UNIVERSITI TEKNOLOGI MARA

PREPARATION AND CHARACTERIZATION OF STRETCHABLE PEDOT: PSS/EG/WPU FABRIC FOR WEARABLE SENSOR APPLICATIONS

AYU NATASHA BINTI AYUB

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science
(Materials Science and Technology)

Faculty of Applied Sciences

December 2022

ABSTRACT

It is a necessity to invent a tool that can help in health monitoring sensors especially in breathing mechanisms because of the third agenda of sustainable development goals (SDG), which is good health and wellbeing. The presence of conducting polymer opens a way to producing electroconductive and stretchable wearable sensors. Over the years, many reports on Poly(3,4ethylenedioxythiophene): poly (styrene sulfonate) (PEDOT: PSS) as a wearable sensor have been published. It is due to its adjustable electrical conductivity, thermal stability, high optical transparency, low-cost monomer, light weight, and fast preparation. However, the low conductivity of pristine PEDOT: PSS became the main limitation. Therefore, this study focuses on improving the electrical conductivity of PEDOT: PSS by using ethylene glycol (EG) as a secondary dopant. Besides, PEDOT: PSS is still lack of stretchability and has poor adhesion when coating with fabric substrate. Following this, Waterborne polyurethane (WPU) was introduced as the polymeric additive that helps in the stretchability enhancement and improves the surface adhesion of PEDOT: PSS. The conductive fabric is produced by immersing the bare fabric into the mixture solution containing blended PEDOT: PSS, and WPU. The effectiveness of EG and WPU to improve conductivity and stretchability properties was confirmed when the conductivity values and tensile strength of PEDOT: PSS/EG/WPU fabric were reached at 2.91 x 10^{-3} Scm^{-1} and 31.09 MPa, respectively. The PEDOT: PSS/EG/WPU fabric is then exposed to the abrasion testing to prove that good surface adhesion occurred between the conducting polymer and the fabric substrate after WPU was added. The findings from this study unravel the brittle mechanism of PEDOT: PSS and the mechanism between PEDOT: PSS and WPU. Besides, it contributes to the production of stretchable and conductive fabrics especially in wearable sensor applications.

ACKNOWLEDGEMENT

In the name of Allah, the most gracious and the most merciful. First and foremost, I am thankful to Almighty ALLAH for giving me strength, knowledge, ability, and opportunity to undertake this study and complete it satisfactorily.

Secondly, my gratitude and thanks go to my teacher and supervisor, Assoc. Prof. Dr. Mohd Muzamir bin Mahat, and Co-supervisors Assoc. Prof. Dr. Noor Najmi binti Bonnia and Puan Safina binti Sulaiman, whose worthy guidance and professional attitude are appreciable in completing this writing. His and her guidance and advice carried me through all the stages of writing my project. I would like to thank my colleagues and friends for helping me through brilliant comments and suggestions and creating enjoyable moments throughout this challenging journey.

I also owe my sincere thanks to Yayasan Terengganu for trusting me and offering me a scholarship to finish my MSc. Without their organization, I might be in trouble giving my full focus on this study. I would also like to give special thanks to my parents, especially my mother, Puan Rohani binti Kotai Meah for her continuous support and understanding when undertaking my research and writing my project. Your prayer for me were what sustained me this far.

This thesis is dedicated to the loving memory of my very dear family as a whole and friends for their vision and determination to educate me. This piece of victory is dedicated to all of you. Finally, I want to thank myself for not giving up, especially on the days that I don't feel like myself. Here I am, still fighting, and I am grateful for that. Alhamdulilah.

TABLE OF CONTENTS

		Page
CONFIRMATION BY PANEL OF EXAMINERS		**ii**
AUTHOR'S DECLARATION		**iii**
ABSTRACT		**iv**
ACKNOWLEDGEMENT		**v**
TABLE OF CONTENTS		**vi**
LIST OF TABLES		**ix**
LIST OF FIGURES		**x**
LIST OF ABBREVIATIONS		**xiii**

CHAPTER ONE INTRODUCTION

1.1	Research background	1
1.2	Problem statements	3
1.3	Significance of study	3
1.4	Research objectives	4
1.5	Scopes of study	5
1.6	Thesis structure	6

CHAPTER TWO LITERATURE REVIEW

2.1	Conducting polymer	7
2.2	Poly(3,4-ethylenedioxythiophene) (PEDOT)	10
	2.2.1 Technique of synthesis PEDOT	12
2.3	Poly (3,4-ethylenedioxythiophene): polystyrene sulfonate (PEDOT: PSS)	22
2.4	Conductivity enhancement of PEDOT: PSS	24
2.5	Technique for producing conductive fabric	28
2.6	Brittleness and adhesion behaviour PEDOT: PSS fabric	30
	2.6.1 Polyurethane (PU) as polymeric additives	30
2.7	Application of stretchable PEDOT: PSS fabric	32
2.8	Characterization	33
	2.8.1 Electrochemical Impedance Spectroscopy (EIS)	34
	2.8.2 Tensile test	36
	2.8.3 Abrasion test	38
	2.8.4 Scanning Electron Microscopy (SEM)	39
	2.8.5 X-Ray diffraction (XRD) technique	42
	2.8.6 Fourier Transform Infrared (FTIR)	44

CHAPTER THREE METHODOLOGY

3.1	Introduction	46
3.2	Materials and chemicals	46
3.3	Sample preparation	47

	3.3.1	Preparation of PEDOT: PSS	47
	3.3.2	Preparation of doped and undoped PEDOT: PSS	48
	3.3.3	Preparation of PEDOT: PSS/PU	49
	3.2.4	Preparation of PEDOT: PSS/PU fabric	49
3.4	Characterization		50
	3.4.1	Electrochemical Impedance Spectroscopy (EIS)	50
	3.4.2	Tensile test	50
	3.4.3	Bending test	51
	3.4.4	Abrasion test	51
	3.4.5	Scanning Electron Microscopy (SEM)	52
	3.4.6	X-ray diffraction (XRD)	52
	3.4.7	Fourier Transform Infrared (FTIR)	53

CHAPTER FOUR RESULT AND DISCUSSIONS

4.1	Introduction		55
4.2	Synthesis of PEDOT: PSS		55
	4.2.1	EIS analysis of commercial and synthesized PEDOT: PSS	56
	4.2.2	FTIR analysis of commercial and synthesized PEDOT: PSS	57
4.3	The effect of different amount of PSS in the PEDOT: PSS solution		58
	4.3.1	The effect of water absorption of PEDOT: PSS fabric	58
	4.3.2	The conductivity behaviour of PEDOT: PSS fabric with increasing amount of PSS	61
	4.3.3	The XRD analysis of PEDOT: PSS fabric with increasing amount of PSS	63
4.4	The different exposure temperature to the PEDOT: PSS fabric		65
	4.4.1	Conductivity measurement	65
	4.4.2	Relationship of the conductivity and bending length of PEDOT: PSS fabric	67
	4.4.3	The morphology of PEDOT: PSS fabric when exposed to different temperature	69
4.5	The effect of the ethylene glycol (EG) to the PEDOT: PSS fabric		70
	4.5.1	EIS analysis of PEDOT: PSS fabric at different temperature	71
	4.5.2	XRD analysis of PEDOT: PSS fabric at different temperature	73
	4.5.3	SEM images	74
4.6	The effect of Waterborne polyurethane W(PU) to the PEDOT: PSS fabric		74