (FESEM), Energy Dispersive X-ray (EDAX), Fourier Transform Infrared Spectroscopy (FTIR), UV-Visible (UV-Vis) Spectrophotometer and Thermogravimetric Analysis (TGA).

Morphology of the f-MWCNT obtained from FESEM after irradiation show that the nanotube diameter changes by about 70% to 90% as compared to the original size before irradiation. XRD confirmed that all the characteristic crystalline peaks after irradiation at 50 kGy represent the structure of PANI in emeraldine salt form which was 2θ= 21.9, 22.0, 22.8, 23.9, 27.5 and 35.6°. However, after the addition of f-MWCNT in the composite system, the intensity of the dominant peak of PANI (2θ = 21°) decreased with the increasing of f-MWCNT content at the highest irradiation dose. It is believed that there is a strong reaction exists between PANI and f-MWCNT. FTIR spectrum showed that the functional group from f-MWCNT (-COOH) has attached to the secondary of amides from PANI monomer and quinoid unit in the nanocomposite film is richer (I_Q/I_B=1.17) as compared to unirradiated film (I_Q/I_B=1.12). It is believed that more conjugated PANI has fully coated over the nanotube sidewall during polymerization process initiated by gamma-radiation.This was further confirmed by UV-Vis analysis that showed the π-π* transition of phenylene rings increasingly red-shifted and polaron-π* transition has a blue-shifted whereby it may assign to the presence of more extended chains of PANI network wrapped on f-MWCNT sidewalls. The calculated value for the optical energy band gap for the nanocomposite film decreases after irradiation which was from 3.33 for 0 kGy to 2.62 eV for 50 kGy. This suggests that the resultant composite is more conductive as compared to the unirradiated film. It was also observed that the degree of disorder in the nanocomposite film also decreased which was from 0.42 to 0.34 eV at 0 kGy and 50 kGy, respectively. This indicates that the structure formed was more ordered after irradiation and thus showed that electric and electronic properties have improved. This can also be seen through the results by TGA technique in which the thermal properties of the nanocomposite film was highly stable due after the irradiation process. This can be observed at maximum temperature (700 °C) in which the total weight loss for the film before the radiation is 96.69 % as compared to the film after irradiation which is 82.83 %.

Results from all characterizations indicated that synthesis of PVA, PANI and f-MWCNT through the gamma-radiation was successful in producing a homogeneous free standing film of PVA/PANI composite film and PVA/PANI/f-MWCNT nanocomposite films. The structural, morphological, optical energy band gap, degree of disorder of the band tail and thermal properties of these composite and nanocomposite films was significantly improves as compared to other methods.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

SINTESIS DAN PENCIRIAN FILEM NANOKOMPOSIT POLIVINIL ALKOHOL/POLIANILINA/NANOTIUB KARBON MULTILAPIS TERFUNGSI MENGGUNAKAN KAEDAH SINARAN GAMMA

Oleh

NORFAZLINAYATI BINTI HAJI OTHMAN

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Nanokomposit polianilina/nanotiub karbon multilapisan (PANI/MWCNT) merupakan kombinasi dua bahan yang menghasilkan sesuatu yang unik dan lebih hebat berbanding bahan asal tunggal. Walau bagaimanapun, kaedah penyediaan untuk menggunakan nanokomposit tersebut kepada industri agak rumit terutamanya dalam menghasilkan filem berdiri bebas dan serba boleh. Rintangan-rintangan yang dihadapi termasuk filem komposit yang tidak teratur, kos tinggi, proses yang tidak bersih, kesukaran untuk membuang sisa-sisa kimia dan had untuk meningkatkan jumlah pengkomersilan adalah faktor utama yang perlu difikirkan oleh saintis dan penyelidik. Selepas menilai teknik yang berbeza dalam sintesis komposit, maka keputusan dibuat untuk menggunakan kaedah radiasi gamma kerana teknik ini menjanjikan teknik mesra alam, proses yang bersih kerana tidak ada ejen pengoksidaan atau ejen surfaktan yang diperlukan dan keaslian produk dikekalkan.

