Proton Conducting Polymer Electrolyte based on Poly (N-vinyl pyrrolidone) Doped with Ammonium Iodide

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ABSTRACT: The present work deals with the characterization of a proton conducting polymer electrolyte based on Poly (N-vinyl pyrrolidone) (PVP)-Ammonium iodide (NH4I) prepared by solution casting technique. X-ray diffraction pattern confirms the amorphous nature of the PVP-NH4I polymer electrolyte. Fourier transform infrared analysis reveals the complexation behaviour of the polymer PVP with NH4I. The glass transition temperature (Tg) of the electrolyte with 70 mol% PVP:30 mol% NH4I has been found to be 343 K from differential scanning calorimetry thermograms. The highest ambient temperature conductivity is 1.78×10-5 S cm-1 for the film containing 30 mol% NH4I. Temperature dependent conductivity follows Arrhenius behaviour. A high dielectric constant has been obtained for the highest conducting film.

Keywords: Solid electrolytes; Differential scanning calorimetry; Dielectric permittivity; Ionic conductivity; Fourier transform infrared spectroscopy

1. Introduction

The potential application of ion-conducting polymer electrolytes as solid electrolytes in a variety of electrochemical devices arises from their advantages such as high energy density, electrochemical stability and easy handling [1]. Among solid polymer electrolytes, proton conducting polymer electrolytes have received much attention because of their unique application as solid electrolyte in various electrochemical devices such as fuel cells, sensors, electrochromic displays and windows, etc. [2]. The recent challenge is to develop a low cost proton conducting polymer electrolyte with high ionic conductivity, good dimensional and mechanical stability. Many researchers have studied the behaviour of proton conducting polymer electrolytes based on the host polymers such as poly (vinyl alcohol) (PVA), poly (ethylene oxide), poly (ethylene imide), poly (acrylic acid), poly (N-vinyl pyrrolidone) (PVP) [3-7] doped with inorganic acids or ammonium salts.

Literature survey reveals that the ammonium salts are good proton donors to the polymer matrix [8-10]. Selvasekarapandian et al. [11-15] have studied the proton conducting polymer electrolytes prepared by using PVA as host polymer and CH3COONH4, NH4SCN and NH4X (X=Cl,Br,I,NO3) as dopant salts. Some work on PVP based polymer electrolyte doped with CH3COONH4 [16], NH4SCN [17] and NH4ClO4 [18] has been reported. We have reported earlier the conductivity studies of PVP doped with ammonium halides like NH4Cl [19] and NH4Br [20] polymer electrolytes. The ammonium halides have decreasing trend of lattice energy as NH4Cl→NH4Br→NH4I. As expected, the ionic conductivity of the polymer electrolyte based on PVP:NH4Br is greater than that of PVP:NH4Cl. As the lattice energy of NH4I is less than that of the other two salts, the electrolyte based on PVP doped with NH4I is expected to exhibit conductivity higher than that of PVP:NH4Br and PVP:NH4Cl. Hence, an attempt has been made to investigate a proton conducting polymer electrolyte based on PVP-NH4I.

2. Experimental Details

Thin films of polymer electrolyte with thickness ranging from 34 μm to 124 μm of pure PVP (Mw = 40,000 from S D Fine-Chem Limited) and PVP doped with NH4I (Loba Chemie) with different compositions in mol% were prepared by solution casting technique using distilled water as solvent. Aqueous solutions of PVP and NH4I had been stirred continuously using a magnetic stirrer for 12-15 hours until they became homogeneous. The solution was then cast onto polypropylene petri dishes and evaporated at room temperature. The samples were vacuum dried before use.

X-ray diffraction (XRD) was performed on the polymer samples with a Philips X'Pert PRO diffractometer using CuKα radiation. XRD patterns of the prepared samples were recorded at room temperature in the 2θ range from 10° to 80°. The fourier transform infrared (FTIR) spectra for the polymer electrolytes were recorded at room temperature in transmission mode using
SHIMADZU IR Affinity -1 Spectrometer in the wavenumber range of 400 cm\(^{-1}\) to 4000 cm\(^{-1}\). Differential scanning calorimetry (DSC) measurements were carried out on the samples using SII, Seiko Instruments Inc. EXSTAR 6000, DSC 6200 at a heating rate of 5 K min\(^{-1}\) under nitrogen atmosphere in the temperature range from 223 K to 393 K. In order to find the ionic conductivity of the samples, AC impedance spectroscopic study has been carried out using a computer controlled HIOKI 3532 LCR HiTester in the frequency range of 42 Hz to 1 MHz over a temperature range from 303 K to 343 K with a cell having aluminium blocking electrodes.

