ESD risk on solar panels at eclipse exit on geostationary orbit

D. Payan(1), T. Paulmier(2),N. Balcon(1), B. Dirassen, (2)
(1) CNES, 18 Avenue Edouard Belin, 31041 Toulouse Cedex 9, France,
denis.payan@cnes.fr, nicolas.balcon@cnes.fr
(2) ONERA,BP 74025, 2 Avenue Edouard Belin, 31055 Toulouse Cedex 4, France,
thierry.Paulmier@onera.fr, bernard.Dirassen@onera.fr

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Chapter 1 - Charging in Eclipse

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Schedule

- During periods where space weather is qualified as “quiet” (NOAA nomenclature – green Kp index), the surface charging current (energy range around 20KeV) is able to reach amplitude level **from 30 to 80pA/cm²**. During an eclipse, the spacecraft will reach a high charging level even under this “quiet” geostationary environment. In that case, where there is no photoemission to limit voltage build-up and where temperature decrease down to -170°C, all the conditions are met to prepare an ESD event when the spacecraft will be powered again at eclipse exit.
- Effect of the temperature on SCA (Solar Cell Assembly)
- Effect of the temperature on SA structure (Carbon CFRP)
- State of a SA at eclipse outcome
- Mitigation techniques

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Absolute Voltages evolutions during eclipse

- Our example during the presentation;
  - irradiation between 30 and 80 pA/cm²

- During an eclipse, the spacecraft will reach a high charging level even under this “quiet” geostationary environment. In that case, where there is no photoemission to limit voltage build-up.
- The spacecraft voltage slew rate will be
  With $C_{S/C} = 1nF$
  $I_{env} = 30$ to $80\ pA/cm^2$
  $S_{S/C} = 200m^2 = 2\ 10^6\ cm^2$
  For $30pA/cm^2$ $dV/dt = 30pA/cm^2 \times 200\ 10^4 cm^2/1nF = 60\ 10^3\ V/s$
  For $80pA/cm^2$ $dV/dt = 80pA/cm^2 \times 200\ 10^4 cm^2/1nF = 160\ 10^3\ V/s$

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Differential Voltages evolutions during eclipse

- Let’s take a Secondary emission yield of two.
  For one incoming electron, two of them are leaving the spacecraft.
- With $C_{S/C}$ = 1nF, I_{Env}/cm² = 30 to 80 pA/cm² and $C_{Dielectri}$/cm² = 30pF/cm²

- For 30pA/cm² dV/dt = 30pA/cm² / 30pF/cm² = 1V/s
  → 3800 Volts in 64min.
- For 80pA/cm² dV/dt = 80pA/cm² / 30pF/cm²= 2.66 V/s
  → >10kVolts in 64min.

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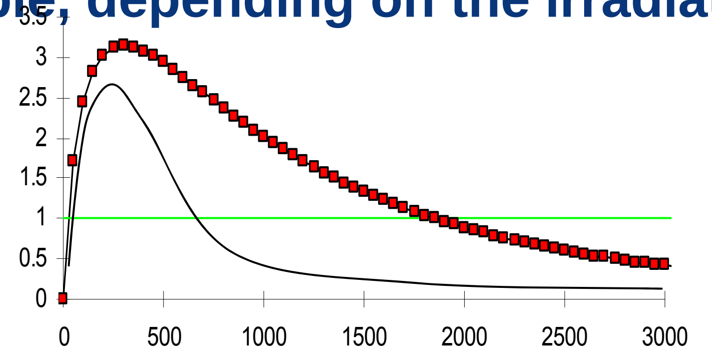
Maximum gradient expected

- As the energy of the second point of crossover is higher on coverglass than on metal, the surface potential on dielectric will be positive with respect to the spacecraft structure and dielectrics will be positively charged (lack of electrons). The higher is this difference, the greater is the risk. This situation is reached between 7 and 17 min in our quiet example, depending on the irradiation current.



1.Secondary emission rate curves
Red square; Tefon®, E_{max}=300eV E_{II}=1850eV, d_{max}=3.2
Black solid line : example for a metal, E_{max}=300eV E_{II}=650eV, d_{max}=2.7

- ESD possible during eclipse but the SA is not powered

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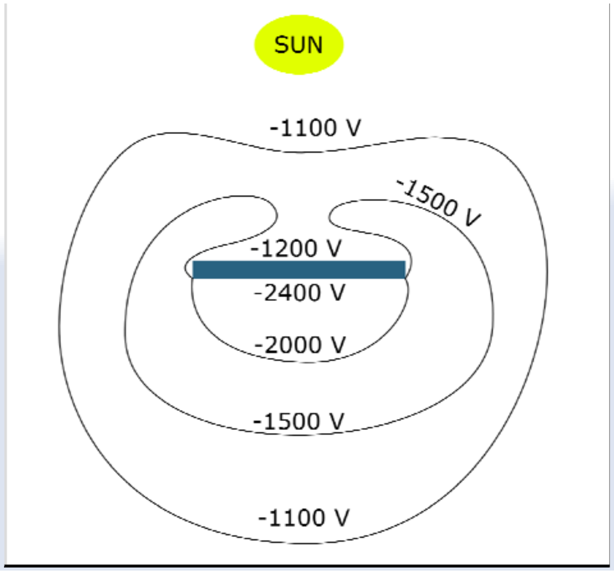
Absolute Voltages evolutions during eclipse exit (1/2)

- When the spacecraft comes out from eclipse and face the sun again, it is already in gradient situation. As the photoemission restarts (typical value around 2nA/cm²), once again in a fraction of time, the absolute voltage rises up until the potential barrier stops the secondary electronic emission leading to a knew equilibrium voltage.
- 3D modelling with SPIS demonstrates easily that the voltage barrier appears when the spacecraft voltage is approximately the double than the dielectric voltage.
- In our example, Vsat= -2400 Volts and VDiel = -1200 Volts
- Potential barrier around the spacecraft



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Absolute Voltages evolutions during eclipse exit (2/2)

- The irradiation to be taken into account is the one on the night side (on sun side it is immediately reemitted), and only half of the dielectrics are involved.
- With $C_{S/C}$ = 1nF, I_{Env}/cm² = 30 to 80 pA/cm², $C_{Dielectri}$/cm² = 30pF/cm²
- For 30pA/cm² dV/dt = 30pA/cm² / 30pF/cm² = 1V/s
  → 3800 Volts in 64min.
- For 80pA/cm² dV/dt = 80pA/cm² / 30pF/cm²= 2.66 V/s
  → >10kVolts in 64min.
- The Charge rate is several orders of magnitude lower in sun compare to the eclipse one.

