CHAPTER 5

SYNTHESIS AND CHARACTERIZATION OF ZEOLITE FILLED CEPU COMPOSITES

This chapter covers the preparation and characterization of inorganic filler namely, zeolite (AlPO₄-5 zeolite) filled CEPU composite. CEPU-zeolite composites have been prepared using tartaric acid (TA) based chain extended PU as a host and AlPO₄-5 zeolite as a particulate filler. The prepared CEPU/zeolite composites have been characterized for mechanical and thermal behavior. The microcrystalline parameters and micro voids of CEPU composites have been measured by using wide-angle X-ray scattering (WAXS) and positron annihilation lifetime spectroscopic (PALS) methods respectively. The morphological behavior of composites has been studied using scanning electron microscopy (SEM).

5.1 Introduction

Polymer based organic/inorganic composites are becoming increasingly important due to the fact that the resultant material shows, superior performance in terms of mechanical toughness, permeability, selectivity and photoconductivity for various applications [1–8]. There are different types of inorganic materials such as, clays [1], SiC particulates [3], ceramic microspheres [5], Al₂O₃, Ti O₂ and mica oxide that are widely used as fillers in fabrication of polymer composites. Zeolites are microporous crystalline aluminosilicates and are being used as fillers in polymer composites mostly to improve the gas separation performances because of their uniform molecular- sized pores [9–11]. They are also being used in many other applications due to their high thermal and mechanical stabilities [12-13]. Zeolites offered various challenges in different areas with their unique properties; however, the powder forms of these materials limit their use in several applications especially in the manufacturing field. Their incorporation into polymers creates a very promising investigation in the field of composites.
The hardness, strength, elasticity and other mechanical characteristics of PUs can be varied greatly according to the chemical composition and microstructure of the polymers [14-15]. The mechanical characteristics of PUs (hardness, strength and elasticity) as well as their physical form (elastomer, foam, adhesive, fiber, etc..) can be varied greatly in the desired direction [16-17].

Enhanced mechanical performances of PUs can be achieved through the incorporation of inorganic fillers (reinforcing) into the polymer matrix and zeolites have been shown to be alternative inorganic fillers for the purpose [18-19]. Unlike traditional fillers, (e.g., clay, flyash clays, glass, alumina, calcium carbonate, carbon black, and silica particles) the conditions of zeolite synthesis can be greatly altered and this provides a broad range of potential properties and the ability to tailor the functions of composite materials [20-21]. As inorganic fillers, zeolite has been shown to increase the mechanical strength of polymers in several studies [18-19].

The unique properties of aluminophosphate zeolites (AlPO₄-5) make them one of the most useful inorganic materials in the world. Zeolites are functional fillers which have good surface chemistry, dielectric behavior and thermal stability. Polymers constitute very important host materials for a variety of filler materials leading to the formation of composites with technological potential. In recent years, there is a growing tendency to search for new properties for materials like zeolites filled polymer composites, optically active molecules such as non-linear optical materials, luminescent materials, magnetic materials, etc. Many scientists have reported the PU/clay composites [22-24]. In the last few decades, researchers have systematically established the fundamental structure-property relationship of PUs [25-28].

The study of CEPU and its composites has become an important area of research in recent years. Kamis et al [29] have studied the preparation and characterization of antibacterial zeolite – PU composites. In this study, antibacterial properties were induced in PU films by the incorporation of Ag⁺ loaded zeolites as fillers. It was demonstrated for the first time that a high-silica zeolite (zeolite beta) and its composite film could be effectively employed as antibacterial materials. Furthermore, mechanical and thermal characterizations of the composites showed that the zeolites enhanced the mechanical properties of the polymer and did not cause any deterioration in its thermal properties.
Gabriela Ciobanu et al [30] studied the use of SAPO-5 zeolite–filled PU membranes in waste water treatment. The SAPO-5 zeolite-filled PU membranes were prepared, characterized and utilized for the ultra filtration. Filtration experiments were operated in cross-flow mode under 50 mm Hg of applied pressure. The temperature-dependent permeability parameter followed the Arrhenius relation from which the energy of activation has been obtained.

