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Decay of Electric Charge on Corona Charged Polyethylene

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Abstract: In this paper, the surface potential decay of corona-charged low density polyethylene (LDPE) films has been investigated. It has been found that for the same sample thickness the faster decay occurs in the sample with a higher charging voltage. For the same charging voltage, the surface potential in the thinner sample shows rapid decay. Our new evidence from both the surface potential measurement on multilayer samples and space charge measurement suggests the surface potential decay is a bulk limited process. More importantly, space charge measurement indicates double injection has taken place during corona charging process.

1. Introduction

There has been considerable interest in the surface potential decay characteristics of corona-charged polymer insulating materials. Many papers have been published but the physical mechanism of decaying process has not been fully understood [1-5]. Generally, there are three possible decay routes for electric charge, i.e. neutralized with charges in air, released along surface and released through the bulk of insulator. In addition, the crossover phenomenon has been widely reported, i.e. initially sample charged to high potential decays more rapid than that charged to lower potential [1]. One theory believes the existence of deep traps on the surface whilst shallow traps in the bulk of the material [5].
In this paper, we studied the decay of surface electric charge on additive-free low density polyethylene film, which was charged by traditional corona discharge process, using Compact JCI 140 static monitor. In addition, we used the pulsed electroacoustic (PEA) technique to detect charge distribution inside of the insulation material. PEA is one of the most popular techniques used to measure space charge distribution in solid dielectrics [6].

2. Experiments

Polyethylene film sample is negatively charged by corona discharge device as shown in Figure 1. As both temperature and humility may have significant effects on charge decay process, both charging and measurements were performed in controlled environment (T=21^{o}C and RH=45%). Surface potential of corona charged film was controlled by the grid potential between the discharging electrode and ground.

The sample was charged for 1 minute by the corona charging device in all experiments of this paper. After that, the sample was transferred quickly to the Compact JCI 140 static monitor to observe the surface voltage decay. In order to understand the decay process of the surface potential, we did the experiments at different electric field by changing the needle and grid electrode potential and film

thickness. For reliable charge deposition on the surface, we kept the potential difference between needle and grid electrode at 9kV.

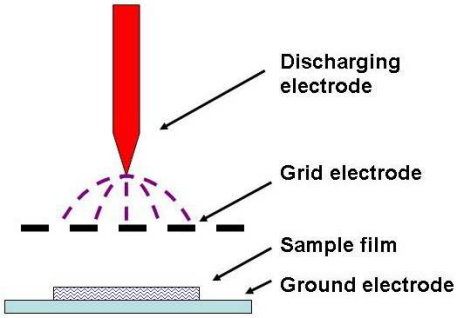

Figure 1 Corona discharge device

PEA is currently the most widely used technique in the field of space charge measurements. This technique utilizes the interaction between high voltage pulses and charge layers accumulated in the insulating material to produce acoustic pressure waves, which traverse across the material and be converted into an electrical signal by a piezo-electric transducer, amplified and captured with a digital oscilloscope. The diagram detailed reviews on the principle of PEA can be found in [7-8].

3. Experimental Result and Discussion

Figure 2 shows the surface potential decay curves for the same thickness film (180μm) at different charging voltages. It is evident that the surface potential does decay faster when the sample was initially charged with higher voltage potential.

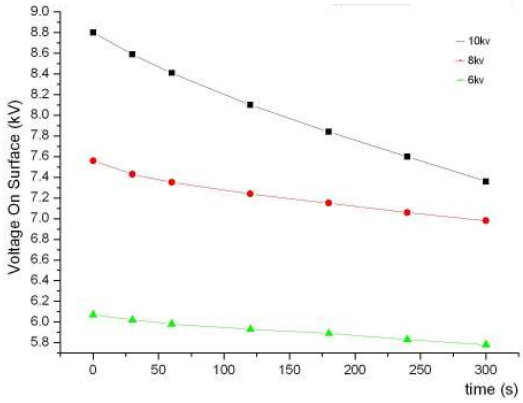

Figure 2 Surface voltage decay of different charging voltage

The decay curves as shown in Figure 3 represent influence of different thickness films (50μm and 180μm) on decay rate when charged at the same voltage. From the results obtained, it shows that there is significant difference in the decay rate for thicker material. These results indicate that the electric field formed plays a crucial role in determining charge decay rate. It seems that the higher the electric field formed, the faster the surface potential decays.

