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Effects of Electron Beam Irradiation on Fluoroelastomer Properties

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ABSTRACT

Fluoroelastomer is a polymer usually used as a sealing material due to some excellent properties comparing to other elastomers, such as good resistance to high temperatures and to the attack of chemical substances. The fluoroelastomer used in this work was a commercial product obtained from two monomers, vinylidene and hexafluoropropylene, containing also carbon black and inorganic fillers. The aim of this work was to study the effect of the ionizing radiation of electron beam (EB) on the tensile, hardness and thermal properties of this sealing material obtained by a conventional curing process. The overall doses applied were 10, 25, 50, 75, 100, 125, 150, 175, 200 and 250 kGy. Tension tests showed that the tensile stress at break increases 34 % in the range of radiation dose applied. On the other hand, the total strain decreases considerably, from 347 % to 109 %, with the increase of the radiation dose. Hardness Shore A values increase 15 % in the range of radiation dose studied. Thermogravimetric curves showed that there are no considerable variations on the onset temperatures for all samples in the range of radiation doses applied. These results indicate that EB radiation produces modifications on the fluoroelastomer mechanical properties, but without promoting considerable chain scission. The modifications on the mechanical properties can be related to a better adhesion, induced by radiation, between the fluoroelastomer and the fillers.

1. INTRODUCTION

Commercial fluoroelastomers were introduced in 1957 to meet the needs in the aerospace industry for high-performance sealing materials. Since then, the use of fluoroelastomers has spread to many other applications, especially in the automotive, fluid power and chemical industries [1]. This is due to its excellent properties such as, resistance to high temperatures, resistance to chemical substances, including oils, fuels and mineral acids, and low permeability to many substances.

There are many different kinds of commercial fluoroelastomers. Besides the polymer, fluoroelastomer sealing materials incorporate some additives in order to assure good processing characteristics and specific properties [2]. The fluoroelastomer studied in this work is a commercial product obtained from two monomers, vinylidene and hexafluoropropylene. The material synthesized for this work contains specific percentages of fluoroelastomer, carbon black and inorganic fillers (magnesium oxide and calcium hydroxide) in order to obtain the necessary properties for a high performance material. The studied material was obtained by a conventional chemical curing process. An important factor to improve performance is the adhesion properties among these components.

As in the case of many other polymeric materials, ionizing radiation has a variety of effects on fluoropolymers. It may cross-link them, cause chain scission or modify their surface structure [3]. Quite often, these effects occur simultaneously. The final result will depend on the material chemical structure, type of radiation, dose and dose rate. In general, compounds from fluoroelastomers irradiated at optimum conditions attain better mechanical properties and thermal stability than non-irradiated chemical cured systems [4].

The aim of this work was to study the effect of the ionizing radiation from EB on the tensile, hardness and thermal properties of a fluoroelastomer sealing material obtained by a conventional curing process.

2. EXPERIMENTAL

2.1. Samples

Fluoroelastomer samples were cut out from a fluoroelastomer plate. Five samples were evaluated for each radiation dose applied and a set of non-irradiated samples was used as blank.

2.2. EB irradiation conditions

Samples were irradiated with high energy electron at the IPEN-CTR facilities using a 1.5 MeV and 37.5 W Dynamitron Electron Accelerator model JOB-188. The irradiation were carried out at a dose rate of 11.20 kGy s^{-1} and the overall applied doses were 10, 25, 50, 75, 100, 125, 150, 175, 200 and 250 kGy.

2.3. Mechanical tests

Tensile strength measurements were carried out in an Instron Universal testing machine model 5565 in accordance to ASTM D1414-78 [5]. Hardness was evaluated using a Type A durometer Woltest model SD300 according to ASMT D 2240-86 [6].

2.4. Thermogravimetry (TG)

TG/DTG curves were obtained by a TGA7 Thermogravimetric analyzer (PerkinElmer, Inc.) in the temperature range from 50 ^{o}C to 900 ^{o}C with a heating rate of 10 ^{o}C min^{-1}, under dynamic nitrogen atmosphere up to 650 ^{o}C, and under synthetic air from 650 ^{o}C to 900 ^{o}C, using sample masses of about 5 mg. The amounts of fluoroelastomer polymer, carbon black and fillers were determined according to ASTM D6370-99 [7].

3. RESULTS AND DISCUSSION

Tension strength measurements showed that the tensile stress at break increases from 113 kg cm^{-2} for non-irradiated samples to 151 kg cm^{-2} in the range of radiation dose applied, corresponding to an improvement of 34 %. On the other hand, the strain decreases considerably, from 347 % for non-irradiated samples to 109 %, in the same dose range. These data are presented in Figure 1. This behavior showed that EB radiation promotes improvements on the fluoroelastomer mechanical properties, which can be related to a better adhesion, in the studied material, between the elastomer and the fillers.

