FABRICATION AND CHARACTERIZATION OF DYE-SENSITIZED SOLAR CELLS INCORPORATING POLYMER ELECTROLYTE LIQUID CRYSTAL SYSTEM

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RESEARCH REPORT SUBMITTED IN PARTIAL

FULFILLMENT OF THE REQUIREMENT FOR THE

DEGREE OF MASTER OF ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF MALAYA

KUALA LUMPUR

2013

ORIGINAL LITERARY WORK DECLARATION

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Name of Degree: Master of Engineering in Materials Engineering and Technology

Title of Research Report: Fabrication and characterization of Dye-sensitized Solar Cells

Incorporating Polymer Electrolyte Liquid Crystal System

Field of Study: Renewable Energy

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ABSTRACT

Gel polymer electrolytes are defined as solid ion conductors formed by dissolving salt in high molecular weight polymers using a balanced ratio in order to form a gel structure. They are typically found in applications such as fuel cells, lithium ion batteries and solar cells. In this research work, the potential of a gel polymer electrolyte doped with nematic liquid crystal, for solar cell applications are discussed. Polymer electrolytes have attracted a lot of attention due to ease of fabrication with low cost, minimum side reactions, long shelf-life, high ionic conductivity and excellent thermal stability. In this thesis, an approach to produce a high electrical conductivity gel polymer electrolyte thin film is presented. Here, a novel polymer electrolyte liquid crystal system consisting of polyvinyl alcohol (PVA), potassium iodide (KI) and 4-Cyano-4'-pentylbiphenyl (5CB) nematic liquid crystal (LC) has been fabricated. First the inclusion of the liquid crystal into the polymer electrolyte was confirmed by using the optical polarizing microscope where the phase transition temperature of the liquid crystal can also be determined. The ionic conductivity is characterized by using the impedance spectroscopy and four point probe method. The ionic conductivities of the sample prepared by two methods will be compared and the temperature dependence of the ionic conductivity will also be elucidated. The highest ionic conductivity achieved is 2.82×10^{-3} S/cm which is 66.9% higher than then one without the inclusion of liquid crystal. The thermal analysis of the sample will also be given using the differential scanning calorimetry. The phase transition temperature of the liquid crystal and the glass transition temperature of the polymer can be obtained from this characterization. Finally, the band gap of this material was obtained from cyclic voltammetry using a thin film of the mixture which was spin-coated onto ITO substrate. The curve obtained from the cyclic voltammetry (CV) test was used to determine the highest occupied molecular orbital (HOMO), lowest unoccupied molecular orbital (LUMO) and electrical band gap

(E_g) of the material. The LC-doped polymer electrolyte showed a band gap of 1.557 eV whereas the LC-undoped polymer electrolyte showed a band gap of 1.657 eV. For a material to be used as a material in solar cell application, a band gap of 1.5 eV or less or less is required. Thus the narrowing of the band gap after the inclusion of liquid crystal shows the suitability of the material to be used as one of the components for solar cell.

