INFLUENCE OF POLARIZATION PROCESSES ON POLYMER ELECTRIC STRENGTH

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The distributions of breakdown waiting time (measured as electric durability τ) of polymers in constant field on sign in two directions (polarity) are determined and τ of polymer samples treated by preliminary polarization is also measured. It is shown that preliminary polarization of the samples in constant electric field decreases their electric strength at influence of the field of the same polarity. This fact evidences about cumulative nature of preparation process to breakdown and increases the electric density for the field of the opposite polarity. This indicates the ability to regeneration of "elements of destruction" caused by field action.

Keywords: polymer films, kinetics of electric destruction, electric durability, polarization and cumulative processes.
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INTRODUCTION

The polymer films are widely used in the capacity of isolated materials in the different industries. That's why the investigation of their electric strength properties is the actual task. In spite of the fact that the study of influence of strong electric fields on polymer fields has continued many decades [1], the conventional point of view on nature of polymer electric strength is absent.

Many authors suppose that the formation of cavities of micron sizes in polymer in which the gas discharges can be formed is the reason of breakdown of polymer film under action of electric field. Note that gas discharges in cavities with sizes less 5mm don't form in the fields usually used in the experiments on study of polymer durability, i.e. in the fields with strength $E \sim 10^8$ V/m [1,2]. It is accepted that cavities appear as a result of molecule destruction [3-5]. At this fact it isn't considered that interatomic bond strength in macromolecule essentially exceeds σ stress which can act in dielectrics in electric field. Moreover, the macromolecule destructions can't lead to cavity formation as the material density at bond breakage doesn't change.

It is established that breakdown itself is the final act of polymer preparation process to breakdown appearance for polymer dielectrics. The experiment results on revealing and study of "electric durability" τ, which is breakdown waiting time at application to polymer samples of electric field strength E (constant or alternative ones) [6 – 8]. τ means that processes preparing the samples to breakdown take place in polymers under field action. From this it is followed that process consists of succession of some elementary acts the waiting time of which defines the process temps. Elementary acts leads to formation of local changes which are conventionally called "destruction elements". The accumulation of these elements for τ time forms the conditions of nucleation and development of magistral breakdown. Thus, the durability is the electric strength characteristics including the preparation process kinetics.

It is shown that under electric constant field action this process is the cumulative one and consists in constant formation in polymer of volume electric charge, the reach of some critic value of which leads to the breakdown [8 – 10]. So, the charge formation is the factor decreasing the electric strength. At the same time it is shown that accumulated charges can be eliminated (by heating of the samples or action of opposite polarity electric field) and thus one can carry out the regeneration of initial polymer strength state [8,9]. Thus, the possibilities of manipulation of polymer charge-strength state take place.

The polarization effect is the one of most essential electron processes causing the main peculiarities of electric structure of ionizing states as it defines the intrinsic energy of charge carrier and state of conduction levels in energy scheme of ionized states.

The study of polarization process influence on polymer electric strength and possibility to use the manipulation of accumulated charges as increasing factor of electric durability of polymer dielectrics is the aim of the given work.

OBJECTS AND INVESTIGATION METHODS

The films of polyethylene terephthalate (PETP) and polytetrafluorethylene (PTFE) with width in several decades of micrometers are the objects. Electrical load and breakdown are carried out in the cells with pressure electrodes with 18mm diameter at electric voltage by constant sign. The durability τ which is the time between moment of electric field application and breakdown appearance is measured. The test results of the similar type for electric destruction of solid states including the polymers are described in [10]. Note that qualitative analysis of test results is carried out without necessary taking under consideration of durability statistics.

As it is known [6,7], the durability values for externally identical samples and conditions of electrical load (electric strength E, temperature T) differ by wide spread (1–2 decade order on durability). That's why the corresponding statistical service of this

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circumstances for the revealing of regularities of electric destruction kinetics.

EXPERIMENTAL RESULTS

The carried out investigations are dedicated to consideration of elementary processes taking place in polymer dielectrics in constant electric field which control the preparation of (breakdown) electric destruction kinetics. The breakdown preparation process in polymers being in electric field follows from test results at constant and alternative field action. The distribution of series from 30 samples of PETP and PTFE on durability is given in Fig.1 (a,b), n_τ/n ratio is on ordinate axis where n_τ is sample number disruptive during τ time, n is total sample number. It is seen that curve of integral distribution on $\lg\tau$ has S – type form that corresponds to unimodal distribution close to normal one (probability integral). The data for two directions (polarities) of applied field at constant values of E and T are given in Fig.1(a,b).