Furthermore, Gabriela Ciobanu et al [31] characterized the SAPO-5 zeolite–filled PU membranes by Fourier transform infrared spectroscopy (FTIR), Bubble-point test, water permeability, swelling in water and several alcohols (methanol, ethanol, 1-propanol and 1-butanol) and density. The incorporated SAPO-5 zeolite in PU matrix also induces changes in the PU membrane morphology. The zeolite acts as cross-linking function in the PU membrane structure.

Recently many scientists used zeolite filler to fabricate the composites and to exploit its uses. In this research work, zeolite has been used to modify the properties of CEPU. However, a thorough survey of the literature indicates that the effect of zeolite filler on dicarboxylic acid based chain extended PU systems have not been investigated. In this chapter the effect of zeolite filler content on the performance of CEPU composites have been discussed. The influence of zeolite filler content on micro voids or free volume holes and microcrystalline parameters of CEPU composites have also been established using positron annihilation lifetime spectroscopy (PALS) and X-ray.

5.2 Synthesis of CEPU / zeolite composites
5.2.1 Preparation of zeolite

Aluminophosphate zeolites (AlPO₄-5) were prepared by hydrothermal method using organic amines as structure directing agents. The aluminophosphate gels were prepared by neutralizing the pseudoboehmte homogeneously in water and adding equimolar amount of dilute orthophosphoric acid. This is referred to as reactive gel. The obtained gel was aged for 3 h on a hot water bath at 60 °C. The di- propylamine
was added to this reactive gel as a structure-directing agent. This is known as precursor gel and aged for 3 h. At each step the pH was recorded. The final precursor gel was charged to the teflon lined stainless steel autoclaves. The hydrothermal treatment was carried out in a hot air oven for a period of 60 h at 150 °C. The hydrothermal runs were arrested by quenching the autoclaves in the cold- water bath. The run products were carefully recovered and washed thoroughly using double distilled water and ultra-sonicated to remove adhered organic amines. Finally, the obtained product was dried in hot air oven at 60 °C. If the obtained AlPO₄-5 is brown or grey in color, indicates that the free diffusion in one-dimensional pores is blocked by stacking faults or by non framework materials such as amines. To remove such blocking materials, sintering has to be carried out. On the other hand, if the resultant product is white in color sintering is not necessary. Hence, the process of sintering depends upon the organic templates used.

5.2.2 Preparation of CEPU/zeolite composite

Castor oil (0.001mol) was initially dissolved in 50 ml of MEK and placed in three-necked round bottomed flask. Toluene diisocyanate (0.002 mol) was added followed by 2 to 3 drops of DBTL as catalyst. The contents of the flask were stirred continuously for about 1 h under oxygen free nitrogen gas purge at 60–70 °C, to prepare the isocyanate-terminated pre PU polymer. A calculated amount of tartaric acid (0.001mol) weighed accurately was completely dissolved in 10 ml MEK and added to the pre PU and stirred for 1 h under nitrogen gas purge at 60–70°C. The calculated amount of AlPO₄-5 zeolite filler was added at this stage and stirred for 10-20 min or until the uniform mixture was obtained. The reaction mixture was poured into a cleaned and releasing agent coated glass mould and allowed to stand for 12 h at room temperature. The mould was kept in preheated circulating hot air oven at 70 °C for 8–10 h. The toughened CEPU composite sheet thus formed was cooled slowly and removed from the mould. The above procedure was repeated for different zeolite filler contents, viz., 2.5, 5 and 7.5 by weight percent.
5.3 Results and Discussion

5.3.1 Mechanical properties

The mechanical properties are very important in selecting a polymer material for suitable applications. The CEPU/zeolite composites were obtained as tough films with golden yellow to yellow color. The measured mechanical properties such as surface hardness, tensile strength and tensile modulus of the CEPU/zeolites are given in Table 5.1. Surface hardness data reflects the resistance to local deformation, which is a complex property and related to cross-link density, modulus, strength, elasticity, plasticity and porosity of the polymer matrix. A slight increase in surface hardness values with increase in filler content was found, which falls in the range 75–95 showed A and the corresponding shore D values lies in the range 33-49 (Table 5.1). The increase in surface hardness as increase in zeolite in CEPU matrix was noticed. This is due to the reinforcing behavior of filler and some kind of physical interaction between CEPU and AlPO₄-5 zeolite. This result indicates that, the incorporation of AlPO₄-5 zeolite filler in the CEPU matrix increases the dimensional stability.

