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Comparative Light Transmission and Light Resistance of Multilayered Polymer Films for Flexible Packaging Production

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Abstract—The effect of structure on the spectral light transmittance of a polymer film material and its light aging resistance is studied. Three types of multilayered films derived from high-pressure polyethylene; high- and low-pressure polyethylene; and high-pressure polyethylene, polyamide, and copolymer of ethylene with vinyl alcohol are investigated. These films are prepared by co-extrusion and are used for the production of flexible packaging materials in the form of laminates. Using the technique of differential scanning calorimetry, the comparative light resistance of the layers incorporated in the films is determined.

Keywords: polymer multilayered films, polyethylene, polyamide, copolymer of ethylene with vinyl alcohol, light transmittance coefficient, transmittance spectrum, light resistance, differential scanning calorimetry, melting point

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At present, there is an expanding use (and, accordingly, production) of multilayered polymer film materials acting as flexible packaging [1, 2].

The structure of multilayered film material is developed in accordance with the function of each layer and is governed by their composition, thickness, layer alteration, and adhesion interaction between layers to provide necessary combination of physicomechanical, optical, operational, and other characteristics. This requires the study of the relationship of the structure and properties of multilayered polymer films and is one of the areas of research being worked at the Kazan National Research Technological University [3–6].

This work is devoted to a study of the effect of structure on the spectral light transmittance of a polymer film material and its light aging resistance. The study was carried out using the example of multilayered polymer films for the production of flexible packaging materials in the form of laminates.

Multilayered films prepared by co-extrusion were chosen as the objects of study:

— three-layered based on high- and low-pressure polyethylene (HPPE and LPPE, respectively), PP-3;

— five-layered on the basis of HPPE, PP-5;

— and nine-layered on the basis of HPPE, polyamide (PA), and copolymer of ethylene with vinyl alcohol (CEVA), PP-9.

The spectral light transmittance coefficient of the films was measured on an SF-256 UVI spectrophotometer. A DRT-40 high-pressure arc discharge mercury lamp with a power of 24.6 W was employed as a source of UV light during light-resistance tests of the film specimens. In this case, the distance from the lamp to the specimens was 30 cm. A DSC Q2000 differential scanning calorimeter (DSC) was used to determine the melting point of the films.

Characteristics of the polymer films are given in Table 1. Young's modulus values E given in Table 1 may represent the comparative characteristics of physical-mechanical properties of the films. It is clear that,

Table 1. Characteristics of films

Type of film	Number of layers	Film thickness, μm	Mass of 1 m^2, g	E*, MPa	V_τ**, %/h
PP-3	3	50	47.7	350	0.2
PP-5	5	50	47.2	286	0.4
PP-9	9	50	49.4	468	1.6
		65	62.3	476	1.3

* Found at tensile tests of the films at longitudinal direction.
** Found after 30 h of UV irradiation of the films.

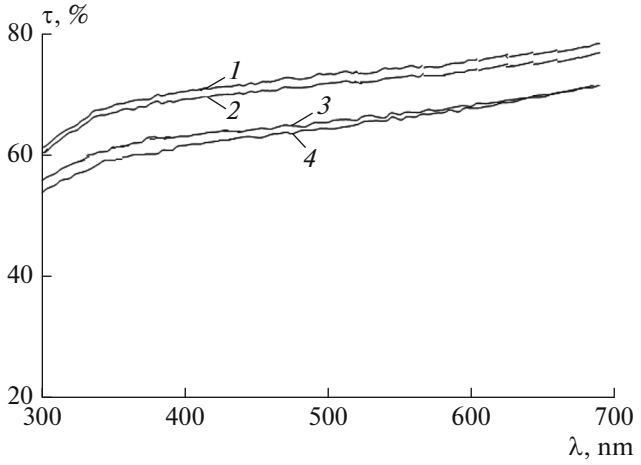

Fig. 1. Light transmittance spectra of (*1*) PP-3, (*2*) PP-5, and (*3*, *4*) PP-9: number of layers is (*1*) three, (*2*) five, and (*3*, *4*) nine. The film thickness, μm, is (*1*–*3*) 50 and (*4*) 65.

