Effect of the interfaces polymeric /electrode and polymeric /polymeric on the formation of the space charges in an insulator polyethylene subjected to a continuous electric field

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Abstract
We are interested in the behavior under tension of metal dielectric interfaces and dielectric / dielectric towards the formation of space charges. The material in question is a widely used polyethylene as an insulator in high voltage cables. The space charges are measured by the pulsed electroacoustic technique during the polarization and depolarization. We considered a period for interfaces formed by the contact metal / semiconductor and polyethylene / polyethylene, and the association of two films of polyethylene, (thus obtaining a physical interface between two similar materials). The results show that the formation and dissipation of space charges depend on the nature of interfaces and a 'physical' interface is not a barrier to the transport of charges.

Key words **Electrical Insulator, polyethylene, space charge, technical pulsated electro acoustics, interfaces, continuous constraint, polarization, depolarization**

I. INTRODUCTION

Insulating materials such polyethylene thermoplastics are increasingly used in the field of electrical engineering and high voltage. They are indeed excellent insulation properties, are chemically inert and can be molded or extruded to meet complex geometries [1].

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The term polyethylene is a generic term which refers to the insulation is different from the base resin (a type of polyethylene, chemically modified or not, cross-linked or not) or by the nature of the additives (antioxidants, other additives). The polyethylene insulation of choice for high voltage cables underground or submarine in which they replace the insulation paper impregnated with oil, for environmental reasons and maintenance (removal of dielectric liquid reserves). However, several factors still limit their use to applications under tension. Electric charges can be injected at the interface electrode / polymer, or created in the volume of chemical species electro dissociation. Due to the nature of the insulating and dielectric environment, these charges are trapped at the interface or volume which leads to a change in the distribution of the electric field. Locally, especially when reverse polarity is necessary for the operation of the liaison, intensifications field can either initiate degradation reactions or cause immediate dielectric breakdown in the most critical [2]. Another element is to be taken in consideration: given the length of routes of energy, connections are needed between sections of cable. They are a weak point in the system in terms of reliability as dielectric interfaces / dielectric are present [3]. The aim of our work is to characterize the spatio-temporal distribution of space charges which appear at the interfaces metal - dielectric and dielectric - dielectric under voltage by direct measurement in terms of constraints and time, phase and polarization depolarization, using the technique pulsed electro-acoustic. The literature shows that work has been performed to study the effect of interfaces on the behavior of space charge in polyethylene. The technique of current thermally stimulated depolarization (TSDC) has for example been used to study interfaces polymer / polymer, polymer / mica and polymer / oil [4-7]. Other studies have been conducted directly by measuring the load space by the technique pulsed electro-acoustic (PEA) [6-10]. The work of G. Chen [9] have shown that the interfaces between two layers of low density polyethylene (LDPE) act as traps for electrons but not for carriers of positive charges. The article says the current behavior of space charges in samples formed by the combination of two films made of

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polyethylene "sandwich" between the electrodes of the measuring device space charges.

II. CONSIDERATION ON THE MECHANISMS OF INTERFACE

Interfaces, regardless of their kind (metal / dielectric or dielectric / dielectric.) Plays a fundamental role in the dynamics of space charges. In the case of interfaces metal / dielectric, it is considered generally that the charges can be extracted and injected depending on the metal electrode and the nature of the interfaces [9-10]. In the case of interfaces dielectric / dielectric, the electromagnetic theory [11] the charge density is governed by the following equation (Maxwell-Wagner-Sillars):

$$\sigma = (\varepsilon_2 - \varepsilon_1 \frac{\gamma_2}{\gamma_1})E_2 = (\varepsilon_2 \frac{\gamma_1}{\gamma_2} - \varepsilon_1)E_1$$

Where σ , ε and E r represent the conductivities, dielectric constants and electric fields in the media (1) and (2). In our study, the two materials are identical, therefore the charge density at the interface should be zero (without disturbing Charge distribution of internal electric field). However, the interfaces we use are not perfect since the interfaces formed by the contact of two films. This suggests that the traps will be introduced, especially because of the weak coupling between films (no chemical bonds). It is these effects that we wish to highlight in the first instance.

