

Surface Potential Decay of Low Density Polyethylene (LDPE) Films under Different Corona Discharge Conditions

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Abstract: The surface potential decay on low-density polyethylene (LDPE) has been studied after negative charge deposition by corona effect as a function of initial potential V_0 and charging time t_c . It was found that the decay rate increases with initial potential and charging time. For high charging level, cross over phenomenon has been observed. Surface potential profile has been recorded with two different charging levels. The surface potential profile indicates the absence of lateral migration of charges along the free surface of the LDPE film and the presence of the hollow for high initial potential, which makes the bulk conduction mechanisms caused by charge injection into the LDPE film bulk, responsible for the observed surface potential decay.

Keywords: Corona charging, Injection, LDPE, Surface potential decay.

I. Introduction

Polymeric insulating materials are used in solid insulations and high voltage equipment such as cables, insulators, transformers and electrical machines [1]. In many applications, polyethylene and its co-products are used as the main insulating material in electrical and electronic engineering, because they have many good properties including a high chemical resistance, high electric strength, flexibility, low permittivity, low dielectric loss and low cost [2].

Electrostatic charges can play an undesired role in divers industrial applications particularly in plastic industry. It is therefore important to have appropriate knowledge on generation and decay of surface charges. The surface potential decay (SPD) measurements of the charged insulating solids has proven to be a useful method for monitoring charge transport mechanism in insulating polymeric materials and more generally to investigate the electrostatic phenomenon and the electrical properties of polymer [3]-[7]. Charge transport in insulators has been studied using the SPD technique with a variety of charging methods including electron beam [8], contact and corona discharge [5,6]. Corona discharge induces surface charges on the material and alters the surface properties [9]. Surface potential measurements without contact have been essential in the development of electrets materials [10], photosensitive materials used in photocopier or laser printers [11] and insulating polymer developments for high voltage

insulation [3,12]. In many cases, the decay is attributed to the volume conductivity (electric conduction through the volume of the insulator), to the surface conductivity of the solid insulator (electric conduction along the surface of the insulator) and/or to neutralization by charge carriers resulting from natural radiation [13,14]. Several authors have experimentally reported the SPD on corona charge polyethylene, but the physical mechanisms responsible for SPD have not been fully understood [6,12].

In this work, we present experimental results of the SPD measured on low-density polyethylene (LDPE) thin films subjected to a negative corona discharge with different potential voltages and different charging times. In addition, we present the measurements of the potential profile over the surface of the LDPE films with two different charging levels. The experimental works in this paper were used to verify the main physical mechanisms responsible for SPD in LDPE after corona charge deposit.

II. Experimental Details

Low-density polyethylene of 50 μm thickness L was used in this work. Samples were cut into square sheets of 5 cm side length and cleaned with distilled water then dried in air ambient. The surface potential decay (SPD) setup is described in Fig. 1. Samples are placed 15 mm under a tungsten metallic point. The output of a negative DC high voltage supply is connected to the point that induces a corona discharge in air. In this

point to surface configuration, discharges take place between the point and the polymer surface. Negative ions are created and deposited on the samples free surface. A metallic grid is inserted between the point and sample surface to produce a uniform distribution of ions on the surface. The adjustable grid voltage determines the maximum of the surface potential (V_s) which could be reached by corona charging. In our experiment, the point voltage was kept constant to 4 kV, greater than the grid voltage and the distance between the grid and the sample d was adjusted to 5 mm, while the corona point was positioned at $D = 10$ mm over the grid.

Once the sample has been charged, it is transferred automatically under a non-contacting Monroe vibrating probe (Monroe 1017 AS). This probe is connected to an electrostatic voltmeter (Monroe 244A-2 model), which measures the surface potential in the ± 3 kV range. The initial surface potential measurement " V_o " is recorded 3 seconds after the end of the charging process and the SPD is recorded during 3 hours.

The potential profile has been recorded after charge deposition by moving the sample holder along a line the charged zone of the LDPE film. These operations were computer-controlled.

