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Development of Electrochemical Cell Based on PEG+NaCl Electrolytic system

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Abstract: *A new sodium ion conducting polymer electrolytic film, that is a mixture of polyethylene glycol (PEG) with NaCl salt, is prepared by solution casting method. The salvation of salt with PEG has been confirmed by IR spectral studies. The thicknesses of the films were measured by gravimetric method. Films were characterized by electrical (AC & DC) conductivity measurements. Using this electrolyte, an electrochemical cell with the configuration of Al/PEG: NaCl/I_2+C/ has been fabricated and the discharge characteristics with 100KΩ load of the above cell configuration is reported. The conduction of the film increases with increasing temperature and with the increase of percentage of NaCl concentration with PEG. The DC conduction study reveals that the prevailing conduction in these films is poole-frankel type. Open circuit voltage (OVC) ranges from 1.36 V to 1.23 V and short circuit current (SS) ranges 550 μA to 350 μA. Other cell parameters like discharge time for plateau, discharge capacity, power density, current density and energy density were also evaluated.*

Key words : Polymer battery, electrolytic cell, PEG, NaCl, ionic conductivity

1. INTRODUCTION

New materials are attracting enormous attention as way to engineer advanced materials with specifically tailored optical, electrical, or mechanical properties. In particular, polymer-electrolyte composites have received a great deal of attention over the past several years as researchers have recognized their potential in thin-film solid state energy storage devices [1-3]. Among the various ion conducting materials, polymer-salt complexes are of current interest on account of their possible application as solid electrolytes as well as their physical nature in advanced high energy electrochemical devices such as batteries, fuel cells, electrochemical display devices, photo-electrochemical solar cells etc., [4-8]. Most of the studies in this field are devoted to PEO based electrolytes using alkali salts [9-11]. Sodium ion conducting polymers based on PEO, PolyPropylene Oxide (PPO), Poly-bis Methoxy Ethoxy Phosphazene (MEEP) complexed with NaI, $NaClO_4$, NaSCN, $NaCF_3SO_3$, $NaPF_6$ have been reported [12-15]. Many rechargeable batteries have also been reported based on the Na^+ ion conducting polymer [16-17]. Similar reports are available using sodium fluoride in the same cell configuration [18]. Ford et al have reported [19] PEG/NaCl particles exhibit particle size oscillation (up to 100 nanometres peak-to-peak) when probed by optical diffraction. The specific behavior observed depends on the concentration and nature of the electrolyte in the PEG host particle.

In this context, we report here a new thin film Na^+ ion conducting polymer electrolyte system based on PEG complexes with NaCl. Experimental techniques such as XRD, Infra-red (FTIR) and electrical conduction studies have been carried out to characterize this new polymer electrolyte. Using this thin film electrolyte, an electrochemical cell with the configuration of Al | PEG : NaCl | I_2 + C | has been fabricated and its discharge characteristics were studied. Several cell parameters like discharge time for plateau, discharge capacity, power density, current density and energy density are evaluated and discussed.

