

# Miscibility Enhancement of PP/PBT Blends with a Side-Chain Liquid Crystalline Ionomer

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Received 26 July 2006; accepted 9 December 2008

DOI 10.1002/app.29874

Published online 24 February 2009 in Wiley InterScience (www.interscience.wiley.com).

**ABSTRACT:** Side-chain liquid crystalline ionomer (SLCI) containing sulfonic acid groups with a polymethylhydrosiloxane main-chain was used in the blends of polypropylene (PP) and polybutylene terephthalate (PBT) as a compatibilizer. The crystalline behavior, morphological, and mechanical properties of the blends were investigated in detail by differential scanning calorimetry (DSC), polarizing optical microscope (POM), Fourier transforms infrared spectroscopy (FTIR), and scanning electron microscopy (SEM). Revealed by the shift of  $T_m$  in DSC thermogram and the shift of the absorbed peak in FTIR spectra, specific interaction led to stronger interfacial adhe-

sion between these phases, which resulted in much finer dispersion of the minor PBT phase in PP matrix. The SLCI containing sulfonate acid groups acted as physical cross-linking agent along the interface, which compatibilized PP/PBT blends. The mechanical property of the blends including 4 wt % SLCI contents was better than that of other SLCI contents in the blends. © 2009 Wiley Periodicals, Inc. *J Appl Polym Sci* 112: 3007–3015, 2009

**Key words:** liquid crystalline polymers; polypropylene; polybutylene terephthalate; blends; compatibilization

## INTRODUCTION

Polymer blending is a common and important way to develop new materials with desirable combination of properties. Among these polymer blends, composites containing a thermotropic liquid crystalline polymer (LCP) are a kind of particularly attractive materials that have their specific rheological and mechanical performance.<sup>1–4</sup> However, the major limitation to the LCP–polymer blends is that the interfacial adhesion between the LCP and matrix polymer is generally poor.<sup>5,6</sup> In the past few years, the literature concerned with compatibilization has grown exponentially, the interfacial adhesion between immiscible polymers may be improved either by adding an interfacial active agent as physical compatibilizer or by promoting chemical reaction to form graft copolymer as it can be served as the reactive compatibilization.

An example of a physical compatibilizer is the zinc salt of lightly sulfonated polystyrene ionomer

(Zn-SPS). It was reported that it could compatibilize the blends of a LCP with nylon 66 (PA66) and bisphenol polycarbonate (PC). Zn-SPS was found to be effective to compatibilize the LCP/PC and LCP/PA66 blends.<sup>7</sup> Other nonreactive copolymers have also been used to promote compatibility between LCP and various thermoplastic polymers.<sup>5,8–16</sup> For example, O'Donnell<sup>8</sup> and Datta<sup>5</sup> used a small amount of the polypropylene grafted by maleic anhydride (PP-MA) as a compatibilizer to improve the adhesion of LCP and polypropylene (PP). Tjong and coworkers<sup>10–12</sup> investigated the miscibility and interfacial adhesion of the LCP/PA66 and LCP/PBT blends. They concluded that the miscibility of polymer components in LCP/PA66 and LCP/PBT blends was attributed to the intermolecular interaction, i.e., hydrogen bonding.

Other researchers have improved the interfacial adhesion by promoting transesterification reactions between LCP and other polymers during processing.<sup>17–23</sup> For instance, Lee and Dibenedetto<sup>17</sup> used a melt transesterification reaction to form covalent bonds between a wholly aromatic liquid crystalline polyester, PC and a compatibilizing polymer. A variety of other reactive functional groups, including epoxy,<sup>24–28</sup> ethers,<sup>29</sup> thiols,<sup>30</sup> and maleated polypropylene<sup>14,16,31–35</sup> have also been used.

In the case of physical compatibilization, miscibility enhancement is based on incorporating specifically groups into the polymers. As a result, the

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Contract grant sponsors: National Natural Science Fundamental Committee of China, HI-Tech Research and development program (863) of China, and Science and Technology Research Major Project of Ministry of Education of China.

interaction on different polymeric chains in blends was formed. Adding ionomers to the composites is proved to be an effective way of achieving this goal.

Thermotropic liquid crystalline ionomer (LCI) is a kind of LCP containing ionic groups; they can offer the possibility for promoting intermolecular interaction through ion-dipole association and the improvement of the interfacial adhesion between the phases in blends. Compared with vast number of studies on LCP/thermoplastic blends, less information is available on the blends reinforced and compatibilized by LCI.<sup>36,37</sup>

In previous studies, we used a main-chain LCI containing sulfonate acid groups for the compatibilization of PP and PBT blends. Specific interactions led to the compatibilization of the LCI in the blends, which was revealed by shifts of the melting temperatures ( $T_m$ s) of the component polymers in DSC. As a result, a significant improvement in the mechanical properties was achieved by the compatibilization of the ionomer in these blends.

