Effect of Zeolite on Flame Retardant of Expanded Polystyrene Foam (EPSF)

Chanin KULSETTHANCHALEE1*, Chanchai THONGPIN23, Poonsub THREEPOPNATKUL23*, Chutima PUNGNUSON2, Thamakorn PHANUWATTANAGUL2 and Nantavat TANGCHANTRA4

1Event and Exhibition Design Department, Suan Dusit Rajabhat University, Bangkok 10300, Thailand
2Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand
3Centre of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Chulalongkorn University, Bangkok 10330, Thailand
4National Metal and Materials Technology Center, National Science and Technology Development Agency, Pathumthani 12120, Thailand

Abstract

In this research, the effects of zeolite on flame retardant of expanded polystyrene foam (EPSF) were investigated. Zeolite 3A, 5A and 13X were used to prepare the EPSF composites. The polystyrene/zeolite composites were compounded by using the twin-screw extruder. Then EPSF composites were prepared as foam by using the CO2 supercritical fluid. According to the results, zeolite could improve flame retardancy of expanded polystyrene foam. EPSF with the addition of smaller pore size of zeolite demonstrated a slower burning rate, more thermal stability, smaller sizes of cell foam and higher density of EPSF composites.

Key words: Polystyrene foam, Zeolite, Flame retardant.

Introduction

The Expanded polystyrene foams are widely used for household furnishings, event and exhibitions purposes and in the entertainment venues. Such uses are likely susceptible to the heat and fire hazards. The concept of this study is how to utilize the usefulness of the nano material such as zeolite. The fact is that the porous structure of zeolite could be beneficial for flame retardant property to polymer. The heat absorption of zeolite is another key characteristic of such inorganic materials.

Zeilote is crystalline aluminosilicates with regular porosity. These pores have variable openings, according to the structure type, usually having internal cavities of variable shape and diameter. Zeolite are used as molecular sieves, liquid and gas absorbents, as well as catalysts for several types of chemical reaction (e.g. hydrocarbon cracking) and used as ion exchanger.

Sales, et al. observe remarkable effects on the properties of zeolite (ZSM-5 or Y)/polystyrene (PS) composites used for heat absorption to increased the thermal stability of composites. While some researchers investigated the effects of zeolite on flame retardant additive and found to improve the thermal stability of materials.

This study deals with preparation and evaluation of flame retardancy of zeolite/polystyrene composite foams using flammability analyze and also other properties including thermal analyses (TGA), scanning electron microscope (SEM), and melt flow index (MFI). Three different grades of zeolite were used in this work.

Materials and Experimental Procedures

Materials

PS was purchased from IRPC. Styrene graft maleic anhydride (SMA® 1000) as compatibilizer was produced from Sartomer. Different grades of zeolite (3A, 5A and 13X) were purchased from Granbiztrading.

Preparation of Composites

Zeolites were prepared by grinding in ball mill for 24 hours and sieving particle of zeolites to 75-150 μm. The 2 wt% of zeolite, PS and 1wt% of
SMA were compounded in twin screw extruder at 175-210°C with screw speed of 50 rpm.

**Preparation of Expanded Polystyrene Foam (EPSF)**

The composite foams were prepared by using the CO$_2$ supercritical fluid. The composites were preheated at 140°C for 10 minutes. Then, CO$_2$ is used as blowing agent at the pressure 18 MPa and 140°C for 1 hour 30 minutes. Then, it was rapidly depressurized for 3 seconds.

**Characterization**

**Flammability analyses** - Burning rate analyses were carried out on vertical direction of sample at 21% oxygen condition. **Thermal analyses** - Thermal analyses were characterized by Thermogravimetric analyses (TGA). The TGA curves were recorded in the course of heating from 50°C to 600°C and were used to determine the percentage weight loss. The highest decomposition temperatures were obtained by the derivative thermogravimetry curves (DTG). **Scanning electron microscopy (SEM)** - Porous structures of the sample were studied through SEM. **Melt flow index (MFI)** of the samples were studied according to ASTM D1238.

