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AC conductivity and dielectric studies of PVA based solid polymer electrolyte

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The solid polymer electrolyte films composed of polyvinyl alcohol (PVA) with various concentrations of sodium nitrate ($NaNO_3$) salt have been prepared by solution casting technique. The bond structure and amorphous nature has been confirmed by Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) analysis respectively. The AC conductivity values have been measured in the frequency range 42 Hz–100 KHz for the films (PVA:$NaNO_3$ = 90:10; 80:20; 70:30; 60:40). The polymer electrolyte with composition 30 wt% of $NaNO_3$ shows the highest conductivity of 2.33×10^{-6} S/cm. Activation energy is found to be 0.19 eV.

Keywords: PVA, $NaNO_3$, XRD, FTIR, conductivity.

Introduction

Solid polymer electrolytes (SPE) are an important class of materials having more number of applications like solid batteries, super capacitors[1]. Broad research is rising to develop new polymer electrolyte with high electrical conductivity. Polyvinyl alcohol (PVA) is soluble completely in water, having melting point 180° to 190°C and high molecular weight. Important properties of PVA are good film forming capability and excellent electrical properties. Amorphous nature, structural vibration and conductivity are carried out by X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy and impedance measurements respectively.

Experimental

PVA as host polymer, its molecular weight 1,24,000 g/mol, $NaNO_3$ as salt was the dopant. Distilled water was used as solvent. The polymer PVA was doped with $NaNO_3$ in different ratios such as 100:0, 90:10, 80:20, 70:30 and 60:40 compositions have been prepared by solution-casting technique and is continuously stirred for 48 h at 60°C. The solution was poured into poly propylene Petri dishes and kept in vacuum chamber at 65°C for 24 h, transparent films were formed. For all samples, XRD pattern was recorded by Philips PANalytical X-ray diffractometer using Cu kα radiation. The FTIR spectrum for this film was recorded by IR Affinity-1 Spectrometer of the range 400 cm^{-1} to 4000 cm^{-1}. AC conductivity parameters were measured by a HIOKI 3532-50 LCR Hitester, frequency range 42 Hz to 5 MHz and temperature from 303 K to 373 K. DC conductivity was measured by a Keithley 6514 electrometer from 308 K to 393 K.

Results and discussion

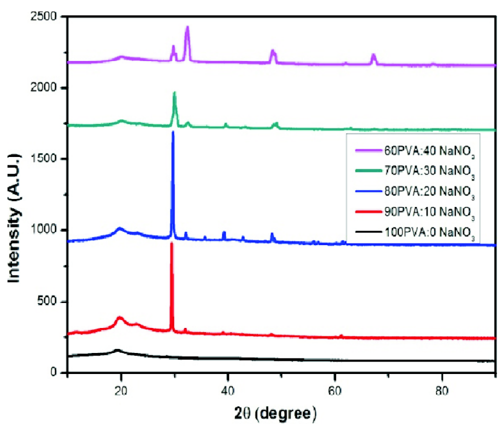

Fig. 1. XRD plots of pure PVA and PVA complexed films for different wt% $NaNO_3$.

Fig. 1 shows the XRD pattern for pure PVA, PVA doped with $NaNO_3$ different ratios. This comprises of a crystalline peak over a broad hump due the amorphous phase[2]. Compare with other concentrations it is clear from the pattern 70:30 SPE film has more amorphous, due to this nature the intensity of the peak decreases and broadness of the diffraction peak increases.

Fig. 2 represents FTIR patterns for pure PVA and PVA-$NaNO_3$ complexes of various concentrations. Na^+ ions are located close to the O-H groups of PVA, lower stretching bond in FTIR spectrum appeared at 3335 cm^{-1} for pure PVA is not displaced. It indicates less chemical interactions among the ions and atoms then shows physical reaction[3].

