INFLUENCE OF UV IRRADIATION ON THE ELECTRICAL PROPERTIES OF A HIGH-DENSITY POLYETHYLENE FILM MODIFIED WITH PHTHALIMIDE ADDITIVE

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This work is devoted to the study of the effect of *UV* irradiation in air on the electrical properties of *LDPE* and its modifications. The results of a study on the effect of phthalimide (PI) additives on electrical durability, the nature of the change in the dependence of the dielectric loss tangent (tgδ) and volumetric electrical resistivity (ρ_υ) on temperature, the volume content of fillers and on the time of exposure to *UV* rays are analyzed. It has been established that the introduction of 0.05 wt% phthalimide into *LDPE* does not practically change the electrical strength of the composites. It is shown that the dielectric characteristics ($tg\delta, \rho_\upsilon$) after *UV* irradiation pass through a maximum at 0.05 wt%

Keywords : ultraviolet irradiation, dielectric loss tangent, phthalimide, livetime

1. INTRODUCTION

It is known that the effect of ionizing radiation on polyolefins is accompanied by the oxidation of polymers due to the reactions of free radicals with atmospheric oxygen. Such oxidation of macromolecules largely determines the efficiency of their radiation crosslinking and destruction [1,2], which determine the properties of polymeric materials. As is known [4-6], the degree of oxidation of polyolefins under *UV* irradiation is mainly determined by the diffusion of oxygen into the bulk of polymers.
It can be assumed that the more ordered structure of polyolefins containing the optimal amount of modifying additives hinders the diffusion of atmospheric oxygen into polymers. In this case, the modified polyolefins should be less susceptible to ionization oxidation.

The paper presents the results of studying the effect of phthalimide on electrical characteristics (lifetime τ, dielectric loss tangent $tg\delta$ and specific volume electrical resistance (ρ_υ) after exposure to *UV* irradiation.

1.1 EXPERIMENTAL TECHNIQUE

High-density polyethylene (*LDPE*) grade 10803-020 was chosen for the study, and the organic compound phthalimide *FI* (chemical formula C3H5NO2) was used as an additive. The ratio of components was expressed in mass percent.

The research was carried out on industrial units for the processing of plastics processing on *LDPE* grades in two stages.

The proposed additives were introduced into the feedstock, granulated *LDPE*, by mechanical mixing. Before the addition of additives to *LDPE*, they were dispersed using sieve analysis on a unit for determining the grain composition. The particle size was less than 500μm. The processing of this raw material into film was carried out at the *URP*-1500 unit. The processing mode was set on the unit and a film with a thickness of 20 to 50 microns was obtained.

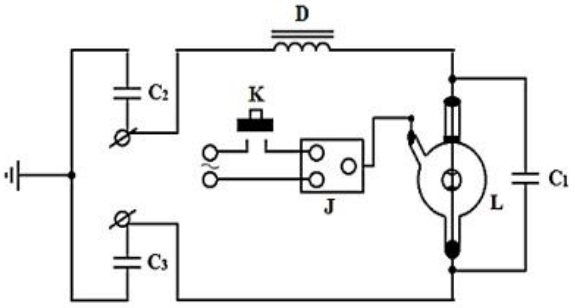

Fig.1. Ignition unit for lamp *DRSH*-500m; *D*-choke; *L*-bulb; *K*- limit switch, *J*-inductor for ignition with a spark length of 15-20 mm; C_1 - capacitor for shunting a lamp with a capacity of 0.05 microfarads, for an operating voltage of at least 250*V*; C_2, C_3-capacitors for blocking the network to the ground with a capacity of 0.5 microfarads, for an operating voltage of at least 250*V*.

UV irradiation was carried out using a *DRSH*-500 illuminator. The main parts of the illuminator are a spherical mercury-quartz lamp of ultrahigh pressure type *DRSh*-500 and a semi-spherical consul (Fig. 1). Mercury - quartz lamp *DRSH*-500 is a powerful, concentrated source of radiation with visible and ultraviolet parts of the spectrum. The lamp operates in a limited volume (casing), provided that the dimensions of the casing and the conditions of its ventilation are such that the air temperature at a distance of 6*cm* from the walls does not exceed 250°*C*.

A sample with a thickness of 50μm, fixed to a duralumin frame with a holder, is fixed on a tripod. *UV* rays are directed to the center of the melt. The distance from the source to the sample is 25*cm*. *UV* rays hit the sample at a right angle. The experiment was carried out at room temperature (20°*C*). The mode of the experiment is as follows: the lamp is clamped using an inductor with a spark length of 15-20*mm*. Rated voltage

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on the lamp 70*V*, current 7.5*A*. In this case, the resulting nominal luminous flux is 22500*lm*. The duration of the irradiation of the sample is 15 hours.

