



## CHARACTERIZATION OF PEO-ENR 50 BASED SOLID POLYMER ELECTROLYTE

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### ABSTRACT

The solid polymer electrolytes (SPE) comprising blend of poly(ethylene oxide) (PEO) and 50% epoxidized natural rubber (ENR 50) as a polymer host and  $\text{LiCF}_3\text{SO}_3$  as a dopant were prepared by solution casting technique. The SPE films were characterized by Field Emission Scanning Electron Microscope (FESEM) to determine the surface morphology, while the presence of the complexes was investigated by [Attenuated Total Reflection Fourier Transform Infrared](#) (ATR-FTIR). Electrochemical Impedance Spectroscopy (EIS) was conducted to obtain ionic conductivity. FESEM analysis showed that, the rough surface morphology of SPE became smoother by addition of salt while ATR-FTIR analysis confirmed the polymer salt complex formation. The interaction occurred between salt and ether group of polymer host where the triple peaks of ether group in PEO merged and formed one strong peak at  $1096\text{ cm}^{-1}$ . Ionic conductivity was found to increase with increasing of salt concentration in the polymer blend complexes. The highest conductivity achieved was  $1.4 \times 10^{-4}\text{ S/cm}$  at 20 wt. % of  $\text{LiCF}_3\text{SO}_3$  and this composition exhibited an Arrhenius-like behavior with the activation energy of 0.18 eV.

**Keywords:** *Poly(ethylene oxide) (PEO) – 50% epoxidised natural rubber (ENR 50), Solid polymer electrolyte (SPE), Ionic conductivity, Arrhenius behavior*

## INTRODUCTION

Ionic conducting polymer electrolytes were first suggested by Fenton and Wright in 1973 (Fenton et al. 1973). They found that the ionic conductivity of polymer based electrolyte of PEO-NaSCN system could achieve  $10^{-5}$  S/cm at room temperature. However, the technological significance especially in development usage of electrochemical was only appreciated after publication of Armand in 1978 (Andrews 1978). To date, polymer electrolytes become main concern of researches due to its ability for new types of electrical power generation and storage systems such as displays, sensors, electrochemical windows, supercapacitors and rechargeable batteries. Several types of polymer have been studied to see their potential as a polymer based electrolyte such as poly(methyl methacrylate) (PMMA), poly(vinyl chloride) (PVC), poly(vinylidene fluoride) (PVDF) and poly(ethylene oxide) (PEO) (Famiza et al. 2006 and Fan et al. 2003)

PEO based polymeric electrolytes are the most extensively studied as polymer ionic conductors due to its electrochemical stability, good solubility of many salts and beneficial structure in supporting fast ionic transport (Fan et al. 2003). Unfortunately, a high crystalline phase concentration limits the conductivity of PEO based electrolyte. Various techniques have been developed to reduce the crystallinity of PEO and enhance the ionic conductivity at room temperature. The most common technique is to add plasticizers such as propylene carbonate (PC), ethylene carbonate (EC), and dibutyl phthalate (DBP) (Glasse et al. 2002, Idris et al. 2001 and Benedict et al. 1998). However, incorporation of plasticizers will promote deterioration of the electrolytes mechanical properties and increases its reactivity towards the lithium metal anode. The recent technique developed for solid polymer electrolyte is the dispersion of nano size inorganic ceramic filler particles such as  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{TiO}_2$ ,  $\text{SnO}_2$ ,  $\text{ZnO}$  and  $\text{ZrO}$  in the system (Kumar et al. 2002, Pitawala et al. 2003, Fan et al. 2003 and Xiong et al. 2003). An alternative to plasticizers and ceramic fillers is to blend a complexing polymer such as modified

natural rubber. This is due to their distinctive characteristics such as low glass transition temperature, soft elastomeric characteristics at room temperature, good elasticity and adhesion that makes them a suitable candidate as a polymer host for polymeric electrolyte systems (Famiza et al. 2006, Glasse et al. 2002 and Idris et al. 2001). The good elasticity and adhesion properties of modified natural rubber will provide an efficient contact between the electrodes in electrochemical contacts (Idris et al. 2001). Besides, modified natural rubber such as 50% epoxidized natural rubber (ENR 50) have a polar group in their epoxy ring that will provide coordination sites for  $\text{Li}^+$  ion conduction. In addition, the usage of modified natural rubber will produce low cost and environmental friendly SPE.

This paper proposes PEO-ENR 50 based polymer electrolyte. PEO-ENR 50 was doped with various wt. % of  $\text{LiCF}_3\text{SO}_3$  to form solid polymer electrolyte by using the solution casting technique. These polymer electrolytes were characterized by using Field Emission Scanning Electron Microscope (FESEM), [Attenuated Total Reflection Fourier Transform Infrared](#) (ATR-FTIR) and electrical impedance spectroscopy (EIS).