**Results and Discussion**

The preparation of expanded polystyrene foam (EPSF) were found to improve flame retardancy with the use of 2% wt zeolite 3A, 5A and 13X. Among these, the one with zeolite 3A tended to be more flame retardant than the others.

Burning results of pure PS and zeolite/EPSF (Table 1) showed the burning rate. The presence of zeolite could slow down the burning rate of composites because oxygen and heat of combustion could be absorbed by the porous structure of zeolite. Pore diameter adversely correlated to the surface area. Therefore, a larger pore (smaller surface area) of zeolite 13X would be more susceptible to be blazed than the one with larger surface area of zeolite 5A and 3A respectively. The data for the pore diameter of zeolite are also presented in Table 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Burning rate (cm/min)</th>
<th>Zeolite pore diameter (Å)</th>
</tr>
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<tbody>
<tr>
<td>EPSF</td>
<td>28.53±3.83</td>
<td>-</td>
</tr>
<tr>
<td>Zeolite 3A/EPSF</td>
<td>5.98±0.30</td>
<td>3</td>
</tr>
<tr>
<td>Zeolite 5A/EPSF</td>
<td>12.88±3.26</td>
<td>5</td>
</tr>
<tr>
<td>Zeolite 13X/EPSF</td>
<td>15.25±5.05</td>
<td>8</td>
</tr>
</tbody>
</table>

According to DTG curve, the thermal stability of zeolite/EPSF was improved when compared to the EPSF without zeolite as seen in Figure 1. The decomposition temperature of EPSF was at 394.7°C. Meanwhile, zeolite 3A/EPSF, zeolite 5A/EPSF and zeolite 13X/EPSF possessed the decomposition temperature at 408.6°C, 407.0°C and 401.8°C respectively.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$T_d$ (°C)</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSF</td>
<td>394.75</td>
<td>99.8</td>
</tr>
<tr>
<td>Zeolite 3A/EPSF</td>
<td>408.59</td>
<td>95.9</td>
</tr>
<tr>
<td>Zeolite 5A/EPSF</td>
<td>407.03</td>
<td>95.3</td>
</tr>
<tr>
<td>Zeolite 13X/EPSF</td>
<td>401.77</td>
<td>95.9</td>
</tr>
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The smaller the pore size, the larger the surface area of zeolite it would be. The heat of combustion was then absorbed within the zeolite itself and delayed the decomposition of the foam composites. The decomposition temperature ($T_d$) and weight loss for our materials are presented in Table 2.

Furthermore, the addition of zeolite to EPSF composites would reduce the cell size due to the zeolite would possibly interrupt the movement of polymer chain as shown in Figure 2.

As a result, the MFI of the more freedom chain of EPSF is thus higher than the EPSF composites as shown in Table 3. Evidently, the densities of the EPSF composites were more than EPSF itself. This can be explained by the difficulty of the foam cell expansion and the chain movement explained previously.
Table 3. MFI and density of 2% zeolite/EPSF.

<table>
<thead>
<tr>
<th>Sample</th>
<th>MFI (g/10 min)</th>
<th>Density (g/cm³)</th>
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<tbody>
<tr>
<td>EPSF</td>
<td>36.3±3.02</td>
<td>0.053±0.002</td>
</tr>
<tr>
<td>Zeolite 3A/EPSF</td>
<td>31.62±1.65</td>
<td>0.057±0.001</td>
</tr>
<tr>
<td>Zeolite 5A/EPSF</td>
<td>33.60±3.81</td>
<td>0.055±0.001</td>
</tr>
<tr>
<td>Zeolite 13X/EPSF</td>
<td>28.58±2.79</td>
<td>0.056±0.002</td>
</tr>
</tbody>
</table>

Figure 2. SEM micrographs of 2% zeolite/EPSF (a) zeolite3A/EPSF (b) zeolite5A/EPSF (c) zeolite13X/EPSF and (d) EPSF.

Conclusions

Zeolite could improve flame retardancy of expanded polystyrene foam. EPSF with the addition of smaller pore size of zeolite demonstrated slower burning rate, more thermal stability, smaller cell foam and higher density of EPSF composites.

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