MODIFICATION OF FLUOROELASTOMER BY ELECTRON BEAM IRRADIATION

Claudia Giovedi[1]*, Eddy S. Pino[2], Luci D. B. Machado[2], Léa S. Montagna[1], Claudio B. Leitão Jr. [1]

[1]Centro Tecnológico da Marinha em São Paulo, Av. Prof. Lineu Prestes, 2468, 05508-000, São Paulo/SP - giovedi@ctmsp.mar.mil.br; [2]Instituto de Pesquisas Energéticas e Nucleares - espino@ipen.br*

Fluoroelastomer is a polymer usually used as a sealing material due to some excellent properties, comparing to other elastomers, such as good chemical and thermal resistance. The fluoroelastomer used in this paper was a commercial product obtained from two monomers, vinylidene and hexafluoropropylene, containing also carbon black and inorganic fillers. Samples were irradiated with electron beam at doses from 10 to 250 kGy. The results obtained showed that electron beam radiation, in the studied conditions, promotes significance changes in the fluoroelastomer mechanical properties ending up in an increase of hardness, tensile strength and stiffness. The modifications on the mechanical properties can be related to a better adhesion between the fluoroelastomer and the fillers, induced by EB radiation. Micrographs obtained by Scanning Electron Microscopy for non-irradiated and irradiated samples confirmed this behavior.

Introduction

Commercial fluoroelastomers were introduced in 1957 to meet the needs in the aerospace industry for high-performance sealing materials [1]. Some of its excellent properties are resistance to high temperatures, resistance to chemical attack of some substances, including oils, fuels and mineral acids, and low permeability to many substances.

Besides the polymer, fluoroelastomer sealing materials incorporate some additives in order to assure good processing characteristics and specific properties [2]. An important factor to improve performance is the adhesion properties among these components.

As in the case of many other polymeric materials, ionizing radiation causes a variety of effects on fluoropolymers. It may cross-link them, induce chain scission or modify their surface structure [3]. 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].

Scanning Electron Microscopy (SEM) is a powerful technique to elucidate polymers morphology [5]. Concerning elastomers, microscopy can be used to characterize the distribution of carbon black and inorganic fillers, as well as the adhesion properties of these components in the studied material.

The aim of this paper was to evaluate the modifications induced by electron beam (EB) radiation on the fluoroelastomer.

Experimental

Samples

The fluoroelastomer studied was a commercial product obtained from two monomers, vinylidene and hexafluoropropylene. The material was composed of specific percentages of fluoroelastomer, carbon black and inorganic fillers (magnesium oxide and calcium hydroxide), 66 %, 25 % and 9 %, respectively. The studied material was obtained by a conventional chemical curing process. The samples were cut out from a fluoroelastomer plate.

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 was 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.

Mechanical tests

Tensile strength measurements were carried out in an Instron Universal testing machine model 5565, in accordance to ASTM D1414-78 [6]. Hardness was evaluated using a Type A durometer Woltest model SD300 according to ASMT D 2240-86 [7].

Scanning Electron Microscopy (SEM)

SEM micrographs of fractured samples were obtained using a scanning electron microscope JEOL model JXA-6400.

Results and Discussion

Tension strength measurements showed that the tensile stress at break increases from 113 kgf cm^{-2} (for non-irradiated samples) to 151 kgf cm^{-2}, within the range of radiation dose applied. This corresponds to an improvement of 34 %. On the other hand, the strain decreases considerably, from 347 % for non-irradiated samples to 109 % for the highest applied dose (250 kGy).

Experimental results also showed that the values of hardness Shore A change from 81 for non-irradiated samples up to 93 for samples irradiated with 250 kGy. Therefore, there is an increase of 15 % in the hardness values within the range of applied doses.

These data are shown in Table 1.

Table 1 – Fluoroelastomer data of stress at peak load, strain at peak load and hardness as a function of applied doses.

Dose (kGy)	Stress at Peak Load (kg cm^{-2})	Strain at Peak Load (%)	Hardness (Shore A)
0	113	347	81
10	114	341	83
25	116	285	85
50	119	239	87
75	123	210	88
100	127	187	89
125	131	168	89
150	135	149	90
200	142	125	92
250	151	109	93

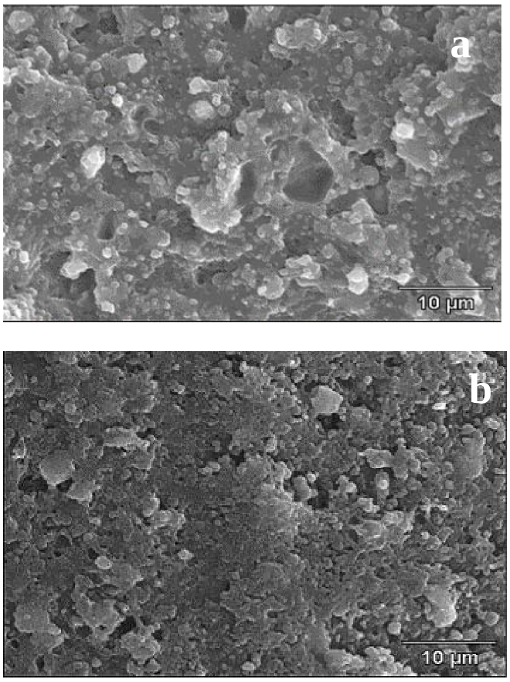

Figure 1 – SEM micrographs of fracture surfaces for different samples: (a) non-irradiated and (b) irradiated with 250 kGy.

The fracture behavior was investigated using SEM. The micrographs obtained of fracture surfaces for different samples are shown in Figure 1.

Observing the micrographs obtained for non-irradiated samples, it is possible to identify several voids between the filler particles and the matrix (elastomer), leading to a very heterogeneous surface. For samples irradiated with 100 kGy, the amount of voids decreases and the fracture surface is more homogeneous than for non-irradiated samples. The micrographs obtained for samples irradiated with the highest applied dose (250 kGy) show a homogeneous surface. This indicates a better adhesion between fillers and matrix, which is responsible for the mechanical behavior observed.

Conclusion

The results showed that EB radiation, in the studied conditions, promotes significance changes in the fluoroelastomer mechanical properties ending up 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 SEM micrographs confirmed that the mechanical performance enhance is associated to a better adhesion between elastomer and fillers. This is an important fact that assures a good performance of sealing materials.

Acknowledgement

The authors gratefully acknowledge the Financiadora de Estudos e Projetos - FINEP (Financial Institution for Studies and Projects) and the Conselho Nacional de Pesquisa e Desenvolvimento - CNPq (National Council of Scientific and Technological Development), for their financial support.

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