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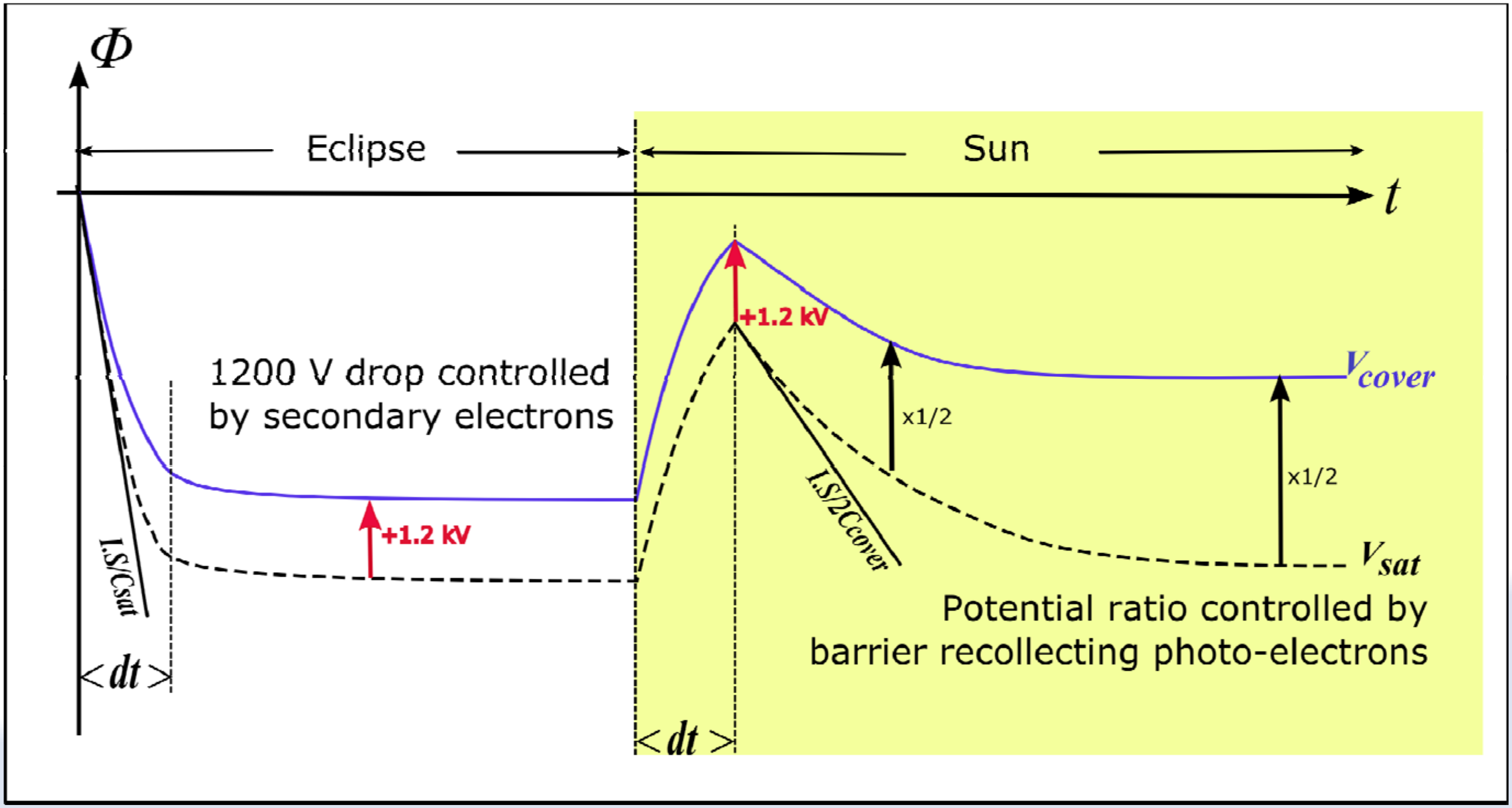
Balance



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CHAPTER 2 - Tests on sample in Vacuum

