2004

Synthesis, characterisation and applications of conducting polymer coated textiles

Jian Wu
University of Wollongong

SYNTHESIS, CHARACTERISATION AND APPLICATIONS OF CONDUCTING POLYMER COATED TEXTILES

A thesis submitted in fulfillment of the requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

JIAN WU, B.Sc.

Department of Chemistry

May 2004

To my parents for their encouragement,

especially in memory of my father

To my husband Xifa Yang and my daughter Wenxin Yang

for their support and patience

THESIS CERTIFICATION

I, Jian WU, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the Department of Chemistry, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Jian WU

May 2004

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my supervisors Professor Gordon G. Wallace and Dr. Dezhi Zhou for their enthusiastic supervision and encouragement through this work.

I also deeply appreciate helpful assistance of the staff and students at the Intelligent Polymer Research Institute, especially Professor Leon Kane-Maguire, Associate Professor Geoff Spinks, Dr. Chee Too, Dr. Peter Innis, Dr. Toni Campbell, Dr. Syed Ashraf, Dr. Jie Ding, Dr. Jun Chen, Dr. Simon Moulton, Dr. Norman Barisci and Dr. Benny Kim. Also, I would like to thank Dr. Violeta Misoska and Dr. Jiazhao Wang for their help in running samples on the SEM. Thanks also to Miss Jenny Causley and Dr. K. Konstantinov for their help on HPLC and TGA analysis. I would like to address the help and support of Binbin Xi, Yanzhe Wu, Chunming Yang and Phil Smugreski. I would like to acknowledge the technical assistances of S. Butler and P. Sarakinotis.

I am grateful to the Intelligent Polymer Research Institute and CSIRO for the award of a postgraduate scholarship. Finally, I would like to acknowledge Dr. Mark Loony and Peter Waters from CSIRO TFT for their technical advice and assistance.

PUBLICATIONS

1 J. Wu, D. Zhou, C. Too and G. G. Wallace, "Conducting Polymers Coated Textile" ICSM 2004 and *Synthetic Metals* (Submitted).

2 "Electromechanical actuators based on fibre and fabrics" G. G. Wallace, J. Wu, V. Aboutanos, G. M. Spinks and D. Zhou, SPIE (2001) [4329-55].

3 G.G. Wallace, G. M. Spinks, J. Wu and D. Zhou, "Electrofunctional materials: strain gauges and actuators in fabric structures (Invited paper), SPIE, Smart Materials and MEMS (2000) [4234-4235].

ABSTRACT

This thesis describes preparation and characterisation of a range of novel conducting polymer coated textiles, which have potential in applications such as static dissipation, EMI shielding, heating elements, composite structures and many military applications.

Conducting polypyrrole coated textiles such as nylon Lycra and polyester fabrics have been synthesised using different approaches (Chapter 3). The present study concentrates on preparation of conducting polypyrrole coated textile using an *in-situ* polymerisation method. A range of characterisation techniques for the inherently conducting polymer (ICP) coated fabrics were used: the stability of the surface resistivity, cyclic voltammetry, Scanning Electron Microscopy (SEM), UV-Vis spectroscopy and Thermogravimetric analysis (TGA). It was found that the PPy-coated nylon Lycra fabric could be used as a wearable strain gauge. The strain gauge characteristics have been investigated using both an Instron machine and a "SmartMotor".

The use of molecular templates to facilitate the polymerisation and the integration of inherently conducting polymers (ICPs) into textiles has been investigated (Chapter 4). Poly(2-methoxyaniline-5 sulfonic acid) or [PMAS] is a water-soluble, fully sulfonated polyaniline that has been used as molecular template. In the first step – "dyeing" of PMAS into the textile, the effect of fabric pre-treatment, solution pH as well as solution temperature have been investigated. In the second step the effects of the ratio of PMAS to aniline, the ratio of aniline to ammonium persulfate and the polymerisation temperature on the polymerisation reaction have also been studied. Characterisation of the templated polyaniline coated fabric prepared using the above "Two step" process has been undertaken (Chapter 4). The stability of the conductivity, cyclic voltammetry, UV-Vis spectra, SEM studies, TGA analysis and strain gauge characteristics have been determined. Results indicate that templated PAn-coated wool nylon Lycra can be used as the strain gauge as tested with either the Instron machine or "SmartMotor".

Conducting polymer coated textile fabrics are easily prepared and integrated into truly wearable clothing and garments to create strain sensors with a wide dynamic range. Functional wearable textile sensing systems can monitor human motion, provide immediate bio-feedback to the wearer without changing the properties and functions of the fabric material and with no interference to normal human body motion. This innovative technique can be widely used for injury prevention, rehabilitation, sport technique modification and medical treatment. It will have a number of further potential applications to be used for daily living, work and recreation in the future.

ABBREVIATIONS

μ	micro
°C	degree Celsius
A^-	anion
ABS	absorbance
Ag/AgCl	silver/silver chloride reference electrode
CEP	conducting electroactive polymer
cm	centimeter
CV	cyclic voltammetry
ΔE	potential difference
E	potential
$E_{p(a)}$	anodic peak potential
$E_{p(c)}$	cathodic peak potential
EB	emeraldine base
ES	emeraldine salt
g	gram
HPLC	high performance liquid chromatography
I	current
ITO	Indium-tin oxide
K	Kelvin
LB	leucoemeraldine base
M	molar
mA	milliampere(s)
mV	millivolt

n	number of electron
NDSA	1,5-naphthalenedisulfonic acid tetrahydrate
PAn	polyaniline
PB	pernigraniline base
PMAS	poly(2-methoxyaniline-5-sulfonic acid)
PPy	polypyrrole
PS	pernigraniline salt
Pt	platinum
R	resistance
RVC	reticulated vitreous carbon
sec	second
SPAN	sulfonated polyaniline
SEM	scanning electron microscopy
TGA	Thermogravimetry analysis
UV-Vis	ultraviolet-visible

LIST OF FIGURES AND TABLES

1. Figures

2. Tables

CONTENTS