CORONA ELECTRETS OBTAINED IN DIFFERENT GAS MEDIA

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The influence of the gas medium in which electrets have been obtained on the time dependence and temperature dependence of the surface potential was investigated. Samples of 20 μm thick polypropylene (PP) film were used. The gases used were air, oxygen and nitrogen. The difference in the effects of gas media on the rate of charge decay of the electrets was supposed to be due to different kinds of surface traps, which arise from the interaction between gas ions and sample surfaces.

1. Introduction

The corona discharge method has been widely used for the production of electrets [1,2]. Many papers [3,4,5] have studied the influence of the gas medium, in which the electrets have been obtained, on their behaviour. The time dependence of the surface potential was studied in [3]. The corona discharge was carried out within the studied gas flow and, depending on the type of gas, different values of the corona voltage were used. Corona electrets obtained in various gases were studied in [4], using the method of thermally stimulated currents. The influence of the corona charging process in various gases on the piezoelectric transducer coefficient of a cellular electret film was investigated in [5].

The present paper studies corona electrets obtained in various gas media at different corona polarities. The dependences of the electret surface potential on time and temperature have been studied for the two types of corona – positive, and negative. In all cases, we maintained the same value of the corona voltage.
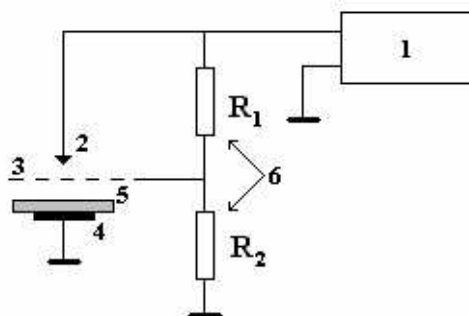
2. Experimental details

Fig. 1. Scheme for obtaining electrets: 1. high voltage source; 2. corona electrode; 3. grid; 4. plate grounded electrode; 5. electret; 6. voltage divider.

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Non-metallised samples of isotactic polypropylene with thickness d = 20 μm and diameter D = 30 μm were studied. Before charging, the samples were cleaned by alcohol in an ultrasonic bath for 4 minutes. They were then washed in distilled water, and dried on filter paper.

We used a three-electrode system (Fig. 1) to charge the samples in a corona discharge. The system comprised eight corona electrodes (needles), a grounded plate electrode and a grid situated between them. The system was placed in a chamber connected to a vacuum pump and a container with the studied gases.

The samples were placed on the grounded electrode, the air was pumped out of the chamber, and the system was left for 24 hours at a lowered pressure (20 Torr). On the next day, the chamber was again pumped down, and then filled up with the measured gas until the pressure became equal to the atmospheric one. A constant voltage of ± 5 kV was applied to the corona electrode for a period of 1 minute. The electrets obtained were stored in dessicators with reduced humidity (RH = 0 %). We measured the surface potential values outside the dessicators, by the method of a compensated vibrating electrode.

3. Results

Two sample series were investigated – charged in positive and negative coronas. In both cases, the gas media used were air, nitrogen or oxygen. The surface potential was measured for several months. Some of the samples were heated, and the temperature dependence of the electret surface potential was also measured.

Table 1. Initial values of surface potential, V_{eo}, Volts.

Type of the corona	Gas medium		
	Air	Nitrogen	Oxygen
Positive	555 ± 25	606 ± 32	399 ± 53
Negative	744 ± 14	1387 ± 85	650 ± 21

Table 1 shows the initial values of the electret surface potential V_{eo} and the respective standard deviations. Each of the table values was taken as the average for a series of 8 samples.
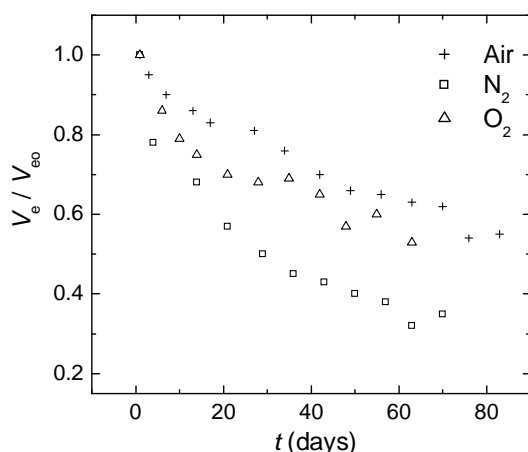