## METHODOLOGY

### *Reagent and electrolyte film preparation*

The starting materials are PEO ( $M_w$  600 000, Sigma Aldrich, St. Louis, MO), ENR 50 (Malaysian Rubber Board, Kuala Lumpur, Malaysia),  $\text{LiCF}_3\text{SO}_3$  (Fluka/Sigma-Aldrich, St. Louis, MO), and tetrahydrofuran (THF; SYSTERM; ChemAR, Kielce, Poland). To prepare the polymer electrolyte film, 2.8 g of PEO and 1.2 g of ENR 50 were dissolved in THF separately and were continuously stirred with magnetic bar for 24 hours. These two solutions were mixed together and further continuously stirred another 24 hours to obtain homogenous solution. Various wt. % of  $\text{LiCF}_3\text{SO}_3$  (5 to 25 wt. %) were dissolved separately in THF and mixed together with the blended PEO-ENR 50 and stirred efficiently for 12 hours to achieve a homogenous mixture. The solution were cast on a Teflon mould and allowed to evaporate completely in the fumed hood at room temperature to produce a film. Then the film was kept in a vacuum oven at  $60^\circ\text{C}$  for 24 hours to remove the residual solvent. Samples were stored in a desiccator until further use. This procedure provided mechanically stable, free standing and flexible films of thickness from 150 to 250  $\mu\text{m}$ . The preparation of SPE was done in an open atmosphere condition at room temperature.

### *Sample characterization*

The morphology of the samples was characterized by FESEM model (SUPRA 55VP, ZEISS) with 3000 magnification and 25 kV electron beam. FESEM analysis was done at the fractured with gold sputtered-coated film. ATR-FTIR analysis was carried out using Perkin Elmer Pectrum 2000 in the range of wave numbers 4000 to 400  $\text{cm}^{-1}$  with scanning resolution of 4  $\text{cm}^{-1}$ . This analysis was conducted to see the functional group and interaction that occur between polymer based and lithium salt. The alternate current (AC) impedance measurement was carried out using high frequency response analyzer (HFRA Solartron 1255, Schlumberger) and electrochemical interface (SI 1286) in the frequency range of 100 Hz – 1 MHz with 30 mV amplitude. The polymer electrolyte was sandwiched between the stainless steel ion-blocking electrodes with a surface contact area of 2.0  $\text{cm}^2$ . The bulk resistance ( $R_b$ ) was determined from the equivalent circuit analysis by use of the analyzer software. The conductivity values ( $\sigma$ ) have been calculated from the equation  $\sigma = (l/R_b)(t/A)$ , where  $t$  is the film thickness and  $A$  is the active area of the electrode. The EIS analysis was conducted at room temperature and temperature range of 298 K to 333 K.

## RESULTS AND DISCUSSION

### *Surface morphology analysis*

FESEM micrographs of pure PEO, pure ENR 50, blended PEO-ENR 50 and PEO-ENR50 with various wt. % of  $\text{LiCF}_3\text{SO}_3$  are shown in Figure 1. It can be seen from figure 1 (a), that pure PEO shows a rough surface morphology with a lot of rumples. It shows the presence of crystalline phase in PEO (Chu and Reddy 2003). Figure 1 (b) shows the surface morphology of pure ENR 50. It shows a smooth surface morphology of ENR 50 due to fully amorphous nature of natural rubber. When the PEO was blended with ENR 50, the surface morphology of PEO changes from rough to almost smooth and the reduction of rumples also found in Figure 1 (c). It shows ENR 50 coated the rumples of PEO and makes the surface morphology of PEO become smoother than pure PEO. The semicrystalline nature of PEO is reduced by ENR50, as evidenced by the reduction of rumples. The homogeneity of PEO-ENR 50 can be seen as no phase separation can be detected. After 5 wt. % salt was added into PEO-ENR 50 system, the improvement of surface morphology can be seen as shown in Figure 1 (d). The rumples of PEO decreased and the rough

surface changed to smooth surface due to the addition of salt. Figure 1 (e) and (f) show SPE with 10 and 15 wt. % of salt respectively. In these systems, the rumples of PEO were completely absent and the surface morphology of SPE turned to smooth with further addition of salt (20 and 25 wt. %) as shown in Figure 1 (g) and (h). The smooth morphology is closely related to the reduction of PEO crystallinity in presence of the salt (Chu et al. 2003). The reduction of PEO crystallinity arises from random distribution and dissociation of salt which may introduce the topological disorder in the electrolyte. The reduction of crystallinity will produced more amorphous phase in the system. The amorphous phase makes the electrolyte more flexible and results in increase of the segmental motion of the polymer. The dissociation of salt caused the interaction between salt and the polymer host. These observations were supported by DSC and XRD studies as reported in previous work (Noor et al. 2009). Besides, the smooth surface morphology indicates salt was completely dissolved in the matrix. It suggests the existence of interaction between salt and polymer host.