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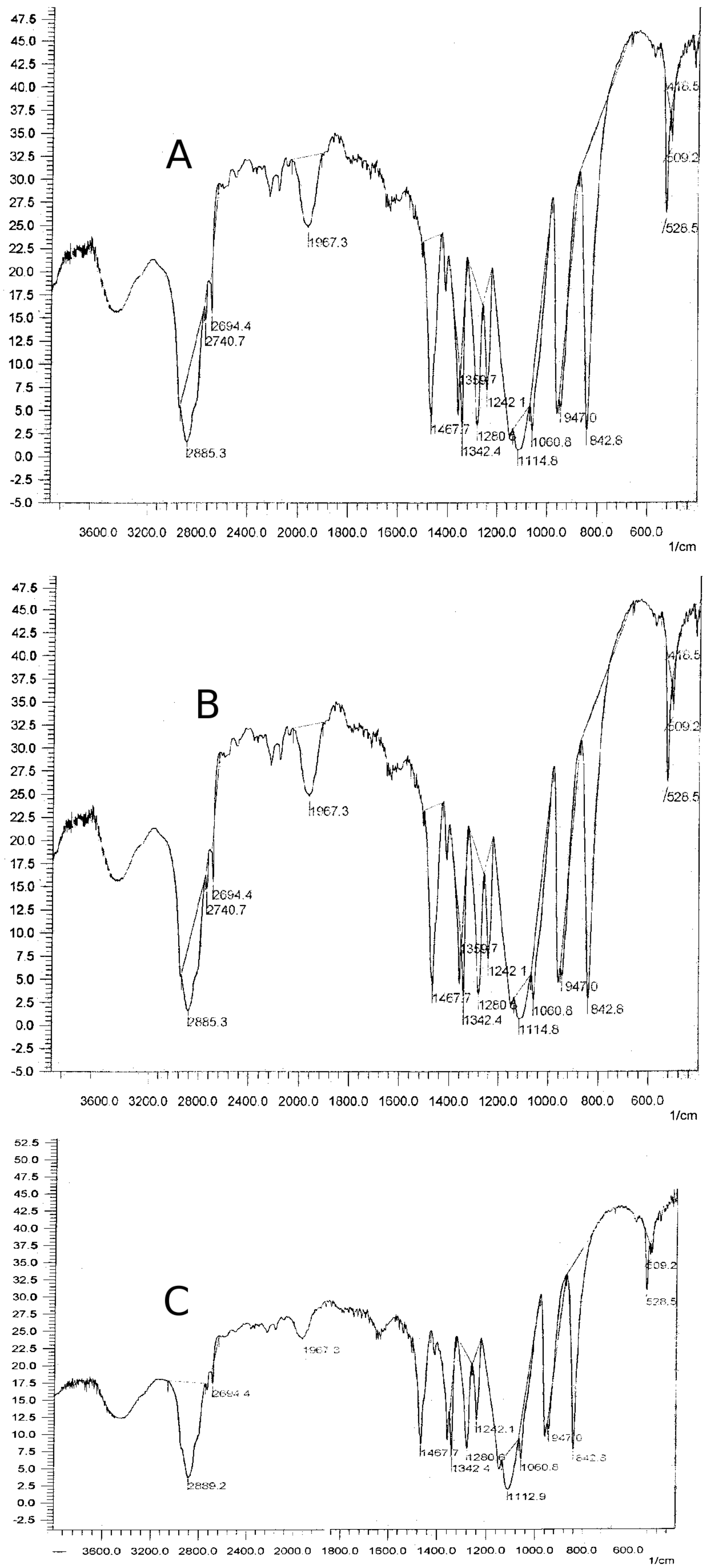

Figure 1: A) IR Spectra for pure PEG Film, B) IR spectra for PEG:NaCl(10:1) film, C) IR Spectra for PEG : NaCl (10 :2) Film

2. EXPERIMENTAL

Thin films of PEG : NaCl system are prepared using solution-cast technique. First dry PEG and NaCl were taken in weight basis (i.e.) 95:5 and 90:10 ratios and mixture was dissolved in benzene. The solution was stirred well for several hours and then casted on well cleaned glass substrates and dried slowly at room temperature. The thicknesses of the films were calculated by measuring the weight of the substrates before and after casting using a Metler microbalance. The IR studies are carried out using Perkin-Elmer FTIR spectrophotometer in the range of 600 to 3600 cm^{-1}. The Metal-Polymer-Metal structure i.e. Al-(PEG:NaCl)-Al has been fabricated to carryout conduction studies. Top and bottom electrodes (Al) are fabricated on to a well cleaned glass substrate by vacuum evaporation under a vacuum of 2 x 10^{-5} Torr. Polymer mixture is grown on bottom electrode by solution grown technique. A.C conductivity studies on the films are carried out using digital Multifrequency LCR meter (Goodwill Instruments, Taiwan) for varying frequencies (12Hz – 10MHz) at different temperatures (30°C to 130°C). An electrochemical cell was fabricated with the configuration of Al | PEG: NaCl | I_2 + C |. The discharge characteristics of the cell were monitored for a constant load 100Kohm, and various cell parameters were evaluated.

3. RESULTS AND DISCUSSION

The FTIR spectra of PEG, PEG:NaCl films are shown in fig 1. The Polyethylene glycol exhibits absorptions those of a primary alcohol. Hence these absorptions, which comprise stretching and bending vibrations restricted to C-C stretch, C-O stretch, C-H stretch (methylene absorptions) and the C-H bending. The O-H stretching vibration is observed in the region 3520-3330 cm^{-1} exhibiting hydrogen bonded nature. The same absorption is observed in PEG: NaCl (0.5gm : 0.1gm) and (0.5gm : 0.05gm) as shown in the fig.1b and 1c respectively. This clearly indicates that the influence of NaCl does not affect the absorption of the respective functional groups. The methylene group found in PEG has been found to vibrate in the stretching mode around 2880cm^{-1}. The absorption around 1465cm^{-1} is due to binding vibration of $–CH_2$. As in the case of primary alcohol, the C-O stretching vibration, a strong bond around 1350cm^{-1} and 1260cm^{-1} is also observed. A similar vibration is exhibited by pure PEG and PEG: NaCl complexes. A sharp – strong bond at 947cm^{-1} and 842.8cm^{-1} is due to the C-C stretching. Addition of NaCl does not produce any change either in the nature of PEG itself structurally or has broken up the chain.

