Electrical and mechanical property of the polyvinyl alcohol based solid electrolyte film contains alum

Sekar Karthik¹ · Jayaseelan Suresh¹ · Venkatesan Thangaraj¹ · Kanagasabai Balaji¹ · S. Selvasekarapandian² · Saravanan Shanmugasundaram³ · Araichimani Arun¹

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Abstract

The solid polymer electrolyte film is prepared using polyvinyl alcohol and alum by the reactive blending method. Different wt% of alum is used for the preparation of the films. Temperature dependent properties of the films were characterized by IR, A/C conductivity, dielectric, conductance, DSC and TGA. The X-ray diffraction pattern of the synthesized film showed an increased crystallinity over pure PVA. The constituent present in the polymer film is found out by EDX measurement. The spin state in which metals present in the film is found out by XPS analysis. The thermal stability of the film is increased over pure PVA. The tensile curve of the polymer sample contains 0.15 wt% of alum showed a strain induced crystallisation behavior due to plasticizing effect of the embedded salt. The polymer sample contains 0.15 wt% of alum showed conductivity (AC) of $1.73 \times 10^{-4} \text{ S cm}^{-1}$. Conduction pattern is studied by dielectric loss experiments.

Keywords Solid electrolyte film · Ionic conduction · Thermal behaviour

1 Introduction

Polymer electrolyte plays important role in the field of optical and electrical fields. More importantly Polymer composites are used as electrolytes in fuel cells, super capacitors, smart windows, drug delivery and electro chromic devices (ECDs) [1–3]. The performance and the application of the polymer electrolyte are highly influenced by the mechanical property of the polymer film. In most of the studies found in the literature, a good ionic conductivity is obtained while using polymer as a gel which encapsulate the conducting moiety. In this way they obtained conductivity is in the order of $1 \times 10^{-3} \text{ S cm}^{-1}$. In recent studies, the nanostructured inorganic salt embedded polymer film showed good conductivity. The inorganic salt employed in this way is Al_2O_3 [4], SiO_2 [5], TiO_2 [6], ferrites [7], etc. These polymers based electrolytes finds a lot of applications in electronic fields. Polyvinyl alcohol based electrolyte film

is one among the polymer based electrolytes which is studied extensively. Agrawal and Awadhia [8] in his paper reported that the $(\text{PVA})\text{--NH}_4\text{SCN}$ gel electrolytes contain Al_2O_3 showed the conductivities of $\sim 10^{-3} \text{ S cm}^{-1}$ [9]. However the presence of the salt in the polymer structure is expected to affect the mechanical property of the polymer film. Several studies were done on improving the mechanical property while retaining the good conductivity of the polymer film. The effect of inorganic fillers on the morphology and mechanical properties of poly (vinyl alcohol) was reported by Ranjana et al. [10] in his paper they found that significant improvement in percentage elongation and elongation at maximum force was observed for all the composites containing metal salts. Fujii et al. [11] prepared PVA/halloysite films using untreated-halloysite and studied its tensile strength, before and after sulphuric acid treated with a film. They conclude that the reason for low tensile strength can be due to the weaker interfacial

✉ Araichimani Arun, aruna2075@yahoo.co.in | ¹PG & Research Department of Chemistry, Government Arts College, Tiruvannamalai, Tamil Nadu 606603, India. ²Materials Research Center, Coimbatore, Tamil Nadu, India. ³Indian Institute of Crop Processing Technology, Tanjavur, Tamil Nadu 613005, India.

adhesion exists between PVA and halloysite. However, after 1 h sulfuric acid treatment on the halloysite showed a positive effect on the tensile properties. Treating halloysite using sulfuric acid also improved optical transmittance of the prepared films. The flexible and transparent films of polyvinyl alcohol doped with potassium dihydrogen phosphate (KDP) were prepared by Uddin et al. [12]. In his study, they reported effect of frequency and temperature on the relative hydrogen-bonded KDP fillers. Their claims that the relative permittivity of the synthesized composite showed 80 fold increases than the pure PVA. The present work is to study the synthesis, conductivity and mechanical property of the polymer electrolyte based on polyvinyl alcohol (PVA) with alum. A different molar ratio of the alum is employed in the synthesis to obtain the excellent mechanical and conducting properties.

