UNIVERSITI PUTRA MALAYSIA

ELECTRICAL CHARACTERISTICS AND THERMAL DIFFUSIVITY OF POLYPYRROLE-BASED CONDUCTING POLYMER

NORFAZLINAYATI OTHMAN

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ELECTRICAL CHARACTERISTICS AND THERMAL DIFFUSIVITY OF POLYPYRROLE-BASED CONDUCTING POLYMER

By

NORFAZLINAYATI OTHMAN

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

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DEDICATED TO MY HUSBAND AND PARENTS

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

ELECTRICAL CHARACTERISTICS AND THERMAL DIFFUSIVITY OF POLYPYRROLE-BASED CONDUCTING POLYMER

By

NORFAZLINAYATI BINTI OTHMAN

September 2009

Chairman: Associated Professor Zainal Abidin Talib, PhD

Faculty : Science

Conducting polymer materials based on Polypyrrole (PPy) and Polypyrrole/Montmorillonite (PPy/MMT) clay composite were synthesis by using chemical reaction process with iron (III) chloride ($FeCl_3$) as oxidizing and dopant agent. During the mixing process of PPy, the solution changed from transparent to dark green indicating that the polymerization process took place instantaneously. The resulting powder was filtered, washed, grounded and press into pellet. The structural, thermal and electrical properties of the conducting polymer and conducting polymer composite were then investigated.

The structure of the samples was analyzed by using X-ray diffractometer (XRD) with the scanning was carried out at 2θ of 15° to 35° for doped PPy and at 2θ of 2° to 35° for PPy/MMT clay composite. The XRD spectra showed dopant and filler effect with

appearance of broad peak at around the 2θ value of 25 to 26° corresponded to highly disordered parts and new peak at low angle at around the 2θ value of 5 to 6° corresponded to successfully intercalation of PPy chain in the galleries of MMT clay. It was observed that all the peak angles shifted and the full width at half maximum (FWHM) values are difference with increasing in dopant concentrations and filler percentages indicate the strong interaction between dopant and filler with the conjugated polymer. The interchain separation showed good agreement with published data.

The thermal diffusivity of PPy and PPy/MMT clay composite was analyzed at room temperature by using photoflash technique. The results showed that the thermal diffusivity, α_c for PPy increased with increasing dopant concentrations with α_c from 1 to 4 x 10^{-3} cm^2s^{-1}. On the other hand, the thermal diffusivity for PPy/MMT clay composite decreased with increasing MMT clay percentages loading in the PPy which is from 3 to 1 x 10^{-3} cm^2s^{-1} indicating some electron motion interruption. It also observed that a correlation between the thermal diffusivity and electrical conductivity for all the samples showed a similar trend.

The electrical conductivity studies were done by using four point probe technique and two probe technique with temperature dependence. At room temperature, the *I-V* characteristic for both techniques showed a linear behavior and obeys the Ohm's law. From the results, the conductivity was calculated and showed a strongly dependent on dopant concentrations and filler percentages. To get more insight into the transport mechanism, various models have been used to fit the data from conductivity plots.

At low temperature range (100-300K), the charge carrier mechanism was dominated by 3-D variable range hopping, VRH transport. However, the electrical conduction transport is also apparently based on hopping of polarons. With regard to high temperature dependence (300-380K), the conductivity showed the same trend with observation in low temperature studies. Nevertheless, the electrical conduction showed a contribution of polarons and bipolarons mechanism which may due to some transformation at energy transport in the materials.

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

SIFAT-SIFAT ELEKTRIK DAN RESAPAN TERMA BAGI POLIMER PENGALIR ELEKTRIK DARI POLIPIRROLE

Oleh

NORFAZLINAYATI BINTI OTHMAN

September 2009

Pengerusi : Profesor Madya Zainal Abidin Talib, PhD

Fakulti : Sains

Polimer konduksi berasaskan pada bahan Polipirrole (PPy) dan Polipirrole/Montmorillonite (PPy/MMT) komposit telah disintesis dengan menggunakan proses tindakbalas kimia dengan iron (III) chloride ($FeCl_3$) sebagai agen pengoksidaan dan dopan. Semasa proses percampuran bagi PPy, sebatian telah bertukar dari jernih ke hijau gelap menandakan proses pempolimeran berlaku serta merta. Hasil serbuk kemudianya dituras, dibasuh, dihaluskan dan dimampatkan menjadi pelet. Sifat struktur, terma dan elektrik bagi polimer konduksi dan polimer konduksi komposit ini telah dikaji.

