ELECTRIC-FIELD PROFILES IN CORONA- OR ELECTRON-BEAM-CHARGED AND THERMALLY TREATED TEFLON PTFE, FEP, AND PFA FILMS

R. Gerhard-Multhaupt,[2*] G. Eberle,[1] Xia Zhongfu,[2**]
Yang Guomao,[2] and W. Eisenmenger[1]
[1]Physics Institute, University of Stuttgart and [2]Institute for Electroacoustics, Technical University of Darmstadt, Germany

ABSTRACT

Charge spreading in three different types of Teflon electrets was studied by means of Piezoelectrically generated Pressure Steps. FEP and PFA samples corona-charged at room temperature usually exhibit only a surface charge layer. Uniform charge spreading throughout the bulk is found in FEP charged at or heated to high temperatures. Charge spreading was much less prominent in PFA because of a smaller retrapping efficiency. In PTFE, charges from the surface and the rear electrode are injected into the bulk already during charging at any temperature. Electron-beam-deposited charge layers broadened significantly upon heating.

INTRODUCTION

During the last decade, a number of high-resolution techniques for the determination of charge or polarization profiles in the thickness direction of thin dielectrics became available; the state of the art is documented in [1]. The pressure-wave methods, which often do not require a deconvolution procedure, fall into two main categories — pressure-pulse and pressure-step techniques. While pressure pulses are employed more frequently, pressure steps have the advantage of directly integrating current signals from charge layers. Because of this integration over the whole range of charge spreading, the relatively small local charge densities of spread charge distributions in non-polar electrets may become detectable. For this reason, piezoelectrically generated pressure steps (PPSs) [2] were employed in this study of Teflon electrets mostly either charged at or heated to elevated temperatures.

EXPERIMENTS

Details of the PPS technique [2] and of its use for the investigation of charge and polarization dynamics [3] are found in the literature. PPS

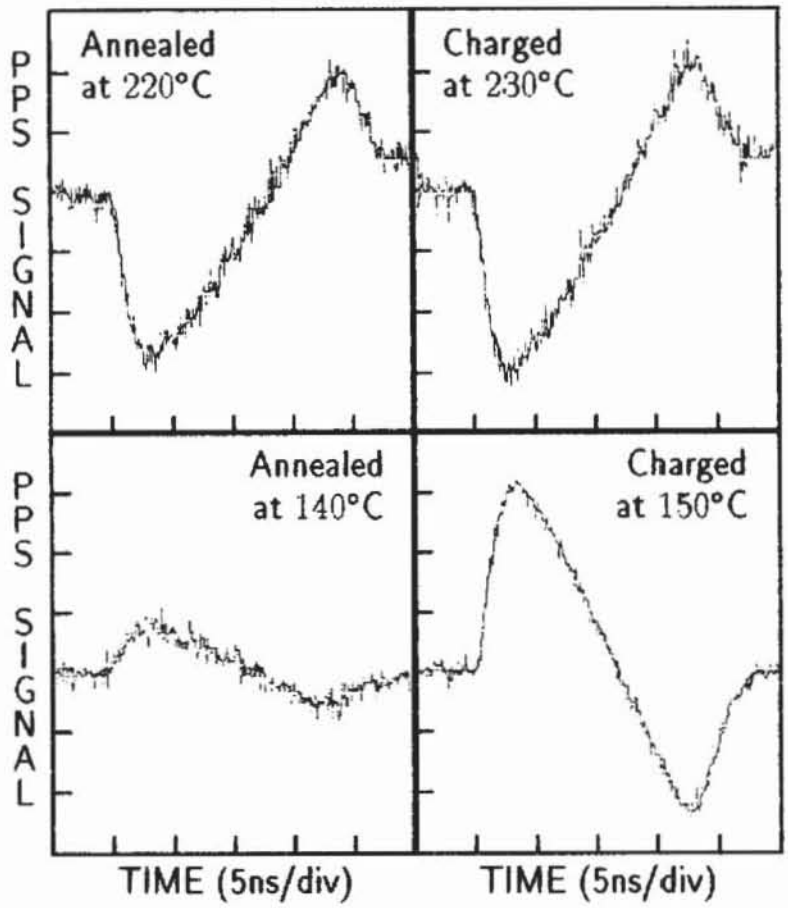

Figure 1: Electric-field profiles in Teflon FEP samples negatively (top) or positively (bottom) charged for 10 minutes with $V_P = \pm 11$kV and $V_G = \pm 300$V at room (left) or elevated (right) temperatures.

measurements in electron-beam-charged Teflon and Mylar [4] demonstrated charge detection in non-polar dielectrics and established the predicted [5] proportionality between signal and electric-field distribution. Here, the current version of the PPS technique with a quartz or a lithium-niobate crystal for pressure-step generation and a Tektronix DSA 602 Digitizing Signal Analyzer for signal pickup is employed.

Samples consist of nominally 1mil thick Teflon FEP, PFA, or PTFE films metallized on their rear surfaces with 100nm aluminum. Charging was performed either in a corona setup with point (voltage V_P) and grid (voltage V_G) or in a modified electron microscope; with electron-beam charging, only one relatively high energy ($E_B = 30$keV) was used for charge deposition. Most samples were subjected to thermal treatment either during corona charging or after charging.