Measured ρ_{υ} using an *E*6-13*A* teraohmmeter in the temperature range 300-500*K* with linear heating at a rate of 3 *deg/min*. Measurements of the dielectric loss tangent were carried out using an automatic bridge E8-4 at a frequency of 1*kHz* in the temperature range of 300-500*K*.

Measurement of the electrical durability of the tested samples was carried out according to the method developed by us [7].

1.1.1 EXPERIMENTAL RESULTS AND DISCUSSION

We have studied the effect of additives in the optimal amount on the change in electrical strength during *UV* irradiation in air. In this case, the change in the electrical strength of the *LDPE* film and its optimal modifications were assessed by taking the curve of their lifetime before and after *UV* irradiation. Obtaining experimental data is shown in fig. 2. It can be seen that the action of *UV* irradiation on *LDPE* films without additive leads to a noticeable decrease in its electrical strength (lifetime). However, ceteris paribus, the introduction of the proposed additive into *LDPE* in the optimal amount contributes to the stability of its modified electrical properties.

This means the light-stabilizing feature of the additives used. Indeed, when evaluating the data presented in fig. 2, it becomes obvious that the introduction of phthalimide additives into *LDPE* in the optimal amount: firstly, to a significant increase in its electrical strength (from to) and secondly, the found increased properties of the modified *LDPE* remain unchanged after *UV* irradiation with a duration of action of 15 hours in the air.

This paper also presents the results of a study of the temperature dependence of the volumetric electrical resistance and dielectric losses.

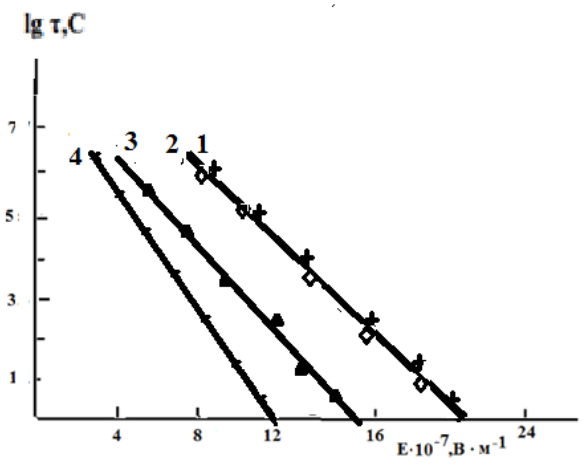

Fig.2. Dependences of the logarithm of the lifetime of the *LDPE* film and its modification with the optimal *PI* content (1) before and (2) after *UV* irradiation in air. *LDPE*+0.05 wt% FI (1) before and (2) after irradiation; *LDPE* (initial) before (3) and (4) after irradiation; $t_{region} = 15$ hours.

In the temperature dependence of the *LDPE* film and its modification after *UV* irradiation in air, the experimental data of which are shown in fig. 3, there is a slight change in the dielectric loss value of the initial *LDPE* film (curve 2).

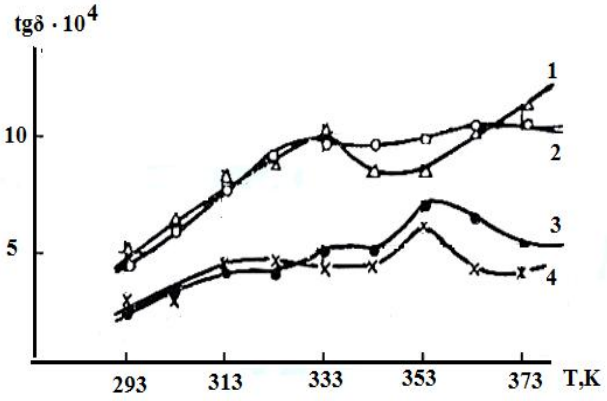

Fig.3. Temperature dependences of the dielectric loss tangent of the *LDPE* film and its optimal modification (1) before and (2) after *UV* irradiation in air at tbl.=15h. *LDPE* before (1) and after (2) irradiation; *LDPE* + 0.05 wt% PI before (3) and (4) after irradiation.

However, when an optimal amount of a modifying additive of phthalimide is introduced into the composition of *LDPE*, the value of the dielectric loss tangent after *UV* irradiation practically does not change (curve 3).

In Fig.4. the time dependence $tg\delta$ of *UV* irradiation is presented. As can be seen from fig. 4, the modified *LDPE* retains a constant value for quite a period of time, and then begins to increase slightly (curve 1). However, as expected, *LDPE* without additive $tg\delta$ begins to increase already in the initial period.

