Mechanical strength of polymer composites LDPE + x vol% $BiSb_3Te_6$ and nanocomposites LDPE + x vol% $BiSb_3Te_6$ + y vol% Fe

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***Abstract*—In this paper, the effect of semiconductor filler, metal nanoparticles and mechanical stress on the mechanical strength of low density polyethylene have been investigated. It was revealed that at low values of mechanical stress, the strength of composites LDPE+xvol.% $BiSb_3Te_4$ and nanocomposites LDPE+xvol.% $BiSb_3Te_6$+yvol.% Fe increases linearly, and at relatively high stresses remains constant and decreases with further increases in the stress.**

Keywords—mechanical strength, composites LDPE+xvol.%$BiSb_3Te_6$, nanocomposite, highly elastic.

I INTRODUCTION

The study of changes in the mechanical strength of compositions based on low density polyethylene under the action of mechanical stress is of great interest, since during the operation of various devices with elements of polymer compositions they are exposed to external factors [1-3]. The strength properties of polymeric compositions depend on the volumetric content of individual components, their structure, interfacial interactions of the bulk filler, as well as on the number of charges accumulated in the compositions during various electrical effects [4-6]. Therefore, when developing the technical capabilities of composites, certain requirements are imposed on them, namely: easy processability, high plasticity, mechanical and electrical strength, increased dielectric constant and certain conductivity. Analysis of the physico-mechanical properties of polymers and composites based on them shows that composites with semiconductor fillers most fully meet these requirements [7–10].

In the literature there is information on obtaining, researching the properties and identifying prospects for the practical possibilities of such materials [ ].

This paper presents the results of a study of the mechanical strength of polymer composites of LDPE + x vol.% $BiSb_3Te_6$ and nanocomposites of LDPE + x vol.% $BiSb_3Te_6$ + x vol.% Fe.

II EXPERIMENTAL PROCEDURE

Samples for testing the strength dependence of mechanical strength were cut from a film in the form of a double blade with a working section length of 10 mm and a width of 3 mm. Test of the samples on the strength dependence of mechanical strength, i.e. measurement of the dependence of strength on mechanical stress at a constant temperature was carried out by uniaxial tension on the installation described in Fig.1. During these measurements there was the time elapsed from the beginning of loading to the moment of breaking the specimens at various mechanical stresses.

An installation for measuring mechanical strength must satisfy two basic requirements: the effective tensile stress and temperature must not change during each test.

As is known, the test sample during the experiment is extended, its cross-section decreases, and the stress at a constant suspended load increases. To maintain a constant stress, a number of lever-type devices are used, which automatically reduce the load acting on the sample as it lengthens. To compensate for the increase in stress during the test, the load P was suspended not directly to the sample, but through the figure lever, the arm of which decreases automatically as the length of the sample increases.

Assuming that the sample cross section decreases in proportion to the relative elongation, i.e. the volume remains unchanged; then, for σ = const, the shoulder should decrease with increasing strain according to the formula $E = R_0 \cdot \frac{1}{1+\varepsilon}$, where ε is the relative elongation, R_0 and R are the projections of the vector radius on the horizontal axis in the initial and loaded positions. The deformation of the sample is recorded by an arrow fixed to the axis of the lever.

The thickness of the samples before the test was measured using devices NZV-2 with an accuracy of 1 μm.

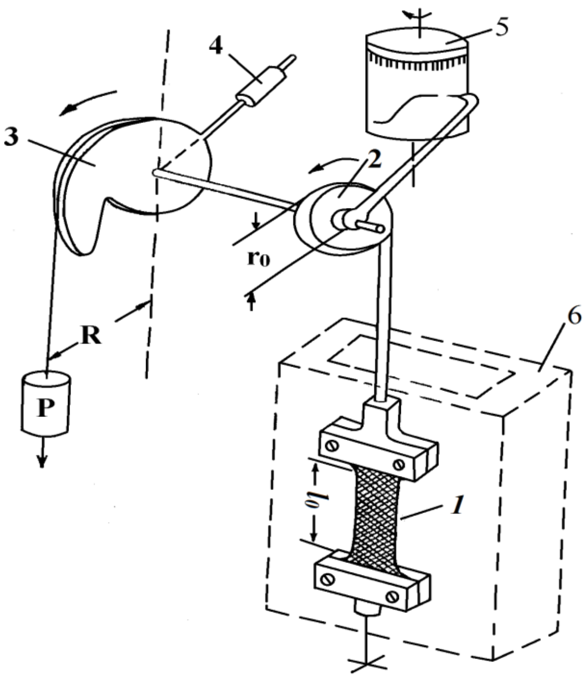

Fig. 1. Installation for determining the mechanical strength of composites: 1 - sample; 2 - block; 3 - rotating disk; 4 - compensation load; 5 - clockwork; 6 - temperature chamber.

