CHANGES OF SPACE CHARGE PROFILES IN PET ELECTRETS AFTER THERMALLY STIMULATED DISCHARGES

E. Motyl
Wrocław University of Technology, Institute of Electrical Engineering Fundamentals, Poland

Abstract
Behaviour of electric charges in the PET film has been investigated under the condition of partial discharging at higher annealing temperatures. The PET electrets corona-charged at room temperature and 440 K were investigated. The step electroacoustic method was used for the measurement of the space charge distributions along the sample thickness. The highest surface charge densities, and charge stability were obtained after negative corona charging at 440 K.

Introduction

In the present paper the step electroacoustic (SEA) technique [1] was applied for observation of charge decay at PET interface after corona triode charging at room temperature and 440K. One-sided metallized Al samples were charged. The second non-polarised sample was put on a charged side of electret to avoid discharging. The measurements of such two-layered samples were conducted at room temperatures using the SEA method. Thin piezoelectric PVDF was used as a detector of acoustic waves. Discharge of specimens was thermally stimulated by annealing them at constant higher temperatures for 30 seconds in order to accelerate the decay process.

Experimental

Samples and Measurement Conditions

Commercial-grade PET films (Hostaphan, 35 μm in thickness, 40 mm in diameter were used as specimens. The aluminium electrode, 12 mm in diameter was evaporated at one side of the film. The non-metallized opposite to electrode side of the sample was corona charged in the system shown in Fig. 1a. Two kinds of PET electret specimens were prepared. One kind of specimens (space-charge

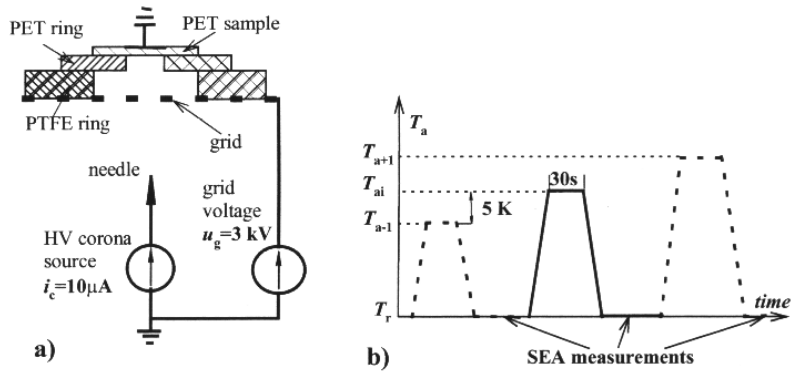

Figure 1. a) Corona triode charged system, b) Annealing condition of corona charged samples

electrets) was charged in corona triode at room temperature for 200s. The second kind (the thermo-corona-electret) was polarized at 440 K for 200s and next slowly cooled to room temperature with the field applied. After corona charging the second non-polarised PET sample was put on the charged sample. Such double-layered samples were next annealed at constant higher temperatures to accelerate charge decay process. The temperature of annealing was raised every 5 K from room to 380 K. Samples were kept at various temperatures for 30 s. Schematic diagram of annealing conditions is shown in Fig. 1b.

11th International Symposium on Electrets, 2002
0-7803-7560-2/02/$17.00 © 2002 IEEE

Measurement System

The space charge distribution was measured after going through various stages of annealing in the system shown at Fig. 2. The evaporated Al. side of charged sample was coupled acoustically with a lower Al plate of a SEA measurement system with a silicone oil. The upper electrode of the non-charged film was faced on a matching layer (conducting polymer, 12 mm in diameter) with the oil.

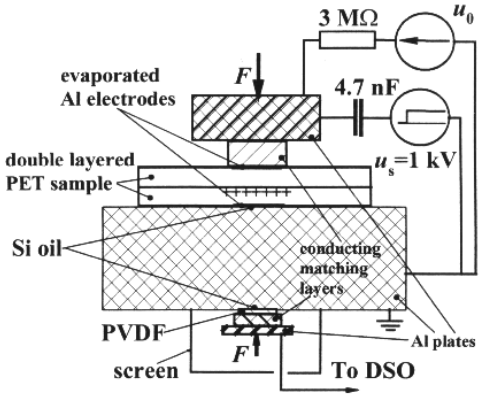

Figure 2. Space charge distribution measurement system

Double-layered sample with matching layer was firmly pressed by upper Al massive electrode (12 mm in diameter). Strain wave generated in the sample originating from the charges at interface and electrodes propagates through the film and lower Al plate (24 mm in thickness) and is detected by a PVDF foil sensor (9 μm in thickness). The piezo sensor is acoustically matched by conducting polymeric layer and it is firmly pressed to the back of the lower Al plate. Electrical signals, generated in PVDF sensor, delayed in time (3.1 μs) were measured using a digital storage oscilloscope (HP 54820A 0.5 GHz, 2 GSa/s) at 50 Ω input. Time domain procedure was applied to analyse the signals.

