EFFECT OF γ-IRRADIATION ON THE STRUCTURE OF HIGH DENSITY POLYETHYLENE COMPOSITES WITH GaAs AND GaAs<Te> FILLERS

N.N. Gadzhieva[1], G.B. Akhmedova[2]

[1]Institute of Radiation Problems, Azerbaijan National Academy of Sciences, Baku, Azerbaijan;

[2]Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

E-mail: gunayehmedova12@gmail.com

IR-Fourier spectroscopy was used to study structural changes in γ-irradiated high density polyethylene composites with GaAs and GaAs<Te> semiconductor fillers at room temperature. From the dose dependence of the crystallinity degree of the HDPE/GaAs and HDPE/GaAs<Te> composites, it was found that the HDPE/GaAs<Te> composites are more radiation-resistant in the absorbed dose region Φ_γ = 5…150 kGy compared to the HDPE/GaAs composites. The observed change in the degree of crystallinity is associated with a change in the supramolecular structure of γ-irradiated composites.

PACS: 541.183:539.26; 537.84:621.315.92

INTRODUCTION

The preparation of new polymer composites largely depends on the nature of the filler, the shape, size, nature of the distribution of particles and the degree of interaction between the constituent components [1, 2]. Typically, new fillers lead to more practical applications of the composite material. From this point of view, polymer composite materials such as polymer-semiconductor fillers are of particular interest. The introduction of semiconductor fillers in a polymer matrix leads to a modification of its structure and properties [3–6]. In this aspect, composites based on high density polyethylene (HDPE) with semiconductor compounds GaAs and GaAs<Te> are of interest. This is due to the fact that these semiconductors have a peculiar crystalline and band structure and are promising materials in micro and optoelectronics. HDPE-GaAs composite films are widely used as neutron detectors [7, 8]. Therefore, it seems interesting to study the effect of radiation, in particular, γ-radiation on the structure of composites HDPE-GaAs and HDPE-GaAs<Te>. Note that in the literature there is virtually no information on the HDPE-GaAs and HDPE-GaAs<Te> composites. Such studies were first conducted by us and their results are reflected in [9]. Based on optical, IR-Fourier, and Raman-Fourier spectroscopic studies, it was shown that a change in the absorption coefficient and crystallinity of the polymer is interconnected with a change in its supramolecular structure.

This work is a continuation of the cycle of these studies and is devoted to studying the effect of γ-radiation on the structure of composite films of HDPE-GaAs and HDPE-GaAs<Te> by IR-Fourier spectroscopy. This method allows you to follow the structural changes due to the introduction of a microparticle into the composition of the polymer matrix, and to identify the patterns associated with them [10, 11].

TECHNIQUE OF EXPERIMENTS

In this work, a homogeneous mixture was prepared by mechanical mixing from HDPE powders and GaAs and GaAs<Te> semiconductors (with particle sizes of ~ 50 μm). Then it was subjected to hot pressing at T = 413 K with a holding time of 15 min and cooled to room temperature for 30 min. This method allows to obtain HDPE films with a uniform distribution of microparticles in the volume of the polymer, which is important for optical and spectral studies. The uniform distribution of microparticles in HDPE films was controlled by the background of the IR-Fourier absorption spectra. The thickness of the initial and γ-irradiated composite films was d = 50…100 μm. The content of the introduced amount of GaAs and GaAs<Te> microparticles varied from 1 to 10 mass%. For the study, samples with a maximum crystallinity of HDPE-2 mass % GaAs and HDPE-6 mass% GaAs<Te> were selected. The choice of these samples is due to the fact that the degree of crystallinity reaches a maximum at these concentrations [12].

The IR-Fourier absorption spectra of the composites before and after γ-irradiation were recorded on a Varian 640 FT-IR spectrometer at room temperature in the region of wave numbers 4000…400 cm^{-1}. Structural changes in the initial and γ-irradiated composite films were observed in the region of wave numbers ν = 750…700 cm^{-1}, corresponding to pendulum vibrations of the CH_2 group of PE.

The degree of crystallinity of the samples was calculated taking into account optical densities, according to the expression

$$K = \frac{1.4 \cdot (D_{730}/D_{720})}{1 + 0.4(D_{730}/D_{720})}$$

the 730 cm^{-1} band characterizes crystalline regions, and the 720 cm^{-1} band characterizes crystallites+amorphous interlayers [13].

Samples were irradiated with γ-quanta from a ^{60}Co source at room temperature with a dose rate $d\Phi_\gamma/dt$ = 1.06 Gy/s. At the same time, the absorbed dose was Φ_γ = 5…150 kGy.

RESULTS AND ITS DISCUSSION

Fig. 1 show, as an example, the IR-Fourier absorption spectra of unirradiated composites HDPE-2 mass % GaAs and HDPE-6 mass % GaAs<Te> (curves 1) and irradiated γ-rays with a dose of 75 kGy (curves

2) and 150 kGy (curves 3). The choice of the mass content of microparticles (2 and 6 mass %) of GaAs and GaAs<Te> is due to the fact that in these contents the degree of crystallinity has a maximum value [9, 12].