Dalam projek penyelidikan ini, filem berdiri bebas polianilina (PANI) dan nanotube karbon polianilina/ karbon nanotiub multilapisan terfungsi (PANI / f-MWCNTs) dengan komposisi f-MWCNT berbeza disintesis dalam matriks PVA oleh kaedah radiasi gamma. Semua filem komposit dan nanokomposit terdedah kepada sinaran gamma dari 10 hingga 50 kGy. Sifat struktur, morfologi, komposisi kimia, ikatan kimia, peralihan elektronik, jurang jalur tenaga optik, tahap kecelaruan jalur ekor dan sifat terma bagi filem komposit PVA/PANI dan filem nanokomposit PVA/PANI/f-MWCNT sebelum dan selepas diradiasi dicirikan oleh Pembelauan Sinar-X (XRD), Mikroskop Imbasan Pancaran Medan (FESEM), Penyebaran Tenaga Sinar-X (EDAX),

Jelmaan Fourier Inframerah (FTIR), Spektrometer UV-Tampak (UV-Vis) dan Analisis Permeteran Graviti Haba (TGA).

Imej jelas dari FESEM di mana morfologi nanotiub dari f-MWCNT selepas penyinaran mendapati bahawa diameter telah berubah sebanyak 70% hingga 90% berbanding dengan saiz asal nanotiub sebelum penyinaran. XRD mengesahkan semua puncak struktur kristal PANI dalam bentuk garam emeraldina dijumpai pada 2θ = 21.9, 22.0, 22.8, 23.9, 27.5 dan 35.6° selepas penyinaran pada 50 kGy. Walau bagaimanapun, selepas penambahan f-MWCNT ke dalam sistem komposit tersebut, intensiti puncak yang didominasi oleh PANI (2θ = 21°) menurun dengan peningkatan kandungan f-MWCNT pada dos radiasi paling tinggi. Adalah dipercayai terdapat tindak balas yang kuat antara PANI dan f-MWCNT. Spektra FTIR menunjukkan bahawa kumpulan berfungsi dari f-MWCNT (-COOH) telah melekat pada amida sekunder dari monomer PANI dan unit quinoid dalam filem nanokomposit adalah lebih banyak (I_Q/I_B = 1.17) berbanding filem yang tidak diradiasi (I_Q/I_B = 1.12). Dipercayai bahawa semakin banyak PANI terkonjugat sepenuhnya menyaluti dinding luar nanotiub semasa proses pempolimeran oleh radiasi gamma. Ini dikukuhkan lagi dengan analisis dari UV-Vis yang menunjukkan peralihan π-π* bagi gelang fenilena semakin berganjak ke merah dan peralihan polaron-π* telah berganjak ke biru di mana ia menunjukkan kehadiran rangkaian rantaian PANI yang lebih panjang membaluti kekisi luar f-MWCNT. Nilai yang dikira untuk jurang jalur tenaga optik bagi filem nanokomposit telah berkurangan selepas penyinaran iaitu dari 3.33 bagi 0 kGy kepada 2.62 eV bagi 50 kGy. Ini menunjukkan bahawa komposit yang dihasilkan lebih konduktif berbanding filem yang tidak diradiasi. Diperhatikan bahawa tahap kecelaruan dalam filem nanokomposit berkurangan iaitu dari 0.42 kepada 0.34 eV pada 0 kGy dan 50 kGy, masing-masing. Ini mencadangkan bahawa struktur yang terbentuk selepas penyinaran adalah lebih tersusun dan menunjukkan bahawa sifat elektrik dan elektroniknya bertambah baik. Ini juga dapat dilihat melalui keputusan dari teknik TGA di mana sifat terma bagi filem nanokomposit sangat stabil selepas proses penyinaran berlaku. Ini dapat dilihat pada jumlah jisim yang hilang pada suhu maksimum (700 °C) yang mana untuk filem sebelum diradiasi adalah sebanyak 96.69% berbanding filem selepas diradiasi iaitu sebanyak 82.83%.

