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Charging at the Steady State in EPMA, SEM and ESEM

J. Cazaux

DTI, CNRS UMR 6107,UFR Sciences, BP 1039, 51687 Reims Cedex 2, France.

Most of the specific effects observed in the e^--irradiated insulators result from charges trapped below the surface. At the very early beginning of this irradiation, $t\sim 0_+$, the charge distribution is very similar to that deduced from standard (non-charging) calculations but, via the rearrangement of electrons and holes generated by the beam, the system evolves towards a steady state rapidly attained under the standard conditions of EPMA, SEM and ESEM. To simplify, only homogeneous and thick (h~1mm) specimens widely illuminated by the beam are considered here.

In EPMA of ground coated specimens, δ is restricted to the conductive coating and a negative charge density, $Q_-(\ C/cm^2)\sim -J_0(1-\eta)t(0_+)$ (1), starts to be established via electrons trapped in the bulk down the range of the primaries, R(Fig.1a). The induced electric field and potential functions, F_Z and V(z), may be evaluated from models of negative charge distribution by solving a one dimensional Poisson equation [1]. Independently from the chosen distribution, the field is always maximum at the coating/dielectric interface where de-trapping processes start when a critical field value, F_C is reached while the de-trapped electrons are evacuated to the ground via the coating. The increase of the electric slowing down reduces the penetration depth of the primaries from R to R_C (subscript C for charging). Shown in fig.1, the steady state is characterized by a depleted region, ($0<z<R_C$), submitted to a uniform critical field F_C due remaining charges trapped between R_C and R in a low field region: $|Q(\infty)|$ (~ εF_C with ε :dielectric constant). The value of F_C depends upon the energy of the trapping sites. Similarly to R, R_C may be expressed in a form of a power law where E_0^n is changed into $(E_0-qF_CR_C)^n$ (2). The main consequence is a compression of the $\phi(\rho z)$ function similar to that previously obtained [1;2] but with a less field strength (see [3] for details).

For bare insulators investigated in SEM at large E_0 values, there is now a double layer system, +&-, at the early beginning of the irradiation: $Q_-\sim -J_0(1-\eta)t(0_+)$ of thickness R and $Q_+\sim J_0\delta\ t(0_+)$ (3) of thickness s as a result of the SEE emission δ (Fig 2 left). The electric field is maximum near to z~s (between + and - charges) where recombination processes take place while the surface potential becomes more and more negative inducing a progressive external slowing down of the primaries. The steady state corresponds to $\delta_C + \eta_C = 1$; it is mainly characterized by a landing energy $E(R_C\sim s)$ ($\sim E_{max}$) in the 1-3 keV range[4]. $E(R_C\sim s)$ is independent from E_0 but it may change from place to place with the local change of s or of δ. The surface potential $V(0)=V_S$ is of the form:$-qV_S=E_0-E(R_C\sim s)$ and it results from some remaining electrons trapped between s and R in a low field region.

The initial situation of ESEM is similar to that of SEM but the deposition of ions+ leads rapidly to a 3-layer system with a 2^d positive (and very thin) layer on the vacuum side of the surface, Q(ion+). The steady state nearly corresponds to the neutrality, $|Q_-| \sim Q_+ + Q(ion+)$, when is neglected the contribution of the space charge in the gap. The potential function, V(z), takes an approximate S-shape form similar to that expected in SEM at an energy E_0 close to E_{02} [4] . Its surface value, V(0), is a function of the density of negative charges trapped below the surface: more electrons are trapped in the bulk and larger is the V(0) value, reducing then δ in consequence (Fig.2 right). This analysis is consistent with Griffin's images where the electron trapping sites appear darker [5].