III. CHARACTERISTICS OF POLYETHYLENE SAMPLES AND MEASURING SYSTEM

III. 1 Samples

Dielectric samples used in this study are films of chemically crosslinked polyethylene (XLPE for cross-linked polyethylene) paid directly into the insulation of medium voltage cables by using a technique of "débobinage" of the 'isolation mass. The result is a polyethylene tape 8 mm wide and 150 m thick over a length of several meters. The characteristics of samples are described elsewhere [12].
An important factor in studying the surface of films. The "débobinage" leads one to obtain surfaces with different roughness states (see table below).

TABLE 1 STATES CHARACTERISTICS OF ROUGHNESS ON BOTH SIDES OF POLYETHYLENE FILMS

Median value of roughness	
Smooth surface	Ra=22.78 nm
Rough surface	Ra=291.6 nm

III.2. The electro-acoustic pulse

The measurement principle is based on the detection of acoustic waves created by impact on the electrostatic charges which are trapped themselves coupled to molecules [13]. The electro-acoustic pulse used is a conventional device described in Figure 1. The acoustic signals generated by the movement of charges submitted to electric pulses (via the pulse generator that delivers pulses with a duration of 10 ns, amplitude adjustable up to 1 kV and frequency of 50hz) propagate through electrode connected to ground (its thickness serves as a delay line for the propagation of acoustic waves) reach the piezoelectric sensor, and are finally reduced by an acoustic impedance. The latter has the effect of limiting thoughts. The signal, issued by the amplifier system is then transferred to an oscilloscope bandwidth with a sampling frequency of 500 MHz to be processed. The sample is fed by a high voltage generator (up to 30 kV) is necessary to perform the calibration and also serves to polarize the material. The two power supplies (pulse generators and food samples) are connected to the upper electrode of the cell.

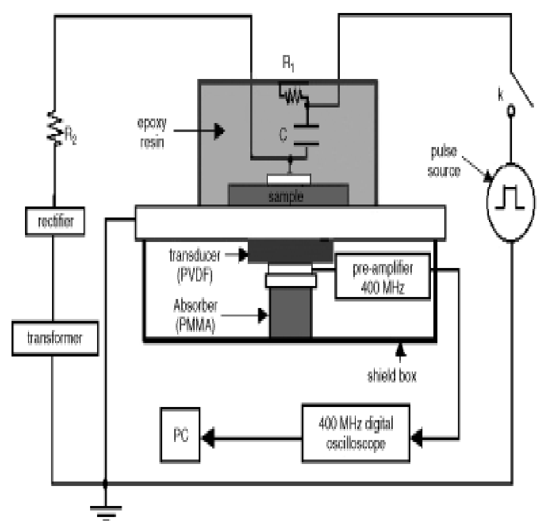

Fig 1. Schematic of experimental device for measuring the space charge technique pulsed electro-acoustic (PEA)

The power generator is connected to the upper electrode through a resistance of current limiting. The pulse generator is connected via a capacity of decoupling. Electrodes measuring system consisting of the mass of aluminum electrode side detection acoustic sensor and a piezoelectric semiconductor electrode (a mixture of polyethylene and carbon black) to the electrode connected to the high voltage (which also provides a better fit with the sound sample).
Broadly speaking, the measuring device is suitable for samples with thickness between 100 µm and 500 µm. Its sensitivity is about 0.1 C/m^3 and spatial resolution of about 10 µm

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III.3. Configuration and measurement protocol of the space charge

Measurements of space charge that we present were performed at room temperature 25 °, for films of polyethylene as a "sandwich" in which the two films are brought into contact: the sides say "smooth" two films that are vis-à-vis the surfaces called "rough" being in contact with the electrodes of the PEA measurements. The interface is kind of "natural", without chemical bonds between films, all of which are maintained by the electrodes of the PEA. Based on the principle of the measure, we verified that the samples were formed in sufficiently intimate contact so as not to disturb the propagation of acoustic waves (good acoustic impedance between electrode and aluminum XLPE 1 and between XLPE1 and XLPE2).

