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CHARGE THERMOSTIMULATED DISCHARGE OF PTFE CORONA CHARGING ELECTRETS, OBTAINED IN DIFFERENT GAS MEDIA

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Abstract. This work presents the results of investigation on 20 μm thick PTFE film electrets, prepared by the corona charging method performed in controlled gas medium. The following gases have been used: argon, carbon dioxide, air and oxygen. The temperature dependence of electret surface potential has been measured. The results obtained show the presence of a maximum in the temperature dependence of the surface potential. The magnitude of this maximum depends considerably on the gas used in the corona charging method. A corresponding interpretation of the results obtained has been given.

Резюме. В настоящей работе представлены результаты исследования коронэлектретов из ПТФЭ толщиной в 20 μm , полученных в контролируемой газовой среде. Использованы следующие газы: аргон, углекислый газ, воздух и кислород. Измерялась температурная зависимость поверхностного потенциала электретов. Температурные зависимости поверхностного потенциала обнаруживают максимум, величина которого существенно зависит от газа, используемого при зарядке в коронном разряде. Дана соответствующая интерпретация полученных результатов.

Introduction

The effect of the gas medium in the production of electrets from teflon-FEP on the temperature/surface potential relationship announced in [1] has been studied. No considerable differences in the nature of the charge decay have been found, though some differences in the electret surface potential values have been observed. The influence of the corona polarity (positive or negative) and the electrode type on the electret surface potential thermograms, as well as the kinetics of the charge relaxation process in PTFE electrets, obtained in a negative corona discharge has been studied in [2]. A maximum has been observed in the temperature dependence of the surface potential, which is different for the electrets obtained in a positive and negative corona discharge. In the case of a negative corona discharge, the form and magnitude of the peak change with the time of storage.

The results obtained show that further studies on the above-mentioned problems are required. The purpose of the present work is to study the effect of the gas medium, in which corona discharge is performed, on the surface potential thermograms of PTFE electrets.

Experimental part

Nonmetallized 20 μm thick PTFE samples have been studied. The electrets were produced by means of a three-electrode system (needle, grid and plate) [3] in a corona discharge taking place in a chamber through which the desired gas was flown. The following gases were used: argon, carbon dioxide, air and oxygen. Negative voltage -5 kV was applied to the needle electrode (for argon -3 kV). The electret surface potential was limited by the grid potential and was of the order of -400 V.

The electrets so prepared were taken out of the chamber and stored on a metal support under ambient conditions — room temperature and room humidity.

Electret surface potential was measured by the method of the vibrating electrode with compensation [4].

The temperature dependence of the surface potential was measured 200 days after electret preparation, since according to [2] appreciable changes occur in the magnitude of peaks after at least half a year of storage.

Figure 1 shows the results from the study on the temperature dependence of surface potential (V_e) of PTFE electrets obtained in a corona discharge in different gas media. The electret surface potential measured at room temperature 200 days after preparation and just before heating was accepted as initial — V_{e0} . The heating rate was 2 K/min.

The results obtained show that: 1) previous results (2) for presence of a peak in the temperature dependence of V_e are confirmed; 2) the magnitude of the peak depends to a considerable degree on the gas used in the corona charging — weakly expressed peaks when argon and carbon dioxide are used and well expressed peaks when air and especially oxygen are used.

Figure 2 shows the results from the twofold heating up to 200°C of the same samples. An electret obtained in oxygen medium has been chosen. The first heating gives the usual peak. At the starting point of the second heating the surface potential appears equal to the V_e at the end temperature of the first heating. In both cases

