7th ISH

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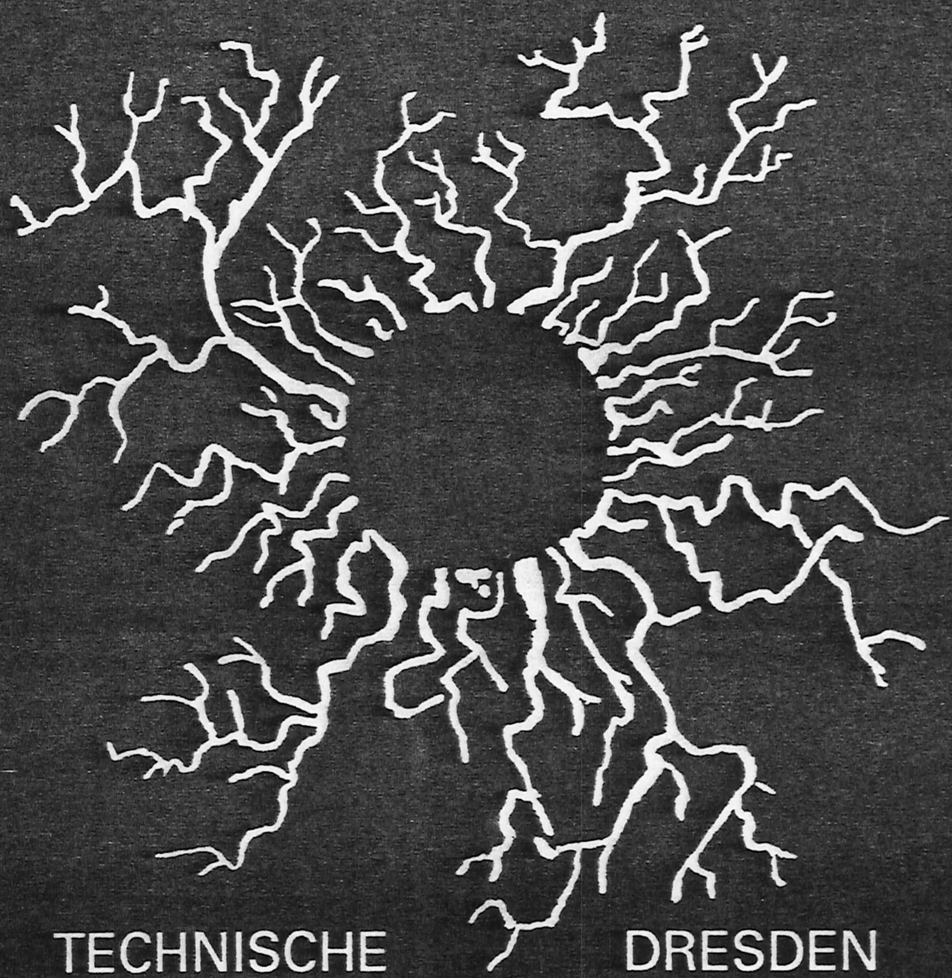
HV MEASURING AND TESTING TECHNIQUES



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IMPULSE CHARGING OF ELECTRETS - APPLICATIONS

RUY A.C. ALTAFIM
EESC - UNIVERSIDADE DE SÃO PAULO

JORGE M. JANISZEWSKI
EP - UNIVERSIDADE DE SÃO PAULO

JOSÉ A. GIACOMETTI
IFQSC - UNIVERSIDADE DE SÃO PAULO

BRAZIL

ABSTRACT

Electrets are made of dielectric materials, which can hold a remanent electric field for a long time. Electrets can be obtained by different methods such as corona triode, electron beam and charge injection. In this work, electret formation by impulse charging is presented, with metallized FEP-Teflon samples inserted between two planar electrodes, with an air gap. The extension of the method for electrodes with different shapes are also studied. Among the applications of the proposed impulse charging, there is the measurement of impulse currents and voltages, which are associate to lightning, with accurate, small and cheap detectors.

INTRODUCTION

The history of electrets was described by Gross, B. /1/, in 1971. Considered, at the beginning, as a scientific curiosity, electrets have had considerable technological advances, by virtue of the great industrial interest as, for example, in the application in microphones of small size and large sensibility.

There are two kinds of electrets: dipolar and excess charge electrets. Dipolar electrets are obtained with materials with permanent dipoles, which can be intrinsic or artificially created. At ambient temperatures, the dipoles are randomly arranged and the material has no external dipolar moment. This is not the case, however, when the dipoles are forced to align in the same direction, resulting an external dipolar moment. These electrets are usually obtained by thermal means, heating the material up to its melting point in the presence of an electric field, which will align the internal electric dipoles, and, then, cooling the material.

Excess charge electrets employ materials with energetic traps, due to impurities or to structural deformations. These traps may be volumetric or superficial and in FEP-Teflon there is a predominance of superficial traps for electrons /2/, with activation energy of 1.2 e V and located at about 0.5µm from the surface. In negativelly charged materials, the trapped electrons can stay there for a long time.