#### *ATR-FTIR Studies*

FTIR analysis was focused in the vibrational portion of the infrared region. Every type of bond has a different natural frequency of vibration and no two molecules of different structure have exactly the same infrared spectrum. Thus, the infrared spectrum can be used for molecules much as a fingerprint can be used for humans. Besides, FTIR is also used to determine structural information about the molecule (Pavia et al. 2001).

Figure 2 represents the FTIR spectra for pure PEO, pure ENR 50 and blended PEO-ENR 50 (70-30) films. For pure PEO, C-H stretching mode can be observed at  $2876\text{ cm}^{-1}$ ,  $\text{CH}_2$  scissoring mode at  $1466\text{ cm}^{-1}$ ,  $\text{CH}_2$  wagging mode at  $1360$  and  $1341\text{ cm}^{-1}$ ,  $\text{CH}_2$  twisting mode at  $1279\text{ cm}^{-1}$  and  $1241\text{ cm}^{-1}$  while  $\text{CH}_2$  rocking mode at  $960$  and  $841\text{ cm}^{-1}$ . The semicrystalline phase of PEO is confirmed by the presence of triplet peak of C-O-C stretching (Rocco et al. 2002 and Tang et al. 2007). C-O-C stretching can be found at  $1145$ ,  $1095$  and  $1059\text{ cm}^{-1}$  vibrations with maximum peak at  $1095\text{ cm}^{-1}$ . For pure ENR 50, the characteristic bands of saturated aliphatic C-H bonds are observed at  $2961$ ,  $2921$  and  $2857\text{ cm}^{-1}$  for C-H stretching, while  $1448$ ,  $1324$ ,  $1250\text{ cm}^{-1}$  correspond to  $\text{CH}_2$  scissoring,  $\text{CH}_2$  wagging and  $\text{CH}_2$  twisting respectively. The band for C-O-C stretching is located at  $1017\text{ cm}^{-1}$  while C=C stretching band at  $1588\text{ cm}^{-1}$ .