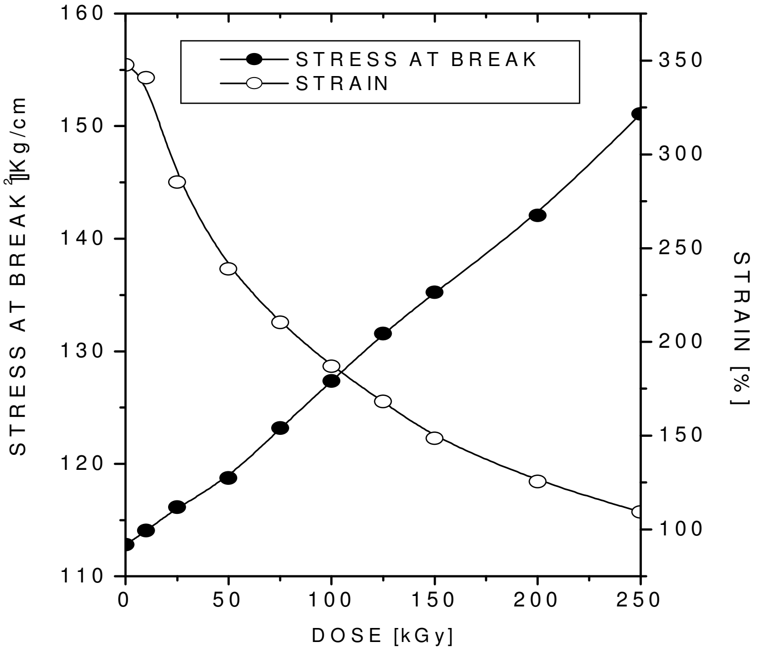

Figure 1. Stress at break and strain as a function of the applied dose.

Experimental results also showed that the values of hardness Shore A changes from 81 for non-irradiated samples to 93 for samples irradiated with 250 kGy. Therefore, there is an increase of 15 % in the hardness values in the range of applied doses. These data are shown in Figure 2.

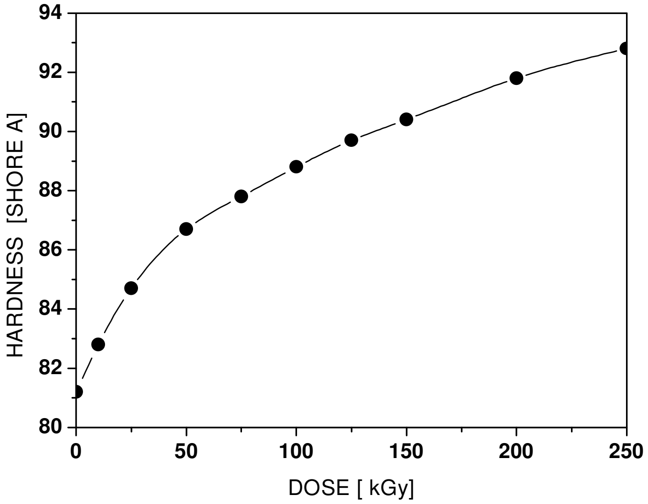

Figure 2. Hardness Shore A as a function of the applied dose.

TG has extensively been used to supply important information on the thermal stability of polymers. Since the profiles of the TG curves for all studied samples in this work are very similar, Figure 3 shows only, as example, the thermogravimetric curves obtained for non-irradiated and irradiated with 250 kGy samples.

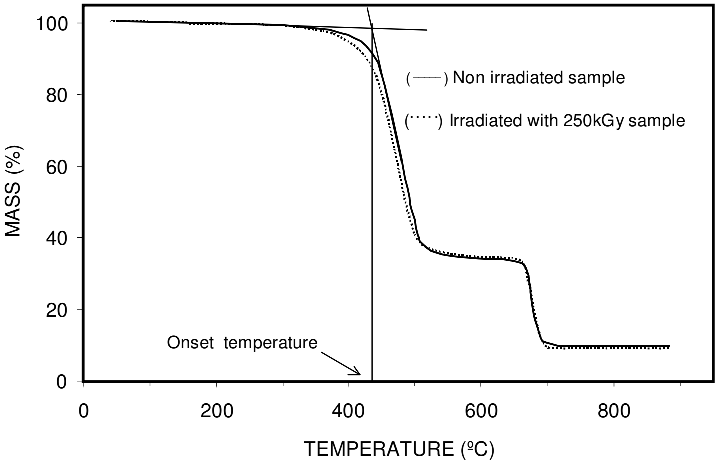

Figure 3. TG representative curves of fluoroelastomer for non-irradiated and irradiated with 250 kGy samples.

From TG experimental data, it is possible to verify that the composition of the samples, in the range of studied doses, is not affected by the irradiation process. Therefore, the amounts of fluoroelastomer and carbon black, corresponding, respectively, to the first and second mass loss steps remain constant at 66 % and 25 % and the content of fillers, corresponding to the final mass residue, at 9 %.

Moreover, the thermal stability estimated by onset temperature, represented in Figure 3, for the first mass loss step is similar for non-irradiated samples and for samples irradiated with doses up to 50 kGy. For these samples the estimated temperature for the beginning of the thermal decomposition is about 445 ^{o}C. In addition, irradiated samples with doses in the range from 75 to 250 kGy present thermal stability slightly lower, at about 435 ^{o}C. Therefore, considering the experimental errors, the variation was not considerable. This fact means that, in the studied conditions, it was not induced significant chain scission.

4. CONCLUSIONS

The results showed that EB radiation, in the studied conditions, promotes significance changes in the fluoroelastomer mechanical properties resulting in an increase of hardness, tensile strength and stiffness. These mechanical changes are important parameters to be considered for the end use of fluoroelastomers under EB radiation exposition.

The thermal behavior for all studied samples showed that no considerable chain scission was induced by EB radiation in the studied conditions.

The improvement of the mechanical performance can be associated to a better adhesion between elastomer and fillers, which is an important factor to assure a good performance of sealing materials.

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