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Influence of the focusing conditions on charging in EPMA and SEM.

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There is a common opinion following which the effective landing energy of e^- irradiating an insulator corresponds, at the steady state, to the critical energy E_2 (where $\sigma°=\delta°+\eta°=1$) when the nominal beam energy, E_0 ,corresponds to an initial total yield $\delta° + \eta°$ less than the unity[1]. This opinion is revisited here for various arrangements and for various focusing conditions.

When a floating conductive film, thickness t, is set on the insulating specimen, most of the SEs are issued from the film while some primary electrons, PEs, are trapped below the coating when their range, R, is R>t>s (s:escape depth of the SEs). Under these conditions, the potential of the coating, V_c, is negative and it progressively decelerates the incoming PEs until they remain confined in the coating. Per time interval, τ, the increase of V_c obeys to $\Delta Q=I_0(1-\sigma)\tau=\varepsilon A\ \Delta V_c/c$. (c: thickness of the insulator; A; area of the coating). Fig. 1a illustrates this evolution where the attained steady state is effectively given by $qV_c=E_2-E_0$ (E_2 being that of the coating material). This behavior results from the fact that electrons, e^-, and holes, h, of the generated pairs recombine easily because they are free in conductors. This analysis also applies for highly carbon contaminated surfaces.

The situation is very different for widely irradiated insulators because e^- & h. are initially trapped over different thickness ranges:s~20-50 nm for h (>0) and R~5 μm for e^- (<0), leading to pseudo-dipolar distributions. The steady state is attained when the newly generated e & h particles may recombine each others i.e when they are separated by distances less than the sum of their mean free paths, s and s_h. The steady situation nearly corresponds to $R=s+s_h\sim 2s$ and it is different from E_2 and the value of the effective beam energy is slightly above E(max) -see Fig 1b and ref.[2] for details-.

For focused fine probe on bare insulators irradiated at E_0 >20 keV, there is now a triple charge distribution at the early beginning of the irradiation (see insert Fig.2). A nearly spherical negative distribution related to electrons implanted into a sphere of diameter ~R and of initial charge $Q_-\sim -I_0(1-\eta)\tau$ .Two positively charged discs of thickness s: one of diameter ~d_0 (probe size), of charge $Q_{1+}\sim I_0\delta_P\tau$ resulting from the emission of the SE_1 and another of diameter ~R of initial charge $Q_{2+}\sim I_0\delta_B\tau$ resulting from the emission of the SE_2. Such a naïve model has been successfully used in the past in SEM [3] and others[4;5]. Here, the key result is a positive surface potential on and around the incident spot (over several beam sizes) surrounded by a large negative halo even when the total algebraic trapped charge is negative, $\delta°+\eta° <1$. This result holds as far as the emission of the SE_1 is more localized than the implantation zone of the PEs, and a maximum potential value, V(0,0), decreases like $1/d_0$ when d_0 increases. A direct consequence of the >0 (next <0) regions is the associated splitting into two parts of the spectral distribution of the SEs (and of the Auger e^-) with a partial freezing of the SE_1 emission and the acceleration of the SE_2 (see Fig.2). Important in EBL, it is also the re-attraction of the laterally emitted SE_2 by the central (>0) region leading to partial charge compensations.

The present model accounts for various published experiments showing ring shape features. The time evolution as well as some consequences in digital scanning (influence of the implanted charge Q, in one pixel on the next beam position) will be easily considered (work in progress).

