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Radiation Vulcanization of EPDM Rubber with Polyfunctional Monomers

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The most important stage in ethylene-propylene–terpolymer rubber processing technology is vulcanization/cross-linking. The effect of polyfunctional monomers as triallylcyanurate, triallylisocyanurate, trimethylopropane trimethacrylate, and zinc diacrylate on the crosslink density of ethylene-propylene–terpolymer rubber processed by electron beam irradiation using a 5.5 MeV electron accelerator was presented. The dependence of cross-link density on the irradiation dose was also determined in the dose range of 50 to 500 kGy. The results have showed that the crosslink density is very sensitive to the polyfunctional monomers use.

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PACS/topics: rubber, polyfunctional monomers, irradiation, dose, properties

1. Introduction

Most rubbers, excepting thermoplastic elastomers, require curing. The process is normally done by sulphur, accelerators or peroxides. An alternative to these curing systems is the processing by means of ionizing radiations which is very clean, requires less energy and permits greater processing speed. Also, ionizing radiations can induce chemical reactions at any temperature in the solid, liquid and gas phase even without using catalysts [1, 2]. The goal of the paper is to present the effect of some polyfunctional monomers (PFMs) as triallylcyanurate (TAC), triallylisocyanurate (TAIC), trimethylopropane trimethacrylate (TMPT) and zinc diacrylate (ZDA) and irradiation dose on ethylene-propylene–terpolymer rubber (EPDM) cross-linked by electron beam irradiation.

2. Materials and equipments

The following raw materials were used: EPDM rubber Nordel 4760, polyethylene glycol PEG 4000, antioxidant Irganox 1010 and polyfunctional monomers (TAC, TAIC, TMPT and ZDA). For the preparation of EPDM/PFMs blends 100 phr EPDM, 1 phr Irganox 1010 and 3 phr PFMs were added. The process variables were: temperature 60–80 °C±5 °C, friction ratio 1:1.1 and total blending time 7 min. The obtained samples are referred below as fallowing: EPDM, EPDM/TAC, EPDM/TAIC, EPDM/TMPT and EPDM/ZDA [2]. The samples irradiation was performed in atmospheric conditions and at room temperature of 25 °C, using the linear electron accelerator of 5.5 MeV, ALID 7. The electron beam dose rate was fixed at 5 kGy/min in order to accumulate doses between 50 and 500 kGy. The sol-gel analysis and crosslink density were performed according to previous studies [2].

3. Results and discussion

The variations of gel fraction and cross-link densities calculated based on sol-gel analysis are presented in Fig. 1. It can be seen that the gel contend highly increased with the irradiation dose until 250 kGy, than still increases but slowly up to 500 kGy. The PFMs influence on gel fraction of samples cross-linked by electron beam irradiation is as follows: TMPT > TAC > TAIC > ZDA. The results show that the higher it is the gel fraction, the more efficient the cross-linking process is. It can be observed that the most spectacular increasing of cross-link density was registered for EPDM/TMPT. Contribution of PFMs to increasing cross-link density is determined by the reactivity, the functionality and solubility of the PFMs in the EPDM rubber.

The use of these co-agents leads to an increase in cross-link density of the vulcanisate and present good compatibility with many elastomers [3, 4].

In an irradiation cured system, the gel content and crosslink density of samples increase with absorbed dose increase and this is due to the formation of a three-dimensional network structure. In order to quantitatively evaluate the yields of cross-linking and chain scission of the EPDM and EPDM/PFMs rubbers irradiated with EB, were drawn the plots of $S+S^{1/2}$ vs. 1/absorbed dose (D) from the Charlesby-Pinner equation for the different blend compositions [1, 5]. From Fig. 2 it is observed that the sample of EPDM/TMP blends is the most effective cross-linked by electron beam irradiation. Low values of p_0/q_0 are suggestive for the relatively improved radical-radical interactions in polymer matrix, probably due to the decrease in free-volume [5, 6].