Hasil daripada semua pencirian menunjukkan bahawa sintesis bagi PVA, PANI dan f-MWCNT melalui teknik penyinaran gamma dalam menghasilkan filem berdiri bebas yang homogen bagi komposit PVA/PANI dan filem nanokomposit PVA/PANI/f-MWCNT telah berjaya. Dapat dilihat juga sifat struktur, morfologi, jurang jalur tenaga optik, tahap kecelaruan jalur ekor dan sifat terma bagi filem komposit PVA/PANI dan filem nanokomposit PVA/PANI/f-MWCNT bertambah baik dengan ketara berbanding dengan kaedah lain.

ACKNOWLEDGEMENTS

All praise to Allah S.W.T., The Lord of The Universe, The Most Beneficent and Merciful. Only by His infinite grace and kindness this thesis has been completed.

First and upmost, I would like to express my deepest gratitude and appreciation to the chairperson of the supervisory committee, Professor Dr. Zainal Abidin Talib for providing and guiding me with his invaluable advice, strong encouragement and patient during the course of work. I would like to extend my acknowledgement to the members of supervisory committee, Professor Dr. Abdul Halim Shaari from Physics Department, Faculty of Science, UPM and Dr. Nik Ghazali Nik Salleh from Radiation Processing Technology Division, Malaysian Nuclear Agency for rendering me their tremendous assistance, recommendations and effort.

Special thanks are also due to the former and existing Dean of Science Faculty, UPM, Professor Dr. Zainal Abidin Talib and Professor Dr. Mohd. Basyaruddin Abdul Rahman, the former and existing Head of Physics Department, UPM, Professor Dr. Zaidan Abdul Wahab and Associate Professor Dr. Zulkiflly Abbas and all staff involved in this project for their co-operation and making accessible different facilities of the department during my study.

In addition, I would like to thank the former and existing Director General of Malaysian Nuclear Agency, Dato' Dr. Mohamad Lebai Juri and Dato' Dr. Mohd. Ashhar Khalid, the former and existing Director of Radiation Processing Technology Division, Malaysian Nuclear Agency, Dr. Zulkafli Ghazali and Dr. Chantara Thevy a/p Ratnam and all staff involved in this project for their technical assistance and facilities.

My sincere appreciation is also extended to my beloved husband Mohd. Hamzah Harun. I am deeply indebted to him as without his prayers, sacrifices and support I really could not manage to complete my study. Special thanks are due to my lovely children Uswatun Hasanah, Muhammad Nasrullah and Muhammad Hidayatullah for their patience and understanding, to my parent Haji Othman Omar and Puan Nabishah Muhammad who always pray for me throughout the hard journey, to my parent's in-law, siblings and good friends who often gave me a lot of motivation to realize this success.

I would also like to extend my gratitude to my colleagues especially to Dr. Emma, Dr. Nordin, Dr. Josephine, Dr. Izrini, Dr. Batool, Dr. Ibrhim, Joel and all my well-wishers, whose names not be mentioned here for have been so helpful and willing to share.

Last but least, I would like to extend my appreciation to Scholarship Division, Ministry of Higher Education for providing financial support to me during the whole course of the study through the MyBrain, MyPhD scholarship program. Financial received from UPM Research Grant Scheme is also gratefully acknowledged.

Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AniHCl	Aniline hydrochloride
APS	Ammonium persulphate
B	Benzenoid
CNT	Carbon nanotube
CP	Conducting polymer
EDAX	Energy Dispersive X-ray
E_g	Energy band gap
ES	Emerladine salt
E_u	Urbach energy
eV	Electron volt
FESEM	Field Emission Scanning Electron Microscopy
f-MWCNT	Functionalized mutiwalled carbon nanotube
FTIR	Fourier Transform Infrared
HOMO	High unoccupied molecular orbital
I_B	Intensity of benzenoid
I_Q	Intensity of quinoid
IR	Infrared
k	Kilo (thousand)
kGy	Kilogray
LUMO	Low unoccupied molecular orbital

MWCNT	Mutiwalled carbon nanotube
n	Nature of the transition
$n\rightarrow$	Nonbonding
PANI	Polyaniline
PVA	Polyvinyl alcohol
pph	Parts per hundred
Q	Quinoid
rpm	Rotation per minute
SDS	Sodium dodecyl sulfate
SWCNT	Single walled carbon nanotube
TGA	Thermogravimetric Analysis
UV-Vis	Ultraviolet-Visible-Near Infrared
Wt%	Weight percent
x	Magnification
XRD	X-ray diffraction
γ	Gamma
^{60}Co	Cobalt-60
θ	Theta (angle of incident x-ray)
π	Pi (bonds)
π^*	Pi-star (antibonding)