- Sirène Facility
- CFRP Honeycomb
- Glued coverglasses

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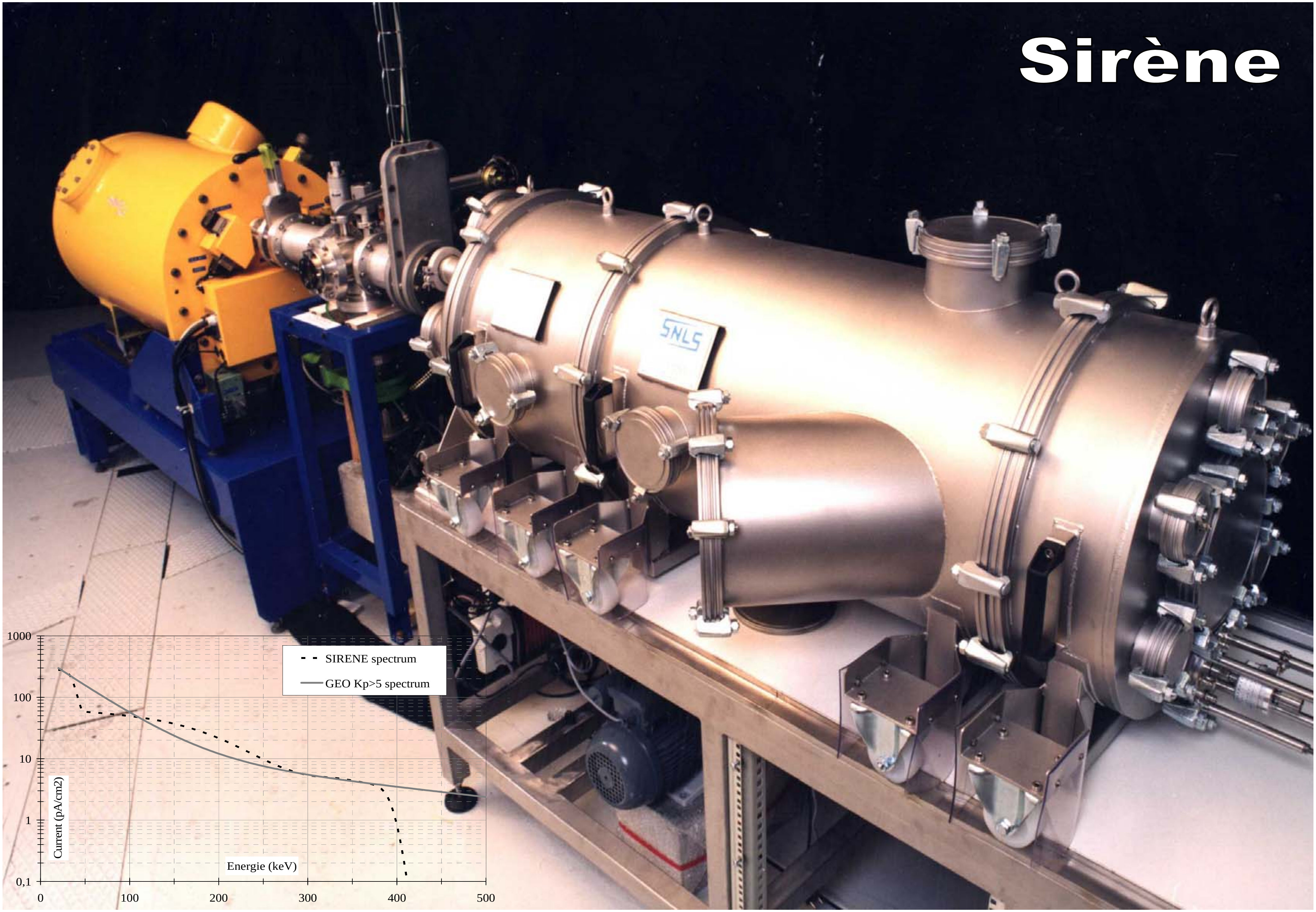
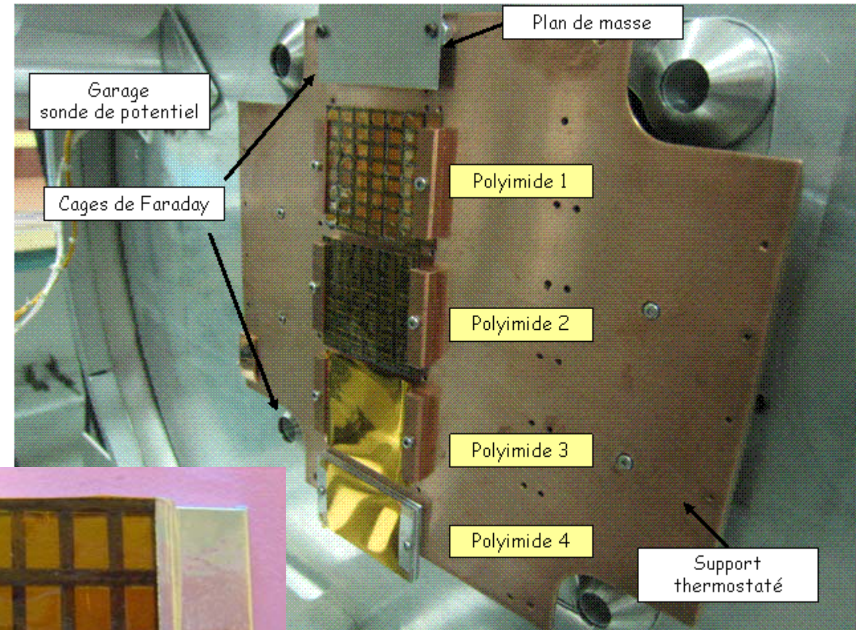
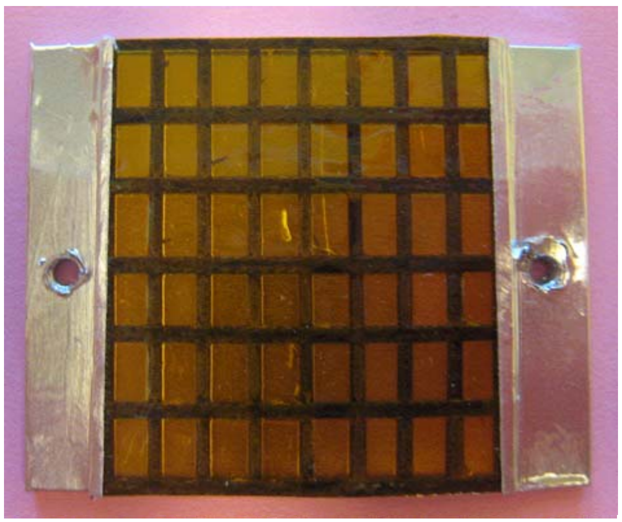
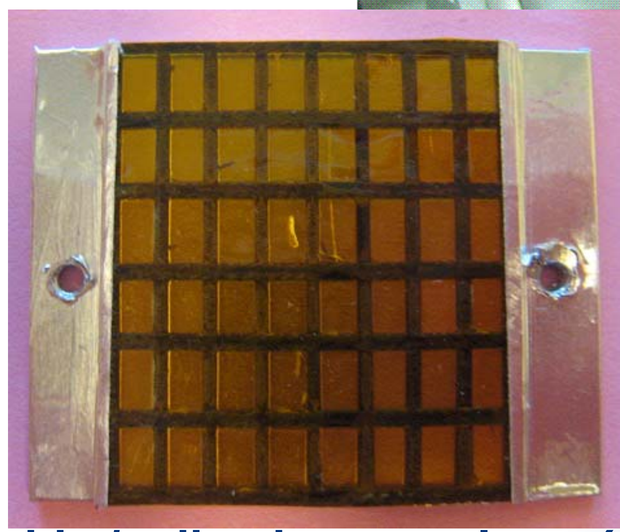

Sirène
SNLS
SIRENE spectrum
GEO Kp>5 spectrum
Current (pA/cm2)
Energie (keV)
1000
100
10
1
0,1
0
100
200
300
400
500