These electrets can be obtained by different methods, such as corona triode /3/, electron beam and charge injection /2/, among others. Injected charge electrets are formed applying to the material, placed between two electrodes, a strong electric field that allows charge to transfer from the electrodes to the material. If the electrode is in contact with the material, the charge transfer will be direct and if not, the transference will exist through an electric discharge in the air. Once the transference has occured, there will be a remanent electric field, with stable characteristics. The applied voltage is continuous and the upper electrode must be removed after the charging process, in order to avoid reverse discharge from the dielectric to the electrode, discharging the material.

IMPULSE CHARGING OF ELECTRETS

In the initial studies of this charging method, the geometrical configuration of Figure 1 was adopted. The electrodes were made of aluminum, with rounded edges and a 3 cm diameter, being the upper electrode at 0.01cm from the dielectric. FEP-Teflon was used as the dielectric, 50µm and 75µm thick, with one side metallized. This material, when negativelly charged, retains the charge for hundreds of years /4/ and presents high dielectric and mechanical strengths.

Samples of the material were prepared cutting pieces with circular form of about 20 cm^2 area. These samples were mounted on the lower electrode, holding them by means of a frame. All samples were previously discharged by an alternating corona procedure.

All measurements for the determination of the charging method features were performed in ambient conditions of 690 mmHg pressure, 25°C temperature and 50% humidity. An unidirectional and fast front negative impulse voltage V(t) with peak values V_P from 0.5 kV to 6.0 kV was applied to the electrodes. V(t) had a rise time of 1.2µs, falling to half its peak value in 50µs, simulating the usual shape of lightning strokes. The impulse peak value was measured with a 1:1000 divider and a 50 MHz storage oscilloscope.

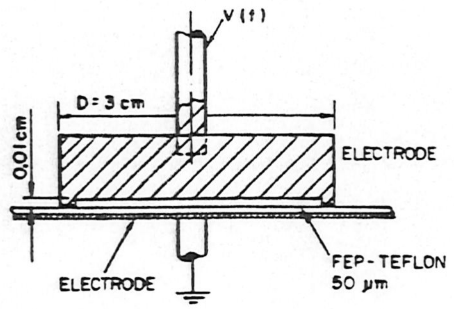

Figure 1. Planar configuration of electrodes for impulse charging.

When a negative impulse voltage V(t) delivered by an impulse generator is applied to the electrodes, the potential across the air gap increases and reaches the disruptive value, producing a Paschen discharge. Negative carriers are, then, transferred from the upper electrode to the dielectric surface, where they are trapped, forming the electret.

Once the discharge had occured, the upper electrode was removed (situation known as" open circuit") and the surface potential of the sample, V_S, related to the surface charge, was measured by an electrostatic probe, scanning the sample along a diameter. The surface potential variation is depicted in Figure 2, where two situations are indicated, for two different values of the peak voltage. It is interesting to notice the uniformity of the charging process.

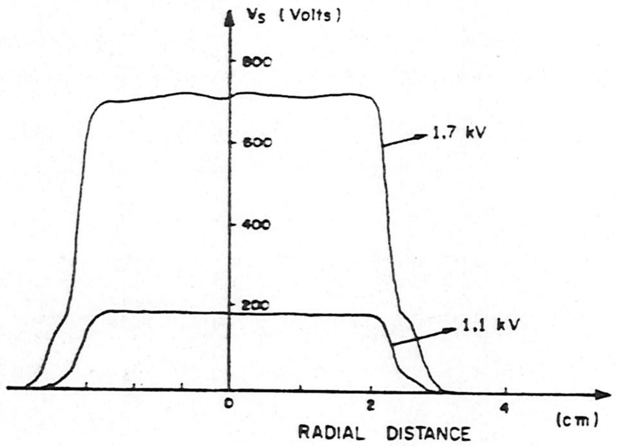

Figure 2. Surface potential for planar electrodes. Sample 50µm thick.

By direct measurement of the surface potential using the electrostatic probe and, also, by the vibrating capacitor method /5/, calibration curves were obtained, relating the surface potential to the applied peak voltage. A typical calibration curve is shown in Figure 3. For a given peak voltage, significative modifications are observed in the surface potential when there are impurity particles on the sample. Thus, all samples were cleaned with alcohol in order to avoid this problem. The surface potential is also dependent on the sample thickness.

