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Effect of electron beam radiation on the polypropylene/polyethylene blends: Radiation stabilization of polypropylene

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Abstract

The effect of incorporation of polyethylene in the polypropylene matrix, on the radiation sensitivity of polypropylene, has been investigated. The changes in the properties such as tensile strength, elongation at break, Shore *D* hardness, density and melt flow index were monitored as function of polyethylene content and electron beam radiation dose. A correlation between the mechanical properties and morphology of the irradiated polymeric blends has been observed, which has been explained on the basis of Fourier-transform infrared spectroscopy, scanning electron microscope and X-ray diffraction studies. Improvement in the mechanical properties of the polypropylene, irradiated to an optimum electron beam dose, could be achieved by blending it with polyethylene >20%. The optimum radiation dose was found to be dependent on blend composition and morphology, however, an absorbed dose of 250 kGy found to be effective enough to ensure good mechanical properties of the polypropylene/polyethylene blends.

Keywords: Polyolefins; Free volume; Electron beam irradiation; Mechanical properties; Polymer blends

1. Introduction

Polyolefins are widely used as structural materials because of their relatively low cost and general availability [1]. Radiation processing of polyolefins is an economically viable and versatile way to produce materials with enhanced chemical, mechanical, physical properties [2–5]. However, the radiation processing of polypropylene (PP) is of limited use as it undergoes predominantly chain scission when subjected to high-energy radiation. In addition to poor radiation resistance of PP, its poor impact resistance at low temperature further restricts its utilization in industrial domain [6].

The toughness and radiation resistance of PP is expected to increase via the addition of PE, as it undergoes predominantly cross-linking on high-energy irradiation [7,8]. However, it is known that PP and polyethylene (PE) are immiscible and incompatible; consequently the mechanical properties of PP–PE blends are inferior to those of pure component. Several studies have been reported to enhance the compatibilization between PP and PE by the addition of interfacial agents or compatibilizers [9].

The present study presents the investigation done on effect of electron beam irradiation on PP–PE blends. The objective was to find suitable blend composition and radiation dose for significant improvement in the mechanical properties of the blends and improve upon radiation resistance of PP.

2. Experimental

2.1. Preparation of PP–PE blends

Different proportions of LDPE (density 0.915 g/cm^3 and melt flow index 1.5 g/10 min) and PP (density 0.904 g/cm^3

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Table 1
Composition and designation of blends

Sample designation	Polypropylene (%)	Polyethylene (%)
PE 00	100	00
PE 20	80	20
PE 40	60	40
PE 60	40	60
PE 80	20	80
PE 100	00	100

and melt flow index 1.01 g/10 min) were mixed in melt condition by using a thermoplastic 2-roll mixing mill (12×6 in.). These blends were compression molded into sheets of dimension $12 \times 12 \times 0.2$ cm using a compression-molding machine under 150 kg/m^2 pressure at 160 °C. Composition and designation of blends employed in present study is given in Table 1.

2.2. EB irradiation

Irradiation was carried out using linear electron beam accelerator (ILU-6) from Budker Institute of Nuclear Physics, Russia under conditions energy ~1.8 MeV, current ~10 mA and conveyor speed 13 mm s^{-1}. Under these parameters the electron beam delivered a dose of 10 kGy/pass. Samples were irradiated in the dose range 50–500 kGy.

2.3. Measurement of mechanical properties

Tensile strength and percentage elongation at break were carried out for on dumbbell shaped specimens using universal testing machine with a crosshead speed of 200 mm/min (ASTM D2240). The notch impact strength (J/mm) was carried out on notch impact tester (ASTM D256). Shore *D* scale was used to determine the hardness of the blends (ASTM D2240). Melt flow index was determined according to the ASTM D 1238-79 standard at 190 °C with a load of 2.16 kg. The density in g/cm^3 was determined by using density gradient columns (ISO 1183:1987).

2.4. Morphological studies

Cryogenically fractured surfaces were examined by a scanning electron microscope (SEM). Acceleration voltages of 30 kV and magnification range from 200× to 10000× were used. The fractured surfaces were coated with a thin layer of gold prior to SEM examination.

2.5. FTIR studies

Fourier-transform infrared spectroscopy (FTIR, JASCO 660) was used for ascertaining compositional characteristics of the blends. Spectra was obtained at 4 cm^{-1} resolution and averages of at least 16 scan in the standard wave number range 400–4000 cm^{-1}.

3. Results and discussion

3.1. FTIR analysis

Compositional characterization of polymer blends was done by following their characteristic bands in the FTIR spectra as shown in Fig. 1. Since, the study of weak interactions in such a non-polar matrices cannot be made without a high level of accuracy, FTIR technique was used in this study to investigate the specific interaction between blend components. Our interest was only to ascertain the compositional characteristic of blends. Changes in the absorbance for different blend compositions at 720 cm^{-1} were monitored with change in the PE fraction. The results from peak height ratio, showed a close agreement between calculated and expected value of PE weight fraction.

3.2. Scanning electron microscopy

The scanning electron micrographs of fractured surfaces have been shown in Fig. 2. For all the compositions phase separation could be clearly figured. At higher PP fractions (PE < 20%), the PE matrix was found to be embedded (disperse phase) in the continuous PP phase, whereas, at lower PP weight fractions co-continuous morphology of PP and PE were observed. SEM of the blends also indicated the lower rigidity of PE 20% blend.

3.3. Density

One of the most obvious effects brought about by blending was the change in density of the blends, since the density of the blends can be accurately predicted by additive rule [10]. Fig. 3 represents the variation in densities of PP–PE blends irradiated to different electron beam

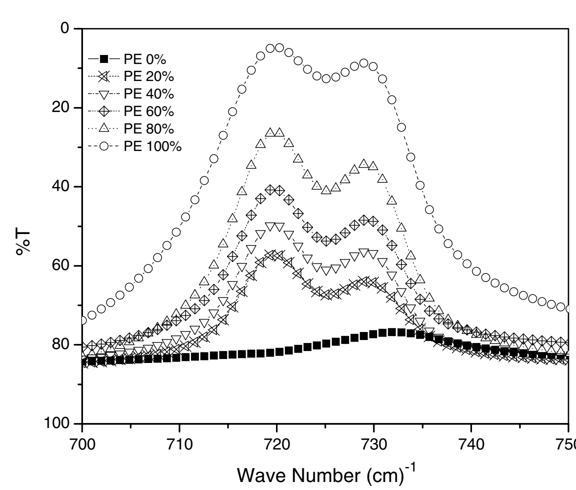

Fig. 1. FTIR spectrum of PP–PE blends.