Laboratoire Plasma et Conversion d'Energie

BEHAVIOUR OF ELECTRON BEAM IRRADIATED POLYMERS: PEA MEASUREMENTS AND SIMULATIONS

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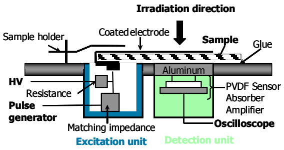
Synopsis: *Under specific space environment conditions, polymeric materials used as cover parts of satellites can store charges, leading to electrostatic discharges. In order to understand the behavior of dielectrics under electronic irradiation, the spatial environment is reproduced at lab-scale. The space charge distribution is studied by Pulse Electro Acoustic (PEA) system that has been implemented to reproduce two configurations (short-circuit and open). To complete these studies simulation models have been developed. Experimental and simulation results obtained on Low Density Poly Ethylene (LDPE) irradiated films are presented and discussed here.*

EXPERIMENTAL SET-UPS

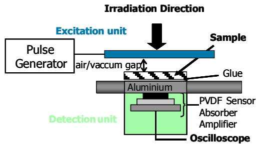
SHORT-CIRCUIT PEA



+ Excitation and detection units on the same side
+ Coated electrode on the front to apply the pulse probe voltage
+ Both surfaces grounded between measurements
+ Measurements at any time during irradiation and relaxation

➡ Configuration representative of dielectrics located on sun lighted satellite side where the photoemission is effective

OPEN PEA



+ Electrode positionned at 1 mm above the sample
+ Extraction of charges only at the ground electrode
+ Measurements performed between two periods of irradiation, and anytime during relaxation

➡ Configuration representative of dielectrics covering the satellite and not exposed to the sun

SIMULATIONS

MODEL DESCRIPTION

Transport and recombination

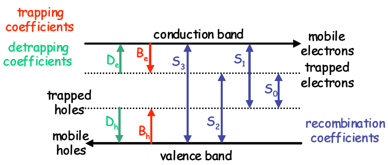


Figure 1: Schematic representation of the conduction mechanisms used in the simulation.The values and definition of the parameters are given in the Table.

Equations

$$j(x,t)=n(x,t).\ .E(x,t) \quad \text{transport}$$

$$\frac{\partial E(x,t)}{\partial x}=\frac{\rho(x,t)}{\varepsilon} \quad \text{Poisson}$$

$$\frac{\partial n(x,t)}{\partial t}+\frac{\partial j(x,t)}{\partial x}=s \quad \text{continuity}$$

Example of source term for mobile electrons

$$s_e\ (x,t)=-\frac{\partial J_0(x,t)}{\partial x}+G(x)-B_e.n_e\ (x,t)\left(1-\frac{n_{et}}{n_{0et}}\right)$$
$$+D_e.n_{et}-S_1.n_e\ .n_{ht}-S_3.n_e\ .n_h$$

Electron beam current density

Refers to electron/hole pairs generation due to the electron beam:

$$G(x)=G_0.D(x)$$

PARAMETERS USED FOR ALL SIMULATIONS

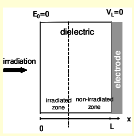
Symbol		Value	units
mobility	μ_e μ_h	1 10^{-14} 2 10^{-13}	$m^2.V^{-1}.s^{-1}$
Deep trapping coefficient	B_e B_h	1 10^{-1} 2 10^{-1}	s^{-1} s^{-1}
injection barrier height	w_e w_h	1.27 1.16	eV eV
Deep trap densities	N_{oet} N_{oht}	100 100	$C.m^{-3}$ $C.m^{-3}$
Recombination coefficients S_0, S_1, S_2,S_3		0	$m^3 .C^{-1}.s^{-1}$
Detrapping barrier height	w_{tre} w_{trh}	0.96 0.99	eV eV
Electron/hole pairs generation coefficient G_0		5 10^{-2}	$C.m^{-3}.s^{-1}$

COMPARISONS BETWEEN EXPERIMENTAL AND SIMULATED SPACE CHARGES PROFILES

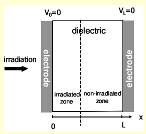
EXPERIMENTAL CONDITIONS :

- LDPE sample of thickness 500 µm
- Electron beam energy: 200 keV
- Beam current density: 50 pA.cm^{-2}
- irradiation: 36 min
- relaxation: 1 day

Open-circuit configuration

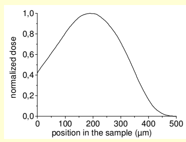


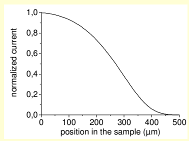
Short-circuit configuration



IRRADIATION DOSE AND CURRENT PROFILES :

Dose D(x) and current (J_0(x)) calculated with GEANT 4 software, used for the simulation of deposited electrons and electron/hole pairs generation dur to the electron beam

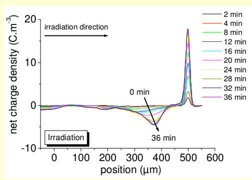




OPEN CIRCUIT CONFIGURATION

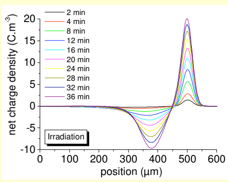
IRRADIATION

Experiment



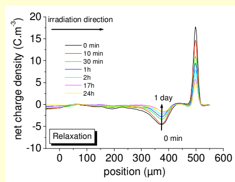
Simulation

Parameters given in the Table



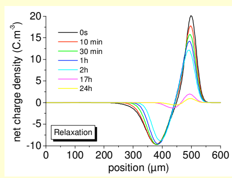
RELAXATION

Experiment



Simulation

Parameters given in the Table



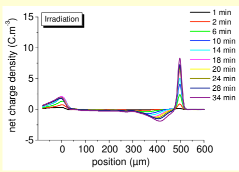
Simulated profiles consistent with experimental ones during irradiation

The dynamic of charges is too fast in the simulation compared with the experiment.

SHORT CIRCUIT CONFIGURATION

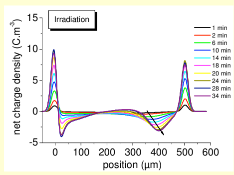
IRRADIATION

Experiment



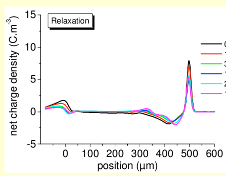
Simulation

Parameters given in the Table



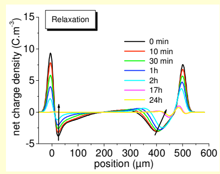
RELAXATION

Experiment



Simulation

Parameters given in the Table



Simulated profiles show the main negative peak at ~400 µm as in the experiments. It also shows a second negative peak next to the irradiation face.

Simulated profiles show a displacement of the negative peak at 400µm, and the relaxation of the majority of the charges after one day.

CONCLUSION

OPEN CIRCUIT Configuration: the model is able to reproduce the dynamic of charge during electron beam irradiation and during relaxation

SHORT CIRCUIT Configuration: Some experimental features are reproduced by the model (peak at ~400µm).

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