Lesson Learned in MOSFET Burn-out Test

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Outline

1 – The usual evaluation process

2 – The results & the surprise

3 – How to explain . . . !

4 – Lesson learned, The message

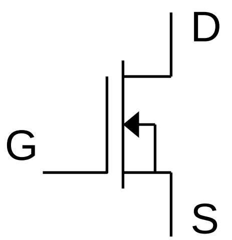
5 – A proposal for a reliability calculation method

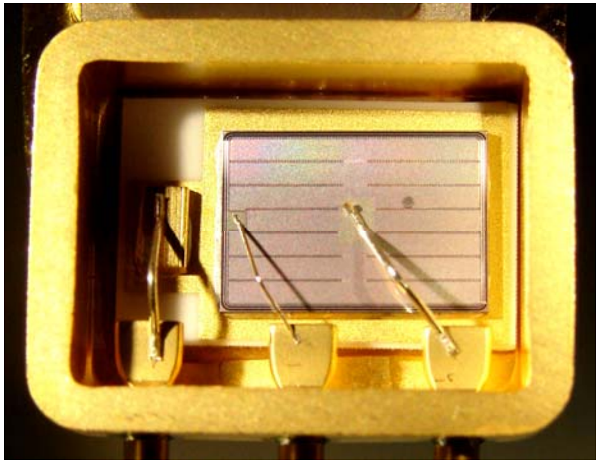
6 – Conclusions

The usual evaluation process

Burn-out :

It is not : *noun* - Burn-out of worker, staff : overwork, exhaustion - Aerospace : final phase of combustion





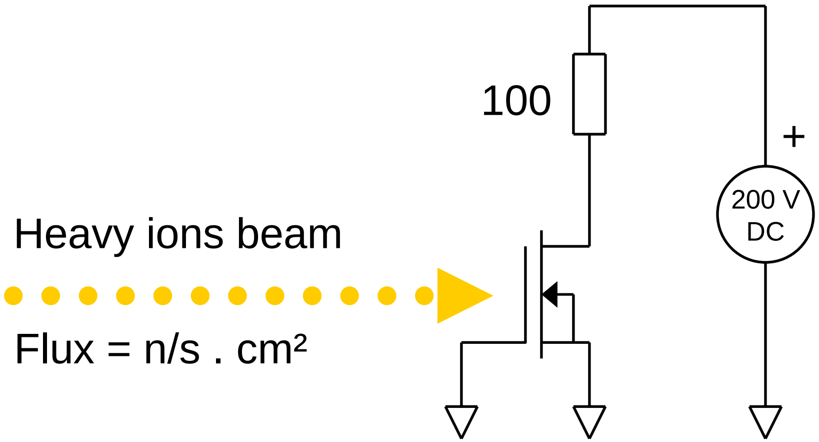
But for our community, It is :

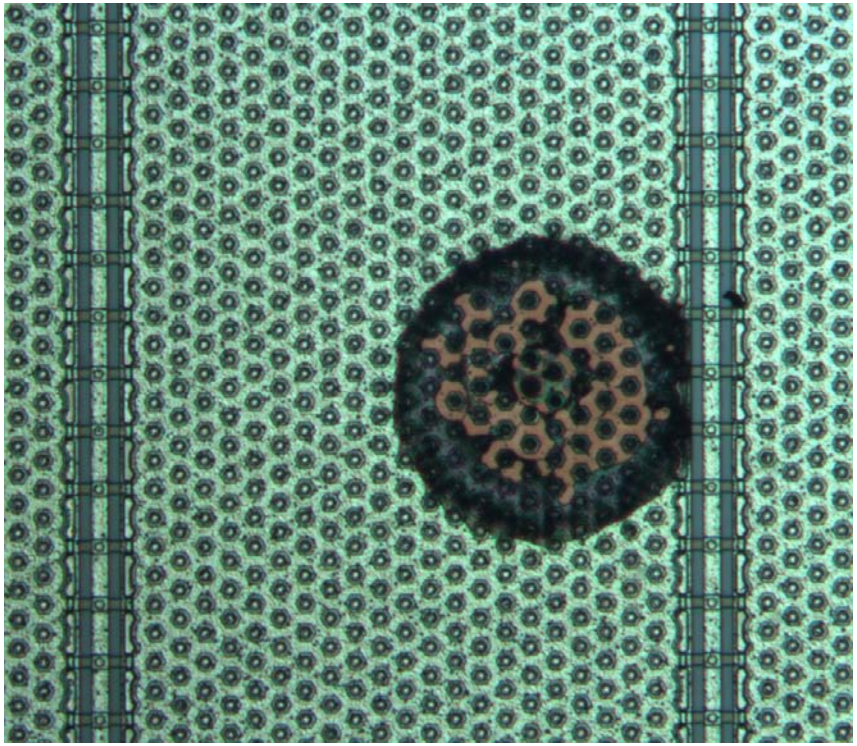
SEB – Single Event Burn-out

The Power MOSFET destruction by ONE ion

Burn-out :

A destructive event !



