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ISSN 0543-5846
METABK 51 (2) 245-248 (2012)
UDC – UDK 669.14-418:539.37:620.17=111

THE UTILIZE OF GAMMA RADIATION ON THE EXAMINATION OF MECHANICAL PROPERTIES OF POLYMERIC MATERIALS

Received – Primljeno: 2011-07-16
Accepted – Prihvaćeno: 2011-09-18
Preliminary Note – Prethodno priopćenje

The article deals about the application area of radiation crosslinking of plastics, which follows after the injection moulding. The main objective of the presented article is the research of influence irradiation dosage on mechanical properties of materials: PP filled by 15 % of mineral filler – talc. Mechanical properties - tensile strength and impact strength by Charpy were examined in dependence on absorbed dose of the gamma rays on various conditions and were compared with non-irradiated samples. Radiation processing involves mainly the use of either electron beams from electron accelerators or gamma radiation from Cobalt-60 sources.

Key words: plastics, irradiation, crosslinking, mechanical properties, radiation dose

Uporaba gama zračenja u ispitivanju mehaničkih svojstava polimernih materijala. U članku je riječ o području primjene zračenja u poprečnom povezivanju polimera, što slijedi nakon injekcijskog prešanja. Glavni je cilj prezentiranog članka istražiti utjecaj doze zračenja na mehanička svojstva materijala: PP ispunjen s 15 % mineralnog punjenja – milovke. Mehanička svojstva – otpornost na vlak i otpornost na udar po Charpyju bila su ispitivana u ovisnosti o apsorbiranoj dozi gama zraka u raznim uvjetima te su bila uspoređivana s uzorcima koji nisu bili izloženi zračenju. Radijacijska obrada uglavnom uključuje korištenje drugih elektronskih zraka iz akceleratora elektrona ili gama zračenja iz kobalta 60.

Ključne riječi: plastika, zračenje, poprečno povezivanje, mehanička svojstva, doza zračenja

INTRODUCTION

Cross-linking of plastics is a term that we meet in many areas and outside the field of technology too. Radiation cross-linking basically improves plastics in three different ways: it gives them better thermal stability, better abrasion resistance and better resistance to chemical and mechanical influences [1, 2].

The cross-linking of plastics is a chemical process, in which particular molecules of plastics are connected together. In an ideal case, all the molecules will be integrated into the above mentioned grid and the process can be activated by radiation in case of many plastics [3].

Cross linking will be initiated by irradiating with high energy electron beams or gamma rays.

The energy resulting from the irradiation is absorbed by the plastic. The main difference between beta and gamma rays lies in their abilities of penetrating the irradiated material [4].

Gamma rays have a high penetration capacity. The penetration capacity of electron rays depends on the energy of the accelerated electrons. The process takes place at room temperature and under normal pressure. Irradiation takes place after the moulding process [5]. The most important properties of cross-linking systems are tensibility and elasticity, which also remain under long-time temperature and mechanical loading.

The majority of industrial applications of radiation processing are cross-linking of wire and cable insulations, tube, heat shrink cables, composites, moulded products for automotive and electrical industry etc. [6, 7].

EXPERIMENTAL WORK

Material tested in this work was PP Hostacom CR 250 F G61330. Commercial polypropylenes have up to 95 % isotactic content, which means that pendant methyl groups are almost all on the same side of the chain. When polypropylene is exposed to ionizing radiation, free radicals are formed and these cause chemical changes [8]. Material PP Hostacom CR 250 F G61330 – is a material, which is filled by 15 % mineral filler – talc. The used material can be found in automotive, electronics, engineering and consumer industries [9, 10].

To prepare of test samples for the irradiation was necessary to mix granulate materials with different cross-linking agent [11]. It was the type of cross-linking agent. TAIC - Tryallyloxy-1,3,5-triazine.

Test samples enriched by cross-linking agent and test samples without cross-linking agent have been produced by injection moulding technology and were used injection mould with replaceable mould boards. Pro-

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duced test samples were irradiated by gamma radiation in the company BGS Beta-Gamma-Service Gmbh, Saal a.d. Donau, Germany by irradiation dose: 15 kGy and 50 kGy.

After irradiation were carried out selected mechanical properties:

• tensile test,

• Charpy impact test.

Individual tests of test samples were made in the environment - standard ambient, degradation of material after UV radiance.

