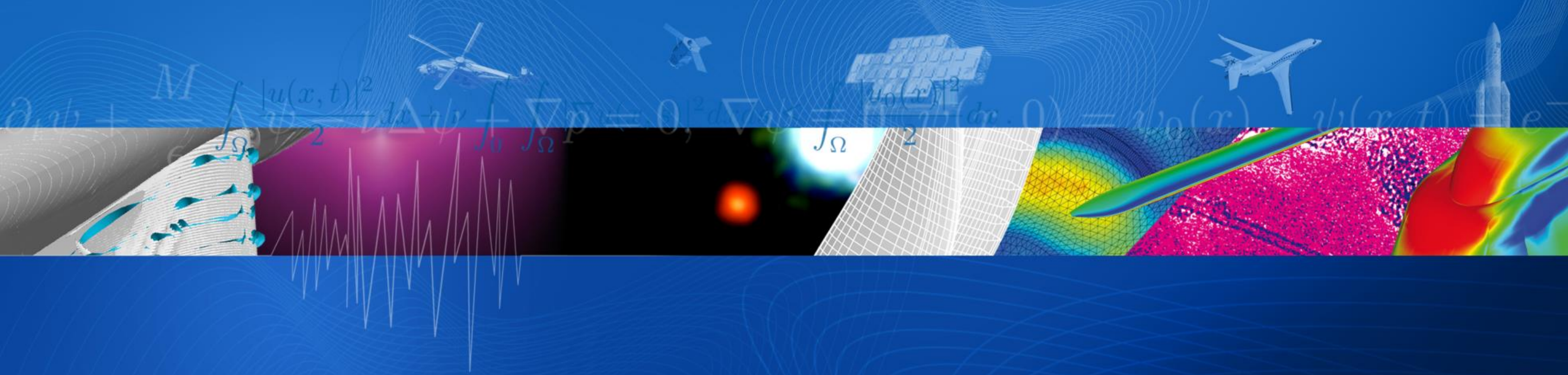

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SEY properties of dielectric materials, modeling and measurements

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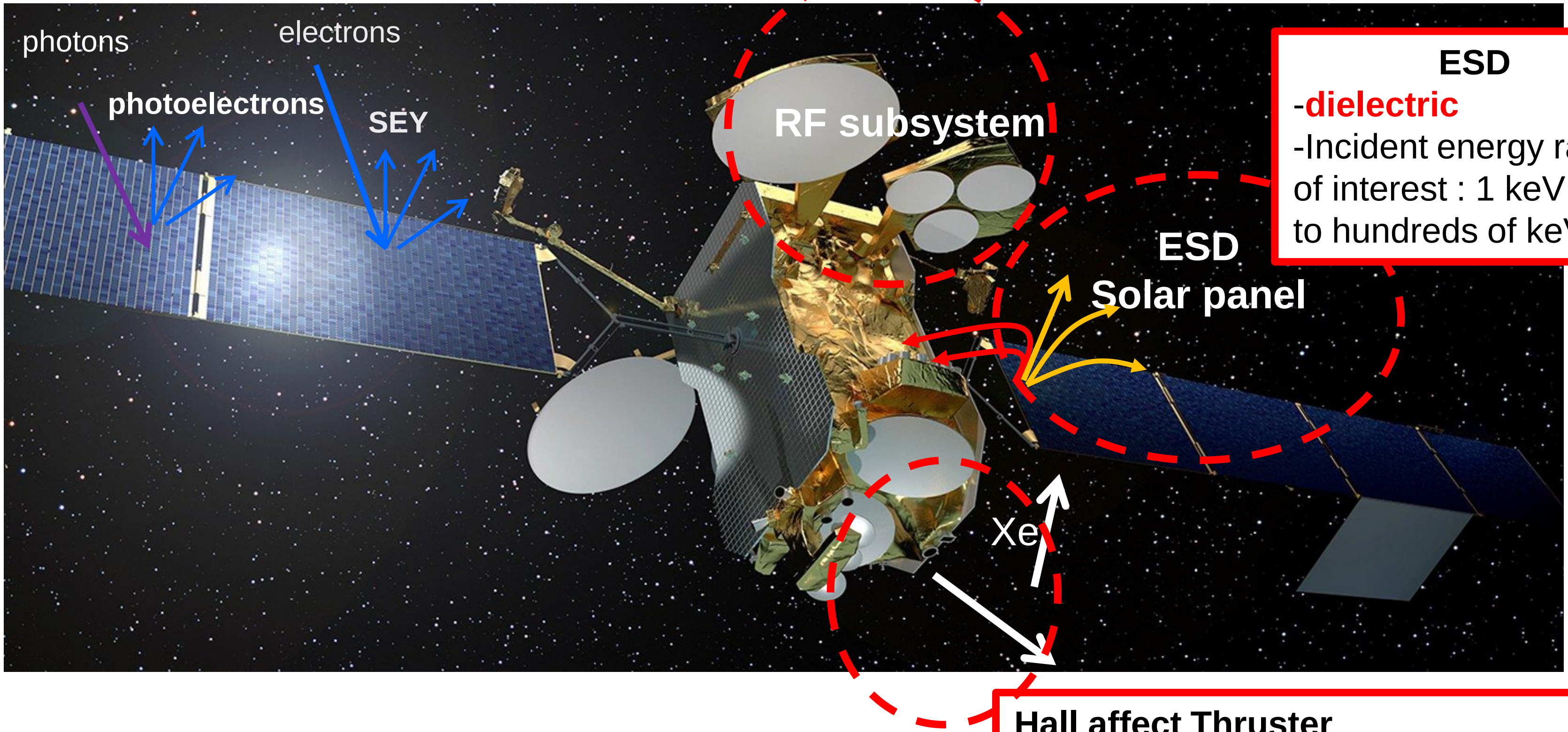
ECLOUD'18 (03-07 June 2018, Elba)

Motivation (@ONERA)