The samples



- **The CFRP**





- **(a)(b)View of the two polyimide / adhesive samples – (a) low density carbon fibres mesh (1 mm fibre distance), (b) high density carbon fibres mesh (5 mm fibre distance)**

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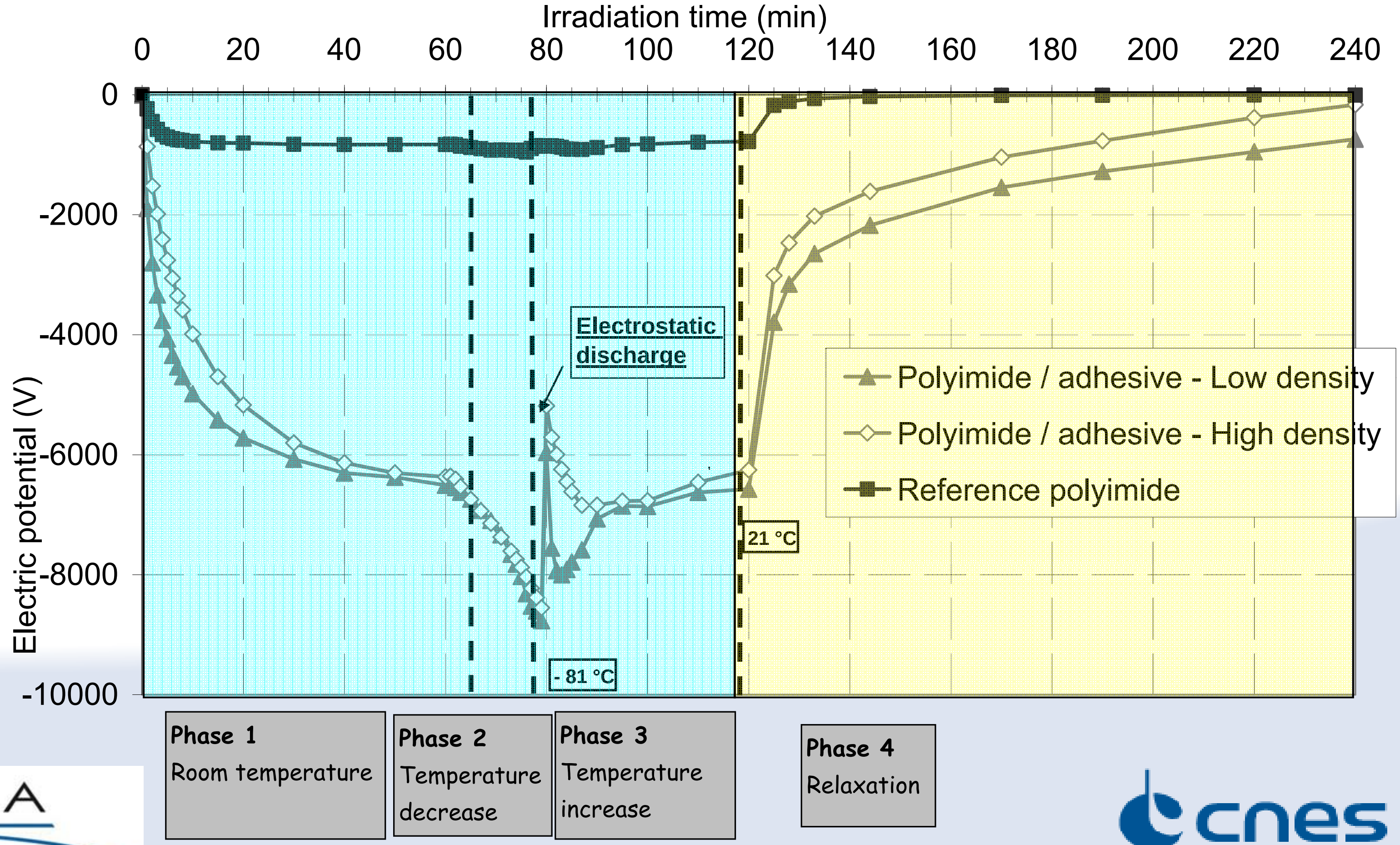
Charging behaviour of solar panel polyimide component during satellite eclipse events

■ Reference Test (No preliminary light – 2h00 Light during Relaxation)



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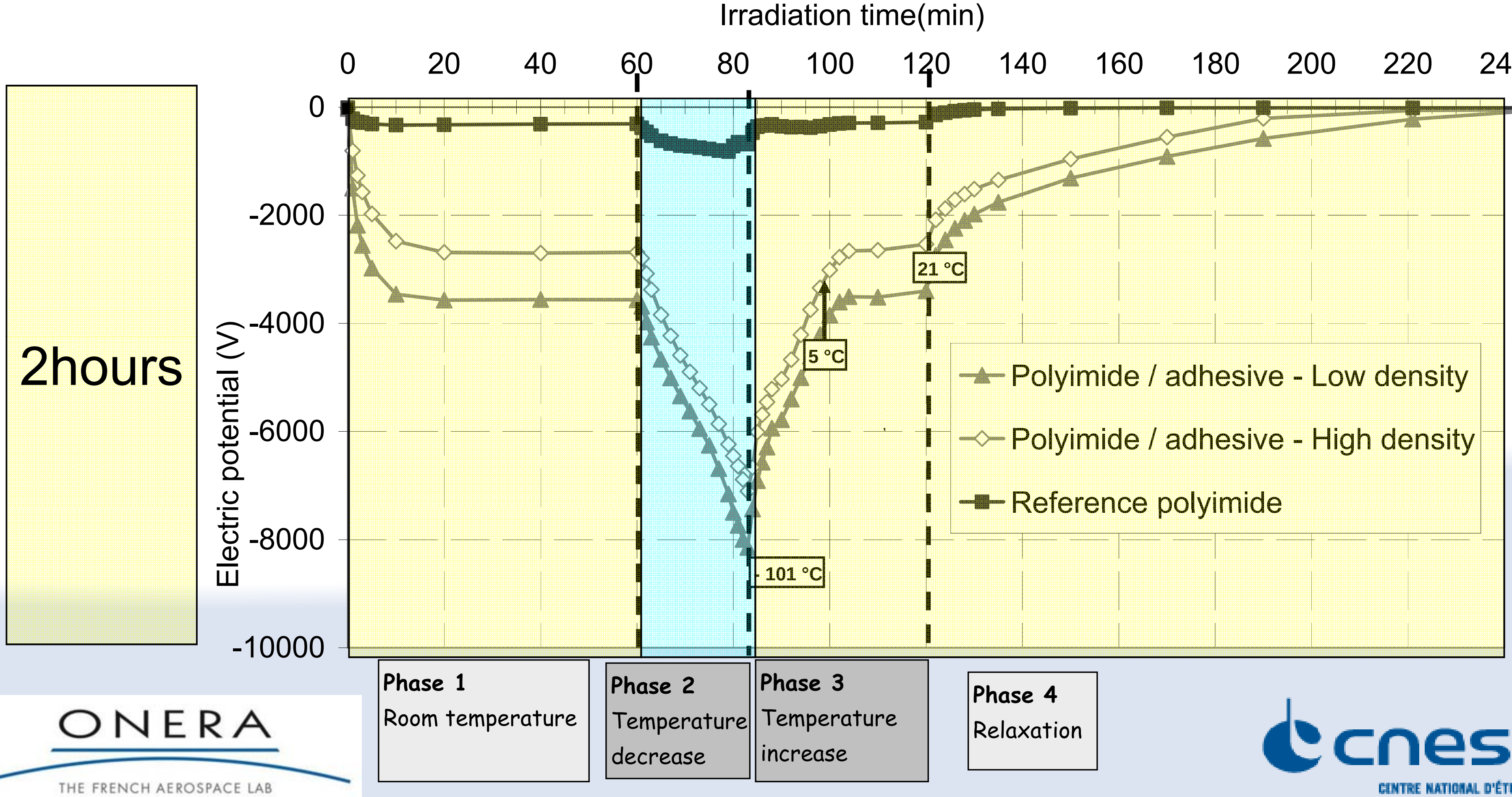
Charging behaviour of solar panel polyimide component during satellite eclipse events