The test samples were controlled after injection moulding process and after the conditioning time. For evaluation of tensile properties of plastics was made according to STN EN ISO 527-1, 2 and was used sample type 1A for testing. Tensile test was carried out on tensile machine TIRA- test 2300. It was tested in 5 samples of each type of materials in standard ambient and after UV exposure chamber. For evaluation of impact resistance of plastics was made according to STN EN ISO 179 – 1. It was tested in 10 samples of each type of materials in standard ambient and after UV exposure chamber.

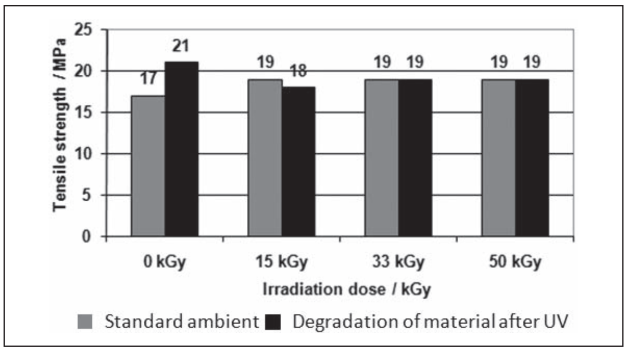

Figure 1 Tensile strength of test samples with different irradiation dose

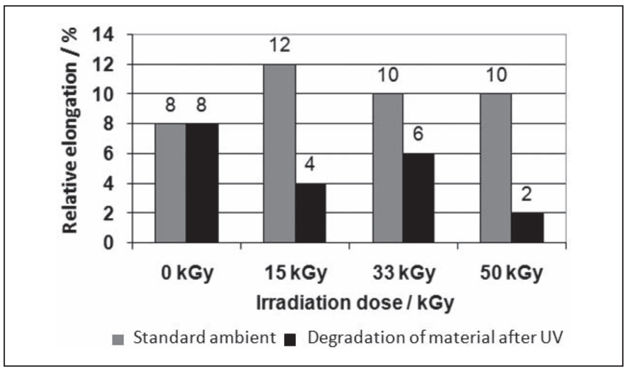

Figure 2 Relative elongation of test samples with different irradiation dose

The test samples were subjected to the tests without notch. Impact strength test was carried out on Charpy hammer type PSW 60/500. It was tested in 10 samples of each type of materials in standard ambient and after UV exposure chamber.

The artificial aging test by fluorescent UV lamps were made in the UV chamber according to STN EN ISO 4892-3, exposure time 28 days at 12 hour cycles for all test materials. The test samples after removal of UV chambers were conditioned according to ISO 291:2008. Afterwards, was performed tensile test and impact strength test by Charpy to detect changes in the properties of the materials after artificial aging by UV fluorescent lamps according to above-mentioned methodology.

ANALYSIS OF THE RESULTS

The graphic dependence of the measured average values of the tensile test of test samples - yield strength of test samples in a standard ambient and degradation in UV chambers, Figure 1.

The graphic dependence of the measured average values of relative elongation of test samples in a standard ambient and degradation in UV chamber, Figure 2.

The fracture areas of test samples after tensile test without exposure and after degradation in UV chamber were observed on scanning electron microscope JEOL JSM - 7000F, Japan.

The fracture areas of test samples of non-irradiated and irradiated materials with different of radiation dose in standard ambient after tensile test were compared, Figure 3. By the influence of cross-linking was observed increasing density of cross-linking. It was created a sufficient number of networked sites. For all test samples there has been a brittle fracture of testing samples.

The spectrum of the chemical composition is shown in Figure 4 confirmed on scanning images of test samples in standard ambient the presence of chemical elements.