Multipactor in RF components

-metals and **dielectric**

-Incident energy range of interest : 0 eV to 400 eV



ESD

-**dielectric**

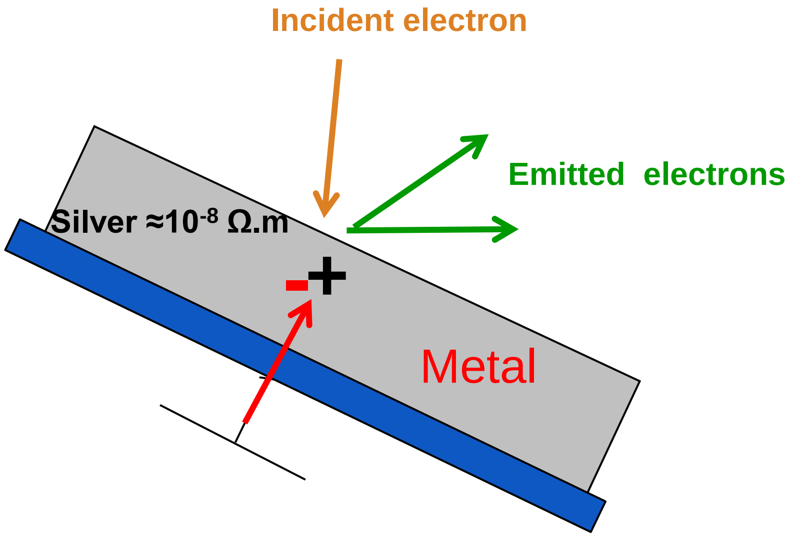
-Incident energy range of interest : 1 keV eV to hundreds of keV

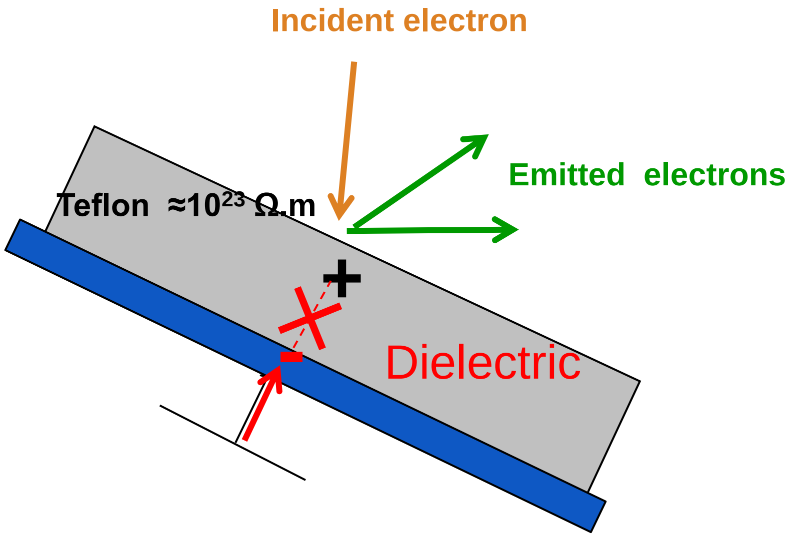
Hall affect Thruster

-dielectrics (ceramics)

-Incident energy range of interest : 0 eV to 100 eV

SEY of dielectrics





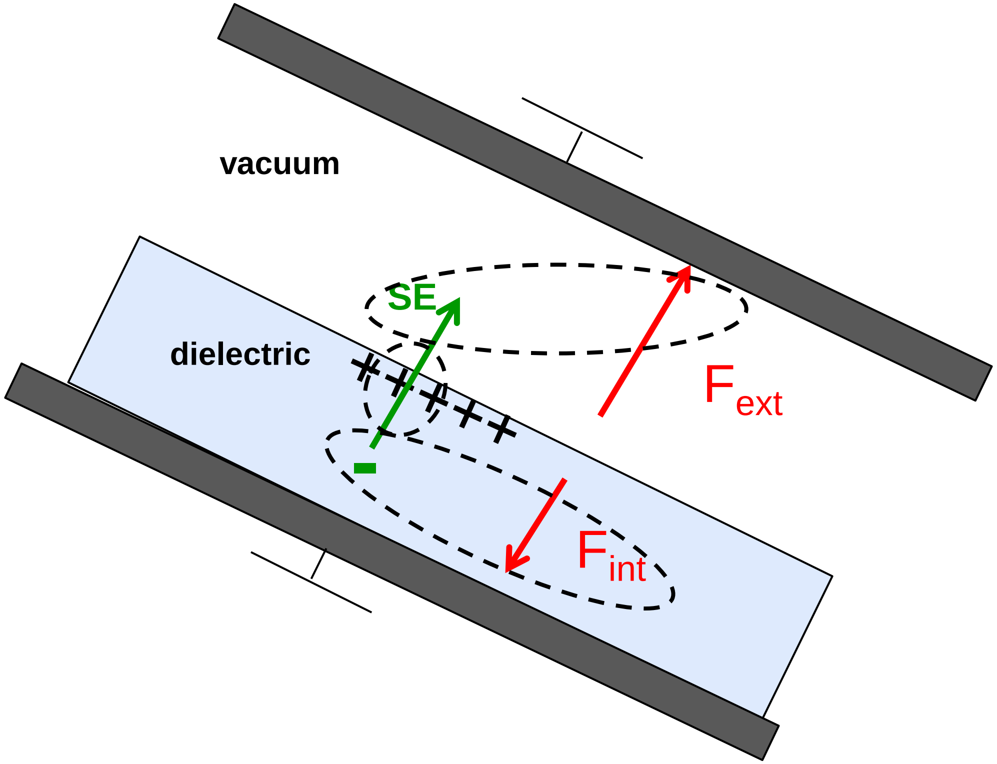
Metals : SEY affected by

- Chemical properties of the surface
- Morphological proprieties (roughness)
- …

Dielectric : SEY affected by

- Chemical properties of the surface
- Morphological proprieties (roughness)
- …
- **And charging effect !**

