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DEVELOPMENT OF AEM VIA SIMULTANEOUS GRAFTING POLYMERIZATION BY IONIZING RADIATION

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1. Introduction

Anion exchange membranes (AEMs) are specifically designed to conduct negatively charged ions (anions) while acting as a barrier to other species, such as gases or neutral molecules. This selective transport capability, coupled with their unique chemical environment, opens a world of possibilities across diverse applications, like fuel cells [1-3]. Gamma irradiation induces significant chemical and physical modifications in polyethylene, mainly through competing chain scission and crosslinking reactions whose predominance depends on dose, atmosphere, and molecular architecture. While the polyethylene phase provides flexibility and processability; under ionizing radiation, it promotes crosslinking and subtle interfacial rearrangements while preserving the overall mechanical integrity of the composite [4, 5].

This study developed an AEM based on low density polyethylene (LDPE) modified by ionizing radiation. The LDPE films were pre irradiated at 12kGy under inert atmosphere and in sequence different volumes of solution were submitted at 16kGy to the simultaneous grafting polymerization using 3,4-vinylbenzyl chloride as monomer and toluene and ethanol as solvent. Radiation induced grafting (RIG) polymerization is a well-known and clean technique to modify polymers, like LDPE is a hydrophobic polymer although after RIG is obtained a hydrophilic polymer that can be used as ionic transfer membrane.

2. Methodology

LDPE films with 50μm were purchased by Goodfellow. The films were pre irradiated at 12kGy under inert atmosphere at gamma rays source, in sequence the films were submitted at 16 kGy to the simultaneous grafting polymerization using 3,4-vinylbenzyl chloride (28%) as monomer and toluene (27%) and ethanol (45%) as solvent; two different total volumes were prepared 16 mL and 25 mL. After the radiation-induced grafting polymerization, the films were immersed in an aqueous trimethylamine (1:1, vol.) solution to provide a functionalization of the grafted films.

In order to evaluate the grafted films and the membranes, mechanical tests and thermal analysis were carried out. The degree of grafting (DOG) was calculated as Eq. 1, where mf is final mass after grafting and mi is the initial mass of the film.

$$\mathrm{DOG} = 100 * \frac{mf - mi}{mi} \quad . \tag{1}$$

3. Results and Discussion

The values of degree of grafting revealed the accordance with the increase of solution volume: for 16 mL was 76% and for 25 mL was 125%. This result was expected, since a higher volume exposed to radiation has a higher probability of radical generation, and these radicals are more efficient to initiate the grafting reactions than in the lower volume of grafting solution.

Table 1 showed the values of mechanical tests. Both grafted films presented similar values of stress and strain at break. Due to the graft chain the strain at break increased, this behavior occurred because of difficulty of the chain aligned; and the opposite occurred to the stress at break, which was lower for the grafted film in comparison to the pristine film because of the crosslinking reactions in the polymer matrix.

Table 1: results of mechanical tests.

Sample	Strain at break / MPa	Stress at break / %
Pristine LDPE	17.5	869
Grafted LDPE	30.7	215

TGA curves are presented in Fig. 1 (a) for the grafted solution of 16 mL and (b) 25 mL, respectively. For both solutions the pristine LDPE present only one step of degradation related to the polymer matrix (from 395 to 535 °C); the grafted films presented two steps the first related to the VBC grafted chains (from 310 to 431 °C); the functionalized films presented three steps of degradation, the first one is related to the amine from the functionalized (from 30 to 176 °C), the second refers the grafted chain ans the third step is due to the LDPE matrix. For TGA results is possible to observe a decrease in thermal stability of the polymer matrix and the grafted chain according to the process carried out.

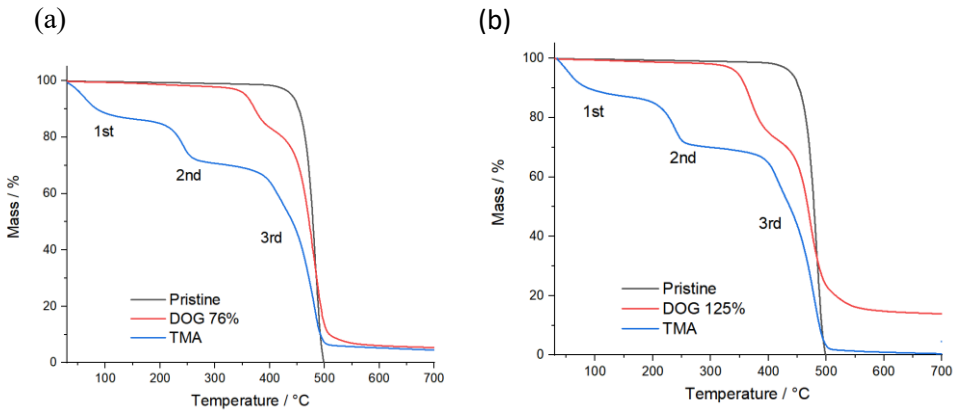


Figure 1: Thermogravimetric curves

4. Conclusions

The results showed that the higher volume of grafting solution achieved a higher degree of grafting but without drastic changes in thermal properties. Mechanical properties of grafted films showed as expected an increase of around 70% in stress at break and a decrease of around 250% in strain at break values, when compared to pristine LDPE, which is related to an increase of crosslinking yeld for grafted membranes. The results indicate a highly promising membrane for application as an anion exchange membrane (AEM), and the conductivity and ionic stability tests are currently in an advanced stage of

evaluation.

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References

[1] R. Yu, H. Yang, X. Yu, J. Cheng, Y. Tan, X. Wang, “Preparation and research progress of anion exchange membranes” *International Journal of Hydrogen Energy*, vol. 50 (A), pp. 582-604 (2024).
[2] K. F. L Hagesteijn,S. Jiang and B. Ladewig, “ A review of the synthesis and characterization of anion exchange membranes” *Journal of Materials Science*, vol. 53, pp. 11131-11150 (2024).
[3] J. Neelima and R. K. Singh, “Recent advances in anion-exchange membranes for electrolyzers, fuel cells and redox-flow batteries” *J. Mater. Chem. A*, vol. 13, pp. 36853-36880 (2025).
[4] Z. R. Sarmazdeh, “Gamma radiation effects on the mechanical stability of polyethylene composites: effects of filler dimension and absorbed dose” *Journal of Nuclear Research and Applications,* vol. 4 (1), pp. 11-22 (2024).
[5] A. A. Moez, S.S. Aly, Y.H. Elshaer, “Effect of gamma radiation on low density polyethylene (LDPE) films: Optical, dielectric and FTIR studies”, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy,* vol. 93, pp. 203-207 (2012)