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Electrical and Optical Properties of Ionic Liquid Mixed Polymer Electrolyte

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Abstract: ***Ionic liquid doped polyethylene oxide (PEO): sodium iodide (NaI) ion conducting polymer electrolytes are prepared by solution cast technique. Ionic liquid (IL), 1-methyl-3-ethylimidazolium tricyanomethanide ([EMIM][TCM]) is then added to increase the ionic conductivity of polymer electrolytes by reducing the crystallinity of polymer electrolyte. Polarized optical microscopy (POM) affirms the reduction of crystallinity in polymer electrolyte by IL doping and shows a good correlation between conductivity data.***

Keywords: Ionic Liquid, Correlation, Polarized optical microscopy, Fuel cell, Solar cells

1. Introduction

The word polymer comes from the Greek words Poly which means many and mero which means a part, in a nutshell, it is a large molecule that is composed of repeated subunits called monomers which are typically connected by covalent bonds. Polymers exhibit anisotropic behavior i.e.; the properties are direction dependent [1, 2]. Based on Origin polymers can be classified into Natural like cellulose, starch, leather etc. and Synthetic which are usually derived from petroleum oil like Bakelite, nylon, polyethylene etc. [3] and synthetic polymers (Polymers synthesized). On basis of polymerization reaction they can be classified into addition polymers which are formed by the repeated addition of monomer molecules. The polymer is formed by polymerization of monomers with double or triple bonds. here is no elimination of small molecules like water or alcohol e.g., polyethene and Condensation polymers which are formed by the combination of monomers, with the elimination of small molecules like water, alcohol e.g., nylon [4] while on Conductivity basis it is like Insulator polymers, semi-conducting polymers and ion conducting polymers or polymer electrolyte. Polymer electrolytes are polymers dopped with salt complexes and ionic liquid to obtain high ionic conductivity 10^{-5}-10^{-1}. Polymer electrolytes can be used in many applications such as electrochemical double layer supercapacitors (EDLC), dye sensitized solar cells (DSSCs), C etc. Different insulating polymers like polyethylene oxide PEO, polyvinyl alcohol PVA and Polyvinylpyrrolidone In polymer electrolytes (Polyethers) the most important issue is their low ionic conductivity. To introduce and enhance ionic conductivity various approaches are popular in market out of which ionic liquid (IL) dispersion in polymer is a novel approach came in literature. Il are organic salts below 100 C. they are classified as a green solvent because they are non-flammable and recyclable. Ionic liquids are also thermally stable. In polymer electrolyte addition of salts/ILs increases the conductivity due to the increase in the number of ions the amorphousity of the polymer which in turn facilitates ion transportation [7-10].

2. Experimental Methods

The materials used in present study are Polymer host: PEO (Polyethylene Oxide), Salt: NaI (Sodium Iodide), Ionic liquid (IL; 1-methyl-3- mthylimidazoliumtricyanomethanide ([EMIM][TCM]), Solvent: Methanol were purchase from Sigma Aldrich (USA) and dried well before used.

2.1 Film Preparation

2.1.1 Calculation of the volume of ionic liquid

The film was prepared using solution cast technique (Figure1) by dissolving 1g of PEO and 12.5 wtperecentNaI (Polymer host). In this polymer electrolyte finally IL has been mixed in different (IL concentration 0.2,0.4,0.6,0.8etc) shown in Table 1.

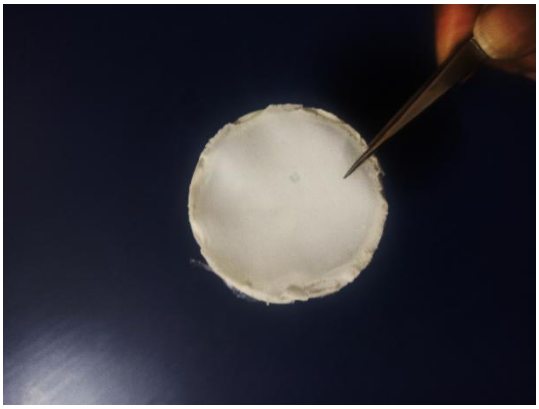
Table 1: Calculation of the volume of ionic liquid used in present study

Label	Volume of ionic liquid (µL)	Sample description
PEO0	-----	Pure PEO film
PEO1	-----	PEO+NaI
PEO2	1.82	PEO+NaI+0.2wt%IL
PEO4	3.64	PEO+NaI+0.4wt%IL
PEO6	5.45	PEO+NaI+0.6wt%IL
PEO8	7.27	PEO+NaI+0.8wt%IL

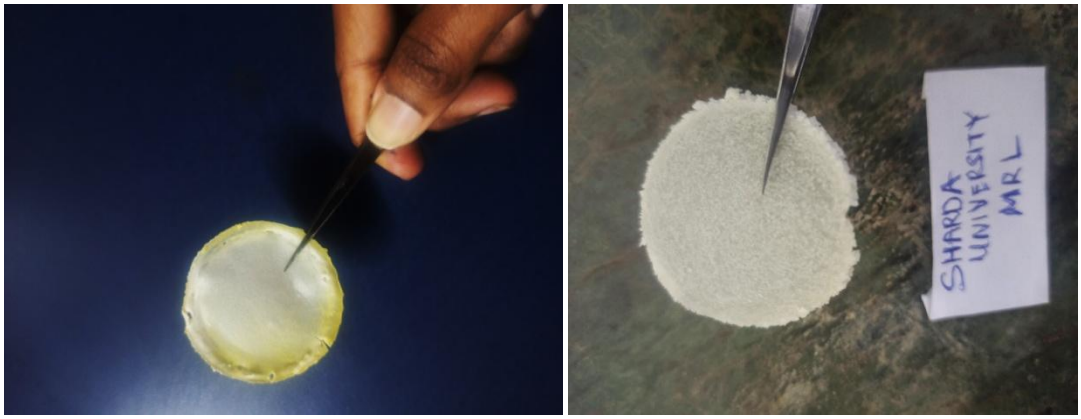
3. Results and Discussion

3.1 Optical photograph

Optical photographs of polymer electrolyte. Salt doped polymer electrolyte and IL doped polymer electrolyte films are shown in Figure 3



