PHYSICAL CHEMISTRY 2016

13th International Conference on
Fundamental and Applied Aspects of
Physical Chemistry

Proceedings
Volume I

B E L G R A D E
September 26 - 30, 2016

ISBN 978-86-82475-34-7
Title: Physical Chemistry 2016 (Proceedings)
Editors: Željko Čupić and Slobodan Anić
Published by: Society of Physical Chemists of Serbia, Studentski trg 12-16, 11158, Belgrade, Serbia.
Publisher: Society of Physical Chemists if Serbia
For Publisher: S. Anić, President of Society of Physical Chemists of Serbia
Printed by: "Jovan", Printing and Publishing Company; 200 Copies.
Number of pages: 6+502; Format B5; printing finished in September 2016

Text and Layout: "Jovan"

200 - *Copy printing*

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13th International Conference on
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Organized by

The Society of Physical Chemists of
Serbia

in co-operation with

Institute of Catalysis Bulgarian Academy of Sciences

and

Boreskov Institute of Catalysis Siberian Branch of
Russian Academy of Sciences

and

University of Belgrade, Serbia:

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THE EFFECT OF γ–IRRADIATION ON MECHANICAL PROPERTIES OF NR/BR/SBR TERNARY RUBBER BLEND REINFORCED WITH CARBON BLACK

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ABSTRACT
In this study the effect of radiation dose on the mechanical properties of ternary NR/BR/SBR (25/25/50) rubber blend reinforced with carbon black (CB) (0–100 phr) has been investigated. The cure characteristics of compounds were assessed using the rheometer with an oscillating disk. The mechanical properties hardness, modulus at 100% elongation, tensile strength and elongation at break were assessed before and after γ-irradiation (100-600 kGy). The vulcanizates were prepared in a hydraulic press. It was estimated that the values for tensile strength increased when the CB content increased up to 80 phr. Tensile strength and elongation at break are decreasinge, but hardness and cross linking density are increasing with the increase of the irradiation dose.

INTRODUCTION
Polymer blend are preparing to meet performance requirement that cannot be satisfied by the current available commodity polymer or properties lacking in the component polymers [1]. Blending of rubbers also enhance the physical properties of the final vulcanized product [2]. The properties of polymer blends can be controlled by regulating blend morphology, compositions and processing condition [3]. A standard tire formulation for trucks as well as cars is a physical blend of natural rubber/styrene-butadiene rubber (NR/SBR) or natural rubber/butadiene rubber (NR/BR) blends. Natural rubber and styrene/butadiene rubber have been blended for a long time for many purposes such as lowering the compound cost [4]. Reinforcement of elastomers is of great importance for the structuring of materials in new technologies, and it is a particularly complicated process if cross linked material contains more than one type of precursor cross linking. By creating a multi-phase system, characteristics of individual phases can be

partly preserved or significantly changed due to the influence of intermolecular interactions. Therefore, the modern research and industrial practice of tire industry leaders are directed towards the use of existing starting polymers and the obtainment of elastomeric materials based on new modified macromolecules. The mechanism of characteristic changes in γ-–ray irradiated polymers, including degradation and cross linking has been studied in lot of publication. Gamma irradiation is also a powerful method for rubber cross linking; however, exposure to higher dosage of final elastomeric products degrades the materials. The cross linking and chain degradation are dependent on chains structural characteristics and the presence of some curing system. The research subject of this study is the multiscale structuring of elastomeric nanocomposites based on different precursors: polyisoprene (NR), polybutadiene (BR) and styrene-butadiene rubber (SBR) and its ternary blend (NR/BR/SBR) and the assessment of the carbon black content on the material mechanical properties before and after γ-–irradiation.

EXPERIMENTAL

Polyisoprene rubber, NR SMR-20 was supplied by Malaysia; polybutadiene rubber, BR SKD N with 94% of 1,4 *cis* content – was supplied by Njižnjekamsk (Russia); Styrene butadiene rubber, SBR Europa Intol 1783, is an emulsion styrene-butadiene rubber with 23.5% bound styrene was supplied by Versalis (Italy). The carbon black type N-330 (primary particle size 28-36 nm) - Volgograd (Russia). Content of filler was 0 - 100 phr. The curing system was: N-cyclohexyl-2-benzothiazolsulfonamide-CBS (1,4 phr); diphenyl guanidine, DPG, (1 phr); N-(cyclohexylthio) phthalimide, CTP 100 (0.2 phr) and sulfur (2 phr). In all rubber blend compounds the network precursor ratio was 25/25/50 (w/w/w). Content of zinc oxide was 3 phr. The stearic acid content was 2 phr. Plastificator as naphthenic oil content was 10 phr. Irradiations have been performed in air in the Co 60 radiation sterilization unit at the Vinca Institute of Nuclear Sciences with the dose rate of 10 kGy h^{-1} and total absorbed dose of 100-600 kGy. The Radiation Unit of the Vinca Institute has been described in more detail elsewhere [5], the facility core is Co-60 gamma irradiator with wet storage working in batch mode (CEA, France).

RESULTS AND DISCUSSION

The essence of cross linking is a chemical reaction between the rubber macromolecules, which in the presence of selected fillers, softeners, activators, curing agents, accelerators and retarders form a crosslink.