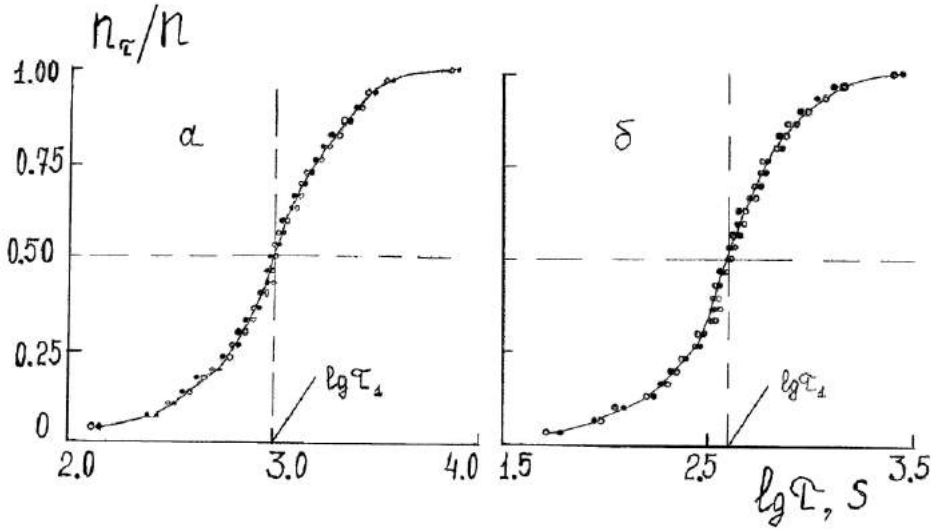

Fig.1. Integral distribution of polymer samples on electric durability in constant electric field. Light and dark points correspond to opposite field polarities. Temperature 100K.
a is - PETP, E=0.62 GV/m
b is - PTFE, E=0.46 GV/m

The distributions practically coincide with each other that establish the symmetry of test cell (diameter of electrodes is 18mm). The last fact will be the essential one at further manipulations.

τ_1 durability values (τ_1=1000sec for PETP, τ_1=400sec for PTFE) corresponding to breakdown of half sample number are defined from Fig.1 (a,b), i.e. during this time the breakdown of half number of electrically loaded samples, takes place. Thus, new series of the same samples are taken and endured at the same voltages and temperature during time τ_1 after which the voltage is taken. As a result, the half of sample number in series treated by field action but "not waiting" the breakdown stay not disruptive ones with which the further operations are carried out.

ANALYSIS AND RESULT DISCUSSION

The meaning and analysis technique of these operations is schematically explained in Fig.2. Here curve 1 is supporting curve corresponding to distribution by durability of second half of sample number in Fig., i.e. which have the durability bigger than τ_1. If after exposure τ_1 and voltage taking off, the accumulated changes are totally saved, so after repeatable field action of the same value and sign, distribution of residual samples on secondary durability τ_2 should take place left than curve 1, i.e. in the form of curve 2. Such position of curve 2, which is absent to reconstruction of curve 1 in $\lg(\tau-\tau_1)$ coordinates should correspond to total absence of regeneration.

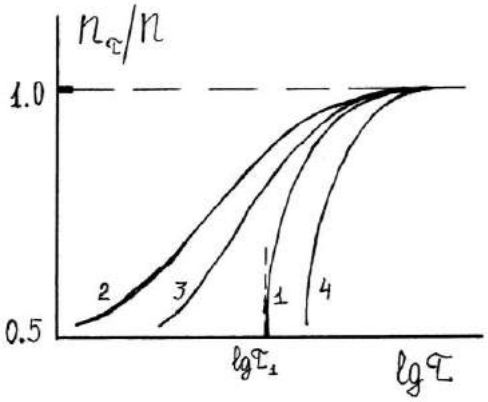

Fig.2. Distributions on durability. 1 is distribution of not disruptive samples after exposure during τ_1 time; 2 is the same distribution in $\lg(\tau-\tau_1)$ on secondary durability (after interruption) at regeneration absence; 3 is distribution on secondary durability of the same samples at partial regeneration; 4 is distribution on secondary durability of the same samples at their strengthening.