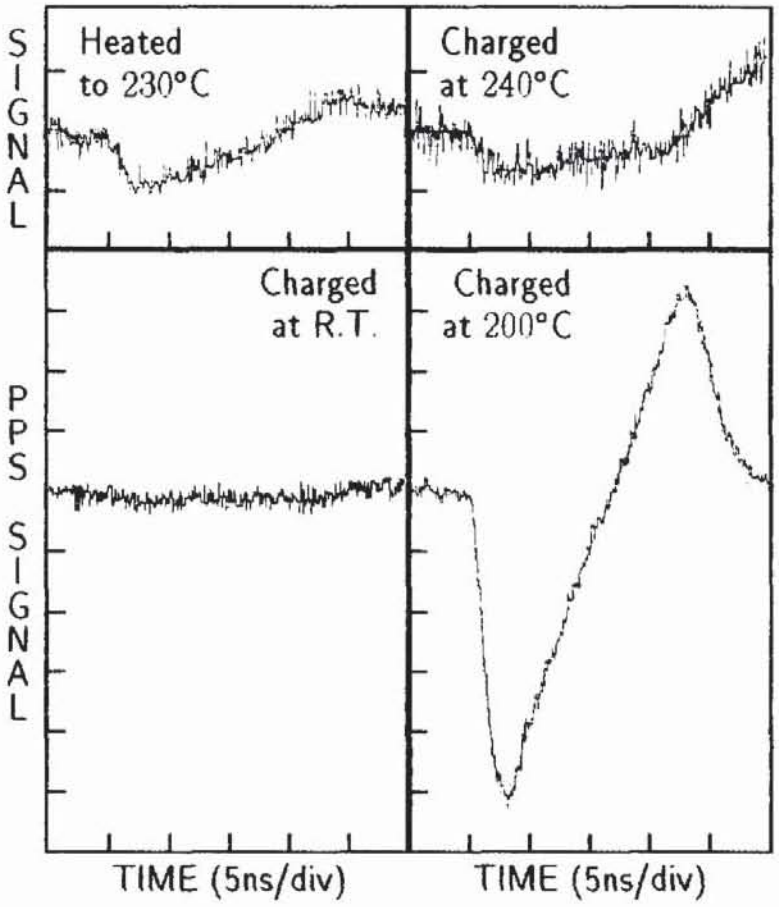

Figure 2: Electric-field profiles in Teflon PFA samples negatively charged for 10 minutes (top) or 8 hours (bottom) with $V_P = -11$kV and $V_G = -300$V at room (left) or elevated (right) temperatures.

RESULTS AND DISCUSSION

Since surface-charge layers are usually destroyed upon application of an electrode, the PPS technique allows only for the detection of bulk charges. All measurements were taken with the pressure step entering through the metallized rear surface. In uncharged parts of the sample volume, a constant electric field is found, and thus a horizontal PPS signal is generated, while constant space-charge densities correspond to linearly increasing or decreasing electric fields and thus to signals with constant slopes. Thin charge layers result in steep signal slopes, since the field steps are convoluted with the pressure step of finite rise time.

Teflon FEP

It is known that Teflon FEP negatively corona-charged at room temperature for moderate periods of time does not contain significant volume

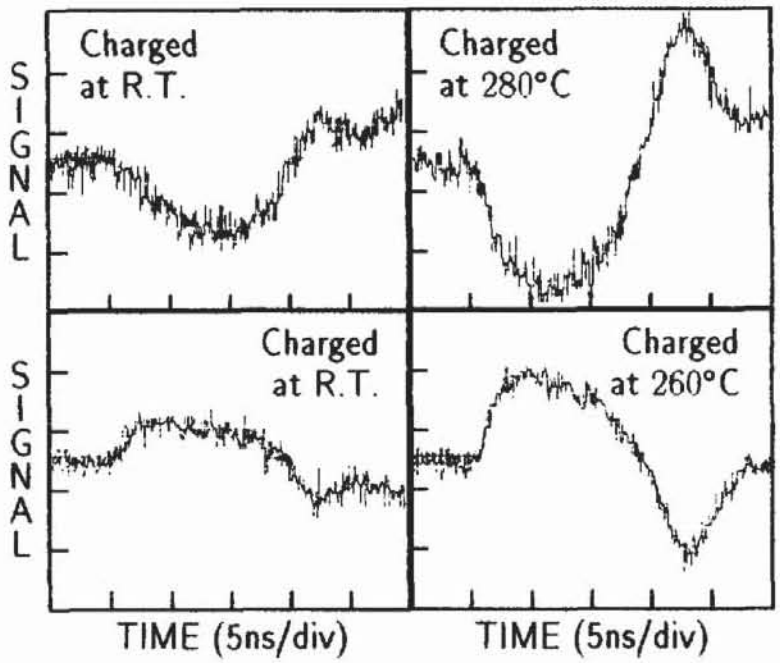

Figure 3: Electric-field profiles in Teflon PTFE samples negatively (top) or positively (bottom) charged for 10 minutes with $V_P = \pm 11$kV and $V_G = \pm 300$V at room (left) or elevated (right) temperatures.

charges [6]; therefore no PPS signal is found. After heating to sufficiently high temperatures, however, most of the surface charge has been retrapped in deep bulk levels and forms a uniform charge distribution (Figure 1). An even higher and also uniformly distributed bulk charge is found after charging at a high temperature. In positively charged FEP, much less retrapping seems to occur so that most charge is lost upon heating; here only charging at an elevated temperature produces a uniform charge distribution of significant magnitude.