Fig. 2. Time dependence of the surface potential of PP electrets obtained by negative corona in various gas media.
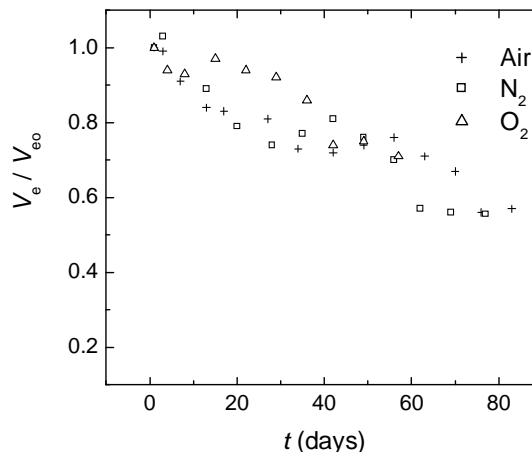

Fig. 3. Time dependence of the surface potential of PP electrets obtained by positive corona in various gas media.

The time dependences of the relative surface potential V_e/V_{eo} for samples charged in the different gas media can be seen in Figs. 2 and 3, for electrets obtained in a negative and a positive corona, respectively. The relative error for each value of V_e/V_{eo} was calculated. For the samples obtained in a negative corona, it was quite small ($< 6\%$). The relative error for the samples obtained in a positive corona was significantly higher, and reached 12%. In all cases, we observed a decay of the surface potential. However, the decay rate was different for samples charged at different corona polarities in different gas media.

The temperature dependences of the relative surface potential are displayed in Figs. 4 and 5, for electrets obtained in a negative and a positive corona, respectively. The heating rate for all samples was about the same: 1.9 K/min. For all samples, the curve shape for V_e/V_{eo} as a function of temperature was approximately the same. At temperatures higher than 55 °C, we observed a sharp drop in the relative surface potential for electrets that had been obtained in a negative corona, while the same behaviour for electrets obtained in a positive corona was observed above 65 °C. The decay of the surface potential with temperature is described by an equation of the Arrhenius type:

$$V_e = V_{eo} \exp(- E / kT) \qquad (1)$$

where E is the activation energy associated with process, which was calculated from plots of $\ln(V_e/V_{eo})$ vs. $1/T$. For electrets obtained in a negative corona, $E = 0.3$ eV irrespective of the gas medium. For electrets obtained in a positive corona, E is different for various gas media: 0.3 eV for air, 0.4 eV for nitrogen, and 0.5 eV for oxygen.
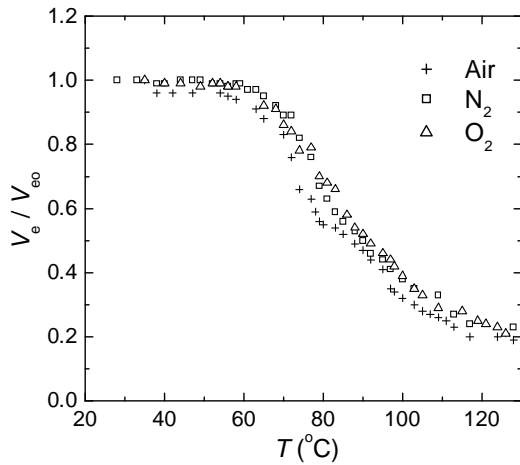
Fig. 4. Temperature dependence of the surface potential of PP electrets obtained by negative corona in various gas media.
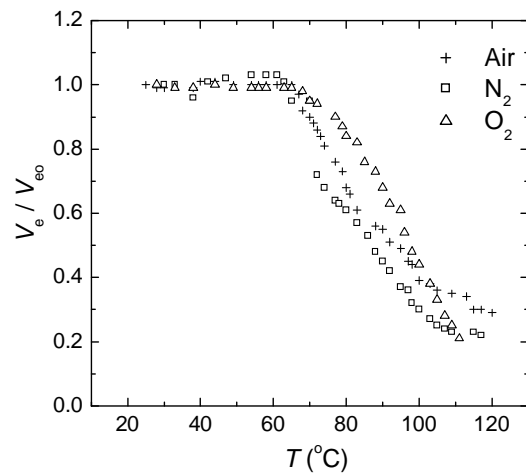
Fig. 5. Temperature dependence of the surface potential of PP electrets obtained by positive corona in various gas media.