References

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Fig. 1 :EPMA

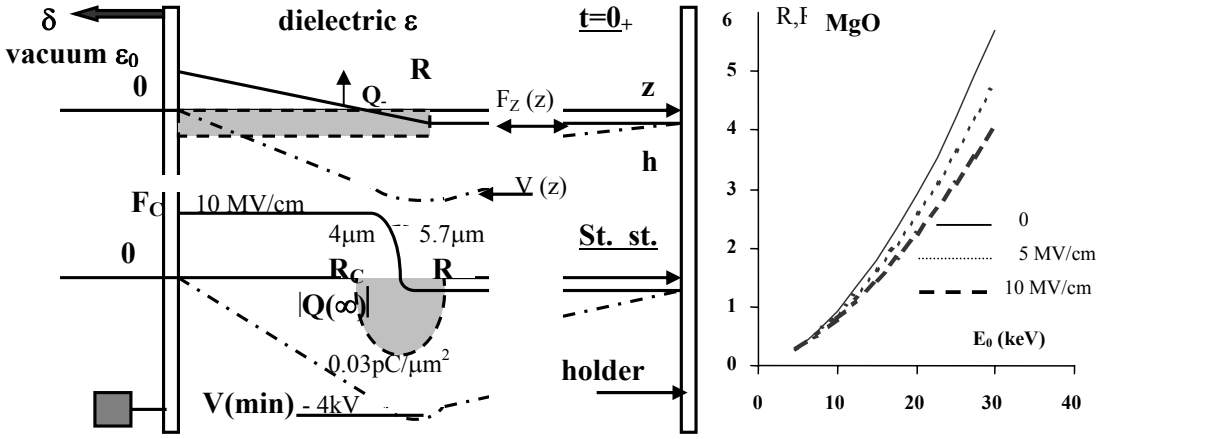

Fig. 2 :SEM **Fig. 2 :ESEM**

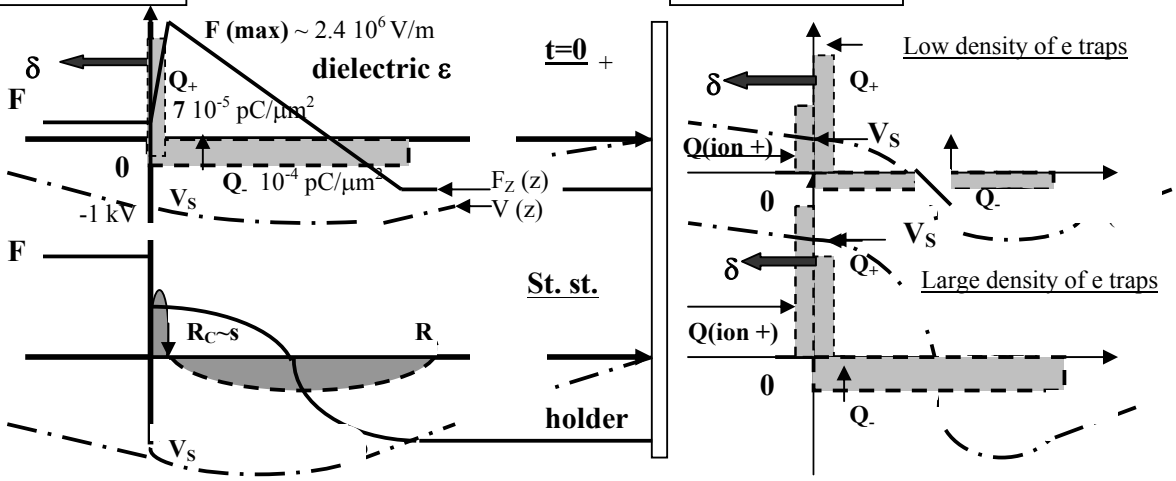

FIG.1. EPMA: V(z) and F_Z (z) functions at the early beginning of the irradiation; $t=0_+$ (top left) and at the steady state (bottom left). For MgO (as an example) with n=5/3 in eq.(2), influence of the field build up on the range R_C of the primaries (right).

FIG. 2.Left, SEM: V(z) and F_Z (z) functions at $t=0_+$ (top) and at the state state (bottom).Like for fig.1, note the very low charge densities, Q (that may be deduced from eqs (1)&(3)) giving very large electric field strengths, F, and potential values, V. Right, ESEM: Expected influence of the density (top: low; bottom: large) of trapped electrons on the surface potential value, V_S and on δ.

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