# Polymer Multilayer Films for Packaging of Building Materials

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**Annotation.** One of the promising applications for thermoplastic polymer materials is their use as packaging shrink films. It is established that the leading direction in the field of transport (pallet) packaging of building materials is taken by polymer films of a multilayer structure. One of the main operational requirements for such films is the resistance to light aging during storage and transportation. The study was carried out when comparing two types of three-layer films based on high-pressure polyethylene obtained on the co-extrusion line for the production of Kiefel 1 bag film using the target components of the formulation, including those for protection against ultraviolet (UV) radiation. It was found that films containing an ethylene-butylene copolymer (SEB) in the inner layer have a higher degree of stability.

**Keywords:** Polymer films · Light aging · Ethylene-butylene copolymer · Films for packaging

## 1 Introduction

Polymer film materials are used as packaging in many sectors of the national economy [1–5]. At the same time, complex multilayer structures are most in demand [6–10]. Unlike traditional single-layer packaging films, the construction of polymer-polymer structures is the most effective way to provide the necessary complex of operational properties of the package. This is due to the unlimited possibilities of varying the components of a multilayer material, the number, thickness, and order of alternation of its layers [6, 11]. For their manufacture, the method of co-extrusion is most often used, which allows a single cycle to obtain a material that is a combination of several polymer layers [12–14].

The leading positions in the field of transport (pallet) packaging of building materials are occupied by polymer films of a multilayer heat-shrink structure [15]. They ensure the ability of oriented polymers to reduce linear dimensions: when heated above the softening temperature, they are able to shrink and tightly fit the packaged products, ensuring their safety, both during transportation and during intermediate storage at the place of application. This type of packaging is more economical in comparison with the traditionally used film materials due to the small volume of the package (tight fit), lower weight, lower material consumption and greater efficiency of the packaging design. The most economical and widespread variant of the three-layer structure is a film, the central


N. Vatin (Ed.): STCCE 2021, LNCE 169, pp. 223–229, 2021.
https://doi.org/10.1007/978-3-030-80103-8_24

layer of which is made from secondary polymer raw materials. This structure practically does not lose strength, compared to a single-layer film made of a mixture of secondary and primary raw materials and allows the manufacturer to reduce the cost of production.

The main consumers of shrink film are companies that produce building materials, such as bricks, cement, aerated concrete, rolled roofing materials, dry mixes, gypsum boards, etc. This takes into account the size and weight of the packaged products, the conditions of transportation and storage, as well as the requirements for the protective properties, appearance and packaging process of the package.

Strict requirements for modern packaging include high values of strength and performance indicators. Packaging for building materials must ensure their safety while transportation and storage. The most important thing is to protect the packaging from external influences, especially ultraviolet (UV) rays, i.e. it must have a good resistance to light aging [16].

The currently known publications usually consider the comparative properties of mono-and multilayer packaging films [17, 18], their production, barrier (protective) and some other indicators of multilayer polymer films for packaging both food and technical products [19–30], as well as the quality of the printing applied to them [31, 32]. There is insufficient data in the publications on the performance properties of polymer films for packaging construction and other materials, including their resistance to light aging.

The relevance of such studies is of both scientific and practical importance for predicting the service life and durability of this type of packaging films. From this point of view, the aim of this work is to determine the influence of the composite composition on the performance indicators, including the resistance to light aging of multilayer shrink films intended for pallet packaging of building materials.

## 2 Research Objects

Samples of two types (**I** and **II**) of three-layer heat-shrinkable films based on high-pressure polyethylene (PE) of the 15303–003 brand with a thickness of 150 microns, obtained in LLC "Kama Plant of Polymer Materials" on the co-extrusion line for the production of Kiefel 1 bag film, were selected for the study. The composition of film layers **I** and **II**, along with PE, includes a concentrate of mineral filler (talc) on the polymer basis of Camlen 4112 (KMN), PE waste, an ethylene-butylene copolymer( SEB), as well as a concentrate based on a photostabilizer of the HALS class and PE (KSS) (Table 1).