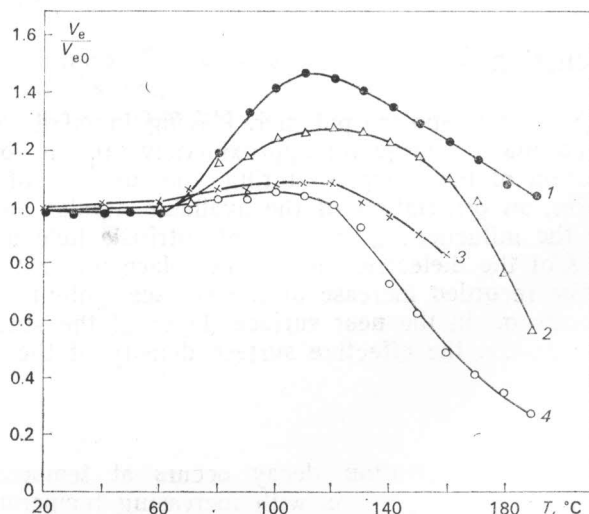


Fig. 1. Temperature dependence of the surface potential of PTFE electrets, charged by negative corona in various gas media: oxygen (curve 1), air (curve 2), carbon dioxide (curve 3), and argon (curve 4). The electrets were heated 200 days after charging

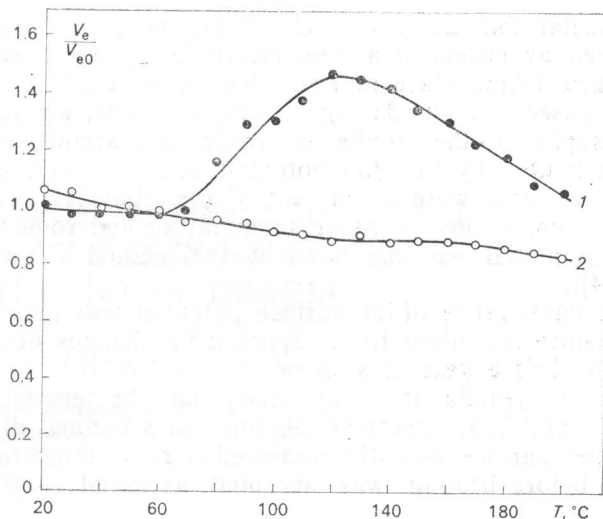


Fig. 2. Temperature dependence of the surface potential of PTFE electrets, charged by negative corona in oxygen medium for two consecutive heatings: first run — 200 days after charging of electrets (curve 1), second run — immediately after cooling of samples (curve 2)

the value V_e at room temperature before the first heating was chosen as initial value of electret surface potential V_{e0} . With the increase of temperature V_e slowly decreases, in the interval from 120°C to 160°C it remains almost constant in the order of $0.9 V_e$ and then decreases slowly.

Discussion

PTFE is a nonpolar polymer. Having in mind that the electrets have been obtained in a corona discharge for approximately 30 s at room temperature, it is evident that polarization of the samples during the process of electret preparation is impossible. However, an orientation of the available dipoles and a moving of weakly bounded ions under the influence of the electret intrinsic field are quite possible, i. e. polarization processes of the dielectric may take place under the impact of the electret intrinsic field. The recorded increase of the surface potential shows that, besides the injected homocharge σ_h , in the near surface layer of the studied samples there is a certain polarization P , i. e. the effective surface density of the charge can be given as follows:

$$\sigma_{ef} = \sigma_h - P. \quad (1)$$

It is well known that polarization decay occurs at temperatures lower than the captured excess charge decay. Therefore, with increasing temperature, polarization decreases, while σ_h remains almost constant, i. e. an apparent increase of the effective surface density σ_{ef} of electret charge is recorded. There is a simple relation between the electret surface potential V_e and the effective surface density σ_{ef}

$$\sigma_{ef} = AV_e, \quad (2)$$

where A is a constant, depending on the dielectric thickness and relative permeability and on the experimental conditions. Therefore, with increasing temperature, V_e also increases. This effect should be particularly apparent in polar polymers and a confirmation of this has been reported [5] with PET.