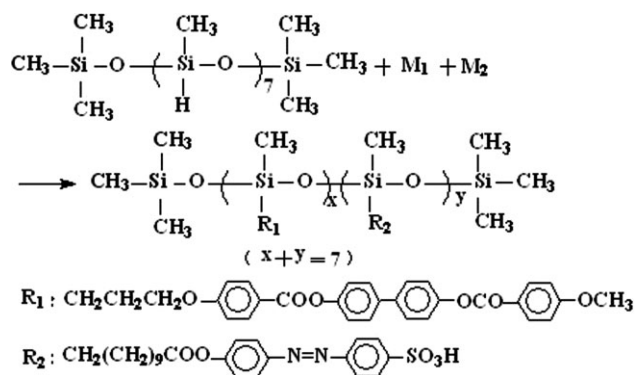
In these experiments, an interesting phenomenon was observed, the main-chain LCI was a copolyester of 4,4'-dihydroxy- $\alpha,\alpha'$ -dimethyl benzalazine, 4-hydro-phenylazobenzene sulfonic acid, and a sebacoyl dichlorides.<sup>38</sup> Although their molecular possessed liquid crystal behavior and the properties of ionomer, the enhancement effect was obviously superior to its compatibilization. As a result, the crystalline degree of blends ( $X_c$ ) increased significantly with the increasing of the LCI content. The main factors were that the rigidity of the molecular chains was strong and sulfonate groups located on the terminal unit of the main chain. Moreover, an investigation on the miscibility of PP and Polyamide-1010 blends with a SLCI containing sulfonic acid groups has been reported,<sup>39</sup> however, the information obtained was incompletely.

In this article, we gained insight into the compatibilization of SLCI as a compatibilizer in PP/PBT blends. On the basis of this, we have not only studied phase transition and crystallization behavior of ternary blends by means of DSC, but also we have researched the morphology and aggregation of these blends through SEM. Meanwhile, the mechanical properties of the blends were investigated by tensile strength test. What is more, we have also involved in Fourier transforms infrared (FTIR) investigation and spectral manipulation, which can show the origin of the compatibilization of SLCI.

## EXPERIMENTAL DETAILS

### Materials

PBT was obtained from Engineering Plastic Plants of YIZHENG Chemical Fiber Group Corp (China). Its



Scheme 1 Synthetic route of the SLCI.

intrinsic viscosity was  $0.75 \pm 0.02$  dL/g and melt mass-flow index (MFI) was 90–120 g/10 min. PP was supplied by Liaoning Huajin Chemical Group Corp (China), and its MFI was 1.7–3.1 g/10 min. Polymethyl hydrosiloxane (PMHS) (weight-average molecular weight = 700–800) was provided by Jilin Chemical Industry Corp. (Jilin City, Jilin Province, China). 4-allyloxybenzoyloxy-4'-methoxy benzoyloxy-*p*-biphenyl ( $\text{M}_1$ ) was a nematic monomer with a broad mesomorphic phase from 183°C to 312°C, and 4-undecylenicoxy-4'-phenylazobenzene sulfonic acid ( $\text{M}_2$ ) was nonmesogenic monomer containing sulfonic acid groups.  $\text{M}_1$  and  $\text{M}_2$  were prepared by our lab, and other solvents and reagents were purified before used.

### Preparation of the SLCI

The synthetic routes were shown in Scheme 1. The thermotropic SLCI was synthesized by the procedure described by J. S. Hu.<sup>40</sup> PMHS (0.5 mmol),  $\text{M}_1$  (3.0 mmol), and  $\text{M}_2$  (0.5 mmol) were dissolved in freshly distilled chloroform. Next, the mixture was heated to 65°C under nitrogen and anhydrous conditions, and then 2 mL THF solution of hexachloroplatinate (IV) catalyst (5 mg/mL) was injected with a syringe. The progress of the reaction had been monitored by IR spectra till Si-H absorption peak of PMHS at  $2160\text{ cm}^{-1}$  disappeared. The crude polymer was precipitated in ethanol, filtered and dried under vacuum. In this way, the SLCI was obtained. IR (KBr,  $\text{cm}^{-1}$ ): 2960–2850 ( $\text{CH}_3\text{-}$  and  $\text{-CH}_2\text{-}$ ); 1732 ( $\text{C=O}$ ); 1603, 1508 (Ar); 1260 (Si-C); 1190 (C-O-C); 1100–1000 (Si-O-Si).

### Preparation of the blends

PP/PBT and PP/PBT/SLCI blends were prepared by melt-mixing. Before blending, PP and PBT were dried at 120°C under vacuum for at least 12 h, and then they were mixed in an XSS-30 Torque Rheogonimeter with a mixing chamber of  $60\text{ cm}^2$  at

TABLE I  
Phase Transition of the Blends

Sample	Composition PP/PBT/SLCI (wt %)	$T_m$ (°C)/heating		$T_c$ (°C)/cooling	
		PP	PBT	PP	PBT
B <sub>0</sub>	80.0/20.0/0.0	166.0	224.5	122.6	197.6
B <sub>1</sub>	78.4/19.6/2.0	166.2	224.2	122.7	197.5
B <sub>2</sub>	76.8/19.2/4.0	165.1	224.4	122.0	196.7
B <sub>3</sub>	75.2/18.8/6.0	165.4	223.0	121.8	195.4
B <sub>4</sub>	73.6/18.4/8.0	166.2	224.0	122.3	193.9
B <sub>5</sub>	70.4/17.6/12.0	165.7	222.2	120.6	187.5

230°C at a rotor speed of 32 rpm for 10 min. All the blends had a fixed ratio of PP/PBT 4 : 1 by weight to which we added different amounts of the ionomer. Compositions of all the blends were listed in Table I.