- Test 2 : 2 hours of preliminary sunlight



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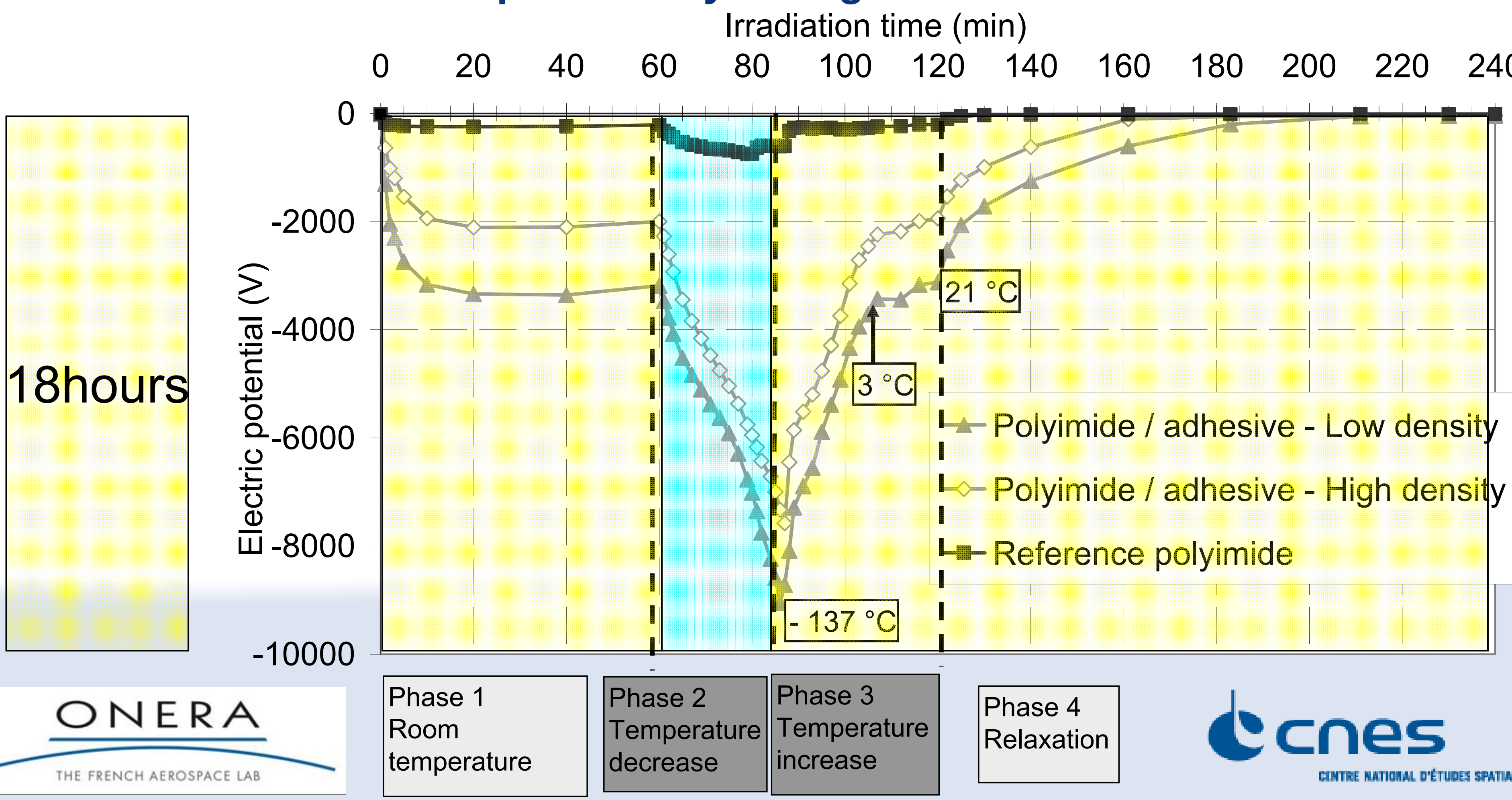
Charging behaviour of solar panel polyimide component during satellite eclipse events

