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CROSSLINKED POLYETHYLENE FOAMS, VIA EB RADIATION

CARDOSO E.C.L; LUGÃO A. B.; ANDRADE E SILVA L.G.

Institute for Energy and Nuclear Research - IPEN/CNEN-SP, p.o. box 11049 05422-70, São Paulo, Brazil

ABSTRACT

Polyethylene foams, produced by radio-induced crosslinking, show a smooth and homogeneous surface, when compared to chemical crosslinking method using peroxide as crosslinking agent. This process fosters excellent adhesive and printability properties. Besides that, closed cells, intrinsic to theses foams, imparts optimum mechanical, shocks and insulation resistance, indicating these foams to some markets segments as: automotive and transport; buoyancy, flotation and marine; building and insulation; packaging; domestic sports and leisure goods. We were in search of an ideal foam, by adding 5 to 15% of blowing agent in LDPE. A series of preliminary trials defined 203° C as the right blowing agent decomposition temperature. At a 22.7 kGys/dose ratio, the lowest dose for providing an efficient foam was 30 kGy, for a formulation comprising 10% of azodicarbonamide in LDPE, within a 10 minutes foaming time.

KEYWORDS

irradiation, crosslinking, polyethylene, foam, mechanical properties.

INTRODUCTION

Plastic foam is commonly used for describing a two-phase system of a gas dispersed in a solid plastic. The ultimate arrangement of solid and gas in a plastic foam is governed predominantly by the interrelationship of three forces existing during the expansion of the plastic. These forces are: (1) the pressure of the gas inside the voids or cells forcing the plastic in the cell walls to flow as the cell volume increases, (2) surface tension forces which cause the flow of plastic from the cell walls to the points at which they intersect, and (3) the counterbalancing viscoelastic retractive force of the plastic, restricting its flow. A foam whose cells are discrete, or noninterconnecting, and whose gas phase is not continuous is designated *"closed-celled"*, object of our present study.(J.D. Griffin; R.E. Skochdopole, (1964).

Low density polyethylene (LDPE) and a blowing agent are melted to form a mixture, further undergone to a hydraulic press to provide a homogeneous and uniform surface (D.A. Trageser, 1977).Resulted sheet was then irradiated and carried into an oven for decomposition of the blowing agent. (N. Sagane, H. Harayama, 1981)

5, 10, 12 and 15% of blowing agent were added to LDPE.

As a preliminary study and after accomplishing a series of trials, we defined **203° C** as the optimum oven temperature for providing blowing agent decomposition.

In a first stage, we searched to find the lowest foaming time into the oven, for providing acceptable foams.

As a second stage, we searched for the "ideal" foam, combining:

- lowest blowing agent amount;
- lowest dose;
- best surface appearance and
- best mechanical properties (higher tensile strength).

METHODOLOGY

Materials

Low Density Polyethylene (MFR: 1.5g/10 min. density: 0.920g/cm^3).
Blowing Agent: Azodicarbonamide - decomposition range = 190°C - 230°C.

Foaming Method

100 parts by weight of LDPE and 5 to 15 parts by weight of azodicarbonamide were fed into a mixer and melted and mixed at 120° C; mass obtained were submitted to a hydraulic press, in order to provide uniform 2mm thickness sheets(T. Kemmotsu; M. Okada; T. Ono, 1993). Sheets were subjected to a 1.5 MeV electron beam accelerator, at a 22.7 kGy/s dose ratio, within 10 to 80 kGy doses. Crosslinked sheets were brought into an oven, by hot air at 203° C, in order to get foamed sheets (Yoneko Tabata, 1981).

Accomplished Inspections:

Surface of foamed sheets were visually inspected.
Foamed sheets were analysed as per gel fraction content (ASTM 3616-82), in order to check crosslinkability efficiency.
Mechanical tests were performed according to ASTM D 638, using a Instron Tester series 5560, table-top, load frames, mod 5567, speed = 20 mm/min (A. G. Sirota; A. P. Verkhovets; V.L. Auslender, 1995).

RESULTS AND DISCUSSION

Table 1 shows relationship between foaming time, in minutes and surface roughness for 4x8 cm^2 rectangular specimens, formulated with 5, 10, 12 and 15% of Azodicarbonamide in LDPE and irradiated within a range from 10 to 80 kGy. Except for samples irradiated with 10 kGy, that "dripped" under 203°C, all samples assessed showed a smooth evenness surface.
When increasing irradiation dose and Azodicarbonamide content in LDPE, a lower foaming time will be required for providing smooth and uniform foams.

