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STRUCTURES OF HDPE/GaAs AND HDPE/GaAs<Te> COMPOSITES IRRADIATED WITH GAMMA QUANTA

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The results of optical studies of structural changes in composite HDPE/GaAs and HDPE/GaAs<Te> films irradiated with gamma quanta at doses of 100, 200, and 300 kGy at room temperature are presented. It was found that gamma irradiation of the initial polymer and their composite films leads to the formation of optical absorption bands at 220 and 280 nm, indicating the formation of C = 0 and –C = C-bonds. It was established that composite HDPE/GaAs<Te> films are the most radiation-resistant in the absorbed dose range of 100…300 kGy.

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INTRODUCTION

Polymer composite materials such as polymer-semiconductor filler are of special interest. Usually, new fillers lead to the expansion of the practical usability of the composite material. The addition of semiconducting fillers into the polymer matrix leads to changes in its structure and properties. From this aspect, it is important to study the composites obtained on the basis of high-density polyethylene (HDPE) and GaAs and GaAs<Te> semiconductor compounds. Using these materials as modifying additives for polymers can lead to the production of new composites with different electrophysical, dielectric, thermal, optical luminescent and mechanical properties. It should be noted that there is not enough scientific information on the study of these composites in the literature [1–4].

Currently, radiation technologies are widely used to improve the physical and chemical properties of the polymer and its composite materials in high-tech applications. Ionization radiation leads to irreversible physical and chemical changes in the structure of these materials at the macromolecular level. Obtaining a data package of structural changes and properties of polymer-semiconductor composite systems under the influence of ionizing gamma radiation will allow the development and production of multifunctional composites. This will allow to develop and obtain new polymer composite materials with desired properties of electronic devices and systems, and will also allow to make new special types of electrical insulation systems, high-voltage technologies. These materials also allow to create effective radiation protection. These materials also provide effective adiation protection of space vehicles, navigation devices, and instrument panels of special devices operating in a high radiation background.

The fact that HDPE is taken as a matrix is due to its much study. Taking GaAs and GaAs<Te> semiconductors as fillers is due to the fact that these semiconductors have a special structure. In addition, GaAs <Te> is more resistant to radiation than GaAs.

Investigations of structural changes of HDPE/GaAs and HDPE/GaAs<Te> composites, optical and electrophysical properties were studied depend on concentrate of fillers. However, structural changes in these composites due to the influence of gamma rays have not been sufficiently studied. Therefore, this paper presents the results of optical studies of structural changes in HDPE/GaAs and HDPE/GaAs<Te> composites irradiated with gamma quanta.

TECHNIQUE OF EXPERIMENTS

As a polymer matrix powdered PE 2 NT11-285D high density polyethylene (Russia, Kazan) with melting point of 130 °C and a density of 947 kg/m^3 was selected. As fillers, GaAs and GaAs<Te> semiconductors are used. HDPE, HDPE/GaAs, and HDPE/GaAs<Te> films were obtained by the method described in [3].

HDPE, HDPE/GaAs and HDPE/GaAs<Te> films a thickness of about 100 μm were irradiated by gamma radiation on a MRX-γ-20 (^{60}Co) gamma-device with exposure rate $d\Phi/dt = 1.06$ Gy/s. The samples were exposed to various irradiations up to doses of 100, 200, and 300 kGy at room temperature.

The optical transmission and absorption spectra of this films were measured in UV-VIS Spectrophotometer Varian-Cary 50 Scan in the of range wavelength (200…800 nm). The spectra were obtained for the polymers and composites absorbance as a function of wave number.

The variation before and after irradiation was compared and the peak analysis was done to study the variation in position and relative intensity of the bands.

RESULTS AND DISCUSSION

Figs. 1–3 show the optical (UV-VIS) absorption spectra of initial (unirradiated) and gamma irradiated HDPE polymer, HDPE/ 4 mass% GaAs and HDPE/4 mass% GaAs<Te> composites. The choice of the mass content of microparticles (4 mass%) of GaAs and GaAs<Te> is because of these content the degree of crystallinity has a same value [1].