(a)



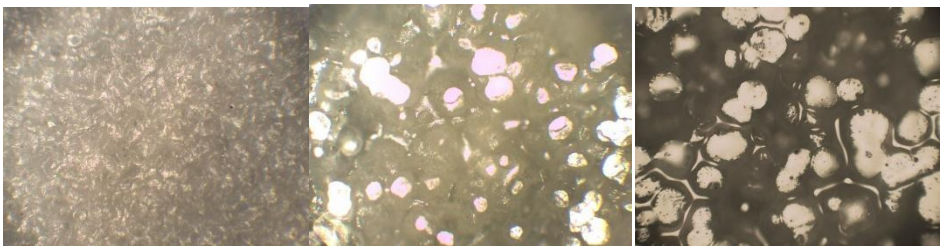
(b) **(c)**

Figure 3: (a) pure polyethylene oxide film, (b) PEO: NaI film, (c) PEO: NaI + IL polymer electrolyte film.

It is noted that in comparison of pure PEO film NaI doped films shows yellowish colour which is due to salt (NaI) which changes colour by absorbing humidity (rection between humidity and NaI). It was also clear that films with good mechanical stability and free standing are obtain after solvent evaporation.

3.2 Polarized Optical Microscope

Polarized optical micrographs (POM) of the polymer electrolyte films have been recorded using a polarized optical microscope (Motic-model no. BA310 Pol, Carlsbad, California, USA) at 10x magnifications to understand the effect of IL doping on the polymer surface. POM of pure PEO, PEO: NaI and PEO: NaI +0.2 wt% IL are shown in Figure 4. The pure polymer film exhibits smooth and dense morphology. The micrographs of the PEO+0.2 wt% IL shows more darkish regions hence more amorphous structure and reduction in crystallinity. The increase in the amorphous nature leads to improved segmental mobility and therefore higher ionic conductivity of the polymer electrolyte films. The observed texture of film using POM is thus in agreement with our published work.



(a) **(b)** **(c)**

Figure 4: Polarized optical microscope image of (a) pure PEO film (b) PEO: NaI film (c) PEO: NaI + 0.2wt% IL

3.3 Impedance Spectroscopy

To measure ionic conductivity polymer electrolyte films of different thickness are sandwiched between two stainless electrode of area 1cm^2 and conductivity was measured using impedance spectroscopy (LCR meter). The Nequist plots carried out using impedance spectroscopy are shown in figure 5.

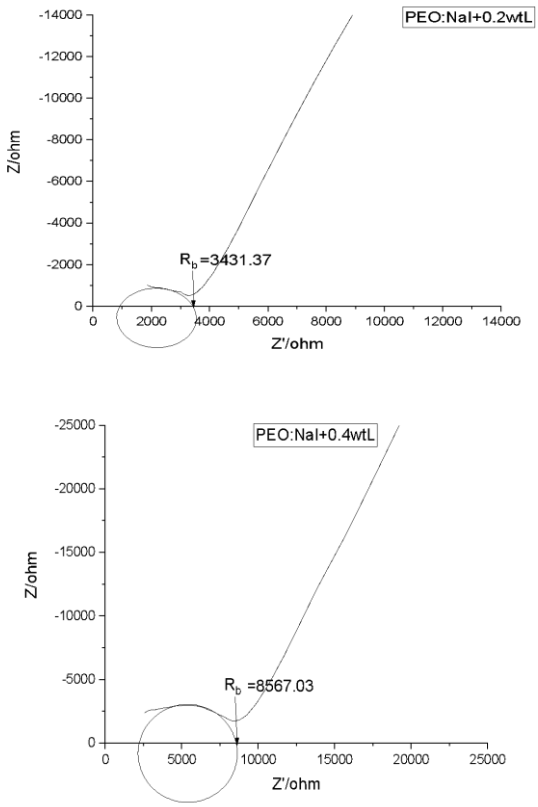


Figure 5: Nyquist plots of films using complex impedance spectroscopy

The electrical conductivity was calculated using the formula below and conductivity values are listed in Table 2.

$$\sigma = \frac{1}{R_B} \times \frac{d}{A}$$

Table 2: Ionic conductivity using complex impedance spectroscopy

Sample	Thickness (cm)	Bulk Resistance (Ω)	Conductivity (S/cm)
PEO1	0.038	11846.01	3.21×10^{-6}
PEO2	**0.037**	**3431.37**	**1.08×10^{-5}**
PEO4	0.039	8373.23	4.66×10^{-6}
PEO6	0.056	5668.95	9.88×10^{-6}
PEO8	0.050	10297.54	4.86×10^{-6}

4. Summary and Conclusion

Ionic liquid doped solid polymer electrolyte were synthesized with optimized conducting sample (PEO:NaI + 0.6 wt% IL) which shows highest value of conductivity ~ 3.13×10^{-4} S/cm at room temperature. It is well known that ionic liquid (IL) and salt complexes are composed of ions and hence increase that lead to the increase in conductivity values. Doping with ionic liquids and salt complexes also leads to the decrease in crystallinity (affirmed by optical micrographs) which enhances ionic mobility. Such a high ionic conductivity itself proves that IL doped solid polymer electrolyte is a novel candidate for future application (as electrolyte)

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