SEY of dielectrics



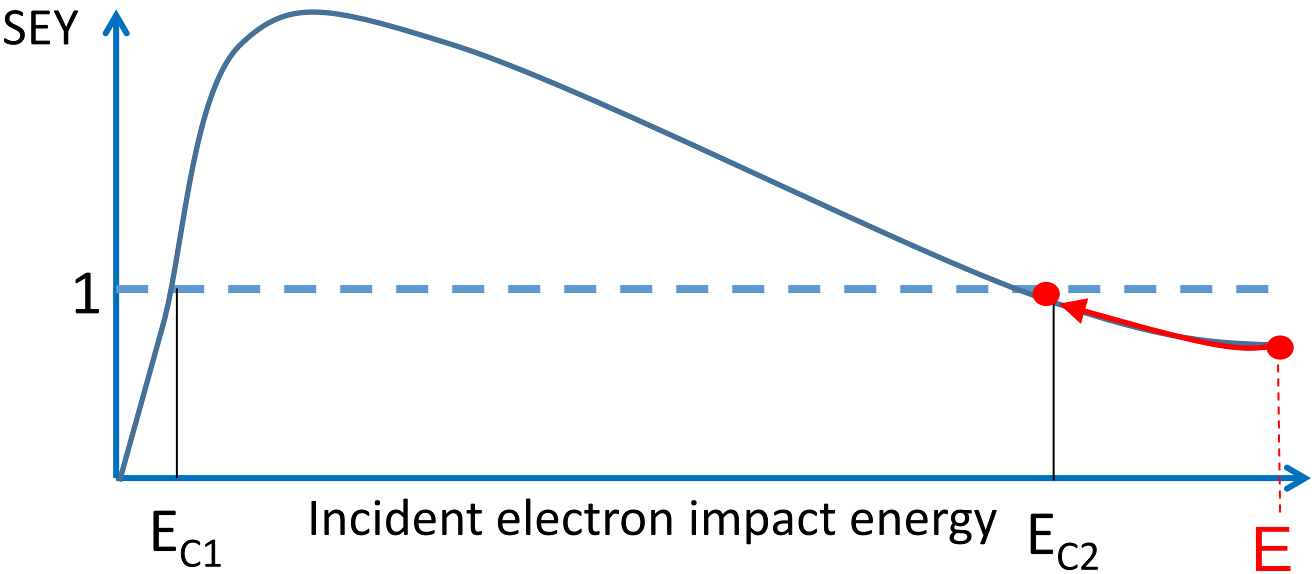
- Charge accumulation:

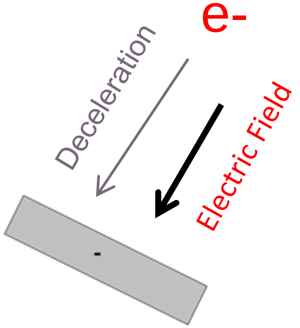
→ Electric field into the vacuum: external effects of charging
→ Electric field inside the dielectric: internal effects of charging

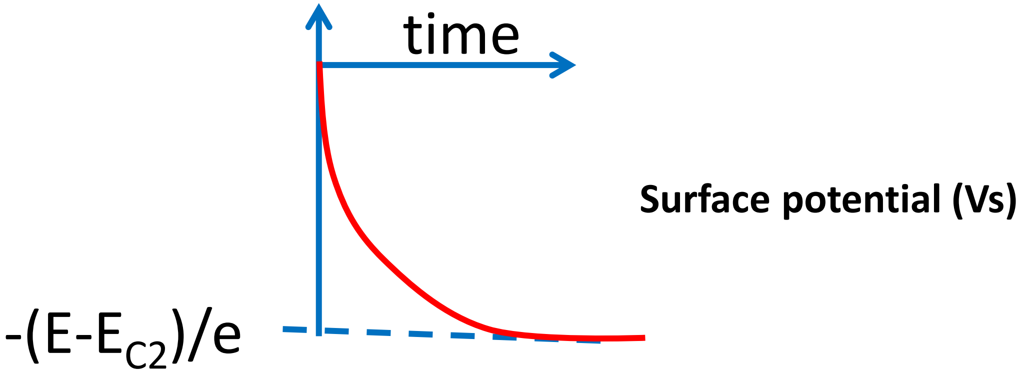
External effects of charging on SEY

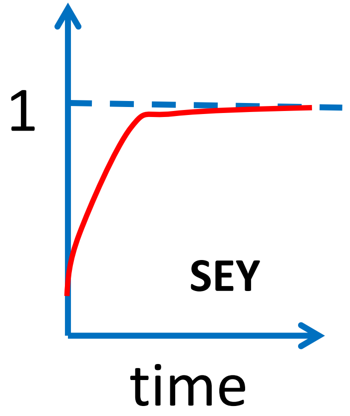
External effects of charging on SEY (1/3)