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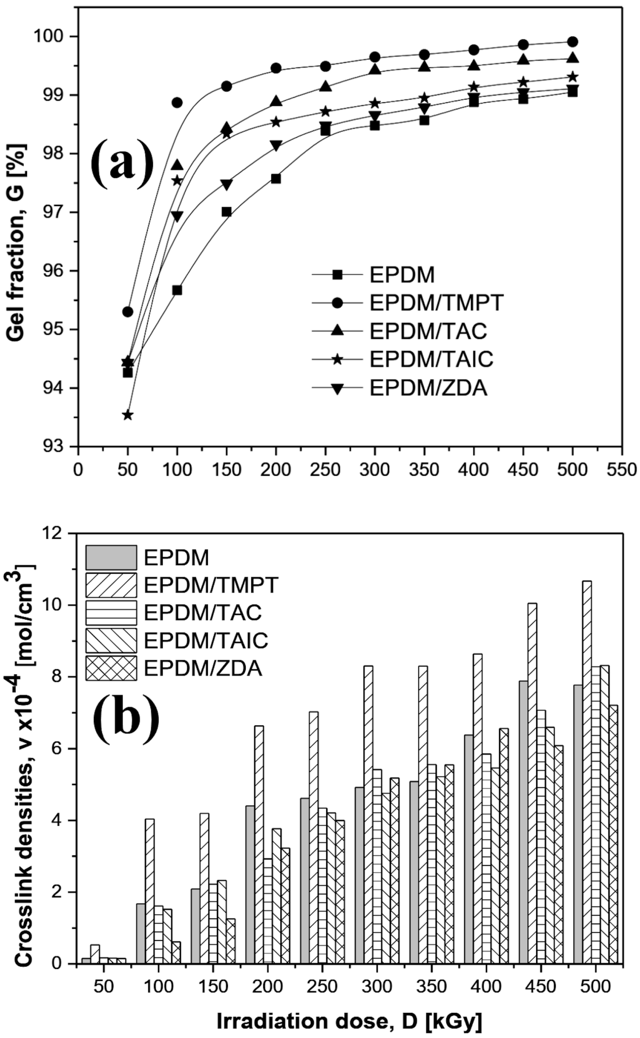

Fig. 1. The effect of irradiation dose and PFMs type on (a) gel fraction (b) and cross-link density.

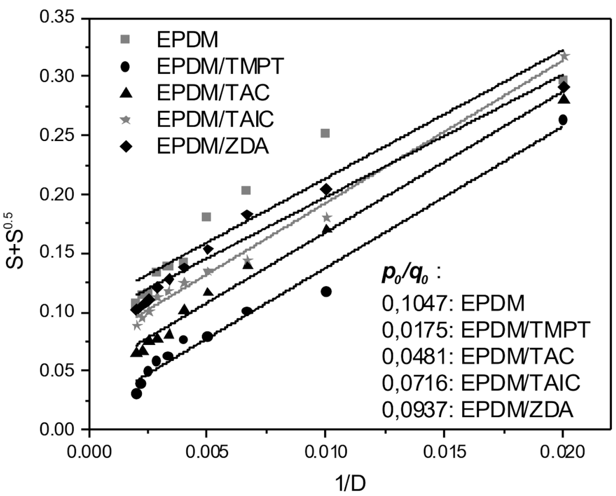

Fig. 2. The Charlesby-Pinner plot made for EPDM and EPDM/PFMs rubbers.

4. Conclusion

The effects of some polyfunctional monomers (TMPT, TAC, TAIC, ZDA) and irradiation dose (between 50 and 500 kGy) on the cross-linking of ethylene-propylene–terpolymer rubber (EPDM) processed by electron beam irradiation were investigated. The PFMs influence on gel fraction of cross-linked samples was as follows: TMPT > TAC > TAIC > ZDA. The highest values for crosslink density were obtained for blend with TMPT irradiated with 500 kGy. The addition of TMPT significantly increases crosslink density when compared with the control samples, EPDM and other PFMs. By using this kind of PFMs (TMPT), not only the rate of cure is increased, but also the crosslink density or state of cure.

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References

[1] D.M. Stelescu, E. Manaila, G. Craciun, *J. Appl. Polym. Sci.* **128**, 2325 (2013).

[2] E. Manaila, G. Craciun, D.M. Stelescu, D. Ighigeanu, M. Ficai, *Polym. Bull.* **71**, 52 (2014).

[3] R.C. Keller, *Rubber Chem. Technol.* **61**, 238 (1988).

[4] H.G. Dikland, T. Ruardy, L. van der Does, A. Bantjes, *Rubber Chem. Technol.* **66**, 693 (1993).

[5] K.A. Dubey, Y.K. Bhardwaj, C.V. Chaudhari, V. Kumar, N.K. Goel, S. Sabharwal, *Polymer Letters* **3**, 492 (2009).

[6] Z.P. Zagorski, *Radiat. Phys. Chem.* **71**, 261 (2004).