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Introduction to Foamability Study of a LDPE Subjected to Gamma Radiation

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Abstract: Nowadays, polymer foams have a wide application area due to their light weight, emphasizing resistance to impact, high thermal insulation and damping properties, among others. So, automotive, packing industry, electronic, aerospace, building construction, bedding and even medical applications are some of the fields where polymer foams are applied. Foams can be classified as open and closed: Closed-cell foam is provided with tiny and discrete pockets of gas, each one totally enclosed within polymer walls; open cell foam has tiny cells which are not completely closed. In this work, LDPE (low density polyethylene) resin foamability was investigated after exposure to ionizing radiation (gamma), at 5, 10 and 15 kGy. Characterizations included: melt flow index, melt strength and scanning electron microscopy.

Key words: LDPE, foams, melt strength, gamma-radiation.

1. Introduction

Ionizing radiation is commonly used for modifying polymers and optimization of their properties is widely used in literature [1-3]. Ionizing radiation, via e-beam or gamma rays, is comprehensively used in LDPE (low density polyethylene) chain branching: irradiation increases molar mass and, consequently, melt resistance [4]. Chain branching occurs when the polymer is radiated with a minimal dose, resulting in formation of side chains, improving its melt processability. LCB (long chain branching) makes the resin more sensible to shear: so, for an adequate processing, it should avoid the operation with materials with very low melt index, to avoid an undesirable high pressure in the extruder [5, 6]. It is known that LDPE melt strength raises function of melt index [7, 8], but a balance is required between these two parameters, on behalf of a safe and effective polymer processing. Rheology poses a fundamental relevance in polymer processing and establishes more favorable conditions in transformation processes. The behavior of thermoplastics flow, during the processing, depends on molar mass, distribution and branching [9, 10]. When LDPE is subjected to high temperatures, there is a decrease in thermal resistance and mechanical properties, especially in foaming. The use of low irradiation doses (up to 30 kGy) will improve the processability, on behalf of a more resistant and thermically more stable matrix [11]. Melt strength of LDPE irradiated [12] is optimized in function of irradiation: besides, a raise in LCB observed in irradiated polymers enhances strain hardening [13, 14] and it is responsible by an effective polymer foaming with build-up of cells exhibiting more resistant walls. LDPE foaming via PBA (physical blowing agent) presents a weak balance between melt strength of melt polymer in expansion and cells internal pressure, occurring in a melting temperature close to polymer crystallization temperature. Foams are created via dissolution of a gas in LDPE melt, expanding into small bubbles or cells, ending with the cooling of expanded polymeric mass [15, 16].

This work aims to investigate resin foamability of a LDPE exposed to ionizing radiation (gamma), at low

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levels: 5, 10 and 15 kGy.

2. Experimental

2.1 Samples

LDPE, EB 853, from Quattor.

LDPE gamma radiated, ^{60}Co source, 5, 10 and 15 kGy, at 5 kGy/h, Multipurpose reactor, in CETER/IPEN.

2.2 Melt Flow Index

Melt flow index analyses were accomplished in a Ceast apparatus, modular line, at 190 °C, 2.16 kg load, 240 s pre-heating, in accordance with ASTM (American Society for Testing and Materials) D1238-04C.

2.3 Melt Strength

Haake extruder was connected to Rheotens 71.97 Göttfert, according to Figs. 1 and 2.

2.4 Foaming

Samples irradiated and non-irradiated were subjected to foaming process, by PBA (carbon dioxide CO_2), in Haake extruder, specific mono-screw, at 30 bar pressure, by using a pressure valve connected to Haake extruder, according to Fig. 3.

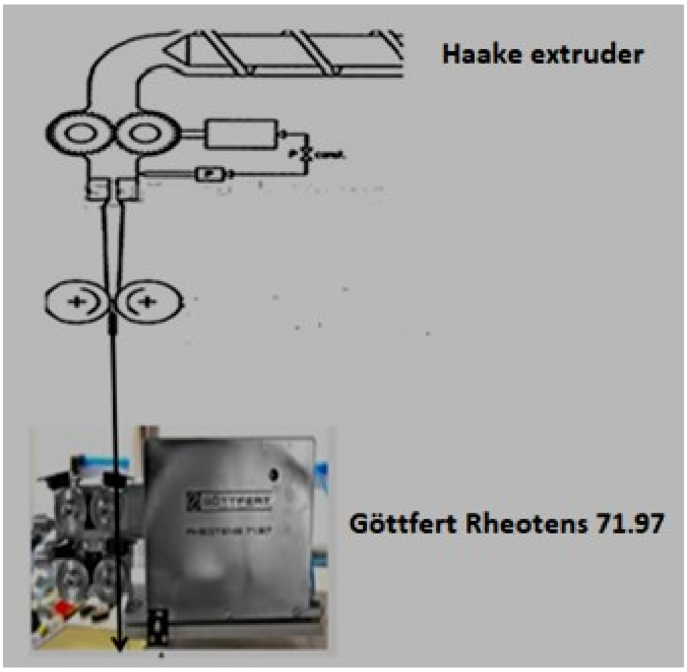

Fig. 1 Scheme of Haake extruder connected to Rheotens 71.97 apparatus.