3. Results and Discussion

3.1 X-ray Diffraction Analysis

When a polymer is complexed with a salt or an acid, the crystallinity of polymeric host could be disrupted by the addition of impurities [21,22]. Figure 1 represents the XRD patterns of pure PVP and PVP doped with different concentrations of NH\(_4\)I.

The diffraction hump observed between ~15°-30° can be associated with the semicrystallinity of pure PVP. The relative intensity of the hump decreases and its broadness increases with respect to pure PVP in the salt-doped systems. This result can be interpreted by considering the Hodge et al. [23] criterion, which establishes a correlation between the intensity of the peak and the degree of crystallinity. These changes indicate that the addition of NH\(_4\)I to PVP matrix reduces the crystalline nature and enhances the amorphous nature of PVP. This is due to the complexation between the host polymer PVP and the dopant salt NH\(_4\)I. No peak corresponding to pure NH\(_4\)I has been observed in the salt-doped polymer system indicating the complete dissociation of the salt in the polymer matrix. Thus, the XRD analysis reveals the complex formation in the polymer matrices.

3.2 Fourier Transform Infrared Analysis

FTIR characterization is a convenient and sensitive method to detect the interaction between two species. The natural vibrational frequencies of atoms in molecules and crystals fall in the infrared region which facilitates the identification of functional groups present in a material. Figure 2 depicts the FTIR spectra of pure PVP and PVP doped with different concentrations of NH\(_4\)I in molar ratios. The FTIR spectral assignments for PVP:NH\(_4\)I polymer complexes having different concentrations of NH\(_4\)I are shown in Table 1.

![Figure 2: FTIR spectra of (a) pure PVP (b) 10 mol% (c) 15 mol% (d) 20 mol% and (e) 25 mol% (f) 30 mol % NH\(_4\)I doped PVP polymer electrolyte](image)

From Figure 2, peak shifts can be observed comparing the peaks of pure PVP. The vibrational band observed at 1474 cm\(^{-1}\) is ascribed to C-H deformation of cyclic CH\(_2\) group of pure PVP [24]. This band has been found to be shifted to lower wavenumber in the NH\(_4\)I doped polymer electrolyte. The vibrational peaks observed at 894 cm\(^{-1}\), 1018 cm\(^{-1}\) and 2135 cm\(^{-1}\) in the FTIR spectrum of pure PVP are attributed to CH\(_2\) bending, C-C stretching and C-N stretching vibration of pure PVP, respectively [25]. The peak at 844 cm\(^{-1}\) is shifted to 841 cm\(^{-1}\) in the lower wavenumber region. The peaks at 2135 cm\(^{-1}\) and 1018 cm\(^{-1}\) of pure PVP are found to be shifted in the polymer complexes with respect to pure PVP as shown in the Table 1. The vibrational peak observed at 896 cm\(^{-1}\) assigned to CH\(_2\) rocking in pure PVP gets shifted to lower wavenumber in the complexed systems.

The vibrational peak at 1328 cm\(^{-1}\) [26] is attributed to CH\(_2\) wagging of pure PVP and is found to be shifted to 1320 cm\(^{-1}\) in the 10 mol% and 20 mol% and 1312 cm\(^{-1}\) in the 15 mol% and 30 mol% and 1326 cm\(^{-1}\) in the 25 mol% of the salt doped films. The broad bands around 3370 cm\(^{-1}\) in the pure PVP and polymer complexes correspond to O-H stretching.

The peak shifts reveal that there exists an interaction between the salt and PVP. The shift in the positions of absorption bands, the change in their intensities and the appearance of a new peak around 1867 cm\(^{-1}\) and the disappearance of some bands in the polymer electrolytes confirm the complex formation between the polymer and the salt.