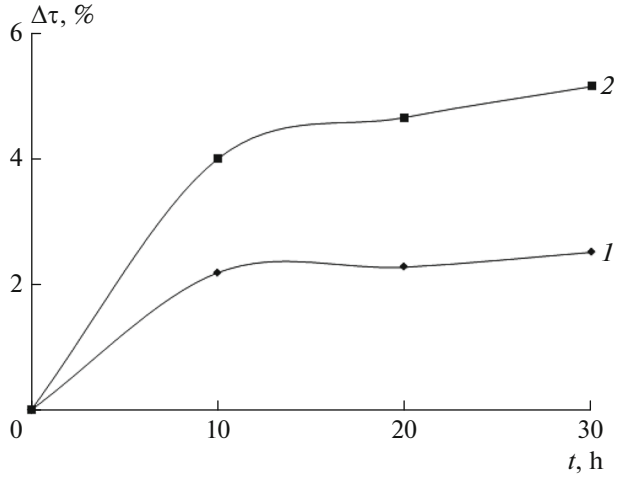

Fig. 2. Kinetic curves of light aging of (*1*) PP-3 and (*2*) PP-5.

at identical film thicknesses, the tensile strength of PP-3 is 22% larger than that of PP-5, whereas that of PP-9 is larger than those of PP-3 and PP-5 by 34 and 64%, respectively.

The light transmittance of the polymer films can be evaluated from the comparative values of light transmittance coefficient τ recorded in the wavelength range of λ = 300–700 nm. The transmittance spectra are given in Fig. 1.

Analysis of the experimental data shows that PP-3 and PP-5 differ marginally according to light transmittance in both the UV (λ = 300 nm) and visible (λ = 400–700 nm) ranges of the spectrum. In this case, PP-3 and PP-5 are characterized by higher light transmittance as compared to that of PP-9. The value of light transmittance coefficient of PP-9 is inversely proportional to their thickness.

The light aging of the polymer films on irradiation to the DRT 240 lamp is represented by a natural decrease in their spectral light transmittance; in this case, the largest decrease in coefficient τ is observed in the UV range of the spectrum. This fact is caused by photo-oxidative destruction of the polymers, which generate chromophoric groups absorbing UV light [7]. For this reason, the relative change of their light transmittance coefficient Δτ during tests at λ = 300 nm was chosen as the criterion of light resistance.

The kinetics of light aging of the films is reflected by dependences $\Delta\tau = f(\tau)$, which are given in Figs. 2 and 3.

In all cases, with an increase in the period of irradiation, the rate of light aging of the films gradually decreases. On the basis of the kinetic curves at $t = 10$ h, the initial rate of light aging of the films was calculated (V_τ) (Table 1): PP-3 possesses a double decreased value of V_τ, that is, higher light resistance than that of PP-5. The mentioned films are far superior to PP-9 of identical thickness according to light resistance, because their values of V_τ are less by a factor of 4–8. The light resistance of PP-9 varies insignificantly with the change of thickness.

It was of interest to reveal the comparative light resistance of the film layers, which was studied using the DSC method. DSC curves of the films showed endothermic peaks, the maxima of which correspond to melting points T_m of HPPE, LPPE, and CEVA [8]. Table 2 shows the T_m values of the aforementioned polymer layers before and after irradiation of the films. After each test, a decrease in the T_m values was

Table 2. T_m values of film layers before and after irradiation

Type of film	Layer material	T_m, °C	
		before irradiation	after irradiation
PP-3	HPPE	107.95	—
	LPPE	119.22	117.02
PP-5	HPPE	112.38	111.97
PP-9	HPPE	113.0	111.80
	CEVA	181.34	162.24

* Time of irradiation is 30 h.

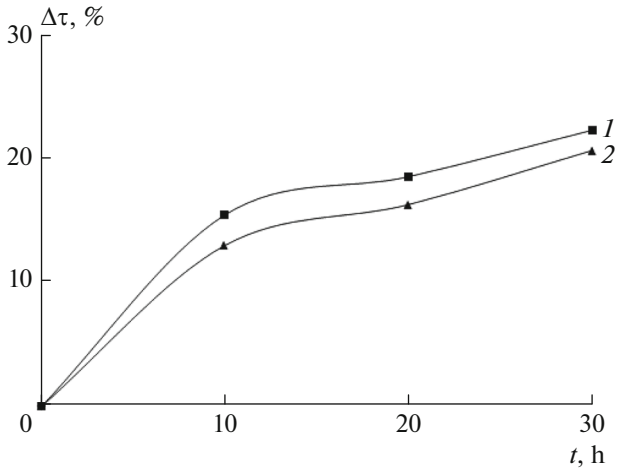

Fig. 3. Kinetic curves of light aging of PP-9. The film thickness is (*1*) 50 and (*2*) 65 μm.

recorded, which was caused by the decrease in the molecular mass of the polymers upon their photo-oxidative destruction.