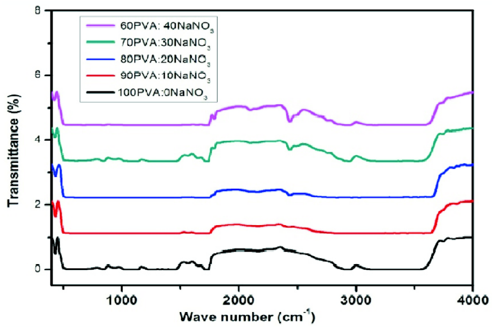

Fig. 2. FTIR spectra of O-H group in SPES of PVA: $NaNO_3$ (100:0, 90:10, 80:20, 70:30, and 60:40).

Fig. 3 represents the electrical characterization of SPE for various concentrations of PVA and $NaNO_3$. In this plots

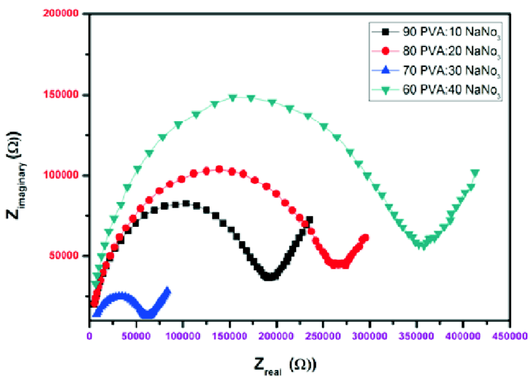

Fig. 3. Real versus imaginary impedances for different concentrations of PVA and $NaNO_3$.

the bulk resistance (R_b) of this SPE has been calculated from low frequency spikes or intercepts of high frequency on real impedance axis (Z_{real})[4]. The conductivity of ions is calculated from the formula.

$$\sigma = l/(AR_b)$$

where A is the area and l is the thickness of the SPE film respectively. The higher ionic conductivity has been found to be 2.33×10^{-6} S/cm for 70 PVA:30 $NaNO_3$ SPE film.

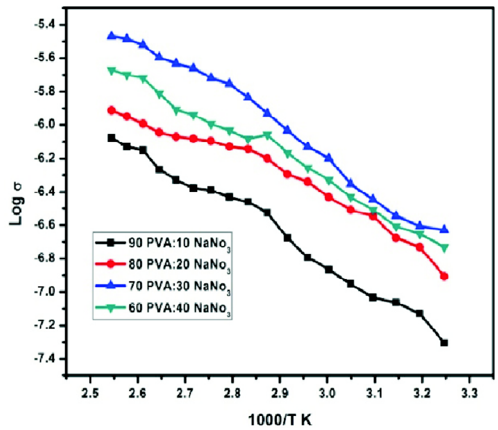

Fig. 4. Log σ versus 1000/T for PVA based SPE films at different weight percent ratios.

Fig. 4 shows the conductivity rises by raising the temperature and also 30 wt% $NaNO_3$ film shows highest conductivity of ions, activation energy (E_a) for same sample is found to be 0.197 eV. The dc conductivity obeys the Arrhenius law.

$$\sigma_{dc} = A \exp [-E_a/kT]$$

where k, T are the Boltzmann constant and absolute temperature respectively. The increase in conductivity with temperature can be connected to the decrease in viscosity and then increases the chain flexibility.

Conclusions

Amorphous natures, vibration mode of molecules have been confirmed by XRD and FTIR respectively. For doped 30% $NaNO_3$ has highest ionic conductivity is found to be 2.33×10^{-6} S/cm at 373 K and activation energy calculated from Arrhenius plots has been found to be 0.197 eV.

References

1. S. Rajendran, M. Sivakumar and R. Subhadevi, *Mater. Lett.*, 2004, **58**, 641.
2. N. Krishna Jyothi, K. K. Venkata Ratnam, P. Narayana Murthy and K. Vijaya Kumar, *Bull. Mater. Sci.*, 2016, **39**, 1047.
3. N. Krishna Jyothi, K. K. Venkata Ratnam, P. Narayana Murthy and K. Vijaya Kumar, *Mater. Today: Proc.*, 2016, **3**, 21.
4. H. J. Woo, S. R. Majid and A. K. Arof, *Solid State Ionics*, 2013, **252**, 102.