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Ground testing of spacecraft/plasma interaction effects

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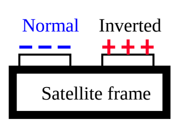
Introduction - Outline

- ground testing
  - preparation to flight
  - shall be as representative as possible of flight configuration
- review of what we do in the field of plasma-s/c interaction to feed the reflexion on flight exp
- needs :
  - environmental data
  - validation of ground experiments and models
- fields :
  - Charging
  - ESD/arcing
  - interaction with plasma propulsion

Charging/material properties

- Conductivity is the key property governing the charge
  - surface conductivity, volume conductivity + RIC
- Secondary emission and photo emission are also key properties for the charge (they are moderating factors for negative charging), and they are major key properties for governing the discharge in the Inverted Gradient Voltage Discharge mode.

- Inverted gradient discharge mode: When the dielectric outer electrode is charged positively with respect to the rear metallized electrode (the satellite local ground)
- Normal gradient voltage: When the dielectric outer surface is charged negatively with respect to the rear metallized electrode



Test methods, Test houses

- Methods
  - Conductivity : measured according to the surface potential decay method.
  - Secondary emission: measured according to the pulsed electron technique.
- Facilities
  - For conductivity : SIRENE in France (Toulouse, ONERA-DESP), REEF in England (Farnborough,QinetiQ)
  - Secondary emission: in France (Toulouse, ONERA-DESP), in Spain (Madrid, ICMM)

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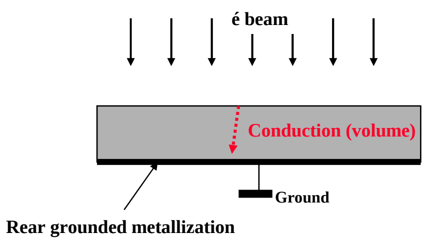
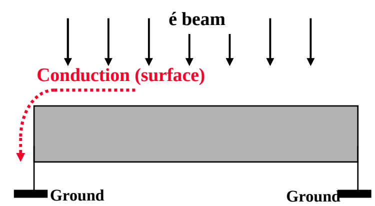
Volume & Surface Conductivity





Conduction through the thickness.

When the sample dimensions are much larger than the thickness, rear side grounded, the potential is uniform along the sample. The potential depends only on the thickness as far as it is taken far from the edge.

Conduction along the surface.

When there is no rear grounded metallization, the potential is dependent on the sample dimensions. It is maximum at the "center" of the sample, where the distance to the edge is maximum. .

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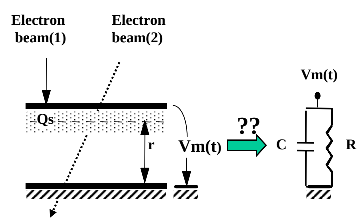
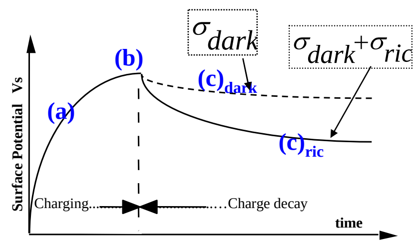
Electron beam charging : 3 methods

a) Under beam not steady state; b) Under beam steady state;
c) Not under beam (charge decay)

•Natural decay (dark conductivity)

•Stimulated decay (Radiation induced conductivity)





$$\sigma = \varepsilon_o \varepsilon \frac{dV_s/dt}{V_s} \Rightarrow \sigma_m = \sigma_{dark} + \sigma_{ric} = \sigma(E, \frac{dD}{dt})$$

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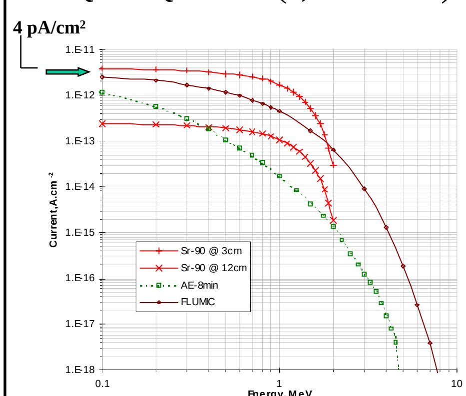
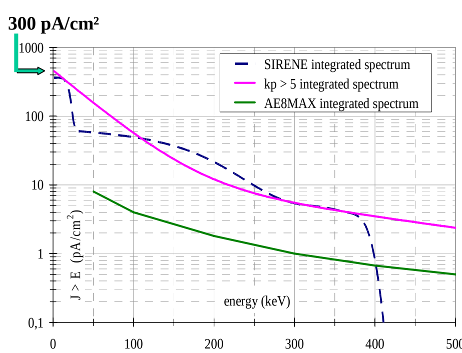
Test methods, European test houses