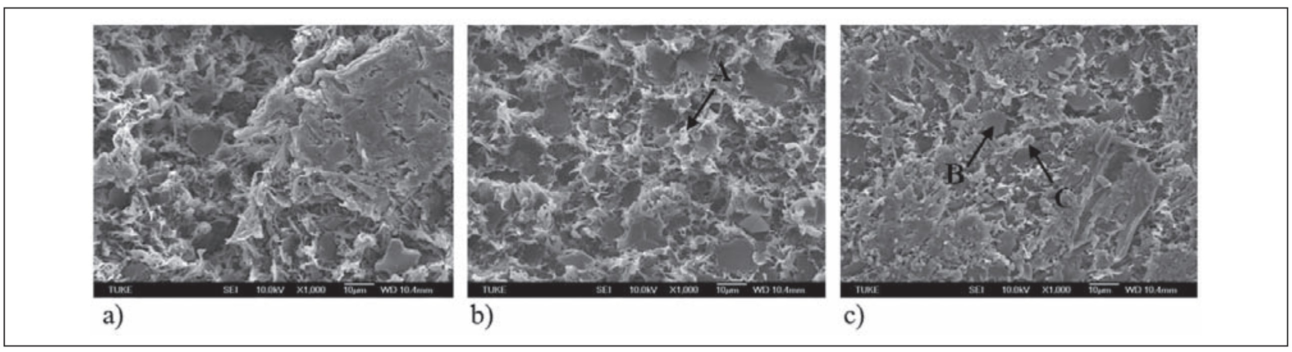

Figure 3 The fracture areas of test samples irradiated by different radiation dose a) test sample non irradiated, b) test sample – 15 kGy, c) test sample – 50 kGy

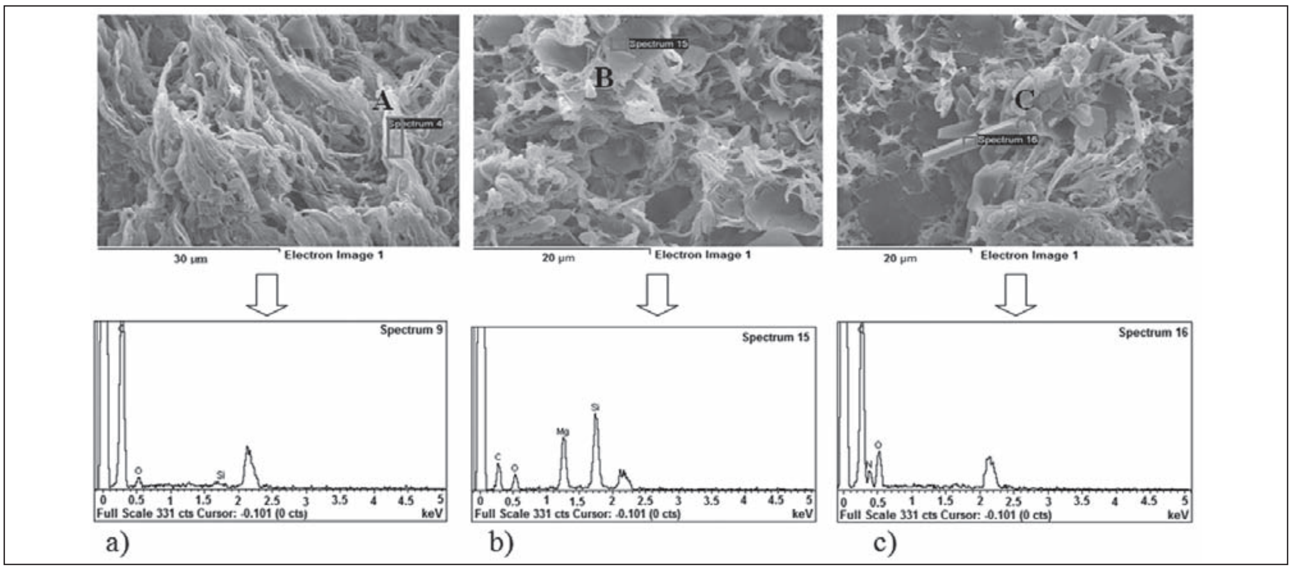

Figure 4 The spectrum of the chemical composition of tested material in standard ambient a) test sample non irradiated, b) test sample – 15 kGy, c) test sample – 50 kGy