If for the time of interruption of the same sign field action the changes in the rest samples are carried out or decrease of accumulated changes cause by temperature and opposite polarity field action, then the distribution on secondary durability should take place between curves 2 and 1 (curve 3).

The overlapping of the curve 3 on the curve 1 takes place at the total regeneration. Finally, for example, if the strengthening changes take place as a result of switching of the field in the samples, then distribution on secondary durability should take place right than curve 1 (curve 4).

The data correspond to experimental observation of curves 2 and 3 for the series of polymers are given in [8,9]. In this case, the samples are put for some time τ_1 in the field (the part of them are disrupted), further the voltage in interval time (τ_n) switches off and switches on again. The "secondary durability" (τ_2) which is the electric durability of not disruptive samples for τ_1 time beginning from the moment of second voltage switching on, is measured. The secondary durability of the samples is defined after changing temperature at definite time; τ_1 value corresponds to breakdown of half of samples. It is revealed that sample distributions on secondary durability shift in the region of least values τ in comparison with distributions in the tests without breaking of field action. Consequently, the sample exposure under voltage during time τ_1 leads to consumption of structural strength part. This evidences about the fact that breakdown preparation process takes place in electrically loaded polymers. As a result the changes which aren't totally regenerated during time τ_n accumulate in the samples during time τ_1, i.e. they show that changes accumulated in the samples for time τ_1 save if in interruption the sample doesn't heated or it isn't treated to action of opposite polarity field.

The distribution of polymer samples on secondary durability defined in tests with breaking of field action closes to distribution on durability in tests without breaking of field action, if for time τ the samples are heated or they are treated in opposite polarity field. This means that change regeneration accumulated in polymer samples for time τ_1 takes place at heating and in the opposite polarity field. Especially this fact (data on opposite polarity field regenerating action) leads to conclusion that sample preparation process to breakdown is connected first of all with formation of volume electric charges (rapidly, with electron accumulation in traps). So, the question arises: can this process lead not only to approach of electric stability losses (i.e. to breakdown approach), but to increase of electric stability.

This question is solved by following simple method. The series of samples (30) are treated under action of electric field of constant sign (E=0.62 GV/m for PETP and E=046 GV/m for PTFE) for the given polarity during time τ_1 (τ_1=1000sec for PETP, τ_1=400sec for PTFE). Further, the rest half of sample number at the same temperature (T=100K) are treated under field action of the same strength of opposite polarity, correspondingly for PETP and PTFE until appearance of sample breakdown. The distribution of this sample part on their secondary durability is shown in Fig.3. (a,b) (curve 2). It is shown that shift of distribution curve right from supporting curve 1 takes place, i.e. to the side of electric durability increase. Thus, it is experimentally established that samples previously polarized in the field of the one polarity are more electrically strength ones in respect of the opposite polarity field.

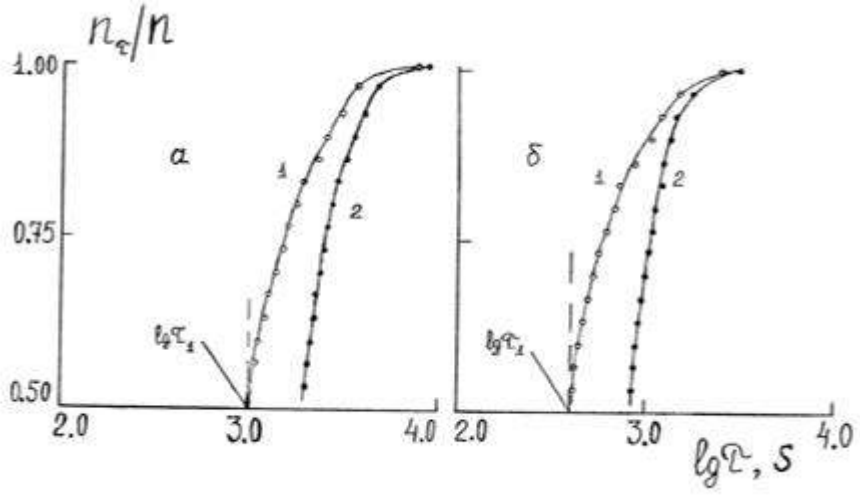

Fig.3. Integral distribution of polymer samples on electric durability. Temperature is 100K.
a is PETP, E=0.62 GV/m
b is PTFE, E=0.46 GV/m
1 - is distribution of disruptive samples after exposure during τ_1(τ_1=1000C for PETP, τ_1=400C – for PTFE) without the change of filed polarity
2 - is distribution of disruptive samples after exposure during $\tau_1$time with change of filed polarity after it.