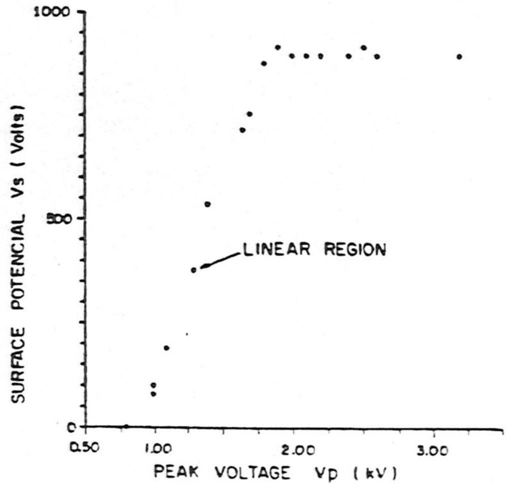

Figure 3. Surface potential variation with peak value of applied voltage. Planar electrodes, 3.0cm diameter and sample 50µm thick. Upper electrode 0.01cm above sample.

Having in mind a possible variation of the calibration curves with temperature, measurements were made in the range from 0°C to 50°C. Experimental results have shown that, from 8°C to 40°C, a small variation of about 2% of the surface potential had occured, for a given peak voltage. For temperatures in the vicinity of 0°C, however, a significative variation of 15% was observed and this is due to humidity condensation on the electrodes, disturbing the discharge process. Figure 3 shows a linear region in which V_S can be written as

$$V_S = \alpha V_P - V_C \quad (1)$$

where V_C is the critical potential for discharge and α is a constant.

For peak voltages higher than $2V_C$, Paschen reverse breakdown occurs, from the dielectric to the upper electrode, causing partial discharge of the electret. This is seen as a "saturation" region in the calibration curve of Figure 3. This fact limits the range of application of the systen.

Searching for a possible wider range of application of the electret, a new configuration was studied, with an upper cylindrical electrode. In this case, the distance h between a point of the electrode and the sample varies with the lateral distance from the system axis. For a certain impulse voltage applied to the electrodes, a discharge will happen and, therefore, charge transfer will occur over the area limited by the critical value h_C in which the electric field has a value smaller than the critical air disruptive field. For this configuration, the sample charged area can, then, be related to the peak voltage V_P. This area can be defined by its width δ and Figure 4 shows a calibration curve for this configuration. The curve can be expressed by the equation

$$V_p = A.e^{B\delta} \tag{2}$$

where A and B are constants.

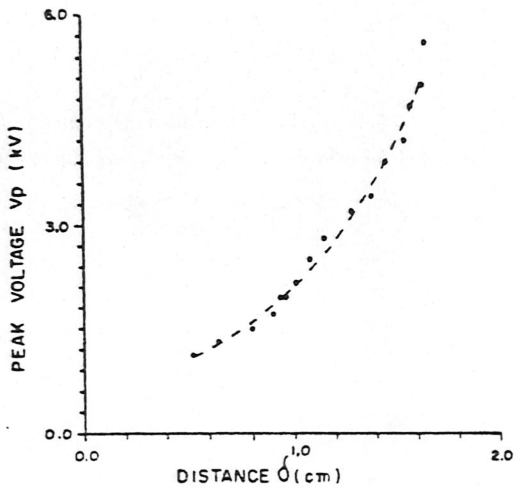

Figure 4. Calibration curve for cylindrical upper electrode on the sample, with 1.85 cm diameter, 2.5 cm length.

It is worth noting that, now, the charge distribuiton on the sample is not uniform but this fact does not impair the measurement of δ and, for this new shape of electrode, the application of the system is not limited to values of V_p smaller than $2V_c$.

APPLICATIONS

As has been shown, the electret associated to electrodes can work as a voltage sensor in two different ways: relating the peak voltage to the surface potential (planar electrodes) or relating it to the charged area (cylindrical electrode).
The first mode presents the advantage of linearity, operating in the range of 800V to 1600V, with uniform charging. For larger voltage values, the devices can be associated in series, with equalization resistors or a voltage divider can be used.
The device with cylindrical electrode, even though having a non-linear calibration curve, has the advantage of presenting a wider range, independent of the non-uniform charging.
In both modes, the calibration of the device, used as a sensor, can be obtained in a simple way. In spite of being utilized an electrostatic probe, other determination methods are suitable. Thus, the surface potential was also measured by the vibrating capacitor technique and the charged area (width δ) was easily determined making it visible by a xerographic toner, which adheres to the sample on the charged region.
The measurement of impulse currents is also possible, with the device associated to series resistors (shunts) or to Rogowski coils.
Among many others, a special device was constructed, with a cylindrical shunt involving the electret assembly. This configuration allows the installation of the device under the base of surge arresters in distribution lines.

CONCLUSION

The development of charging process by impulse voltages makes electrets a new option for the measurements of impulse voltages and currents /6/.
Employing an upper cylindrical electrode, the detection range can be extended, as can be seen when comparing Figures 3 and 4. In this way, voltages up to 20 kV and currents up to 100 kA can be measured.
Various prototypes were constructed and tested, showing the viability of the application.
The work is not finished yet and research will continue, both in its theoretical and practical aspects.

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ADDRESS:

Ruy A.C. Altafim
Universidade de São Paulo - EESC
Av. Dr. Carlos Botelho, 1.465
13.560 - São Carlos - SP
Brazil