The DSC curve of PP-3 shows two endothermic peaks, which are related to T_m values of HPPE and LPPE, whereas an endothermic peak corresponding to T_m of HPPE layers was recorded for PP-5. As a result of irradiation, the extent of the decrease in the T_m of LPPE corresponds to only 1.9%, whereas there is no endothermic peak corresponding to T_m of HPPE. This indicates that the HPPE layer in the structure of PP-3 underwent photooxidative destruction to a much larger extent than the LPPE layer, which was more resistant to light aging.

In the case of PP-5 consisting only of the HPPE layers, the T_m value decreased by 3.6% as a result of irradiation, which is higher than in the case of PP-3. This fact explains the origin of a higher light resistance of PP-3 as compared to PP-5. Consequently, the difference in the light resistance of PP-3 and PP-5 is caused not only by the different number of film layers, but also the difference in their composition. In this regard, a much larger difference between the aforementioned films and PP-9 was determined.

The DSC curve of PP-9 shows two endothermic peaks corresponding to HPPE and CEVA layers. The endothermic peak corresponding to the PA layer was not recorded, which is presumably caused by its relatively small thickness. After irradiation, a decrease in the T_m of the HPPE layer is marginal (slightly larger than 1%). At the same time, the T_m of the CEVA layer decreases by about 11%. This fact indicates that the HPPE layers are much more resistant to light aging in PP-9 and explains the increased light resistance of PP-3 and PP-5 as compared to that of PP-9.

CONCLUSIONS

The effect of the structure of multilayered films based on HPPE (PP-5); HPPE and LPPE (PP-3); and HPPE, PA, and CEVA (PP-9) on the light transmittance of the polymer film material and its light aging resistance has been studied.

It has been determined that PP-3 and PP-5 differ marginally according to light transmittance value and are superior to PP-9.

A higher light resistance of PP-3 as compared to PP-5 is caused not only by the number of layers, but also the presence of LPPE layers, which are characterized by the increased light resistance as compared to HPPE layers.

A higher light resistance of PP-3 and PP-5 as compared to PP-9 has been discovered, which is explained by the relatively higher light aging resistance of polyethylene layers rather than CEVA layers.

REFERENCES

1. E. G. Lyubeshkina, “Large-scale polymeric materials for food packaging: Requirements and selection principles,” Polim. Mater., No. 4, 4–10 (2009).
2. I. I. Bogomolov, “Functional polymers for multilayer barrier films,” Polim. Mater., No. 12, 8–10 (2014).
3. V. N. Serova, D. V. Sugonyako, M. L. Verizhnikov, and A. A. Tyuftin, “Operational properties of mono- and multilayer polymeric packaging films,” Plast. Massy., Nos. (5–6), 54–56 (2014).
4. V. N. Serova and E. N. Noskova, “Optical characteristics and lightfastness of polymer packaging films and paint layers applied to them,” Vestn. Kazan. Tekhnol. Univ. **19** (15), 61–63 (2016).
5. V. N. Serova, E. R. Mirkhusainov, Zh. Yu. Gerkina, and A. I. Khasanov, “The quality of paint coatings on polymer packaging films,” Klei, Germetiki, Tekhnol., No. 8, 42–47 (2017).
6. V. N. Serova and A. I. Zagidullin, “Thermal shrinkage of polymer packaging films and its effect on the quality of the paint coatings applied to them,” Klei, Germetiki, Tekhnol., No. 1, 37–42 (2019).
7. B. G. Ranby and J. F. Rabek, *Photodegradation, Photooxidation, and Photostabilization of Polymers: Principles and Applications* (Wiley, 1975; Mir, Moscow, 1978).
8. *Handbook of Plastics,* Ed. by V. M. Kataev, 2nd ed. (Khimiya, Moscow, 1975) [in Russian].

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