CHAPTER 1

INTRODUCTION

1.1 Overview of Conducting Polymers and CNT

The word polymer is already familiar with our daily life as we use the materials in huge volume. Look at our tables, clothes, books, all made by polymers as a base material. The new millennium in this era as speculated by research scholars disclose that polymers or plastics could replace metal as presence technology is becoming more advance. Conjugated polymers (CP) in which exhibit uniqueness in their molecular structure and dramatic response towards electrical field contributed to new application of polymer materials (MacDiarmid, 2001). These unique polymers offer huge prospects for new devices such as smart windows, artificial muscles, membranes, batteries, capacitors and corrosion protection.

Polyaniline (PANI) is a CP that can act as a semiconductor due to the π-electron delocalisation along their polymer backbone. It has been more extensively studied as compared to other conducting polymers due to its tunable electrical conductivity, easy preparation from common chemicals, and excellent thermal and environmental stabilities (Kumar et al., 2017; Tang et al., 2011; Jeon et al., 2010; MacDiarmid, 2001). The uniqueness of PANI is that its conductivity can be controlled by simply doping with acid or dedoping with the use of base materials. When it is doped with acid, PANI will be a conductive polymer in the form of emeraldine salt (ES) and with a dark green colour. When it is dedoped with acid, it will turn into a bluish colour, indicating that it is in PANI emeraldine base form. It can also change properties and colours, such as white or colourless for leucoemeraldine form and violet-coloured for (per)nigraniline form, by simply changing the oxidation state during the polymerisation process. The different colours of PANI corresponding to the different oxidation states and the acid/base doping response has led to polyaniline being considered as favourable candidate for acid/base chemical vapour sensors, supercapacitors and biosensors.

Carbon nanotubes, (CNT) is a hot subject and hot material discussed throughout the world due to its amazing properties. Due to its ideal core materials characteristic by acting as carbonaceous nanofillers, CNT play a crucial role as it possesses structural features and ultra-high charge carrier mobility, huge thermal conductivity, outstanding mechanical strength and high flexibility properties (Kumar, 2016). Scientists have reported that the electrical conductivity can reach up to 5,000 S/cm and elastic modulus up to 640 GPa (Trojanowicz, 2006). Research has shown that nanotubes devices have

higher stress generation, switching speed and durability compared to other materials. These advantages have led application in hydrogen storage, sensing material and component in supercapacitors (Trojanowicz, 2006).

Similar coincident happened before these two novel materials had been discovered. In 1974, the visit of Shirakawa to MacDiarmid and Heeger at University of Pennsylvania led to the discovery of conducting polyacetylene in 1977 (Shirakawa et al., 1977); a prototype conducting polymer. This discovery has opened new field of polymers for electronic applications. Sometimes history repeats itself. The same situation experienced by Kroto whereby he visited Smalley and Curl at Rice University in 1985 drove to a Noble-Prize-winning discovery of buckminsterfullene C60; a conjugated molecule with a soccer ball like structure consisting 12 pentagons and 20 hexagons facing symmetrically (new structure of carbon) (Kroto et al., 1985). Kroto and his Noble prize fellows had obtained arch competition as Max Planch institute also studied the same material led by Kratschmer (Kratschmer et al., 1990). They were at the same stage chasing to dig out the new structure of C60 called fullerene. The subsequent discovery of carbon nanotubes by Iijima in 1991 opened up a new era of science in nanotechnology (Iijima, 1991).

The combination of PANI and other types of conducting polymers with MWCNTs has been widely applied in various electronic industrial applications including photovoltaic cells, organic light emitting diodes, electromagnetic shielding, electrostatic dissipation, antennas, batteries, supercapacitors, gas sensors, solar cells, optical pH sensing, etc. (Thakur et al., 2017; Abdulla et al., 2015; Bachav et al., 2015; Kulkarni, et al., 2013). From the chemical and physical properties point of view, PANI provides redox (reduction and oxidation) mechanism whereas CNT has high surface area and nanoporosity. It is undoubtedly that, tough and hard materials equipped with high conductivity and high electroactivity could be produced and soon replacing metal-based materials as universally known that metal based materials have high corrosion and damage environment due to the aging oxidation process (Stenger-Smith, 1998).