A considerable improvement in both tensile strength and tensile modulus of composites with increase in zeolite content in CEPU matrix was noticed. Tensile strength and tensile modulus falls in the range 8.07–9.45 MPa and 6.7–12.0 MPa respectively (Table 5.1). About 79 % improvements in tensile modulus for 7.5 % zeolite filled CEPU composites was noticed. The improvement in tensile strength and tensile modulus with increase in filler content is due to some kind of interaction and good interfacial adhesion between CEPU and zeolite filler. A considerable increase in dimensional stability, tensile strength and drastic improvement in tensile modulus data clearly supports the reinforcing behavior of zeolite fillers in CEPU matrix [32-33].

The improvement in tensile strength of CEPU/zeolite composites due to the cohesive matrix transfers load and stress into filler zeolite. This leads to effective and uniform stress distribution. Hence, the composite possesses good mechanical properties [34–36]. This reveals that, with an increase in zeolite content there is a change in behaviour of material; tough material has been changing over to brittle mass.
According to Ali et al [37] both hardness and tensile strength enhancements follow a gain in the crosslinking density; the hardness is the index of the cross linking density at the surface, while the tensile strength is the index of the cross linking density through the bulk of the entire composite. This suggests that there is interlocking of polymer chains through physical interaction between the zeolite and CEPU matrix.

The drastic improvement in tensile modulus with increase in zeolite content in CEPU matrix was noticed. This is due to the incorporated zeolite particulate filler interlocking between the flexible polymer networks of PU which reduces the segmental movement. With the increase in zeolite filler content, there is a reduction in the microvoids and the chain mobility leading to increased chain rigidity. An increase in chain rigidity seems to increase the surface hardness and tensile modulus. The variation in tensile modulus follows the same trends of tensile strength [34].

### Table 5.1. Mechanical properties of CEPU/AlPO₄ zeolite composites

<table>
<thead>
<tr>
<th>Zeolite content in CEPU (% wt/wt)</th>
<th>Tensile strength (MPa) ± 0.5</th>
<th>Tensile modulus (MPa) ± 0.5</th>
<th>Surface hardness ±1.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shore A</td>
</tr>
<tr>
<td>0</td>
<td>8.07</td>
<td>6.70</td>
<td>75</td>
</tr>
<tr>
<td>2.5</td>
<td>8.21</td>
<td>7.81</td>
<td>89</td>
</tr>
<tr>
<td>5</td>
<td>8.43</td>
<td>8.06</td>
<td>92</td>
</tr>
<tr>
<td>7.5</td>
<td>9.45</td>
<td>12.0</td>
<td>95</td>
</tr>
</tbody>
</table>

#### 5.3.2 Heat aging

The CEPU/zeolite composites were subjected to heat ageing at different temperatures viz., 150, 200, 250 and 350 °C for one hour and the change in weight was monitored. The measured weight loss at different temperatures for all PU composites is given in Table 5.2. From the heat aging test it was observed that there was a marked improvement in heat ageing behaviour after incorporation of zeolite filler into PU matrix. This is because zeolite is an inorganic filler. From the table it was noticed that CEPU shows poor heat aging behaviour as compared to CEPU/zeolite composites [19-20]. However, there was no considerable weight loss of chain extended PUs upto 200 °C. Hence, chain extended PU composites may be safely used upto 200 °C.
Table 5.2. Percent weight loss of CEPU/zeolite composites after heat ageing for 1h at different temperatures

<table>
<thead>
<tr>
<th>Zeolite content in CEPU (%, wt/wt)</th>
<th>Weight loss at different temperatures (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150</td>
</tr>
<tr>
<td>0</td>
<td>1.02</td>
</tr>
<tr>
<td>2.5</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>0.83</td>
</tr>
<tr>
<td>7.5</td>
<td>0.70</td>
</tr>
</tbody>
</table>