- **Test 3 : 18 hours of preliminary sunlight**



Test on glued Coverglasses

- **Batch 1 - Two kinds of sample:**
  Two OSR plates fixed to the grounded support using Wacker S690® or Dow Corning 93500® adhesive films on their rear face.
- **Batch 2 –Two kinds of sample: one metallized CMX plate fixed to the support with Kapton® adhesive films at the four corners of the sample (the CMX plate is then directly in electric contact with the grounded support), and one metallised CMX plate fixed to the support using Dow Corning 93500® adhesive film on its rear face.**
- **The first batch has been tested using either monoenergetic 20 keV electron beam (for surface charge) or the GEO distributed electron spectrum in SIRENE (to study the effect of radiation induced conductivity on the system). The applied temperature ranges from 20°C down to -90°C.**
- **The second batch has been tested using the same type of electron beams (20 keV and GEO electron spectrum) with an applied temperature ranging from 20°C to -60°C.**

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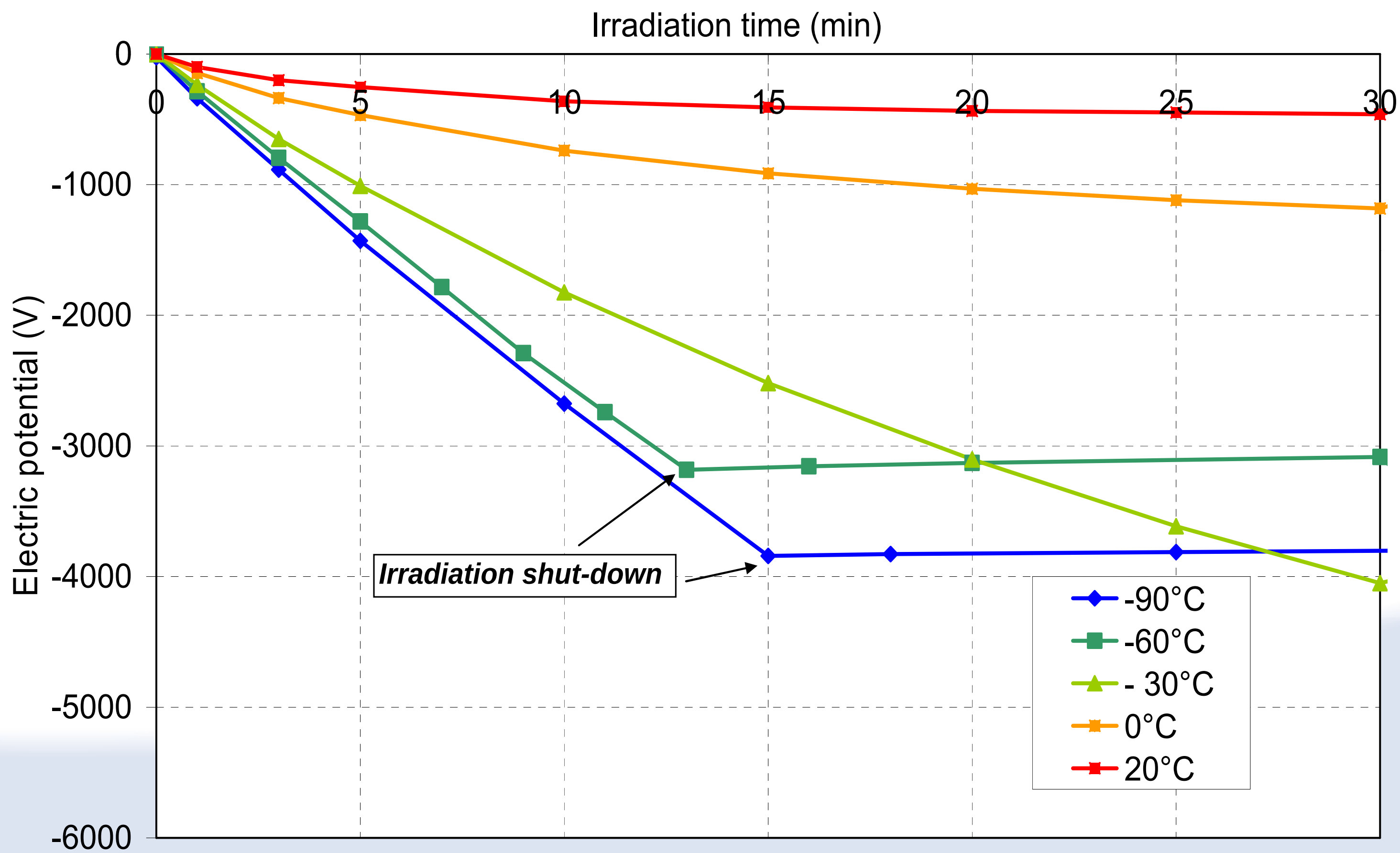
Evolution of the charging potential of the OSR / S690® system irradiated with the GEO spectrum electron beam from 20°C down to -90°C