AC conductivity measurements have been carried out on pure PEG, PEG : NaCl compounds at different temperature ranges from 30° to 130°C (303 to 403K). The AC conductivity values are found for all samples at different temperatures and are given in table.1. The conductivity value slowly increases with an increase of temperature. The conductivity also increases with increase of salt concentration for all temperatures. At room temperature conductivity values of PEG:NaCl is in the order of 10^{-3} S/cm. At room temperature the conductivity values of PEG: NaCl (10:1) and PEG: NaCl (10:2) are found to be 2.197 X 10^{-3} S/cm and 3.423 X 10^{-3} S/cm respectively. Typical conductivity versus frequency plot for PEG: NaCl film at various temperatures is shown in fig.2. From this plot, it is observed that there are two regions in the temperature range studied (303 to 403 K). The linear variation shows an Arrhenius type of thermally activated process.

Table 1:

Temp. (K)	Conductivity (σ) S/cm		
	Pure PEG	PEG : NaCl (10 :1)	PEG : NaCl (10 :2)
303	1.6359 x 10^{-3}	2.197 x 10^{-3}	3.423 x 10^{-3}
323	1.700 x 10^{-3}	2.2823 x 10^{-3}	3.629 x 10^{-3}
363	1.912 x 10^{-3}	2.3001 x 10^{-3}	3.678 x 10^{-3}
383	1.982 x 10^{-3}	2.535 x 10^{-3}	3.986 x 10^{-3}

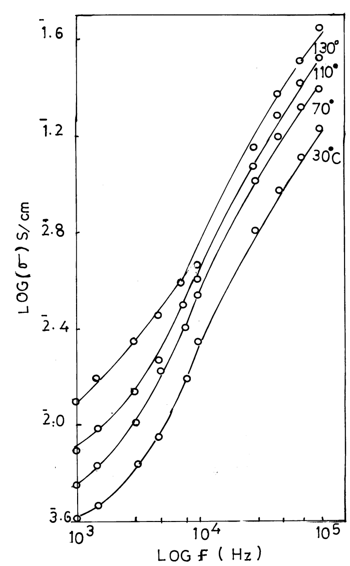

Figure 2: Log Conductivity vs Frequency for PEG : NaCl (10:1) Film

The DC conduction study also reveals that the conductivity increases with increase in salt concentration and with increase in voltage. The I-V characteristics of PEG: NaCl (10:2) film of thickness 1.5 μm for different temperatures on a logarithmic scale is shown in fig.3. The current (I) exhibits an applied voltage dependence of the form,

$$I \alpha V^n$$

where n is found to be less than 1 at low fields and attaining the values greater than one at higher fields. Two regions have been observed for higher temperatures (>363K). A comparison of the conductivity of pure PEG with PEG: NaCl film reveals that the conductivity increases with increase in salt concentration. It is in good agreement with observation mode by Khare et al [17] for polymer film. The activation energy has been evaluated from the plot of log I versus 10^3 /T for PEG: NaCl film. The activation energy was found to be 0.423eV [fig 4] low field (2V).