Teflon PFA

Teflon PFA, the electret properties of which were investigated recently [7], exhibits much less retrapping in deep bulk traps than FEP. As shown in Figure 2, heating to relatively high temperatures during or after negative charging does not lead to high charge densities in the sample bulk unless very long charging times are employed. The injection of negative charges from the surface into the bulk can, however, only be achieved at elevated temperatures.

Teflon PTFE

A completely different situation is found in corona-charged PTFE (Figure 3): Already at room temperature, there is significant charge injec-

tion from the rear electrode and from the charged surface, with positive charges (downward field slopes) extending further into the bulk. The amount of bulk charge and its depth increase for higher charging temperatures, but its distribution does not become uniform.

Electron-Beam-Charged Samples

Field profiles for electron-beam charged FEP samples were reported in an earlier publication [4]; here (Figure 4), significant charge spreading into the non-irradiated rear volume of the samples was observed not only for FEP, but also for PFA after heating to temperatures, at which charges in shallower trap levels may be freed and retrapped in deeper traps. Similar charge spreading (indicated by the changing slopes of the PPS signals) is found for PTFE after heating.

CONCLUSIONS

Heating of corona- or electron-beam-charged Teflon FEP and PFA films leads to a rearrangement of charges from confined layers into uniform bulk distributions; similar bulk charging with larger densities is achieved by high-temperature charging. The geometrical rearrangement is connected with retrapping in more stable levels; thus there seems to be a trade-off between good stability (best with broad bulk-charge distributions) and large external field (best with pure surface-charge layers) in electrets. This choice appears not to exist for Teflon PTFE, since charge injection occurs already at room temperature. More detailed and quantitative investigations of the reported behavior are under way.

FOOTNOTES AND REFERENCES

*Permanent address: Heinrich-Hertz Institute, Einsteinufer 37, D-1000 Berlin 10, Germany

**Permanent address: Pohl Institute of Solid-State Physics, Tongji University, Shanghai, China

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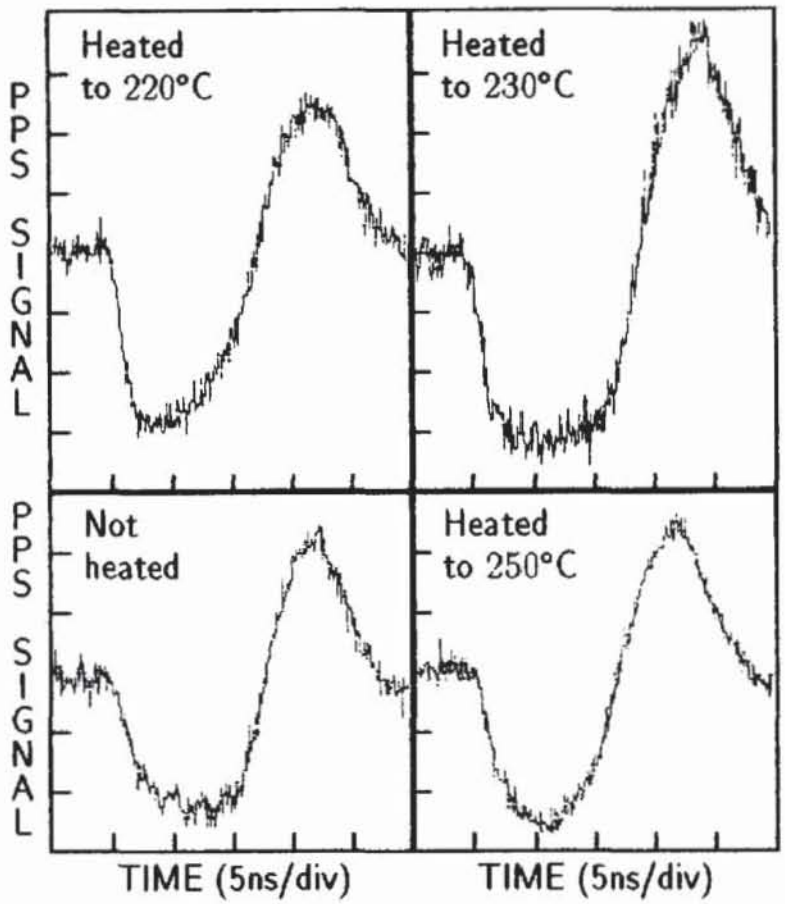

Figure 4: Electric-field profiles in Teflon FEP (top left), PFA (top right), and PTFE (bottom) samples electron-beam charged with $E_B = 30$keV at room temperature and annealed at different temperatures.

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