Stuktur sample-sampel ini telah dianalisis dengan menggunakan pembelauan sinar-X (XRD) pada sudut 2θ ialah 15° hingga 35° bagi PPy dan 2° hingga 35° bagi PPy/MMT

clay composite. Spektra XRD menunjukkan kesan dopan dan penyendat dengan kemunculan puncak lebar iaitu pada 2θ ialah 25 hingga 26° yang merupakan bahagian yang sangat tidak tersusun dan puncak yang baru disudut rendah iaitu pada 2θ ialah 5 hingga 6° yang menujukkan rantaian PPy telah masuk ke dalam galeri tanah liat MMT. Dapat diperhatikan bahawa semua puncak sampel telah berganjak dan separuh maksimum kelebaran puncak (FWHM) telah berubah-ubah dengan peningkatan kepekatan dopan dan peratusan tanah liat MMT menandakan tindak balas yang kuat diantara dopan dan penyendat dengan polimer. Nilai jarak pemisah rantaian menunjukan persamaan dengan nilai yang telah diterbitkan oleh penyelidikan yang terdahulu.

Proses resapan terma bagi PPy dan PPy/MMT komposit telah dianalisis pada suhu bilik dengan menggunakan teknik fotokilat. Keputusannya menunjukan resapan terma, α_c bagi PPy meningkat dengan peningkatan kepekatan dopan iaitu α_c dari 1 hingga 4 x 10^{-3} cm^2s^{-1}. Manakala, resapan terma bagi PPy/MMT komposit menurun dengan peningkatan peratusan tanah liat MMT didalam PPy iaitu α_c dari 3 hingga 1 x 10^{-3} cm^2s^{-1}dimana ia menandakan pergerakan elektron terganggu. Walaubagaimanapun, perkaitan antara resapan terma dan kekonduksian elektrik bagi kesemua sampel menunjukan bentuk yang sama.

Kajian kekondusian elektrik tdijalakan dengan meggunakan teknik penduga empat titk dan penduga dua dalam mengkaji sifat permukaan dan pukal dengan penggantungan suhu. Pada suhu bilik, sifat *I-V* bagi kedua-dua teknik telah menunjukan garis lurus dan menepati hukum Ohm. Melalui keputusan ini, kekonduksian elektrik telah dikira dan menunjukkan bahawa sangat bergantung kepada kepekatan dopan dan peratusan penyendat. Untuk mengkaji lebih jauh lagi tentang pergerakan mekanisma, pelbagai modul telah digunapakai untuk memandankan data dari plot kekonduksian.

Pada julat suhu rendah (100-300K), mekanisma cas pembawa telah didominasi oleh pergerakan pelbagai julat lompatan (VRH). Walaubagaimanapun, pergerakan kekonduksian elektrik juga kelihatan melibatkan lompatan polaron. Berkenaan dengan suhu tinggi pula (300-380K), kekonduksiannya menunjukkan corak yang sama dengan pemerhatian pada suhu rendah. Namun begitu, kekonduksian elektriknya menunjukkan penglibatan mekanisma polaron dan bipolaron dimana ia mungkin disebabkan oleh perubahan pergerakan tenaga dalam bahan tersebut.

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I certify that an Examination Committee met on date of viva to conduct the final examination of Norfazlinayati Hj. Othman on her Master of Science thesis entitled "Electrical Characteristics and Thermal Diffusivity of Polypyrrole Based Conducting Polymer" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination are as follows:

Zaidan Abd. Wahab, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

W. Mahmood Mat Yunus, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

W. Mohd. Daud W. Yusoff, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Muhammad Deraman, PhD
Professor
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
(External Examiner)

Bujang Kim Huat, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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

Zainal Abidin Talib, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Anuar Kassim, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 8 April 2010

DECLARATION

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

NORFAZLINAYATI HJ. OTHMAN

Date: 14 September 2009

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES