INFLUENCE OF CORONA CHARGING ON SURFACE POTENTIAL DECAY IN INSULATING MATERIALS

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Abstract: *In this paper, an experimental investigation on surface potential decay (SPD) after negative corona charged polyethylene terephtalate (PET) is presented. The effect of the charging time t_p on the decay characteristic of surface potential is presented for samples of two different thicknesses (0.5mm, 1mm). The measurements are carried out in situ, in a commercial climatic chamber in which humidity and temperature are controlled. The experimental results show clearly that the charging condition when a corona source is employed can have a marked effect on the decay characteristics of charge on PET samples. It is suggested that the degree of exposure PET surface to the light and the excited gas molecules from the corona discharge play an important role and acts on the kinetics of potential decay.*

Key words: *Surface Potential Decay, Corona discharge, PET, Charge injection.*

1. Introduction

Since Several years, synthetic polymers have known a large application in electrical industry due to their excellent electrical, thermal, and mechanical proprieties [1]. At the same time, solid insulating polymers are used in hostile environments where they may be subjected to attack water, high static non-ionizing radiation and other corrosive materials or reaction.

Electrostatic charges can play an undesired role in diverse industrial application, particularly in the plastics industry and in high-impedance circuitry. The main fields of industry source of numerous work on surface potential decay are: Electrooptics (photo-copies and laser printers) [2], electrets materials [3] and electrical industry for the development of insulating polymers for high voltage insulation [4, 5].

During the last two decades many theories were developed to formulate the kinetics of surface potential decay on initially charged highly resistive solids in terms of surface conduction, injection, trapping and polarization processes [6, 7, 8].

In this paper we presented experimental measurements on a thick of insulating materials which are not considered in the past by similar studies. Indeed, surface potential kinetics has proved to be a powerful tool in investigating the charge carrier transport processes in insulating polymeric materials [6, 7]. But this technique is usually used for thin films (samples of μm) so, it seems important and interesting to provide a contribution of experimental measurements thickness samples which are not taken into consideration. This could be of industrial interest for some application (electric cable and insulation of electric motors coils).

This investigation has demonstrated that, for negative charge, the rate of surface potential decay depends on the duration of charging and the degree of exposure to the light corona discharge. On the other hand, in a recent investigation on the decay of the surface potential of the PET samples [8, 9, 10], we have seen that, for negative charge, the charge injection mechanism in material bulk seems to be the more probable hypothesis to explain charge flow in PET.

2. Experiment

A. Samples

The polyethylene terephtalate (PET) is a material of thermoplastic family. It is largely known under the commercial names: mylar, melinex or hostaplan. The PET is often used as a dielectric in high performance foil capacitors [11]. In the last years the technological importance of PET in electrical engineering has increased significantly in the cable industry and motors. On the other hand, PET is one of the major electrets materials which has been studied and widely used in charge storage application for a long time [12].The optimization of its performance requires the comprehension of the charge transport processes.

B. Experimental details

The surface potential decay experiment is described in figure 1

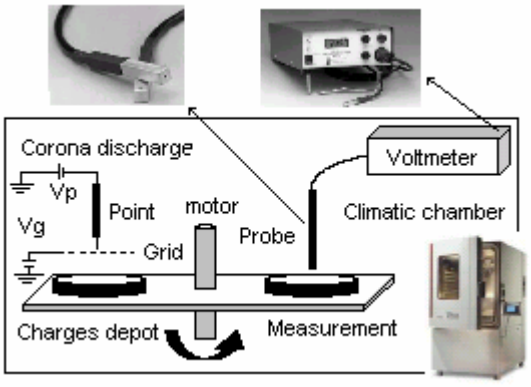

Fig. 1. Experimental setup

The PET used in the experiment is square sheet of 5 cm side-length of 1 and 0.5 mm thickness. One face of the samples was coated by silver paint to ensure a good contact with the grounded metallic plate electrode on which they were laid. The other free surface has been exposed to a corona discharge generated by a needle electrode situated above the metallic plate and connected to a negative DC high-voltage supply V_p. A ground metallic grid, connected at different negative DC potential V_g is inserted between the needle and the sample surface in order to control the density of ions deposited and to allow a homogeneous distribution of these ions. Prior to corona exposure, the samples were maintained for one hour in the conditions prescribed for each experiment.

By selecting appropriate corona point and grid potential V_p and V_g, respectively, it is possible to charge the polymer surface with ions of either sign and to a potential value limited by the grid potential V_g.