### MATERIALS CHARACTERIZATION

The crystallization behaviors and miscibility of the blends were measured with a Netzsch DSC 204 (Bayern, Germany) equipped with a liquid nitrogen cooling system. Operating at nitrogen flow, specimens were first heated to 200°C in 20°C/min heating rate to eliminate heating history, and then cooled to 20°C in 10°C/min cooling rate; the second heating rate was the same as the first process. The melting transition temperature ( $T_m$ ) and the crystallization temperature ( $T_c$ ) was determined as the maximum of accordingly transition peak.

FTIR spectroscopy of the blends in solid state was obtained by the diffuse reflection method performed on a Nicolet (Madison, WI) 510P spectrophotometer.

The blend morphology was characterized with a model 505 scanning electron microscopy (SEM) from Philips Corp. (Eindhoven, Netherlands). The samples were freeze-fractured in liquid nitrogen, and the fracture surface was observed.

Visual observation of the blends under cross-polarized light was made by Linknm (Wetzlar, Germany) THMSE 600 Polarizing optical microscope (POM) equipped with a Leica (Shenyang, China) DMRX heating stage, the samples were the granules cutting from the melting blends with a QLB-D350 Molder at 240°C for 10 min.

Tensile strengths and ultimate elongation to the break of the blends were measured with a model 1000N Tensile Tester (Shanghai, China). The blends were molded in plates with a QLB-D350 Molder at 240°C for 10 min at an elevated pressure. The pressure was released suddenly, and then increased again; this procedure was repeated several times to remove any trapped bubbles. The molded plates were cut into a Dumbbell shape. Tensile tests at an elongation rate of 5 mm/min were performed by

GB1040-92 standard method on dumbbell samples with an overall length of 11.5 mm and a narrow-section diameter of 6.5 mm.

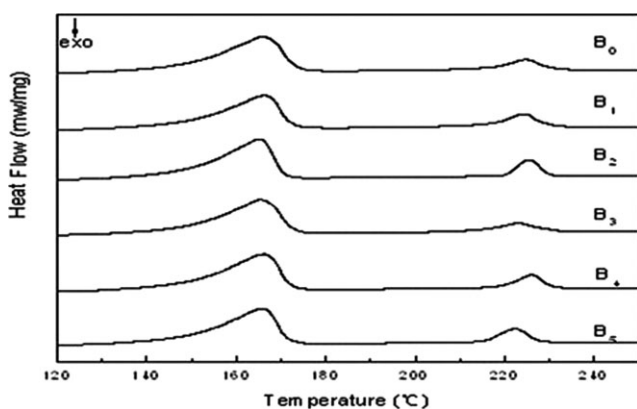
### RESULTS AND DISCUSSION

#### Synthesis and characterization of the SLCI

The SLCI was prepared by hydrosilylation from PMHS, the mesogenic monomer  $M_1$  and ionic monomer  $M_2$ . The catalysts used in the reaction are the THF solution of the hydrogen hexchloroplatinate (IV) hydrate. The progress of the reaction had been monitored by IR spectra till Si—H absorption peak of PMHS at 2160  $\text{cm}^{-1}$  disappeared. To remove the nonreactive monomers, the product was washed by acetone and ethanol. We had measured its structure by IR and their characteristic absorption bands were mentioned above. In IR spectrum of the product, the absorption band of C=O stretching vibration (1732  $\text{cm}^{-1}$ ) was clearly identified, which showed the successful incorporation of mesogenic monomer  $M_1$  into the polysiloxanes chains. For organic sulfonic acid, the IR absorption range of the O=S=O asymmetric and symmetric stretching mode lied in 1150–1260 and 1010–1080  $\text{cm}^{-1}$ , respectively; and the S—O stretching mode of the IR absorption range lied in 600–700  $\text{cm}^{-1}$ . Because of the overlap between stretching bands of O=S=O and stretching bands of ester C—O in the SLCI, we chose S—O stretching mode (600–700  $\text{cm}^{-1}$ ) to identify sulfur groups in the ionomer.<sup>5</sup> A weak band at 668  $\text{cm}^{-1}$  was found for the sample of the SLCI. This result clearly indicated the successful incorporation of the ionic monomer into the polysiloxanes chains.

#### Thermal behavior

DSC thermogram at second heating of PP/PBT and PP/PBT/SLCI blends was illustrated in Figure 1. The melting temperature determined from DSC thermogram was summarized in Table I. Detecting  $T_m$  was one of the most effective ways to characterize the miscibility of blends on condition that the components of the blends had a  $T_m$  difference larger



**Figure 1** DSC thermograms at second heating of PP/PBT/SLCI blends.

than 20°C. For PP/PBT binary blend, two distinct absorbed peaks corresponded to the two melting temperature ( $T_m$ ) of the component polymers individually. The peak identical to PP phase could be seen at 166°C; simultaneously, another peak that corresponded with PBT phase was at about 225°C. That is to say, PP and PBT phases are completely immiscible in the blend; we can see that PP is nonpolar while PBT is polar.

