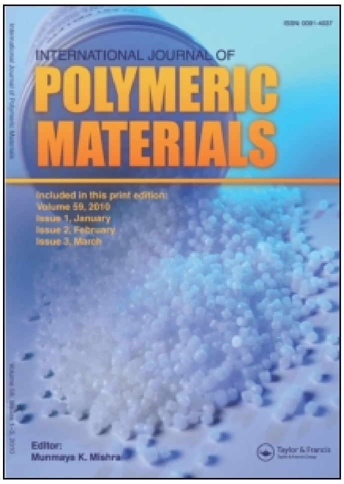

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Mechanical Properties and Compatibility of High Density Polyethylene with Some Oligoesters

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Miscibility of high density polyethylene and modifiers was evaluated using polymer-polymer interaction parameter and determined with the help of inverse gas chromatography. Mechanical, rheological properties and melting point changes were investigated. Measurements of mechanical properties showed that alloying of high density polyethylene with different oligoesters may produce higher strength and elongation than pure PE. The results obtained showed that compatibility of PE and additives may influence overall characteristics of the compositions. Mechanical properties of compatible alloys change monotonously when the concentration of modifiers increases. For unmiscible systems, the relationship between mechanical properties and oligoester concentration appears to display a curve with extremum. The performed study made it possible to choose optimum systems for use as an optical cable.

KEY WORDS Polyethylene, oligoesters, compatibility, mechanical properties.

1. INTRODUCTION

During recent years there has been an increased interest in modification of structure and properties of industrial polymers with small amounts of oligomers. However, the mechanism of the modifiers action depends on the molecular structure of the polymer and additive and their compatibility. In this work, inverse gas chromatography (IGC) has been extended to the investigation of polyethylene-oligoesters blends. IGC is widely used and can provide the following features: polymer-solvent and polymer-polymer interaction parameters, glass and melting temperatures, degree of the crystallinity (DC) of semicrystalline polymers and solubility parameters.[1] In this paper, the thermodynamic interaction parameters for the systems PE-oligoesters and the degree of crystallinity of modified PE have been studied. The polymer-polymer interaction parameter can be determined with the help of several techniques. IGC is one of the most often used. A commercial sample of high density polyethylene-, dibutyl-ester of polydiethyleneglycoladipinate (PDA), oligoester based on decanedicarboxylic acid and C 18-20 glycol (DGB) and oligoester based on maleic acid (MAE) were used. The chromatographic apparatus was a LHM-8MD dual column gas chromatograph with a flame ionization detector. The degree of crystallinity of modified PE can be easily obtained from the retention diagrams utilizing the following equation: $X = 100[1 - (V\text{sample}/V\text{amorphous})]$. The experimental procedure is reported elsewhere.[2] Experimental data were obtained using an automatic measurement of the gas chromatograph retention time. Helium was used as a carrier gas.

2. THEORETICAL ANALYSIS

In recent years, an important part of the applied polymer research has been aimed at preparing polymer and polymer-oligomer blends with improved properties. Miscibility or polymer matrix and a modifier may influence the overall characteristics of the material. It was shown that in unmiscible polymer blends mechanical properties appeared to display a curve with extremum. Maximum strength and elongation was observed when the modifier's concentration was about 1 ÷ 3%. It was shown that in presence of small amounts of uncompatible additives polymer structure tends to be more regular, spherulite dimensions decrease and relaxation processes accelerate.[2] Yu. S. Lipatov showed[4] that there is a connection between viscosity of polymer blends and the interaction parameter of its components. The estimation of compatibility of polymer blends by IGC techniques is based on Flory's equation of state theory. The expression for calculation of interaction parameter was used in Reference 5. The equation obtained refers to the interaction of mixed stationary phase components:

$$X_{23} = V_2/V_1[(X_{12}\cdot Y_2 + X_{13}\cdot Y_3) - X_{123}/Y_2\cdot Y_3],$$

where: X_{12}-sorbate-component 2 interaction parameter, X_{13}-sorbate-component 3 interaction parameter, Y_2, Y_3-components 2,3 of stationary phase volume fractions, X_{123}-sorbate-mixed stationary phase interaction parameter, X_{23}-component 2-component 3 interaction parameter.

3. RESULTS

Dependences of the degree of crystallinity of pure PE and PE with oligoesters upon temperatures are shown in Figures 1–3.

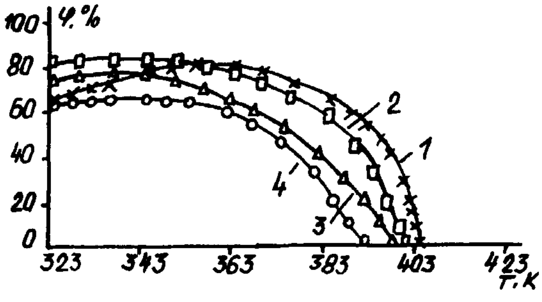

FIGURE 1 Variation of degree of crystallinity with temperature. 1 = PE, 2 = PE + 1% PDA, 3 = PE + 5% PDA, 4 = PE + 10% PDA.

