Role of holes in conduction phenomenon of Low Density Polyethylene under high fields

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ABSTRACT

In the present work, an insight has been given to understand the role of holes in the conduction phenomenon of low density polyethylene (LDPE). Leakage current measurement has been done using the three terminal electrode in series with an electrometer. Incompetency of conventional conductivity model has been shown after their comparison with the experimental results. Extension of a recently proposed conduction mechanism has been presented. On the basis of estimated mean-square-log error, for different possibilities, the contribution of holes in conduction mechanism of LDPE under the condition of high fields and high temperatures.

KEYWORDS

HVDC Cables, LDPE, leakage current, three electrode setup, electron and holes mobility, conductivity.

INTRODUCTION

Being a promising candidate for High Voltage Direct Current (HVDC) transmission system LDPE has shown notable electrical insulating properties at par with the transmission system requirements [1]. However, under high dc stress (in the order of 10^7 V/m), it was witnessed that, an ununderstood conduction current flows through the material. At the same time space charge accumulation inside the material has been also reported, which is another serious concern. These two phenomena may have direct or indirect relationship with each other and cumulatively create distortion in the internal field distribution, which in turn tap the breakdown capability of the insulating material [2-6]. To address the conduction phenomenon, conventional charge transport models has been proposed, such as Pool-Frenkel, Hopping etc. Conventional models put forth the explanation of charge transport in presence of different kinds of traps present [7-9]. Existing models could easily follow the experimental conductivity for a short range of temperature and field. Meanwhile for a wide-ranging electric field and temperature, these conventional models fail to follow the experimental conductivity.

In a recent work [10], a conductivity model of LDPE has put forth with due consideration of its integral regions, i.e., crystalline, interfacial and amorphous regions. Proposed conduction mechanism satisfactorily comprehends the experimental conductivity for a wide-ranging electric field and temperature. It has been shown that the movement of electrons in interfacial region of spherulites determines the overall conductivity of the material. In extension of [10], present work studied the behavior and contribution of holes in conduction phenomenon under high field (> 100 kV/mm) and high temperature (50°C).

EXPERIMENTAL DETAILS AND RESULTS

Sample manufacturing

Granules of LDPE, provided by a supplier, were melt-blended with the help of two-roll mill for the duration of 1 hour at 110ºC. Furthermore, with the help of hydraulic press at pressure of 100 bar and at 110ºC temperature for half an hour, 100 µm thick sheet of LDPE were prepared.

Measurements

The leakage current was measured using a well-known three terminal electrode setup, particularized in [10], in series with Keithley-6517B Electrometer.

Leakage current experiments were done at 303K, 323K temperatures. At each temperature the applied voltage, using a 100kV DC source, was varied from 2kV to 20kV with 2kV step. Leakage current was recorded for ten hours. Three samples were tested for each case. To maintain the constant temperature, hot air oven was used and the measurements were started after three hours of switching on the oven, to permit it for the steadiness of temperature, as shown in Fig. 1.

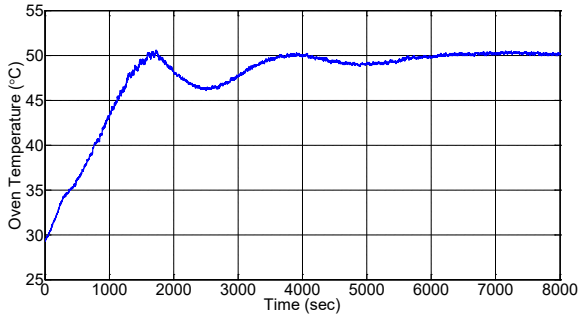

Fig. 1: Stabilization of temperature of hot air oven. Reproduced from [10], with the permission of AIP Publishing

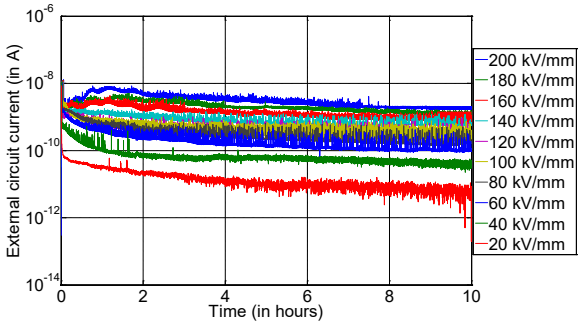

Fig. 2. Volumetric current variation of LDPE with respect to time at different applied field and 303K temperature plotted in a log-normal scale. Reproduced from [10], with the permission of AIP Publishing