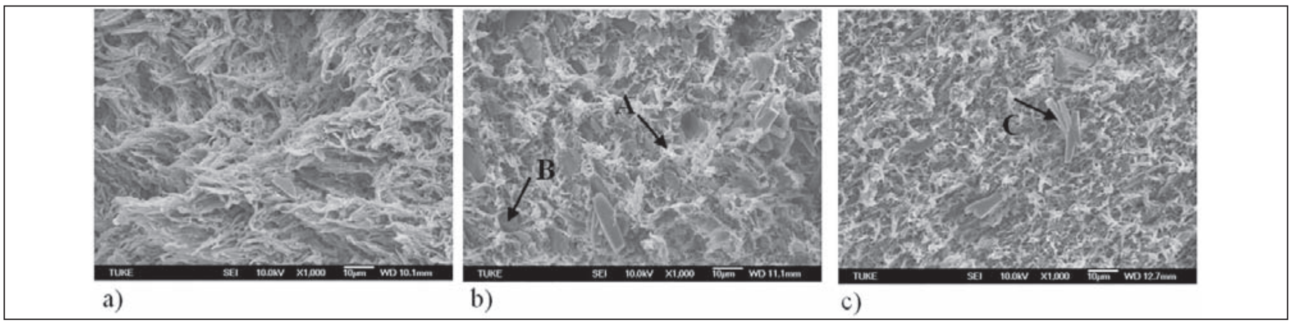

Figure 5 The fracture areas of test samples irradiated by different radiation dose after degradation in UV chamber, a) test sample non irradiated, b) test sample – 15 kGy, c) test sample – 50 kGy µ

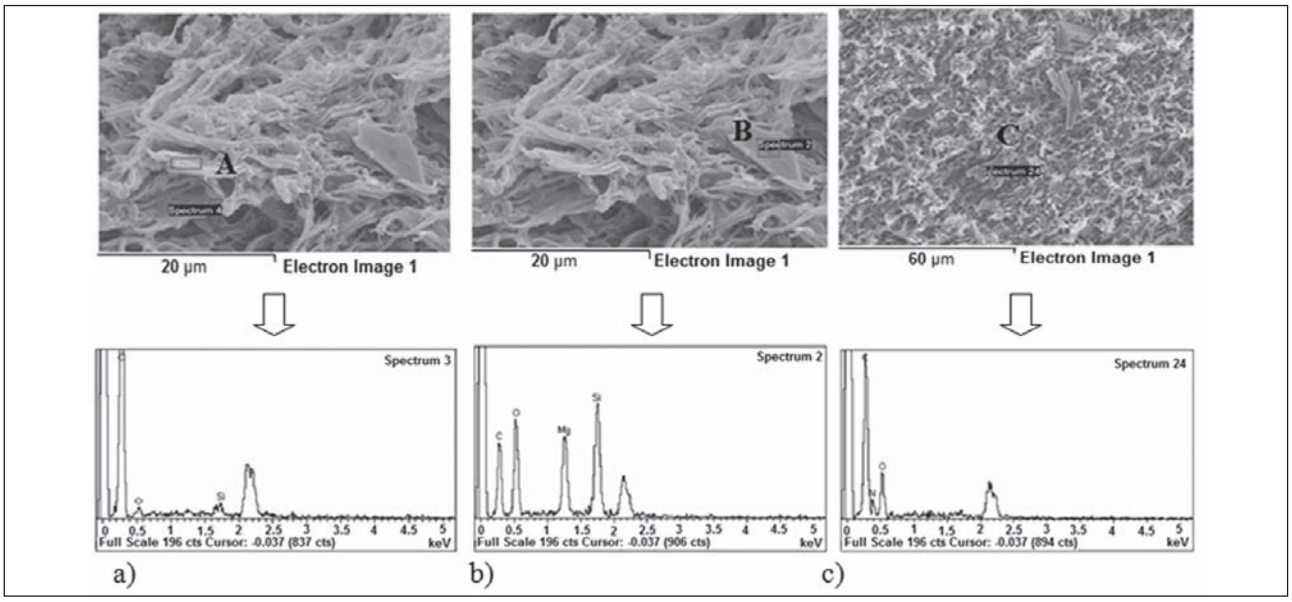

Figure 6 The spectrum of the chemical composition of tested material after degradation in UV Chamber a) test sample non irradiated, b) test sample – 15 kGy, c) test sample – 50 kGy

These were the elements of the polymer - A label, the elements of filler - B label and the elements of cross-linking agent (TAIC) - label C.

The fracture areas of test samples of non-irradiated and irradiated materials with different of radiation dose after degradation in UV chamber after tensile test were compared, Figure 5.

As in the previous case, it is possible to observe a sufficient number of networked sites. Primary radicals are created, that react together in the subsequent chemical reaction. It was created expected connection called link.

The spectrum of the chemical composition is shown in Figure 6 confirmed on scanning images of test samples after degradation in UV chamber the presence of chemical elements. These were the elements of the polymer - A label, the elements of filler - B label and the elements of cross-linking agent (TAIC) - label C [12].

We can state, that the values of tensile strength and relation elongation were influenced by irradiation dose – Figures 1, 2.