Results

Calibration of SEA Signals

Short-circuit current is related to space charge distribution along the sample thickness if no reflected wave enters the PVDF sensor. In order to calibrate the measuring signals the sample was additionally polarised by voltage source u_0 within the range –3 to +3 kV. The measured signals are shown in Fig. 3a. The signals were integrated twice to obtain signals related to potential profiles shown in Fig. 3b.

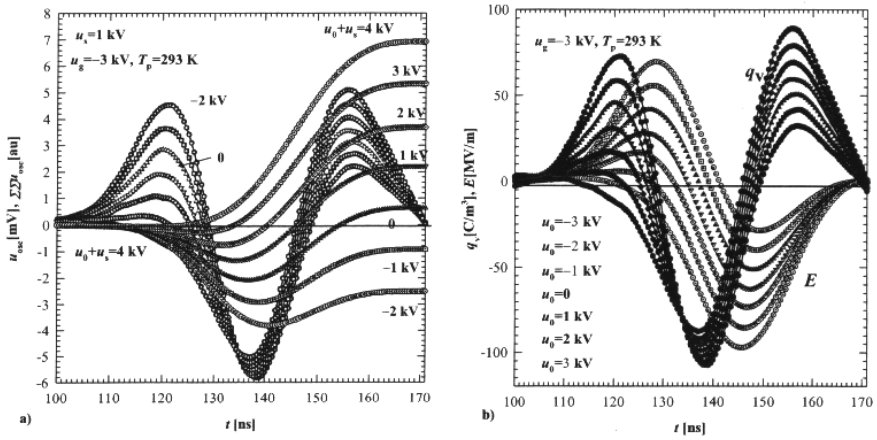

Figure 3. a) Measurement signals related to short-circuit currents and double integrated signals related to potential distribution along the sample thickness; b) Calibrated profiles of electrical field and space charge.

Potential curves were calibrated first. Next the calibrated profiles of electrical field were obtained by differentiation of the potential profiles. The space charge density calibrated profiles q_v were obtained from the field profiles by next differentiation. Positive charges at t = 120 ns and 155 ns are related to electrode charges. Negative charges at 138 ns are related to interfacial charges. Space charge, electric field and potential profiles depend on sum of polarised u_0 and step u_s voltages as well as on interfacial charges.

Decay of Interfacial Charges

Decay of interfacial charges was observed at u_0 = -1kV and u_s = 1kV. Changes of space charge profiles due to annealing at higher temperatures for corona charged samples at room temperature are shown in Fig. 4 for negative corona and in Fig. 5 for positive charged samples. Charges are stored in the centre

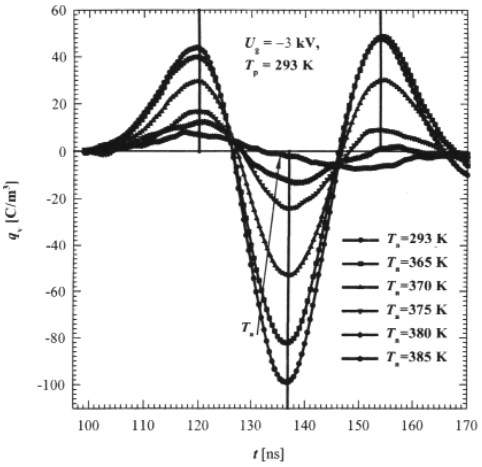

Figure 4. Changes of space charge profiles due to annealing for negative corona charged samples at room temperatures.

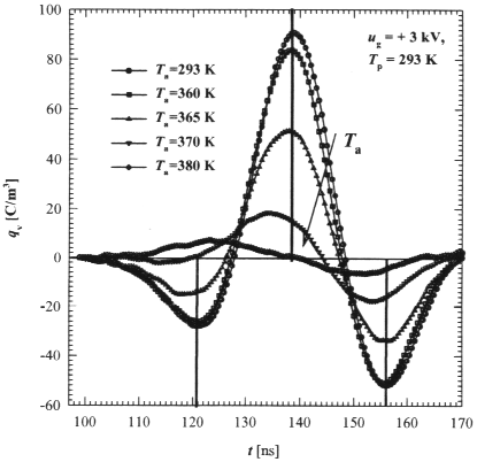

Figure 5. Changes of space charge profiles due to annealing for positive corona charged samples at room temperatures.

