# THE MECHANICAL AND ELECTRIC DURABILITIES OF POLYMER COMPOSITIONS ON THE BASE OF POLYVINYLIDENEFLUORIDE AND PIEZOCERAMICS

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Mechanical and electric durabilities of polymer compositions on the base of polyvinylidenefluoride (PVDF) and piezoceramics of the type PCR3M and PCR8 have been studied.It was shown, that at other equal conditions the mechanical and electric durabilities of polymer compositions depend on the physical structure of piezoceramics and temperature-temporary conditions of crystallization of compositions.

At last time compositions on the base of polymers and piezoceramics are widely used in different sensors and converters devices, because they possess by piezoelectric, electric, electret and other properties [1, 2]. It is obvious, that at exploitation of such devices with elements from a polymer-piezoceramics composition, the main part plays its strength properties (the mechanical and electric durabilities).

The mechanical and electric durabilities of polymer compositions on the base of polyvinylidenefluoride (PVDF) and piezoceramics of the type PCR3M and PCR8 and the influence of temperature-temporary conditions of crystallization on these strength properties have been studied in given work.

PCR3M and PCR8 piezoceramics had zirconate-titanate-lead ( ZTL) composition and, correspondingly, possessed by rhombohedral and tetragonal structure. Piezocemics were taken with sizes of particles $d$<50 mkm.

The powdery piezoceramics PCR3M and PCR8 were inserted in the powdery PVDF by means of the mechanical mixing of polymers with admixtures (piezoceramics).

The compositions have been received from mixtures by method of the hot pressing at the melting temperature of the polymer matrix under the pressure 15 Mpa during 15 minutes with the following cooling.

For receipt of samples with different physical structures, the process of film preparation from compositions took place in two conditions: in the first case samples, received by hot pressing, were cooled with the high rate 2000 grade/minute by means of plunging of the melt between two aluminum foils into the ice-water mixture. These samples (films) of compositions were called as «quick cooled» (QC). In the second case the melt in the press was cooled slowly up to the room temperature with the average rate 2 grade/minutes, that is was received so-called «slowly cooled» (SC) samples (films) of compositions.

Force dependences of the mechanical durability $\tau_\sigma$ (dependences of time passed from the moment of the sample loading till its burst on the constant mechanical stress $\sigma$) and field dependences of the electric durability $\tau_E$ (dependences of time passed from the moment of application of a high electric field to samples till its breakdown on the intensity of the field $E$) were registered. Dependences of $\tau_\sigma$ on $\sigma$ and $\tau_E$ on $E$ have been determined at the temperature 293K by methods, described in works [3, 4].

Dependences of $lg\tau_\sigma$ on $\sigma$ for QC PVDF-PCR3M compositions, containing different quantities in volumetric compositions of PVDF and PCR3M, are presented on fig.1 in semilogarithmic coordinates. It is seen that in all cases $lg\tau_\sigma$ reduces in a linear fashion versus $\sigma$. It means that $\tau_\sigma$ reduces exponentially in the dependence on $\sigma$, when the equation is fulfiled:

$$\tau_\sigma = Ae^{-\alpha\sigma},$$

where $A$ and $\alpha$ coefficients are parameters, defining the mechanical durability properties of the material; moreover $A$ and $\alpha$ depend on the nature of the studied material and on the temperature of durability testing. It is seen from fig.1, that the decrease of the mechanical durability and the strength of PVDF-PCR3M composition takes place in dependence on the quantity of the inserted PCR3M admixture. According to graphics, given on fig.1, the parameter $A$ in the exponential equation does not change, and the decrease of the mechanical strength properties of PVDF-PCR3M composition in the dependence on the content of the inserted PKR3M admixture reflects on the growth of the coefficient $\alpha$.