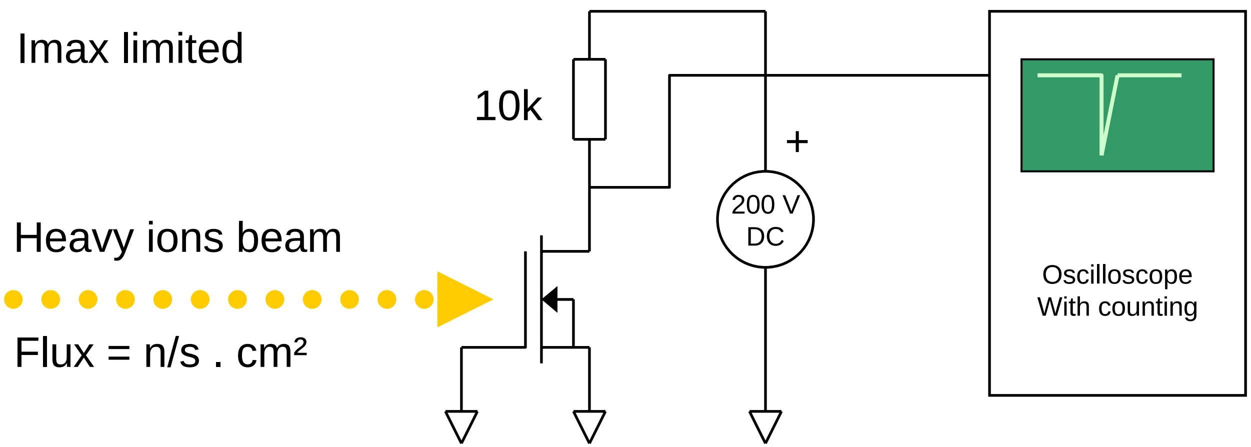


The usual evaluation process

Test process objective :

search for the LET threshold of the SEB for a given Vds

- Ions beam is perpendicular to the surface (worst-case)
- We detect and count the SEB . . .



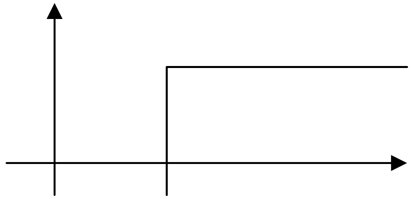
σ = Ne / Fluence

Fluence = Flux . Time
Fluence : n/cm²
Flux : n/s . cm²
Time : s
Ne : Nbr of event
σ : cm²

The usual evaluation process

With the LET threshold, by assuming that

- The solid angle of sensitivity is a cone 60° open
  - (ref : D.L. Oberg and all – First Destructive Measurement of Power MOSFET SEB Cross-Section – IEEE Vol NS-34, N° 6, December 1987 PP 1736 – Fig 11)
- The σ vs LET a step function



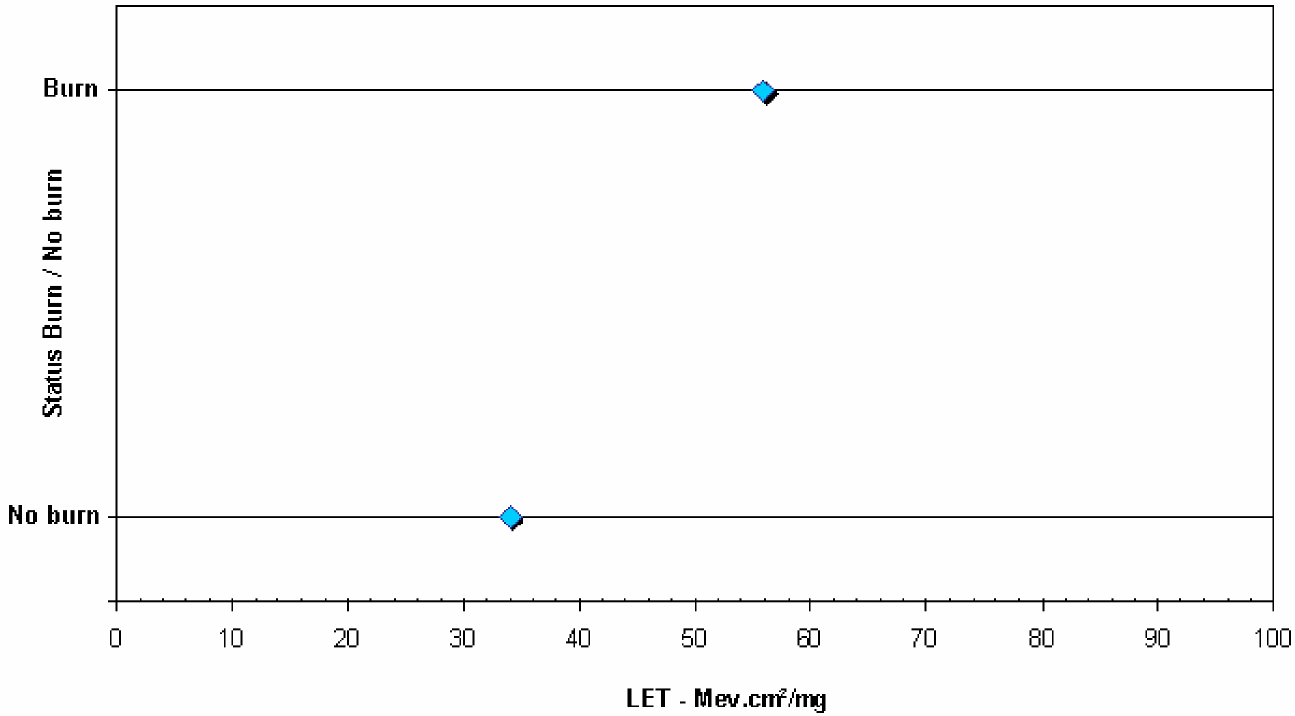
We can compute the reliability . . .