After tensile test with material Hostacom CR G61330 250 F G61330 by test samples in standard ambient was found increasing tendency of tensile strength and relation elongation.

The value of tensile strength achieved increasing tendency by irradiated test samples in standard ambient against the base material about 10 %. By irradiated test samples after degradation in UV chamber were achieved the values of tensile strength decreasing tendency. These values were influenced by irradiation dose about 10 – 15 %.

Irradiated test samples in standard ambient had against non-irradiated material progressive tendency of relative elongation.

These values were influenced by irradiation dose about 25 – 50 %. Irradiated test samples after degradation in UV chamber had against non-irradiated material decreasing tendency of relative elongation. These values were influenced by irradiation dose about 25 – 75 %.

The graphic dependence of the impact resistance of test samples with different irradiation dose, Figure 7.

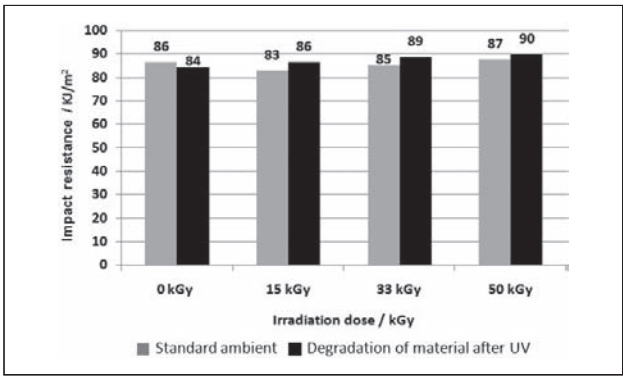

Figure 7 Impact resistance of test samples with different irradiation dose

On the basis of the experimental results could be formulated these results:

- At the material Hostacom CR G61330 250 F G61330 is not explicit influence of radiation dose to the impact resistance.
- The increasing tendency of value was recorded in irradiated test samples after degradation in UV chamber.
- The highest values of parameter of irradiated test samples were evaluated at 50 kGy radiation dose.

CONCLUSION

Obtained knowledge in this paper are only parts of the general problem of possible applications of plastics cross-linking. As the automotive industry using a wide range of plastics, it would be suitable to extend the experiments to other materials and monitoring of other properties such as:

- bonding – gluing and coating (adhesion improvement),
- the influence on welding property,
- thermo-analyses, recycling of cross-linked plastics.

Acknowledgements

This paper is the result of the project implementation: Center for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS:26220120060) supported by the Research &Development Operational Programme funded by the ERDF and KEGA 263-049TUKE-4/2010.

REFERENCES

[1] Z. Brocka, Strahlenvernetzte Kunstoffe Verarbeitung, Eigenschaften, Anwendung, Springer VDI Verlag, Düsseldorf. 2006, pp. 1 – 30.
[2] D. Manas, M. Manas, M. Stanek, M. Danek, Materials Science and Engineering, 32 (2008), 2, 69-76.
[3] A. Zyball, Radiation Processing of Polymers. In: Emerging applications of radiation processing, IAEA-TECDOC-1386, Vienna, 2004 pp. 117–125.
[4] Gamma irradiatiors for radiation processing, International atomic energy agency, Vienna, Austria, pp.1 – 40.
[5] B. Tauzin, L. Hermitte, S. Ponsart, European Cells and Materials 11 (2006), 2, 34.
[6] I. Pucić, Polimeri, 30 (2009), 4, 193 – 204.
[7] Kunstoff Magazin: Hart im Nehmen Strahlenvernetzung für hohe Temperaturen, 2009, pp. 46 – 47.
[8] J. G. Drobny, Radiation Technology for polymers, New York. New York. 2003, pp. 63 – 85.
[9] S. Shukushima, H. Hayami: Radiation Physics and Chemistry, 60 (2001), 4 - 5, 489 – 493.
[10] R. J. Woods, A. K. Pikaev: Applied Radiation Chemistry: Radiation Processing, New York. New York, 1994, pp. 13 – 20.
[11] D.W. Auhl, Molekulare Struktur und rheologische Eigenschaften strahlenmodifizierter Polypropylene, Dissertation, Universität Erlangen-Nürnberg, 2006, pp. 56 – 65.
[12] J. Varga, The influence of radiation crosslinking on mechanical properties of plastic parts, PhD thesis, Košice, 2009, pp. 100 – 140.

Note: The responsible for English language is Helena Mazúrová, Technical University of Košice.