- QinetiQ: REEF (a,b methods)
- ONERA: SIRENE (b,c methods)





internal charging

surface (external) charging

thick samples

thin external coatings

long irradiations

both : material

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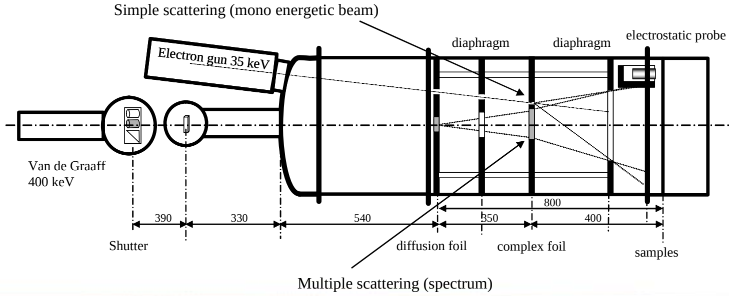
Deep dielectrics charging
SIRENE facility



SIRENE – GEO reference spectrum

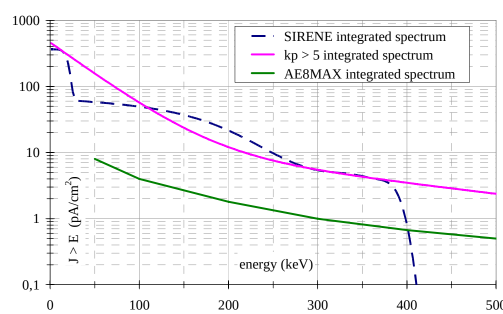
- Spectre de référence GEO : Kp>5
- Kp>5 (index caractérisant l'activité géomagnétique) bien modélisée par la double Maxwellienne

$$J(>E) = A\,e^{-\frac{E}{E_a}} + C\,e^{-\frac{E}{E_c}}$$

A=9,52*10^7 E_a= 268,64 keV
C=2,8*10^9 E_c =44,16 keV

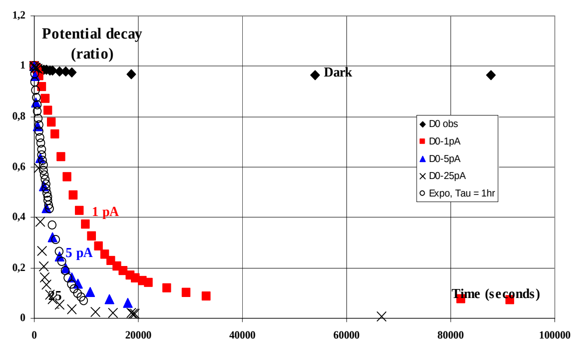
- le spectre AE8MAX n'est pas adapté pour l'étude des phénomènes de charge

- **SIRENE spectrum, standard flux :**
  E=20 keV, Φ=250 pA/cm² +
  E=0-400 keV, Φ=50 pA/cm²



SSM Téflon FEP 127 µm

Potential decay: [V(t)/V(0)] = f [t]; SSM Teflon 127 µm



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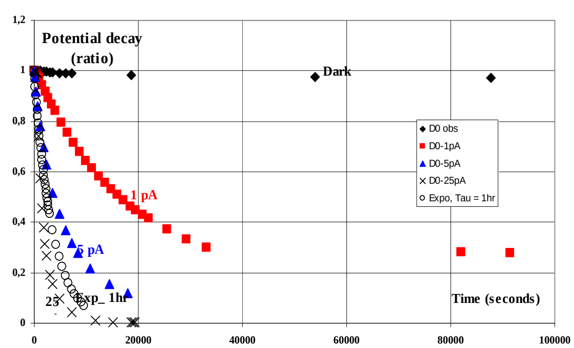
Kapton 25 µm