5.3.3. Thermal stability

The thermal stability of zeolite-filled CEPU systems was evaluated by TGA curves. A typical TGA thermograms for all CEPU composites are shown in Figure 5.1. The thermograms obtained during TGA scans were analyzed to determine the percentage weight loss as a function of temperature. The relative thermal stability of the CEPU/zeolite composites was evaluated by a comparison of the decomposition temperatures at various weight losses. $T_0$ (temperature of the decomposition onset), $T_{20}$ (temperature of the 20% weight loss), $T_{50}$ (temperature of the 50% weight loss) and $T_{\text{max}}$ (temperature of the maximum weight loss) were the main criteria indicating the thermal stability of the CEPU/zeolite composites (Table 5.3). The higher values of $T_0$, $T_{10}$, $T_{20}$ and $T_{50}$ indicate the higher thermal stability of CEPU/zeolite composites. Figure 5.1 shows that the TGA thermograms of the CEPU composites were stable up to 290 °C and degraded completely above 485 °C.

The TGA thermograms of CEPU and its composites showed three step thermal degradation processes at the temperature ($T_{\text{max}}$) of 312, 370 and 466 °C for first, second and third steps respectively. The weight loss which occurred in the temperature range 250–350 °C is referred as first step thermal degradation. The weight loss in this step decreases with increase in inorganic filler loading. This result clearly indicates that the weight loss in the first step is due to the loss of low volatile impurities along with the degradation of soft segment of CEPU. The weight loss that occurs in the temperature range 350–410 °C is called a second stage thermal degradation process. The weight loss in this step may be assigned to the partial thermal degradation or decrosslinking of hard segment of CEPU and organic components present in the zeolite [34]. In the final step the weight loss occurs in the
temperature range 415–515°C. The weight loss occurring in this step is due to the complete decomposition of cross linked CEPU.

From TGA thermograms it was observed that the percentage of ash content increased from 14.5% to 26% with increase in zeolite content from 2.5 to 7.5%. It may be due to the fact that the zeolite is inorganic filler which retards the rate of burning.

![Figure 5.1. TGA thermograms of AlPO4-5 zeolite filled CEPU composites, (a) CEPU, (b) 2.5% zeolite, (c) 5% zeolite and (d) 7.5% zeolite](image)

Table 5.3. Data obtained from TGA curves for tartaric acid based CEPU and CEPU/zeolite composites

<table>
<thead>
<tr>
<th>Zeolite content in CEPU (% wt/wt)</th>
<th>Transition temperature (°C) ± 2</th>
<th>OI values ± 0.085 %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T₀</td>
<td>T₂₀</td>
</tr>
<tr>
<td>0</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td>2.5</td>
<td>290</td>
<td>322</td>
</tr>
<tr>
<td>5</td>
<td>290</td>
<td>335</td>
</tr>
<tr>
<td>7.5</td>
<td>299</td>
<td>342</td>
</tr>
</tbody>
</table>

The weight loss in each steps are not following any systematic order with the composition of composites. Generally, CEPU's under observation do not break down
in a simple manner. There is a change in the morphological structure of the CEPUs at each and every instant of pyrolysis and that affects the rate of decomposition. This reveals that the composite seems to exhibit good flame retardant behaviour. It is also seen from Table 5.3 that the oxygen index (OI) values are low and lies in the range 0.946-1.670 %. Based upon the mass carbonaceous char and OI values, it can be concluded that there is a slight improvement of flame-retardant nature of PU/zeolite composites.

5.3.4 X-ray diffraction

The X-ray patterns of AlPO₄-5 zeolite, CEPU and CEPU/zeolite composites are shown in Figure 5.2. The AlPO₄-5 zeolite has a grain size of 48.86 nm at 2θ 21.54° (Figure 5.3).

![Figure 5.2. XRD profiles of CEPU/zeolite composites](image)

![Figure 5.3. Grain size of AlPO₄-5 by XRD method](image)
The unfilled CEPU matrix showed two sharp peaks at 2θ of 37.5° and 43.8° with hkl values of 431 and 531 respectively. The X-ray pattern of zeolite shows multiple sharp peaks. This is due to the highly crystalline nature of zeolite than that of CEPU. After incorporation of zeolite filler into CEPU matrix, the peaks shape, size and position are changed. The CEPU/zeolite composite showed one sharp peak at 37°. Also the peak position and intensity changed with composition of composites. This is due to the change in microcrystalline behavior of composites with increase in filler content. The calculated crystalline cell parameters including the cell volumes of CEPU-composites are given in Table 5.4. The cell parameters were calculated using the Crysfire software. The cell volume is lowest for unfilled CEPU (128.3 Å³) and highest for zeolite (1841.9 Å³). Zeolite filled CEPU composites cell volume values are lies in between the cell volume of values of unfilled CEPU and zeolite. For composites it increases significantly with increase in filler content and it lies in the range 331.8–449.9 Å³. This result clearly indicates some kind of physical interaction between CEPU and AlPO₄-5 zeolite.

