



FABRICATION AND CHARACTERIZATION OF POLY (ETHYLENE OXIDE) FOR PHOTO-ELECTRONIC DEVICES

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ABSTRACT

Ionic conducting polymer thin films consist of poly (ethylene oxide)-chitosan blend, ammonium iodide NH_4I and iodine crystal I_2 were prepared by solution cast technique at room temperature. To improve the mechanical properties of the polymer thin film, chitosan ($\text{C}_6\text{H}_{11}\text{NO}_4$) is added to the electrolyte, ammonium iodide (NH_4I) is added to supply charge carrier and iodine crystal (I_2) added to provide redox couple. From the complex impedance plot, the bulk resistance R_b was determined and the conductivity of the thin film was calculated. The highest conductivity was observed for the polymer blend containing, 45 wt % ammonium iodide which yield at $(1.18 \pm 0.7) \times 10^{-5} \text{ S cm}^{-1}$ by Impedance spectroscopy. Optical characterization of the highest conducting PEO and chitosan ionic conductor shows at the corresponding wavelength, 330 nm that the thin film has a band gap of 3.7 eV. The polymer thin films were smooth, flexible and transparent. Thin film polymers are more favourable for photo-electronic applications.

Keywords: photo-electronic, polymer, thin film, ionic conductivity, semiconductor.

INTRODUCTION

Conducting polymers have been widely investigated and applied in various applications such as sensors, super capacitors, energy storage devices, solar cell and others. They are conductive materials and can undergo fast redox reactions [1]. The conductive polymers use as a counter electrode function as an electron transfer agent as well as the regenerator of redox couple. Conducting polymers have been studied most intensively due to their easy synthesis, high conductivity, environmental stability, cost effectiveness and unique electrochemical redox properties [2]. During the last decade, semiconducting polymers have been developed as a novel class of optoelectronic materials with applications including both light-emitting diodes and photovoltaics. Conducting polymers are not only exhibiting conduction properties, but also have specific electronic, magnetic, wetting, optical, mechanical and microwave-absorbing properties. They combine the electronic and optical properties of semiconductors with the mechanical and physical properties of polymers. This is motivated in large part by their promise of low cost, less toxic manufacturing methods, tunable optical properties, and the possibility of lightweight, flexible large area panels. The research work on polymer electrolyte dates back to the pioneering processing of Wright and co-worker, who first reported the ionic conduction in poly (ethylene oxide) (PEO) and alkali metal salt complexation [3]. Poly (ethylene oxide) (PEO) is one of the most studied polymer hosts for polymer electrolyte formation. It is a semi crystalline material (about 70-85% crystallinity) at room temperature and they remain present in an amorphous elastomeric phase. The partial crystallinity carries over to many of the polymer-salt complexation [4]. The advantages are the capability of

PEO to gel in situ is low cost and also used in combination with other polymers in order to enhance their possibility and biocompatibility. The disadvantage of PEO is poor mechanical properties that can overcome this problem by adding some biopolymer such as Chitosan to the electrolyte [5].

EXPERIMENTAL PROCEDURE

Ion conducting polymer films were prepared by the solution cast technique. The polymer electrolyte used in this research was a PEO-Chitosan blend, complexed with NH_4I with excess I_2 added. 0.25 g PEO powder ($M.W=1.0 \times 10^5 \text{ g/mol}$ from Aldrich) and 0.25 g of chitosan (FLUKA) with medium molecular weight were dissolved in 1% acetic acid (CH_3COOH) solution. Ammonium salt (NH_4I) was added to the solution in different amounts (wt %) weight ratios to supply the charge carriers for the polymer electrolytes. The mixture was continuously stirred until complete dissolution of the salt inside the beaker. To get the redox couple, some iodine crystals I_2 were added to each of the solutions containing different amounts of NH_4I and mixed thoroughly. Subsequently, solutions were cast into plastic Petri dish and allow evaporating in room temperature to formed ionic conducting polymer thin films.

RESULTS AND DISCUSSIONS

Impedance measurement of ionic conductivity polymer blends

Impedance spectroscopy was measured using the HIOKI 353-01 LCR Hi-Tester interfaced to a computer with frequency from 50 Hz to 1Hz. The software calculates the real (Z_r) and imaginary (Z_i) parts of the



impedance to obtain the bulk resistance (R_b). The electrical conductivity of the sample was calculated using the Equation (1).

$$\sigma = \frac{t}{R_b A} \quad (1)$$

Where σ is the conductivity, t is the sample thickness, A is the area of the contact and R_b is the bulk resistance. Table-1 shows the electrolyte composition of the Chitosan and ammonium iodide and its conductivity at room temperature which was within the range of all solid polymer conductivities (10^{-5} - 10^{-7} Scm^{-1}) at room temperature [6]. Figure-1 shows the Cole-Cole plot for the highest conducting sample. The figure also shows how the bulk resistance R_b was determined.

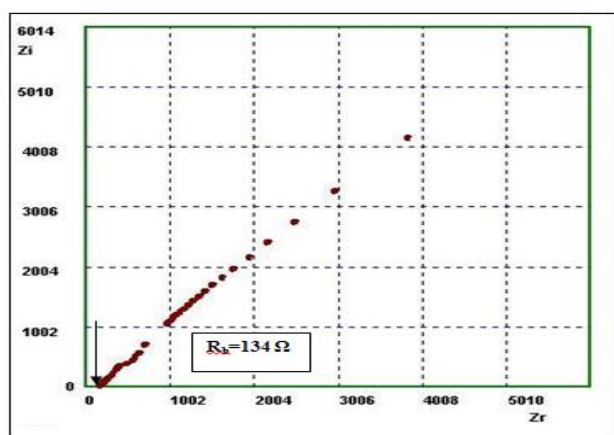


Figure-1. The COLE-COLE plot showing bulk resistance R_b of the best sample containing 45 % ammonium iodide.