These are just some examples showing that newest advanced materials could be developed from the combination of PANI and CNT. The tiny size of nanotubes implies that they are energy efficient whereas PANI has both electrical and electronic properties due to redox mechanism. These unique properties are able to contribute for the development of novel sensors and functional materials better than other available type of materials.

1.2 Problem Statements

The first reported work in synthesis of polymer composite and MWCNTs with excellent mechanical property was by Ajayan and coworkers (Kulkarni & Kale, 2013) by mixing the MWCNTs with polymer epoxy. Since then, there have been extensive efforts to combine CP and MWCNTs by various methods especially in synthesizing MWCNTs/PANI nanocomposites. Among them include solution mixing (Razak et al., 2009; Ben-Valid et al., 2010), interfacial polymerization (Jeon et al., 2010) in-situ polymerization (Philip et al., 2004; Yang et al,2010) and electrophoretic method (Dhand et al., 2008; Fadhil et al., 2011). However these methods have their own weaknesses and most of these studies normally require toxic organic solvents which may be harmful to the environment. For instance, solution mixing and electrophoretic method are quite expensive due to the reliance in electricity and continuous mixing whereas for in-situ polymerization and interfacial polymerization, these methods are unclean, difficulty to dispose the chemical residues and unscalable. Therefore, it is important to develop facile and efficient method in order to synthesizing the nanocomposite. After evaluating different technique in synthesizing the composite, it is decided to use gamma-radiation method as this technique is promising to be an eco-friendly technique.

Gamma irradiation has been used for many years in modification of materials (Abdulla et al., 2015). The major advantages of radiation processing are neither oxidizing agent is used to polymerize PANI nor surfactant agent is needed to functionalize MWCNTs with PANI. Therefore, γ-radiation method promises us to be an eco-friendly technique as well as clean technique as it is free from chemical contaminants.

1.3 Hypothesis

γ-radiation is electromagnetic radiation of high frequency and high energy able to liberate an electron from an atom or molecule by altering the chemical bonds and removing electrons from the atoms. In polymeric materials, the backbone of the polymer absorbs energy which then liberates free radicals (Charlesby, 1965). By employing Compton scattering principle in which high radiation energy capable to dislodge electron from outer orbitals, the outcome can be seen in the improvement of the properties of the bombarded materials. The properties namely molecular structure, surface morphology, optical properties and thermal analysis are improved thus soon the as-prepared composite materials with with radiation induced properties will be ready for industrial application.

1.4 Scope of the Study

The aim of this study is inclusive to the preparation of nanocomposite film comprises conducting polyaniline (PANI) and functionalized multiwalled carbon nanotubes (f-MWCNT) hosted by polyvinyl alcohol (PVA) in solid phase films by gamma, γ-irradiation. In such realm the ionizing γ-radiation is being used as an oxidizing agent to polymerize aniline hydrochloride, (AniHCl) into conductive polyaniline salt i.e. emeraldine salt and in subsequent the in-situ formation of PANI from AniHCl which grows on f-MWCNT lattice. Furthermore the study will involve the characterization of as prepared nanocomposites in terms of molecular structure, surface morphology, optical properties and thermal analysis.

1.5 Objectives of the Study

The objectives in this study are as follow:

1. To synthesize PVA/PANI composite and PVA / PANI / f-MWCNT nanocomposite film in producing a homogeneous free standing film.

2. To investigate the effect of γ-radiation at different doses on morphology structure, elemental analysis, optical and thermal properties of as synthesized PVA/PANI composite and PVA/PANI/f-MWCNTs nanocomposite film

3. To study the nature of PANI behavior on f-MWCNT and vice versa through in-situ polymerization initiated by gamma-irradiation method with different concentration levels of f-MWCNTs.

4. To identify optimum conditions of PVA / PANI composite and PVA / PANI / f-MWCNTs nanocomposite film in order to improve the optical properties to ensure the nanocomposite have the ability to be a good material in electronic devices.