$$FIT = Flux(@\,LET_{Th}) \times \sigma \times 6.048 \times 10^{8}$$

- FIT : 1 failure / 10^9 h = 1 failure / 114 077 years
- Flux : Flux at the LET_{th} in ion/m^2.sr.s

The result & the surprise

A first campaign done at HIF facility . . .



The result & the surprise

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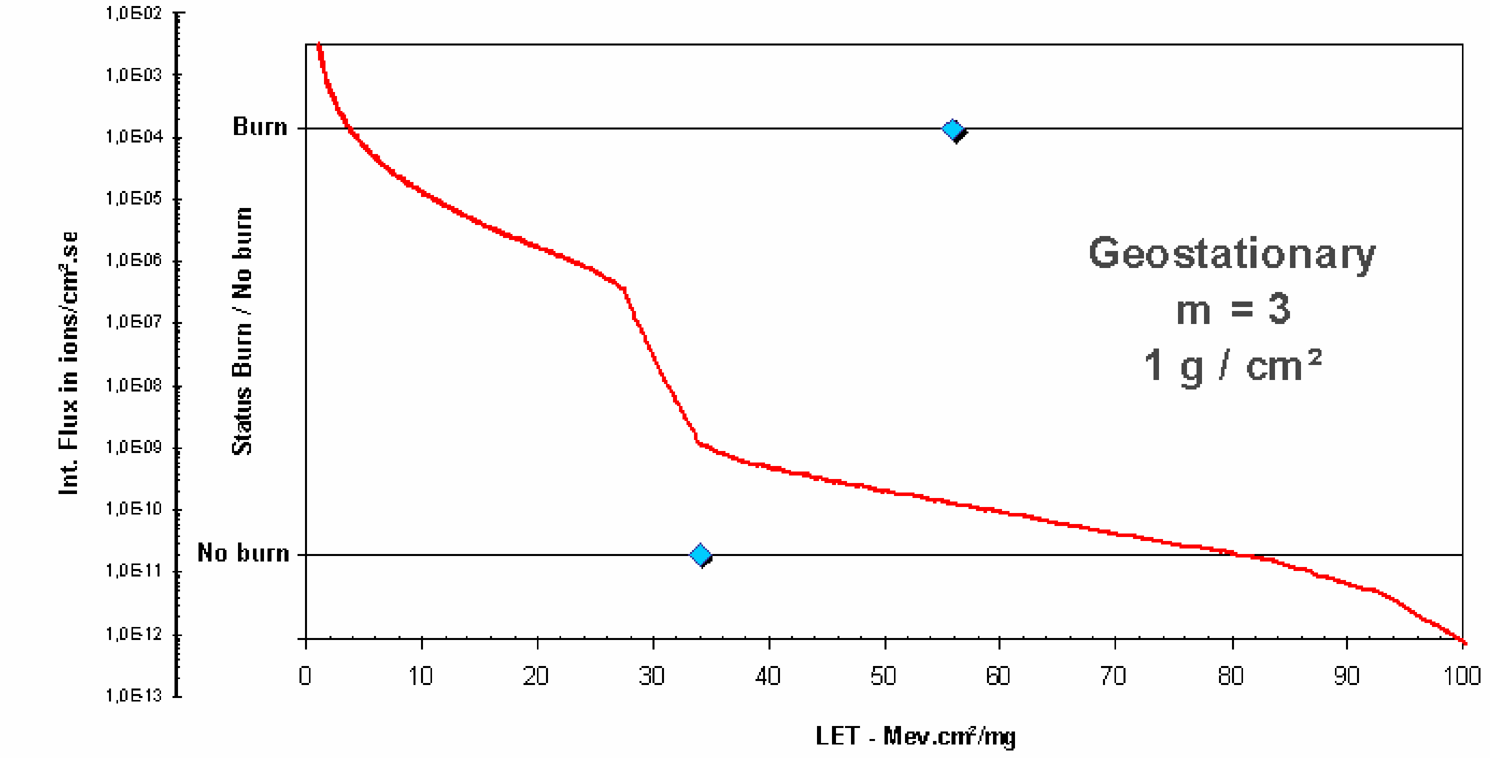
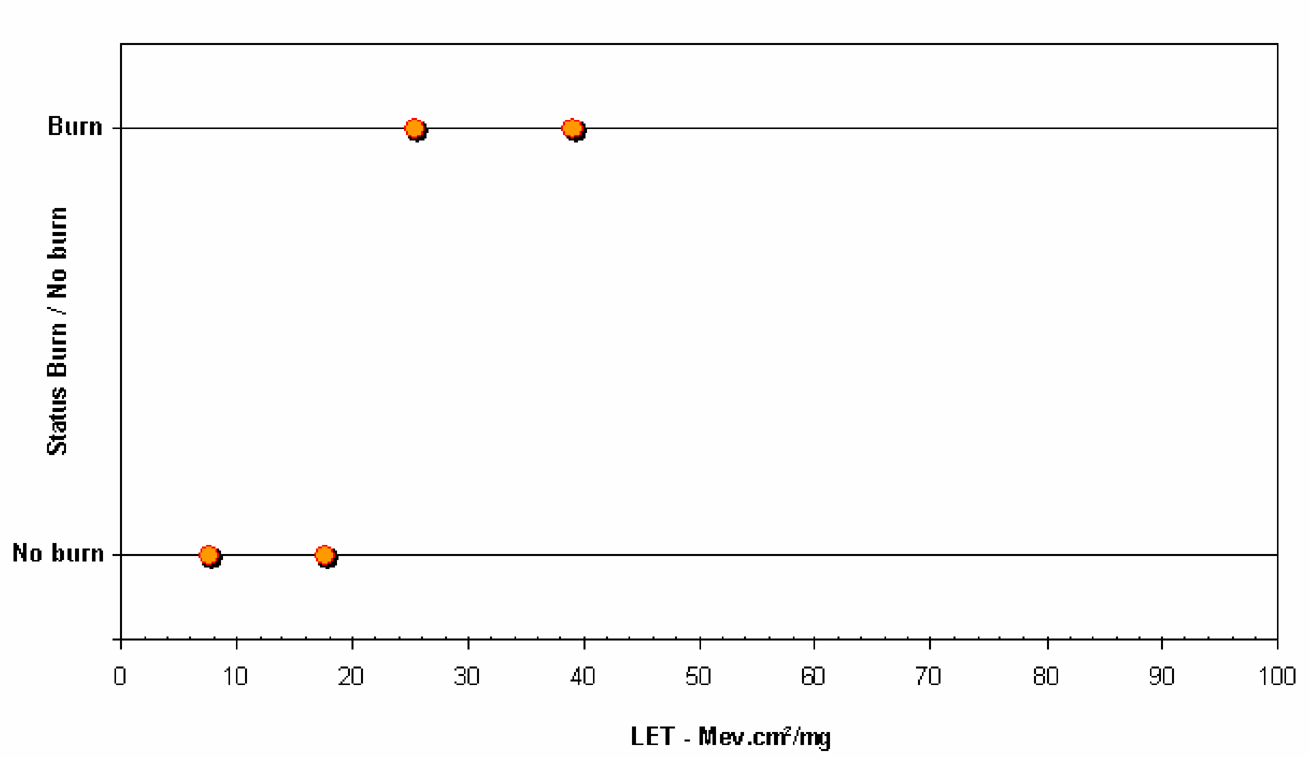