From Figs. 1–3 it is clear to see that the unirradiated HDPE polymer and its composites has not absorption bands in the studied wavelength range (λ=200…800 nm). On the other hand, spectra of irradiated HDPE polymer (see Fig. 1) and HDPE/GaAs composite films showed a shoulder band in ~ 220 nm. This band is attributed to the C=O group in molecular macromolecule (ketones). This indicates that the band gap width decreases with irradiation and the absorption coefficient value increases with irradiation [5–8].

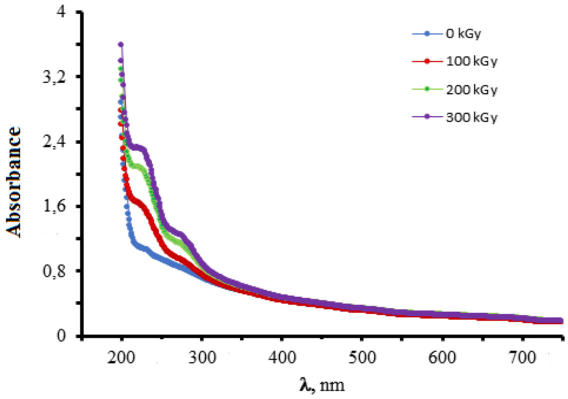

Fig. 1. Absorption spectra of initial and gamma irradiated HDPE polymer

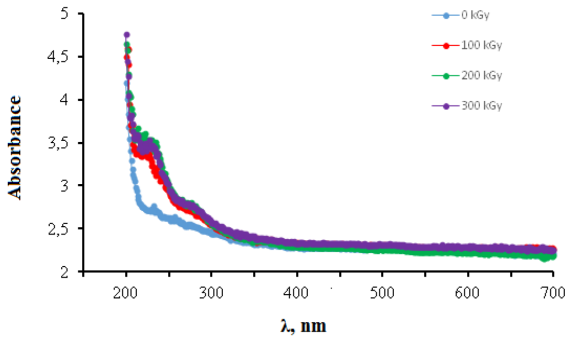

Fig. 2. Absorption spectra of initial and gamma irradiated HDPE/GaAs composites

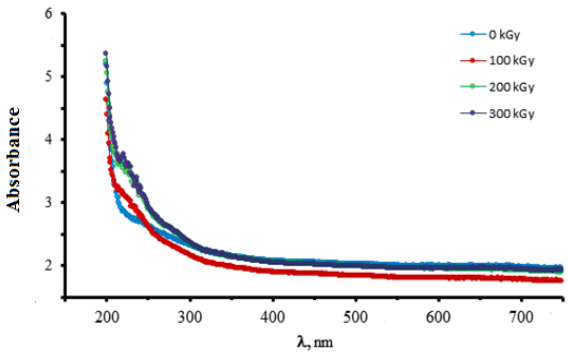

Fig. 3. Absorption spectra of initial and gamma irradiated HDPE/GaAs<Te> composites

It should be noted that the absorption band shifts towards longer wavelength with increasing gamma irradiation dose. Gamma irradiation induced the cleavage of C-C-bond and dehydrogenation of polymeric chains (i.e. escape of hydrogen atoms) and this resulted to the production of conjugated –C=C- bonds (λ=280 nm). The increase in the number of conjugated –C=C-bond with increasing gamma dose irradiation results in a shift of the absorption band towards longer wavelength side. The behavior is generally interpreted as caused by the formation of extended systems of conjugate bonds i.e. possible formation of carbon clusters [9–13]. The absorption bands in ~ 280 nm are associated to the electronic $\pi\rightarrow\pi^*$ transitions occur in the unsaturated centers of the molecules i.e. in compounds containing double or triple bands and also in aromatics. The excitation of π-electron requires smaller energy and hence, transition of this type occur at longer wavelength.

For HDPE irradiated with gamma quanta at 1.2 MeV, they detected new bands at 1650 and 1735 cm^{-1}, attributed to –C=C-formation and polymer oxidation (formation of carbonyl group C=O) [14].