Potential decay: [V(t)/V(0)] = f [t]; Kapton 25 µm



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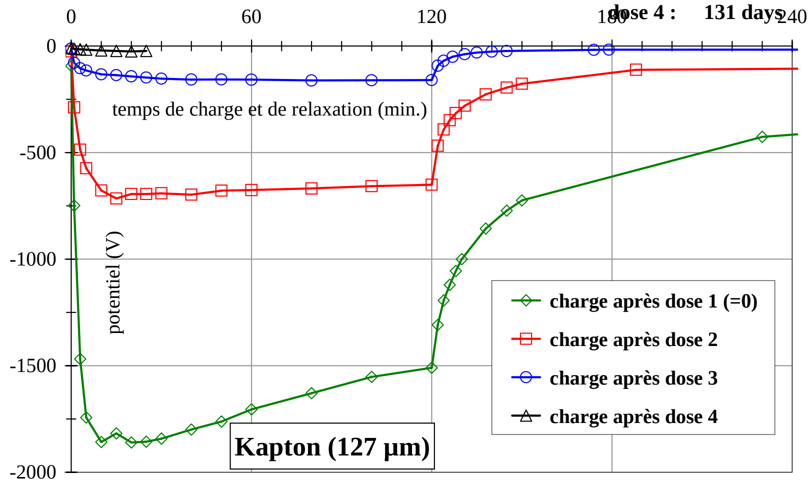
Ageing effect

dose : 400 keV, 2,5 nA/cm-2
charging : SIRENE spectrum
equivalent dose in GEO for kapton 127µm

dose 2 : 6 days
dose 3 : 31 days
dose 4 : 131 days



Increase of conductivity with dose

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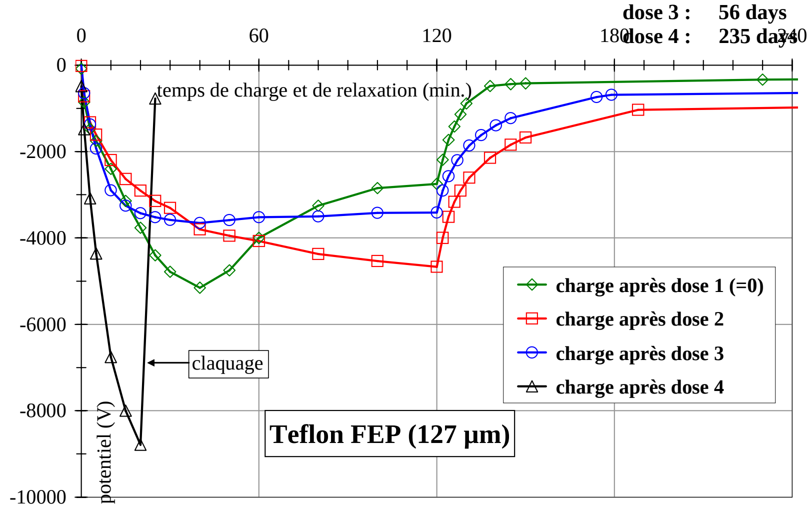
Ageing effect

dose : 400 keV, 2,5 nA/cm-2
charging : SIRENE spectrum
equivalent dose in GEO for teflon 127µm

dose 2 : 11 days
dose 3 : 56 days
dose 4 : 235 days



Competition between RIC and dose

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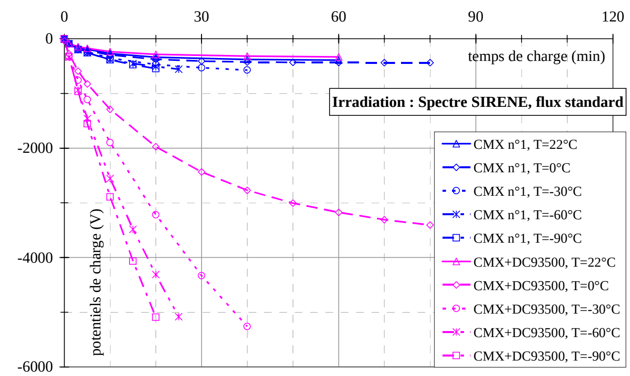
Effect of temperature

(glued or non glued) OSR Conductivity test
CMX samples – Potential time evolution vs. Temperature
<u>SIRENE multienergetic flux</u>



conclusions on charging studies - needs

Importance of different parameters on measured conductivity :

- RIC and Delayed RIC (ageing effect)
- temperature
- complex assemblies

- needs of flight data:
  - environmental data
  - potentials

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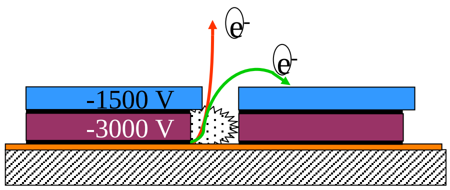
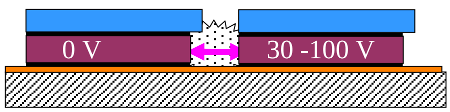
ESD/ARCING issues



- ESD: aborted arc
  - electron emission;
  - metallic vapor plasma;
  - microscopic damages;

