A.7.5. Etude des interfaces électrode-isolant par la mesure simultanée du courant externe et des distributions de charges d'espace

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A.7.5. Study of the electrode-insulator interfaces by simultaneous measurement of external current and of space charge distributions

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Résumé

Un dispositif expérimental permettant de mesurer simultanément les profils de charges d'espace par la méthode de l'onde de pression et le courant externe pendant la polarisation et la décharge d'un échantillon a été réalisé et appliqué à l'étude du polyéthylène basse densité. A partir des résultats expérimentaux, le courant de déplacement puis le courant de conduction sont calculés dans tout l'échantillon, et en particulier au niveau des interfaces. L'évolution temporelle des champs électriques et du courant de conduction aux interfaces permet de déterminer les caractéristiques champ-courant des deux jonctions conducteur-isolant. Celles ci sont comparées à la loi d'injection Schottky, ce qui permet de déterminer la forme et l'intensité de la barrière de potentiel.

Abstract

An experimental setup which allows for simultaneous measurements of charge profiles by the Pressure Wave Propagation (PWP) method and total external current during polarization and discharge periods has been developed. It has been applied to the study of low density polyethylene. The displacement and the conduction currents can be determined everywhere in the sample, especially at the electrode-insulator interfaces. Characteristics of both interfaces are calculated from the evolution in time of the electric fields and of the conduction currents at both contacts. They are fitted with the Schottky injection law in order to determine the shape and the magnitude of the potential barrier.

Introduction

Numerous publications deal with electrode-insulator contacts which are of great importance, particularly in high voltage cables. Yet, traditional current measurements do not permit to distinguish easily bulk conduction phenomena from those occurring at interfaces in presence of space charges [1]. Another difficulty is due to the fact that some injection models (Schottky injection) and conduction in the bulk models (Poole-Frenkel effect) lead to very similar dependences in electric field and temperature. Moreover, while metal-insulator junctions are often studied, very little work has been done with semiconducting electrodes such as those used in cables.

Non-destructive methods have been developed in order to measure charge and field distributions in dielectric materials [2], [3] and [4]. It is well known that space charges may induce a significant distortion of the electric field, particularly in the vicinity of the electrodes. This can lead to charge transfer and to injection of carriers in the insulator. Yet, even using these methods, it is difficult to obtain a good model for the injection laws.

So far few studies of both external current and space charge profile measurements have been reported [5,6]. As shown in [6], an experimental setup which allows for simultaneous measurements of charge profiles by the Pressure Wave Propagation (PWP) method and total external current by an electrometer has been developed by the authors.

Polarization and depolarization currents can be measured while following the evolution of the space charge and electric field distributions during poling and discharge periods. In this paper, a quantitative analysis of the behavior of electrode-insulator contacts in low density polyethylene (LDPE) samples with semiconducting electrodes is reported.

1 Injection laws

The most likely injection process at fields below 10^8 Vm^{-1} is the field assisted thermoionic emission, known as the Richardson-Schottky effect. In order to be transferred at an electrode-insulator interface, an electron has to pass a potential barrier [7]. Under a local field, the barrier height is reduced and the probability for an electron to be transferred is increased. If the conductor-insulator junction is perfect, the potential is of a coulombic form and the law which relates the conduction current density J_c to the interfacial field E_{int} is :

$$J_c = J_0 \, exp(-\frac{\phi}{kT}) \, exp(\frac{e \, \beta \, E_{int}^{1/2}}{kT}) \qquad (1)$$

$$\text{with } \beta = (e^2/4\pi\varepsilon)^{1/2}$$

where ϕ is the total barrier height. Currents which obey equation (1) will thus show up as straight lines on a $log(J_c)$ versus $E_{int}^{1/2}$ plots, known as "Schottky plots".

In conventional $I(V)$ measurements, two difficulties arise. First the conduction current is determined in steady state conditions, for which it is equal to the external current. This may require a very long time. Second, evaluating, in this case, appropriate values for the interfacial field is not easy since space charges are frequently present in polymers under