The results of polarization strength of polymer samples are obtained in the tests of another type on PTFE films. With this aim the dependence of breakdown waiting time (durability) on constant electric field strength of the given polarity is measured. The results of such measurements for T=293K are given in Fig.4 (dependence 1). Each point in graph is the result on averaging by 12 durability measurements at each value of field strength.

Many series of the same samples are treated by previous action of constant electric field of strength E=0.038 GV/m during 1 hour at 380K. Further, the electric durability of such samples at 293K at the both field polarity and opposite one is measured. If field polarity coincides with field polarity of previous polarization, then decrease of sample electric durability is observed (Fig.4., dependence 2). Vice versa, if the polarity is opposite one, then sample electric durability increases (Fig.4, dependence 3) and exceeds the durability of initial samples (not treated by previous polarization). The corresponding data for PETP are the similar.

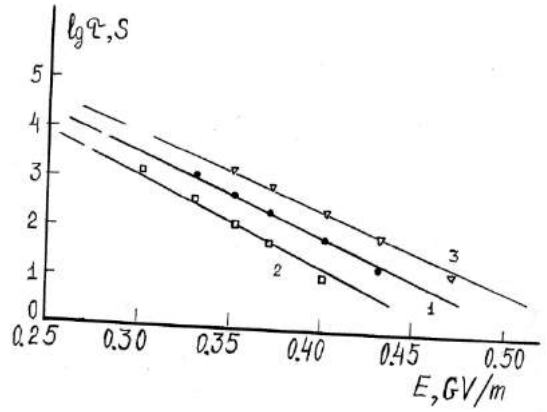

Fig.4. The dependence of PTFE durability on electric field strength (by sign). Temperature is 293K. 1 is durability of the samples without previous polarization; 2,3 are disabilities of the samples after exposure in constant field E=0.038 GV/m during 1 hour at 380K; 2 is durability of the disruptive samples in the field of the same polarity; 3 is the durability of the disruptive samples in the field of opposite polarity.

Thus, previous polarization of polymer samples in constant electric field decreases their durability at action of opposite polarity and increases the durability for opposite polarity field. The similar behavior of electric durability coincides with consumption of charge accumulation in polymer volume. The durability reduction (after some film exposure under voltage) up to primary value takes place at polymer heating or its placing for some time in electric field of opposite polarity. This means that the discharge of accumulated charge in the field of opposite polarity at heating takes place. Such operation leads even to that the electric durability of polymer films in field of opposite polarity (after action of initial field) is the highest than in continuously acting field. The durability estimations of polymer film carried out on the base of such consumptions in constant electric field is in the agreement with experimental data [8].

At transfer of described polarization phenomena on electric ones, the polymer destruction in alternating field should be expected for the polymers with continuous durability. However, as it is well known [11,12] in alternative field the breakdown takes place even rapidly than in constant one (at equality of amplitude strength values of alternative and electric fields), i.e. electric strength of polymer dielectrics in alternative electric field is essentially lower than in constant one [13] and in particular, it is known, that polymer durability in alternative field approximately on two orders less than durability value in constant field [14-16]. Thus, the revealing of general and specific moments in mechanisms of electric destruction for constant and alternative fields has the more actuality.

Finally, the possibility of technical use of "electret" strengthening of polymer dielectrics can serve the subject of further development.

CONCLUSION

The regeneration of electric density properties of polymer dielectric films after previous polarization which are reconstruction and strengthening of electric durability by the way of heating or action of opposite polarity field is studied. On the base of regeneration kinetics analysis the conclusion that regeneration is caused by discharge of volume charges, is made. This means that previous polarization of polymer films in them takes place and the binary volume charges (of double electric layers), i.e. polarization heterocharges, form.

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