Table 1. Relationship between foaming time, in minutes, and surface roughness

AZODICARBONAMIDE, %, BY WEIGHT, IN LDPE	Dose 10(*) (kGy)	Dose 20 (kGy)	Dose 30 (kGy)	Dose 40 (kGy)	Dose 50 (kGy)	Dose 60 (kGy)	Dose 80 (kGy)
5	-	15	15	14	11	11	10
10	-	11	10	10	9	9	8
12	-	10	9	9	9	9	8
15	-	8	8	7	7	7	6

(*) All specimens tested failed, i.e., they "dripped" under 203° C temperature.

According to Table 1, we can state that formulations containing 10 and 12%, at 30 and 40 kGy doses, showed a better appearance, that is, a more uniform, soft and smooth surface compared to other ones.

Foamed samples were, then, subjected to gel fraction and mechanical tests; results obtained are shown in Figures 1 and 2.

Figure 1 results show that for higher content of Azodicarbonamide, lower results for gel fraction will be obtained for irradiated samples. So, added amount of Azodicarbonamide will promote a decrease in crosslinkability of foams. In addition to that, we can state too that higher irradiation doses will foster foams crosslinkability. It is observed too that for doses higher than 40 kGy, gel fraction results will slightly increase, for all tested formulations, aiming to a medium value around 66%.

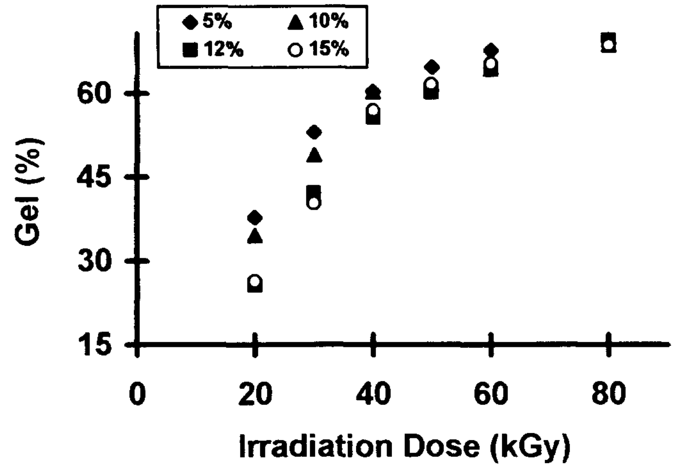

Figure 1: Variation of Gel Fraction in foamed sheets formulated with 5, 10, 12 and 15% of Azodicarbonamide in LDPE, irradiated via EB, within 20 to 80 kGy doses

Figure 2 shows excellent tensile strength results for foams comprising 5% of Azodicarbonamide in its formulation. Other formulations show a similar behavior, that is, in spite of better results obtained for 10% formulation, results are very close among them.

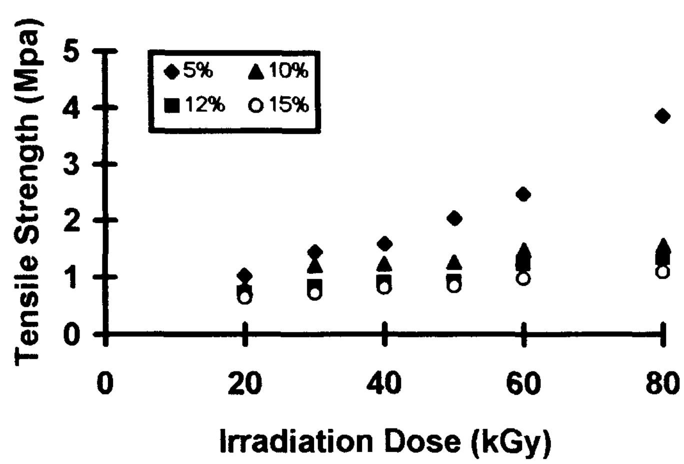

Figure 2: Effect of irradiation dose (20 to 80 kGy) on tensile strength of foams formulated with 5, 10, 12 and 15% of Azodicarbonamide in LDPE

CONCLUSION

For samples investigated comprising 5, 10, 12 and 15% of Azodicarbonamide in LDPE we attained following conclusions:

Results obtained for gel fraction and mechanical tests allow defining 5% formulation as the best one. However, other parameters should be considered before indicating it as the "ideal one". An important point is related to appearance of foams. 5% formulation has a good surface appearance, but non superior to that one shown by **10% formulation**. We can even state that as high formulation content, a better and soft appearance is obtained. But we can not neglect the fact that an extra amount of azodicarbonamide will tend to reduce closed cells and to impart a prejudice in mechanical tests.

Tensile strength results for 10% formulation, at 30, 40 and 50 kGy are very close; so, we can define **30 kGy** as the lowest dose capable of producing resistant foams.

Finally, we concluded that a formulation containing **10% of Azodicarbonamide in LDPE**, will require a **foaming time of 10 minutes** and will provide, **at 30 kGy, 22.7 kGy/s dose ratio, crosslinked foams of excellent surface appearance and optimum resistance.**

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