Since it is well known that potential decay depends

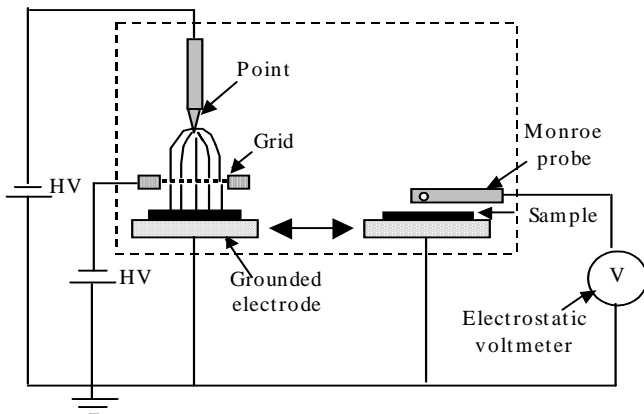


Fig. 1: Surface potential decay principle. Corona discharge (a) and surface potential measurement (b).

sharply on the experimental charging conditions, such as temperature and the relative humidity [15], all experiments were carried out, in situ, in a climatic chamber in which humidity and temperature are controlled (temperature of 22 °C under approximately 40 to 50 % of relative humidity). The initial potential used for charges deposition was varied from 1100 to 2770 V and the charge duration t_c from 5 to 60 s.

III. Experimental Results and Discussion

III-1. Influence of the deposited surface charge density on the SDP

The time dependence of the surface potential $V_s(t)$ decay after negative corona discharges, under the same conditions ($T = 22$ °C, $RH = 45$ % and $t_c = 5$ s) and different initial potentials surface V_o , is presented in Fig. 2.

The SPD is more important when the sample was

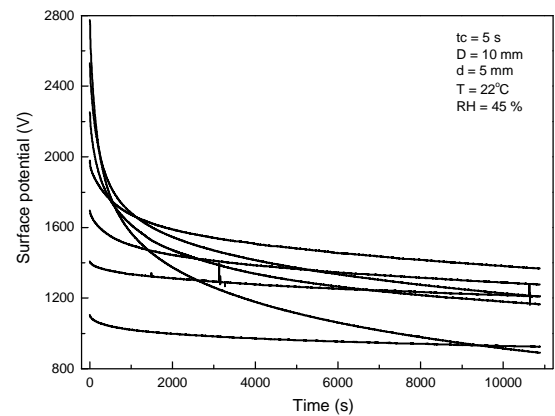


Fig. 2: Surface potential decay for different initial potentials V_o . initially charged with higher voltage potential and a cross over phenomenon occurs. In Fig.3, is represented the variation of the SPD rate as a function of the initial surface potential for four different measurement times. The rate of the SPD increases

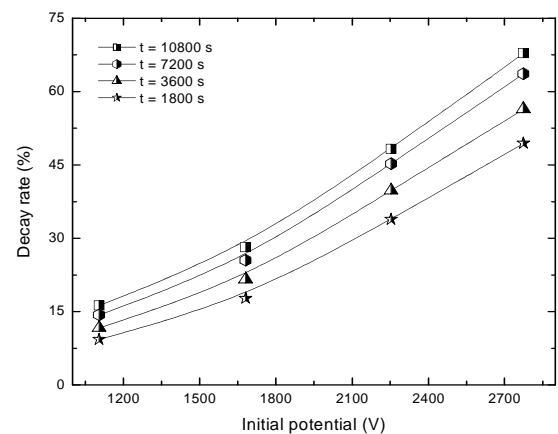


Fig. 3: Decay rate variation with the initial potential V_o . nonlinearly with the potential voltage. The charge deposited on the LDPE penetrated into the polymer bulk and the charge injection depends on the charging

voltage. This implies that the field effect on the surface potential is significant. The cross over phenomenon was first observed by Ieda *et al.* [12] in LDPE and subsequently observed in others materials as well [5]. Based on previous works [5,6], it may be assumed that the charges formed at high corona voltage are able to drift with their own electric field through the bulk by hopping between shallow traps of the bulk, leading by consequence to fast SPD. On the other hand, charges deposited at low voltage corona are likely to stay on the surface in deep surface traps. Recently, using multilayer together with space charge measurement technique [6], it was clearly demonstrated that the surface potential crossover phenomenon is related to charge injection.

III-2. Influence of the charging time on the SDP

The corona discharge is not only a means of electric charges deposition on the surface of the polymers but also a means to modify their properties [9]. Therefore, it is important to study the effect of the charging time on the decay rates. The characteristic of surface potential of charged LDPE for different corona charging times with a grid potential of - 2000 V is presented in Fig. 4.

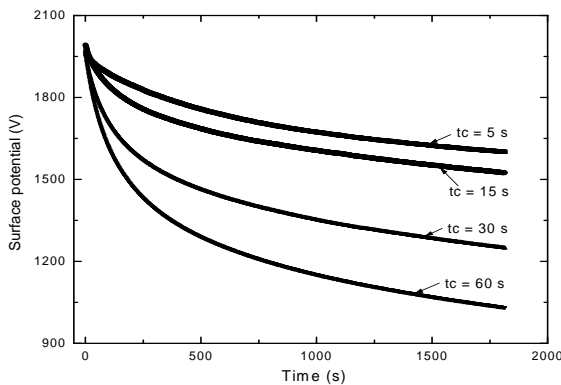


Fig. 4: Surface potential decay for different charging time t_c .