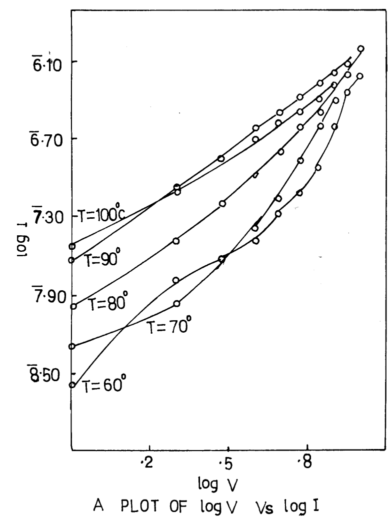

Figure 3: Log I vs Log V for PEG : NaCl(10:2) Film

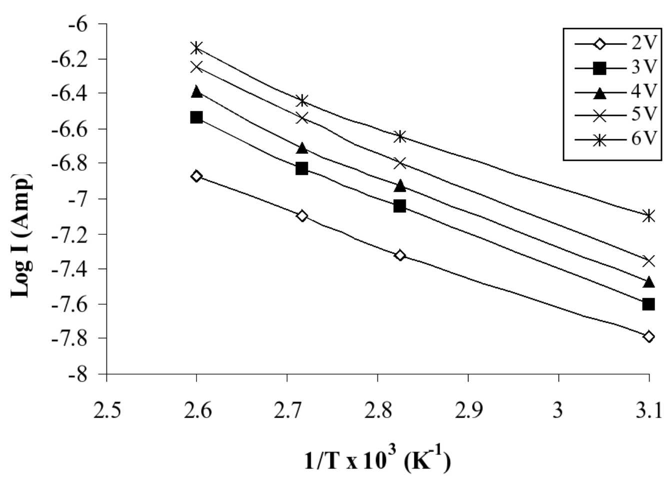

Figure 4: Log I vs Inverse Temperature for PEG:NaCl Film

Using these polymer electrolytes the electro chemical cells have been fabricated in the configuration. Al | PEG : NaCl | I_2+ C +Electrolyte (fig 5). In the battery, the charge transfer takes place due to ion exchange between NaCl and iodine and thereby collecting positive and negative ions at the respective terminals of the battery. Thus potential difference exists between the terminals of the battery. Since the weight of the cell is an important factor in determining its performance, the weighing is done using digital balance. The cell parameters like discharge capacity ie. Discharge current per unit time (μA/H), power density (W/Kg), current density (current per unit area : μA/H), and the energy density (W H/Kg) were evaluated and listed in table.2.

Table 2:

Cell Parameters	PEG : NaCl cell (10 : 1)	PEG : NaCl cell (10 : 2)
Area of the cell (Cm^2)	1.413	1.73
Weight of the cell (Gram)	0.368	0.289
OCV(v) SCC(μA) Discharge time for plateau region (hγ)	1.36 550 60	1.235 535 63
Discharge capacity (μA/h)	9.166	8.492
Power Density (W/kg)	2.033	2.286
Current Density ($\mu A/cm^2$)	389	309
Energy Density (wh/kg)	121.98	144.018

From the discharge characteristics it is found that PEG : NaCl (10 : 2) is higher compared to the other two systems. The open circuit voltage (OCV) short circuit current (SCC) have respectively found to be 1.235V and 535μA for the above cell. Several other parameter of the cell are measured and given in Table 2.

4. CONCLUSION

We have presented the first results on various conduction and electro chemical studies on Al/PEG:NaCl system. The addition of salt with PEG increases the conductivity value the discharge films (Plateau region) for PEG : NaCl (10 :2) film is 63 hrs (Wh/kg = 144.018). From these studies it is suggested that the 10 : 2 ratio of PEG : NaCl is suitable for applications in batteries. Clearly, the direct observation phase transition observed herein is the first step in realizing the structural dynamics in isolated microparticle environments.

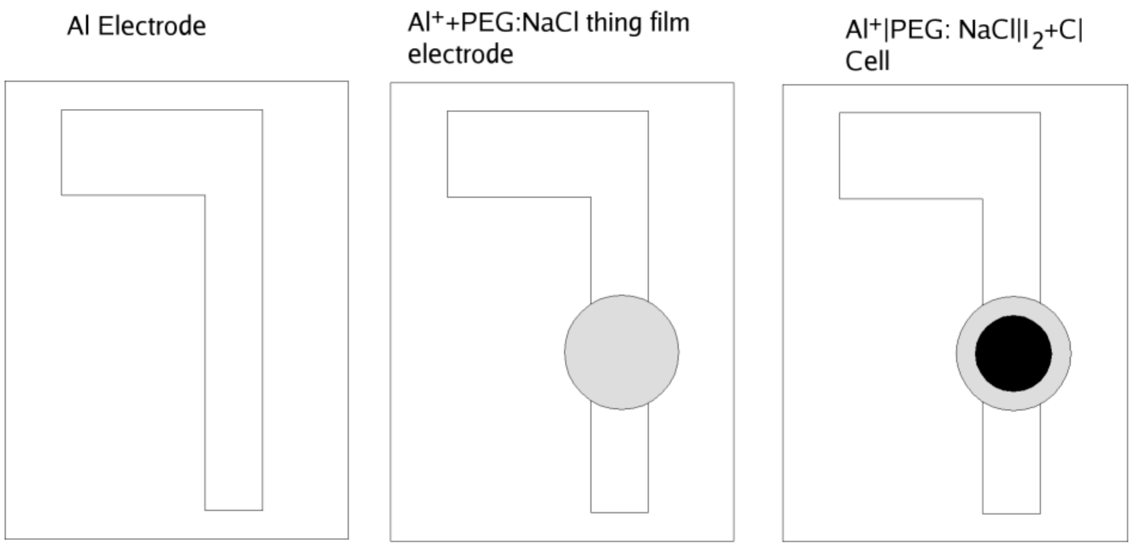

Figure 5: Al^{+}| PEG:NaCl | I_2+C| Cell thin film electrolyte

5. ACKNOWLEDGMENTS

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