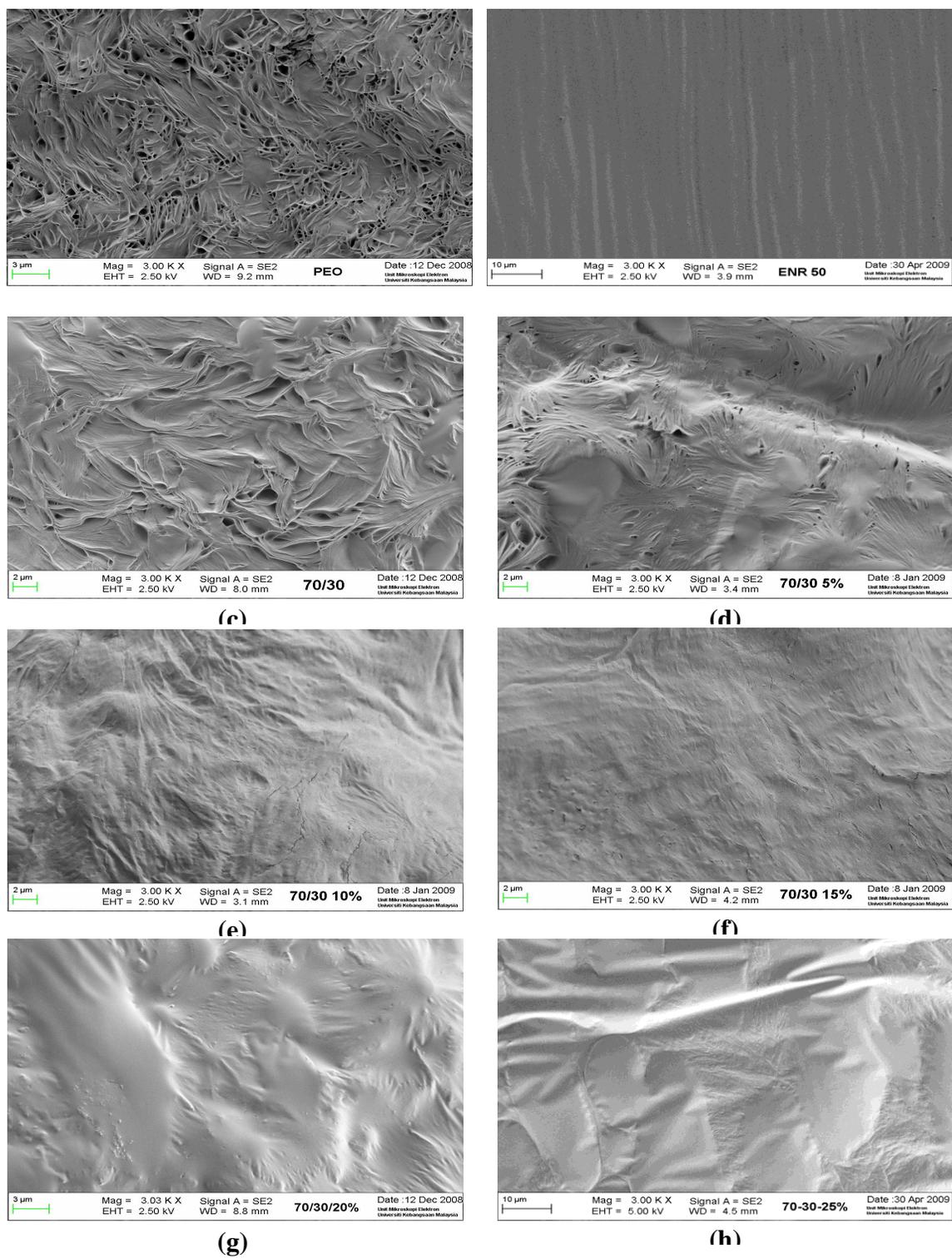


Figure 1 FESEM micrographs for pure PEO (a), pure ENR 50 (b), PEO-ENR 50 (c), PEO with various wt. % of LiCF<sub>3</sub>SO<sub>3</sub> (d) 5%, (e) 10%, (f) 15%, (g) 20% and (h) 25%

For blended of PEO-ENR 50, it was observed that the triplet peak of PEO C-O-C stretching slightly shifted to 1146, 1100 and 1060  $\text{cm}^{-1}$ . Besides, one of the split in the  $\text{CH}_2$  wagging mode, in the pure PEO disappeared and only band at 1341  $\text{cm}^{-1}$  was observed in the blend. Furthermore, the C-O-C stretching from the epoxide ring also disappeared. These observations show the existence of intermolecular interaction between oxygen from the epoxide ring and methylene group from the PEO (Daisuki et al. 2002). On the other hand, the slightly shifted triplet peak of PEO showed insignificant changes in the chemical properties in PEO. It shows that 30% of ENR 50 was able to improve the semicrystalline property of PEO without any drastic change in its chemical properties (Famiza et al. 2006).

The characteristic band regions of ether group in PEO and ENR 50 are the main focus in the detection of ionic interaction. These regions show interesting changes because if the cations were coordinated with the ether oxygen, changes in the ether oxygen vibrational modes are expected to be observed (Reddy et al. 2006). The oxygen atom at the C-O-C functional group carries lone pairs of electron, which are donated to  $\text{Li}^+$  in the formation of complexes with the lithium salt (Ali et al. 2008 and Famiza et al. 2006). Figure 3 shows the comparative infrared spectra of  $\text{LiCF}_3\text{SO}_3$ , PEO-ENR 50 and various wt. % of  $\text{LiCF}_3\text{SO}_3$  in PEO-ENR 50. The region of C-O-C was shown in Fig 3(a). From the spectra, the maximum of triplet peak C-O-C band (1100  $\text{cm}^{-1}$ ) for the polymer host became wide and broad as the wt. % of  $\text{LiCF}_3\text{SO}_3$  increased. Meanwhile, the two minor peaks of triplet peak C-O-C band at 1045 and 1060  $\text{cm}^{-1}$  almost disappeared by increasing the wt. % of  $\text{LiCF}_3\text{SO}_3$  because both peaks is combine into their corresponding peaks. This observation shows that the C-O-C band is strongly effected by cation complexation. The complexations that occur at C-O-C group were via dative bond formation between the  $\text{Li}^+$  from the doping salt and the lone pairs of the oxygen atom from the polymer host (Ali et al 2008 and Famiza et al. 2006). According to Famiza et al. (2006), the broadening of the peaks also may be due to the overlapping of the free C-O-C with the complexation bands of C-O-C. Besides, the broadening of peaks also indicates a reduction of PEO crystallinity (Tang et al. 2007). On the other hand, the peak of  $\text{SO}_3$  symmetric stretching from the triflate anion at 1045  $\text{cm}^{-1}$  shifted to lower wavenumber in the complexes which is at 1030  $\text{cm}^{-1}$ . This behavior also can be seen when MG30 was added with  $\text{LiCF}_3\text{SO}_3$  as reported by Ali et al.(2008). However, this peak became sharper as the wt. % of  $\text{LiCF}_3\text{SO}_3$  increased. These behaviors indicate that

there was a certain amount of lithium salt that was able to be dissolved in the polymer matrix and hence limit the number of lithium ion for coordination (Famiza et al. 2006). The C-O-C band of ENR 50 at  $1018\text{ cm}^{-1}$  cannot be observed at all composition. The absence of this band is due to the intermolecular interaction between oxygen from the epoxide ring and methylene group from the PEO (Daisuki et al. 2002).