1.6 Significance of the Study

This study discusses the synthesis of nanocomposite of PANI/f-MWCNT/PVA by gamma radiation method. Two reasons drive the motivation to embark in this work. Firstly, due to less communication that is reported by scientific community on functionalized CNT composites with PANI using ionizing radiation. The second motivation is due to expected amazing properties obtained from CNT/PANI composite materials (Reddy et al., 2009) is obtained and interesting spectra observed from IR spectroscopy where there was evolvement of new chemical bond associated with CNT (Men et al., 2010, Park et al., 2008, Marshall et al., 2006, Showkat et al., 2006). The effect of

radiation is also within the proposed work as for sake to obtain more information on radiation effect on these novel materials. It is hoped that there will be some unique properties obtained from these novel materials after exposing to irradiation source. As reported by Ago et al., (1999) the delocalized π-electrons of CNT and π-electron associated with alternating of bond in PANI might provide interesting results that will be discussed extensively among scientific community. Moreover, an exposure to irradiation might provide modification in their chemical structural and provide changes at macroscale and molecular level (Gopalan et al., 2007). Properties (namely; optical, thermal and structural) are directly affected thus different findings might be obtained before and after irradiation. Finally the promotion of using radiation technique in preparing PANI/f-MWCNT nanocomposite is implemented which is more safe and clean as compared with traditional chemical approach.

1.7 Outlines of the Thesis

The skeleton of this thesis is built upon five chapters. **Chapter 1** deals with the general introduction about PANI and CNT, problem statement, scope, objectives and significant of the study. **Chapter 2** concerns with the related work researcher that have been done in investigating the PANI and CNT behaviour and also common preparation of PVA/PANI/f-MWCNT nanocomposite and its advantageous and disadvantageous. **Chapter 3** highlights the methodology of the study, including materials, sample preparation and measurement. **Chapter 4** deals with the results and discussion on characterization of PVA control film, composites of PVA/PANI and PVA/PANI containing f-MWCNT nanoparticles (PVA/PANI/f-MWCNT) using X-ray diffraction (XRD), Field Emission Scanning Electron Microscopy-Energy Dispersive X-ray (FESEM-EDX), Fourier Transform Infrared (FTIR), Ultraviolet-Visible-Near Infrared (UV-vis) and Thermogravimetric Analysis (TGA). Finally, **Chapter 5** gives the conclusions of the key findings and recommendations for future research.

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LIST OF PUBLICATIONS AND AWARDS

Paper published in peer reviewed journal

Norfazlinayati O., Talib Z. A., Nik Salleh N.G., Shaari A. H., and Mohd Hamzah H. Synthesis and Characterization of Polyvinyl alcohol/Polyaniline/Functionalized Multiwalled Carbon Nanotube Composite by Gamma Radiation Method. *International Journal of Nanoelectronics and Materials*. Volume 11, No. 4, 2018 [435-448]

Mohd Hamzah Harun, Nik Ghazali Nik Salleh, Mohd Sofian Alias, Mahathir Mohamed, Mohd Faizal Abdul Rahman, Mohd Yusof Hamzah, Khairil Nur Kamal Umar and **Norfazlinayati Othman**. Removal of Oxidative Debris from Chemically Functionalized Multi-Walled Carbon Nanotube (MWCNT) *International Journal of Nanoelectronics and Materials.* Volume 11, No. 1, 2018 [43-48]

Mohd Hamzah Harun, Zainal Abidin Talib, Nor Azowa Ibrahim, Josephine Liew Ying Chyi, Nik Ghazali Nik Salleh, Mohd Sofian Alias, Mahathir Mohamed and **Norfazlinayati Othman**. Characterization of Transparent Hydrophobic Coating with Silica and Graphene Oxide Fillers by Sol-Gel Method. *International Journal of Nanoelectronics and Materials.* Volume 11, No. 3, 2018 [283-292]

Paper presented at conference

Norfazlinayati O., Talib Z. A., Salleh N.G., Shaari A. H. and Mohd Hamzah H.2. *Effect of ¥-radiation on dispersion of carbon nanotubes in poly(vinyl-alcohol) as a polymer Matrix*. Paper presented at Nuclear Science, Technology and Engineering Conference (NUSTEC), UNITEN. Mei 2012