2 Experimental section

2.1 Materials and methods

Poly vinyl alcohol (PVA) (Mol% wt% = 79,000–90,000), Alum ($(\text{NH}_4\text{Al}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O})$) AR grade were purchased from S.D. Fine Chemicals. Triple distilled water was prepared and used as a solvent in the reaction. Triple distilled water is used for the reaction to avoid any ionic impurities in the crystal. FT-IR spectrophotometer was recorded using an ALPHA BRUKER instrument by KBr pellet method. Perkin Elmer DSC 7 apparatus is used for measuring DSC spectra which is operated with a PE 7770 computer and TAS-7 software. Approximately, 10–15 mg of copolymer sample is used and the heating rate will be 20 °C/min. Thermo gravimetric analysis (TGA) method is used to find out the thermal stability of the polymers using DuPont 951 thermo gravimetric analyzer. The operating temperature is from 30 to 500 °C at the heating rate of 10 °C/min under nitrogen atmosphere. ESCA–3 Mark II spectrometer (VG Scientific Ltd., England) is used for X-Ray photoelectron spectra (XPS) analysis of the polymer using Al K α (1486.6 eV) as a radiation source. The binding energy of C (1 s) (285 eV) is used as a reference. X-ray diffractograms were recorded by using Siemens D5005 diffractometer which is using Cu K α ($\lambda = 0.1542$ nm) as a radiation source. The morphology and the constituent of the film is evaluated using SEM with EDX instrument. CARL ZERSS MA15/EVO 18 (SEM) and OXFORD INSTRUMENTS (EDX) Nano Analysis INCA Energy 250 Microanalysis System. The conductivity of the prepared samples was measured using HIOKI-3532 LCZ meter operated in the frequency range of 42 Hz–5 MHz at different temperatures. The stainless steel electrode is used as blocking electrodes. The Stress–strain curve of the polymer is measured using the rectangular shape film using Pack Test

UTM model KC-3000 fitted with 500 N load cell. The tensile measurement was carried out at a strain rate of 0.4 s^{−1} which corresponds to the speed of 60 mm/min. The E-modulus were obtained from the strain of 0.1–0.25%. The formula used for calculating true fracture stress is,

$$\sigma_{\text{true}} = (\epsilon_{\text{fracture}} + 1) \times \sigma_{\text{fracture}} (\text{MPa})$$

2.2 Synthesis of solid electrolyte

Reactive blending strategy is employed for the preparation of the solid electrolyte film. Different weight composition of PVA and alum are used for the preparation of the film and the effect of concentration on the AC conductance is studied in detail. As an example, the strategy employed in the preparation of polymer blend A is provided here. In a three necked round bottom flask, 10 g of PVA (99.85%) and 0.015 g of aluminium alum (0.15 wt%) are taken and the flask is fitted with mechanical stirrer and nitrogen inlet tube. The content of the flask is kept under a nitrogen atmosphere and stirred at 150 °C for 3 h. The content in the flask is dissolved in hot water and placed in a Teflon Petri dish. The petri dish is then dried overnight in an air oven at 80 °C for solvent evaporation. The formed film is then peeled from the petri dish and kept in the vacuum desiccators for further studies. A similar procedure is adopted for the synthesis of polymer film, which contains different compositions of alum and PVA.

