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INVESTIGATION OF STRUCTURAL CHANGE OF HDPE/α-Fe_2O_3 COMPOSITE SYSTEM MODIFIED BY GAMMA RAYS BY THE INFRARED-FOURIER SPECTROSCOPY

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Abstract: Structural changes in HDPE/(1-5%)α-Fe_2O_3 composite systems under the influence of γ-irradiation were studied by IR-Fourier spectroscopy. It was found that regardless of the concentration of the α-Fe_2O_3 oxide filler, there was no strong change in the spectra, and the effect of γ-irradiation on the system with this composition is also weak. Thus, it was determined by the IR-Fourier spectroscopy that the structure of samples of HDPE/(1-5% volume) α-Fe_2O_3 composite system is more resistant to the effect of γ-radiation (up to 500 kGy) based on the bands of $-CH_3$, $-CH_2$, etc. groups in the spectrum.

Keywords: Fourier, polymer, composite, spectroscopy, infrared, structure, gamma radiation, spectrum

1. Introduction

In modern times, in the development of electronics technology, the production and application of polymer composite materials (PCM) are relevant from the point of view of reducing the size of electronic devices, transitions of technologies to a molecular level that allow performing complex functions of targeted transfer of electric charges and energy. At present, in the technique of heterogeneous systems, certain questions arise about their physical properties and the stability of these properties, several problems related to both the theoretical description and the application of such heterogeneous systems are understudied or even unknown. [1, 5]. The metastability of electrical parameters of composite materials places serious limits on the possibilities of operation of composite materials, including in electronic devices. However, the expansion of the practical use of polymer composite materials is limited by the lack of accurate information about the adhesion between particles and the matrix, interphase interaction, the mechanism of transfer of charge carriers, the role of electron-ion and polarization processes of the interphase boundary in the formation of their active properties. It should also be noted that the modification of polyolefins with fillers and then with high-energy rays (e^-, γ, and -UV) enables the creation of materials with new properties. Materials with new properties are widely used in chemical, atomic, space, construction, electronic, radio engineering, and other fields of industry [1].

It is known that Fourier-IR spectroscopy has an indispensable role in studying the structures of polymer-based composite materials. This method allows the monitoring of structural changes in composites under the influence of external factors (irradiation, temperature, etc.) [2, 4]. In this study, the changes in the HDPE/(1-5%)α-Fe_2O_3 structure of the obtained composites under the influence of γ-irradiation were studied by Fourier-IR spectra.

The method of obtaining composite samples.

High-density polymer (HDPE) was used as a matrix and α-Fe_2O_3 (hematite) oxide as a filler in the preparation of composite samples.

The technology of obtaining composite samples is performed using the following operations:

- materials used as filler are sieved;
- the volume fraction of fillers was 1-5%;
- HDPE matrix and α-Fe_2O_3 (hematite) filler are mixed together in a porcelain container;
- composite samples with a thickness of 50-170 μm and a diameter of 20-40 mm are obtained from this homogeneous mixture by keeping it in a hydraulic press at a pressure of 15 MPa at a temperature of 423 K for 5 minutes;
- samples were provided with reliable electrical contacts consisting of thin 7 μm aluminum foil.
- the obtained samples are immediately cooled in a water-ice mixture.

IR-Fourier spectroscopy was used to study the structural properties of materials. The study of molecular spectra of polymer and polymer composite samples before and after γ-irradiation (oscillation and rotation) was carried out in the Varian 640-IR FT spectrophotometer at room temperature in the range of 400-4000 cm^{-1}. For this, the IR-Fourier spectra of the initial sample (HDPE) and HDPE/α-Fe_2O_3 composite samples are given in Fig. 1-4.

As can be seen from Figure 1, the 730 cm^{-1} band in the IR-spectrum of HDPE cooled (crystallized) in the water-ice mixture characterizes the crystal regions, and the 720 cm^{-1} band characterizes the crystallites+amorphous layers [2, 3, 4]. This doublet results from the splitting of the 722 cm^{-1} bands corresponding to the oscillations of the -CH_2- (methylene groups) group in the crystallite lattice. It can be considered that the observation of 1472-1462 cm^{-1} and 1376.6 cm^{-1} absorption bands is related to polar elements formed due to thermal oxidation during sample collection.