ABSTRAK

Elektrolit polimer gel adalah ditakrifkan sebagai konduktor ion pepejal yang dihasilkan dengan melarutkan garam ke dalam polimer berat molekul tinggi menggunakan nisbah yang seimbang untuk membentuk satu struktur gel. Ianya biasa ditemui di dalam aplikasi seperti sel bahan api, bateri litiumion dan sel solar. Dalam kerja penyelidikan ini, potensi a elektrolit polimer gel didopkan dengan cecair hablur nematik, untuk aplikasi sel solar akan dibincangkan. Kekonduksian ionik tertinggi yang dicapai adalah 2.82×10^{-3} S/cm iaitu 66.9% lebih tinggi daripada elektrolit polimer yang tiada mengandungi cecair hablur. Elektrolit polimer telah menarik banyak perhatian disebabkan oleh proses pembikinan yg mudah dan kos yang rendah, tindak balas sampingan minimum, hayat simpanan yang lama, kekonduksian ionik yang tinggi, dan kestabilan haba yang sangat baik. Di dalam tesis ini, satu pendekatan untuk menghasilkan elektrolit polimer gel yang mempunyai kekonduksian elektrik yang tinggi akan dibentangkan. Di sini, sistem cecair hablur elektrolit polimer baharu, yang terdiri daripada polivinil alkohol (PVA), kalium iodida (KI) dan 4-Cyano-4'-pentylbiphenyl (5CB) cecair hablur nematik telah disediakan. Yang pertama di kemasukan cecair hablur ke dalam elektrolit polimer telah disahkan dengan menggunakan mikroskop optik polarisasi di mana suhu peralihan fasa cecair hablur juga boleh ditentukan. Kekonduksian ionik ditentukan dengan menggunakan spektroskopi impedans dan probe empat pin. kekonduksian ionik sampel yang disediakan oleh dua kaedah akan dibandingkan dan kebergantungan suhu kekonduksian ionik juga akan dijelaskan. Analisa terma sampel juga akan diberikan menggunakan kalorimetri pengimbasan kebezaan. Suhu peralihan fasa cecair hablur dan suhu peralihan kaca daripada polimer boleh diperolehi daripada pencirian ini. Akhir sekali, laung jalur bahan ini telah diperolehi daripada voltammetri berkitar menggunakan satu filem nipis campuran itu yang telah di spin-coat ke atas substrat ITO. Lengkung yang diperolehi dari eksperimen

voltammetri berkitar telah digunakan untuk menentukan orbital molekul tertinggi terisi (HOMO), orbital molekul terendah tidak terisi (LUMO) dan luang jalur elektrik (Eg) bahan tersebut. Elektrolit polimer yang didopkan dengan cecair hablur menunjukkan luang jalur 1.557 eV manakala elektrolit polimer yang tidak didopkan menunjukkan luang jalur sebanyak 1.657 eV. Untuk sesuatu bahan digunakan di dalam sel solar, luang jalur sebanyak 1.5 eV atau kurang diperlukan. Oleh itu, pengurangan luang jalur selepas penambahan cecair hablur menunjukkan kesesuaian bahan tersebut untuk digunakan sebagai salah satu komponen di dalam sel solar.

Acknowledgement

First and foremost, I would like to express my deepest gratitude to my supervisor, Dr. Suhana Mohd Said. Her wide knowledge and logical way of thinking have been of great value for me and as well as her understanding, encouraging and personal guidance have provided a good basis for the present thesis. Despite my lack of knowledge on the subject, she patiently explained every single thing.

I thank my fellow lab mates in LCD Lab for the stimulating discussions we had and for supporting me during my ups and downs. These helped me to get through graduate school.

Last but not the least; I would like to thank my family, without which I could have not started my master degree in the first place and for also supporting me spiritually throughout my life.

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ABBREVIATIONS AND NOMENCLATURE

CO_2	Carbon dioxide
ppm	Parts per million
DSSCs	Dye-sensitized solar cells
LCs	Liquid crystals
Si	Silicon
TiO_2	Titanium dioxide
I_3^-/I^-	Triiodide/iodide
PCE	Power conversion efficiency
NaI	Sodium iodide
I_2	Iodine
OPM	Optical polarizing microscope
NMR	Nuclear magnetic resonance
UV	Ultra-violet
IR	Infra-red
PVA	Poly(vinyl alcohol)
5CB	4'-pentyl-4-biphenylcarbonitrile
KI	Potassium iodide
DMSO	Dimethyl sulfoxide
DSC	Differential scanning calorimetry
IS	Impedance spectroscopy
CV	Cyclic voltammetry
LUMO	Lowest unoccupied molecular orbital
HOMO	highest unoccupied molecular orbital
TBAHFP	Tetra(n-butyl)ammonium hexafluorophosphate
THF	Tetrahydrofuran
PDLC	Polymer dispersed liquid crystal
PELC	Polymer electrolyte liquid crystal

E_a	Activation energy
T_g	Glass transition temperature