4. Discussion

The results presented in Table 1 show that the gas medium in which the corona discharge occurs has a significant influence on the initial surface potential. The polypropylene samples that had been charged in a negative corona manifest higher initial values of surface potential compared to those charged in a positive corona, irrespective of the gas medium for the corona. The difference is highest when the medium is nitrogen. This is due to the different critical corona voltages for the different gases used, at different polarities of the applied voltage. As pointed in [5], the minimum breakdown strength is different for various gas media: Air – 327 V; N_2 – 251 V; O_2 – 450 V. This could be an explanation for the higher initial potential in the nitrogen medium.

The results in Figs. 2 to 5 show that the gas medium in which the corona discharge occurs influences the decay rate of the relative surface potential only when the electrets have been kept at

room temperature. It has practically no influence if the electrets are heated. In the latter case, the relative surface potential decay is mainly due to processes taking place within the volume of the electrets [6], and it does not depend on surface processes. At room temperature, discharge takes place mainly because of surface processes [6,7], and the surface potential decay is of the form:

$$V_e / V_{eo} = a + b \exp(-ct), \tag{2}$$

as reported in [8] under the assumption that there is ion desorption from the surface.

The types of ion generated in a positive or negative corona strongly depend on the gas medium. According to [2] if the corona discharge occurs in air, the prevailing ions are of the type $(H_2O)_nH^+$, $(H_2O)_nNO^+$ and $(H_2O)_n(NO_2)^+$ for positive coronas, and of the type CO_3^- and $(H_2O)_nCO_3^-$ for negative coronas. Neutral, chemically active, groups and radicals are also created in the coronas. At the time of charging, they are swept along by the ions and electrons and then deposited onto the polymer surfaces [9]. As outlined in [10], the corona discharge modifies the sample surfaces, i.e. additional traps are generated at the sample surfaces. Different kinds of trap are generated in different gas media. X-ray photoelectron spectroscopy has been used to study the changes in the surfaces of polymer electrets obtained by a corona discharge in air [11]. For polypropylene corona electrets, it was established that there was a change in the binding energy for the C1s and O1 peaks and for the O1s/C1s ratio. These results confirmed the assumption that the corona discharge creates additional traps in the surface layers of the samples.

5. Conclusions

The investigations we performed have shown that the corona electrets obtained in various gas media and at different corona polarities differ by their time stability. We assume that this is a consequence of an electret surface modification at the time of the corona discharge that leads to the creation of different kinds of traps.

The electret behaviour when they was stored at room conditions ($T = 20$ °C) is basically determined by the processes that take place on their surfaces while when their temperature gets higher the processes within electret bulk become predominant.

Beside the scientific interest of the problems we have discussed we believe they also are of great technological importance for the development of various electret devices.

Acknowledgement

References

[1] G. F Leal Ferreira, M. T. Figueiredo, IEEE Trans. Electr. Ins. **27**, 719 (1992).
[2] J. A. Giacometti, O. N. Oliveira, IEEE Trans. Electr. Ins. **27**, 924 (1992).
[3] P. G. Karmazova, M. S. Mintchev, G. A. Mekishev, Bulg. J. Phys. **20**, 42 (1993).
[4] J. N. Marat-Mendes, M. Raposo, P. A. Ribeiro, Equilibrium Structure and Properties of Surfaces and Interfaces, Ed. A. Gonis and G. M. Stocks, NATO ASI Series, Ser. B: Physics Vol. 300, Plenum Press, New York and London, 1992, p. 353.
[5] M. Paajanen, M. Wegener, R. Gerhard-Multhaupt, J. Phys. D: Appl. Phys. **34**, 2482 (2001).
[6] P. G. Karmazova, G. A. Mekishev, Europhys. Lett. **19**, 481 (1992).
[7] T. A. Yovcheva, G. A. Mekishev, A. Marinov, J. Phys.: Condensed Matter **16**, 455 (2004).
[8] G. A. Mekishev, T. A. Yovcheva, E. Guentcheva, S. Nedev, Sci. Works Plovdiv University **34**, 159 (2001).
[9] M. Raposo, P. A. Ribeiro, J. A. Giacometti, M. A. Bento, J. N. Marat-Mendes, Proc. 7th Internat. Symp. Electrets, Berlin, Ed. R. Gerhard-Multhaupt, W. Kunstler, L. Brehmer and R. Danz, Single Publications Sales Department, Piscataway, USA, 1991, p. 687.
[10] H. Steinhauser, G. Ellinghorst, Ang. Makromol. Chem. **120**, 177 (1984).
[11] P. Karmazova, J. Marinova, V. Krastev, G. A. Mekishev, Bulg. Chem. Com. **29**, 94 (1995).