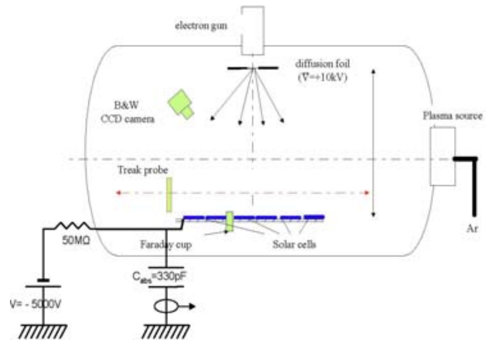


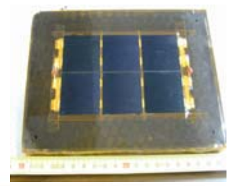
- Secondary arcs : vacuum arcs
  - ESD in the active gap
  - duration depends on conditions (arc current);
  - damages depend on duration: contacts, cells, Kapton..

ESD/Arcing issues

- ESD and transition to arcs on Solar arrays
- importance of flash-over on this transition to arc
- importance of ESD (including FO) on cells degradations
  - warning : importance of set-up to test this degradation
  - qualification of SA => ECSS 20.06 and ISO drafts for ESD testing of SA.
    - ISO draft : collaboration between Japan (KIT, JAXA), USA (NASA), France (ONERA, CNES)
- extension of the pb of arcing to other equipments such as S/R
  - study of arcing on S/R

Samples & the Jonas vacuum chamber at ONERA/DESP





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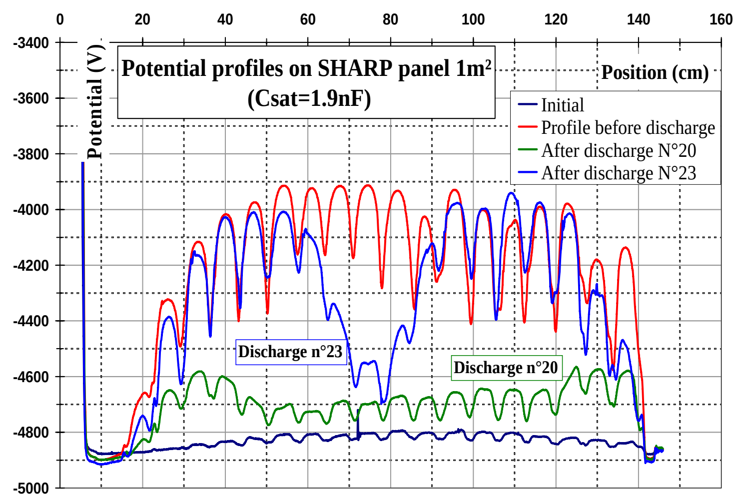
Typical potential profiles before and after different kinds of discharges



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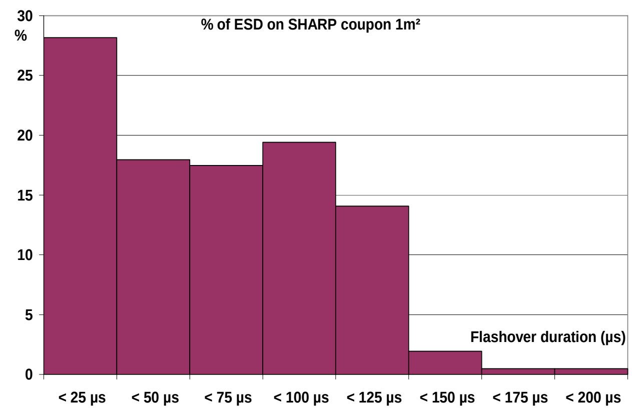
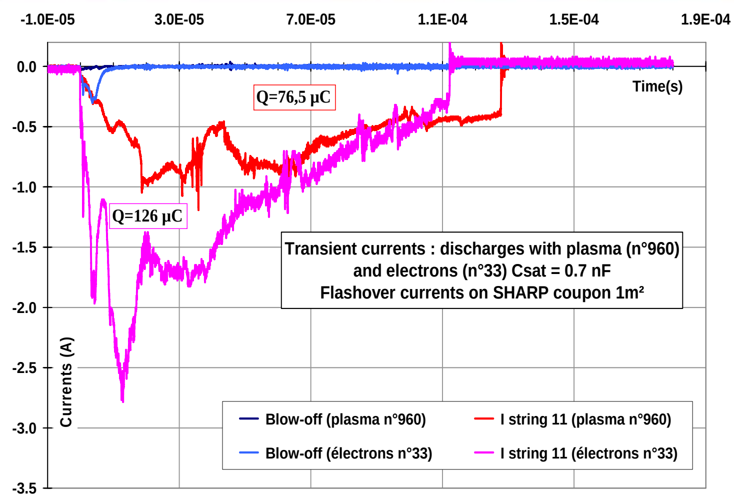
Distribution of ESDs as a function of their duration