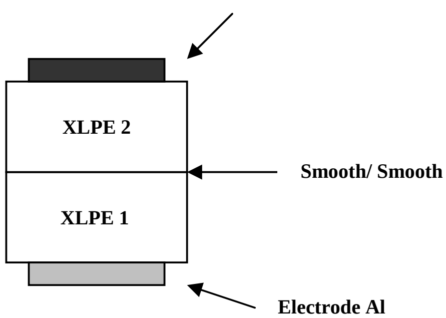

Fig 2. The samples are formed by the combination of two films of polyethylene (physical interface) in contact with the electrodes of the PEA measurement system.

The measurement configuration adopted is illustrated in Figure 2. The reference electrode against tension applied is the semi-conductive electrode. The cycle of tension is shown in Figure 3. The measurements were performed on each level of tension in phase bias (sample under tension) and at different times of depolarization phase (sample short-circuited).

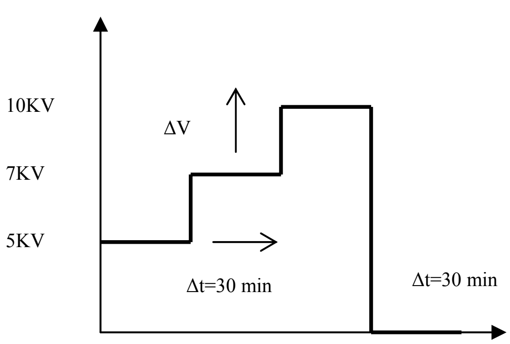

Fig 3. Cycle voltage used for the measurements of space charge

III.4.1 Distribution of the space charge for a polarization in positive tension

A.Polarisation

The profiles show a significant accumulation of charge up to 10 kV, under the experimental protocol adopted (see Fig. 4). A 5 kV and 7 kV, the profiles show only the capacitive loads associated with the application of tension. No expense is detected in volume for these conditions polarization. A 10 kV, there is a significant increase in negative charges that have migrated in volume from the cathode. The behavior of charges in the volume of the two layers is best illustrated in the phases of depolarization, since the charges on the surface of the electrodes are due to image (there are more charges related to the surface application of tension).

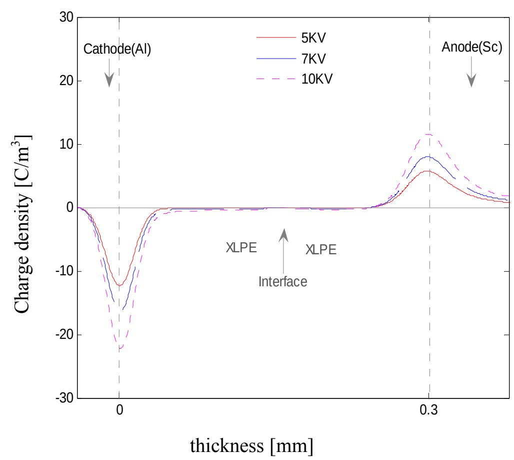

Fig 4. Charge distribution under positive tension in polarization

B. Depolarization

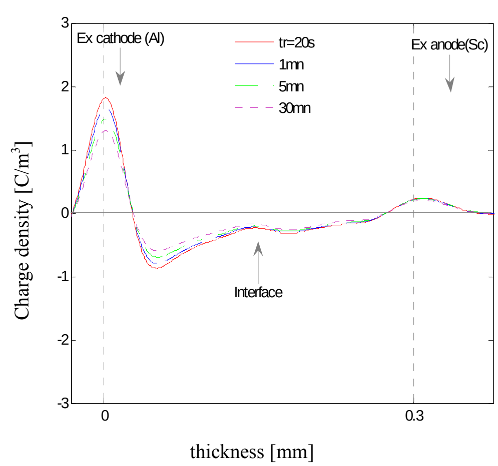

Fig 5. Profile of space charge in depolarization

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The profiles confirm the presence of the negative charge which is detected in all the volume of the sample. We note a more important density in the vicinity of cathode, but the transport of load was effective until in layer XLPE2. The interface physical between two films thus does not seem to constitute a barrier for the transport of load.

Let us note that the pulsated electro acoustic technique detects the clear load. Negative distribution is thus not a proof of absence injection in the vicinity of the anode, but a prevalence of the negative charges in this area. It thus seems that the injection electrons starting from the electrode aluminium is the mechanism dominating in the formation of the loads d' space. The interface physical between the two dielectric layers does not seem to introduce a distribution of deep traps which would limit the transport of the loads of the first layer about the second.