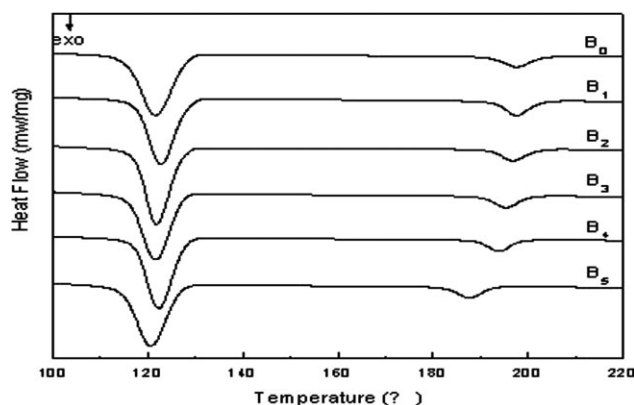
Generally, the blend of immiscible polymers could be reduced through the addition of suitable compatibilizer. A compatibilizer is frequently a block or graft copolymer, owning the segments that were capable of interaction with each component of the blend. Thermotropic LCPs exhibited unique physical, mechanical, rheological, and thermal properties and could modify the properties of thermoplastic resins. However, they are immiscible with the resins, so the blends often require the addition of a compatibilizer to improve the dispersion and adhesion of phases. The SLCI containing the sulfonic acid was used to compatibilize the PP and PBT blend.

For PP/PBT/SLCI ternary blends, the thermal behaviors of the blends were also demonstrated by DSC thermogram. Because of the limited amount of the SLCI, we failed to detect its glass temperature ( $T_g$ ) in heating course. Comparing with the binary blend, we noticed that the  $T_m$  of PP phase had no significant shifts while the  $T_m$  of PBT phase decreased with the composition in the blends. When the SLCI was added for about 2.0 wt %, the  $T_m$  of PBT reduced by 0.3°C. With the increasing of the SLCI concentration in the blends, the  $T_m$  of PBT phase decreased much more. For example, if we added 6.0 wt % SLCI, the temperature went down by 1.5°C. Similarly, if the content of the SLCI was increased to 12.0 wt %, the temperature decreased by 2.3°C.

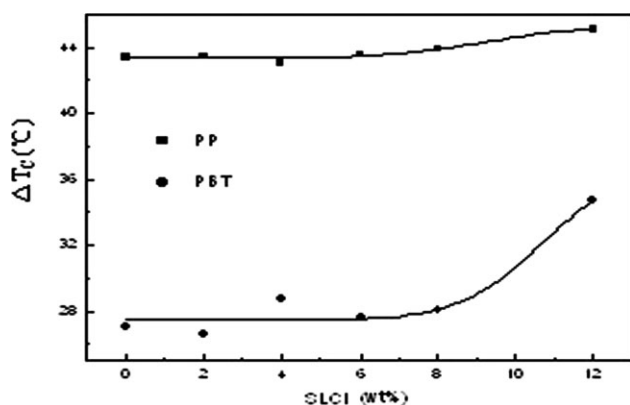
Moreover, we also observed the change of the crystallization temperature ( $T_c$ ) of PP and PBT

phases in cooling course. Figure 2 showed the cooling DSC thermogram of PP/PBT and PP/PBT/SLCI blends, and the  $T_c$ s were listed in Table I. In PP/PBT blend, compared with the heating course, the  $T_c$ s of PP and PBT tended to shift to a lower temperature region because of the supercooling. In PP/PBT/SLCI blends, it was interesting to notice that the  $T_c$ s of PP and PBT phases both decreased with the increasing of the SLCI content. And what was more obvious, the  $T_c$  of the PBT decreased more than the  $T_c$  of PP did. When the SLCI concentration was increased to 6.0 wt %, the  $T_c$  of the PBT decreased 2.2°C. When the SLCI concentration was increased to 12 wt %, the  $T_c$  of PBT decreased 10.1°C. These  $T_m$  or  $T_c$  shifts suggested that the compatibilization in PP/PBT blends could be modified by the addition of the SLCI. It also indicated that SLCI had a greater influence on PBT phase, compared with PP phase in the blends. As to the same PBT phase, the effect on the crystallization in cooling course was more apparent than the melting transition course.

Several researchers have used  $\Delta T_c$  values to describe the crystallization behavior of polymer blends.  $\Delta T_c$  value was defined by the difference between the melting temperature and crystallization temperature. When the miscibility between the components was improved in blends, the crystallization rate of the components decreased so that  $\Delta T_c$  values increased.  $\Delta T_c$  values of PP and PBT versus SLCI content were given in Figure 3. The result showed that  $\Delta T_c$  values of PP and PBT both increased with increasing the SLCI content in the blends,  $\Delta T_c$  values of PBT increased more remarkable than that of PP. An increase in  $\Delta T_c$  values generally indicated that the crystallization rate of the polymer was retarded. Therefore, the crystallization rate of PP and PBT phases in the ternary blends are depressed due to the introduction of SLCI.