$E > E_{C2}$; TEEY < 1



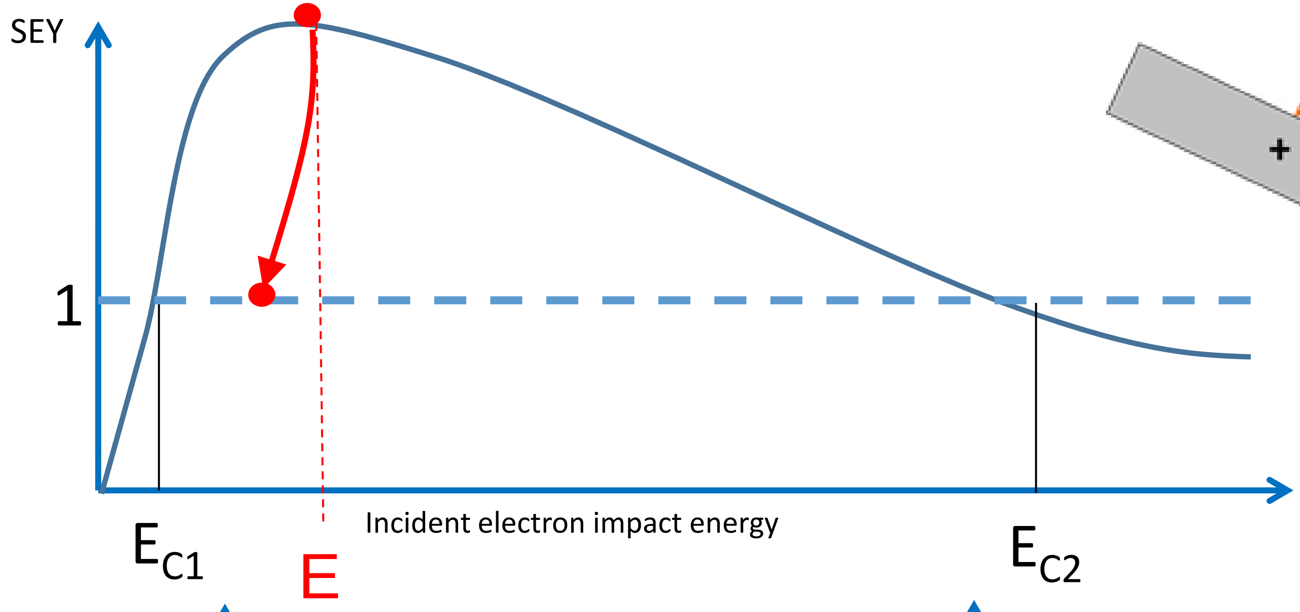


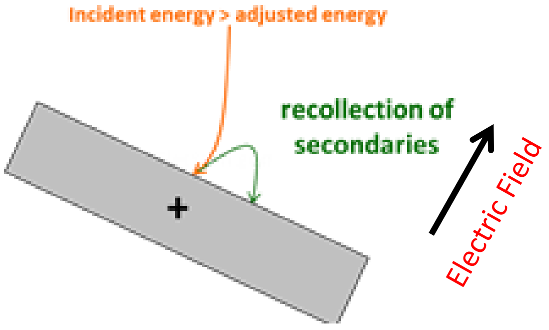


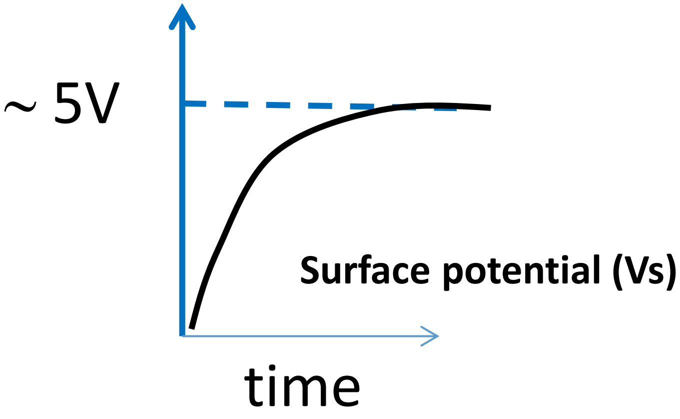


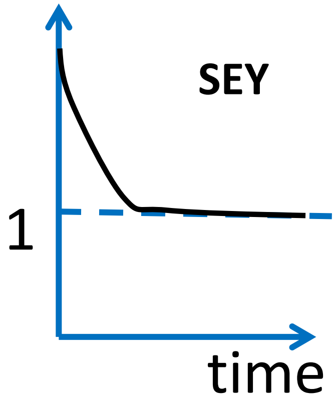
External effects of charging on SEY (2/3)

