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Modification of Polypropylene Films by Laser Radiation

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Abstract. In work the effect of laser radiation on the structure, surface activity and tensile strength of polypropylene films is investigated, which is confirmed by IR spectroscopic studies. As a result of experimental studies of the contact angle of wetting after laser irradiation of the studied samples, changes in their surface activity were observed: with an increase in the density of laser radiation with a power of up to 1.63×10^5 W/cm^2, the contact angle of wetting decreases, the highest values of the studied parameter are observed in a film irradiated with a power of 2.26×10^5 W/cm^2. Analyzing the results of strain- strength tests, it can be concluded that after laser treatment, the tensile strength of films increases, while the highest strength and elongation value are observed in a sample irradiated with a laser with a power density of 2.26 × 105 W/cm^2. The work shows that the physical and mechanical characteristics of polypropylene films depend on the modes of laser radiation, the optimal results of the studied indicators are achieved with laser irradiation with a power density of 2.26×10^5 W/cm^2.

Keywords: laser radiation, polypropylene films, modification, surface activity, supramolecular structure.

Introduction.

Laser radiation affects the chemical construction, structure, physico-chemical and physico-mechanical properties of polymer materials. Effects associated with changes in crystallinity, morphology, hardening and formation of a certain charge state of the surface layer are observed. The nature of the exposure is primarily determined by the irradiation modes. Lasers with different wavelengths of radiation in the range from near-ultraviolet to far-infrared are widely used to modify polymers. The ability to adjust the parameters of laser processing in a wide range of modes allows you to adjust the structure of the surface layer and its properties, such as hardness, wear resistance, roughness, etc.

The energetic activation of the surfaces of polymeric materials by laser action leads to an increase in operational properties. Activated surfaces acquire new qualities due to the removal of adsorbed low molecular weight products and contaminants from them [1,2].

The purpose of this research is to study the peculiarities of changes in the supramolecular structure, durability and surface activity of polypropylene films subjected to laser irradiation.

1. Research methodology

As a material for the study, there were used a polypropylene (PP) film of the BOPP STT brand 0.020 × 105 TU RB 00204079.164-97 produced by JSC Mogilevkhimvolokno and a film of the BOPP STT brand 0.020 × 105 TU RB 00204079.164-97 produced by Irplast.

The samples were irradiated using an YAG laser with a radiation wavelength of λ = 532 nm with power densities of $q_1 = 1{,}01\times10^5$ W/cm^2; $q_2 = 1{,}63\times10^5$ W/cm^2; $q_3 = 2{,}26\times10^5$ W/cm^2; $q_4 = 2{,}77\times10^5$ W/cm^2.

The designations of the samples are given in Table1.

Table1. Designations and interpretation of test samples

Sample designation	Interpretation of sample designation
I.1	PP of the JSC Mogilevkhimvolokno brand
I.2	PP of the JSC Mogilevkhimvolokno brand, irradiated with laser radiation with a power density of $q_1 = 1{,}01\times10^5$ W/cm^2
I.3	PP of the JSC Mogilevkhimvolokno brand, irradiated with laser radiation with a power density of $q_2 = 1{,}63\times10^5$ W/cm^2
I.4	PP of the JSC Mogilevkhimvolokno brand, irradiated with laser radiation with a power density of $q_3 = 2{,}26\times10^5$ W/cm^2
I.5	PP of the JSC Mogilevkhimvolokno brand, irradiated with laser radiation with a power density of $q_4 = 2{,}77\times10^5$ W/cm^2
II	PP of the Irplast brand

The adsorption properties of the films were evaluated by the contact angle of wetting in accordance with GOST 7934.2-74. The tensile strength was determined on a breaking machine model RM-30-1 according to GOST 14236-81. The morphology and topography of the surface of the films were studied using an atomic force microscope NANOTOP-206. The surface structure of the samples was studied by infrared spectroscopy. The studies were carried out on an ALPHA spectrometer. Identification and analysis of IR spectra were carried out according to known methods using data on IR spectra of polymer materials [3].