Figure 2 (a, b) shows the IR-Fourier spectra of HDPE/1%α-Fe_2O_3 composite sample before and after γ-irradiation. The 588.132 cm^{-1} absorption bands related to Fe_2O_3 observed in these composites before irradiation disappear at D=300kGy irradiation dose and new 1712.895 cm^{-1} C=O (carbonyl groups), 1301.94 cm^{-1} (C–O) absorption bands appear. It should also be noted that the observed 1376.646-1468.543 cm^{-1} absorption bands belong to the side groups –CH_3 (methyl) and –CH_2- and characterize deformation oscillations [3].

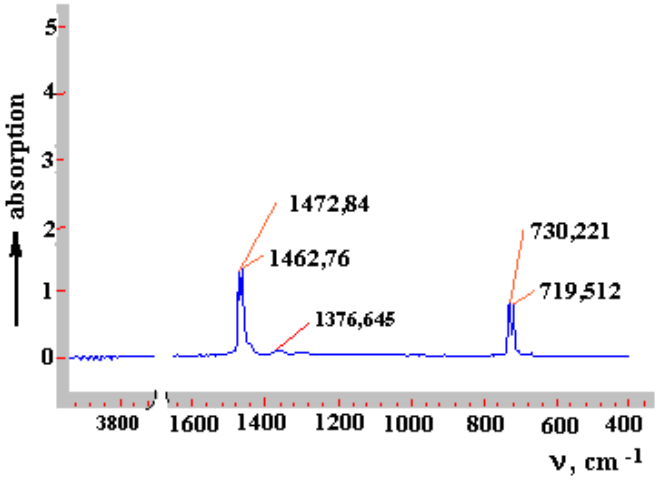
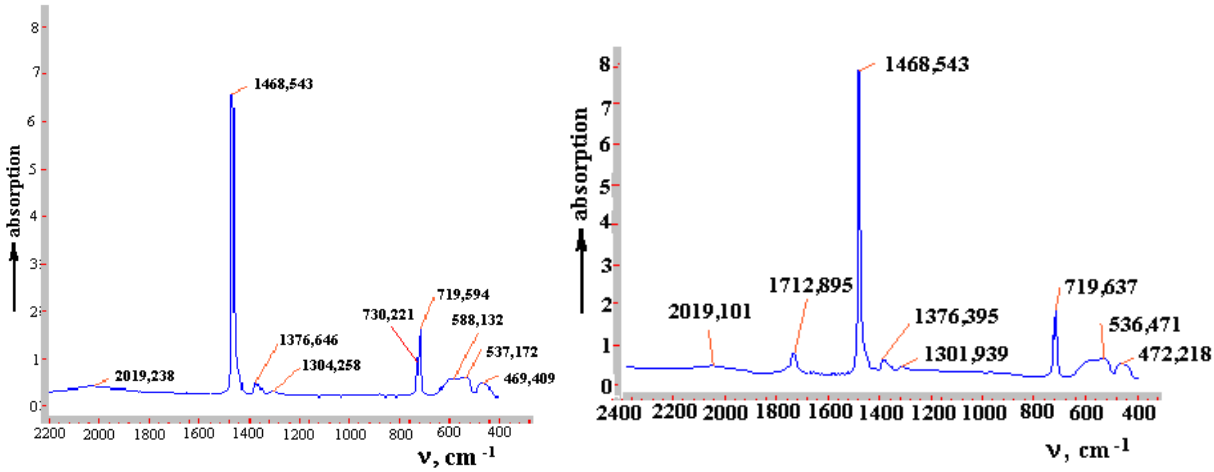


Fig. 1. Fourier-IR-spectrum of pure high-density polyethylene (HDPE).



