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Modelling of space charge density in polymeric insulating

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Abstract

Charge transport and storage in polyethylene has been put forward recently. The aim of this study is to present a model able to reproduce the behaviour of space charge in low density polyethylene (LDPE), under DC polarisation. The numerical results shown here are compared with experimental data obtained from PEA, carrier charge measurements. Finally, we discuss model limitations and possible improvements.

Key words: space charge, polymer, PE, numerical simulation.

Introduction

Polymeric materials, especially polyethylene, are more and more used in high voltage (HV) cables (90 to 400kV) for electrical energy transport. A problem of application in high voltage DC (HVDC) transport is its tendency to accumulate charge through either injection at the interfaces or internal generation processes [2]. These so-called space charges may induce field distortion [4] within the insulation, and also catastrophic damage. The aim of this work is to propose a numerical model of charge transport considering one deep trap level associated with an effective mobility for charges in the conduction bands.

MODEL DESCRIPTION

The set of equations which describe the transport of charge, for a time-dependent current density j(x,t), without diffusion, are as follows [3]:

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Poisson equation:

$$\frac{\partial E(x,t)}{\partial x} = \frac{\rho(x,t)}{\varepsilon} \qquad (1)$$

Continuity equation:

$$\frac{\partial n_a(x,t)}{\partial t} + \frac{\partial j_a(x,t)}{\partial x} = s_a \qquad (2)$$

Transport equation:

$$j(x,t) = \mu . n . E(x,t) \qquad (3)$$

Equations for injection, at the cathode and anode respectively, are as follow [3]:

$$j_e(0,t) = AT^2 \exp\left(-\frac{w_e}{k_B T}\right) \exp\left(\frac{e}{k_B T}\sqrt{\frac{e.E(0,t)}{4\pi\varepsilon}}\right) \qquad (4)$$

$$j_h(d,t) = AT^2 \exp\left(-\frac{w_h}{k_B T}\right) \exp\left(\frac{e}{k_B.T}\sqrt{\frac{e.E(d,t)}{4.\pi.\varepsilon}}\right) \qquad (5)$$

In the bulk the of carriers migrate by the hopping process and others are trapped, the mobility is given by the following equation:

$$\mu = \frac{2.\upsilon.a}{E} \exp\left\{-\frac{\omega}{k_B T}\right\} \sinh\left\{\frac{e.E.a}{2k_B T}\right\} \qquad (8)$$

The parameters of the model are shown in table 1.

RESULTS

In order to resolve these equations we have used the finite difference method; the thickness of the dielectric is divided in small elements with length of Δx.

Fig. 1 shows the density of charges obtained from simulation in LDPE after polarisation with 60 kV during 60S.

Fig. 2 shows the conduction currents in LDPE after polarisation with 60 kV during 3600S.

CONCLUSION

We have developed a model based on bipolar transport including trapping and recombination aiming at describing conduction processes in low density polyethylene. Conduction processes are described through a constant effective mobility. The model shows accumulation of homocharges besides the electrodes, negatives homocharges at the interface cathode polymer and positive homocharges at the interface anode polymer. Results of simulation correspond qualitatively to the experiment results. We can say that the model and this numerical method is a tool to test the sensitivity of the results to certain critical parameters.

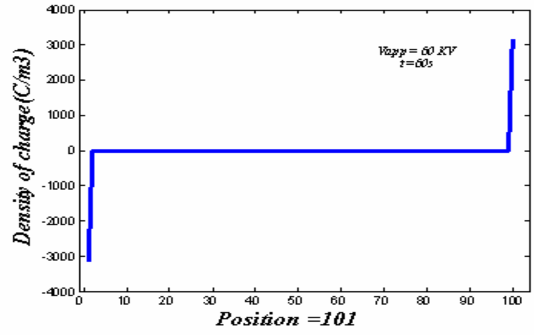

Figure 1: charge density distribution in LDPE
Field = 60 kV/mm.

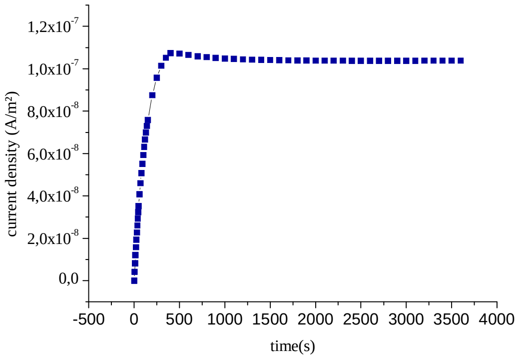

Figure 2: Current density in LDPE on of time under DC polarisation. Simulation results

References

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Table 1: Parameter of the Model

Symbol	**value**	**Unity**
Richardson constant A	1.6.10-	A.m^2.K^2
Depth traps *w*	1.1	eV
Intersite distance a	2.10^{-10}	m
Dielectric thickness	150.10^{-6}	m
Jump frequency υ(Hz)	$6.2.10^{12}$	Hz
Trapping Coefficients		
B_e electrons	7.10^{-3}	S^{-1}
B_h trous	7.10^{-3}	S^{-1}
recombination Coefficients		
S_0 trapped electrons /trapped holes	4.10^{-3}	$m^3.C^{-1}.S^{-1}$
S_1 mobile electrons/ trapped holes	4.10^{-3}	$m^3.C^{-1}.S^{-1}$
S_2 trapped electrons/mobile holes	4.10^{-3}	$m^3.C^{-1}.S^{-1}$
S_3 mobiles electrons/mobile holes	0	$m^3.C^{-1}.S^{-1}$
Mobilities		
Electrons μ_e	9.10^{-15}	$m^2.V^{-1}.S^{-1}$
holes μ_h	9.10^{-15}	$m^2.V^{-1}.S^{-1}$
Barrier detrapping		
Wtre electrons	0.95	eV
Wtrh holes	0.95	eV
Maximum density of traps		
electrons	100	$C.m^{-3}$
holes	100	$C.m^{-3}$
higher barrier for injection		
Electrons	1.2	eV
holes	1.2	eV