**Figure 2** DSC thermograms at second cooling of PP/PBT/SLCI blends.



**Figure 3** Crystallization rate ( $\Delta T_c$ ) of the blends with SLCI content.

To explore the crystallization behavior of PP and PBT phases in the blends in detail, we also measured the crystalline enthalpy ( $\Delta H_f^*$  at  $T_c$ ) of PP and PBT phase in binary and ternary blends. The  $\Delta H_f^*$  of PP and PBT phases were  $63.53 \text{ J g}^{-1}$  and  $9.60 \text{ J g}^{-1}$  in binary blend, respectively. Compared with the  $\Delta H_f^0$  of pure PP ( $99.0 \text{ J g}^{-1}$ ) and PBT ( $48.4 \text{ J g}^{-1}$ ), both of them decreased. This result indicated that the crystallization of the two phases in binary blend was not perfect. However, in ternary blends, the  $\Delta H_f^*$  of PP and PBT phases decreased more than those in binary blend.

The percent degree of crystallinity ( $X_c$ ) of PP and PBT phases in the blends was calculated with the help of the following equation<sup>41</sup>:

$$X_c = (\Delta H_f^* / \Delta H_f^0) \times 100$$

Where  $\Delta H_f^*$  is the crystalline enthalpy for PP or PBT in the corresponding blends while  $\Delta H_f^0$  is the crystalline enthalpy of raw PP or PBT as follows:  $\Delta H_f^0$  (PP) =  $99.0 \text{ J g}^{-1}$  and  $\Delta H_f^0$  (PBT) =  $48.4 \text{ J g}^{-1}$ .

Figure 4 showed the variation of the  $X_c$  of PP and PBT phases in the blends with different SLCI content. We could see that the  $X_c$ s of PP and PBT both decreased with increasing of the SLCI content, especially that of the  $X_c$  of PBT phase. This implied that the crystallinity of PP and PBT phases in ternary blends was depressed when the SLCI existed.

According to the literatures, the crystallizability of PP and PBT phases in PP/PBT blends was related to the intrinsic property of the components and the compatibility between the phases. PP and PBT were crystalline polymers and immiscible completely because PP is nonpolar whereas PBT is polar.

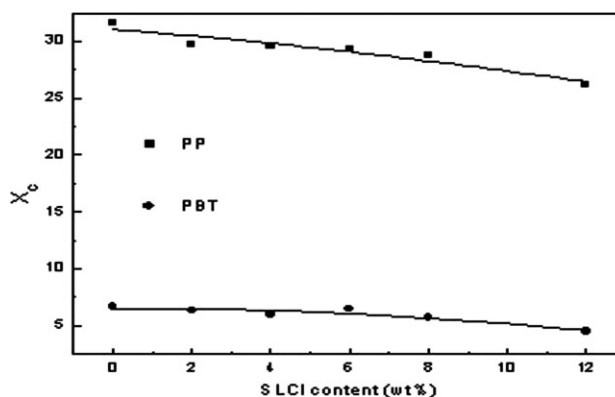
In ternary blends, the SLCI was a polymer containing ionic groups. That is to say, mesogenic segments and ionic groups both located on the side-chain with a flexible polymethylhydrosiloxane main-chain in the SLCI molecule, especially ionic groups

were on the terminal of the long and flexible spacer. When the SLCI was introduced into PP/PBT blend, the SLCI performed the mesomorphic behavior of a LCP and the compatibilization of an ionomer simultaneously. The incorporation of mesogenic phase into PP phase resulted in the decreasing of  $X_c$  of PP. Meanwhile, the incorporation of ionic phase into PBT phase led to the decreasing of the  $X_c$  of PBT. According to the results illustrated earlier, PP and PBT phases were both depressed by the existence of the SLCI in ternary blends.

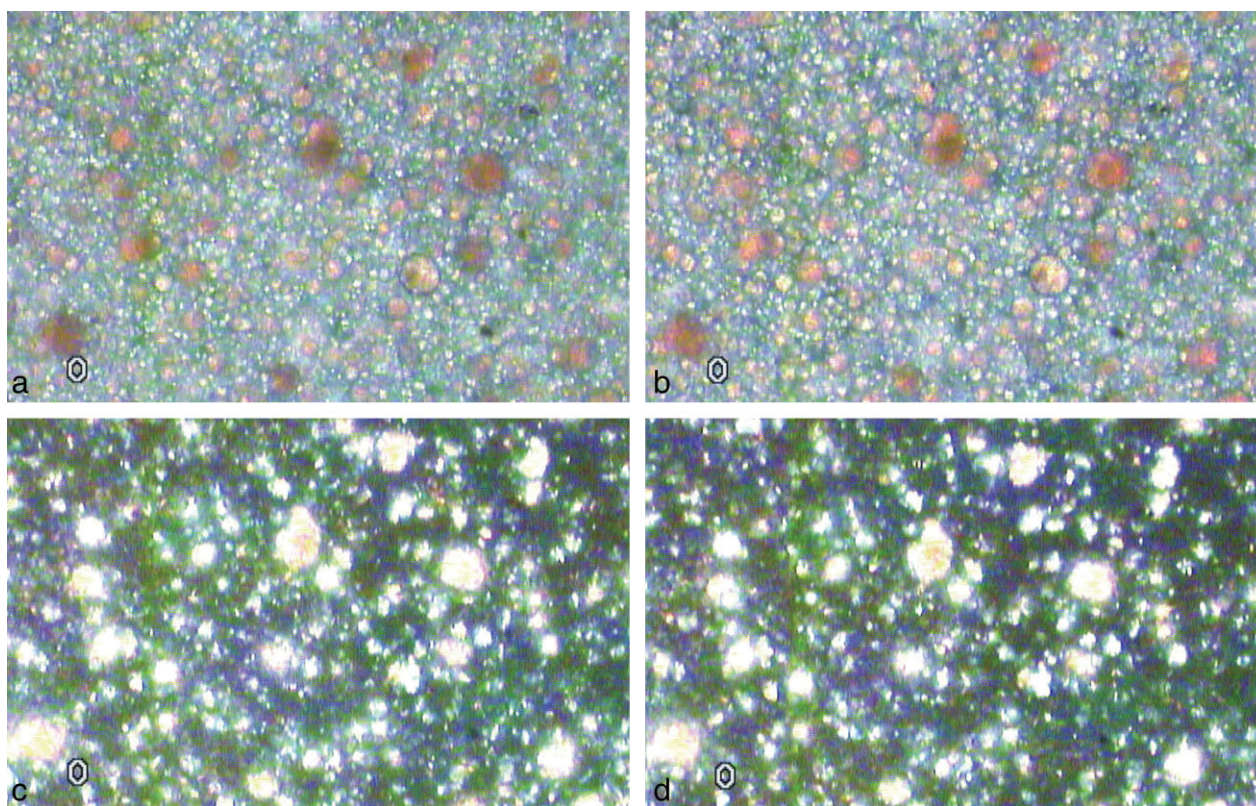
To investigate the phase transition of the blends, we also observed their polarizing optical texture by POM. The POM observations showed the change of colorful texture during heating and cooling cycles. Figure 5 showed the micrographs of the blend B<sub>3</sub>. When B<sub>3</sub> was heated to  $147^\circ\text{C}$ , PBT obviously dispersed in PP phase [Fig. 5(a)]. When it was heated to  $189^\circ\text{C}$ , PP phase became liquid melt so that its polar texture disappeared [Fig. 5(b)]. What is more, PBT texture also disappeared as the heating temperature was  $227^\circ\text{C}$ . We only observed the texture of the SLCI because PBT phase was liquid melt, too [Fig. 5(c,d)].