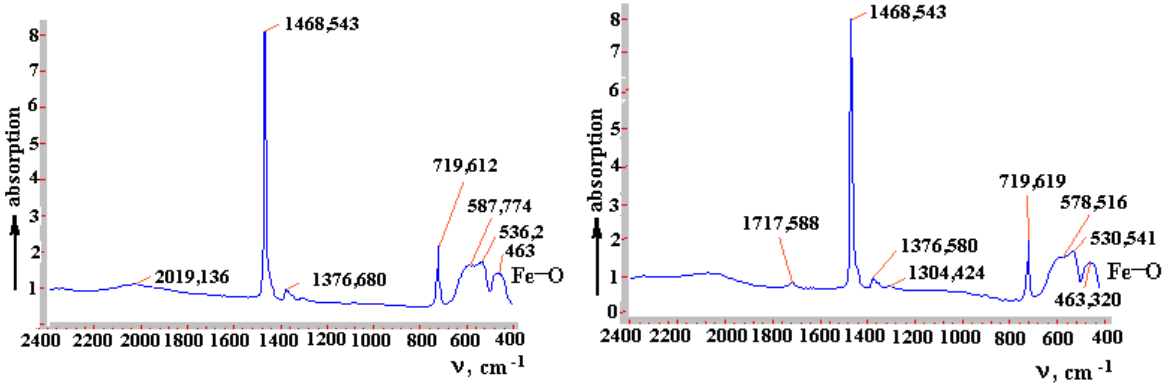
a) ***b)***

Fig. 2 (a, b). Fourier-IR spectra of HDPE/1%α-Fe_2O_3 composite sample before (a) and after irradiation (D=300 kGy) (b).

Figure 3 (a, b) shows the Fourier-IR spectra of the HDPE/3% α-Fe_2O_3 composite sample before and after irradiation (D=100 kGy). As can be seen from the figure, the IR spectrum of pure HDPE differs from the spectrum of HDPE/3% α-Fe_2O_3 composite. Here, compared to the HDPE/1% α-Fe_2O_3 sample, in the volume fraction of filler Φ=3% and at a slightly lower radiation dose (D=100 kGy), the absorption band of 2019.136 cm^{-1} (–N=C) disappears and 1717, 588 m^{-1}(C=O) and 1304.424 cm^{-1}(C–O) bands are observed (Fig. 3 b).

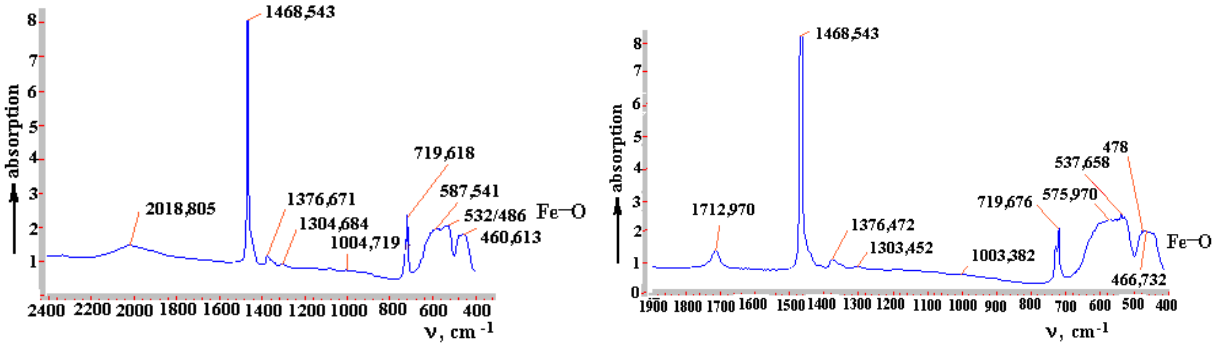
Figure 4 (a, b) shows the absorption spectra of HDPE/3% α-Fe_2O_3 composite before (a) and after (D=500 kGy) (b) γ-irradiation. The absorption band of 719,618 cm^{-1} belongs to both the amorphous and crystalline regions of the polymer. The 1304.648 and 1376.671 cm^{-1} bands of HDPE/5%α-Fe_2O_3 composite belong to C–O, side $–CH_3$ (methyl) and $–CH_2$ (methylene) groups in the amorphous phase, and have double or trans conformation. The 1004.719 cm^{-1} band characterizes the region of relatively weak crystallinity.

