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Study of ionizing radiation on the properties of polyamide 6 with fiberglass reinforcement

Clovis Pinto[a,b], Leonardo G. Andrade e Silva[a,*]

[a]*Instituto de Pesquisas Energéticas e Nucleares—IPEN/CNEN-SP, Centro de Tecnologia das Radiações—CTR, Av. Prof. Lineu Prestes 2242, Cidade Universitária, 05508-000 SãoPaulo, SP, Brazil*
[b]*Universidade Nove de Julho—UNINOVE, São Paulo, SP, Brazil*

Abstract

The use of polymers reinforced with fiberglass is becoming more and more common in the switches for household industries. These compounds perform a good tension resistance to the impact and the humidity absorption being used at the present time and also are in the automobile industry in parts underneath the hood, especially in the radiator frames. The aim of this work is to study the effect of ionizing radiation on the properties of polyamide 6 with fiberglass reinforcement and undergone to different irradiation doses. Samples were prepared and irradiated on JOB 188 accelerator with an electron beam energy of 1.5 MeV in air with different doses and a dose rate of 27.99 kGy/h. Afterward, the properties of the non-irradiated and irradiated polyamide 6 with fiberglass reinforcement were evaluated.

Keywords: Polyamide; Ionizing radiation; Fiberglass reinforcement

1. Introduction

Plastic is one of the most utilized raw materials in our daily life and is a material of utmost importance.

The use of polymeric materials is not new and they have been used since the ancient times. Some of these polymers are used as plastics in engineering. Currently, amongst the engineering materials, several polymers are used. The polyamide is distinguished as the most important of all (Mano, 1991).

Polyamides are characterized by their possessing of high-tensile strength, elasticity, tenacity and resistance to abrasion. These mechanical properties are maintained even under high temperatures and therefore, the polyamides can be used in temperatures up to 200 °C in applications of short-term.

High-energy radiation is a well-known technique for modification of polymers. Polymers become electronically excited or ionized after absorption of energy. The excited molecules are able to enter into chemical reactions leading to chemically reactive products that initiate the cross-linking reaction. The electron beam technology improves productivity, speeds up production, lowers cost and makes news and often better products. At the same time, it uses less energy, drastically reduces polluting emission and eliminates flammable and polluting solvents. This technology is widely used. The cross-linking among the polymer molecules improves their thermal, electrical and mechanical properties thereby enabling its application in different fields where the improvements of these properties are required. A heterogeneous cross-linking formation in the hydrocarbon polymers by gamma and electron beam irradiation has been extensively investigated (Singh and Silverman, 1992; Woods and Pikaev, 1994; Drobny, 2003).

During the last few decades, the industrial employment of the ionizing radiation has been growing for cross-linking thermoplastic, with excellent results in several sectors (Domb and Slager, 2001). The aim of this paper is to study the effect of ionizing radiation with different doses, on mechanical properties and in a incandescent wire of polyamide 6 (PA 6) with 30% of fiberglass reinforcement and compare these results with those of non-irradiated samples. The study is carried out due to the ever-growing

*Corresponding author. Fax: +55 11 3816 9186.
E-mail address: lgasilva@ipen.br (L.G. Andrade e Silva).

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employment of this type of polymer, strengthened with fiberglass, in the switches for household and electrical components industries. No previous study exists in the literature about the resistance to the incandescent wire of the PA 6 with 30% of fiberglass reinforcement and undergone to the radiation.

2. Experimental

Samples of PA 6 with 30% of fiberglass reinforcement with density of 1.36 g/cm^3 exempt of UV additive of protection, antirust substances or thermostabilizers, supplied by Radici Plastics Ltd. were used for the accomplishment of the work.

The assays were carried through the following two steps:

First, the characterization of non-radiated composites (PA 6 with 30% of fiberglass reinforcement) was made, determining both mechanical properties and properties in incandescent wire.

Second, the samples of PA 6 with 30% of fiberglass reinforcement were irradiated with doses of 100, 200, 300, 400, 500 and 600 kGy in a dose rate of 27.99 kGy/s in the electron accelerator Dynamitron JOB 188 of energy of 1.5 MeV and current of 25 mA, at the Center of Technology of Radiation in IPEN—CNEN/SP. Afterward, the mechanical properties and incandescent wire of irradiated polymer were studied.