### Table 5.4. Cell parameters obtained from X-ray profiles for CEPU/zeolite composites

<table>
<thead>
<tr>
<th>Zeolite content in CEPU (%, wt/wt)</th>
<th>a (Å)</th>
<th>b (Å)</th>
<th>c (Å)</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>Volume (Å³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.39</td>
<td>4.31</td>
<td>12.41</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>128.3</td>
</tr>
<tr>
<td>2.5</td>
<td>2.06</td>
<td>9.28</td>
<td>17.33</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>331.8</td>
</tr>
<tr>
<td>5</td>
<td>4.34</td>
<td>4.54</td>
<td>18.41</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>363.7</td>
</tr>
<tr>
<td>7.5</td>
<td>4.57</td>
<td>9.25</td>
<td>10.62</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>449.9</td>
</tr>
<tr>
<td>AlPO₄-5</td>
<td>8.73</td>
<td>12.70</td>
<td>16.60</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>1841.9</td>
</tr>
</tbody>
</table>

### 5.3.5 Positron annihilation lifetime measurement

The calculated free volume parameters according to equations (14) and (15) of Chapter 2 by using PALS data for CEPU/zeolite composites are given in Table 5.5. From the table it was noticed that for blank zeolite sample 1.51 ns lifetime with free volume cell size of 53.96 Å³ does not correspond to the size of the channel of 6.3 Å diameters. If this channel was available for Ps, we could have observed a lifetime of around 3.03 ns. The absence of this lifetime in the positron lifetime spectra does suggest this channel is loaded with moisture (water molecules) as it is known that AlPO₄-5 zeolite is highly hydrophilic in nature [35]. Furthermore, the sorbed water
quantity in AlPO₄-5 zeolite channels is exceptionally large [35]. Since the same zeolite filler is used for making the CEPU composite, the CEPU composites also do not show the long lived lifetime component although four component analysis was carried out. Therefore the properties that could have been influenced by this particular channel of the particulate filler are absent in the present study. The channel or sometimes called the microvoids corresponding to 1.51 ns lifetime not being accessible to water molecules may be due to repulsive nature of the local sites in the AlPO₄-5 zeolite [36-37] and hence is probed by Ps. Probably as a result of this, a marginal increase in free volume fraction (Fᵥ) with increase in zeolite filler content up to 5% was noticed. Above 5% zeolite filled composites, Fᵥ value decreases marginally. From Table 5.5 it is observed that the influence of filler content on τ₃ is clear, since τ₃ is related to free volume or the pore size. Similarly, a relative number density of free volume holes in the composites (I₃) also exhibit similar trend with increase in filler content.

Figure 5.4 (a) Tensile strength and Fᵥ as a function of zeolite, (b) Cell volume and Fᵥ as a function of zeolite
Table 5.5. Positron annihilation lifetime results for CEPU/AlPO$_4$ composites

<table>
<thead>
<tr>
<th>Zeolite content in CEPU (% wt/wt)</th>
<th>$\tau_3 \pm 0.01$ (ns)</th>
<th>$I_3 \pm 0.1$ (%)</th>
<th>$V_f \pm 0.8(\text{Å}^3)$ (%)</th>
<th>$F_V$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.05</td>
<td>13.8</td>
<td>102.2</td>
<td>2.54</td>
</tr>
<tr>
<td>2.5</td>
<td>2.11</td>
<td>21.3</td>
<td>108.0</td>
<td>4.14</td>
</tr>
<tr>
<td>5</td>
<td>2.09</td>
<td>21.6</td>
<td>106.1</td>
<td>4.13</td>
</tr>
<tr>
<td>7.5</td>
<td>2.05</td>
<td>19.6</td>
<td>102.2</td>
<td>3.61</td>
</tr>
<tr>
<td>AlPO$_4$-5</td>
<td>1.51</td>
<td>16.7</td>
<td>53.96</td>
<td>1.62</td>
</tr>
</tbody>
</table>