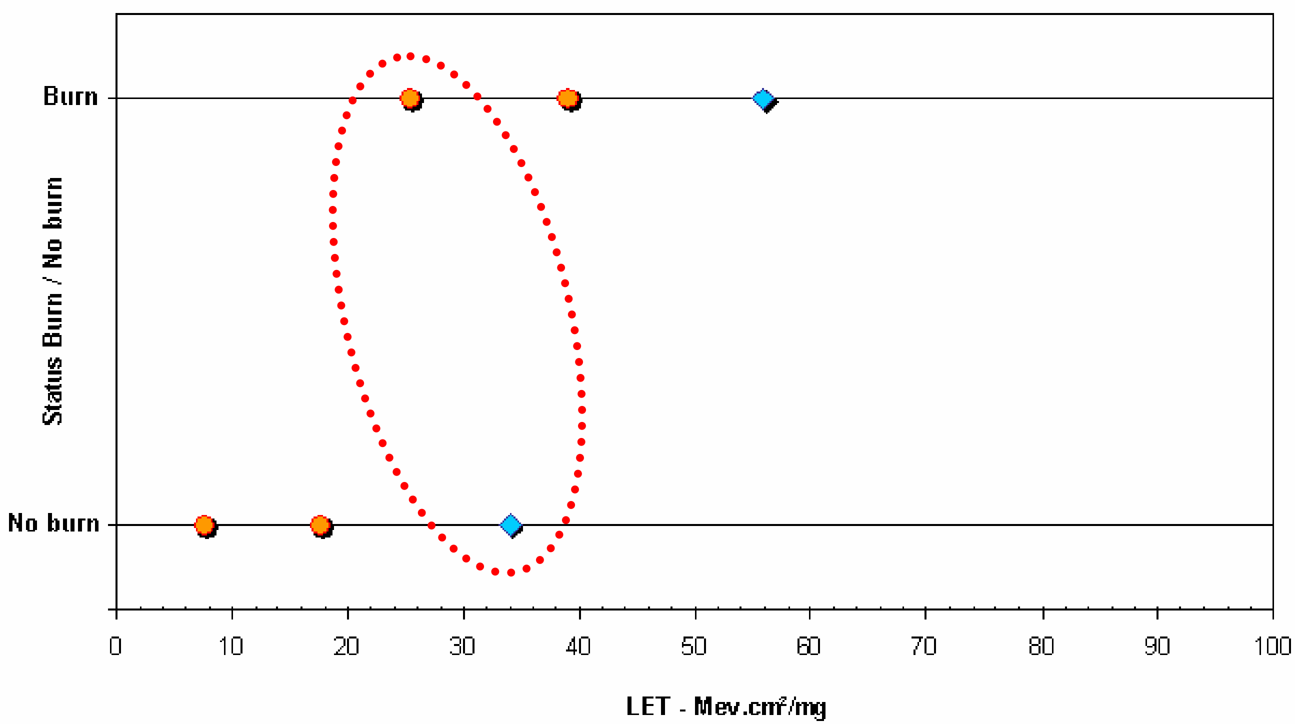
The result & the surprise

A second campaign done at TAMU facility . . .



The result & the surprise

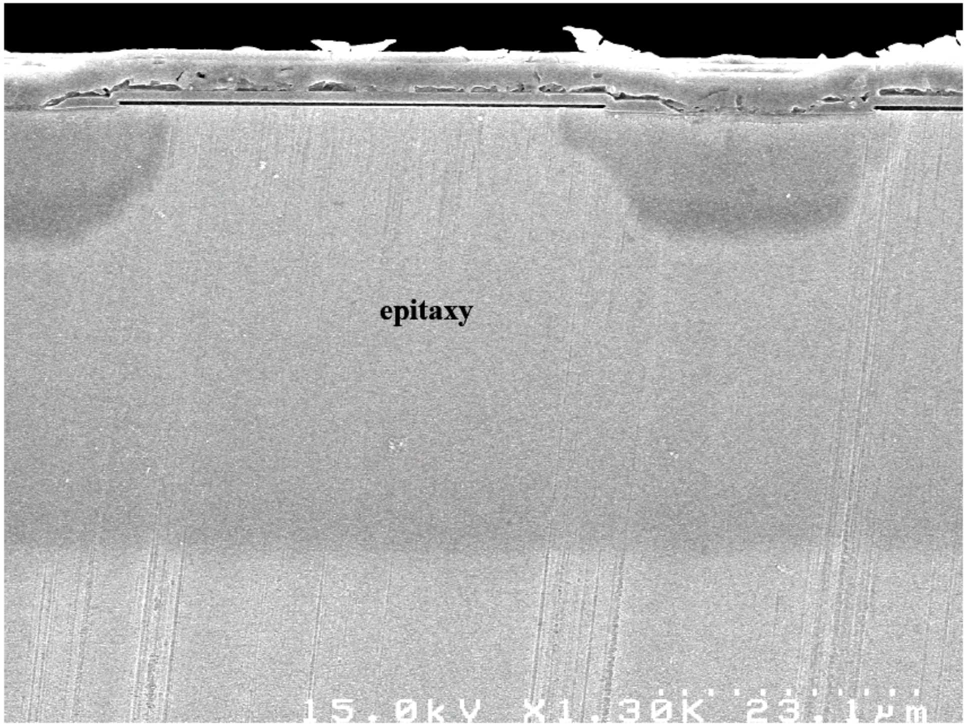
The global results seems illogical !



How to Explain . . . !

The key : The active zone is deep !