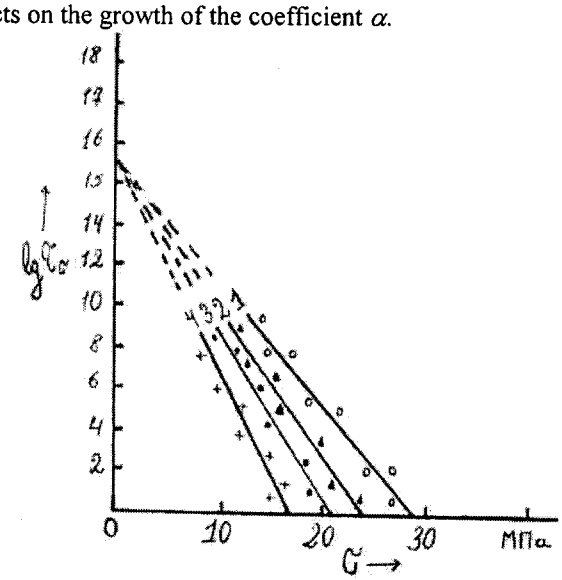


*Fig. 1.* Force dependences of the mechanical durability of QC samples of the PVDF-PCR3M composition in different relations of components in volumetric contents: 1 - 90+10 ob %; 2- 80+20 ob %; 3 - 70+30 ob %; 4 - 60+40 ob %.

Force dependences of the mechanical durability in semilogarithmic coordinates of $lg\tau_\sigma$ versus $\sigma$ were registered for QC PVDF-PCR8 compositions, containing different quantities in volumetric contents of PVDF and PCR8 components. Field dependences of the electric durability in semilogarithmic coordinates of $lg\tau_E$ versus $E$ were also registered for QC PVDF-PCR3M, PVDF-PCR8 compositions, containing the different quantities in volumetric contents of components.

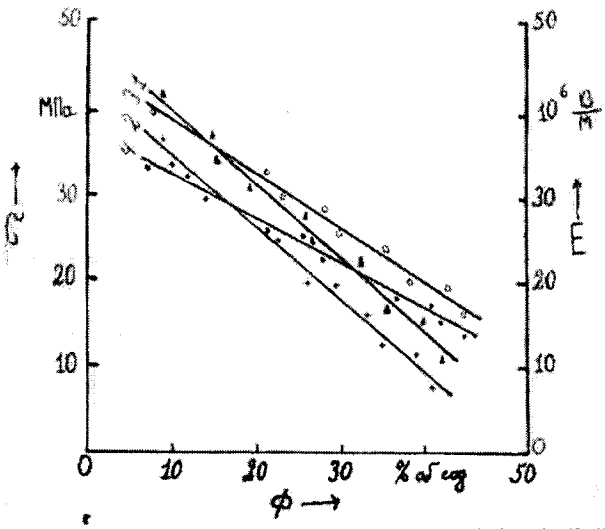


*Fig. 2.* Dependences of the mechanical (1,2) and electric (3,4) strengths of QC of PVDF-PCR3M and PVDF-PCR8 compositions on volumetric contents of PCR3M and PCR8 piezoceramics. 1 - PVDF-PCR3M; 2 - PVDF-PCR8; 3 - PVDF-PCR3M; 4 - PVDF-PCR8

For clarity, on the base of the force and field dependences of the mechanical and electric durabilities, correspondingly, dependences of the mechanical strength (as the mechanical strength $\sigma$ the value of the explosive stress at $\tau_\sigma$=1s; i.e. at $lg\tau_\sigma$=0 was taken) and the electric stability (the value of the puncture voltage at $\tau_E$=1s., i.e. at $lg\tau_E$= 0 was taken as the electric stability $E$) were built for QC samples of PVDF-PCR3M and PVDF-PCR8 compositions on the quantity $F$ of inserted PCR3M and PCR8 admixtures. Such dependences of the mechanical strength $\sigma$ and the electric strength $E$ of PVDF-PCR3M and PVDF-PCR8 compositions on the content of $F$ admixtures of PCR3M and PCR8 piezoceramics are shown on fig.2. It is seen that the mechanical strength $\sigma$ and the electric strength $E$ of PVDF-PCR3M and PVDF-PCR8 compositions reduce at the growth of the quantity of PCR3M and PCR8 admixtures. It is also seen from fig.2 that at the same contents of PCR3M and PCR8 admixtures the mechanical strength $\sigma$ and the electric strength $E$ of the PVDF-PCR3M composition are more in comparison with $\sigma$ and $E$ of the PVDF-PCR8 composition. These experimental results are explained by the fact that the value of the rheorientation polarization and the degree of made (in the process of the polarization) domain reorientations different from 180° for PCR3M piezoceramics are more in comparison with the piezoceramics PCR8 [5]. As a result, interphase interactions in the case of PVDF-PCR3M composition are more in comparison with the interphase interactions in PVDF-PCR8 composition, that leads to the growth of the stable properties of the PVDF-PCR3M composition.