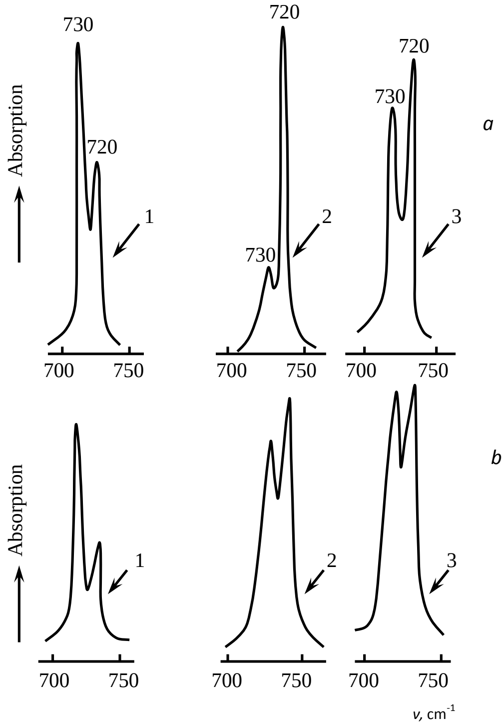

Fig. 1. IR-Fourier spectra of the initial (1) and γ-irradiated dose of 75 (2) and 150 kGy (3) of HDPE/GaAs composites (a) and of HDPE/GaAs<Te> composites (b)

As can be seen from Fig. 1, with an increase in the absorbed dose, the intensities of absorption bands with maxima of 730 and 720 cm^{-1} are redistributed. It is seen that in polymer composite films, the intensities of the IR bands of crystalline – 730 and amorphous – 720 cm^{-1} phases change as compared to the intensities of the bands of the initial unirradiated films. changes in K_{irrad}/K_{init} values for HDPE/GaAs composites (curve 1).

The dose dependences of the relative degree of crystallinity of K_{irrad}/K_{init} in the absorbed dose range Φ_γ = 5…150 kGy of HDPE/GaAs and HDPE/GaAs<Te> composites are shown in Fig. 2.

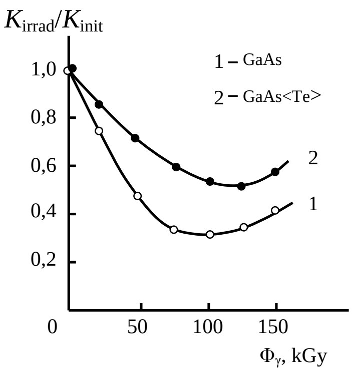

Fig. 2. Dose dependences of the relative crystallinity of the HDPE/GaAs (1) and HDPE/GaAs<Te> (2) composites

As can be seen from the figure, the K_{irrad}/K_{init} values for HDPE/GaAs and HDPE composites/GaAs<Te> with an increase in the absorbed dose to Φ_γ = 80 kGy decrease. The dose dependence consists of a linear (Φ_γ = 5…100 kGy) region. In this case, the rate of change of K_{irrad}/K_{init} values for HDPE/GaAs composites (curve 1) is ~ 1.4 times higher than the rate of change of K_{irrad}/K_{init} values for HDPE/GaAs<Te> composites (curve 2). At values Φ_γ = 80…150 kGy, the $K_{irrad}/K_{init} = f(\Phi_\gamma)$ curve goes to saturation. Comparison of dose dependences indicates that HDPE/GaAs<Te> composites are more radiation-resistant than HDPE/GaAs composites.

The observed features are associated with the formation of radiation defects in the HDPE matrix and a change in the interaction at the interface. Due to changes in interfacial interaction, the supramolecular structure (SMS) of the polymer changes [13]. The active centers created in the matrix after γ-radiation interact with the surface of gallium microarsenide GaAs and gallium microarsenide GaAs doped with tellurium (GaAs<Te>), which leads to a change in the degree of crystallinity and, accordingly, the structure of the composites.

CONCLUSION

The possibility of using IR-Fourier spectroscopy for structural changes in polymer composite materials with semiconductor microparticles when exposed to γ-radiation is shown. From the dose dependence of the relative crystallinity of the HDPE/GaAs and HDPE/GaAs<Te> composites, it was found that the HDPE/GaAs<Te> composites are more radiation-resistant in comparison with the HDPE/GaAs composites in the region of the absorbed dose Φ_γ = 5…150 kGy. The observed change in the degree of crystallinity is associated with a change in the supramolecular structure of γ-irradiated composites.

REFERENCES

1. M.F. Galikhanov, D.A. Eremeev, R.Y. Deberdeev. Elektret effects in compounds of polystyrene with aerosol // *Russian Journal of Applied Chemistry*. 2003, v. 76, N 10, p. 1651-1654.

2. L.I. Trachtenberg, G.N. Gerasimov, V.K. Potanin. Nanocomposite metal-polymer films: sensory, catalytic, and electrophysical properties // *Bulletin of Moscow University*. 2001, v. 42, N 5, p. 325-331.