If the surface potential is influenced by the electric field, this implies that the bulk process may dominate the decay process. To verify this sample consisted of three-layers (50μm +50μm +100μm) LDPE film were corona-charged and the surface potential was observed when the top layer and the middle layer were removed as shown in Figure 4. The observed potential when the top layer was

removed provides a direct experimental evidence to support the bulk transport process. The crossover phenomenon may be explained in terms of shallow traps within the bulk of the material and field dependent mobility.

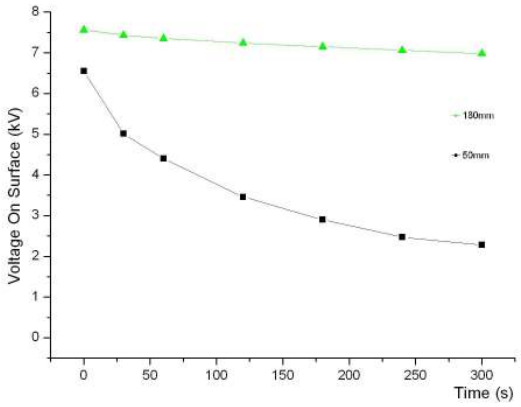

Figure 3 Surface voltage decay of different thickness film

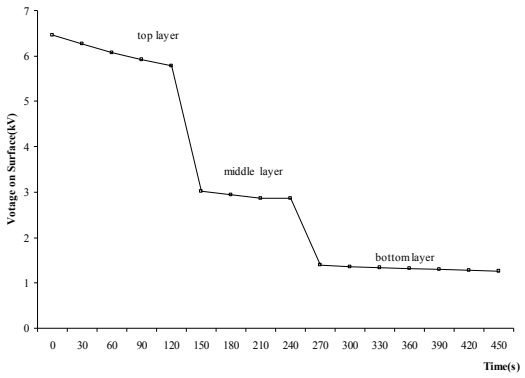

Figure 4 Surface potential measured for multi-layer sample

It is clear to us that bulk charge transport is responsible for the surface potential decay. As the surface potential changes relatively slow it is possible to monitor charge evolution using the space charge measurement. Space charge measurement was made on a corona-charged 180μm LDPE sample. To avoid disturbing charge on the surface during measurement, two 50μm LDPE virgin films were attached to both top and bottom of the corona-charged sample. Figure 5 shows charge distribution across the sample. There are four distinctive charge peaks present across the sample from the left to right. The first and fourth peaks are known as induced charge peaks on the PEA electrodes. Definitely the presence of the two peaks is due to the existence of charge in the sample. The second peak corresponds to the bottom surface of the 180μm corona-charged film while the third peak to the top surface. The third negative peak is expected as the sample was exposed to negative corona. It can also seen that a small amount of negative charge presents across the sample. This may be served as the evidence that charge injection from the top has taken place. The injected charge is captured by traps on its way towards the opposite electrode. Surprisingly, a layer of positive charge is observed at the bottom surface of the sample. We believe this layer of positive charge is injected from the earth electrode during corona-charging. This is possible as the electric field in this case is well over the threshold field found in polyethylene [9]. This implies that the double injection has taken place during the corona-charging process.

The results presented so far strongly support the surface potential decay of corona-charged polymer insulating material is bulk-limited process. Double injection has taken place, however, this feature has not been taken into account in the existing theories and models that have been developed to explain decay process.

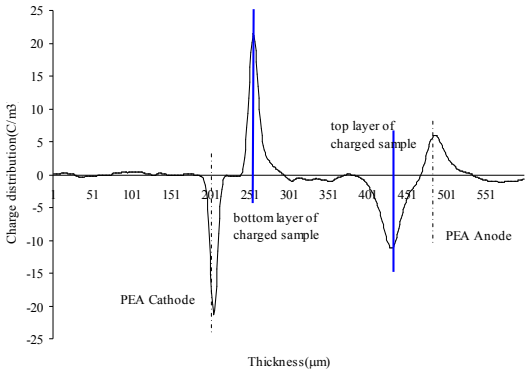

Figure 5 Charge distribution measured by PEA

4. Conclusion

In this paper we have studied the surface potential decay of corona-charged LDPE. New evidence from both the surface potential observed from corona-charge multilayer LDPE films and space charge measurement supports the dominant factor that controls the surface potential is charge transport via the bulk.

Field dependent mobility may be partially responsible for the crossover phenomenon but bipolar charge carrier model should be deployed to fully understand the exact mechanism.

Space charge measurement provides an alternative tool to explore phenomena related to charge decay process. Significant progress has been made and this will be published shortly.

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