3 Results and discussion

3.1 Synthesis of polymer film

PVA based polymer electrolyte film is prepared using the procedure given in the experimental section. The thermal decomposition of the alum is performed in situ, which then leads to the formation of metal oxide dispersed in the PVA matrix. The proposed reaction pathway for the synthesized film is presented in the Scheme 1. The NH_3 present in the alum is completely eliminated from the reaction mixture which is confirmed by the EDX test. However, the SO_3 evolved during the thermal decomposition of the alum can be reabsorbed by the PVA matrix and it is difficult to eliminate from the reaction mixture [13]. The presence of sulphur atom is confirmed by the EDX analysis and discussed in the later section of the manuscript. Therefore, the proposed reaction is confirmed by the FT-IR and SEM with EDX measurements. The prepared film thickness is found to be in the range of 90–120 μm . The constituent of the film is maintained in such a way that the wt% of PVA is not altered and the wt% of alum is varied systematically. By this way the effect of concentration of the alum on the conductivity of the membrane is studied in detail.

Scheme 1 The synthetic route of solid polymer electrolyte

There are three compositions is studied which contains 0.15 (A), 0.35 (B) and 0.50 (C) weight percentage of alum in the PVA matrix. The mole fractions of the alum and the PVA used in the solid electrolyte preparation is presented in the Table 1. Figure 1 is the optical photograph of the film A and similar type of transparent films is obtained for other two compositions.

Highly transparent optical photograph of the polymer A (Fig. 1) confirms that the host PVA matrix is uniformly and homogeneously mixed with the guest alum material.

3.2 FT-IR spectra

The structural elucidation of the polymer blend is conveniently studied using FT-IR spectroscopic technique. The IR spectrum of the polymers is recorded in the region of 4000–600 cm^{-1} at room temperature. The Fig. 2 shows the IR spectrum of the polymers A, B, C and pure PVA at room temperature. The pure PVA shows the characteristic peaks around 3300, 2900 and 1736 cm^{-1} corresponds to OH, C–H symmetric stretching and C=O stretching of acetate groups respectively. The PVA used in this study is in the 88% hydrolyzed form and fraction of the unhydrolysed acetate group is showed the peak at 1736 cm^{-1} . The peak at 1430 cm^{-1} and 1336 cm^{-1} and 1254 cm^{-1} are assigned to CH_2 wagging and C–OH plane bending and C–O–C stretches respectively.

Fig. 1 Optical photograph of transparent film A

Fig. 2 FT-IR spectrum of polymers at room temperature

The IR spectrum of the PVA complexed with the alum showed remarkable variation in the absorption pattern. Prominent differences observed in the region of absorptions for hydroxyl, carbonyl and metal oxide. The absence of strong peak and appearance of very broad peak around

Table 1 Weight fraction, DSC, TGA and AC conductivity value of Polymer films

Polymer code	Weight fraction (g)		DSC ($^{\circ}\text{C}$)				AC Conductivity (σ) at 303 K Scm^{-1}	TGA($^{\circ}\text{C}$) (50% decomposition)
	PVA	ALUM	Tg	Tm	Tc	Tm-Tc		
PVA	10	–	83.4	188.5	157.2	31.3	–	345
A	10.85	0.15	84.9	212	165	47	1.73×10^{-4}	380
B	10.65	0.35	84.7	206.5	165.2	41.3	2.53×10^{-5}	377
C	10.50	0.50	84.5	203	164	39	1.67×10^{-5}	375

3300 cm^{-1} is due to the absorption of the OH group present in the PVA which is associated or bonded with Al_2O_3 [13]. This further confirms that the OH group in the PVA chain connected to two or more aluminum atom [13]. The schematic association pattern of the PVA complexed with the alum is presented in the Scheme 1. The C=O stretching frequency of the acetate group is shifted to lower frequency upon PVA is blended with the alum. The shift in the carbonyl band at lower frequency is due to the complexation of Al^{3+} cation to the carbonyl oxygen. Prominent peak appears around 650 cm^{-1} in the polymers A and C is due to the stretching frequencies of Al–O which is presented in the PVA matrix. The appearance of this peak further confirms that the alum is in the form of $\alpha\text{-Al}_2\text{O}_3$. The absence of peak around 1100 nm further confirms that the Al bonded as Al–O and not as Al–OH [14].