## Morphology

Figure 6 showed SEM micrographs of the fractured surfaces of PP/PBT and PP/PBT/SLCI blends. The morphology of a melt-blended, immiscible polymer blend depended on a variety of factors that included the interfacial tension, the viscosity ratio of the components, the volume fraction, the shear, and extensional stresses encountered during processing. In general, an immiscible blend had high interfacial tension, which resulted in a coarse morphology and a relatively large domain size for the minor component.<sup>42–46</sup> Figure 6(a) provided direct evidence that phase separation occurred in PP/PBT blend. This sample had a distinct two-phase morphology, i.e., a



**Figure 4** Degree of crystallinity of the blends with SLCI content.



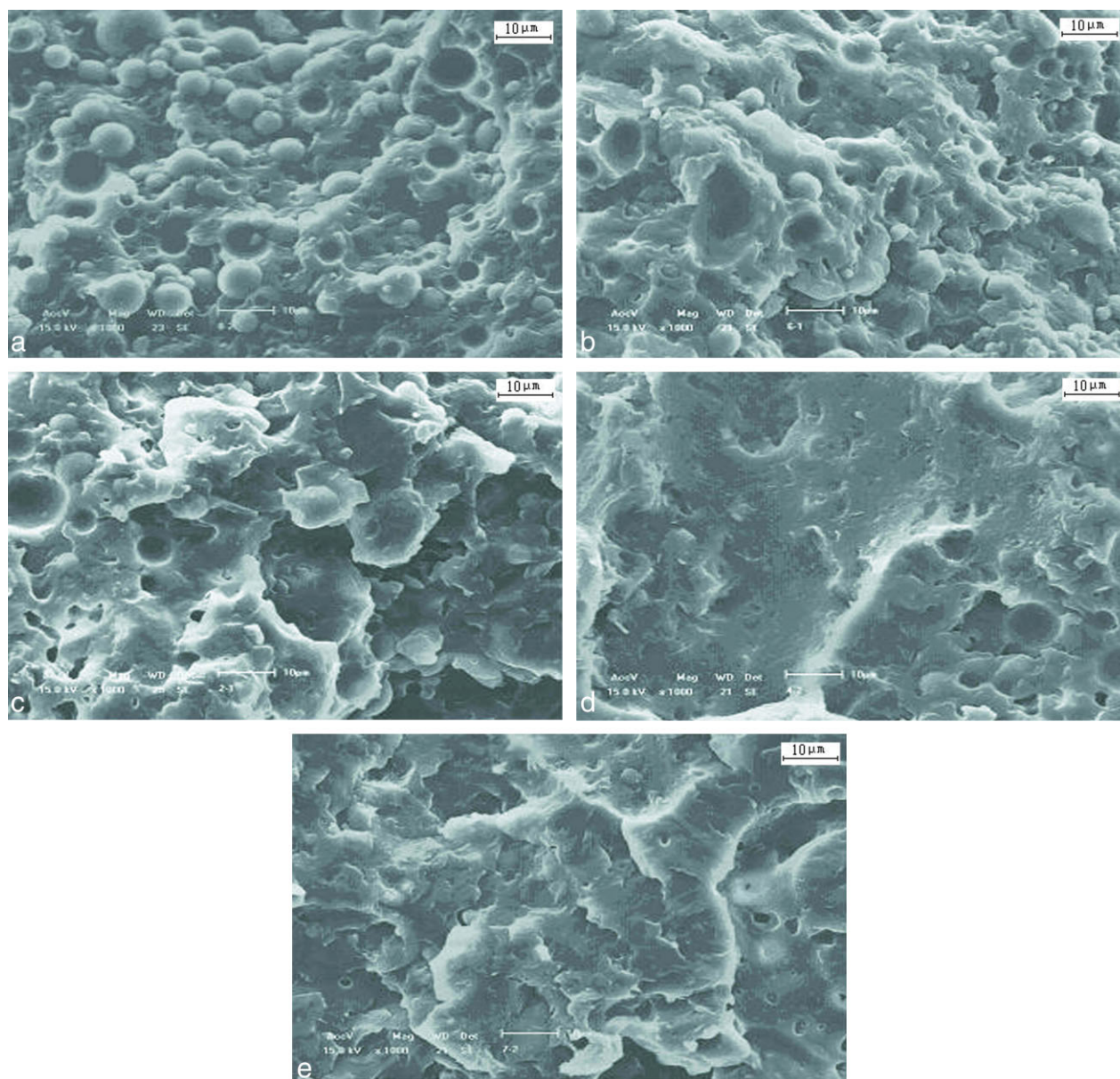
**Figure 5** POM micrographs of B<sub>3</sub> ( $\times 200$ ) (a) 147°C, (b) 189°C, (c) 227°C, and (d) 247°C. [Color figure can be viewed in the online issue, which is available at [www.interscience.wiley.com](http://www.interscience.wiley.com).]