Mohd Hamzah Harun, Mohd Sofian Alias, Mahathir Mohamed, Mohd Yusof Hamzah, Mohd Faizal Abdul Rahman, Nik Ghazali Nik Salleh, Kamarudin Hashim, Mohamed Iqbal Shueb, **Norfazlinayati Othman**, Muhamad Taufik Abdul Jalil and Mohamad Azrul Adnan. *Observation of Locally Produced Of High Purity Carbon Nanotubes by Modified Chemical Vapor Deposition Technique*. Paper presented at 11th International Annual Symposium on Sustainability Sceince and Management, UMT. July 2012

Mohd Hamzah Harun, Zainal Abidin Talib, Nik Ghazali Nik Salleh, Mahathir Mohamed, Mohd Sofian Alias, Nor Azowa Ibrahim, Josephine Liew Ying Chyi and **Norfazlinayati Othman**. *Transparent hydrophobic coating by sol gel method*. Paper presented at Seminar R&D Nuklear Malaysia, MINT. November 2016

Paper submitted consider for publication

Norfazlinayati O., Talib Z. A., Nik Salleh N.G., Shaari A. H., and Mohd Hamzah H. Optical Characterization of Pani/Functionalized CNT/Pva Nanocomposites Induced by Gamma Irradiation. *International Journal of Nanoelectronics and Materials. 21st March 2019*

Mohd Hamzah Harun, **Norfazlinayati Othman**, Mohd Sofian Alias, Mahathir Mohamed, Khairil Nur Kamal Umar and Mohd Faizal Abdul Rahman. Influence of Gamma Irradiation on the Electrical Conductivity And Dielectric Properties of Polypyrrole Conducting Polymer Composite Films *International Journal of Nanoelectronics and Materials. 16th April 2019*

Award

Gold Medal for 'Functional Multiwalled Carbon nanotube as nano-adsorbent for industrial water treatment' by Mohd. Faizal Abdul Rahman,Mohd. Hamzah Harun, Khomsatun Abu Bakar, Mohd Sofian Alias, Mahathir Mohamed, Mohd Yusof Hamzah, **Norfazlinayati Othman** and Natasha Isnin at the Ekspo Inovasi Islam 2012, 20-21 October 2012, USIM.

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Polyaniline/multiwalled carbon nanotubes (PANI/MWCNT) nanocomposite is one type of materials that has properties that are unique and improved as compared to the nature of the individual original materials. However, the fabrication process to apply the nanocomposite to the industry is quite complicated especially in producing a versatile free standing film. The hindrances that are encountered included inhomogeneous composite film, high cost, unclean procedure, difficult to dispose chemical residues and limitation to scale up for mass commercialization. These are among the main factors that scientists and researchers need to resolve before the material can be used commercially. After evaluating different synthesizing techniques, it was decided that gamma-radiation method has the potential to be a promising eco-friendly technique where no oxidizing agent or any surfactant agent was needed and the purity of products is maintained. In this research project, a free standing film of polyaniline (PANI) and polyaniline/functionalized-multiwalled carbon nanotubes (PANI/f-MWCNTs) with different f-MWCNT composition were synthesized in the PVA matrix by γ-radiation method. All films were exposed to gamma-rays from 10 to 50 kGy. The structural, morphological, chemical composition, chemical bonding, electronic transition, optical energy band gap, degree of disorder of band tail and thermal properties of PVA/PANI composite film and PVA/PANI/f-MWCNT nanocomposite films before and after irradiated by gamma-radiation were characterized by X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray (EDAX), Fourier Transform Infrared Spectroscopy (FTIR), UV-Visible (UV-Vis) Spectrophotometer and Thermogravimetric Analysis (TGA). Results from all characterizations indicated that synthesis of PVA, PANI and f-MWCNT through the gamma-radiation was successful in producing a homogeneous free standing film of PVA/PANI composite film and PVA/PANI/f-MWCNT nanocomposite films. The structural, morphological, optical energy band gap, degree of disorder of the band tail and thermal properties of these composite and nanocomposite films was significantly improves as compared to other methods.