3.3 DSC analysis

The DSC spectrum of the first cooling and the second heating curve of the polymer samples, pure PVA, A and C is given in the Fig. 3 and the T_g , T_m and T_c value is presented in the Table 1. This analysis has been carried out to see the effect of interaction of the ionic salt upon the chain mobility in turn the crystallinity polymer sample. The pure PVA sample showed two transitions at 83 and 188.5 $^{\circ}\text{C}$ corresponds to the T_g and T_m respectively. The melting transition of the pure PVA is shallow and the melting enthalpy value is difficult to measure. The T_g value of the polymer samples A and C has a little higher than the pure PVA value and centered around 85 $^{\circ}\text{C}$. This slight increase in the T_g value of the samples A and C confirms that there is an ordered arrangement in the chain and it facilitate the packing of the chain even at high temperature. Remarkable differences were observed when compared to the T_m value of the pure PVA and the samples A and C. On

contrary to the pure PVA, the sample A and C showed prominent melting peak and the heat of the enthalpy is much higher than the pure PVA. The T_m and the heat of the enthalpy of the crystalline structure is increasing with increase in the concentration of the alum. The increased in the T_m value is due to increase in the crystallinity of PVA. The added salt is placed in between the two PVA chains and thereby crystallizes in a better way than the pure PVA. This increase in the T_m can be otherwise called as the plasticization effect of the electrolyte with addition of salt. This type of plasticization effect is due to weak dipole–dipole interactions existing between the PVA to that of added salt. Similar to the heating curve, the cooling curve shows much better crystallization peak when the salt is added to the pure PVA sample. Also, from the DSC values it is confirmed that the crystallization window ($T_m - T_c$) is very small and the values are mentioned in the Table 1. The high crystallinity with fast crystallisation is due to the ordered arrangement in the melt [15]. This ordered arrangement in the melt is brought out by the presence of alum in the PVA matrix. Therefore, the DSC data clearly proved that the crystallinity of the pure PVA is increased when the pure PVA is blended with alum.

3.4 TGA analysis

The TGA curve of the polymers is shown in the Fig. 4 and the data are presented in the Table 1. TGA curve shows that the polymers are undergone single decomposition and the peak is centered around 350 $^{\circ}\text{C}$. Also, the TGA data showed the residual content of the polymer A and C are 8.6% and 10.6% respectively. The single stage decomposition appeared at 300 $^{\circ}\text{C}$ is due to the breaking of polymer backbones. The higher residual value of the sample C over A confirms that the used alum during synthesis is effectively added into the polymer matrix. The high decomposition temperature value of these polymers confirms the thermal stability at elevated temperatures.

3.5 XRD analysis

The XRD pattern of the polymer samples is presented in the Fig. 5. Noticeable broad peak appears as the 2θ value of 20 $^{\circ}$. However, the intensity of the peak varies with the constituent of the polymers. The peak intensity of the Pure PVA is found to be lower than that of the PVA contains alum material. The peak intensity can be directly correlated with the crystallinity of the polymer and therefore it is found that the crystallinity of the PVA containing alum is higher than the pure PVA. The increase in crystallinity is due to the close packing of PVA chain which is also proved by DSC data. When you compare the XRD pattern of the polymer samples A and C, there is not much difference

Fig. 3 DSC heating and cooling curve of pure PVA, A and C polymers

Fig. 4 TGA curve of pure A, and C polymers

Fig. 5 XRD pattern of pure PVA, A, B and C polymers

and it further proves that the optimum concentration of the alum in the PVA matrix lies around 0.15 wt% under test conditions.