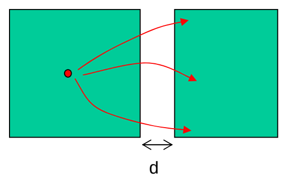
Comparison between transient currents (blow-off and flash-over) measured in IVG obtained either with plasma or with electrons.



importance of test configuration(plasma /electrons)

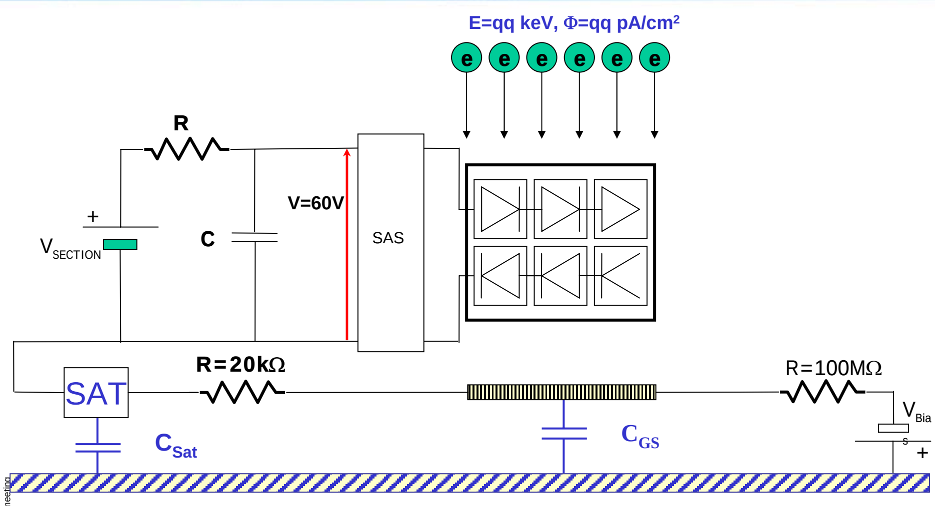
Flash over → Main results

- Maximum surface discharged : 1 m^2
- Maximal length discharged : 1.40 m (in Japan : 2.8 m)
- Flash over between 2 panels : gap distance *d* > 0.20 m



- Equivalent flash over velocity in plasma and electron : 10^4 m/s (consensus with USA and Japan on this velocity)

Electrical set-up for secondary arc studies



Dependence of sample size on secondary arc occurrence

Sample	SAS conditions (60V)			
	1 A	1.5A	1.75A	2A
0.01m²	20µs	200µs	1.6ms	permanent arcs
1m²	250µs	permanent ARCS	x	x
0.01m² + 200 nF	Coupling with ground	x	x	x
0.01m² + 50 nF	Coupling with ground	x	x	x

very high influence of test set up :

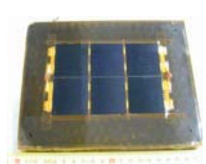
size of the test coupon, capacitances, harness length…

Influence of test setup

- Arc duration and solar cell degradation depend on the solar array simulation: external capacitance – small or large coupons

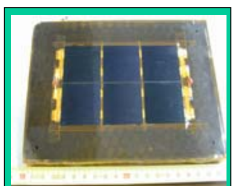
Long 2^{ary} arc duration

≠



Short 2^{ary} arc duration

≠!!

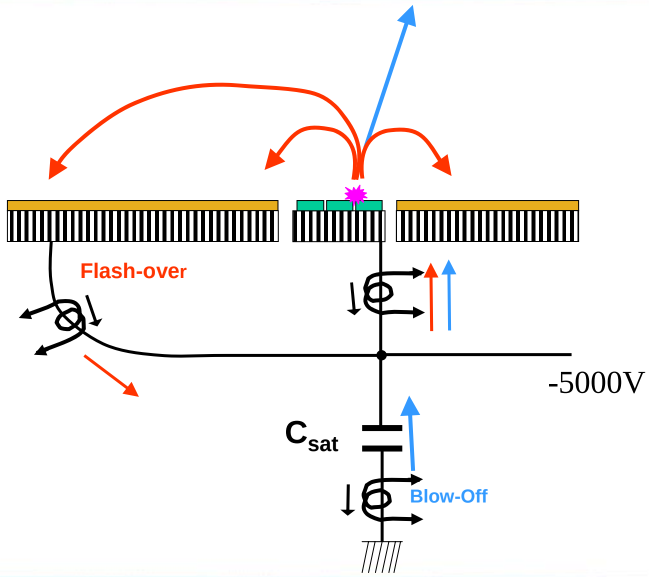


+ external capacitance "simulating coverglasses"

Same energy released
but in a shorter time
Not representative of FO
Risk of coupling with ground

Need of a realistic Flash over simulator

How to simulate the flash-over ? Which surface to simulate ??