3.3 Differential Scanning Calorimetry Analysis

DSC analysis has been carried out to find the glass transition temperature, \(T_g\), of the polymer electrolyte. The DSC curves for pure PVP and PVP doped with different concentrations of NH\(_4\)I in mol% are shown in Figure 3. The DSC curves exhibit step-like transitions
**Table 1:** FTIR spectral assignments for different compositions of PVP: NH₄I polymer electrolyte

<table>
<thead>
<tr>
<th>Compositions of PVP: NH₄I (mol%)</th>
<th>Glass transition, $T_g$ (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure PVP</td>
<td>359</td>
</tr>
<tr>
<td>95:5</td>
<td>352.5</td>
</tr>
<tr>
<td>90:10</td>
<td>349.5</td>
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<tr>
<td>80:20</td>
<td>348</td>
</tr>
<tr>
<td>75:25</td>
<td>344</td>
</tr>
<tr>
<td>70:30</td>
<td>343</td>
</tr>
</tbody>
</table>

**Table 2:** Glass transition temperatures for different compositions of PVP: NH₄I polymer electrolyte

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<td>80:20</td>
<td>348</td>
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<tr>
<td>75:25</td>
<td>344</td>
</tr>
<tr>
<td>70:30</td>
<td>343</td>
</tr>
</tbody>
</table>

3.4 AC Conductivity Analysis

The complex impedance plot (Cole-Cole plot) for the polymer electrolyte PVP: NH₄I with different compositions at 303 K is presented in Figure 4a. The inset of Figure 4a shows the complex impedance plot for 70 mol% PVP:30 mol% NH₄I in the high frequency region at 303 K.

![Figure 3: DSC curves for (a) pure PVP and PVP doped with (b) 5 mol% (c) 10 mol% (d) 20 mol% (e) 25 mol% and (f) 30 mol% of NH₄I](image)

**Figure 3:** DSC curves for (a) pure PVP and PVP doped with (b) 5 mol% (c) 10 mol% (d) 20 mol% (e) 25 mol% and (f) 30 mol% of NH₄I

**Figure 4a:** Cole-Cole plot for the polymer electrolyte PVP: NH₄I with different compositions at 303 K

The plot shows a high frequency semicircle which is due to the bulk effect of the electrolyte and a low frequency spike corresponding to the effect of the blocking electrodes [28]. As the concentration of the salt increases, the diameter of the semicircle decreases. This indicates that the bulk resistance ($R_b$) of the polymer electrolyte decreases. The $R_b$ of the polymer electrolyte has been obtained from the intercept of the high frequency semicircle or the low frequency spike on the $Z'$ axis.
The ionic conductivity of the polymer electrolyte is calculated using the equation \( \sigma = I/R_A \) where \( I \) is the thickness of the electrolyte film and \( A \) is the area of the film. The conductivity values for the polymer electrolyte having different concentrations of NH\textsubscript{4}I at different temperatures are given in Table 3.

It can be seen from the Table 3 that the ionic conductivity increases with the increase of salt concentration and also with temperature. The polymer electrolyte with 30 mol\% NH\textsubscript{4}I has the highest conductivity of \( 1.78 \times 10^{-5} \) S cm\(^{-1} \) at room temperature. The conductivity decreases for further increase of salt concentration (35 mol\% NH\textsubscript{4}I). The increase in conductivity with increasing salt concentration may be due to the increase in number of mobile charge carriers and the increase in amorphous nature of the polymer electrolyte which is consistent with the XRD results. The decrease in conductivity at higher salt concentration may be due to the aggregation of ions. The highest conductivity for 30 mol\% salt-doped system is consistent with the DSC results which show low \( T_g \) for this system.

It is to be noted that the conductivity value of PVP doped with NH\textsubscript{4}I is less than the conductivity value of PVP doped with NH\textsubscript{4}Cl and NH\textsubscript{4}Br. It is expected that the conductivity value with PVP:NH\textsubscript{4}I should be greater than that of PVP doped with other two salts as the lattice energy of NH\textsubscript{4}I is less than that of other two salts. The reason for the reduction in the conductivity may be due to quick formation of ion aggregates which reduces the conductivity.

It is observed from the Table 3 that for compositions of PVP:NH\textsubscript{4}I polymer electrolyte up to 25 mol\% NH\textsubscript{4}I content, the conductivity value has increased by two orders of magnitude from 303 K to 343 K. For the polymer electrolyte 70 mol\% PVP:30 mol\% NH\textsubscript{4}I (highest conducting sample), the conductivity has increased by one order of magnitude for the same temperature range. For 65 mol\% PVP:35 mol\% NH\textsubscript{4}I, the conductivity has increased by two orders of magnitude from 303 K to 343 K but it has decreased from that of 70 mol\% PVP:30 mol\% NH\textsubscript{4}I.