3.6 XPS analysis

XPS analysis of the synthesized polymer blend of PVA with aluminium alum exhibits the chemical states of the element present in that polymer blend. The wide XPS spectrum of the sample A is presented in the Fig. 6, which is the representative of the series of polymer blend made up of PVA with aluminium alum. Figure 7a–d is the XPS spectrum of the Al, S, C and O respectively. This clearly shows that the blend contains only Al, O, S and C. Absence of nitrogen confirms that the ammonia, which is present in the aluminium alum is removed as a gas during the blending process.

XPS spectrum of aluminium is shown in the Fig. 7a, the peak appears at 74.2 eV. It corresponds to 2p electron of the aluminium. The aluminium present in the polymer

Fig. 6 Wide XPS spectrum of sample A

blend is in the form of Al_2O_3 . The binding energy of the Al 2p electron in the blend is 74.4 eV, which is in good agreement with the literature value [16], as well as with XPS handbook [17] for the Al in Al_2O_3 structure. Figure 7b is the XPS spectrum of sulphur; the peak appears at 165.8 eV corresponds to sulphur in its $2p_{3/2}$ chemical states. The presence of sulphur in the polymer A is in sulfite form, which will show the peak in XPS around 165.8 to 168 eV. [17]. Therefore, it confirms that the sulphur present in the polymer A is in the form of sulfite. Figure 7c is the XPS spectrum of carbon; here the peak appears at 286.1 eV which corresponds to 1s electron of carbon bonded with sulphur. According to the XPS handbook, carbon attached to the sulphur atom shows the value of 285.5–286.5 eV. Figure 7d is the XPS spectrum of oxygen; the peak appears at 530.1 eV corresponds to 1s states of oxygen. A similar XPS spectrum was reported for oxygen 1s electron by Li et al. [18]. The oxygen of metal oxide, exhibits the XPS peak between 528 and 531 eV. Again, these values of Al and oxygen present in the PVA matrix, aluminium alum are in the form of Al_2O_3 . On the basis of the above XPS data, the synthesized polymer blend

Fig. 7 XPS spectrum of atoms **a** Aluminum **b** sulphur **c** Carbon and **d** Oxygen of A

contains the expected elements in the polymer matrix. And it is also good supporting information about the proposed reaction scheme of PVA with aluminium alum. From the XPS value of aluminium and oxygen, it is confirmed that the metal oxide in the blend is presented as in the form of Al_2O_3 .

3.7 SEM with EDX

The SEM pictures of the sample A and C is presented in the Fig. 8. The sample A showed a uniform distribution of the alum particles in the PVA matrix. However the sample C showed some agglomeration or aggregation or ionic clusters of alum in the PVA matrix. The presence of this type of aggregations of alum in the

solid matrix can be due to the high percentage of alum, salt employed during polymer preparation (0.50 wt%). This aggregation of salt will severally affect both the conductivity as well as the mechanical property of the polymer electrolytes which will be discussed in the later section of this manuscript. The EDX spectrum the sample A is shown in the Fig. 9. This shows that the peaks corresponds to the elements C, O, Al, and S at different energies. The inset table which is presented in the Fig. 9 describes the percentage composition of the element present in the sample A. The high percentage of the oxygen content in the polymer film confirms that the film is in fact containing some moisture in it. The absence of peak for nitrogen in the EDX picture confirms that the NH_4 ions present in the reactants are completely

Fig. 8 SEM pictures of (a) A, and (b) C polymers

Fig. 9 EDX pictures of C polymers (Insert table shows the percentage of constituents present in the polymer C)

Fig. 10 Stress-strain curve of the polymer sample: O: pure PVA; *: polymer C (0.50 wt% of alum); Δ : polymer A (0.15 wt% of alum)

removed during the reactive blending process. Therefore, this EDX data confirm the formation of the proposed structure in the Scheme 1. The EDX spectrum also shows the sulphur present in the polymer matrix. This can be due to the entrapment of SO_2 molecules in the PVA matrix during the reactive blending process.