The increase in fractional free volume as filler content increases, suggests a few additional free volume holes being generated in the composite in the presence of the filler upto 5% of zeolite. The plot of the tensile strength and $F_V$ is shown in Figure 5.4 (a) and cell volume and $F_V$ in Figure 5.4 (b) as a function of zeolite respectively. The tensile strength and $F_V$ shows increasing trend as zeolite content increases in CEPU matrix upto 5% of filler and thereafter it shows decreasing trend. It was noticed that the inverse relation between tensile strength and fractional free volume holds good beyond 5% of zeolite. This is possibly due to better reinforcing behavior of AlPO$_4$-5 zeolite in CEPU matrix; hence improvement in tensile strength and decrease in fractional free volume was noticed with increase in filler content. The increase in $F_V$ upto 5% of the filler could be due to rearrangement of the filler particulate resulting in additional cavities or voids being generated. It can also be noticed from Figure 5.4 (b) that the cell volume data from XRD also exhibits a similar trend like the free volume fraction and the tensile strength (Figure 5.4(a)). Although the cell volume and free volume are on a different size scale, we suppose that as the zeolite content increases, due to highly crystalline nature of zeolite filler (from XRD) the opposite trend observed in Figure 5.4 (b) beyond 5% of filler is justified from the fact that amorphous domains scanned by positrons decreases.

5.3.6 Morphological behavior

The morphology of CEPU/zeolite composites has been studied by using SEM. The obtained SEM photomicrographs for 0, 2.5, 5 and 7.5% zeolite filled CEPU composites are shown in Figures 5.5 (a)–(d) respectively. From SEM photographs of unfilled CEPU (Figure 5.5 (a)) revealed the two-phase morphology. This is because CEPUs consists of both hard and soft segments. The SEM photomicrographs also reveal the 48.8 nm grains size of zeolite distributed in CEPU matrix.
The zeolite filler is embedded in the CEPU matrix, which may be due to physical interaction between CEPU and filler. From the photographs, it was observed that uniform distribution of zeolite occurs in the continuous CEPU phase. As the zeolite filler content increases, the domain size of second dispersed phase also increased, which may be due to the increase in filler-filler interaction. In all the CEPU composites uniform distribution of second phase was noticed.

![SEM photomicrographs of CEPU/zeolite composites](image)

**Figure 5.5. SEM photomicrographs of CEPU/zeolite composites**

### 5.4 Conclusions

The improvement in tensile strength, tensile modulus and dimensional stability of CEPU–zeolite composites was noticed with an increase in zeolite filler content. This can be attributed to the fact that the zeolite is acting as reinforcing filler in CEPU matrix although the filler is fully loaded with moisture. The thermal stability of CEPU/zeolite composites was greater than 254 °C; they completely degraded at 520 °C. TGA thermograms showed three significant thermal degradation steps that occurred approximately in the temperature range 250–350, 350– 410 and 415–515 °C for first, second and third steps respectively. This might be due to the complicated
chemical structure and morphology of the CEPU composites. Improvement in thermal stability was noticed in CEPU composites after incorporation of zeolite filler. This is because zeolite is an inorganic filler. Microcrystalline parameters changed significantly after incorporation of zeolite filler into CEPU matrix. PALS results showed an increase in $F_V$ up to 5% filler content and thereafter a decrease. Beyond 5% of filler content, the inverse relation between tensile strength and fractional free volume was observed. The data obtained from X-ray showed the physical interaction or interfacial adhesion between the CEPU and zeolite filler. The PALS and X-ray data supports the improvement in the mechanical performance of the CEPU composites. SEM photomicrographs revealed that uniform distribution of zeolite filler in CEPU and the domain size of the second phase depend on the filler content. The advantages of using zeolite as filler lies in the fact that there is a good physical interaction between the CEPU and zeolite filler and it also exhibits good fire retardant behavior.
5.5 References