Mechanical Properties of Electron Beam Irradiated Polyamide 6,6

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Abstract. The tensile, impact, hardness and wear properties of electron irradiated Polyamide 6,6 were evaluated under electron beam irradiation. Samples of polyamide 6,6 without additives, for the mechanical tests were injection-molded. These samples were irradiated at different doses at a dose rate of 22.42 kGy/s and the doses were 70, 100, 150, and 200 kGy. Tensile strength, impact, hardness and wear measurements were performed according to the standards ASTM D 680, ASTM D 256, ASTM D-2240 and ASTM D 1242, respectively. Experimental results have shown that yield stress hardness and resistance to abrasion values increase with increase of radiation dose. This can be attributed to the increase of the bulk and surface strength due to the increase of cross-linking density in the irradiated material. Furthermore, the impact behavior can be explained by the increase of fragility and brittleness produced by the increase of cross-linking density. This leaves the material weak and brittle to withstand efficiently impact loads.

1. Introduction

Radiation Processing has been applied to improve product quality, energy saving and to manufacture products with special properties as a result of inducing reactions in solid state at room temperature [1]. This radiation processing brings, many advantages comparing to the conventional chemical processing [2,3]. Polyamide 6,6 due to its excellent mechanical, thermal and electrical properties and its great performance for multiple industrial applications is considered one of the most important engineering polymer [4]. However, in specific applications, some of its properties need to be improved by means of additives or fillers to reach the required properties, what also increases its final cost. By these considerations, the aim of this work was to apply the ionizing radiation to improve the natural mechanical properties of polyamide 6,6. Also, to evaluate the irradiation parameters, and the mechanical performance of the irradiated polymer in order to use the cross-linking, induced by ionizing radiation, as a substitute of additives and fillers.

2. Experimental

The polymer used in this work were Polyamide 6,6 without additives. Samples for the mechanical tests were injection-molded using a Battenfeld injector. These samples were irradiated with electrons at the CTR- IPEN irradiation facilities, using a Dynamitron JOB 188 electron accelerator with 1.5 MeV and 37.5 kW, and the doses were 70, 100, 150, and 200 kGy. These irradiated samples were conditioned at 23°C and 50% humidity for 40 hours before being mechanically tested. Tensile strength measurements were made with an EMIC Universal Testing Machine, model MEM-10000. Izod Impact measurements were carried out with notched samples. Hardness Shore D was measured with a Zwick equipment using a load of 1kgf for 10 seconds. Wear measurements were made with an abrasion tip, using a load of 250 g for 3 h. All measurements were carried out in air and at room temperature,

3. Results and Discussion

The experimental results of tensile, impact, hardness and wear measurements, as a function of dose, are given in Table 1, and their behavior are reported graphically in Fig. 1, 2 and 3, respectively.

In fig. 1, the yield stress, of the tensile measurements, increases continuously up to about 24% of the value of non-irradiated samples in the dose range applied. In this same dose range, the impact values decreases relatively fast from 15 to about 8 kJ/m^2 in a doses range from 0 to about 100 kGy and then the decay is slow up to 3.5 kJ/m^2 at 200 kGy; The total decrease is about 77%.

TABLE I: YIELD STRESS, IMPACT, HARDNESS AND WEAR BEHAVIOR OF ELECTRON BEAM IRRADIATED POLYAMIDE 6,6.

Dose [kGy]	**Yield Stress [MPa]**	**Impact [kJ/m^2]**	**Hardness [Shore D]**	**Abrasion loss [%]**
0	55	15	80	1.20
70	58	12	82	1.00
100	60	8	90	0.50
150	65	5	90	0.30
200	68	3.5	90	0.06

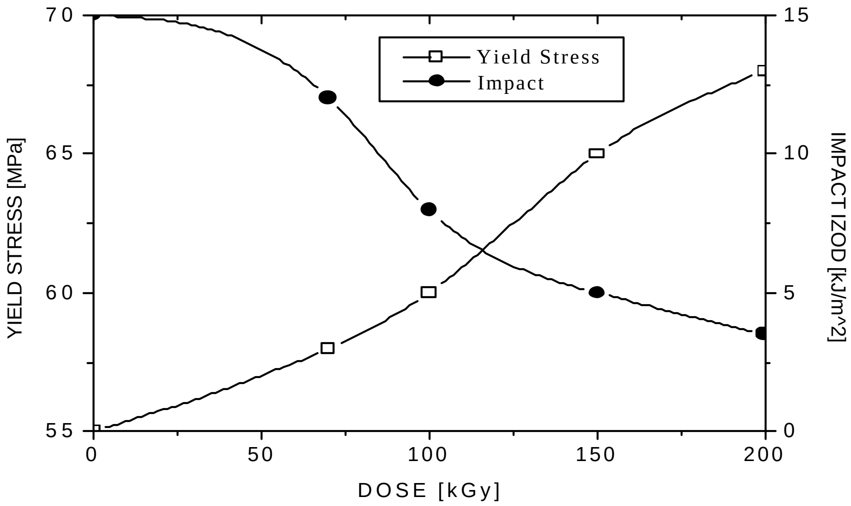

FIG. 1. Yield Stress and Impact behavior of Polyamide 6,6 as function of radiation dose.