$E_{C1} < E < E_{C2}$; SEY > 1



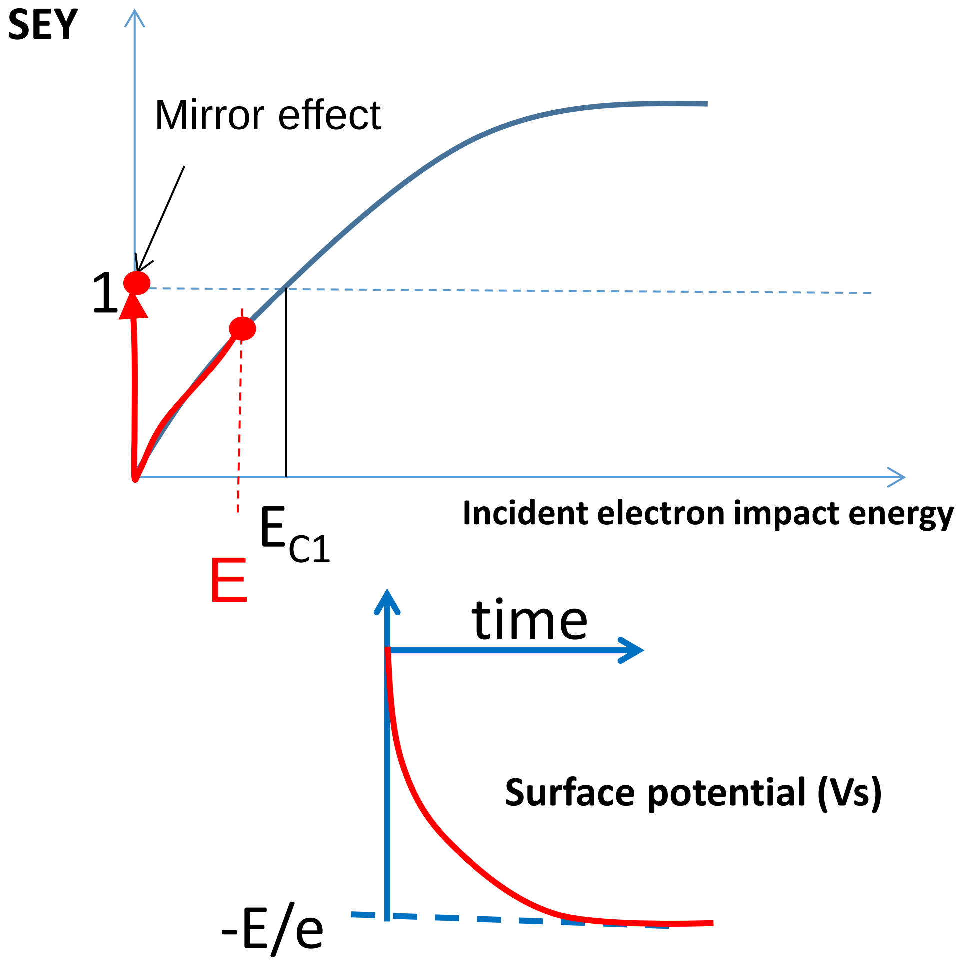


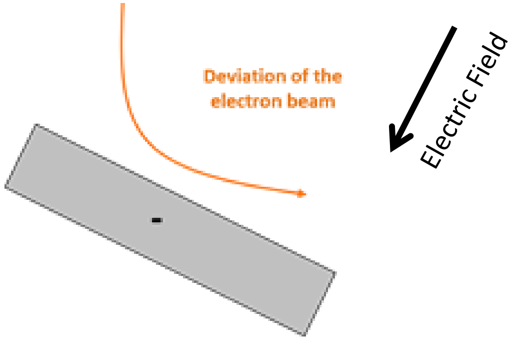


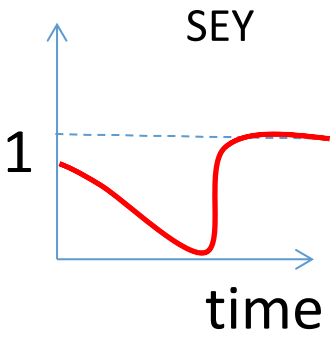


External effects of charging on SEY (3/3)

$E < E_{C1}$; TEEY < 1

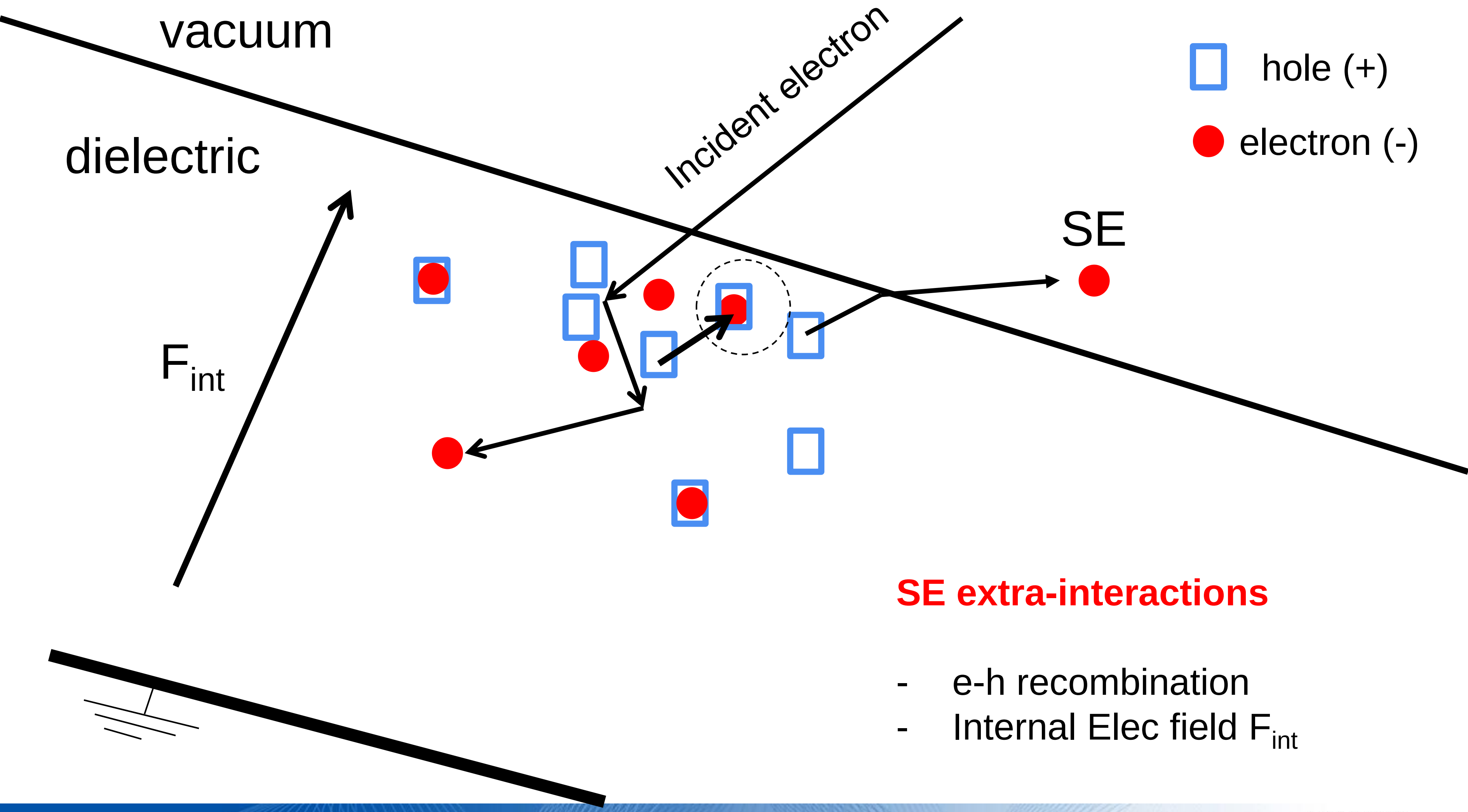






Internal effects of charging on SEY

Internal effects of charging on SEY (1/4)



SE extra-interactions

- e-h recombination
- Internal Elec field F_{int}

Internal effects of charging on SEY (2/4)