After charging the turntable was rotated under a non-contacting probe. The probe is connected to an electrostatic voltmeter (Monroe type), which transmits data to the computer. The surface potential was then measured and continuously recorded. All operations are controlled by a computer.

Experiments with a new sample for each measurement of surface potential decay provided fairly reproducible results. We have carried four measurements on different samples, a common trend is easily observed. The reproducibility of the data obtained with the same sample provides also reproducible results, provided that, all the charge on its surface should be neutralized. A cleaning with cotton soaked in alcohol is carried out, but it's only effective if the alcohol in the drying does not introduce a film of impurities on the surface, whose effect is to quickly evacuate the filed charge. In our experimental work, we used new samples for each measurement.

All the measurements of surface potential decay were carried out in situ, in a commercial climatic chamber, in which humidity and temperature are controlled and fixed at 50% and 40°C respectively. The initial potential for charge deposit is equal to -1800V and the charging time of sample to the corona discharge was: 1s, 10s, 15s and 30s.

3. Results and discussions

A characteristic family of surface potential decay after negative charging with different deposit time of the samples of 1 and 0.5 mm thickness is shown in figure 2 and figure 3. The results provide an evidence for the importance of the charging condition and particularly the charging time. It is observed a difference in decay rates.

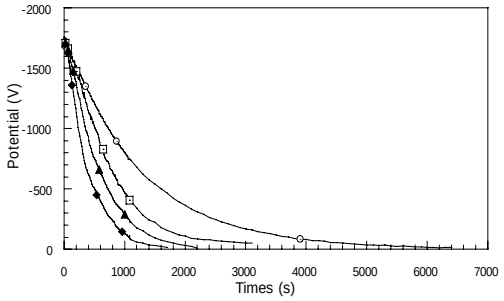

Fig. 2 Surface Potential Decay for Various Deposit Time: e = 0.5 mm; T= 40°C; RH = 50%; V0=-1800 V and tp = O : 1 s ; □ : 10s ; ▲ : 15 s ; ◆ : 30 s

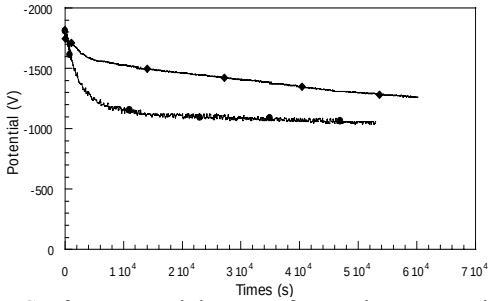

Fig. 3 Surface Potential Decay for Various Deposit Time: e = 1mm; T= 40°C; RH = 50%, V0= -1800 V and tp = ◆: 1 s ; •: 10s

The experiment illustrate clearly that the corona discharge can not only used as a means of charging polymer samples but, also play an important role in the kinetics of charge carriers , it can have a marked affect on the decay characteristics. Several features should be noted. The nature of the decay is shown to depend on the deposit time of initial potential and the presence of the incident light on the samples surface during charging leads to a much more rapid decay of charge.

Perhaps, the light from the corona discharge plays the most important role in negative charging by inducing more rapid charge decay. It is suggested that the light aids the injection of electrons from surface states into the bulk.

Furthermore, it would appears, that the fast decay is caused by photo-injection of electrons from the PET surface states into mobile bulk states induced by the corona discharge light. This deduction assumes that the photon energies play an important role in facilitating charge originally deposited in deep surface states to become injected into bulk states where it became mobile.

On the other hand, the possibility that the corona discharge causes permanent structural changes and morphologic changes of the surface it self and of its trapping capability leading to an increase of mobile bulk carriers proportion by the decrease in surface

energy states in also possible.
It is well known that the corona discharge produce in the surrounding air ions CO_4^-, OH^-, O^-, O^{2-}, and also neutral species with excited states or electronic vibrational may have a role in the charge injection mechanism [11, 12].

In addition, these results seem to indicate that the sample thickness plays a crucial role in the behavior of surface potential decay. After charging, the initial potential V_0 created by this charge accumulated at the surface of the PET for all deposit time is the same for two different thicknesses. After few hours, we have observed the complete disappearance of the charge of the thin sample while on the thick sample, the surface maintains an important quantity of charge and a constant potential for long time periods (months or years). Moreover, the potential decay of the thicker sample is much slower than the thinner sample. Concerning the decay characteristics of 0.5 mm sample, we noted a fast initial decay at all deposit time and after few hours, the potential decay becomes equal to zero. The initial fast decay may be attributed to the all injection of deposited charges into the polymer bulk under the electrical field generated by the charge themselves. Once injected into the bulk the electron may be expected to the drift towards the back electrode under the influence of this field. On the other hand, the potential decay characteristics of 1mm sample thickness do not return to zero. This behavior may be attributed to the partial injection of the deposited charges into the polymer bulk. The remaining charges do not have sufficient energy to be injected into the polymer bulk and remain deeply trapped at the surface. The traps in PET are characterized by higher energetic depth at the surface than in the bulk [13, 14]. These results suggest that the electric field formed at the surface plays a most important role in the conduction kinetics of charge carriers, and it seems that surface potential decay faster when the samples has an initial high electric field.