If polarization was due to the moving of weakly bound ions, the recorded effect ought to be almost the same in all cases. The fact that it is different with the electrets obtained in various gas media shows that in this case a dipole orientational polarization has occurred. The oxygen atoms play an important role here, probably by combining with the C-atoms of the main chain and thus forming groups with certain dipole moment. In the course of time these dipoles can get oriented in the electret field.

From the data in Fig. 1 we can calculate the relative polarization $P(T)/P_0$ at different temperatures, where P_0 is the maximum polarization value at room temperature at the beginning of the experiment, and $T(P)$ is polarization at temperature T . For the purpose, assuming that σ_h does not change in the studied temperature interval, from (1) and (2) we can write the following:

$$P_0 = AV_{eo} \left(\frac{V_e^{\max}}{V_{eo}} - 1 \right) = AV_{eo}(a - 1) \tag{3}$$

$$P(T) = AV_{eo} \left(\frac{V_e^{\max}}{V_{eo}} - \frac{V_e(T)}{V_{eo}} \right) = AV_{eo}(a - b(T)), \tag{4}$$

where V_e^{\max} is the maximum surface potential value.

From (3) and (4) we find

$$\frac{P(T)}{P_0} = \frac{a - b(T)}{a - 1}, \tag{5}$$

where $a = \frac{V_e^{\max}}{V_{eo}}$ and $b(T) = \frac{V_e(T)}{V_{eo}}$.

The established relations (5) are presented in Fig. 3. Curve (1) refers to an electret obtained in oxygen medium, while curve (2) refers to an electret obtained in air. It appears that both curves have the same course. Therefore, in both cases we have

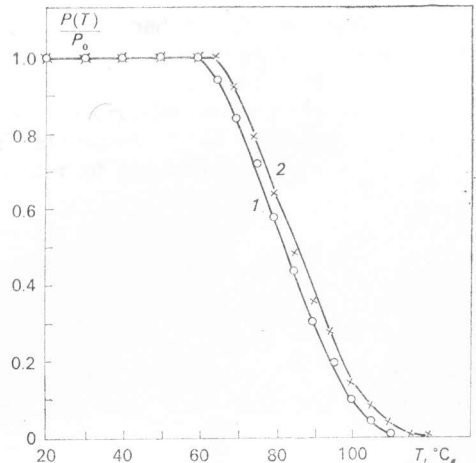


Fig. 3. Temperature dependence of polarization, calculated by formula (5) from data in Fig. 1 for electrets charged in oxygen (curve 1) and air (curve 2) media

relaxation of one and the same type of dipoles with the same activation energy. But the different oxygen concentration in the two cases determines the different concentration of the dipoles obtained, and hence the lower polarization value of the air medium as compared to the oxygen one. As to the lower rate of increase in surface potential for the electrets obtained in carbon dioxide, this may be attributed to the fact that oxygen is bound to carbon and cannot form groups with the C-atoms from the main chain.

Conclusion

The studies carried out showed that the previously recorded peak in the temperature dependence of PTFE electret surface potential depends on the type of gas medium, where the corona discharge is accomplished, and disappears after heating to an appropriate temperature. The presence of such a peak is due to the availability of oxygen in the gas medium, which results in the formation of dipole groups with a certain dipole moment. In the course of time these groups become oriented in the electrical field of the electret and give rise to the available polarization, which decays upon heating to a definite temperature.

References

1. Electrets, ed. by G. M. Sessler, Springer-Verlag, Berlin-Heidelberg-New York, 1980.
2. Кармъзова, П. Г., Г. А. Мекишев, Научни тр. на ПУ, 22, 1984, 1, 17-21.
3. Walkup, L. E., USA Patent No 277, 1957, p. 7957.
4. Reedyk, C., and M. M. Perlman. — J. Electrochem. Soc., 115, 1968, 1, 49-51.
5. Turnhout, J. van Thermally Stimulated Discharge of Polymer Electrets, Elsevier, Amsterdam, 1975.

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