SEY Dionne* conventional model for metals

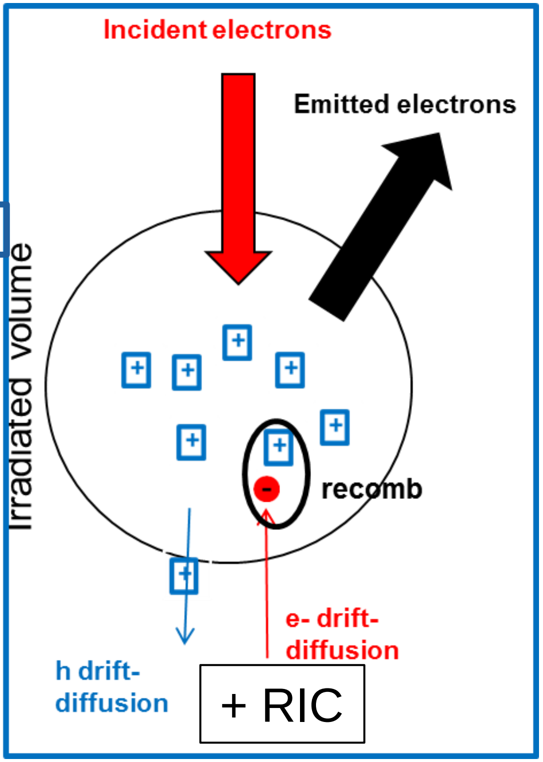
ξ:e-h excitation energy
λ_0: mean electron escape depth
R: mean electron penetration range

$$\delta = \underbrace{(\frac{B}{\xi})}_{\text{Escape}}\underbrace{(Ap\lambda_0)^{\frac{1}{p}}(\frac{R}{\lambda_0})^{\frac{1}{p}-1}}_{\text{Generation}}\underbrace{(1-e^{-\frac{R}{\boxed{\lambda_0}}})}_{\text{Transport}}$$

= cst

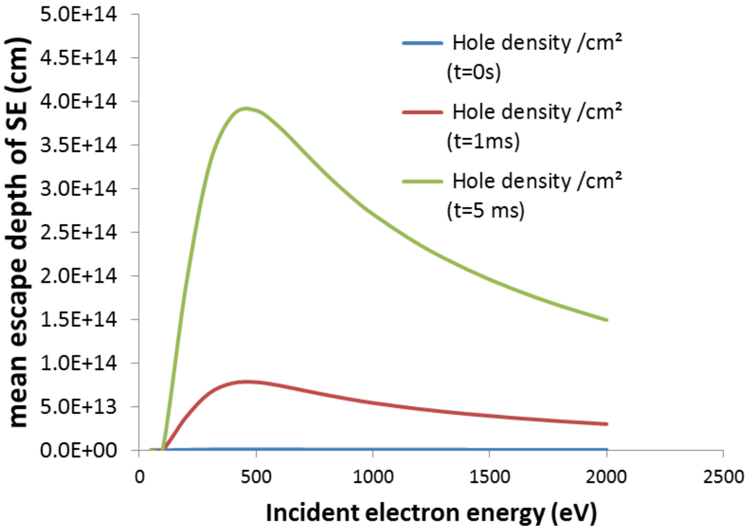
SEY Dionne* adapted model for dielectrics

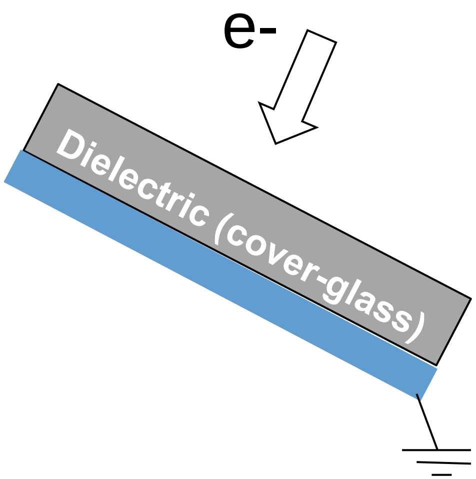
$$\delta = (\frac{B}{\xi})(Ap\lambda_0)^{\frac{1}{p}}(\frac{R}{\lambda_0})^{\frac{1}{p}-1}\underbrace{(1-e^{-\frac{R}{\lambda(\text{charge,carrier emobility})}})}_{\text{Transport}}$$