4. Conclusion

The surface potential decay method appears to be a valid tool for the investigation of PET for thicker sample.

The present investigation has shown that the charging condition and during charging when a corona source is used can have a marked effect on the decay characteristics of charges on the PET samples. An increase of exposure time increases the decay degree.

The most convincing proof of the effect of corona discharge is probably provided by photon energies and excited neutral species present in the air surrounding a negative corona discharge and play an important role in accelerating charges injection mechanism.

On the other hand, the experiments demonstrate clearly that the samples thickness in able to affect transfer of negative charges from deep surface into more shallow bulk states in PET. Increasing the thickness leads to increasing transport limitations and higher residual potentials. The effect of thickness is even more enhanced when the mobility itself is field dependent.

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References

1. Batra I. P., Kanazawa K. D., Seki H.: *Discharge Characteristics of Photoconducting Insulators*. In: J. Appl. Phys. (1970), Vol. 41, No. 8, Jul. 1970, pp. 3416–3422.

2. Vance D. W.: *Surface Charging of Insulators by Ion Irradiation*. In: J. Appl. Phys. (1971), Vol. 42, No. 13, Dec. 1971, pp. 5430–5443.

3. Sessler G. M.: *Charge Storage in Dielectrics*. In: IEEE Trans-Elec. Insul. (1989), Vol. 24, No. 3, Jun. 1989, pp. 395–402.

4. Coelho R.: *The Electrostatic Characterization of Insulating Materials*. In: J. Electrostatics (1985), Vol. 17, No. 1, May. 1985, pp. 13–27.

5. Wintle H. J.: *Decay of Static Electrification by Conduction Processes in Polyethylene*. In: J. Appl. Phys. (1970), Vol. 41, No. 10, Sep. 1970, pp. 4004–4007.

6. Llovera P., Molinié P.: *Charge Injection Dynamics On Thin Films: Limited by Surface Detrapping or by Charge Drift Mobility? A New Contribution Using Surface Potential Measurements*. (2002), In: Proceedings of the 3rd. Conference. Société Française d'Electrostatique, Jul. 2002, Toulouse.

7. Jestin P., Coelho R.,Goldman M.: *Surface Potential Decay on Epoxy Resin*., Inst. Phys. Conf. Ser. N°85 sec.2, 1987, pp. 193–196.

8. Herous L., Nemamcha M., Remadnia. M.: *Measure and Analysis of Potential Decay in Polymers*. In: Algerian journal of technology. (2007), Special Issue, Nov. 2007, pp. 108–112.

9. Herous L., Nemamcha M.: *Experimental Kinetics in Polyethylene Terephtalate (PET)*. In: Journal of Engineering and Applied Sciences. (2006), Vol. 1, No. 4, 2006, pp. 329–334.

10. Herous L., Nemamcha M., Remadnia M., Dascalescu L.: *Factors that influence the surface potential decay on a thin film of polyethylene terephthalate (PET).* In: Journal of Electrostatics. (2009), Vol. 67, No.2-3, May 2009, pp. 198-202.

11. Baum E. A., Lewis T. J., Toomer R.: *Further Observations on the Decay of Surface Potential of Corona Charged Polyethylene films*. In: J. Phys. D: Appl. Phys. (1977), Vol. 10, No. 18, Dec. 1977, pp. 2525–2531.

12. Haridoss S., Perlman M. M., Carlone C.: *Vibrationally Exited Diatomic Molecules as Charge Injectors During Corona Charging of Polymers Films*. In: J. Appl. Phys. (1982), Vol. 53, No. 9, Sep. 1982, pp. 6106–6114.

13. Seggern H. V.: *Detection of surface and bulk traps*, J. Appl. Phys. vol. 52, pp. 4086–4089, 1981.

14. Berlepsch. H. V.: *Interpretation of surface potential kinetics in HDPE by a trapping model*, J. Phys. D., vol. 18, pp. 1155–1170, 1985