We have obtained dose dependences of the intensities of the optical absorption bands C=O and –C=C- in HDPE (1), and composites HDPE/GaAs (2), and HDPE/GaAs<Te> (3) (Fig. 4).

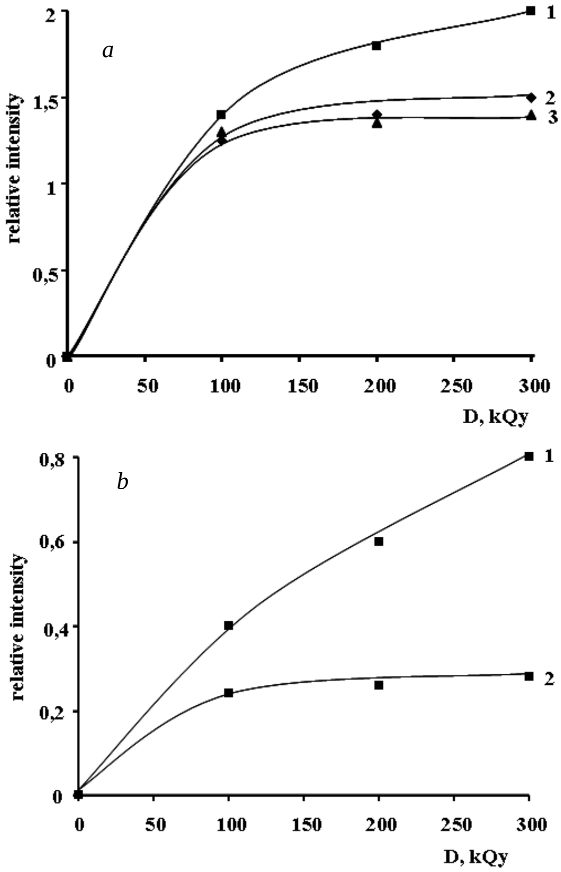

Fig. 4. Dose dependences of the intensity of optical absorption bands at λ = 220 nm (a) and λ = 280 nm (b)

It should be noted that radiation changes in the structure of HDPE/GaAs<Te> composites caused by the influence of gamma irradiation occur only at a dose of 300 kGy (see Fig. 4). These changes are accompanied by the appearance of a weak shoulder in the absorption spectra at λ=220 nm. At the same time, the absorption band at λ=280 nm is absent in the spectra.

Analysis of these dependencies shows that composites are more radiation resistant compared to pure polymer. Among composites, the most radiation resistant are HDPE/GaAs<Te>. Since, in the optical spectra of this composite, the absorption band at λ~220 nm is blurred, and the band at λ~280 nm is completely absent.

CONCLUSIONS

For the first time, structural changes caused by the influence of gamma irradiation of initial HDPE and in HDPE/GaAs and HDPE/GaAs<Te> composites at doses of 100, 200, 300 kGy at room temperature were studied. It has been shown that gamma irradiation of these composites leads to the formation of optical absorption bands at 220 and 280 nm. These absorption bands belong to C=O and –C=C-bonds. Analysis of the intensities of these bands depending on the gamma irradiation dose indicates that, in the absorbed dose range of 100…300 kGy, the HDPE/4 mass% GaAs<Te> composite has a higher radiation resistance.

REFERENCES

1. M.I. Aliev, N.N. Gadzhieva, G.B. Ahmadova. Fourier-IR study of the high-density polyethylene composites with semiconductor fillers GaAs and GaAs // *International Journal of Composite Materials*. 2014, N 1, p. 1-3.

2. M.I. Aliev, N.N. Gadzhieva, G.B. Ahkmedova. A Fourier Transform Raman Spectroscopic Study of the Structures of Polyethylene Composite Films Containing GaAs and GaAs<Te> // *Polymer Science*. *Series A.* 2016, v. 58, N 3, p. 438-442.

3. N.N. Gadzhieva, G.B. Ahmadova. Effect of γ-irradiation on the structure of high-density polyethylene composites with GaAs and GaAs<Te> fillers // *PAST*. 2020, N 4(128), p. 28-30.