The properties studied were

- *Tensile strength in accordance with standard test method* (ASTM, 2003). This test was conducted in an Instron universal testing machine, model 5567, at 50 mm/min speed of testing.
- *Resistance to the Impact Izod with notch in accordance with standard test method* (ASTM, 2006a). This test was conduced in an Emic machine in the standard laboratory atmosphere of $23\pm2\,^{\circ}C$ and $50\pm5\%$ relative humidity.
- *Incandescent wire in accordance with standard* CEE 14 and UL-20 (1980). This standard describes the test of resistance of insulating materials to abnormal heat, to fire and to tracking for switches for household for nominal voltages up to 250 VCA and nominal currents up to 30 A.

This test should:

- be sure that the wire heated electrically within the defined conditions for the test provokes the burning in the insulating parts; and
- be sure that one part of the insulating material which can burn during the test is within the defined conditions and has a limited time of burning, without spreading the fire by flame or by incandescent parts.

A sample is considered being according to the test of incandescent wire, if:

- it does not show any visible flame or some prolonged incandescence; and
- the flames and the incandescence over a sample extinguish within 30 s right after the removal of the incandescent wire.

In the incandescent wire test, the resistance to the abnormal heat was determined. This assay simulated the resistance of the plastic material in an electrical short-circuit situation at different temperatures of 750, 850 and 960 °C with body-of-test of 3.00 mm of thickness. This is a qualitative test very common in switches for household and electrical components industries.

3. Results and discussion

Comparing the results obtained during the mechanical assays (Table 1) of the samples irradiated with the ones that were non-irradiated, it was observed that up to 200 kGy the tensile strength stayed constant, but for doses above 300 up to 600 kGy the tensile strength increased, indicating the cross-linking of PA 6 with 30% of fiberglass reinforcement. It was also observed that the resistance to the impact decreases with the increase of the dose up to 500 kGy; the material became harder and fragile and the tenacity, an important characteristic of the polyamides, dwindled. Thus, to some extent, the irradiation of PA 6 with 30% of fiberglass reinforcement above 300 kGy increased the property of tensile strength, indicating the predominance of the cross-linking, and such performance corroborates Thorp's (1970) statement that polyamides, without cross-linking agent, are cross-linked only if undergone to high doses of irradiation.

With an aim of the employment of PA 6 with 30% of fiberglass reinforcement in the switches for household and electrical components industries, the study was carried through the assay of incandescent wire, according to the standard CEE 14 and UL-20 with temperatures of 750, 850 and 960 °C, with samples of 3.00 mm thickness; the results are shown in Table 2.

In accordance with Table 2, it was observed that the results of incandescent wire assay of the samples of PA 6 with 30% of fiberglass reinforcement were surprising. In samples irradiated in doses up to 600 kGy for temperature

Table 1
Results of the assays of tensile strength and resistance to the Impact Izod with notch of PA 6 with 30% of fiberglass reinforcement non-irradiated and irradiated with different doses

Radiation dose (kGy)	Tensile strength (MPa)	Resistance to the impact (J/m)
0	154.27	100.00
100	154.75	74.95
200	154.52	65.70
300	157.10	62.25
400	159.06	62.94
500	159.59	60.05
600	159.49	63.45

Table 2
Results of the incandescent wire assays, with temperatures of 750, 850 and 960 °C, of PA 6 without and with 30% of fiberglass (FG) reinforcement non-irradiated and irradiated with different doses

Irradiated dose (kGy)	PA 6			PA 6, 30% FG		
	750 °C	850 °C	960 °C	750 °C	850 °C	960 °C
0	R	NR	NR	R	NR	NR
100	R	NR	NR	R	NR	NR
200	R	NR	NR	R	R	R
300	R	NR	NR	R	R	R
400	R	NR	NR	R	R	R
500	NR	NR	NR	R	R	R
600	NR	NR	NR	R	R	R

NR, does not resist; R, resist.

of 750 °C, a great resistance to ignition of combustion was observed. A resistance to ignition of combustion when the samples were irradiated with dose of 200 up to 600 kGy for the temperatures of 850 and 960 °C was also observed. When the samples of PA 6 were non-irradiated and irradiated at different doses, they do not resist at the incandescent wire in the temperatures of 850 and 960 °C. For the temperature of 750 °C, they resist up to 400 kGy.

4. Conclusions

It was verified, in general, that the irradiation of PA 6 with 30% of fiberglass reinforcement improved the tensile strength, indicating a possible cross-linking of the polymer with dose above 200 kGy.

Electron beam processing of PA 6 with 30% of fiberglass reinforcement is very promising for industrial applications when one wants to use this composite as switches for household or as an electrical component in accordance with the incandescent wire results.

Acknowledegments

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