3. E.G. Efendiev, N.N. Gadzhieva, T.M. Ilyasly, R.F. Abbasova, F.F. Yakhyaev. Structure of polyethylene films containing copper nanoparticles // *Journal of Applied Spectroscopy*. 2006, v. 73, N 3, p. 462-465.

4. E.M. Godjayev, A.M. Magerramov, Sh.A. Zejnalov, S.S. Osmanova, E.A. Allahjarov. Coronoelectrets based on high density polyethylene composites with a semiconductor filler $TlGaSe_2$ // *Surface engineering and applied electrochemistry*. 2010, N 6, p. 91-96.

5. H.A. Mamedov, L. Parali, M.A. Kurbanov, A.A. Bayramov, F.N. Tatardar, I. Sabikoglu. Piezoresistive and posistor effects in polymer-semiconductor and polymer-ferropiezoceramic composites // *Physics of the Solid State*. 2016, v. 50, N 5, p. 633-638.

6. A.M. Magerramov, R.S. Ismayilova, M.A. Nuriyev, A.A. Nabiyev. Dielectric properties of nanocomposites based on ultra-high molecular weight polyethylene and α-SiO_2 // *Plasticheskie massy*. 2019, N 1-2, p. 6-9 (in Russian).

7. D.S. McGregor, R.T. Klann, H.K. Gersch, Yang Hong Yong. Thin-film-coated bulk GaAs detectors for thermal and fast neutron measurements // *Nuclear Instruments and Methods. A.* 2001, v. 466, p. 126-141.

8. D.S. McGregor, S.M. Vernon, H.K. Gersch, S.M. Markham, S.I. Wojczuk, D.K. Wehe. Self-biased Boron-10 coated high purity epitaxial GaAs thermal neutron detectors // *IEEE Transactions on Nuclear Science*. 2000, v. 47, N 4, p. 1364-1370.

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

10. D.F. Rustamova, A.M. Magerramov, Kh.V. Bagirbekov, M.A. Nuriyev. Dielectric properties and radiothermoluminescent features of polypropylene/ α-Al_2O_3 highly filled compositions // *Surface Engineering and Applied Electrochemistry.* 2013, v. 49, N 2, p. 176-178.

11. I.M. Nuriyev, A.M. Magerramov, R.N. Mekhtiyeva, M.A. Nuriyev. The effect of gamma-radiation on the dielectric properties of composite materials PE + x% by volume $TlGaSe_2$ // *Surface engineering and Applied Electrochemistry.* 2018, v. 54, N 4, p. 14-19.

12. 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.

13. A.M. Magerramov. *Structural and Radiation Modification of Electret, Piezoelectric Properties of Polymer Composites.* Baku: “Elm”, 2001, p. 327.

Article received 01.06.2020

ВЛИЯНИЕ γ-ОБЛУЧЕНИЯ НА СТРУКТУРУ КОМПОЗИТОВ ПОЛИЭТИЛЕНА ВЫСОКОЙ ПЛОТНОСТИ С НАПОЛНИТЕЛЯМИ GaAs И GaAs<Te>

Н.Н. Гаджиева, Г.Б. Ахмедова

Метод ИК-фурье-спектроскопии применен при изучении структурных изменений в γ-облученных композитах полиэтилена высокой плотности (ПЭВП) с полупроводниковыми наполнителями GaAs и GaAs<Te> при комнатной температуре. По дозовой зависимости степени кристалличности композитов ПЭВП/GaAs и ПЭВП/GaAs<Te> установлено, что композиты ПЭВП/GaAs<Te> по сравнению с композитами ПЭВП/GaAs являются более радиационно стойкими в области поглощенной дозы Φ_γ = 5…150 кГр. Наблюдаемые изменения степени кристалличности связаны с изменением надмолекулярной структуры γ-облученных композитов.

ВПЛИВ γ-ОПРОМІНЕННЯ НА СТРУКТУРУ КОМПОЗИТІВ ПОЛІЕТИЛЕНУ ВИСОКОЇ ЩІЛЬНОСТІ З НАПОВНЮВАЧЕМ GaAs І GaAs<Te>

Н.Н. Гаджиєва, Г.Б. Ахмедова

Метод ІЧ-фур'є-спектроскопії застосовано при вивченні структурних змін у γ-опромінених композитах поліетилену високої щільності (ПЕВЩ) з напівпровідниковими наповнювачами GaAs і GaAs<Te> при кімнатній температурі. За дозовою залежністю ступеня кристалічності композитів ПЕВЩ/GaAs і ПЕВЩ/GaAs<Te> встановлено, що композити ПЕВЩ/GaAs<Te> у порівнянні з композитами ПЕВЩ/GaAs є більш радіаційно-стійкими в області поглиненої дози Φ_γ = 5...150 кГр. Спостережувані зміни ступеня кристалічності пов'язані зі зміною надмолекулярної структури γ-опромінених композитів.