2. Results and discussion

The obtained absorption spectra are shown in Figure1.

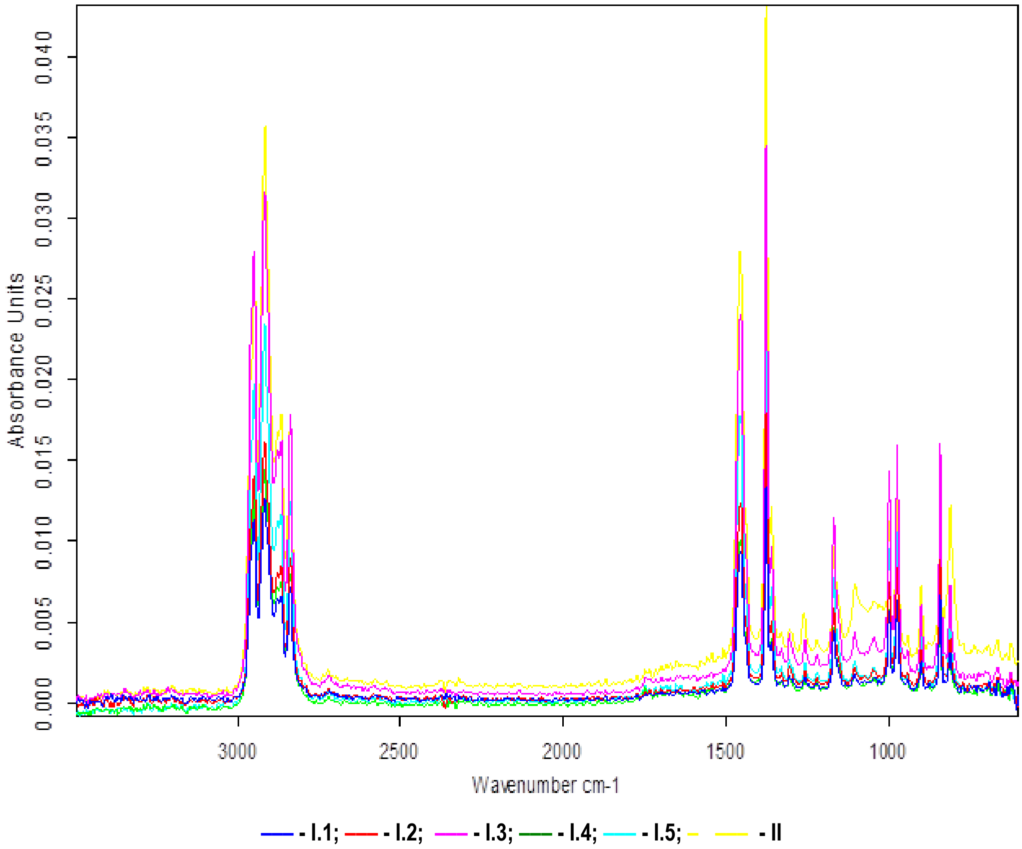


Fig. 1. – IR spectra of the studied samples in the far-infrared region

IR spectroscopic studies have shown that after laser irradiation, the structure and phase state of the substance in the samples under study change. Signs of structural transformations of polypropylene film samples are: redistribution of groupings with C-C bonds (790 cm^{-1}); change in the intensities of a number of absorption bands at 1455 cm^{-1} and 1375 cm^{-1} (deformation vibrations of CH_3 groups in trans-conformations); 2920 cm^{-1} and 2838 cm^{-1} (valence fluctuations of CH and CH_2 groups in trans-conformations); as well as the redistribution of the intensities of the absorption bands in the area corresponding to the transparency zone (1500 cm^{-1} – 2600 cm^{-1}) [4].

Structural changes in the surface layers of polypropylene films cause another important effect – a change in surface activity, estimated by the value of the contact angle of wetting.

Table 2 shows the values of the contact angle of wetting of polymer films.