The complexation that occurred at the C-O-C effects the region of vibration assigned to the methylene ( $\text{CH}_2$ ) units. The regions are in the range of  $1520 - 1400\text{ cm}^{-1}$  for  $\text{CH}_2$  scissoring mode,  $970 - 800\text{ cm}^{-1}$  for  $\text{CH}_2$  rocking mode and  $1300 - 1150\text{ cm}^{-1}$  for  $\text{CH}_2$  twisting mode. The region of  $\text{CH}_2$  scissoring and  $\text{CH}_2$  rocking mode were shown in the Figure 3(b) and 3(c) respectively. From the spectra, these bands became less intense but have similar shape due to the effect of  $\text{CF}_3\text{SO}_3$  anion (Wen et al. 1996). In the region of  $1300-1150\text{ cm}^{-1}$ ,  $\text{CH}_2$  twisting mode was observed at  $1241$  and  $1279\text{ cm}^{-1}$ . The characteristic of salt also can be observed at this region. The vibrational frequencies of several functional groups presence in triflate anion can be used to show ion dissociation and the interactions of salt in the complexes. The asymmetric stretching of  $\text{SO}_3$  mode is located at  $1292$  and  $1252\text{ cm}^{-1}$  and the symmetric stretching of  $\text{CF}_3$  at  $1189\text{ cm}^{-1}$ . These bands have merged to form a small shoulder and a broad band centered at  $1252\text{ cm}^{-1}$  when the concentration of salt added to polymer host was up to 20 wt. % as observed at figure 3(d). These changes suggest that the environment of the  $\text{CF}_3$  and  $\text{SO}_3$  vibrational mode has change as a result of complexation with PEO-ENR 50 (Joykumar et al. 2003). Besides, the broad band in CH stretching mode also almost merged and centered at  $2880\text{ cm}^{-1}$  when the concentration of salt was increased up to 15 wt. % as shown in Fig 3(e). These observations are similar to the findings reported by Frech and Huang (1995). They compared the vibrational spectra of pure PEO with those of 5:1 PEO:LiTf mixtures and found a significant effect of complexation on the  $\text{CH}_2$  modes. The sensitivity of the  $\text{SO}_3$  symmetric stretching and  $\text{CF}_3$  symmetric deformation modes to the formation of ion pairs and aggregates allows one to assess the state of dissociation of this salt as a function of solvent, concentration and temperature.

It was also observed that the  $-\text{OH}$  band between  $4000-3500\text{ cm}^{-1}$  was broaden as the amount of  $\text{LiCF}_3\text{SO}_3$  was increased. This was attributed to the increased in moisture content due

to hygroscopic nature of  $\text{LiCF}_3\text{SO}_3$ . The presence of moisture explained why the films obtained were damped as the amount of salt increased.

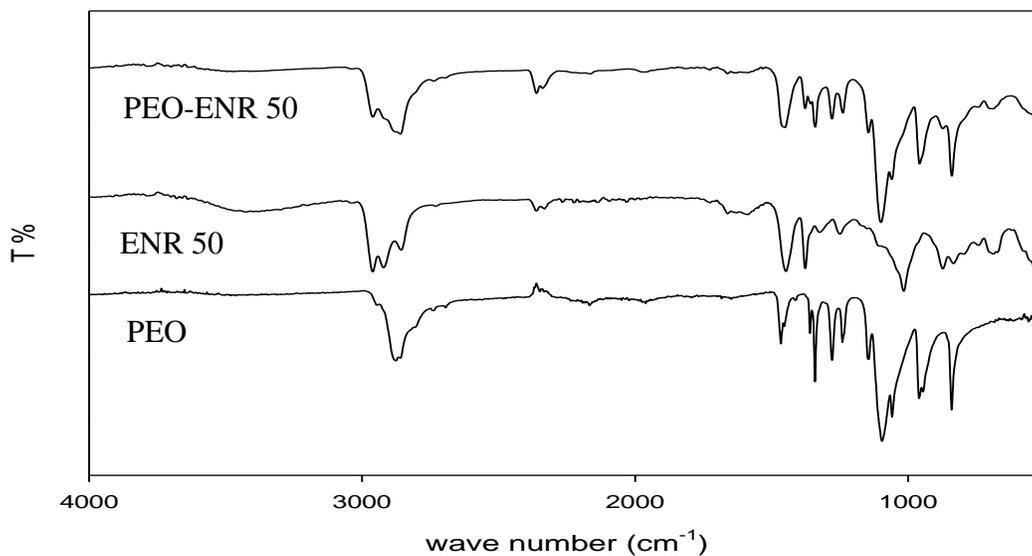


Figure 2 FTIR spectra of pure PEO, pure ENR 50 and blended PEO-ENR 50 (70-30)