III EXPERIMENTAL RESULTS AND DISCUSSION

The results of experimental studies of the mechanical strength of LDPE + x vol% $BiSb_3Te_6$ composites are shown in Fig.2. As follows from Fig. 2, when a sample is stretched, only elastic deformation arises first, due to a change in the state between the elements of the structure and a change in valence angles. The first sections of the stretching curves of Fig. 2 and 3 is a right line, consistent with Hooke's law. With an increase σ, starting with some of it value when the values $\alpha \cdot \sigma$ become comparable with U_0, the relaxation time decreases rapidly. Under the action of a large stress, elementary acts of transition of kinetic units to new positions are carried out, and consequently, the conformations of the chain molecules change. The rate of stress reduction in the sample, which occurs as a result of straightening of the chain molecules, increases and finally becomes equal to the rate of its increase. Further, the deformation occurs at almost constant stress.

As is well known, with sufficiently large values of external forces, a law enters into force that determines the dependence of the relaxation time (τ) on an external force. This dependence provides for a decrease in the action of external stress σ

$$\tau = \tau_0 e^{\frac{U_0 - \alpha\sigma}{kT}}$$

where U_0 the potential barrier of the transition of a kinetic unit from one position to another in the absence of a deforming force, α is the volume of the kinetic unit, σ is the stress, τ_0 is the period of oscillation of the kinetic unit near the position with a minimum of potential energy; k - Bolsmann constant, T - absolute temperature. As follows from Fig. 2, as the voltage increases to a certain value, the strength remains constant. Then $\frac{d\sigma}{d\varepsilon} = 0$, i.e. the rate of increase in stress is finally made equal to the rate of its resorption, which is called the limit of forced elasticity, and the deformation that develops when this limit is reached, is forced elastic.

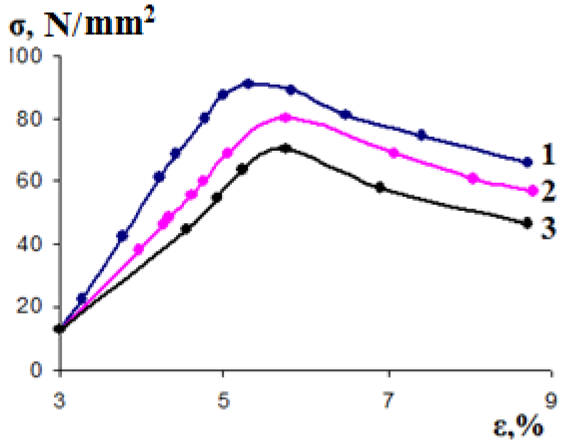

Fig. 2. The dependence of mechanical strength on the stress of composites LDPE + x vol% $BiSb_3Te_6$, where, 1 - x = 3; 2 - x = 5; 3 - x = 7.

For our studied composites, the general is the beginning of a steep section and a flat part of the curve. The transition from the first part of the curve to the presence of the second is made mostly monotonous, but, sometimes with maxima. The deviation from linearity is due to the fact that a certain amount of highly elastic is added to the elastic deformation. In the initial part of the stretching curves of the samples, it is caused by the change in the internal energy. Deformation is mainly associated with changes in the intermolecular distances, valence angles, and inter-atomic distances. Since the modulus of elasticity depends on the rate of deformation, highly elastic is added to the elastic deformations. The decrease in the slope of the $\sigma(\varepsilon)$ curve during the transition to a maximum is also associated with the development of forced elastic elastic deformation in the samples. The nature of the development of forced-elastic deformation indicates that it, like plastic, is caused by stresses causing a shift of some layers of material relative to others. In the deformation region corresponding to the maximum in the curves (Fig. 2.), the beginning of the formation of the so-called “neck” is noticed. In the absence of a maximum on the curve, the deformation occurs without the formation of a neck. In the area of voltage drop, neck formation occurs. By the end of the decay, the neck formation voltage ends. On the gentle part of the stretch curve, the stress remains almost constant. At this stage of deformation, the neck cross-section varies little and the sample elongation occurs due to the propagation of forced elastic deformation to the adjacent parts of the sample. This process is accompanied by an increase in the length of the neck. The voltage drop on the curves is mainly due to the narrowing of the sample in the neck. Naturally, with a decrease in the cross section, the deforming force also decreases, but if this reduced value is attributed to the initial section, then the stress will decrease.

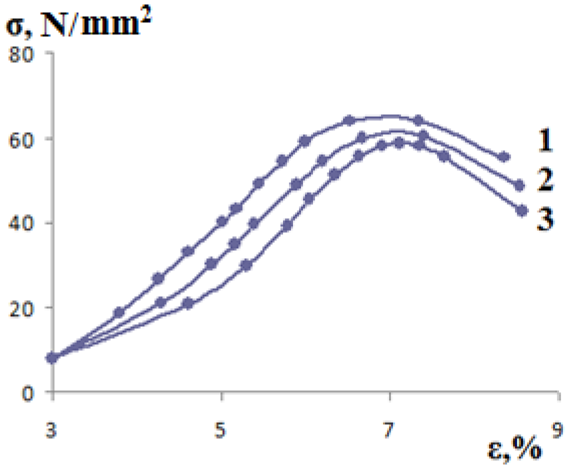

Fig.3. Dependence of mechanical strength on the voltage of nanocomposites LDPE+xvol%$BiSb_3Te_6$+ yvol%Fe, where, 1 - x = 10, y = 10; 2 - x = 3, y = 7; 3 - x = 7, y = 3

IV References

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