3.8 Tensile test

The mechanical strength of the polymer film is measured using the tensile experiment. The film is cut into a rectangular shape and used for the tensile experiment. The tensile graph of the pure PVA, polymer A and polymer C is presented in the Fig. 10 and the tensile data were presented in the Table 2. The pure PVA showed low stain percentage due to its low molecular weight. The tensile strength and the elongation at break of the pure PVA are similar to the reported value [19]. The polymer C has shown a similar trend as pure PVA with respect to that of elongation at break, but the tensile stress is higher than the pure PVA due to the presence embedded ionic molecule which gives the tensile strength. Surprisingly, the polymer sample A showed a strain induced crystallization behavior which is a unique nature of the thermoplastic elastomers. The polymers code A showed lower yield strength with a high fracture stress and fracture strain values. This type of strain induced crystallization is observed when the calcium carbonate is mixed with the polypropylene [20]. However, probably this is the first time we observed alum dispersed in the polymer matrix showed a strain induced crystallization behavior. This unique feature makes these systems very interesting. The E-modulus and the yield strength of the polymer C sample is higher than the polymer A due to the fact that the polymer C contains a higher concentration of alum than the polymer A. However, the polymer A showed higher fracture stress and fracture strain due to the complete dispersion of ionic molecule in the polymer PVA matrix which in turns involved in the crystallization process. The increased fracture stress and a higher strain of the polymer A is due to the strain hardening of the PVA segments. This type of strain hardening reported for the thermoplastic elastomer materials [21]. The fracture stress and fracture strain combined together we called as the true fracture stress. Again the true fracture stress of the sample A showed a very high value compared to that of the polymer sample B and C due to the fact of high values of the fracture stress and fracture strain value of the sample A (Table 2). Dissimilarities in the test condition, restrict further the comparison of true stress value with that of the available literature value of similar system. However, it is confirmed that the uniform and lower concentration

Table 2 Tensile data of the polymer film

Polymer code	Alum (wt%)	E-Mod (MPa)	ϵ_{yield} (%)	σ_{yield} (MPa)	$\epsilon_{\text{fracture}}$ (%)	σ_{fracture} (MPa)	σ_{true} (MPa)
PVA	–	7	10	20	21	22	484
A	0.15	11	11	57	80	89	7209
B	0.35	14	10	31	38	26	1014
C	0.50	18	11	23	32	28	924

of the alum produced excellent materials with high stress strain values.

3.9 Impedance analysis

The col-col plot for the PVA-Alum film at different temperature is presented in the Fig. 11. In a typical plot, high frequency semicircle followed by a low frequency straight line will be observed corresponds to the bulk conductivity which is again a collective effect of bulk resistance and bulk capacitance of the polymer. In the Fig. 11, the semi circle portion is disappearing at high frequency confirms that the current carriers in our system are mainly due to the result of ion conduction. A curvature appears at low frequency is due to the double layer blocking at the electrodes. The intercept value at Z' axis will give the resistance of the bulk electrolyte (R_b).

The total conductivity of the polymer electrolyte has been calculated using known the formula:

$$\sigma = L/R_b.A \text{ (in } S\text{cm}^{-1}) \quad (1)$$

where σ , L , R_b and A are ionic conductivity, polymer film thickness, bulk resistance and area of the stainless steel electrode respectively.

The conductivity of the polymer electrolyte samples at 303°K is presented in the Table 1. The table shows that the high conductivity of $1.73 \times 10^{-4} S\text{cm}^{-1}$ is observed in the system contains 0.15 wt% of alum with PVA (sample A). However, the sample which contain, 0.50 wt% of alum with PVA showed the conductivity of $1.67 \times 10^{-5} S\text{cm}^{-1}$ which is lower than the sample A value. The observed low conductions are the outcome of the agglomeration of the salt, which plays a predominant factor at high salt concentrations. The temperature plays a vital role in the bulk resistance as it has been found in our case that the

bulk resistance decreases with increasing temperature. The possible reason for this observation can be due to increase in carrier ions and its mobility with an increase in the temperature.