The decay rates increases with the increase of the charging time (the time of charging varies from 5 to 60s). We observe that the longer charging time is, the faster surface potential decays. A possible reason for the faster decay is that the longer charging time allows more charge carriers injection into the bulk. If the exposition time to the corona discharge increases, the photons produced by the negative corona discharge (photons due to the corona discharge light) creates more charge carriers, which enhance the surface conductivity [2].

This deduction assumes that the energetic photon play an important role in increasing the SPD.

III-3. Potential profile with two different charging levels

Potential profiles have been recorded after the charging process. Fig. 5 shows two typical centerline potential profiles evolution on LDPE film with two different values of the grid potential (1100 and 2900V).

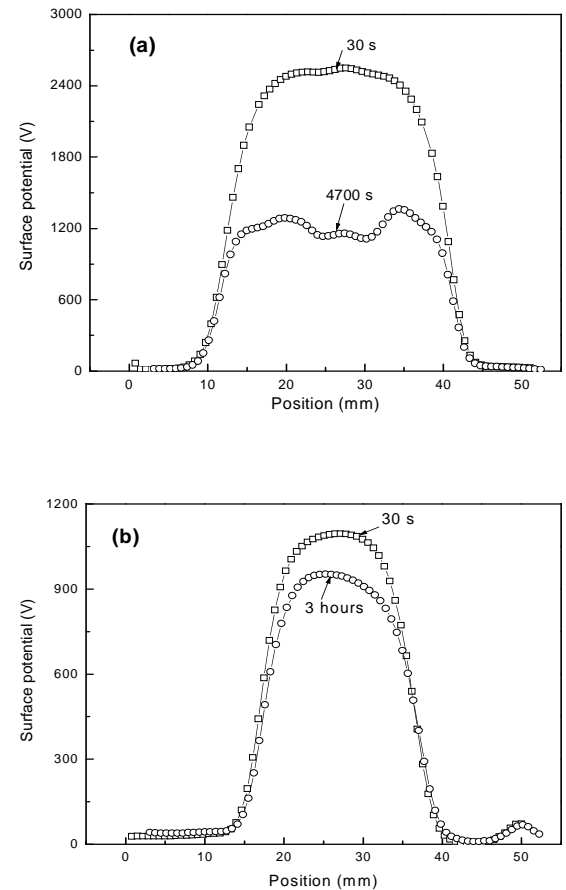


Fig. 5: Surface potential profiles on LDPE, (a) 30 s and 4700 s for - 2900, (b) 30 s and 3 hours for -1100 V.

The peak value of the surface potential decays without any noticeable evidence of lateral charge migration on the free surface of the LDPE film. The absence of lateral charge migration over the films surface shows that the diffusion phenomena under the concentration gradient effect and on the surface conduction under the tangential electric field effect did not contribute to the surface potential decay. Furthermore, as the width of the charge profile remained practically constant, it can be assumed that there was no significant charge neutralization by atmospheric ions [4]. The hollow observed in potential profile of Fig. 5.a, is clearly linked with the crossover of the decay curves and

shows that charge injection takes place in the center of the charged zone, where the initial potential under the grid is higher ($V_g = 2900$ V). Potential profile at low potential ($V_g = 1100$ V) is given as reference (Fig. 5.b). Cross over in the potential decay curves and hollows in the potential profiles shows that the charge injection process in the bulk of LDPE films plays a crucial role in the behavior of SPD [16].

VI. Conclusion

The behavior of surface potential decay of negatively corona charged low-density polyethylene (LDPE) has provided some interesting results. Firstly, the SPD is strongly dependent on the surface charge density (initial potentials V_0) and charging times. The evolutions of the SPD with time showed that the faster decay in the LDPE samples occurs with a higher charging voltage, indicating the influence of the high electric field. Secondly, the profile of surface potential showed clearly the absence of lateral migration of surface charges on LDPE film. The presence of the hollow for high initial potential and the width of the charging zone remained practically constant, indicating that surface diffusion of charges, surface conduction and atmospheric neutralization play a negligible role in the SPD process.

From the combination of surface potential measurements, influence of the initial potential and the charging time and the hollow observed in the potential profile (linked with the cross over of the potential curves for high charging level), it appears that the charge injection mechanism can be considered to explain the SPD.

V. References

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