Fig. 2 Haake extruder.

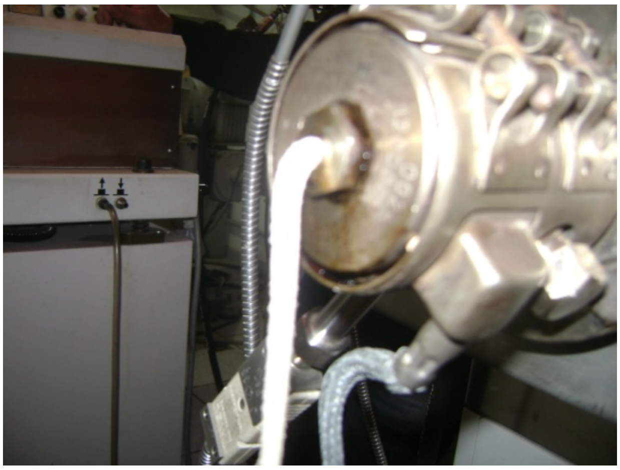

Fig. 3 Foaming operation, by using a rectangular die.

Table 1 Melt index and melt strength for LDPE, irradiated and non-irradiated.

	Melt index (g/10 min)	Melt strength, 200 °C (cN)
0 kGy	2.62	1.5
5 kGy	1.45	2.3
10 kGy	1.01	3.1
15 kGy	None flow	5.8

In Figure 4 are shown micrographs of closed cells foams, aleatory chosen, according to selected dose:

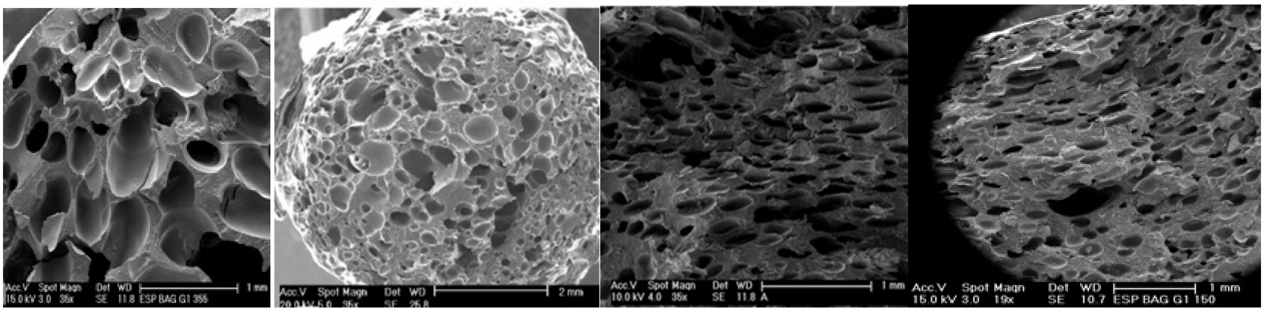

Fig. 4 Micrographs for 0, 5, 10 and 15 kGy, respectively, from left to right.

2.5 Scanning Electron Microscopy

Foamed samples were further analyzed in a FEG (Field Emission Gun) equipment model F-50 in powder previously gold coated in a Balzers SCD (Single Crystal Diamond) 050 sputtering system.

3. Results and Discussion

3.1 Melt Index and Melt Strength

Results for LDPE analyzed are shown in Table 1.

3.2 Scanning Electron Microscopy

Samples from Table 1 presented following micrographs when investigated in FEG equipment:

4. Conclusions

Ionizing radiation, via gamma, within 5 to 15 kGy, contributed for a raise in closed cells, according to what is shown in obtained micrographs, emphasizing that even non-irradiated LDPE presented discrete closed cells. Nevertheless, there should be a balance between processability, indicated by melt index, and closed cells generation, in order to avoid an undesirable high pressure in extruder. It was not possible to obtain a melt index reading for LDPE irradiated at 15 kGy sample that presented a dramatically high result for melt strength.

Acknowledgements

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