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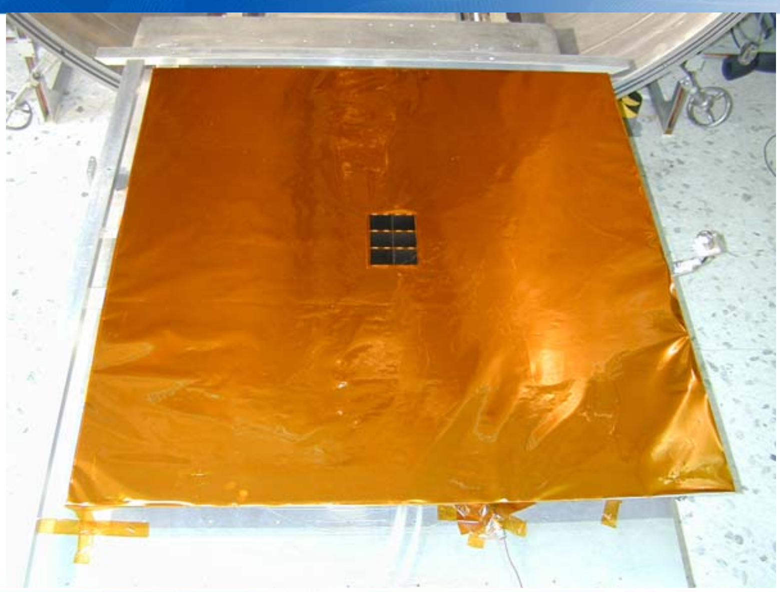
How to simulate the flash-over ?



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conclusions on charging/ESDs studies - needs

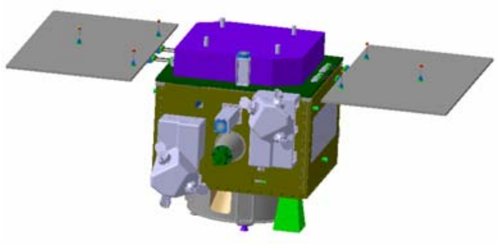
- representativity of test set up ???
- needs in flight data : mainly : validation of ground experiments
    - environment characteristics : density, energy
    - ESD frequency of ocurrence, potential which triggers an ESD
    - absolute potential, differential potentials
    - FO extension : instrumentation of strings
    - transient signals measurement
    - ageing of solar cells
    - ….
    - dedicated coupon on a wing?
    - ESD counter?

Interaction with electric propulsion

- Plume effects :
    - erosion
    - contamination (eroded species, propellant)
    - electrical interaction : neutralisation
- European Teams :
    - erosion/contamination (grid thrusters) : Germany, Leibniz-Institute for Surface Modification, Leipzig.
    - erosion/contamination (FEEP, HET) : France, GDR propulsion plasmique (CNRS Orléans, GREMI), ONERA/DESP
    - neutralisation : test of FEEP neutraliser in ONERA/DESP

Interaction with electric propulsion

- ex : R&T CNES Propulsion : interaction FEEP / MICROSCOPE



→ neutralisation and contamination issues

- objectives : improve our knowledge on the use of neutralisers (TAS)
  - test in JONAS Chamber
  - Simulations with SPIS
  - Estimation of floating potential

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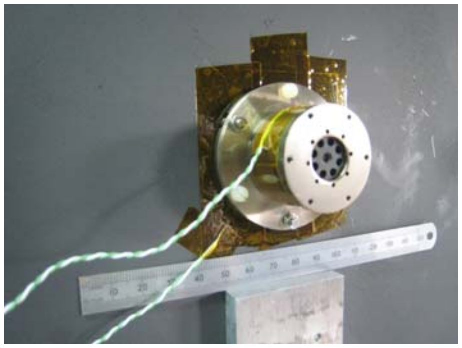
neutralizer in JONAS