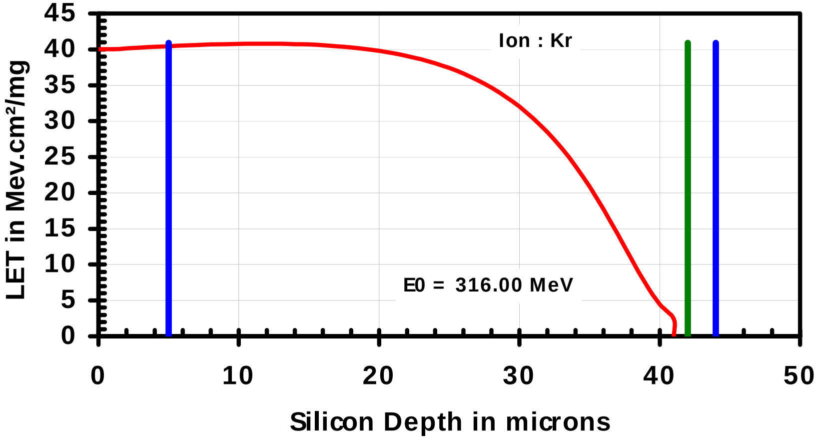
- 5 µm for SiO2 and Al
- 39 µm for epitaxial Si (n doped)
- Then let consider the LET evolution within the active zone as previously published in IEEE TNS

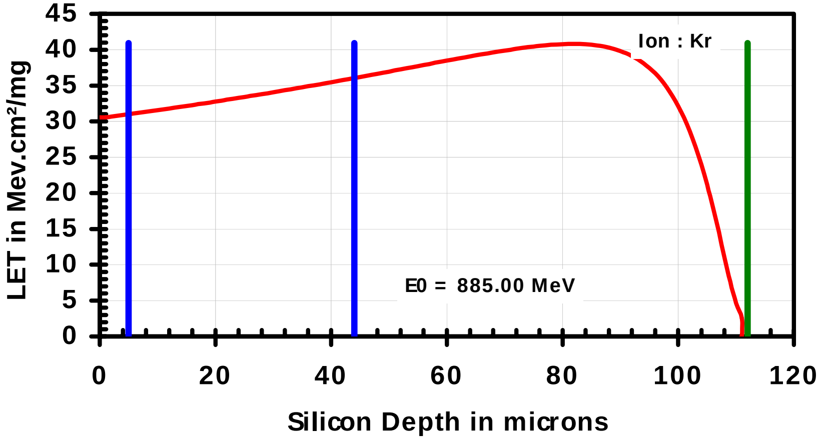


How to Explain . . . !

Calculation of the charge deposited

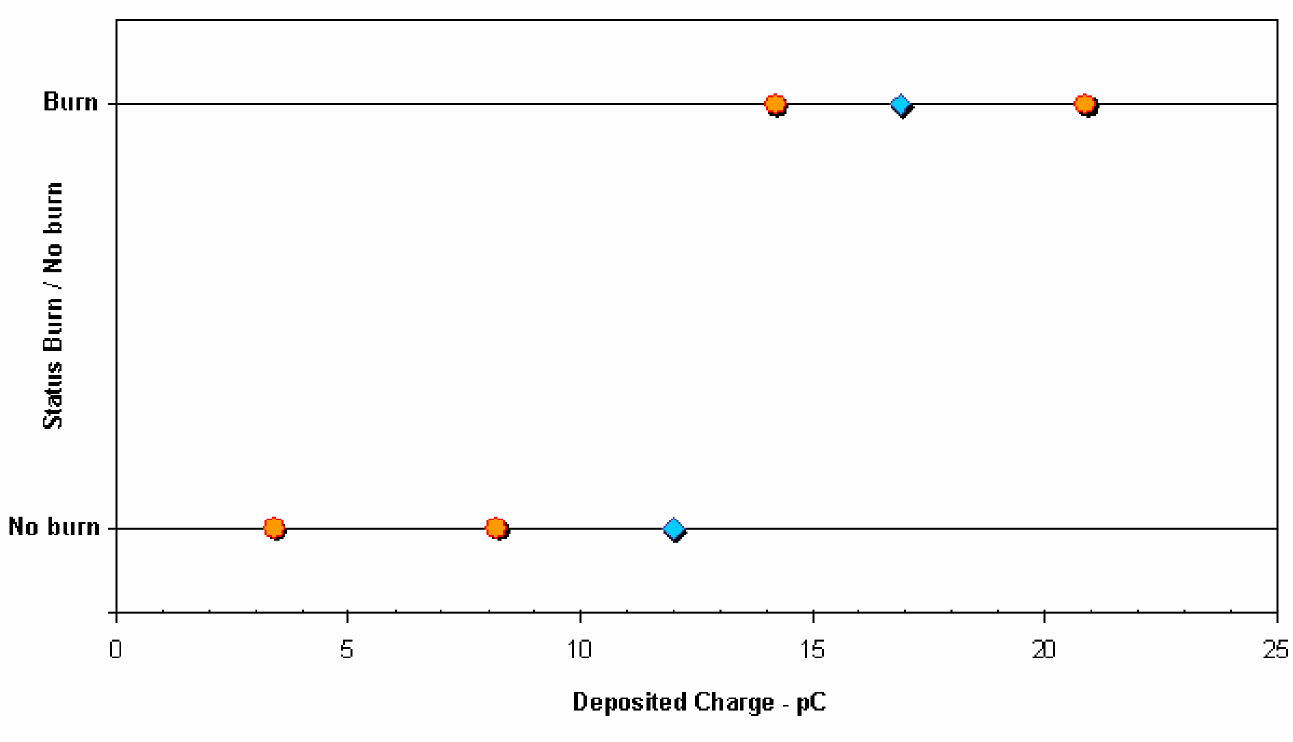
- Cyclotron : UCL vs TAMU
- Energy : Kr 316 MeV vs Kr 885 MeV
- LET : 40 MeV.cm²/mg vs 30.6 MeV.cm²/mg
- Deposited charge : 12.0 pC vs 13.1 pC





