2026 International Nuclear Atlantic Conference – INAC 2026
Escola de Guerra Naval, Rio de Janeiro, RJ, August 24 - 28, 2026

Effects of Gamma Radiation onto LDPE/Molecular Sieve Composite

V.S. Henrique[1], H.A. Zen[2] and A.B. Lugão

[1] *vinicius_henrique@usp.br, Av. Prof. Lineu Prestes, 2242 – IPEN-CNEN/SP*
[2] *helozen@ipen.br, Av. Prof. Lineu Prestes, 2242 – IPEN-CNEN/SP*

1. Introduction

Numerous research projects in chemical and materials engineering are being driven by the search for new materials that combine the properties of polymeric matrices with the functionalities of inorganic fillers. Low-density polyethylene (LDPE) is widely used due to its versatility and processability but often requires structural modifications to meet more demanding applications
Gamma radiation exerts a great influence on the structure of polymers, being able to promote two competitive processes: crosslinking and chain scission. In polyethylene, radiation induces the formation of a crosslinked network in the amorphous phase, which tends to increase the Young's modulus and yield strength [1].
Simultaneously, gamma radiation also impacts the structure of aluminosilicates. Exposure to gamma rays can generate paramagnetic defect centers, such as oxygen centers and peroxy radicals, which are influenced by the thermal history of the sample [2]. In zeolites (a specific subgroup of aluminosilicates), radiation promotes the contraction of the unit cell volume due to the elimination of water molecules from the micropores through radiolysis [3]. It is interesting to note that moderate doses of radiation (below 400 kGy) can promote an ordering of the crystalline network, increasing the crystallinity of the material, while excessive doses lead to the degradation of the structure [3]. The efficiency of this filler is linked to its level of dispersion in the matrix, where the aluminosilicate can restrict the mobility of the polyethylene chains, altering the mechanical response of the assembly [4].
This work investigates the development of LDPE-based composites with the addition of 3A molecular sieve (aluminosilicate), subjecting these mixtures to gamma radiation at doses of 25 kGy and 50 kGy.

2. Methodology

The samples were made using low-density polyethylene (LDPE) and zeolite 3A molecular sieve (aluminosilicate with 3 Å pores) as matrices. The mixtures were prepared in mass proportions of 2%, 5%, and 10% inorganic filler. The incorporation process occurred via twin-screw extrusion at 220 °C. The extruded composite, in wire form, was subjected to rapid cooling in water at room temperature and cut into 1.5 mm pellets by a shredder. After this process were obtained films with 1 mm of thickness by thermopress processing.
The films ready were submitted at gamma radiation from a Cobalt-60 source, at doses of 25 kGy and 50 kGy, at room temperature and air atmosphere.
The materials were evaluated before and after irradiation by scanning electron microscope for evaluating the surface morphology, topography in Jeol MEV-FEG equipment, at 1,000x magnification.
Mechanical tests were carried out to evaluate the mechanical properties of the samples after the irradiation process under different absorbed doses. The specimens were prepared with dimensions of 6 cm × 1 cm and a width of 10 mm. The tests were conducted at a speed of 50 mm/min, obtaining results for tensile strength, elongation at break, and modulus of elasticity.

3. Results and Discussion

Scanning Electron Microscopy (SEM) images showed in Fig. 1-3 reveal for the non-irradiated LDPE topographically uniform, smooth surface. This type of surface is characteristic of semi-crystalline polymer films processed under rapid cooling from the molten state [5]. The sample with 2% of molecular sieve, the presence of isolated inorganic particles and small finely dispersed agglomerates anchored on the polymer surface is observed; with 5% filler, the number of bright sites increases, it is possible to record the beginning of the formation of discrete micrometric agglomerates; and with 10% the micrographs show dense and larger particulate agglomerates scattered throughout the polymer matrix.

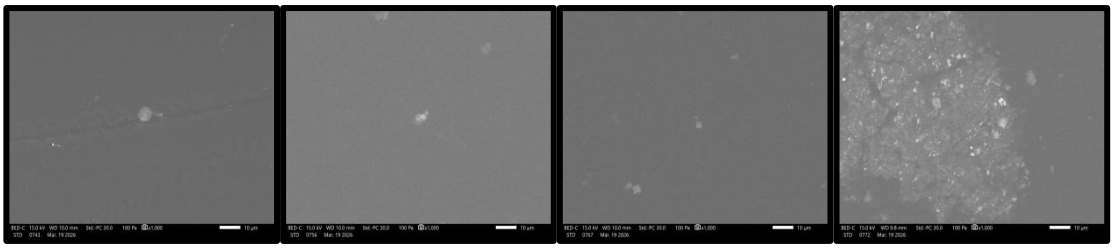


Figure 1: SEM images at 1000x, of non-irradiated samples.

In Fig. 2 was observed a morphological transition promoted by exposure to the intermediate dose of 25 kGy reveals that the basic physical integrity of the composite and the distribution of bright particles were maintained without the generation of sharp surface microcracks.

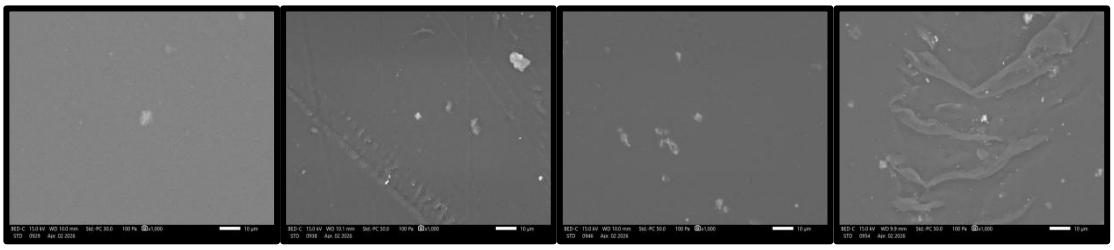


Figure 2: SEM images at 1000x, of irradiated samples at 25 kGy.

