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The influence of temperature on electrical conduction and space charge in LDPE

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Electrical conduction in polymeric materials very much depends on temperature. A slight change in operating temperature (few degrees Celsius) would result a significant change in external measured current. This change reflects the mobile charge carriers passing through the sample. The pulsed electro-acoustic (PEA) system measures the total net charge in the sample. Under the condition of application of the external voltage the total net charge includes trapped and mobile charges. It has been reported that if there is a major charge carrier movement caused by electrode charge injection at very high field (>100 kV/mm) it can be picked up by the PEA system and also reflected in the external measured current. High temperature is believed to encourage not only mobile charges movement but also increase the probability of trapped charges getting detrapped, which therefore contributes to the external measured current. However, it is not known whether such a change in the external current leads to any change in amount of measured space charge or charge distribution.

Using our improved PEA system that equips with the quality of measuring the external current and charge density distribution concurrently under a controlled temperature environment, we have carried out tests using additive-free LDPE of 200μm thick. Effect of elevated temperature can be illustrated by one of the test we had performed. A LDPE film sample was stressed at a voltage of 10 kV at a constant temperature of 30°C in a convention oven. At about 2 ½ hours after the applied stress, temperature was adjusted to 40°C for a period of 5 minutes (rise time from 30°C to 40°C) and was then later re-adjusted back to 30°C. Almost instantaneously a significant increase in the external measured current (~80% increased) was observed as shown in figure 1. Charge density profiles at the beginning and peak of the external measured current were used to analyze the relationship between them. There is neither significant change in amount of measured net charge nor its distribution as shown in Figure 2. Small shift in the second peak is attributed to the thermal expansion. A significant increase in the external current indicates an increase in the amount of mobile charge in the sample. No significant change in measured charge suggests that the mobile charge is only a small portion of the measured charge. To validate our assessment a similar procedure was carried out 30 minutes later with the same sample except this time the temperature was increased from 30°C to 35°C. The space charge distributions prior to and at the peak current are illustrated in figure 3. Further tests were carried out at a constant voltage with various different temperatures and the results clearly showed that the trapped charge in the sample is affected by the temperature.

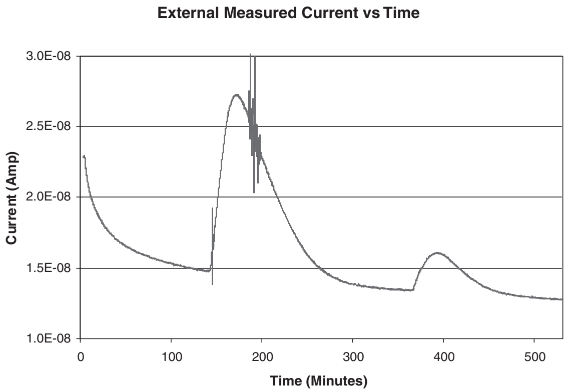

Fig. 1. Relationship between current and temperature variation at 10 kV.

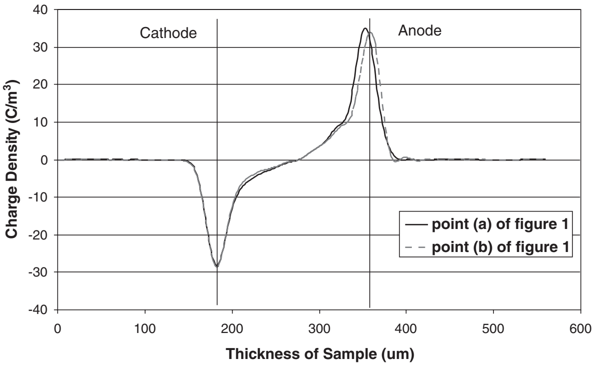

Fig. 2. Charge density profiles prior to and at 1st current peak as shown in figure 1.

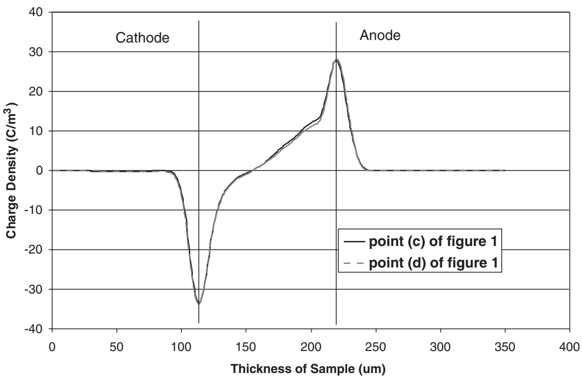

Fig. 3. Charge density profiles prior to and at 2nd current peak as shown in figure 1.