Figure 4b shows the impedance plot of the highest conductivity sample, 70 mol\% PVP:30 mol\% NH\textsubscript{4}I at different temperatures. It has been observed that the diameter of the semicircle decreases with increasing temperature indicating a decrease in bulk resistance. The ionic conductivity of the polymer electrolyte increases with increase of temperature.

### Table 3: Ionic conductivity values for different compositions of PVP:NH\textsubscript{4}I polymer electrolyte at different temperatures (from Cole-Cole plots)

<table>
<thead>
<tr>
<th>PVP:NH\textsubscript{4}I (mol%)</th>
<th>Ionic conductivity, ( \sigma ) (S cm(^{-1} ))</th>
<th>Activation energy, ( E_a ) (eV)</th>
<th>Regression value, ( R )</th>
<th>Relaxation time, ( \tau ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85:15</td>
<td>( 1.20 \times 10^{-9} ), ( 3.93 \times 10^{-8} ), ( 4.22 \times 10^{-8} ), ( 1.76 \times 10^{-7} ), ( 5.52 \times 10^{-7} )</td>
<td>1.47</td>
<td>0.994</td>
<td>1.72 \times 10^{-3}</td>
</tr>
<tr>
<td>80:20</td>
<td>( 2.81 \times 10^{-8} ), ( 8.44 \times 10^{-8} ), ( 3.53 \times 10^{-7} ), ( 2.21 \times 10^{-6} ), ( 7.30 \times 10^{-6} )</td>
<td>1.31</td>
<td>0.995</td>
<td>3.7 \times 10^{-4}</td>
</tr>
<tr>
<td>75:25</td>
<td>( 2.19 \times 10^{-7} ), ( 1.32 \times 10^{-6} ), ( 5.48 \times 10^{-6} ), ( 1.14 \times 10^{-5} ), ( 2.99 \times 10^{-5} )</td>
<td>1.11</td>
<td>0.990</td>
<td>3.93 \times 10^{-5}</td>
</tr>
<tr>
<td>70:30</td>
<td>( 1.78 \times 10^{-5} ), ( 4.6 \times 10^{-5} ), ( 7.59 \times 10^{-5} ), ( 1.46 \times 10^{-4} ), ( 2.40 \times 10^{-4} )</td>
<td>0.60</td>
<td>0.996</td>
<td>7.38 \times 10^{-7}</td>
</tr>
<tr>
<td>65:35</td>
<td>( 8.10 \times 10^{-6} ), ( 1.50 \times 10^{-4} ), ( 3.45 \times 10^{-4} ), ( 6.07 \times 10^{-4} ), ( 1.05 \times 10^{-4} )</td>
<td>0.61</td>
<td>0.998</td>
<td>7.98 \times 10^{-7}</td>
</tr>
</tbody>
</table>

**Figure 4b:** Cole-Cole plot for 70 mol\% PVP:30 mol\% NH\textsubscript{4}I at different temperatures

### 3.5 Conductance Spectra Analysis

The frequency dependent conductivity for different compositions of PVP:NH\textsubscript{4}I polymer electrolyte at room temperature is shown in Figure 5a and that of 70 mol\% PVP:30 mol\% NH\textsubscript{4}I at different temperatures is shown in Figure 5b.

The plot consists of a low frequency dispersion region describing electrode-electrolyte interface phenomena connected with the space charge polarization at the blocking electrodes followed by the frequency independent plateau region connected with the dc conductivity of the polymer complexes. The high frequency region of the curve corresponds to the bulk relaxation phenomena. The dc conductivity values of the PVP:NH\textsubscript{4}I films calculated by extrapolating the plateau region to the log \( \sigma \)-axis agree well with those obtained from the Cole-Cole plot. It has been found that the dc conductivity increases with increasing temperature which suggests that the free volume around the polymer chain enhances the mobility of ions, polymer segments and hence the conductivity [29].

