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Polyethylene foams cross-linked by electron beam

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Abstract

Cross-linking of low-density polyethylene by electron beam irradiation was studied in this work with the aim of foam production by thermal expansion. Mechanical and thermal properties of the obtained foams were studied and it was found that relatively low doses up to 40 kGy could be used leading to a product with excellent surface appearance.

Keywords: Polyethylene foams; Cross-linking; Electron beam

1. Introduction

The plastic foams generally consist of a minimum of two phases, a solid polymeric matrix and a gaseous phase, derived from a blowing agent. In some cases, it can have more than one solid phase present, as in the case of a blend (Klempner and Frisch, 1991). A hot thermoplastic polymer casting, containing a volatile solvent dissolved under pressure, may expand when the pressure is reduced. In the electron beam process, cross-linking is induced by the interaction of high-energy electrons with the polymeric material (Charlesby, 1952; Rado, 1993; Chodak, 1995). The study of cross-linked polyethylene foam by electron beam is necessary due to its great consumption and for being a simple process with high productivity.

2. Experimental

The denomination and density of industrial materials under this study are summarized in Table 1. The samples were supplied by Trocellen Company.

All samples were produced using 2–4 wt.% azodicarbonamide as blowing agent and plasticizing agent.

The density of the samples was determined according to ASTM D1622-98.

Polyethylene sheets (dimensions: $200 \times 200 \times 1.91$ mm) were irradiated in the electron accelerator, model JOB 188 of energy of 0.5–1.5 MeV and current of 0.1–25 mA at different irradiation doses (20, 30, 40, 60 and 80 kGy). After irradiation, samples with dimensions $50 \times 50 \times 1.91$ mm were placed into an oven, at 200–229 °C under hot air circulation, for 240–360 s to obtain uniform foams.

The gel content of each foam was determined by the method of soxhlet extraction with xylene. After the extraction at 132 °C for 24 h, the sample with mass of approximately 0.3 g was washed and dried in an oven at 80 °C. The gel fraction was calculated when the sample reached constant mass.

Cross-linking yield of foams were determined according to ASTM D2765-95.

An Instron tensile strength measuring machine (Model 5567) was used to determine the tensile strength of the foam samples. It was operated at a speed of 50 mm/min according to ASTM D638-03.

Thermal analyses were carried out using a Shimadzu TGA-50, under a flow rate of 50 ml/min of synthetic air and heating rate of 20 °C/min. The sample mass was around 5 mg.

3. Results and discussion

3.1. Sol–gel analysis

Fig. 1 shows that gel content of each polyethylene (PE) sample increased, as a function of the irradiation dose. In

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Table 1
Denomination and density of the materials

Samples	Denomination	Density (g/cm^3)
LDPE unfoamed	TR 9004 W3	0.930
LDPE foamed	TR 9004 W3	0.070–0.090

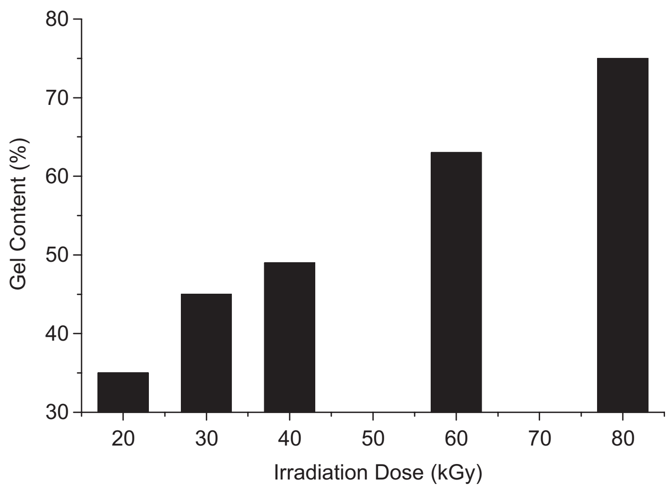

Fig. 1. Gel content of irradiated PE foam.

irradiation with electron beams the cross-linking occurs predominantly in the amorphous regions. The mechanism of cross-linking in PE under interaction of high-energy electrons is well known (Charlesby, 1952; Kircher, 1987; Lazar et al., 1990).

However, at doses higher than 60 kGy, the enhanced cross-linking does not contribute to the growth and stabilization of the bubbles during the process of formation of the foam.

3.2. Tensile properties

In Table 2, the tensile strength and elongation at break are presented for the PE foam as a function of the irradiation dose. As it has been widely observed for radiation-cross-linked polyethylene (Adem et al., 1995; Cardoso et al., 1998), the foams also show increase of tensile strength and decrease of elongation at break, with increasing dose.

3.3. Thermal analysis

The TGA results in Table 3 show that at doses higher than 60 kGy, the polyethylene decomposition temperature decreases, indicating a possible degradation of the polymer. In this case, it was obtained non-uniform foams.

Table 2
Elongation at break and tensile strength of the foamed PE as function of irradiation dose

Irradiation dose (kGy)	Elongation at break (%)	Tensile strength (MPa)
20	330	0.18
30	310	0.30
40	290	0.33
60	240	0.40

Table 3
Decomposition temperature as a function of irradiation dose

Irradiation dose (kGy)	Decomposition temperature (°C)
0	455
20	455
40	458
60	454
80	451

4. Conclusions

The polyethylene foams obtained by electron-beam irradiation process presented smooth and homogeneous surfaces, formed mainly by closed cells.

The experimental results have shown that in the interval of irradiation dose studied, the tensile strength increases with the cross-linking degree.

The foams obtained with doses of 20 and 60 kGy have presented non-uniform surface. The dose of 80 kGy did not form foam indicating the occurrence of the thermal collapse.

The foams with closed cellular and more homogeneous structure were obtained with irradiation dose of 40 kGy.

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