continuous PP phase with a dispersed PBT phase. The PBT particles had diameters in the range of 5 to 15  $\mu\text{m}$ . All the spheres and holes have smooth surfaces, which implied poor interfacial adhesion between PP and PBT phases. That is to say, PP and PBT phases in the blend are immiscible, and the interfacial tension between the PP and PBT phases were relatively high.

For PP/PBT/SLCI ternary blends, because all the samples were obtained in a mixer, the lack of field effect made it difficult to generate SLCI micro-fibril in these blends. However, with the addition of the SLCI, the morphology of fractured surfaces changed dramatically. With 2 and 4% SLCI in ternary blend, the number of PBT particles decreased [Fig. 6(b,c)]. With 8% SLCI in the blend, the domain size of the PBT phase decreased significantly and the diameter of the largest particles was smaller than 5  $\mu\text{m}$  [Fig. 6(d)]. When the content of SLCI was 12%, the interface between PP and PBT phase became more blurred, and the domain size of PBT phase became further small [Fig. 6(e)]. From these phenomena, it was evident that the miscibility between PP and PBT phases was enhanced when the SLCI was present. This conclusion was consistent with the results of thermal behavior above in PP/PBT/SLCI blends.

#### FTIR investigation of miscibility enhancement

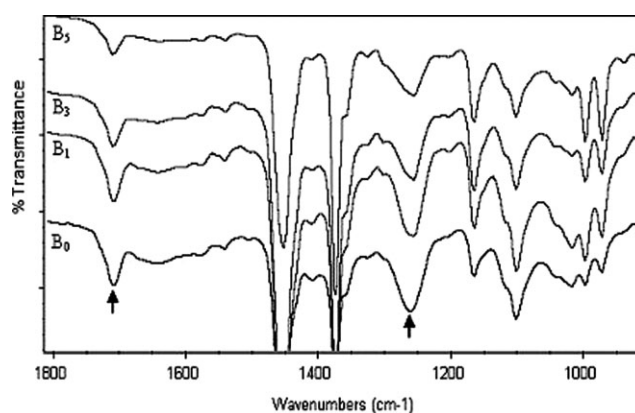
Olabisi proposed a concept of 'complementary dissimilarity' in enhancing the miscibility of polymer blends, wherein constituents of individual polymer chains were quite different, but the interactions between these groups provided the necessary driving force for mutual miscibility.<sup>20</sup> The presence of specific interactions was responsible for the improvement of miscibility. The specific interaction between SLCI and PBT phase in ternary blends was confirmed by the FTIR spectra. Figure 7 showed the IR spectra of B<sub>0</sub>, B<sub>1</sub>, B<sub>3</sub>, and B<sub>5</sub>. The characteristic absorbencies of PBT phase were the stretching vibration of C=O band at 1710, 1263  $\text{cm}^{-1}$ . When the SLCI was added into the PP and PBT blend, the absorption peak of C=O moved to higher wave numbers, i.e., 1710  $\text{cm}^{-1}$  in B<sub>0</sub>, 1711  $\text{cm}^{-1}$  in B<sub>3</sub>, and 1712  $\text{cm}^{-1}$  in B<sub>5</sub>. Meanwhile, the absorption peak of C=O also shifted from 1263  $\text{cm}^{-1}$  in PP/PBT to lower wave numbers in PP/PBT/SLCI blends, i.e., 1263  $\text{cm}^{-1}$  in B<sub>0</sub>, 1261  $\text{cm}^{-1}$  in B<sub>1</sub>, 1258  $\text{cm}^{-1}$  in B<sub>3</sub>, and 1257  $\text{cm}^{-1}$  in B<sub>5</sub>. This IR result confirmed an intermolecular interaction between PBT and SLCI, and the interaction came from the ion-dipole interaction between the ionic groups of SLCI and the polar groups in PBT. Moreover, the



**Figure 6** SEM micrographs of the blends (a) PP/PBT, (b) PP/PBT/2% SLCI, (c) PP/PBT/4% SLCI, (d) PP/PBT/8% SLCI, and (e) PP/PBT/12% SLCI. [Color figure can be viewed in the online issue, which is available at [www.interscience.wiley.com](http://www.interscience.wiley.com).]

strength increased with the increase of the SLCI component.