4. N.N. Gadzhieva, G.B. Ahmadova S.Z. Melikova, F.G. Asadov. X-ray diffractometric study of HDPE/GaAs and HDPE/GaAs<Te> composites // *Physics and Chemistry of Solid State.* 2023, v. 24, N 1, p. 23-25.

5. D.E. Abulyazied, E.F.M. El-Zaidia. Nanoindentation and optical properties of high-density polyethylene/ZnO nanoparticles composites // *Journal of Ovonic Research.* 2018, v. 14, N 5, p. 359-370.

6. A.M. Abdul-Kader. The optical band gap and surface free energy of polyethylene modified by electron beam irradiations // *Journal of Nuclear Materials.* 2013, v. 435, p. 231-235.

7. E.A. Kamoun, O.I. Sallam, E.E. Khozemy, M. Morsy, Y. Al-Faiyz, S.M. Matar, A.I. Ali, J.Y. Son, G.H. Ramzy. Effect of gamma irradiation on the electrical and optical properties of PEVA composite membrane embedded with conductive copper fluoroborate glass powder // *The Royal Society of Chemistry*. 2024, N 5, p. 5658-5670.

8. I.I. Mustafayev, S.Z. Melikova, E.G. Hajiyeva, R.I. Gasimov, M.A. Bayramov, N.I. Babayeva. Spectral investigations of γ-irradiated polyethylene/CdS+ZnS composite films // *Acta Physica Polonica A.* 2023, v. 144, N 1, p. 35-37.

9. M.K. Ismayilova, I.I. Mustafayev, S.Z. Melikova, F.N. Nurmammadova, M.H. Aliyeva. The studies on dehydration reaction mechanism of irradiated solid acid-nanostructured sodium-bentonite clay // *Physics and Chemistry of Solide State.* 2024, v. 25. N 2, p. 362-367.

10. R.M. Sardarly, F.T. Salmanova, N.A. Alieva. Type of Optical Transitions at the Fundamental Absorption edge in $TlGaSe_2$ and $TlInS_2$ crystals subjected to qamma radiation // *Optics and Spectroscopy.* 2019, v. 127, N 3, p. 454-458.

11. R.K. Dhillion, P. Singh, S.K. Gupta, S. Singh, R. Kumar. Study of high energy (MeV) N^{6+} ion and gamma radiation induced modifications in low density polyethylene (LDPE) polymer *// Nuclear Instruments and Methods in Physics Research B.* 2013, v. 301, p. 12-16.

12. A.A. Moez, S.S. Aly, Y.H. Elshaer. Effect of gamma radiation on low density polyethylene (LDPE) films: optical, dielectric and FTIR studies // *Spectrochimica Acta Part A – Molecular and Biomolecular Spectroscopy*. 2012, v. 93, p. 203-207.

13. S.K. Raghuvanshi, B. Ahmad, A.K. Srivastava, J.B.M. Krishna, M.A. Wahab. Effect of gamma irradiation on the optical properties of UHMWPE (Ultra-high-molecular-weight-polyethylene) polymer // *Nuclear Instruments and Methods in Physics Research B.* 2012, v. 271, p. 44-47.

14. A.A. Nabiyev, A. Oleyniczak, A. Pawlukajc, et al. Nano-ZrO_2 filled high-density polyethylene composites: structure, thermal properties, and the influence γ-irradiation // *Polymer Degradation and stability.* 2020, v. 171, p. 109042.

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СТРУКТУРА КОМПОЗИТІВ ПЕВП/GaAs І ПЕВП/GaAs<Te>, ОПРОМІНЕНИХ ГАММА-КВАНТАМИ

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Представлено результати оптичних досліджень структурних змін композитних ПЕВП/GaAs- та ПЕВП/GaAs<Te>-плівок, опромінених гамма-квантами до доз 100, 200 та 300 кГр при кімнатній температурі. Виявлено, що гамма-опромінення вихідних полімерних та композитних плівок призводять до утворення смуг оптичного поглинання при ~ 220 і 280 нм, що свідчить про утворення C = O та –C = C-зв'язків. Встановлено, що композитні плівки ПЕВП/GaAs є найбільш радіаційно стійкими в області поглиненої дози 100…300 кГр.