Different amount of ammonium iodide were added to equal weights of PEO and Chitosan and the highest conductivity at room temperature of the resulting electrolyte is shown in the Table-1.

Table-1. The electrolyte, composition and its conductivity.

Chitosan n (g)	PEO (g)	NH ₄ I		σ (S cm^{-1})
		Wt %	(g)	
0.25	0.25	0	0.000	$(5.17 \pm 1.7) \times 10^{-10}$
0.25	0.25	5	0.026	$(1.59 \pm 3.5) \times 10^{-10}$
0.25	0.25	10	0.055	$(2.35 \pm 0.9) \times 10^{-10}$
0.25	0.25	15	0.088	$(8.52 \pm 2.4) \times 10^{-9}$
0.25	0.25	20	0.125	$(1.84 \pm 0.5) \times 10^{-8}$
0.25	0.25	25	0.166	$(1.84 \pm 0.6) \times 10^{-8}$
0.25	0.25	30	0.214	$(9.21 \pm 2.6) \times 10^{-8}$
0.25	0.25	35	0.269	$(2.25 \pm 1.3) \times 10^{-7}$
0.25	0.25	40	0.333	$(9.5 \pm 1.6) \times 10^{-7}$
0.25	0.25	45	0.409	$(1.18 \pm 0.7) \times 10^{-5}$
0.25	0.25	50	0.500	$(9.83 \pm 5.7) \times 10^{-6}$

The best room temperature conductivity was observed for the polymer blend containing, 45% ammonium iodide.

Figure-2 shows the variation of polymer conductivity σ with the weight ratio of ammonium iodide NH₄I (wt %).

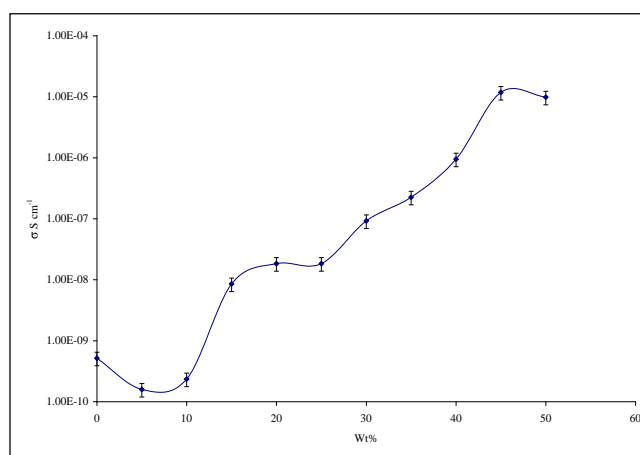


Figure-2. PEO-Chitosan: NH₄I ionic conductivity.

The conductivity is obviously increasing when larger amounts of NH₄I is added to the solution which means, the number of ions is accordingly increasing and the highest conductivity is recorded at 45 wt % of NH₄I weight ratio, above which the conductivity starts decreasing and the curve drops down which can be attributed to the higher viscosity whereby the ionic mobility decreases and the positive and negative ions may recombine.



Optical characterization of highest conducting PEO-Chitosan

Figure-3 shows the absorption spectrum of the highest conducting sample that confirms the energy gap of the complexed polymer blend.

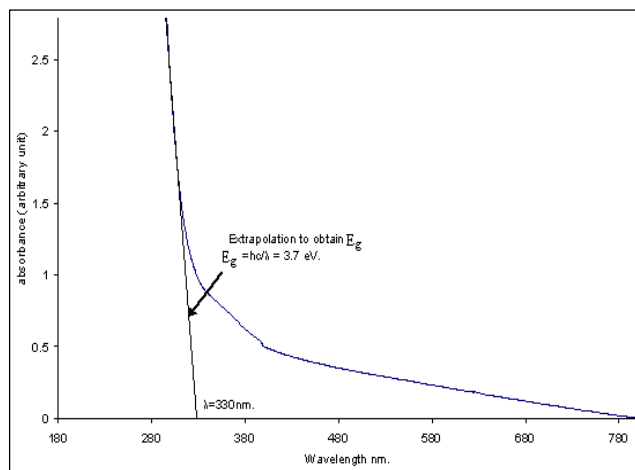


Figure-3. The absorption spectrum of PEO-chitosan ionic conductor.

The Figure-3 shows how the absorption edge is extrapolated to the wavelength axis and the intercept noted at the corresponding wavelength, 330 nm, giving an energy gap of 3.7 eV.

PEO is completely soluble in water, it can be readily cast with high flexibility and its ultra-high molecular weight and coagulating characteristics enable thin film formation. Ammonium salt doped polymer electrolytes, produce proton conductors to supply the charge carriers for polymer electrolytes. The salt is dissociated into its cation and anion. In NH_4I doped polymer, NH_4I will dissociate into NH_4^+ and I^- . On the other hand, iodine (I_3^-/I^-) added to provide redox couple. The redox couple enhance charge transfer at the interface. Chitosan is a biopolymer which has electron donating in the form of oxygen and nitrogen. It prevents folding of the polymer blend with PEO, improved mechanical properties and transparency of the polymer which could lead to better photo-conversion efficiency.

CONCLUSIONS

Poly (ethylene oxide) (PEO) prepared by solution cast technique and doped with ammonium iodide (NH_4I) and iodine (I_2) can be used as a conductive polymer with optimized conductivity equal to $(1.18 \pm 0.7) \times 10^{-5}$ which is in the range of the conductivity of conductive polymers. The absorption spectrum of highest conductivity of the polymer indicates the wavelength at 330 nm, gives the energy gap 3.7 eV.

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