

EVALUATION OF THE COMPATIBILITY INDUCED BY IONIZING RADIATION ON POLYMERIC BLENDS

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ABSTRACT

To produce new polymers is a costly and time consuming task. Therefore, the utilization of existing polymers in form of blends enables to obtain new polymeric materials at a competitive cost. In this sense, polymer blending has become a growing scientific and commercial development activity. In most of the cases, polymeric blends have immiscible components and this represents an unbecoming situation on blend design. For such immiscible blends, it is required the use of compatibilizers to gain properties advantage. Compatibilization process can be achieved by chemical handling using additives and heat. On the other hand, ionizing radiation induces compatibilization by free radicals, which improve the dispersion and adhesion of the blend phases, without use of chemical additives and at room temperature. In this work, a polyamide 6.6/low-density polyethylene 75/25% wt/wt composition blend was electron beam irradiated up to 250 kGy, and thereafter mechanical tests were carried out. Tensile measurements have shown that the strength at break increases, the elongation at break decreases, the resistance to impact decreases and hardness increases when the radiation dose increases. Since this mechanical behavior is due to cross-linking and to the radiation induced blend compatibilization, this compatibility was evaluated by the approach of the glass transition temperatures for both components using DMA measurements. The results have shown that the glass transition temperatures of the blend components got closer in 8°C in the irradiated sample, when compared to the glass transition temperature values obtained for non-irradiated blend.

1. INTRODUCTION

Polymeric blends are design materials made from the mixing of two polymers to obtain a material with adequate mechanical, chemical and physical properties at a low cost/beneficial ratio [1]. In most of the cases, polymeric blends have immiscible components due to its different chemical structures, and this represents an unbecoming situation on blend design. The improvement of miscibility between the polymer components and the enhancement of blend performance is denominated of compatibilization of the blend. This compatibilization

can be achieved by chemical handling using additives and heat or other process, such as, ionizing radiation, which will improve the dispersion and adhesion of the blend phases by free radicals [2, 3] without use of chemical additives and at room temperature.

The interfacial adhesion of the blend components is an important condition for mechanical and other blend properties, which will determine its end use.

Blends based on expensive engineering thermoplastic, such as polyamides, and low cost polyolefins are very important polymeric systems making it possible to obtain materials with a wide range of physical and mechanical properties at low cost and also allowing the recycling of wasted raw materials. Polyolefins improve the mechanical properties of the polyamide, and the polyamide increases the resistance to oxygen permeability, resulting in an adequate material for packaging industry. Unfortunately, polyamides and polyolefins form highly incompatible blends due to its extremely different chemical structures, thus many efforts have been devoted to compatibilize these blends [4].

The ionizing radiation induces, in polymeric material, extremely reactive species like free radical and ions, which modify their molecular structures, inducing cross-linking, scission and modification of crystalline structure. The main effects, of the interaction of ionizing radiation with polymers are cross-linking, that is the formation of chemical links between molecular chains, and degradation or scission of polymer chains, which destroys its molecular structure. Although, these effects occur simultaneously, one plays a dominating role depending mainly on the chemical structure of the polymer and the radiation dose applied.

An important property that characterizes polymeric material is the glass transition temperature (T_g), which is the temperature where the polymer goes from a hard, glass like state to a rubber like state. T_g is routinely being measured by Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analysis (DMA). In miscible blends, the components form a unique phase and by this reason have only one T_g , on the other hand, in immiscible blends the components form independent phases and consequently present two glass transition temperatures, which by a compatibilization process will become closer and, at a complete compatibilization, the blend will present only one T_g .

In this work, the evaluation of the compatibility induced by electron beam radiation on PA 6.6/LDPE blend, and the evaluation of their mechanical performance were carried out.

2. EXPERIMENTAL

In this work, the materials used were polyamide 6.6 (Rhodia) and low density polyethylene (Dowlex 2500). Blends have the following composition PA6.6/ LLDPE 75/25% wt/wt..

The dumbbell-shaped and parallelepiped samples for tensile, hardness and impact tests were injection-molded. These specimens were electron irradiated at the CTR-IPEN irradiation facilities using a 1.5 MeV and 37.5 kW Dynamitron Electron Accelerator model JOB-188 up to doses of 50, 100, 150, 200 and 250 kGy. After irradiation, these samples were kept at standard conditions of 23°C and 50% humidity for 40 hours before being mechanically tested.

The tensile strength properties were measured according to the ASTM D-638 standard, using an Instron Universal Testing Machine (Model 5655). All measurements were carried out at room temperature, crosshead speed of 50 mm min⁻¹, and with a load cell of 10 kN.

The behavior of the glass transition temperatures to evaluate the compatibility of this immiscible blend was carried out using a DMA 2980 Dynamic Mechanical Analyzer of the TA Instruments at a temperature range from -100 to 100 °C, frequency of 1 Hz and at a heating rate of 2 °C min⁻¹.

3. RESULTS AND DISCUSSION

The experimental data of mechanical properties of the blend as a function of radiation doses are given in Table 1.

Table 1. Stress at break, Hardness Shore D and Impact Izod of PA 6.6 / LDPE Blend.

Dose (kGy)	Stress at Break (MPa)	Hardness (Shore D)	Impact (kJ.m ⁻²)
0	11.30	63.3	4.85
50	13.03	66.80	4.65
100	14.05	67.3	4.51
150	16.04	68.50	4.31
200	16.50	68.20	4.20
250	16.60	69.30	4.21

In the irradiation doses range from 0 to 250 kGy the improvement of the tensile strength at break increases about 47% , the Shore D hardness increases by 9.5%, and the Impact Izod decreases about 13.2 %. This mechanical behaviour of the bulk and surface properties implies that ionizing radiation produce changes in the mechanical performance of the irradiated blend due to a combined radiation inducing effects, cross-linking and the compatibilization of blend components.

In order to evaluate the contribution of the induced compatibilization by radiation, the experimental results of the T_g were analyzed. In Table 2, the values of glass transition

temperatures of blend components are given.

Tabela 2. T_g for PA 6.6 and PEBD in the PA 6.6/PEBD 75%/25% blend as function of radiation dose.

Dose (kGy)	T_g PA 6.6 (°C)	T_g PEBD (°C)	T_g (PA 6.6) - T_g (PEBD) (°C)
0	70	-17	87
50	61	-18	79
100	63	-19	82
150	60	-18	78
200	62	-17	79
250	62	-17	79

DMA measurements have shown that the difference between the values of glass transition temperatures of the PA 6.6 and LDPE is reduced with the increase of the irradiation dose, and between 0 and 250 kGy it reaches 8° C, this fact shows that a compatibilization effect, induced by ionizing radiation, took place. Even though, these experimental results represent an effect of only about 10% in the process of compatibilization, in polymeric materials, few structural modifications have a sensible contribution to the mechanical performance of the irradiated blend. For further pursuit to increase the compatibilization process by radiation, there is a limitation given by the stability of the polymeric components of the blend to the irradiation dose before starting to degrade.

4. CONCLUSIONS

The mechanical performance behavior of the irradiated blend confirms that the electron beam radiation enhances the mechanical properties of the immiscible polyamide and polyethylene blend by cross-linking and radiation induced compatibilization. This compatibility was evaluated by the approach of the glass transition temperature of the components using DMA measurements. The results have shown that the glass transition temperatures of the blend components got closer in 8°C when the blend was electron beam irradiated up to 250 kGy, in comparison to the T_g values obtained for the non-irradiated blend.

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