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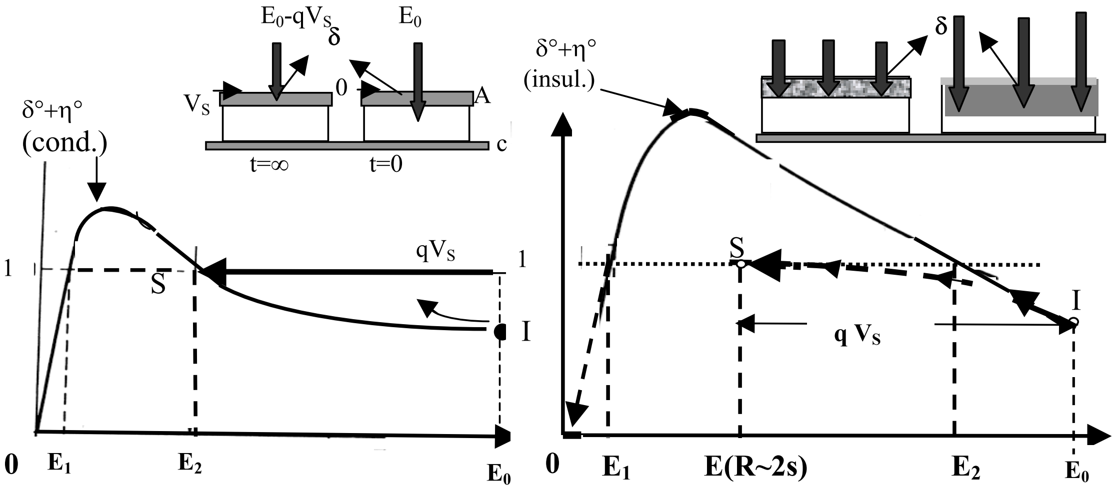

FIG.1. Comparison between the time evolution of the total yield in a floating conducting film on an insulator (left) and a widely irradiated insulating sample (right).

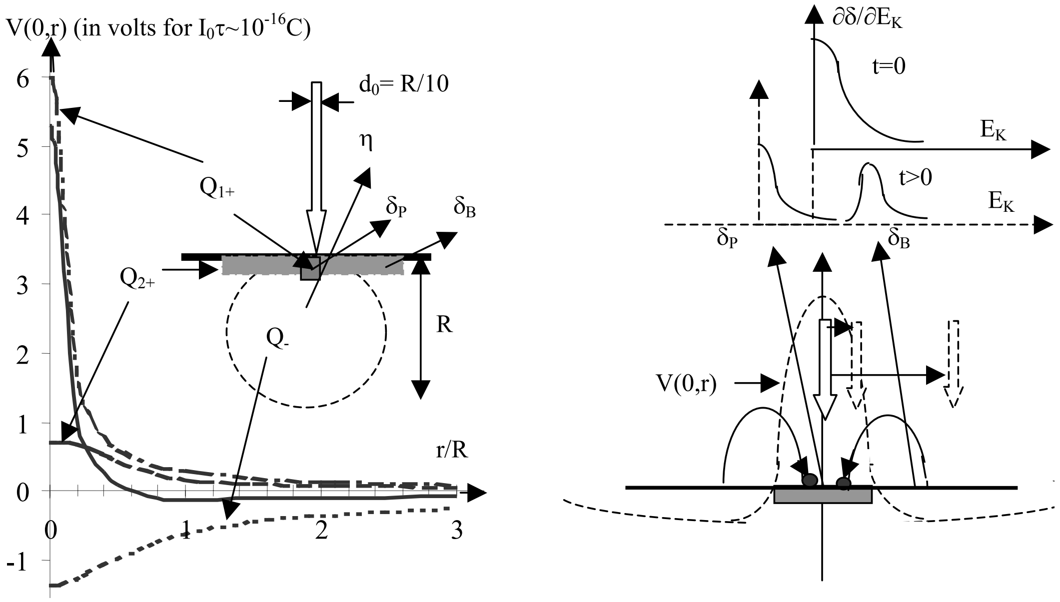

FIG.2. Left. The 3 contributions to the surface potential function, V(0,r), of a focused probe with :d_0~R/10~0.5µm; $I_0\tau \sim 10^{-16}$C.; δ_P~0.375; δ_B~0.225 ; η ~0.15 (then $\delta+\eta=0.85<1$). Right: Some consequences of a central region positively charged surrounded by a negative halo