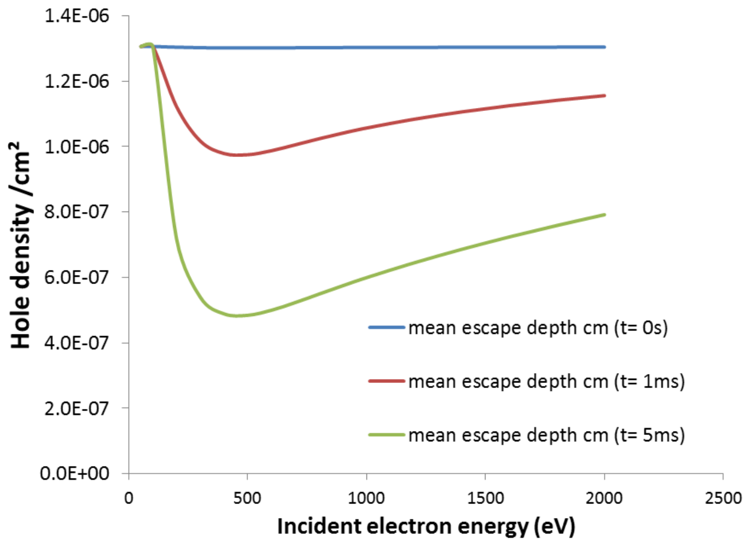


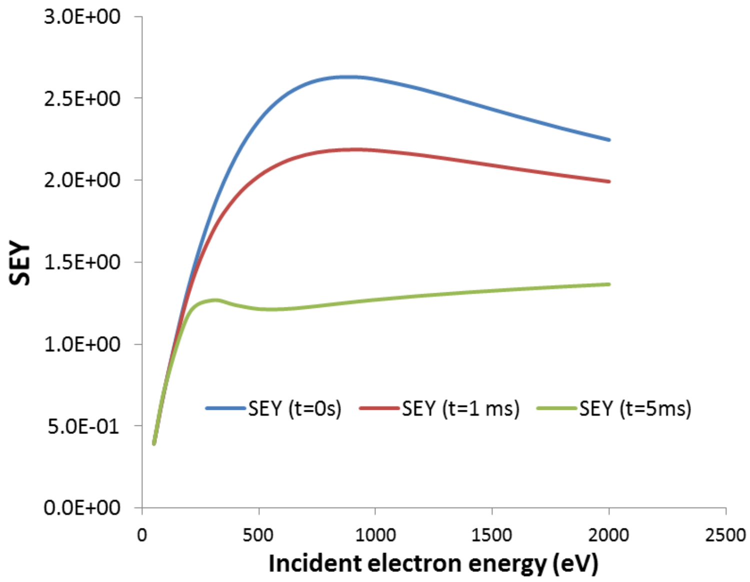
* G. F. Dionne Origin of secondary electron emission yield curve parameters J. Appl. Phys. (1975) 46, 3347

Internal effects of charging on SEY (3/4)



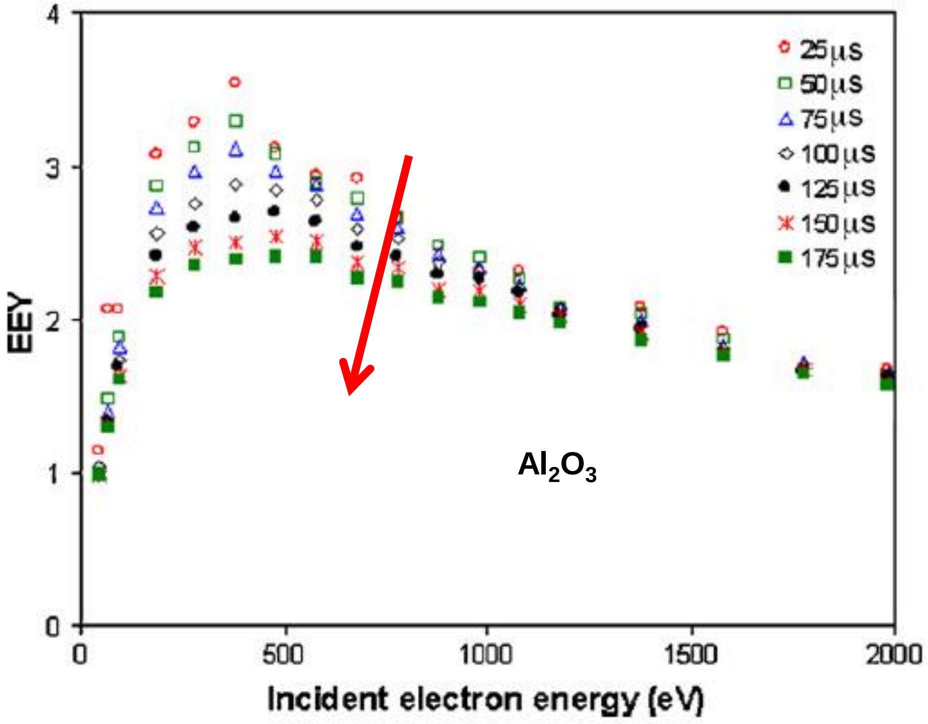






Internal effects of charging on SEY (4/4)

Experimental illustration: effect of the incident electron pulse duration on the SEY of Al_2O_3



Consequences on the measurement strategy

Consequences on the measurement strategy (1/3)

- Minimize the incident electron dose → use a short electron pulses and low incident current density

- Define a protocol to discharge the sample during the SEY measurement or before (initial charge) → use a flood gun with appropriate incident energy, UV photons source,… to compensate the trapped charge (positive or negative)

- … many other strategies are listed in the following papers:

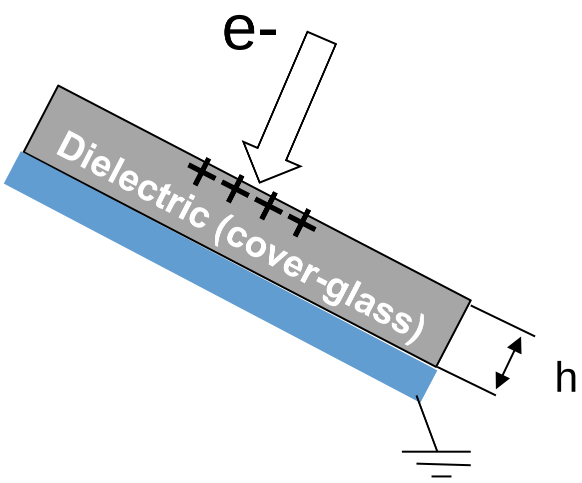
J. Cazaux, About the charge compensation of insulating samples in XPS, in Journal of Electron Spectroscopy and Related Phenomena 113(1):15-33 · December 2000
S.Hofmann, Charging and charge compensation in AES analysis of insulators, in Journal of Electron Spectroscopy and Related Phenomena 59(1):15-32 · June 1992

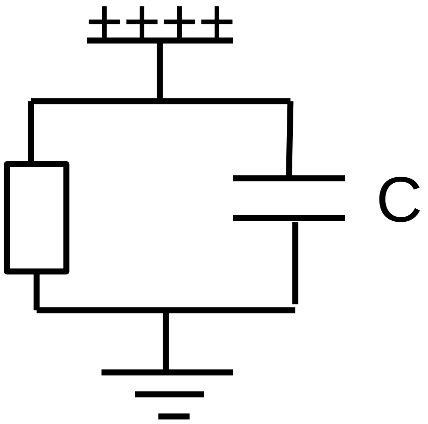
! All these method should be controlled by a in situ charging diagnostic technic (Kelvin Probe, monitoring the shift of the SE pic, displacement current on the sample holder, etc…)