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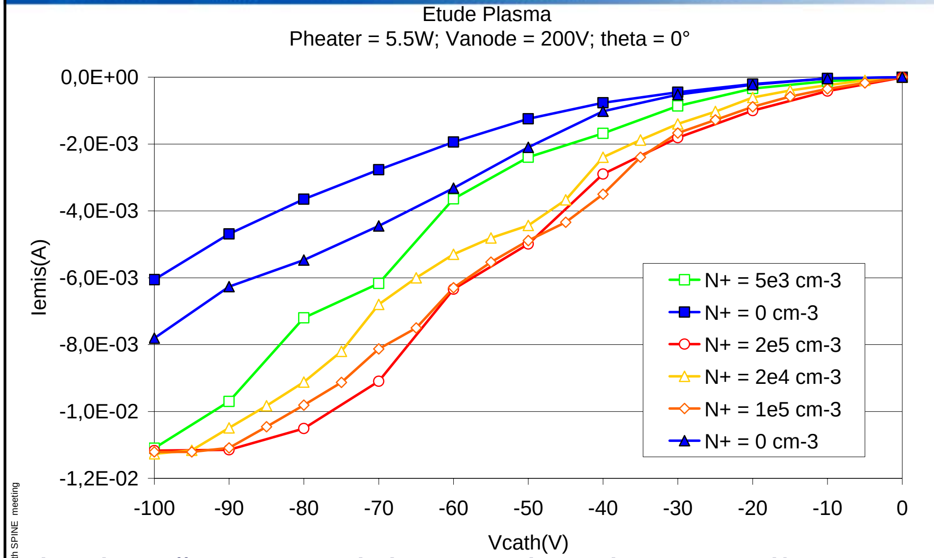
Influence of plasma density on emitted current



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plasma density effect : increase strongly electronic emitted current decreasing potential barrier
Space charge effect has to be taken into account
- need to know in-flight plasma density.

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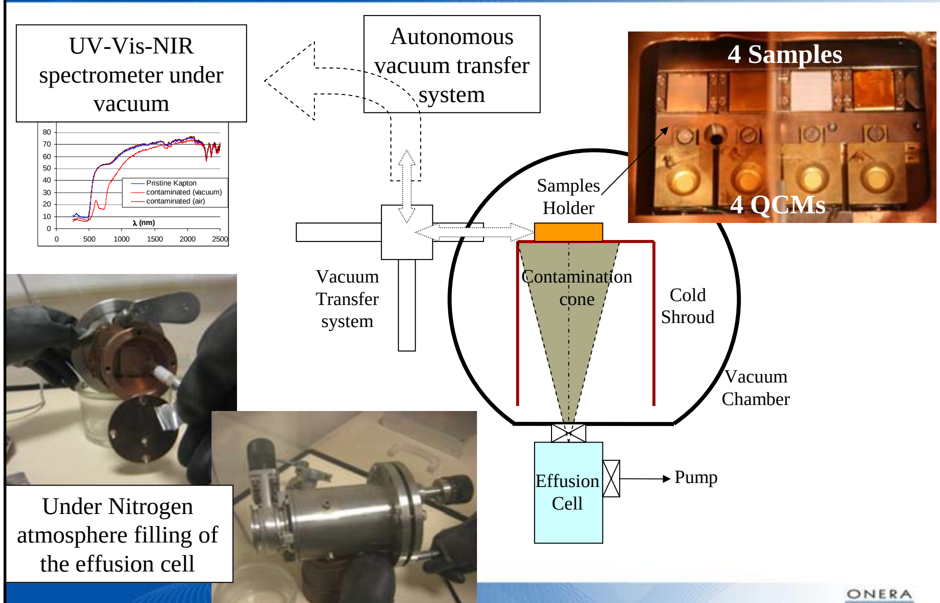
Thermal control materials contamination