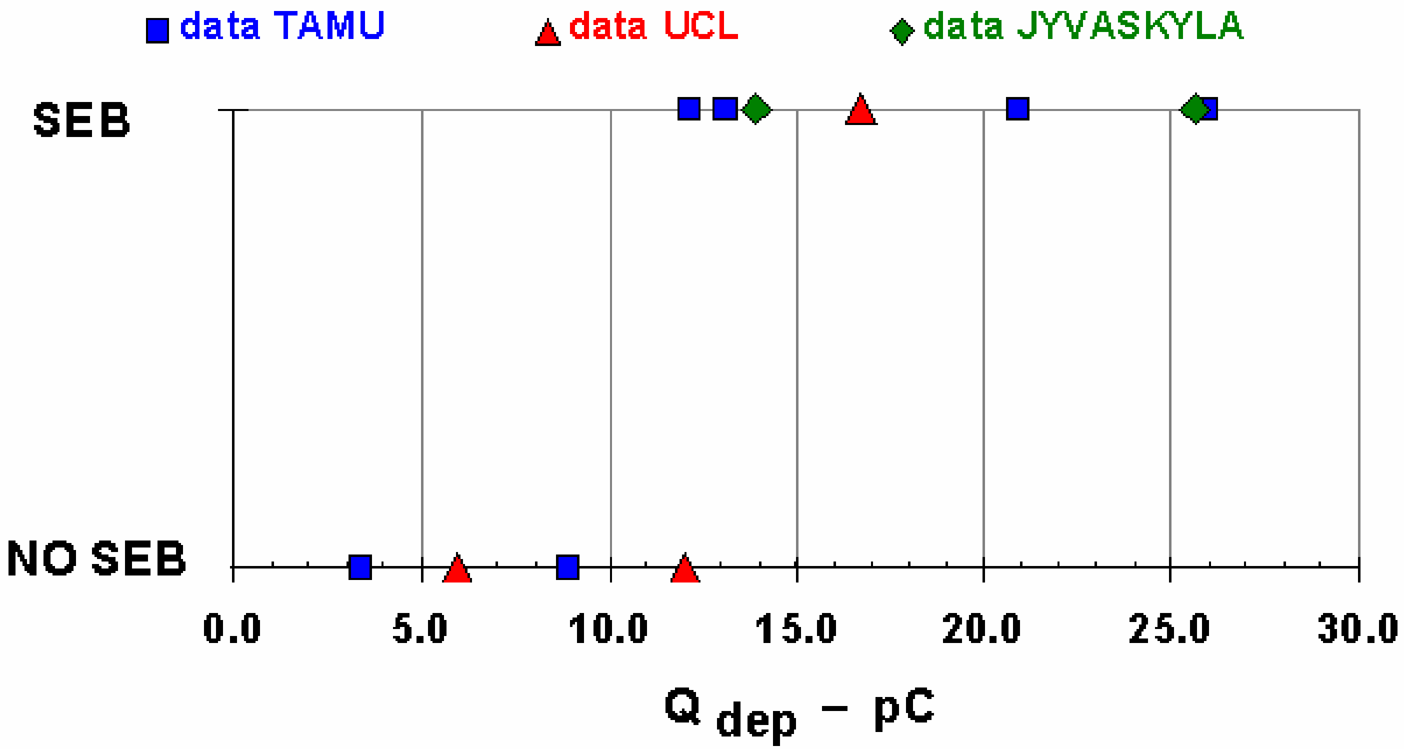
How to Explain . . . !

Everything is now logical !



How to Explain . . . !

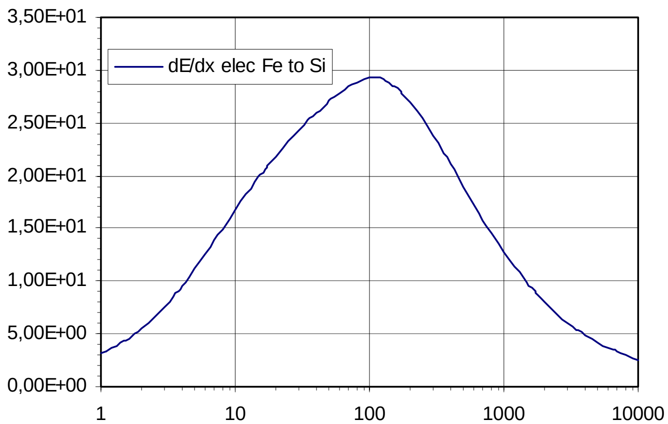
And confirmation with a third machine and an other device