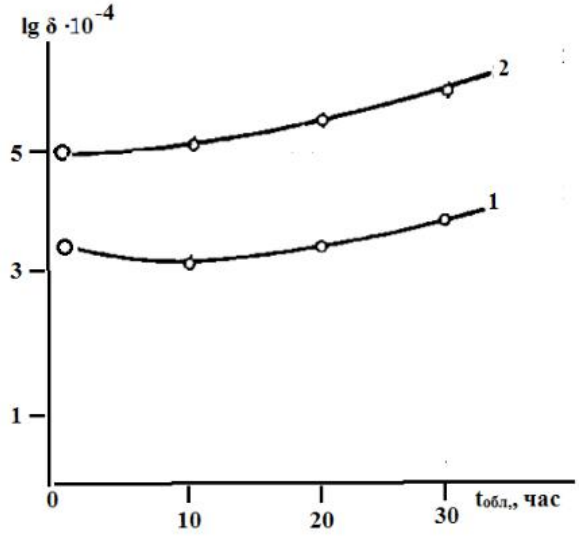

Fig.4. Change in the value of the dielectric loss tangent of a *LDPE* film and its modification with time under *UV* irradiation in air. 1-*LDPE* + 0.05 mass% *FI*, 2-*LDPE* (without additive)

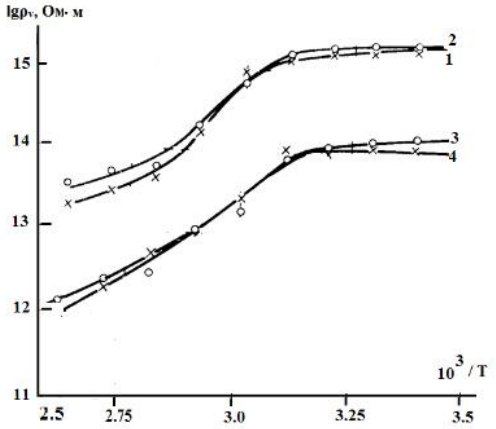

Fig.5. Temperature dependence of the logarithm of the specific volumetric electrical resistance of the original *LDPE* film and its optimal modification before and after *UV* irradiation in air at t reg.=15. *LDPE*-0.05 wt% *FI* (1) before and (2) after irradiation; *LDPE* (3) before and (4) after *UV* irradiation.

The obtained experimental results allow us to consider that the addition of phthalimide reduces the change in the $tg\delta$ film under the action of *UV* irradiation.

Temperature, electric field, exposure to ionizing radiation, and various additives also have a significant effect on the specific volume electrical resistance of polymeric dielectrics.

Figure 5 shows the results of experiments on the radiation of the temperature dependence of the specific-volume electrical resistance of the *LDPE* film and its optimal modifications before and after *UV* irradiation.

As can be seen from fig.5. the specific volumetric electrical resistance of the modified *LDPE* after exposure to *UV* irradiation practically changes in the same way as before irradiation.

However, as can be seen from Fig.6. as well as the dielectric loss tangent, with prolonged exposure to *UV* irradiation, the specific volumetric electrical resistance of modified *LDPE* slightly decreases, while for *LDPE* without additive, it decreases by one order of magnitude.

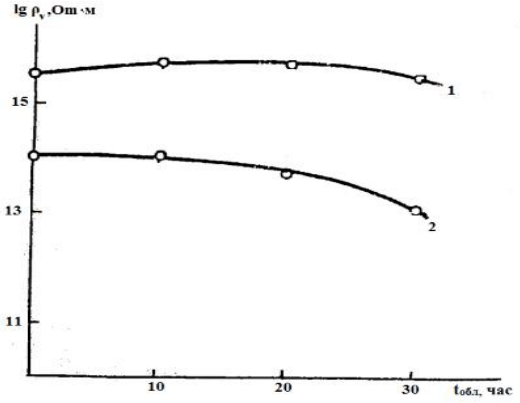

Fig.6. Change in the value of the specific volumetric electrical resistance of the *LDPE* film and its modification depending on the time of *UV* irradiation in air 1-*LDPE* + 0.05 wt% *FI*, 2-*LDPE* (without additive).

The resistance of of the proposed additive is the result of the formation of optimal structures in the polymer.

the *LDPE* film established by us with the introduction Thus, based on the foregoing, the discovered resistance to ionization radiation of the electrophysical properties of the *LDPE* film with the introduction of optimal amounts of additives can be explained on the basis of changes in the physical structure of *LDPE*.

At the same time, due to the physical structure former, the heterogeneity of the polymer structure apparently decreases and the degree of order in the mutual arrangement of macromolecules increases, as a result of which the process of vaporization and ionization processes in them is significantly slowed down.

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