Consequences on the measurement strategy (2/3)

- The SEY (at < 1keV) concerned only by the first tens of nm material depth

Alternative strategy: reduce the dielectric thickness → reduce the induced surface potential → reduce the external electric field





Capacitance $\propto$ 1/h ; h ↓ → surface potential ↓

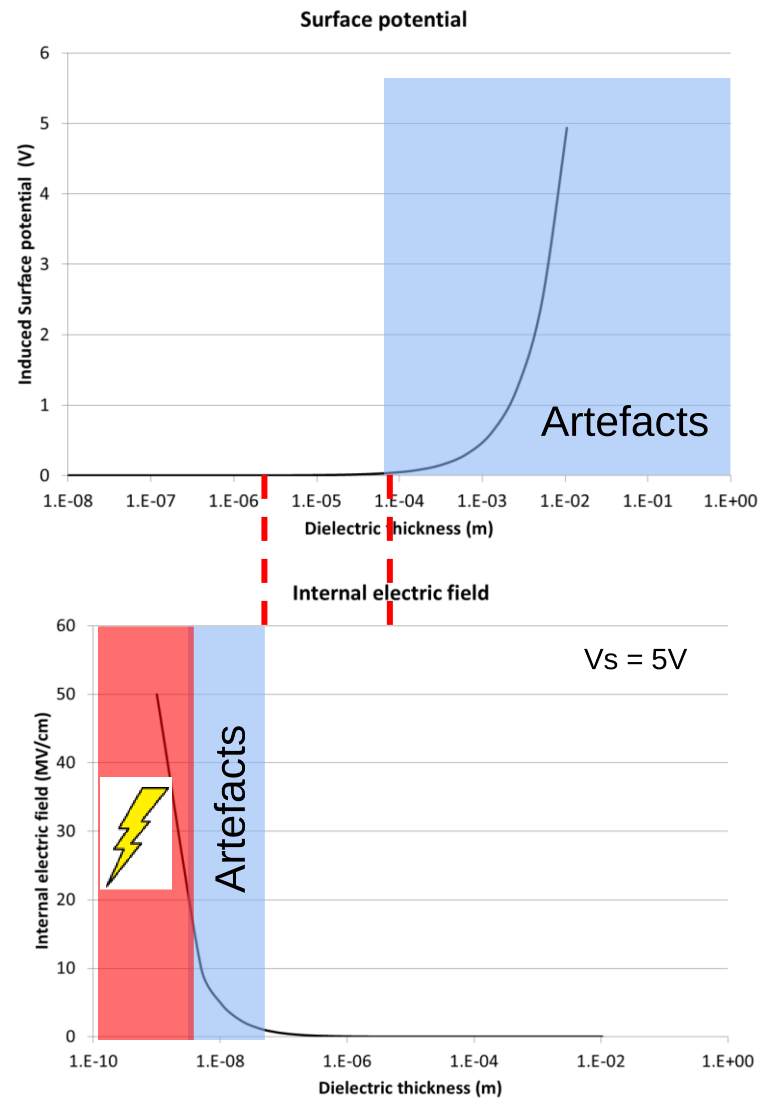
Consequences on the measurement strategy (3/3)

Exemple: SiO_2
After: **1** e-pulse (10 nA/mm², 10 µs)

SEY measurement on dielectric : trade off between:

- S/N (e-pluse)
- Available time to spend
- Needed accuracy

The used strategy should be defined according to the sample characteristics (conductivity, thickness, incident energy range, available discharging technics,…)



Practical impact on the RF multipactor modeling

Practical impact on the RF multipactor modeling (1/1)

The described charge dependence above (internal and external) was implanted of SEY on multipactor model and applied RF component including dielectric (Teflon)*

Simulated structure*

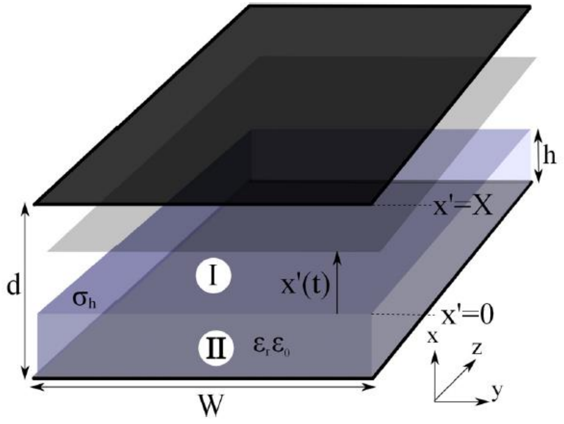


FIG. 1. Sketch of the parallel-plate waveguide with a dielectric slab.

The analysis of the results obtained shows that:

- The multipactor power threshold increases with the charge deposited within the dielectric (- or +).
- The specific SEY properties and dynamics of dielectrics must be considered in order to accurately model the multipactor dynamics of realistic RF devices

* E. Sorrola, M. Belhaj, J. sombrin and J. Puech, New multipactor dynamics in presence of dielectrics, in PHYSICS OF PLASMAS 24, 103508 (2017)

Conclusion (1/2)

- Electrical charge can be accumulated when dielectric is submitted to e- irradiation

- The charge can be negative or positive according to the incident electron energy (SEY < 1 or SEY>1).

- The charge affects externally (vacuum) and internally (inside the material) the electron emission that in turn affects the charging rate.

- The dynamic competition between charging and electron emission results for “bulk materials” on all the cases to a steady state situation where the SEY =1.

- The dynamic of the SEY of dielectrics should be included in models when dielectric are exposed to e- radiation.

Conclusion (2/2)

Dielectric is may be not the worst case materials regarding multipactor and e-cloud even if their initial SEY is many cases higher then that of metals

However others charging problems should be considered specially at dielectric/vacuum/metal triple junction (electric surface flashover, breakdown, …)