**Table 1.** Structure of three-layer PE-based shrink films

| Composition of layers | |
|---|---|
| **I** | **II** |
| 1) PE + KMN<br>2) PE + PE-waste + SEB<br>3) PE + KMN | 1) PE + KMN<br>2) PE + KSS<br>3) PE + KMN |

## 3 Methods

The strength and deformation of polymer films were determined under tension (rupture) according to GOST 14236 (ASTM D 882) on an automatic Shimadzu breaking machine model AGS-X with an extensometer SES-1000 [33]. The measurement error did not exceed ± 10%. Samples of each film were cut out with a special device in the longitudinal and transverse directions. During the test, the stretching diagrams of the samples were automatically recorded. The value of the breaking stress (σ) was determined by the formula:

$$\sigma = F/S,$$

where F is the breaking force, H; S is the cross-sectional area of the film sample. The arithmetic mean of at least 5 determinations in each direction was taken as the test result. The rapid method for assessing light resistance consisted in irradiating film samples with a UV light source – a high-pressure arc discharge mercury lamp DRT 240, the beam flux of which lies in the wavelength range of 240–320 nm, and its power is 24.6 W [34]. The film samples were placed on a substrate, their distance from the lamp was 30 cm.

## 4 Results and Discussion

The results of determining the physical and mechanical parameters of the films - the values of σ and the relative elongation (ε) are presented in Table 2. The different composition of the inner layer of the films does not lead to a noticeable difference in the values of these indicators, and regardless of the direction of their measurement, i.e. the films of structures **I** and **II** practically do not differ either in strength or in the amount of tensile deformation. The kinetics of light aging of films is illustrated by the corresponding dependences of σ and ε on the duration of their UV irradiation (t), shown in Figs. 1, 2, 3, 4.

According to the dependences shown in Figs. 1 and 2, in all cases, with an increase in the duration of UV irradiation t, a decrease in the values of σ and ε is observed to some extent. In order to compare the resistance of films **I** and **II** to light aging, the relative change in the parameters σ and ε after the test was determined – Δσ and Δε, respectively. The values of Δσ and Δε are also included in Table 2.

Based on the found values of Δσ and Δε, it can be noted that UV irradiation of the films of structures (**I** and **II**) for 20 h does not lead to a significant change in ε, since the values of Δε in all cases are within the measurement error.

It is determined that the strength of the films after the light resistance test, especially measured in the transverse direction, decreases much more noticeably. It was found that the degree of reduction in the strength of the films is also influenced by their structure. Thus, despite the presence of KSS in the inner layer, the structure **II** film has a more significant decrease in σ after the test, namely, the values of Δσ are almost 3 times greater than those of the structure **I** film. Therefore, film **I**, which contains SEB along with PE waste, is more resistant to light aging.

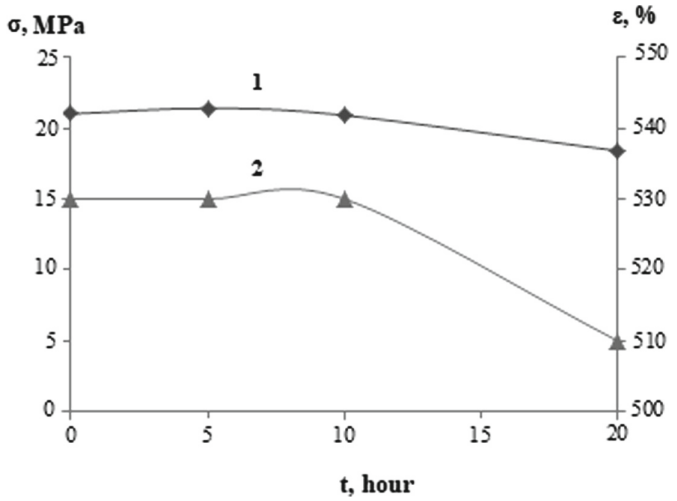


**Fig. 1.** Dependence of the breaking stress (1) and the relative elongation (2) of samples **I** measured in the longitudinal

Directions on the duration of UV irradiation.

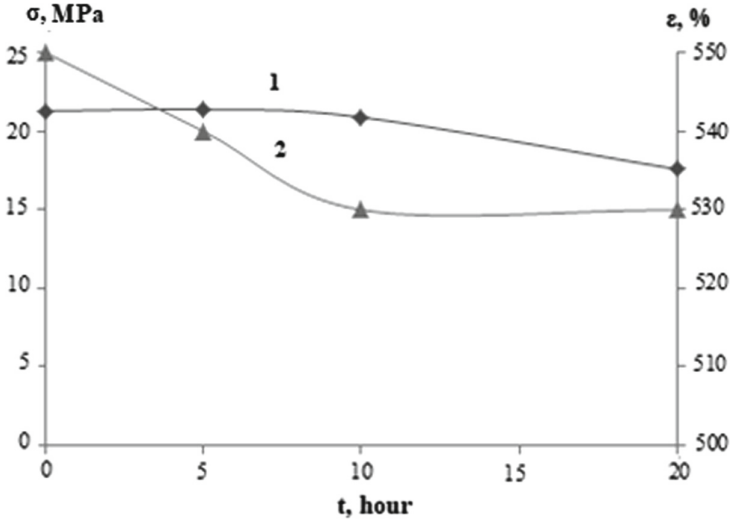


**Fig. 2.** Dependence of the breaking stress (1) and the relative elongation (2) of samples **I** measured in the transverse directions

On the duration of UV irradiation.