3.10 Conduction spectra

The Fig. 12 shows the conduction spectra of the polymer electrolyte sample A and C at different temperature. In this figure two parameters were varied with respect to the conductions of the polymer electrolytes namely, frequency and temperature. At a particular temperature, the graph contains two regions, a low frequency dispersive region and the plateau region. A low frequency dispersive region can be due to the electrode polarization effects. At a low frequency region, the ionic conductivity is high enough to produce a significant build up of charges at the electrodes. The plateau region is called as DC conductivity. The AC conductivity at high frequency region is called as the DC conduction value. At high frequency the period of the applied field is very short and the conduction value is said to be frequency independent value. The Fig. 12 also reveals that the temperature has a pronounced effect on the conduction. As the temperature increases the conduction increases. The increase in conduction due to two factors, i.e., increase in the free volume of the polymer electrolyte and increase in the ionic mobility in the polymer electrolyte.

3.11 Dielectric spectra

The amount of charge that a material can store can be generally presented as a dielectric property of a material. Also, this property can tell us whether the conductivity of a material is due to the increase in charge carriers or due to the mobility of free ion. The increase in dielectric property

Fig. 11 Represents the col-col plot sample A and sample C of alum for different temperatures

Fig. 12 The complex impedance plot of the sample A and C at different temperatures

of the material is directly related to the amount of charge stored in that particular material.

Figure 13 represents the plot of $\log F$ vs. ϵ'' for 0.15 wt% and 0.50 wt% of alum at different temperatures respectively. The dielectric plot at a given temperature has got two distinct regions. At low frequency, the dielectric loss becomes very large can be due to free charge motion. The value is not related bulk dielectric process instead it is due to the free charges that built up between the two interfaces, i.e., material and the electrodes. The very large value of ϵ'' of low frequency due to the availability of time for charges to build up at the interface before the field changes its direction and this phenomenon is called as conductivity relaxation. Generally the α -relaxation caused by the movement of a main chain dipole segment is responsible for the observed low

frequency peak. On the other hand, β -relaxation which is caused by the side group dipoles is responsible for the high frequency peak. From the graph it is confirmed that the α -relaxation is decreasing with an increase in the salt content and on other words, the β -relaxation will become predominant at a higher salt content. The temperature has got a pronounced effect on the dielectric spectra. As the temperature increase the ϵ'' value is increasing sharply. Similarly, in the dielectric relaxation, peak is shifted to the high frequency at higher temperature. The decrease in the relaxation time upon increase the temperature leads to increase in the conductivity. The increase in the conductivity at high temperature can be due to the dissociation of the ion aggregates which in turn produces higher number of free ions or charge carriers.

Fig. 13 The dielectric spectra of A and C

4 Conclusions

Using reactive blending method, PVA and aluminium based solid electrolyte film is prepared and characterized by several techniques. The prepared film is transparent without any hue. The FTIR method confirms the formation desired product. DSC data reveal that the T_m value increases with an increase in the concentration of the alum in the polymer film. TGA data showed the prepared polymer film is thermally stable at elevated temperatures. The crystallinity of the PVA is increased upon blending with alum. The chemical constituents present in the polymer film is estimated by EDX and found to be supporting the proposed reaction bath way, i.e., ammonia is released during the reaction and the aluminium is presented as Al_2O_3 . The tensile data showed that the elastic behavior is found to be excellent for the polymer containing a low alum concentration and it also reveals that the strain induced crystallization is observed in our system. The true fracture stress value decreases with an increase in the concentration of the alum. The observed tensile data confirm that there is an agglomeration of alum occurs at high alum concentration which leads to decrease in the fracture values. The conductivity of the polymer film is measured using impedance analysis. The polymer contains a low alum concentration showed an excellent AC conductivity value of $1.73 \times 10^{-4} \text{ K S cm}^{-1}$ at room temperature.

Compliance with ethical standards

Conflicts of interest There are no conflict of interest to declare.

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