The polarized infrared spectroscopy was used to evaluate the molecular orientation in films of LCP, Rodrun LC®5000, PET and their blends obtained by extrusion. A compatibilizer agent was tested. The results showed that the molecular orientation of the LCP phase along the draw direction decreases drastically in the blends. For the PET phases, an alignment of the amorphous phase in the draw direction in presence of LCP and compatibilizer agent was obtained. The crystalline phase however did not show to be oriented in the draw direction. The compatibilizer agent proved to be efficient.

**Introduction**

Characterization of molecular orientation in blends of thermoplastic and liquid crystalline polymer (LCP) is important since most of the rheological, physical and mechanical properties of the blends depend on the extent of LCP orientation. It is also known that the orientation depends of the processing conditions. Polarized infrared spectroscopy is one of the most convenient methods that can be used to quantify the degree of molecular orientation in the polymer film. In this work, the molecular orientation of components in blends formed from poly(ethylene terephthalate) (PET) and a liquid crystalline polymer was determined by polarized infrared spectroscopy and analyzed as a function of composition.

**Experimental**

**Materials**

The PET resin used was a copolymer of 3.5mol% terephthalic acid and 3.0mol% diethylene glycol, kindly donated by Rhodia Ster of Brazil. The LCP was a thermotropic copolyester of 80mol% poly(hydroxybenzoic acid) and 20mol% poly(ethylene terephthalate), trade name Rodrun®LC5000, supplied by Unitika Co., Ltd. of Japan. The compatibilizer agent Lotader®AX8900, supplied by Atofina of France, is a random terpolymer of 67wt % ethylene, 25wt% acrylic ester and 8wt% glycidyl methacrylate. These materials were dried in vacuum oven at 150°C for 5h before blending.

**Film Processing** [1]

Three blends of PET/LCP with concentrations of 95/5, 90/10 and 85/15, and one compatibilized blend, PET/LCP/Lotader, with composition of 90/7,5/2,5 were prepared. The blends films were processed by extrusion using a twin screw extruder, Werner & Pfleiderer model ZSK30, with a slit die at temperature between 240 and 275°C. Immediately after extrusion, the films were cooled by air jet followed by immersion in water bath at 70°C and drawn at a constant draw rate.

**Results and Discussion**

In this study, the absorption band at 1601cm⁻¹, assigned to the stretching mode of –C = C – in the benzene ring, was used to characterize the chain orientation of the LCP [2]. For the PET, two bands at 974 and 1370cm⁻¹ were used for the analysis of the molecular orientation. The absorption band at 974cm⁻¹ is associated with the CH₂ vibration mode of the trans conformers. The band at 1370cm⁻¹ is assigned to the CH₂ wagging mode of the gauche conformer [3]. The dichroic ratio (RD) of the bands was calculated from the ratio of the absorbancies A_

\[
\frac{A_{\parallel}}{A_{\perp}}
\]
$A_\parallel$ measured with the infrared radiation polarized parallel to and perpendicular to the draw direction, respectively, $RD = \frac{A_\parallel}{A_\perp}$. Table 1 summarizes the dichroic ratios based on this equation.

To overcome the difference in the thickness of the samples, all spectra were normalized by examining the 794 cm$^{-1}$ band, which is insensitive to orientation and crystallinity. This band is assigned to benzene ring vibration of the PET [4].

The infrared spectra of the LCP film with polarization directions parallel (full line) and perpendicular (dashed line) to the draw direction are shown in Figure 1. The absorbance of the 1601 cm$^{-1}$ band is strongest along the draw direction. This band has a parallel character.

Figure 1: Infrared spectra of LCP using polarized light parallel to and perpendicular to the flow direction.

The typical polarized infrared spectra of PET/LCP blends are illustrated in Figure 2. The spectra shown in this figure were recorded for the 90/10 PET/LCP film. It can be observed that both 974 and 1370 cm$^{-1}$ bands of PET have also parallel character.

Figure 2: Infrared spectra of 90/10 PET/LCP blend using polarized light parallel to and perpendicular to the flow direction.

The obtained $RD$ value for the LCP film is higher than 1, thus indicating that the average orientation of the “c” axis of the aromatic ring, which is representative of the chain orientation, is parallel to the draw direction.

However, the molecular orientation in the draw direction of the LCP phase decreases drastically in the PET/LCP blends, as indicate by the $RD$ values in Table 1. The decrease is stronger for the 95/5 blend. The compatibilizer agent reduces any more the molecular orientation of the LCP phase in the compatibilized blend. This result suggests an increased adhesion between the components of the blends and a consequent decrease in the molecular motion of LCP in the draw direction.

Table 1: Dichroic ratio ($RD$) of the analyzed bands.

<table>
<thead>
<tr>
<th></th>
<th>$RD_{1601}$</th>
<th>$RD_{974}$</th>
<th>$RD_{1370}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET</td>
<td>-</td>
<td>0.93</td>
<td>1.12</td>
</tr>
<tr>
<td>95/5</td>
<td>0.87</td>
<td>0.79</td>
<td>1.30</td>
</tr>
<tr>
<td>90/10</td>
<td>0.90</td>
<td>0.87</td>
<td>1.20</td>
</tr>
<tr>
<td>85/15</td>
<td>1.06</td>
<td>0.87</td>
<td>1.27</td>
</tr>
<tr>
<td>90/7.5/2.5</td>
<td>0.85</td>
<td>0.80</td>
<td>1.25</td>
</tr>
<tr>
<td>LCP</td>
<td>1.34</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

For the PET phases it was observed that the average molecular orientation of the gauche segments (amorphous phase) of the chain increases in the draw direction with the presence of LCP and compatibilizer agent. The 95/5 blend shows the higher increase. The trans conformers (crystalline phase) did not show orientation in the draw direction. A negligible decrease of the $RD$ values with the presence of LCP and compatibilizer agent was obtained.

**Conclusion**

It was observed that by the described processing conditions, the LCP has a relative high degree of molecular orientation in the draw direction. However, when blended with PET, the degree of orientation decreases drastically. An alignment of the amorphous phase of the PET in the draw direction was also verified. On the other hand, the PET crystalline phase any orientation was observed in the draw direction. The compatibilizer agent used was effective.

**Acknowledgement**

The authors thank to FAPESP for the financial support.

**References**