### 3.6 Temperature Dependence of Ionic Conductivity

**Figure 6** presents the ionic conductivity as a function of temperature (Arrhenius plots) for PVP:NH\textsubscript{4}I polymer electrolytes of various compositions. From Figure 6, it is clear that the proton conductivity of the electrolyte increases with increase of temperature for all compositions.
of a nice asdfasdghadsfha gasdfg hfdh adfg h asdfg

**Figure 5a:** Conductance spectra for different compositions of PVP:NH$_4$I at 303 K

**Figure 5b:** Conductance spectra of 70 mol% PVP:30 mol% NH$_4$I at different temperatures

obeying the Arrhenius equation which can be represented as below,

$$\sigma = (\sigma_o/\tau) \exp(-E_a/kT)$$

(1)

where $\sigma_o$ is the pre-exponential factor, $E_a$ is the activation energy, $T$ is the absolute temperature and $k$ is the Boltzmann constant. Similar Arrhenius behaviour has been observed for the systems PVA:NH$_4$I [8] and PVP:NH$_2$SCN [30]. At higher temperatures, thermal movement of the polymer segments, mobility of the charge carriers and dissociation of the salt would be improved which increase the ionic conductivity. According to Druger et al. [31], the increase in conductivity with temperature in polymer electrolytes can be attributed to segmental motion which results in an increase in free volume of the system. The segmental motion either permits the ions to move from one site to another or provides a path way for ions to move. The activation energy values for ionic conduction in different compositions of the polymer electrolyte calculated from the Arrhenius plots are shown in Table 3. It has been observed that the activation energy decreases with increasing salt concentration up to 30 mol% NH$_4$I which may be due to the increase in amorphous nature of the polymer electrolyte that facilitates the ionic motion in the polymer network. The activation energy is found to be low (0.60 eV) for 30 mol% NH$_4$I doped electrolyte. This result is consistent with thermal analysis which shows low $T_g$ for 30 mol% NH$_4$I doped polymer sample. For further increase of salt content (35 mol% NH$_4$I), the activation energy increases due to aggregation of ions, leading to the formation of ion clusters, thus decreasing the number of mobile charge carriers.

**Figure 6:** Temperature dependence of ionic conductivity for different compositions of PVP:NH$_4$I polymer electrolyte

**Figure 7:** Frequency dependence of (a) real part $\varepsilon'$ and (b) imaginary part $\varepsilon''$ of dielectric permittivity for various compositions of PVP:NH$_4$I at 303 K
3.7 Dielectric Spectra Analysis

The dielectric response of a system is generally described by the complex permittivity or dielectric constant,

\[ \varepsilon^* = \varepsilon' - j \varepsilon'' = \varepsilon' - j(\sigma/\omega \varepsilon_\infty) \]  

(2)

where \( \varepsilon' \) and \( \varepsilon'' \) are real and imaginary parts of the dielectric constant respectively, \( \sigma \) is the conductivity, \( \omega \) is the angular frequency and \( \varepsilon_\infty \) is the permittivity of free space. The variation of \( \varepsilon' \) and \( \varepsilon'' \) as a function of frequency for different compositions of PVP:NH\textsubscript{4}I polymer electrolyte at room temperature is shown in Figure 7a and Figure 7b, respectively. The values of \( \varepsilon' \) and \( \varepsilon'' \) are very high at low frequencies and relatively constant at higher frequencies. These values are found to be increased with the NH\textsubscript{4}I content in the polymer complexes. The polymer electrolyte with 70 mol% PVP:30 mol% NH\textsubscript{4}I exhibits the high \( \varepsilon' \) and \( \varepsilon'' \) values at 303 K. The high values of \( \varepsilon' \) and \( \varepsilon'' \) can be attributed to the localization of the charge carriers. The low frequency dispersion region is attributed to the contribution of charge accumulation at the electrode-electrolyte interface [32]. At higher frequencies, due to the high periodical reversal of the electric field, there is no excess ion diffusion in the field direction. The polarization due to the charge accumulation decreases leading to decrease in the values of \( \varepsilon' \) and \( \varepsilon'' \) [33]. The large value of \( \varepsilon'' \) is also due to the free charge motion within the material [34].

The variation of \( \varepsilon' \) and \( \varepsilon'' \) as a function of frequency for 70 mol% PVP:30 mol% NH\textsubscript{4}I at different temperatures is shown in Figure 8a and Figure 8b, respectively.

These figures show that the real and imaginary parts of dielectric permittivity increase with increasing temperature and it is related to an increase in charge carrier concentration. As temperature increases, the degree of salt dissociation and redissociation of ion aggregates increases, which results in an increase in the number of free ions. The variation of \( \varepsilon'' \) as a function of frequency (dielectric loss spectrum) shown in Figure 8b clearly indicates the existence of \( \beta \) relaxation due to some local movement of side group dipoles [35].