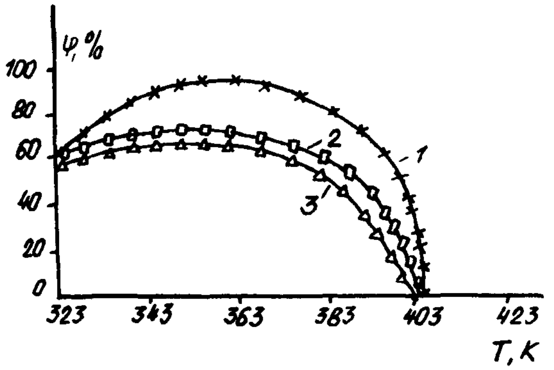

FIGURE 2 Variation of degree of crystallinity with temperature. 1 = PE, 2 = PE + 5% DCG, 3 = PE + 10% DCG.

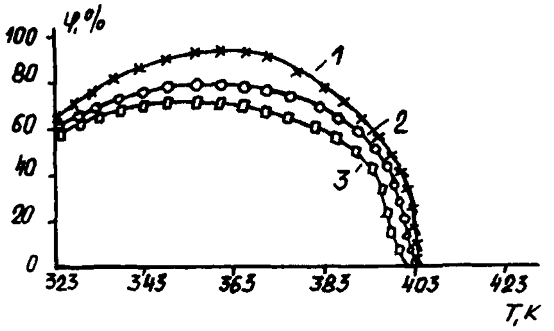

FIGURE 3 Variation of degree of crystallinity with temperature. 1 = PE, 2 = PE + 5% MAE, 3 = PE + 10% MAE.

The addition of 1–5% PDA causes an increase in the degree of crystallinity at 323 K. The temperature of the end of fusion (*Tf*) increases from 403 K up to 413 K. When PDA concentration rises up to 10%, the degree of crystallinity at 323 K at the range of temperatures 323–383 K does not change much, but the temperature of the end fusion diminishes (Figure 1). The degree of crystallinity of pure PE increases in the interval 323 ÷ 360 K, suggesting recrystallization processes. Introduction of PDA causes the increase of crystallinity and the temperature of the end of fusion in comparison with pure PE, but 10% PDA induces diminution of *Tf* and DC. The addition 5 ÷ 10% DCG and MAE to PE results in essential reduction of the degree of crystallinity, but *Tf* does not change (Figures 2 and 3). Mixtures of PE with PDA exhibit high positive values of interaction parameters indicative of incompatibility of the systems. Other oligoesters are miscible with PE at any relationships at temperatures higher than 300 K. At lower temperatures, these systems are miscible on a limited scale.

4. DISCUSSION

The IGC method was applied to the mixtures of high density polyethylene with different oligoesters. Modifiers influence on polymer properties in viscous flow state, on process of structural formation, on performance properties, nucleation rate and crystallization kinetics was studied. PE with 1 ÷ 5% PDA displays an enhanced degree of crystallinity and temperature at the end of fusion, more regular structure, no recrystallization during heating. Further growth of PDAs concentration induces lowering of DC and *Tf*, PE-PDA strength and elongation dependences as a function of PDA concentration display a curve with maximum at 1 ÷ 3% PDA. Unmiscible additives locate in polymer amorphous defect zones and induce expansion of polymer free volume. Relaxation processes accelerate, polymer structure turns to be more regular and mechanical properties grow.[3] Mechanical properties of compatible alloys of PE with DCG and MAE change monotonously when concentration of modifiers increases: the tensile strength diminishes and the elongation rises. The degree of crystallinity for PE blends with compatible modifiers in the range of temperatures under study is lower than that of pure polyethylene. There is no unanimous opinion about modifiers' influence on crystallization kinetics of polymers. Introduction of significant amounts of additives to polymers results in insulation of growing spherulities. Therefore the modifiers may concentrate on the spherulites boundaries. The viscosity of all blends diminishes with the increasing content of additives. No direct connection between interaction parameter and viscosity values of blends was found.

5. CONCLUSION

1. The influence of different oligoesters on the structure and properties of high density polyethylene was studied with the help of inverse gas chromatography.

2. Measurements of the mechanical properties showed that alloying of high density polyethylene with different oligoesters may produce higher strength and elongation than pure PE.

3. The results obtained showed that compatibility of PE and additives may influence the overall characteristics of compositions.

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