of double-layered samples. The charge carriers are deposited in the surface layer and do not penetrate into the material. Figure 6 shows the space charge distribution in the double-layered PET film obtained at negative corona application u_g = –3 kV at temperature 440 K. Figure 7 presents the

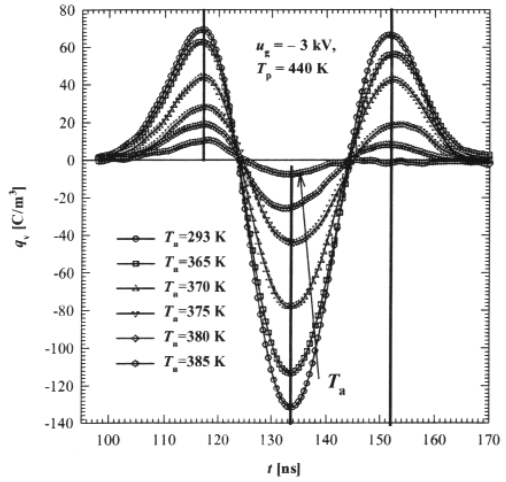

Figure 6. Changes of space charge profiles due to annealing for negative corona charged samples at 440 K.

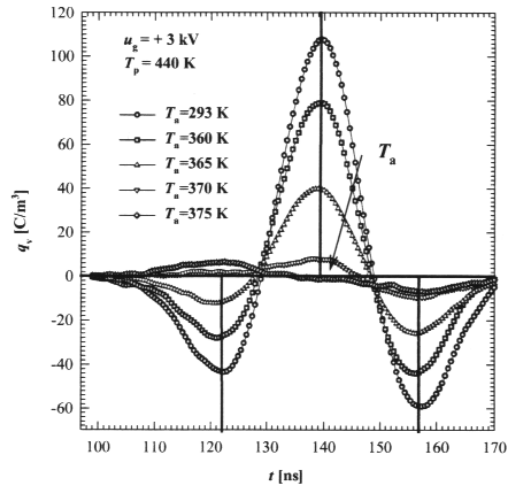

Figure 7. Changes of space charge profiles due to annealing for positive corona charged samples at 440 K

space charge distribution profiles for positively charged samples at 440 K. Negative charges penetrate deeper that positive ones. Penetration depth is about 2μm and 1μm for negatively and positively corona charged samples respectively.

Surface Interfacial Charge Density

Corona charge density at the interface was obtained by integration of space charge distribution profiles. Figure 8 shows changes of corona charges due to annealing at temperatures T_a for 30 s. Corona charging at higher temperatures gives higher surface charge densities than charging at room temperatures. Negative charging gives surface charge densities equal about –345 nC/cm^2. This value is higher than the one obtained from applied grid voltage using the equation $q_s = \varepsilon_0\varepsilon_r u_g/(d-d_p) = -250$ nC/cm^2, where ε_0 is the permittivity of vacuum and ε_r is the relative permittivity (3.1 for PET), $d-d_p$ is the sample thickness reduced by mean charge penetration depth (2 μm). The difference between measured and evaluated values in charge densities equals 95 nC/cm^2 and it may be due to polarisation charges. Negative corona charged PET thermoelectrets have the highest stability, and the positive corona thermoelectrets show the fastest decay.

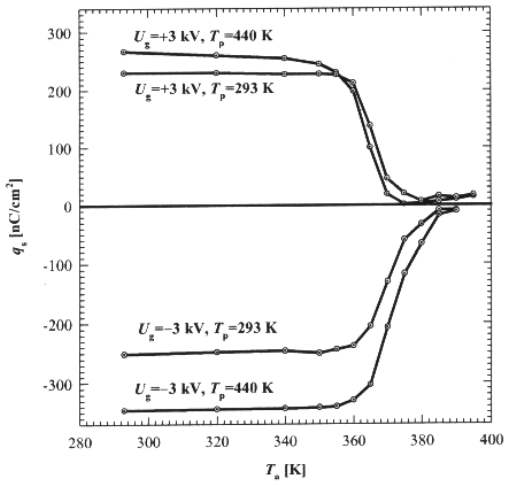

Figure 8. Decay of interfacial charges due to annealing at temperatures T_g for negative and positive corona charged PET samples at room temperature and 440 K.

Conclusions

Real charges deposited by corona at PET-film surface decrease after annealing at high temperatures without changing the position of homocharges. Charges are deposited at surface after corona charging at room temperature and penetrate into near surface region after charging at 440 K. The highest charge density and stability of charge was obtained for negative corona charging at 440 K.

Acknowledgements

This work was supported by the Grant No 4 T10C 008 22 from the State Committee of Scientific Research (KBN) Poland

References

[1] E. Motyl, J. Electrostatics, 51-52 (2001) 334.