The samples exposed at 50 kGy were shown in Fig. 3 reveal fundamental interfacial phenomena to correlate the morphology with the macroscopic properties of the material. The developed irradiated composites maintain the contrast pattern and stability of the bright phases

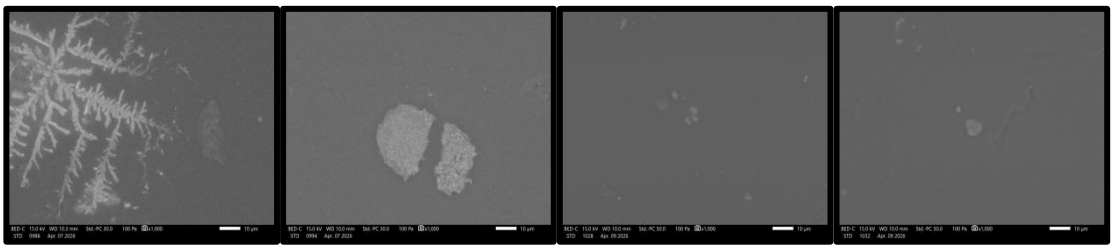


Figure 3: SEM images at 1000x, of irradiated samples at 50 kGy.

The results of mechanical tests are demonstrated in Table I. For non-irradiated samples, the properties in the linear elastic deformation regime indicate that the incorporation of molecular sieve acts by

promoting an increase in the stiffness polymer matrix. At 25 kGy the average modulus of elasticity increased with increasing filler content; this behavior can be associated with the incorporation of aluminosilicate attenuates the elastic degradation of the matrix.

Strain at break properties records a severe transition in the ductile-brittle behavior of the polymeric composite. For non-irradiated samples the average rupture stress oscillated discretely between 7.12 MPa and 8.92 MPa under all conditions. With increasing radiation dose, there was a slight increase in tensile strength at break. However, the stress at break suffered a drastic reduction with the increase of radiation dose, which was expected due to the effect of crosslinking reactions that is predominant for LDPE under radiation process in both evaluated doses [6].

Table I: Results of nechanical tests for non-irradiated and irradiated fims.

Sample	Young's Modulus (MPa)	Stress at break (MPa)	Strain at break (%)
Pure Non-Irradiated	1417.02	7.12	973.69
2% Non-Irradiated	698.43	8.80	824.82
5% Non-Irradiated	402.88	8.06	470.90
10% Non-Irradiated	629.81	8.92	87.65
Pure + 25 kGy	20.61	7.83	493.71
2% + 25 kGy	19.79	9.48	358.27
5% + 25 kGy	176.79	8.46	326.86
10% + 25 kGy	276.19	8.17	50.93
Pure + 50 kGy	86.42	7.85	219.43
2% + 50 kGy	67.28	8.20	200.78
5% + 50 kGy	219.05	7.68	77.21
10% + 50 kGy	313.13	8.19	88.65

4. Conclusions

The results demonstrated that the rigorous control of the gamma irradiation dose and the 3A molecular sieve content allowed for precise modulation of the mechanical properties of LDPE.
SEM images confirmed a homogeneous spatial dispersion of the bright inorganic particles at levels up to 5%, with the emergence of dense micrometric agglomerates at the limit concentration of 10%. These particles maintained their physical integrity and stable interfacial anchoring even after bombardment by high-energy photon.
Mechanical tests revealed that the predominant effect of gamma radiation was crosslinking reactions when the values of stress at break were reduced. Local crosslinking in the amorphous region surrounding the zeolites raised Young's modulus to maximum levels.

Acknowledgements

CNPq for the grant and SETER-IPEN for irradiation process.

References

[1] E. Quero, C. C. Puig, C. Albano, A. Karam, "γ-Radiation (0–150 kGy) effects on slow and fast cooled HDPE/LDPE blends", *Polymer Bulletin*, vol. 59, pp. 517-526 (2007).

[2] E. Vanea, V. Simon, "Low dose gamma irradiation effect on aluminosilicate compounds", *Journal of Optoelectronics and Advanced Materials*, vol. 12, pp. 365-369 (2010).

[3] M. B. Z. Gili, F. A. Pares, A. L. G. Nery, N. R. D. Guillermo, E. J. Marquez, E. M. Olegario, "Changes in the structure, crystallinity, morphology and adsorption property of gamma-irradiated Philippine natural zeolites", *Materials Research Express*, vol. 6, art. 125552 (2019).

[4] A. C. Lopes, P. Martins, S. Lanceros-Mendez, "Aluminosilicate and aluminosilicate based polymer composites: Present status, applications and future trends", *Progress in Surface Science*, vol. 89, pp. 239-277 (2014).

[5] A. M. Paredes, "Scanning Electron Microscopy", *Encyclopedia of Food Microbiology: Second Edition*, vol. 2, pp. 693-701, Oxford & United Kingdom (2014).

[6] K. K. Chawla, "Mechanical Properties: Tensile Properties", *Encyclopedia of Condensed Matter Physics*, vol. 1, pp. 312-318, San Diego & USA (2005).