During depolarization, we notes a slow reduction in the density of negative charge in the vicinity of the interface dielectric /metal as the simultaneous decrease of the load image attests some on l' electrode. it' is well the behaviour awaited because part of the electrons is recalled towards the electrode taking into account the electric field to which they are subjected.

III.4.2 Polarization under negative tension

A. Polarisation

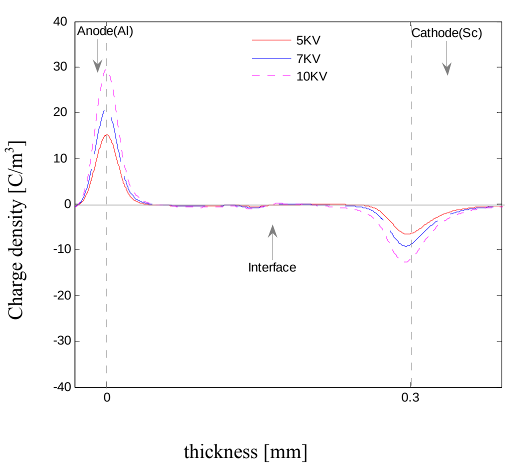

Fig 6. Charge distribution under negative tension in polarization

The development d' is noted; a load d' space positive in the vicinity of l' anode, and negative in the vicinity of cathode, this being especially visible starting from 10 Kv. The charge distribution in volume is clearly revealed in depolarization.

B. Dépolarisation

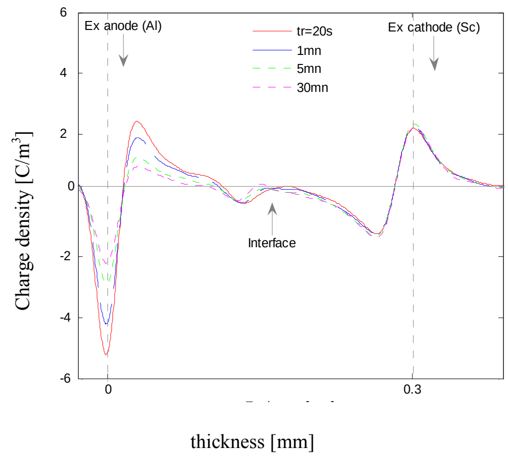

Fig 7. Profile of space charge in depolarization

Profil de charge d'espace en dépolarisation

We clearly observe a bipolar distribution with a maximum of negative charge close to the electrode Sc (cathode) and a maximum of positive charge near to the electrode Al (anode) what means that the injection is produced with the two electrodes and that the charge were transported in volume. A minimum of charge is detected with interface XLPE1/XLPE2 what can to interpret if the positive and negative charges are compensated exactly. Distribution in the vicinity of a dielectric/dielectric interface, which appears complex, results from the compensation or the recombination between opposite charges of signs.

Let us note that the weakening of the positive charge with time is rather fast, contrary to what is observed for the negative charges in the vicinity of semiconductor electrode.

IV.DISCUSSION

The preceding results clearly show that the electrode materials have a significant effect on the formation of space charge. The charges identified in this study appear from the electrodes. The material used is a thermoplastic industrial and other phenomena could be causing the internal charges. But the distributions shown are "homo charges" which accredits the hypothesis of the injection. It seems therefore an aluminum electrode injects electrons as well as holes in the polyethylene. For against, the semiconductor electrode seems to promote the electronic injection. It notes that the extraction of positive and negative charges of polyethylene to the aluminum electrode is relatively easier than in the case of semi-conductive electrode. Interface physical "between two dielectric" does not seem to present a barrier for the transport of charge.

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V. CONCLUSION

In this article we studied the effect of interface electrode / polymer and polymer / polymer on the phenomena of space charge in XLPE. Based on these results we can draw the following conclusions:

-electrode material to a significant effect on the injection and extraction of charge,

-in the absence of ionization / dissociation in the volume of dielectric, the distribution depends on the rate of injection and extraction of charges to the two electrodes and the mobilities of carriers of charges,

-a "physical" interface between two layers of XLPE does not seem to introduce a barrier to the transport of charge.

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