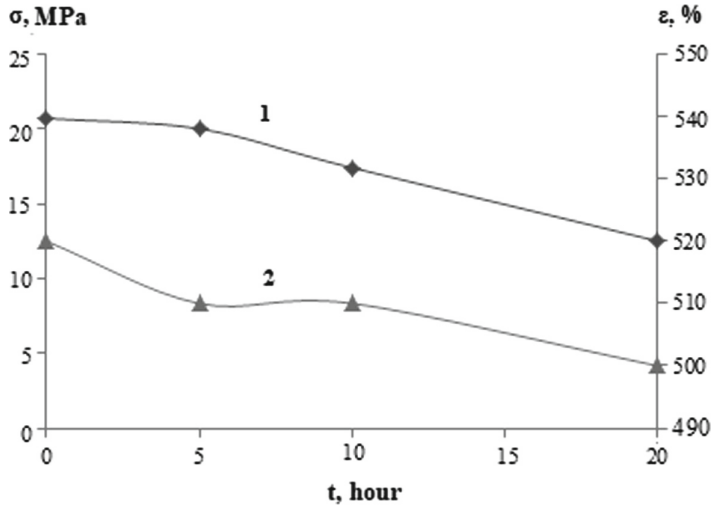


**Fig. 3.** Dependence of the breaking stress (1) and the relative elongation (2) of samples **II** measured in the longitudinal directions

On the duration of UV irradiation.

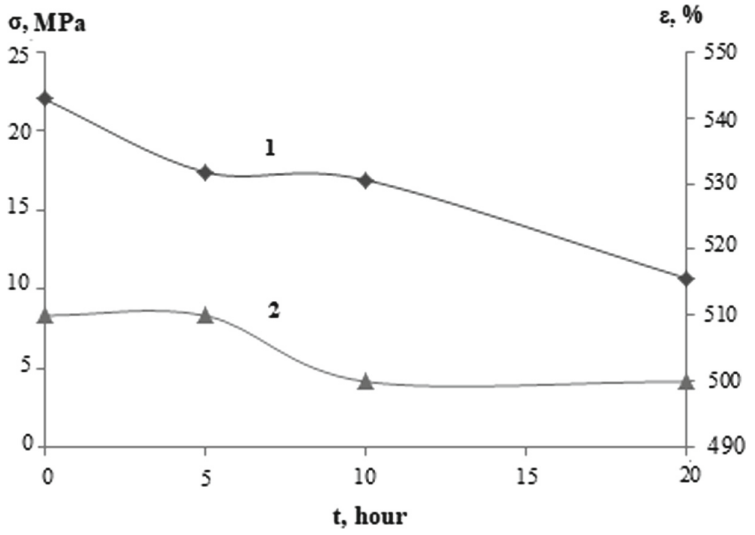


**Fig. 4.** Dependence of the breaking stress (1) and the relative elongation (2) of samples **II** measured in the transverse directions

On the duration of UV irradiation.

**Table 2.** Physical and mechanical properties of films and their relative change after the light resistance test

| Indicator | Film structure | |
|---|---|---|
| | **I** | **II** |
| σ, MPa | | |
| – in the longitudinal direction<br>– in the transverse direction | 21<br>21 | 21<br>22 |
| ε, % | | |
| – in the longitudinal direction<br>– in the transverse direction | 530<br>550 | 520<br>510 |
| $\Delta\sigma^*$, % | | |
| – in the longitudinal direction<br>– in the transverse direction | 11,9<br>16,6 | 33,3<br>43,2 |
| $\Delta\varepsilon^*$, % | | |
| – in the longitudinal direction<br>– in the transverse direction | 3,8<br>3,6 | 2,9<br>2,7 |

*Determined after 20 h of testing

## 5 Conclusion

Thus, the influence of the structure of heat-shrinkable three-layer films based on high-pressure polyethylene on the kinetics of light aging (UV radiation) is established in the form of a dependence of the destructive stress (σ) and the relative elongation (ε) on the duration (t) of irradiation.

The data obtained can be useful for predicting the service life of **I** and **II** under harsh UV irradiation conditions.

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