Table 2. Values of the contact angle of wetting of polymer films

Sample designation	I .1	I .2	I .3	I .4	I .5	II
Values of the contact angle of wetting θ, grad	55	43	46	59	40	43

Analysis of the data in Table 2 showed that the smallest wetting angle is observed in the initial sample of the Irplast brand. The surface tension of BOPP STT films after irradiation varies ambiguously: with an increase in the power density to 1.63 ×105 W/cm^2, the contact angle of wetting decreases and then increases, its highest value is observed in the irradiated film with a power density of 2.26×105 W/cm^2. The surface of all films is hydrophilic, because the contact angle of wetting θ is less than 90 degrees [5].

The results of deformation and strength tests are presented in Figures 2,3

As a result of stress-strain tests, it was found that after laser treatment, the tensile strength of films increases. The highest strength and elongation value are observed in a sample exposed to radiation by the laser a power density of which is 2.26×105 W/cm^2. With a further increase in the power density of the laser radiation, the strength of the films decreases

As a result of scanning the surface of the films with an atomic force microscope, AFM images of the microrelief were obtained in the phase contrast mode (a), as well as in the topography mode (b). The test results are shown in Figure 4.

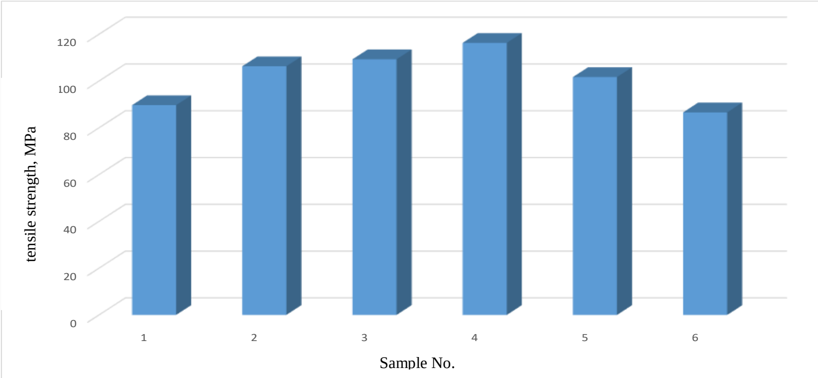


Fig. 2. – Values of the tensile strength of films

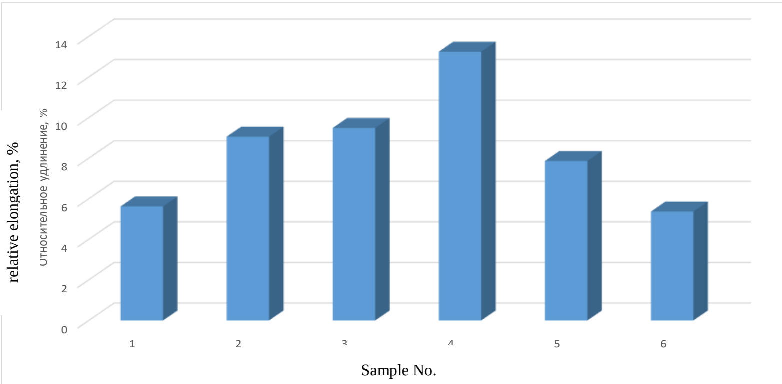
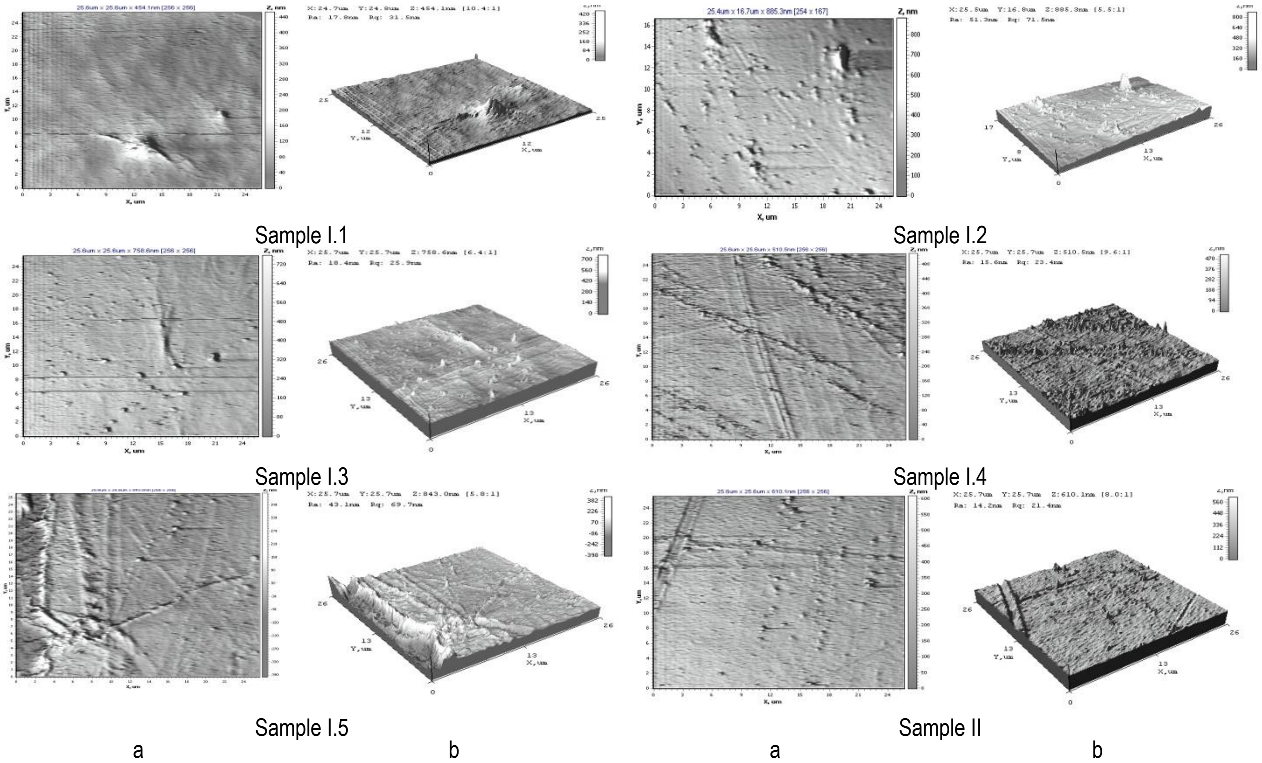


Fig. 3. – Values of relative elongation of samples



a) – AFM-image in phase contrast mode; b) – AFM -image of microrelief in topography mode

Fig. 4. – Morphology and topography of the surface of samples

Analyzing the results of atomic force microscopy, it was found that the shape and structure of the film surface changes under the influence of laser irradiation. The surface of the initial film (sample II) is smoothed, single protrusions are observed. When exposed to laser irradiation, the surface of the films (samples I.1, I.2, I.3) acquires a more structured, ordered form. During irradiation of the film (sample I.4) with a laser irradiation power density of 2.26×105 W/cm^2, a cluster structure is formed on the surface. With a further increase in the power density to 2.77 ×105 W/cm^2, microcracks and micro-depressions are observed on the surface of the films. It should be noted that the results of atomic force microscopy correlate with the results of deformation and strength tests [6].

Conclusions

Based on the results obtained, it can be concluded that high-energy processing of polypropylene films leads to a transformation of the supramolecular structure and a change in surface activity and, as a consequence, to a change in the deformation and strength characteristics of polypropylene films. Thus, with the help of laser irradiation, it is possible to directionally change the structure of polymer films in order to improve their service characteristics. Optimal physical and mechanical characteristics of the studied samples are achieved by laser irradiation with a power density of 2.26 × 105 W/cm^2.

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