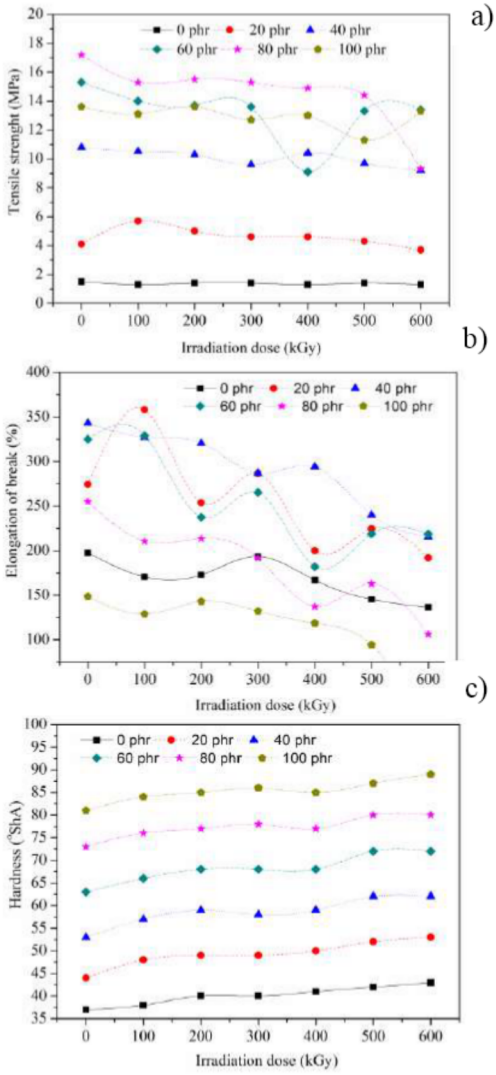

Figure 1. The mechanical properties after irradiation aging of ternary NR/BR/SBR rubber blend reinforced with CB: a) Tensile strength, b) Elongation of break and c) Hardness.

Cross linking of rubber macromolecules represent topologically critical phenomenon, when the ensemble of linear chains forms a three-dimensional crosslink's of macromolecules. The aging experiments conducted under high energy radiation exposure offer useful information for the selection of technological parameters [6]. High-energy radiation is a well-known tool for the modification of polymers. In polymer irradiation, two phenomena occur at the same time: cross-linking and chain scission. The balance of cross linking and scission reactions in polyolefin chains, exposed to high-energy radiation processes that produce free radicals, may result in good properties and new applications. Figure 1. illustrates the variation of the mechanical properties as a function of irradiation dose for unloaded as well as loaded blends.In cross linked materials based on ternary rubber blend, the values of tensile strength increase with CB content increase up to 80 phr. This is also optimum charging for NR/BR/SBR rubber blend. The values of elongation at break increase with the amount of CB increase up to 40 phr (343.3 %), and then decrease.

The tensile strength values attained for unloaded as well as loaded blends increase with irradiation dose reaching its maximum value at 200 kGy for CB filler and then they decrease over any further increase in dose (Figure 1 (a)).

The variation of elongation at break values, as a function of irradiation dose is depicted on Figure 1 (b). As it was expected, the values of elongation at break for filled and unfilled ternary NR/BR/SBR rubber blends decrease with irradiation dose increase. The hardness values of ternary NR/BR/SBR rubber blends composites are increase effectively with the filler content increase (Figure 1 (c)). On the other hand, comparatively a limited increase has been attained for the hardness value for one and the same composition, whether filled or unfilled, with the irradiation dose increase from 100 to 600 kGy.

CONCLUSION

The mechanical properties and service life of rubber blends could be improved using reinforcing fillers and irradiation process to increase crosslinking process. The effect of irradiation dose on mechanical properties (tensile strength, hardness and elongation at break) of the sulphur cured NR/BR/SBR ternary rubber blends have been investigated. NR/ BR/SBR ternary rubber blends with 80 phr CB content have better mechanical properties as compared to compounds with other CB content. For the NR/BR/SBR/80CB blends with increase in irradiation dose up to 200kGy, the tensile strength and elongation at the break decrease, while the hardness increase. Irradiation increase in crosslink density of NR/BR/SBR/80CB ternary rubber blend. At higher filler content and higher irradiation doses a chain degradation process becomes more predominant than cross linking.

Acknowledgment

This work was partially supported by the Ministry for Science and Technological Development of the Republic of Serbia (Projects Num. 45022 and 45020).

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CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

544(082)
66.017/.018(082)
502/504(082)
663/664:658.56(082)
615.31:547(082)

INTERNATIONAL Conference on Fundamental and Applied Aspects of Physical Chemistry (13 ; 2016 ; Beograd)
Physical Chemistry 2016 : proceedings. Vol. 2 / 13th International Conference on Fundamental and Applied Aspects of Physical Chemistry, Belgrade, 26-30 September 2016 ; [editors Željko Čupić and Slobodan Anić]. - Belgrade : Society of Physical Chemists of Serbia, 2016 (Belgrade : Jovan). - IV, 507-930 str. : ilustr. ; 24 cm

Tiraž 200. - Bibliografija uz svaki rad.

ISBN 978-86-82475-33-0

1. Society of Physical Chemists of Serbia (Beograd)
a) Физичка хемија - Зборници b) Наука о материјалима - Зборници c) Животна средина - Заштита - Зборници d) Животне намирнице - Контрола квалитета - Зборници e) Фармацеутска хемија - Зборници
COBISS.SR-ID 225802508

08. 09. 2016