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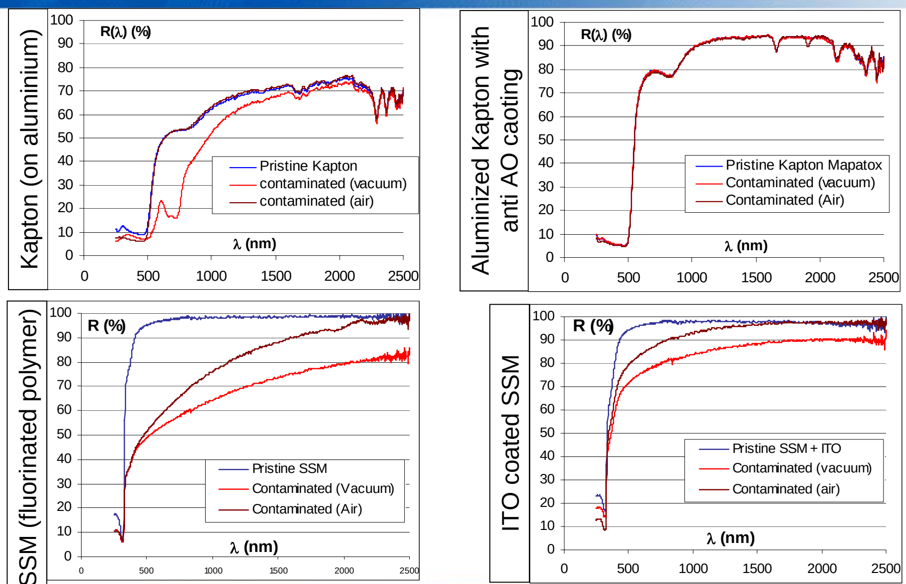
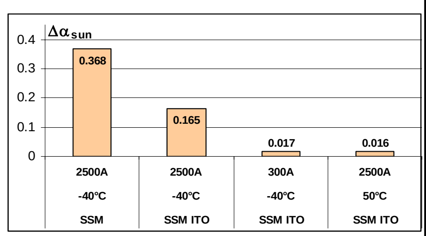
Optical properties after chemical contamination **(2500Å)**



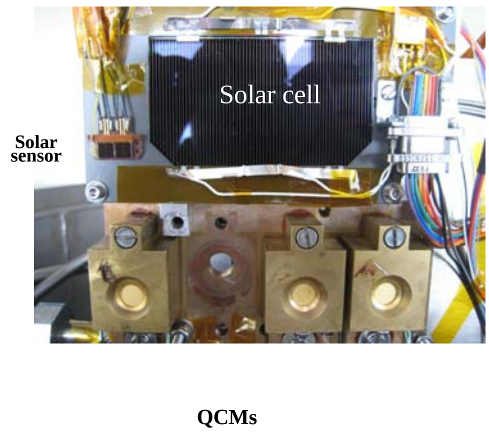
Effects of Cesium chemical contamination

- Optical effects : specific to chemical contamination
  - Strongly depends on the material surface :
  - Spectral absorption bands appear (depends on material)
  - Healing can occur after air exposure
    - Oxydation of the surface reduced by cesium
    - Under vacuum measurements necessary
- Thermo optical effects
  - Solar absorptance increase
    - Fluence effect (depends on material)
    - Temperature effect
  - No emissivity variations



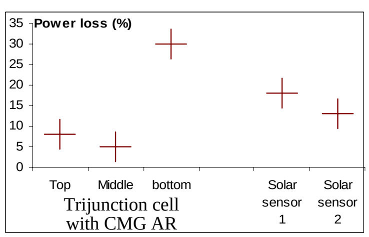
Photovoltaic elements testing

- In situ approach
  - Flash illumination
  - Short cut current measurement
  - Physical and chemical contamination
  - Power loss **measurement**

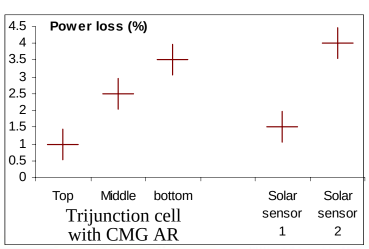


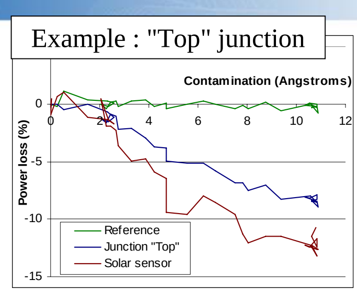
In situ power loss of contaminated photovoltaic elements

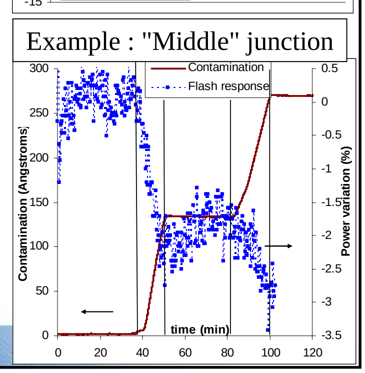
- Physical contamination 10Å at -100°C



- Chemical contamination : 150Å at 50°C







Interaction with plasma propulsion

- NEEDS :
  - environmental parameters : density, temperature, floating potential, plasma potential
  - erosion : erosion rates on materials (ex : interconnectors...)
  - contamination measurements (ex : Cs on OSR)
  - surface potentials
  - instruments : QCM, RPA, Langmuir probe