On the basis of the literatures, if polymers were miscible, molecular chains of one component could be mixed closely with the other component chains so that the intermolecular interactions would be strong enough to change their molecular environment. These would cause the shifting and broadening of the IR peak; if the two polymers were immiscible, it was possible to synthesize an infrared spectrum of the blend just by adding up the spectra of the two pure component polymers with appropriate weight fractions respectively. The infrared spectrum was at least identical to the experimental

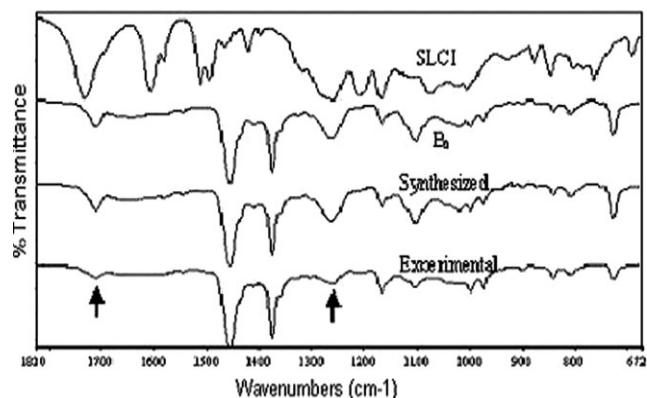


**Figure 7** FTIR spectra of B<sub>0</sub>, B<sub>1</sub>, B<sub>3</sub>, B<sub>5</sub>.

spectrum of this blend theoretically. Figure 8 shows the experimental spectrum and a synthesized spectrum of B<sub>3</sub> recorded in 1000–1800 cm<sup>-1</sup> ranges. The spectrum labeled 'synthesized' was obtained by adding up the spectra of pure PP/PBT and SLCI with their corresponding weight fractions (i.e., in this case, 94% for PP/PBT and 6% for SLCI, respectively). By comparing synthesized spectrum and experimental spectrum of B<sub>6</sub>, it was clear that the experimental spectrum for the carbonyl groups of PBT is different from its synthesized spectrum. The absorbency bands at 1710 and 1263 cm<sup>-1</sup> shifted to 1712 and 1258 cm<sup>-1</sup> individually. These shifts were evidence for a distinct interaction between sulfonate groups of SLCI and polar groups of PBT. What was reported above agreed with the results of Lu and Weiss's research.<sup>47</sup>

### Mechanical properties

To seek for structure–property relationships in ternary blends, it was essential to analyze the mechanical properties. As an effective compatibilizer, the effect of the SLCI on the tensile properties of PP/PBT/SLCI blends was shown in Table II. Compared with the tensile behavior of PP/PBT blend, the tensile strength of PP/PBT/SLCI blends increased dramatically when the content of the SLCI content was less than 4 wt %. With the addition of 4 wt % SLCI to PP/PBT blends, the tensile strength of the blend B<sub>4</sub> exhibited a maximum and it was 7.336 MPa. As the content of SLCI was more than 4 wt %, the tensile strength decreased obviously. Moreover, the elongation at break of the blends increased slowly with the addition of SLCI. When the content of SLCI was more than 4 wt %, the elongation of the blends began to go down. The result of the tensile strength corresponded to that of the elongation of the blends. This could be explained that a small amount of the SLCI would improve the mechanical properties, but



**Figure 8** FTIR spectra of SLCI, B<sub>0</sub>, B<sub>3</sub>, and synthesized spectrum of B<sub>3</sub>.

**TABLE II**  
Mechanical Properties of the Blends

sample	SLCI (wt %)	Strength (MPa)	Ultimate elongation (%)
B <sub>0</sub>	0.0	5.428	0.22
B <sub>1</sub>	2.0	6.687	0.25
B <sub>2</sub>	4.0	7.336	0.30
B <sub>3</sub>	6.0	7.304	0.29
B <sub>4</sub>	8.0	7.287	0.27
B <sub>5</sub>	12.0	7.175	0.26

excessive SLCI addition would impair the mechanical performances.

### CONCLUSIONS

The miscibility of PP and PBT blends were enhanced by the SLCI containing sulfonate acid groups. Unveiled by the shift of the absorbed peak in IR spectra, specific interaction was formed by ion–dipole interaction between the ionic groups of SLCI and the polar groups in PBT. The interaction led to the compatibilization of the SLCI in PP/PBT/SLCI blends. This resulted in much finer dispersion of the minor PBT phase in PP matrices and stronger interfacial adhesion between these phases. The morphological structure of the blends was improved. The compatibilization effect of 4 wt % SLCI content was better than that of other SLCI contents in the blends. It was clear that the thermotropic SLCI was a practically acceptable compatibilizer for the blends.

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