3.8 Loss Tangent Spectra Analysis

Figure 9a shows the loss tangent with frequency of PVP:NH\textsubscript{4}I films for different concentrations of NH\textsubscript{4}I at room temperature. The loss tangent spectra characterized by peak appearing at a characteristic frequency for all the samples suggest the presence of relaxing dipoles in all the samples. The strength and frequency of relaxation depend on characteristic property of dipolar relaxation [36]. The loss tangent peaks shift towards the higher frequency side on the addition of salt, indicating a decrease in relaxation time. For maximum dielectric loss at a particular

![Figure 8: Frequency dependence of (a) real part \( \varepsilon' \) and (b) imaginary part \( \varepsilon'' \) of dielectric permittivity for 70 mol% PVP:30 mol% NH\textsubscript{4}I at different temperatures](image)

![Figure 9a: Variation of Tan\( \delta \) of PVP:NH\textsubscript{4}I films with frequency for different concentrations of NH\textsubscript{4}I at room temperature](image)

![Figure 9b: Variation of Tan\( \delta \) of 70 mol% PVP:30 mol% NH\textsubscript{4}I film with frequency at different temperatures](image)
temperature, the lost tangent peak is described by the relation \( \tan \delta = \frac{I_f}{I_i} \) where \( \tau \) is the relaxation time and \( \omega \) is the hopping frequency of the applied electric field [25]. The relaxation times at 303 K are calculated for the films and are presented in Table 3. It has been observed that the 30 mol% salt doped polymer electrolyte is found to have a low relaxation time, \( \tau = 7.38 \times 10^{-5} \) s which is consistent with the conductivity studies which shows higher conductivity for 30 mol% salt doped polymer complex. It is evidenced by the peak shifting towards higher frequency side, thereby reducing the relaxation time. Figure 9b shows the variation of \( \tan \delta \) as a function of frequency for different temperatures. As the temperature increases, the relaxation peak shifts to higher frequencies. This indicates that the charge carrier is thermally activated which results in an increase in the ionic conductivity.

3.9 Transference Number Measurement

The ionic transference number of the mobile species in the PVP:NH4I polymer electrolyte system has been calculated by Wagner’s dc polarization method. Figure 10 shows the variation of polarization current as a function of time for Al/70 mol% PVP:30 mol% NH4I/Al cell configuration at 303 K on the application of the dc voltage of 1.35 V. The ionic transference number has been calculated from the polarization current versus time plot using the equation,

\[
t_{\text{ion}} = \frac{(I_i - I_f)}{I_i}
\]

where \( I_i \) is the initial current and \( I_f \) is the final residual current.

For all the compositions of the PVP:NH4I electrolyte system, the values of the ionic transference number \( (t_{\text{ion}}) \) have been found to be in the range of 0.93-0.97. The ionic transference number obtained is nearly unity. This suggests that the charge transport in these electrolyte films is mainly due to ions [13].

![Figure 10: Variation of polarization current as a function of time for 70 mol% PVP:30 mol% NH4I](image)

4. Conclusion

Various compositions of proton conducting polymer electrolyte based on PVP:NH4I have been prepared by solution casting technique. The increase in amorphous nature of the PVP with the addition of salt has been confirmed by the XRD analysis. The FTIR analysis reveals the complex formation between the polymer and the salt. The DSC thermograms show low \( T_g \) of 343 K for the sample with 30 mol% NH4I. Among all compositions of PVP:NH4I, the one with 70 mol% PVP:30 mol% NH4I has achieved highest ionic conductivity of \( 1.78 \times 10^{-5} \) S cm\(^{-1}\) at room temperature. The conductivity has been increased to \( 2.40 \times 10^{-5} \) S cm\(^{-1}\) when the temperature is increased to 343 K. The activation energy values for all samples have been calculated from the Arrhenius plots and found to be in the range from 0.60 eV to 1.47 eV. The variation of dielectric loss as a function of frequency for the highest conductivity sample, 70 mol% PVP:30 mol% NH4I indicates the existence of \( \beta \) relaxation in the prepared polymer-salt complexes which may be caused by the movement of side chains. The calculated relaxation parameters reveal the low relaxation time for 70 mol% PVP:30 mol% NH4I polymer electrolyte which is consistent with the conductivity studies. The loss tangent peaks appearing at a characteristic frequency suggest the presence of relaxing dipoles in all the samples. The Wagner’s polarization measurement shows that the conducting species in these electrolytes are mainly ions.

References


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