As can be seen from the figure, after irradiation, the absorption band of 2018.805 cm^{-1} disappears and a new band of 1712.970 cm^{-1} (C=O) appears. On the other hand, with the formation of a new absorption band of 478 cm^{-1} (characteristic of O^{2+} ion), there is a broadening of the absorption band belonging to Fe_2O_3. We assume that this expansion is related to the volume fraction of the filler and the radiation dose (D).



a) ***b)***

Fig. 3 (a, b). Fourier-IR spectra of HDPE/3% α-Fe_2O_3 composite sample before (a) and after irradiation (D=100 kGy) (b).



a) ***b)***

Fig. 4 (a, b). Fourier-IR-spectra of HDPE/5%α-Fe_2O_3 composite sample before (a) and after irradiation (D=500 kGy) (b).

2. Conclusion

As a result of the comparative analysis of the spectra, it was found that there is no strong change in the spectra of the HDPE/(1-5%vol.)α-Fe_2O_3 composites regardless of the concentration of the oxide component. The effect of γ-irradiation on the system with this composition is also weak. Thus, it was determined by the IR-Fourier spectroscopy that the structure of samples of HDPE/(1-5%vol.)α-Fe_2O_3 composite system is more resistant to the effect of γ-radiation (up to 500 kGy) based on the band of the groups $-CH_3$, $-CH_2$, etc. in the spectrum.

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ИССЛЕДОВАНИЕ ИЗМЕНЕНИЯ СТРУКТУРЫ МОДИФИЦИРОВАННОЙ ГАММА-ЛУЧАМИ КОМПОЗИТНОЙ СИСТЕМЫ ПЭВП/α – Fe_2O_3 МЕТОДОМ ИНФРАКРАСНОЙ - ФУРЬЕ СПЕКТРОСКОПИИ

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Резюме: Структурные изменения, возникающие при воздействии γ-излучения в композитных системах ПЭВП/(1-5об.%) α-Fe_2O_3, были исследованы методом ИК- Фурье спектроскопии. Оказалось, что независимо от концентрации оксидного наполнителя α-Fe_2O_3 сильных изменений в спектрах не произошло и влияние γ-излучения на систему этого состава, также слабое. Так, методом ИК-Фурье спектроскопии было установлено, что композитная системы ПЭВП/(1-5об.%) α-Fe_2O_3, согласно структуре образцов, расположения групп - CH_3, -CH_2 и др. в полосе спектра более устойчивы к воздействию γ-излучения (до 500 кГр).

Ключевые слова: Фурье, полимер, композит, спектроскопия, инфракрасный, структура, гамма-излучение, спектр

QAMMA-ŞÜALARLA MODİFİKASİYA OLUNMUŞ YSPE/α-Fe_2O_3 KOMPOZİT SİSTEMİNİN QURULUŞ DƏYİŞMƏSİNİN İNFRAQIRMIZI- FURYE SPEKTROSKOPİYA METODU İLƏ TƏDQİQİ

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Xülasə: YSPE/(1-5%)α-Fe_2O_3 kompozit sistemlərində γ-şüalanmanın təsiri zamanı yaranan quruluş dəyişmələri İQ- Furye spektroskopiya metodu ilə tədqiq olunmuşdur.Məlum olmuşdur ki, α-Fe_2O_3 oksid doldurucusunun konsentrasiyasından asılı olmayaraq spektrlərdə güclü dəyişiklik baş verməmişdir və bu tərkibdə olan sistemə γ-şüalanmanın da təsiri zəifdir. Beləki, İQ- Furye spektroskopiya metodu ilə müəyyən edilmişdir ki, YSPE/(1-5% həcm) α-Fe_2O_3 kompozit sistemi nümunələrinin quruluşu, –CH_3, –CH_2 və s. qrupların spektrdə yerləşmə zolağına əsasən γ-şüalanmanın təsirinə (500 kQr-yə qədər) daha dayanıqlıdır.

Açar sözlər: Furye, polimer, kompozit, spektroskopiya, infraqırmızı, quruluş, qamma-şüalanma, spektr