To establish the influence of the physical structure (temperature-temporary condition of the crystallization) of compositions on its mechanical durability $\tau_\sigma$ and the electric durability $\tau_E$, force dependences of the mechanical durability and field dependences of the electric durability of SC and QC compositions were compared at other identical conditions.

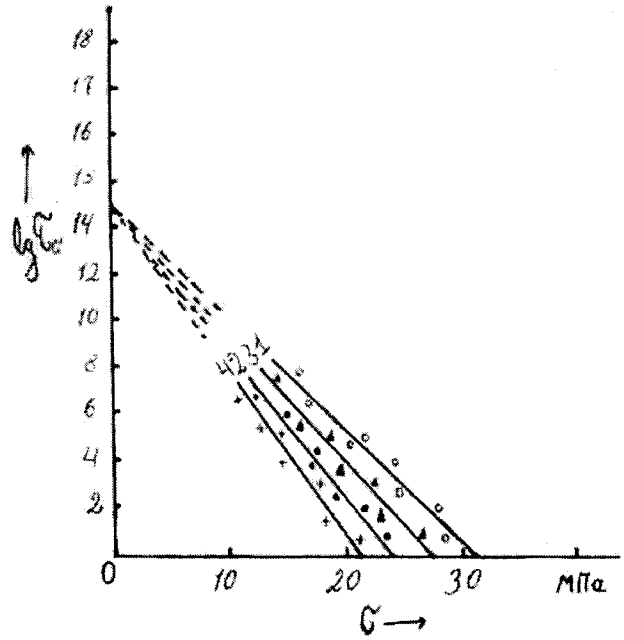


*Fig.3.* Force dependences of the mechanical durability of SC and QC of PVDF-PCR3M (1,2); PVDF-PCR8 (3,4) compositions in relation of components 80-20 volume %: 1,3- SC samples; 2,4- QC samples.

Force dependences of the mechanical durability of SC and QC for PVDF-PCR3M and PVDF-PCR8 compositions in the relation of components 80-20 volume % were built on fig.3. It is seen, that for both compositions the mechanical durability $\tau_\sigma$ of SC compositions is more in comparison with $\tau_\sigma$ of QC compositions at other equal conditions (at the same values of the explosive stress and temperature of measurement). The analogous results were received also in the case of force dependences of the electric durability, and exactly, the electric durability $\tau_E$ of SC compositions is more in comparison with $\tau_E$ of QC compositions. These experimental results could be connected with the thermal treatment of compositions, which takes place in the case of slow cooling. Then the amplification of the interaction occurs between phases, which is connected with the growth of the near-boundary layer and with structural changes in polymer compositions and also adhesion between the polymer matrix and piezoceramics [6-8]. It, in its turn, leads to the growth of the mechanical and electric strengths of SC PVDF-PCR3M and PVDF-PCR8 compositions.


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## POLİFİNİLDENFTORİD VƏ PYEZONKERAMİKALAR ƏSASINDA ALINMIŞ POLİMER KOMPOZİSİYALARININ MEXANİKİ VƏ ELEKTRİK YAŞAMA MÜDDƏTİ

Polivinildenftorid və PKR3M, PKR8 markalı pyezonkeramikalar əsasında alınmış polimer kompozisiyalarının mexaniki və elektrik yaşama muddəti öyrənilmişdir. Göstərilmişdir ki, digər eyni şəraitlərdə polimer kompozisiyalarının mexaniki və elektrik yaşama müddətləri pyezokeramikaların fiziki quruluşundan və kompozisiyaların kristallaşmasının temperatur – zaman rejimindən asılıdır.

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## МЕХАНИЧЕСКАЯ И ЭЛЕКТРИЧЕСКАЯ ДОЛГОВЕЧНОСТИ ПОЛИМЕРНЫХ КОМПОЗИЦИЙ НА ОСНОВЕ ПОЛИВИНИЛДЕНФТОРИДА И ПЬЕЗОКЕРАМИКИ

Изучены механическая и электрическая долговечности полимерных композиций на основе поливинилденфторида (ПВДФ) и пъезокерамиков марки ПКР3М и ПКР8. Показано, что при прочих равных условиях механическая и электрическая долговечности полимерных композиций зависят от физической структуры пъезокерамиков и температурно-временного режима кристаллизации композиций.

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