### *Ionic conductivity*

The ionic conductivity measurements were carried out with the aim to observe the effect of  $\text{LiCF}_3\text{SO}_3$  addition on the electrical properties of the electrolyte system. Ionic conductivity was measured at five different  $[\text{O}]/[\text{Li}]$  ratios as shown in Table 1. The symbol of  $[\text{O}]$  represents numbers of oxygen atoms in both PEO and ENR 50 while  $[\text{Li}]$  is the number of lithium cations from the doping salt. The ionic conductivity of PEO-ENR 50 without  $\text{LiCF}_3\text{SO}_3$  is  $1.45 \times 10^{-9}$  S/cm. The ionic conductivity increased rapidly by two orders of magnitude with addition of 5 wt. % of  $\text{LiCF}_3\text{SO}_3$  as  $\text{Li}^+$  charge carriers were added to the system. It was observed that the ionic conductivity increased gradually as the wt. % of  $\text{LiCF}_3\text{SO}_3$  increased, to 20 wt. % of  $\text{LiCF}_3\text{SO}_3$  and began to decrease at 25 wt. % of  $\text{LiCF}_3\text{SO}_3$ . The maximum value achieved for ionic conductivity was  $1.39 \times 10^{-4}$  S/cm. The increase in ionic conductivity with the addition of salt is attributed to a reduction of crystallinity of polymer electrolyte as reported in our earlier work (Noor et al. 2009). The coordination interactions among the ether O atoms from PEO-ENR 50 chains and  $\text{Li}^+$  cations, resulting in a reduction in recrystallization of PEO, are responsible in the increasing of ionic conductivity.