The increase of yield stress follows the increase of cross-linking density what contributed for the tenacity of the PA 6,6. On the other hand, the increase of cross-linking above 100 kGy leaves the material brittle and fragile so that it can not withstand efficiently impact loads.

Fig. 2 shows that the shore D hardness values increase only 13% as compared with the values of the non-irradiated samples, in this dose range studied. Beside that, above 100 kGy these values remain stable at about 90. The crosslinking density data reach its maximum value about 120kGy [2] and it is at this dose that the hardness also reaches its maximum value, remaining constant up to 200 kGy.

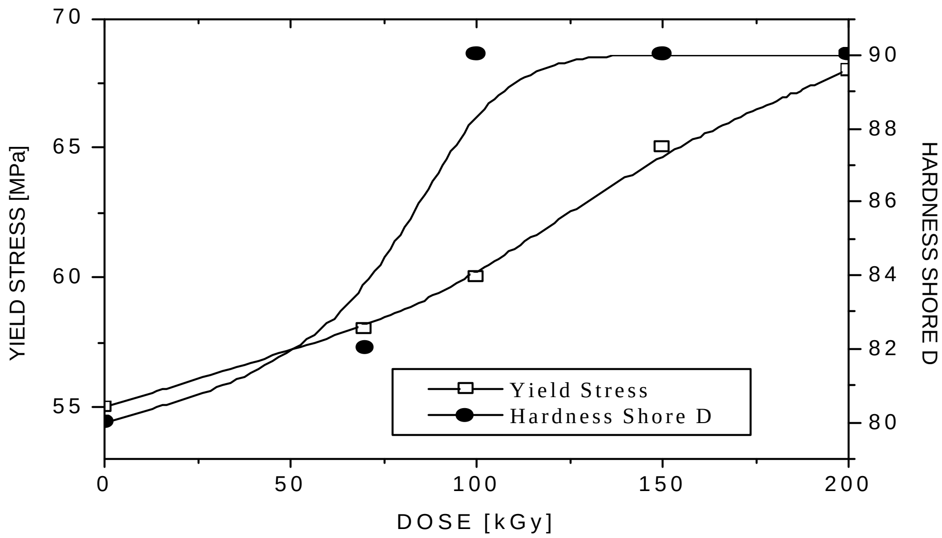

FIG. 2. Yield Stress and Hardness behavior of Polyamide 6,6 as function of radiation dose.

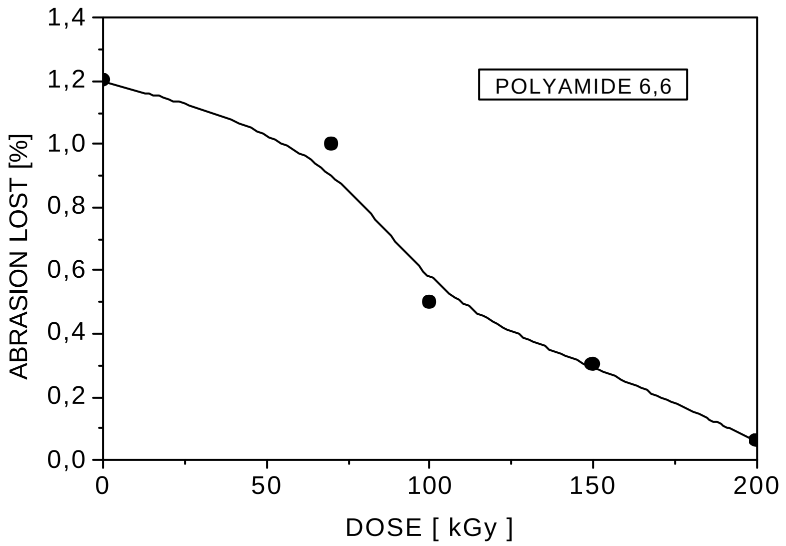

FIG. 3. Wear behavior of Polyamide 6,6 as function of radiation dose.

In Fig.3 the behavior of the wear measurements data is presented. It was observed that the abrasion loss decrease 20 times between 0 and 200 kGy. This result was the most important effect produced by the electron beam irradiation on the surface properties of Polyamide 6,6.

4. Conclusions

The experimental results of this work have shown that, the ionizing radiation in the dose range from 0 to 200 kGy, improves tensile strength, hardness and resistance to abrasion of Polyamide 6,6. On the other hand, the radiation induced cross-linking has a negative effect on the impact properties of this polymer. Therefore, it can be stated that, the cross-linking induced by radiation can replace efficiently the use of additives or fillers to improve some mechanical properties of Polyamide 6,6.

5. References

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