Variation of Flow Induced Phase Morphology of Fluoroelastomer and Polycarbonate Blends and Their Mechanical Properties

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Abstract: The variations of the flow induced phase morphology of fluoroelastomer/polycarbonate (FL/PC) extruded blends and their mechanical properties were investigated in this paper. The phase morphology and mechanical property of extruded blends under the capillary die were examined by scanning electron microscope (SEM) and tensile machine, respectively. From SEM observation, the dispersed phases in the longitudinal direction for these extruded blends were categorized as sphere, ellipsoid, rod, and fiber. Furthermore, the processing window for the deformation of phase morphology in the longitudinal direction for FL/PC 10/90 w/w and 25/75 w/w extruded blends at 235 and 260 °C was studied. As shear stress was smaller than 7.0 × 10⁴ Pa, the spherical phase almost did not deform. The transformation from the sphere to the fiber form occurred in the range of shear stress 7.0 × 10⁴ Pa and 15.8 × 10⁴ Pa. In particular, as shear stress was larger than 15.8 × 10⁴ Pa, the fiber broke up into a series of small droplets. Finally, it was concluded that the morphology with the mixture of fiber-like and spherical structures in the longitudinal direction could enhance the FL/PC blends with longer break elongation and higher Young's modulus.

Keywords: Phase morphology, Mechanical property, Fluoroelastomer, Polycarbonate, Shear stress.

Introduction

The majority of polymer blends are produced by mechanical melt mixing of existing polymers. Most of such polymer blends are immiscible blends, which possess two-phase morphology induced by the flow field in the mixing device. The phase morphology of immiscible blends depends on the chemical nature of the component polymers, the melt rheological properties, the interfacial tension, and the flow history in the mixing device. The phase morphology largely governs the mechanical properties of the blends such as tensile strength, toughness and impact strength.

As summarized by Heikens et al. [1,2] and Sperling [3], the two-phase morphology may be categorized into four general types including ribbons and lamellae (stratified structure), rods and fibrils, droplets, and co-continuous phases. Heikens et al. [1] studied the particle dimensions in polystyrene/polyethylene (PS/PE) blends as a function of the melt viscosity of component polymers and of the concentration of an added graft copolymer. They concluded that a high viscosity matrix and a low interfacial tension would lead to smaller particle size.

By means of SEM, Liang et al. [4] observed the cross-section phase morphology for polypropylene/nylon-6 (PP/PA-6) blends under static-mixing extruder. The SEM microphotographs displayed discrete islands and sea structure. The finest dimension was found in the PP/PA-6 75/25 w/w blends and the coarsest dimension in the PP/PA-6 50/50 and 25/75 w/w blends. The size of the dispersed phase was observed to decrease as the shear rate was increased. However, at higher PA-6 contents, the development of dispersion was chiefly determined by the balance between interfacial tension and viscous force.

Min et al. [5-7] did a series of studies of phase morphology of blends, including PE/PS, polyethylene/poly carbonate (PE/PC) and polyethylene/nylon-6 (PE/PA-6). The finest phase morphology was found in the PE/PS blend and the coarsest in the PE/PA-6 blend. They concluded that the size of the dispersed phase was mainly determined by interfacial tension. They also studied the deformation of

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droplets during extrusion. For a high $P$ (viscosity ratio) > 2.2 and a small $K$ (the product of local stress and radius of the particle to the interfacial tension), non-deformed droplets were observed. At $P < 0.7$, the droplets deformed into thin fibers with increasing shear stress or $K$. Within the range of $1.4 < P < 1.9$, ellipsoids were observed. Favis and Chalioux [8] also reported that viscosity ratio has a significant effect on the dispersed phase. The phase size of polypropylene/polycarbonate blends increased 3 to 4 times as the viscosity ratio increased from 4.5 to 17.3. Beyond this range, the deformation of the dispersed phase becomes difficult. The minimum particle size was achieved at a viscosity ratio of 0.15.

Subramanian, et al. [9-11] observed that stratified structure can be obtained for modified nylon/polyolefin blends by film extrusion or blow molding. This morphology, having a polyolefin matrix and a nylon dispersed phase, has improved permeability barrier properties because of the longer path length that the permanent molecules have to travel. They also found that the morphology is dependent on a low mixing-shearing history during the melting step before extrusion. Chalioux and co-workers [12] observed PP/PA-6 blends extruded into ribbons at different draw ratios. The size and the distribution of the dispersed phase was coarse. After adding an ionomer (Surlyn 902) to PA-6 before blending, the phase produced much finer domains.

In this paper, we investigated the variations of two phase morphologies of fluoroelastomer and polycarbonate blend prepared according to varying extrusion conditions. Then, their mechanical properties were illustrated with variations of two phase morphologies.

### Experimental

1. Materials

   The materials used in this study were fluoroelastomer (FL) (DuPont Company, Viton B50) and polycarbonate (PC) (G.E. Company, Lexan 141). The Mooney viscosity ML-10 of FL was between 50 and 60 at 100 °C. The melt flow index of PC was 9.5 g/10 minutes according to ASTM D1238 (condition O).

2. Blending

   Various compositions of FL/PC blends were prepared in an internal mixer at 260 °C as listed in Table I. The mixing time was 5 minutes after completely loading the polymers through the ram port. Rotor speed was 45 rpm. The fill factor was 0.7. Before blending, PC was dried in a vacuum oven for 8 hours at 90 °C.

### Table I. Conditions for blending various polymers.

<table>
<thead>
<tr>
<th>Blends</th>
<th>Composition FL/PC (w/w)</th>
<th>Temperature (°C)</th>
<th>Blending machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL/PC</td>
<td>1/99, 5/95, 10/90</td>
<td>260</td>
<td>internal mixer</td>
</tr>
<tr>
<td></td>
<td>25/75, 50/50, 75/25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

for 8 hours at 90 °C.

3. Extrudates from capillary rheometer

   The extrudates were collected at different cross-head speeds from the capillary rheometer at 260 and 235 °C, respectively. The blends prepared from the internal mixer were first placed into and then extruded in the barrel of the Instron Capillary Rheometer. The capillary die has a length/diameter ratio 20 and a diameter of 1.506 mm. The extrudates were collected for morphological study and mechanical testing.

4. Characterization

   (1) Two phase morphologies

   The phase morphologies of all blends and extrudates were investigated by a Scanning Electron Microscope (SEM, ISI SX-40). Fracture surfaces of all blends and extrudates were prepared in liquid nitrogen. The surface was then coated with a gold-palladium alloy using a coating machine (Polaron E5400).

   (2) Mechanical property

   The extrudates from the capillary rheometer were placed between the clamps of the tensile machine (Instron Tensometer, Model 4204) at room temperature. The initial gauge length is 30 mm and cross-head speed was fixed at 10 mm/min.

### Results and Discussion

1. Two phase morphology of various FL/PC blends

   The SEM microphotographs of the cross-sections of FL/PC blends prepared from the internal mixer at 260 °C are shown in Figure 1. Figure 1 demonstrates that the size of the dispersed phase increases with the increase of FL content. The shape of the dispersed phase is spherical. In the FL/PC 10/90 and 25/75 blends, FL is the dispersed phase surrounded by PC continuous phase. In order to extract PC phase, the FL/PC 50/50 and FL/PC 75/25 blends were immersed in benzene for 6 hours and for 90 minutes, respectively. Figure 2 shows SEM microphotographs of fracture surfaces of FL/PC 50/50 and 75/25 blends extracted in benzene.