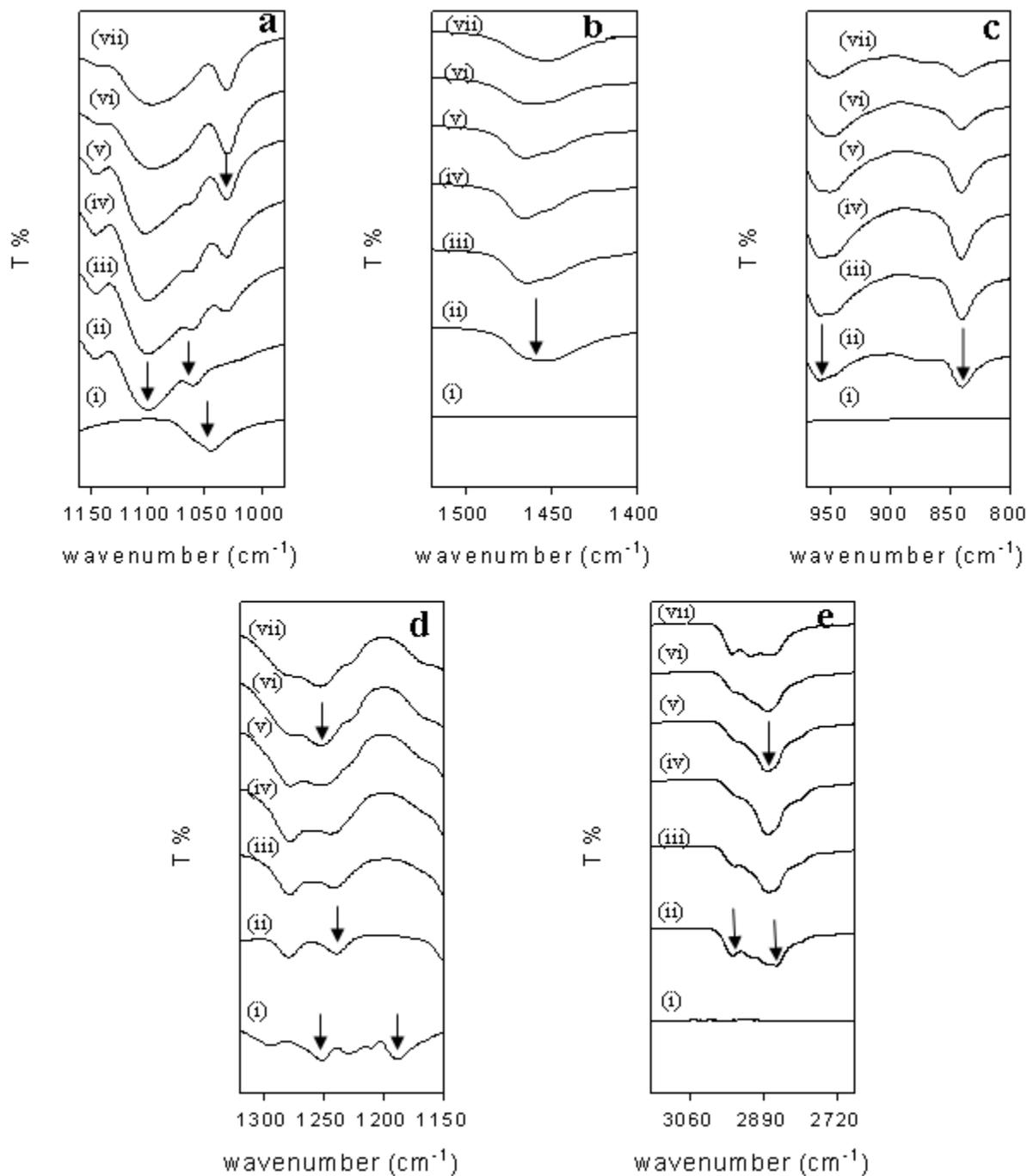


Figure 3 FTIR spectra of (i) pure LiCF<sub>3</sub>SO<sub>3</sub>, (ii) PEO-ENR 50, and PEO-ENR 50 with various wt. % LiCF<sub>3</sub>SO<sub>3</sub> (iii) 5%, (iv) 10%, (v) 15%, (vi) 20% and (vii) 25%

This maximum value shows the maximum and an effective interaction between oxygen atoms and  $\text{Li}^+$  cation in the electrolyte. The interactions between  $\text{Li}^+$  cations and polymer host have been proved by FTIR analysis as discussed earlier. A reduction crystallinity of PEO can be seen from the FESEM analysis that shows the rough surfaces with a lot of rumples undergo drastic changes to smooth surface and the rumples was completely disappear. A polymer chain in the amorphous phase is more flexible, which results in an increase of segmental motion of the polymer (Park et al. 2003). An additional factor in enhancement of ionic conductivity is salt dissociation. Salts with large monovalent anions such as  $\text{LiCF}_3\text{SO}_3$  will have low lattice energy and as a result they will dissolve easily in polyethers (Gray 1997). The dissociation of salts will promote more free lithium ions to transfer into the electrolyte. However, the ionic conductivity decreased at 25 wt. % of salt. According to Gray (1997), the ionic conductivity reduced after the maximum value due to an ever-increasing number of transient crosslinks in the system, thus reducing the chain mobility. The ionic conductivity of the samples at room temperature (25 °C) was summarized in Table 1.

Ramesh et al. (2008) reported that the highest conductivity achieved for PEO- $\text{LiCF}_3\text{SO}_3$  system was  $1.10 \times 10^{-6}$  S/cm at room temperature. However, their result is slightly lower than the ionic conductivity found within this research. This result is due to the effect of blended PEO with ENR 50. In terms of molecular structure of the polymer, ENR 50 has active oxygen in the epoxy group attached to the main chain (Glasse et al. 2002). It is assumed that the ENR 50 oxygen atom takes a role similar to the ether group in the PEO polymer structure which provides co-ordination sites for Li ion conduction and will produce a great number of charge carriers for ionic transport (Glasse et al. 2002, Idris et al. 2001 and Famiza et al. 2006).

Figure 4 shows the plot of conductivity ( $\log \sigma$ ) versus the inverse absolute temperature for the PEO-ENR 50 with 20 wt. %  $\text{LiCF}_3\text{SO}_3$ . The measurements were carried out from 298 K to 333 K. The plot exhibits a straight line indicating this system obeyed the Arrhenius rule which the ionic conductivity increase with increasing the temperature. It shows the system was thermally assisted. Therefore, as temperature was increased, the number of free lithium ions were also increased hence increased the conductivity of the material. In addition, the rise in conductivity can also be explained by the free volume model that has been proposed by Miyamoto et al. (1973). As the

temperature increased, the free volume around the polymer chain was also increased due to expansion of the polymers. Therefore, the ions, solvated molecules or the polymers segments could move into the free volume. The increase in the ionic mobility and also the segmental motion will enhance the transport of ions in the polymer blend (Famiza et al. 2006 ; Reddy et al. 1999). The ionic conductivity can be expressed as  $\sigma = \sigma_0 \exp [-E_a / KT]$  where  $\sigma_0$  is the conductivity pre-exponential factor,  $E_a$  is the activation energy and  $K$  is the Boltzmann constant. The activation energy is a combination of energy of charge carrier creation (defect formation) and the energy of ion migration that can be evaluated by linear fitting to the plot (Famiza et al 2006 and Sharmila et al. 2008). Therefore, it can be suggested that the value of  $E_a$  is due to the energy that is required to provide a conductive condition for the migration of ions. Figure 4 reveals that conductivity does not show any abrupt change with the temperature indicating that this system exhibit a completely amorphous nature (Kim et al. 1999). The  $E_a$  for this system is 0.18eV with the regression line of 0.989.