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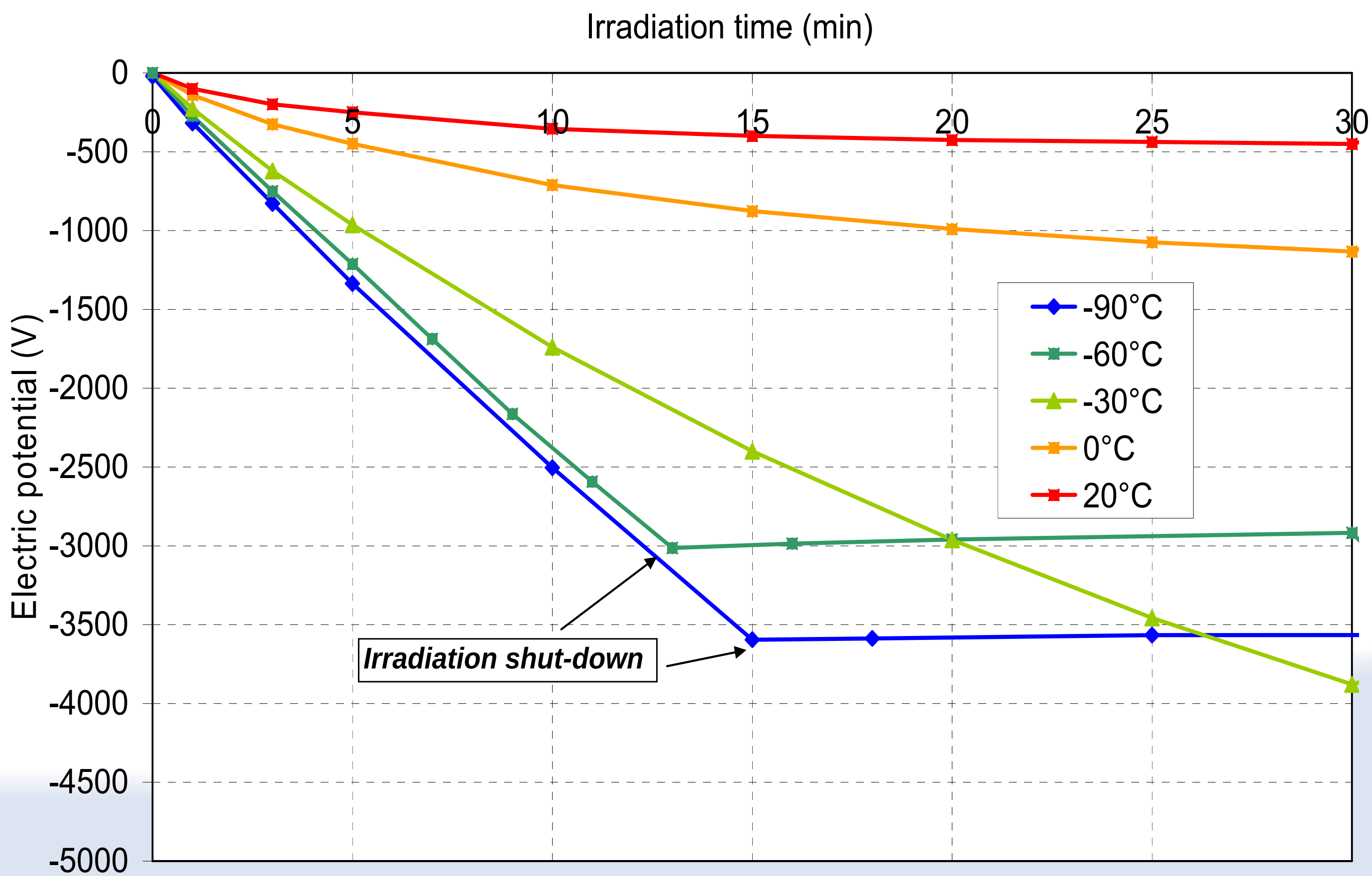
Evolution of the charging potential of the OSR / DC93500® system irradiated with the GEO spectrum electron beam from 20°C down to -90°C



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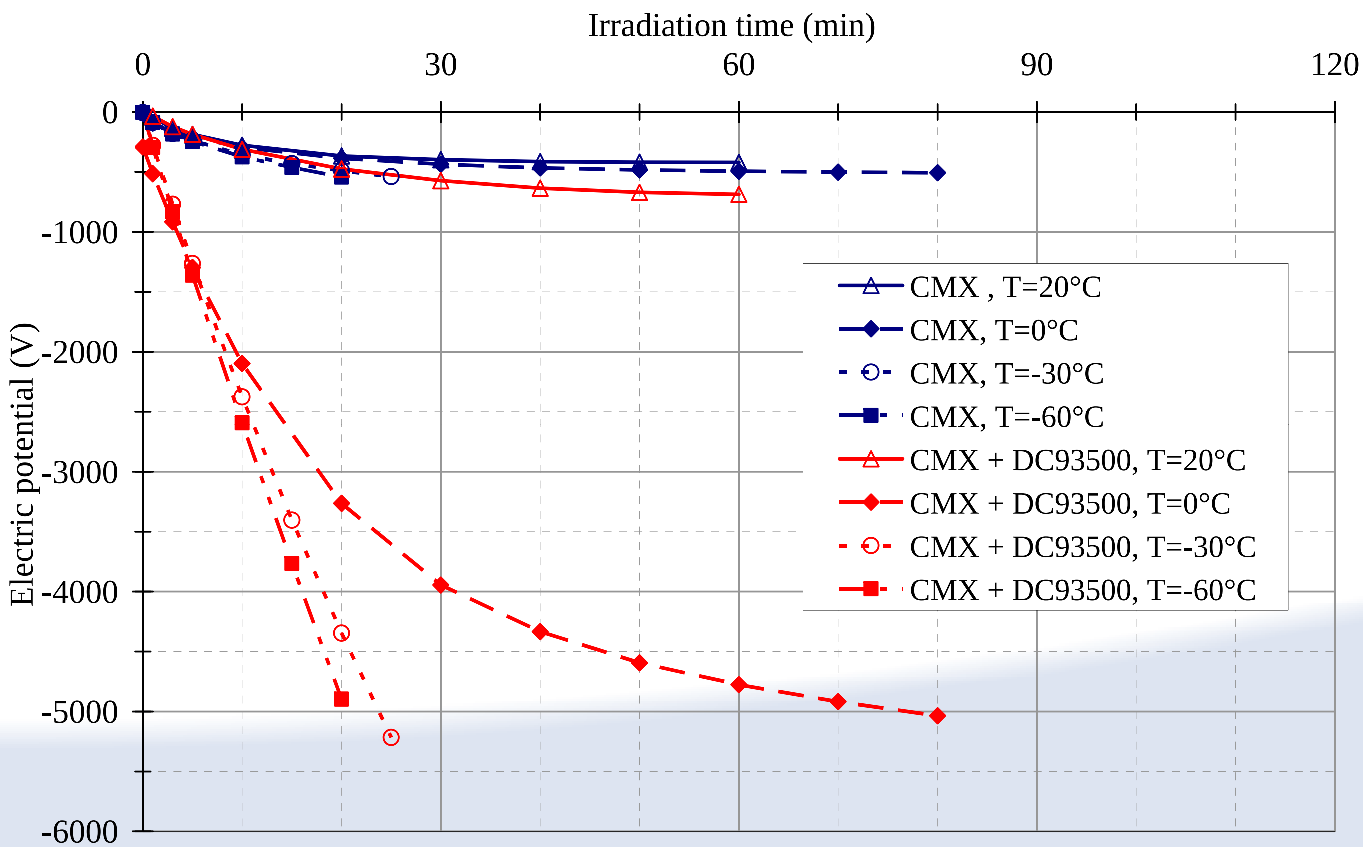
Comparison with reference samples (rear metalized) Evolution of the electric potential of CMX and CMX / DC93500 system irradiated with the 20 keV monoenergetic electron beam from 20°C down to -60°C



