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Use of Dynamic Space Charge Measurements to Differentiate Charge Injection and Ionic Dissociation in Polypropylene

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The time resolved fast pulsed electro-acoustic (PEA) [1-3] method is used to investigate the space charge characteristics in an additive-free poly(propylene-ethylene) (PPE) copolymer in film form. The 190 μm -thick films were submitted to DC and low frequency AC stress for various durations at various temperatures. Upper electrode (UE) and lower electrodes (LE) is semi-conductive polyethylene and aluminum, respectively.

When positive 50 kV_{dc}/mm is applied to UE at 25 °C, negative charge is injected from LE and shifts up to UE during 1 hour stress. No positive charge is detected by PEA. However, at 50 °C, hetero-charge formation is observed with approximately equivalent densities for positive and negative carriers under the same applied field (Figure 1). Negative charge in the bulk becomes more and more dominant for long stressing time. A similar process (i.e. symmetrical hetero-charge accumulation at first and then dominance of positive charge carriers in the bulk) occurs when a negative voltage is applied to the UE. The symmetrical hetero-charge arises after HV application for 30 s.

Two frequencies of 5 mHz and 100 mHz are selected: the half-periods are therefore respectively longer and shorter than the time for hetero-charge detection at that field. At 50 °C, surprising periodical symmetrical hetero-charge accumulation is observed under 5 mHz square 50kV/mm RMS stress, while only injected charge is observed at 0.1 Hz square 50 kV/mm RMS stress (Figure 2). Because the charge injection rating is symmetrical not for the asymmetrical electrode structure, the symmetrical hetero-charge can not be attributed to the injected charge transiting across the bulk. Combining dc data with ac data, it is shown that the charge build-up in the bulk results from different processes for homo-charges and hetero-charges: The homo-charge is injected from electrodes and the molecular dissociation in the bulk can be the original source of the symmetrical hetero-charge.

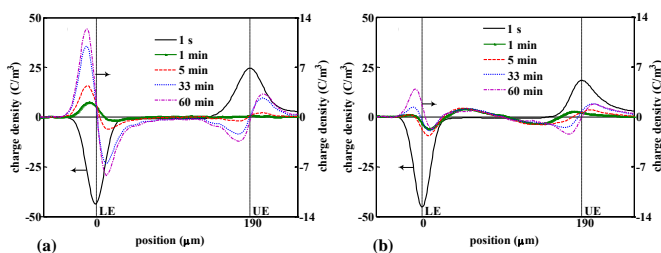


Figure 1. Space charge dynamics in PPE film under 50 kV_{dc}/mm at (a) 25 °C and (b) 50 °C

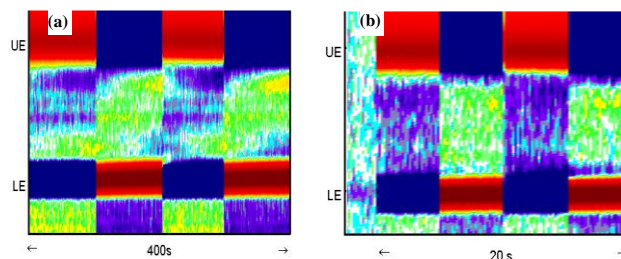


Figure 2. Space charge dynamics in PPE film under 50 kV_{dc}/mm at 50 °C at (a) 5 mHz and (b) 0.1 Hz

Table 1. Time for the onset of quasi-symmetrical hetero-charge apparition in PPE film under different field at 50 °C

applied field (kV/mm)	15	30	50	100
time (s)	1800	340	30	0.3

The time of the hetero-charge emergence under high voltage application depends on the field intensity, being shorter for higher field (Table 1). The time resolved hetero-charge migration shows ionic transport characteristics, which can be well fitted with an ionic transport model. The molecular dissociation is temperature and applied field dependent [4]. We observed the symmetrical hetero-charge again in the film bulk under 100 kV_{dc}/mm at 25 °C.

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