Table 1 [O]/[Li] ratio and ionic conductivity at room temperature (25°C) for PEO-ENR50-LiCF<sub>3</sub>SO<sub>3</sub> solid polymer electrolyte.

LiCF <sub>3</sub> SO <sub>3</sub> (wt%) to PEO/ENR50	[O]/[Li]	Ionic Conductivity (S/cm)
0%	0/1	1.45 x 10 <sup>-9</sup>
5%	16/1	4.70 x 10 <sup>-7</sup>
10%	8/1	4.02 x 10 <sup>-6</sup>
15%	5/1	4.23 x 10 <sup>-5</sup>
20%	4/1	1.39 x 10 <sup>-4</sup>
25%	3/1	9.05 x 10 <sup>-5</sup>

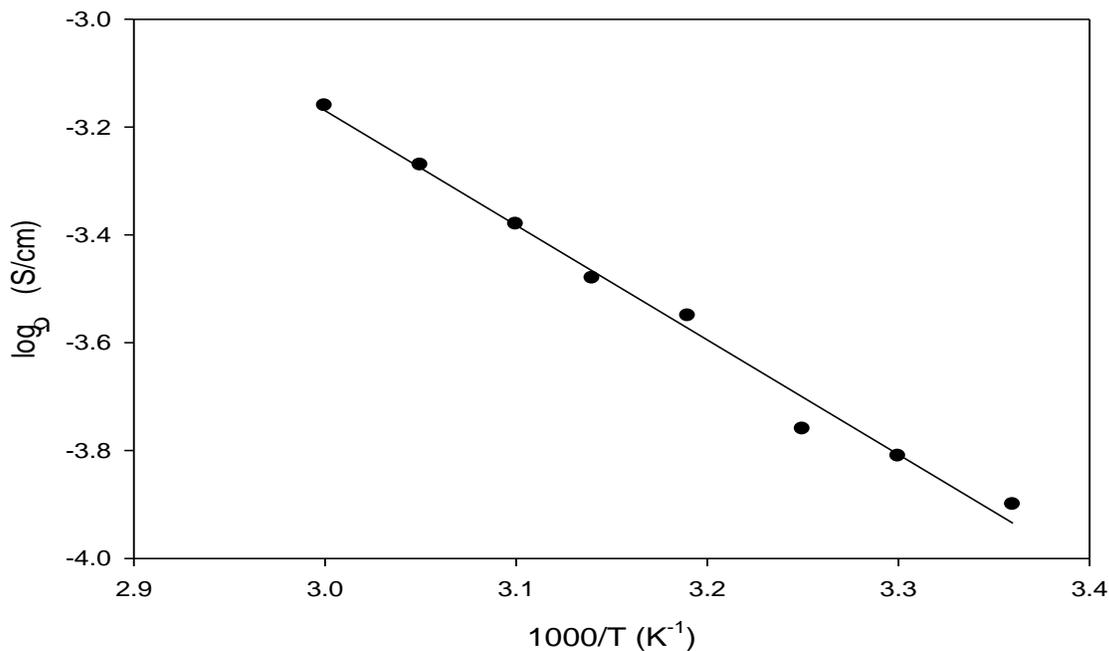


Figure 4 Temperature dependent of ionic conductivity of PEO-ENR 50 at 20 wt. %  
LiCF<sub>3</sub>SO<sub>3</sub>

### CONCLUSION

SPE of PEO-ENR 50-LiCF<sub>3</sub>SO<sub>3</sub> has been prepared by solution casting technique. The effect of LiCF<sub>3</sub>SO<sub>3</sub> salt on the PEO-ENR 50 based polymer electrolyte was investigated by FESEM, FTIR and AC impedance spectroscopy. The FESEM results showed the rough surface of pure PEO turned to smooth as addition of salt that showed the reduction of PEO crystallinity. The interaction between polymer host and lithium salt was confirmed by ATR-FTIR analysis. The triple peak of C-O-C stretching was combined to form a wide and broad peak centred at 1096 cm<sup>-1</sup> when 20 wt. % of salt was introduced in the system. From the impedance analysis, the ionic conductivity was found to increase with increasing the wt. % of salt and reached the maximum value of 1.39 x 10<sup>-4</sup> S/cm at 20 wt. % of LiCF<sub>3</sub>SO<sub>3</sub>. The temperature dependent conductivity obeyed the Arrhenius rule with the E<sub>a</sub> of 0.18 eV.

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