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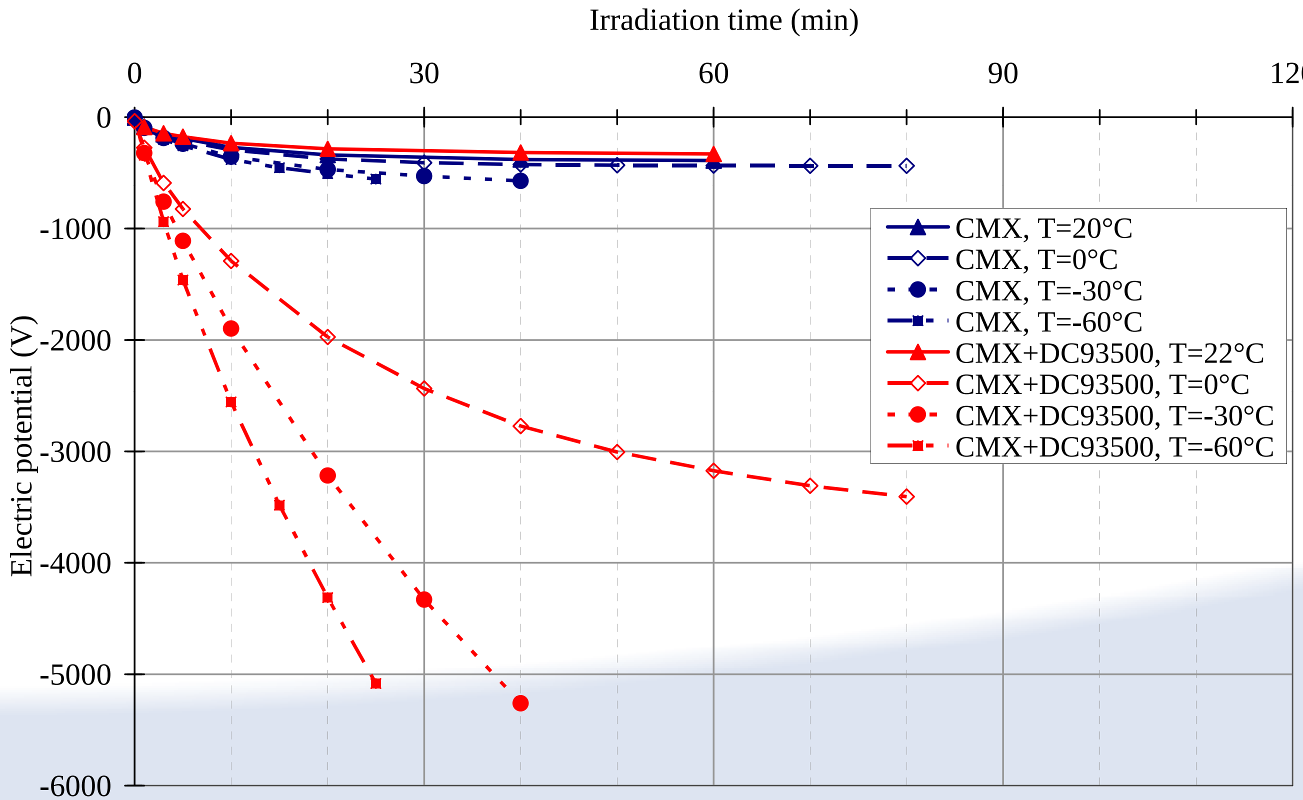
Comparison with reference samples (rear metalized) Evolution of the electric potential of CMX and CMX / DC93500 system irradiated with the GEO spectrum electron beam from 20°C down to -60°C



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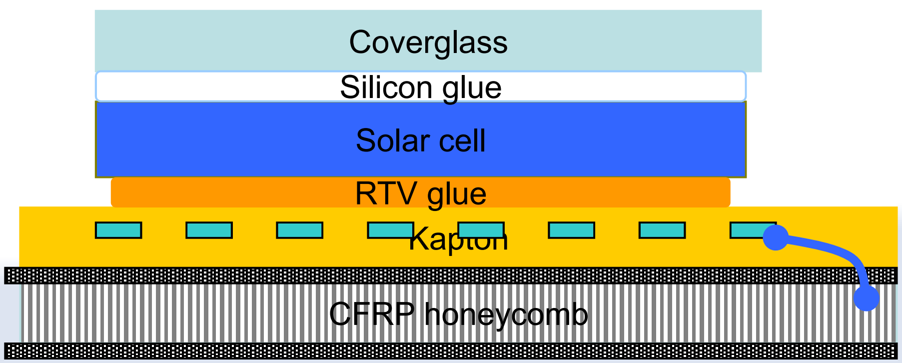
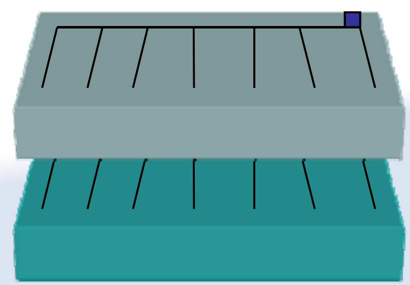
Conclusion

- At low temperature, the adhesive electric conductivity drops down dramatically: for temperature equal or lower than 0°C, the adhesive film steers the overall surface charging potential of the CMX / adhesive system.
- We are in a situation where coverglass is insulated from cell and kapton® from Solar panel structure.
- Due to hysteresis effect f the temperature, we need to wait to reach positive temperature to recover conductivity. It takes tens of minutes.
- During that time many ESD are possible and the SA is powered.
- Eclipse exit is the favourite situation for failures.

Mitigation technique

- Bulk conductivity is the solution
- Structural component (glues) are not able to make the job!
- We need to use an extra component to meet the condition.
- A metallic comb is a solution (CNES patent) to “shortcircuit” the glue and maintain acceptable gradient. The step of the comb have to be designed thank to the conductivity of the material connected to.
- An comb identical to the cell comb can be added to the rear face of the coverglass to warranty charge bleeding (CNES patent).





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