Lesson Learned – The Message

1 – The LET provide by cyclotron administrator are given at the device surface

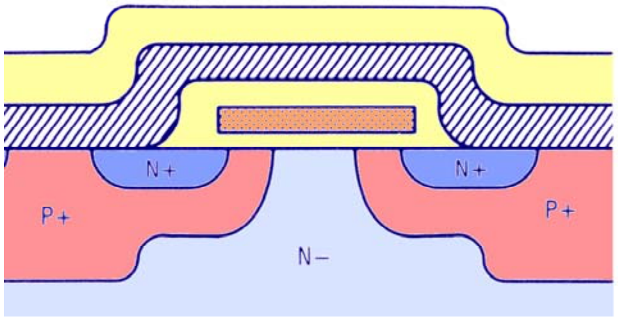
- As the particle penetrate the silicon, the energy droop and the LET change
- Look out for device with deep active zone
  - Power MOSFETs and medium voltage analogue integrated circuits



2 – The model use to calculate the LET value is not normalized

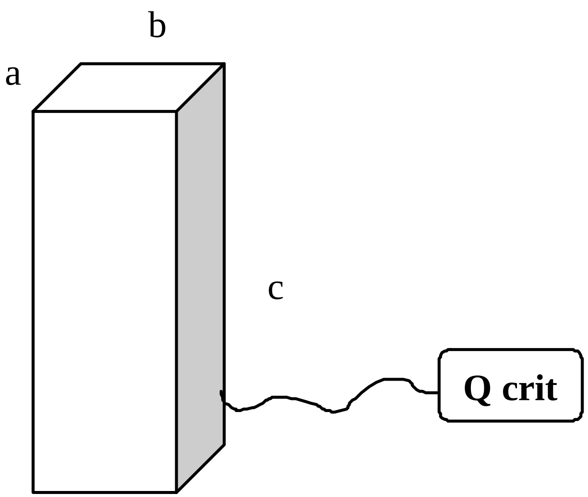
- Look out when using test results
  - For comparison
  - For reliability calculation

Proposal for Reliability Calculation

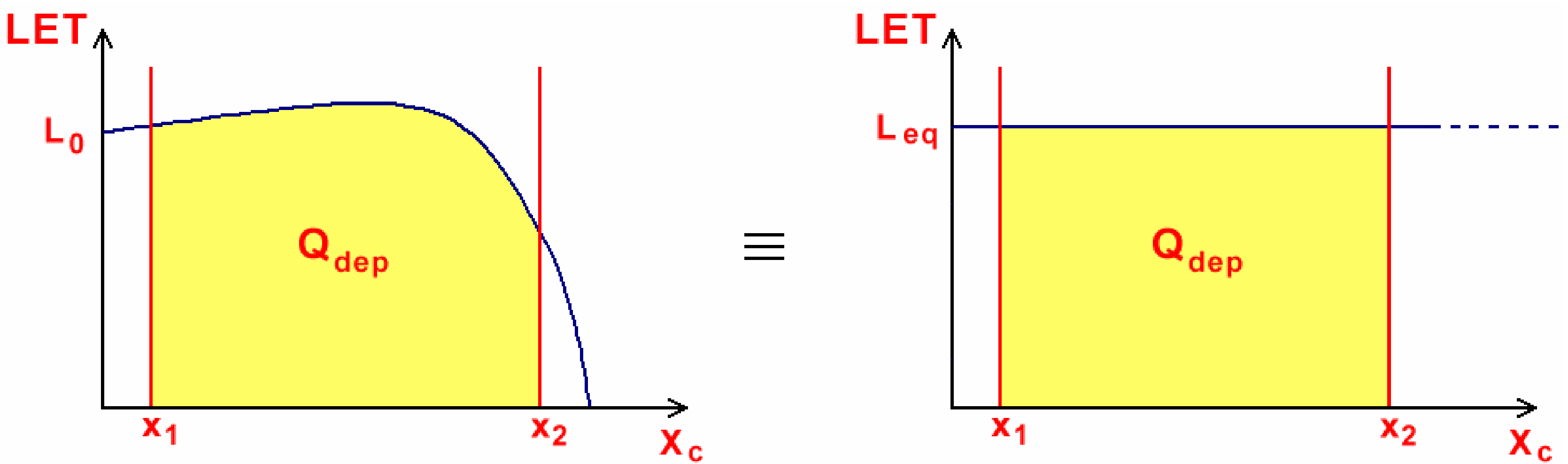


Facts & Hypothesis

- The MOSFET is made up elementary cells
  - 42000 cells for IRF360
- We can measure cross-section
  - Use of non-destructive method
- The sensitive volume is parallelepipedal
  - Dimension 5 µm x 5 µm x 39 µm for IRF360
- The collected charges = deposited charge



Proposal for Reliability Calculation



$$Q_{DEP} = \int_{x_1}^{x_2} k * LET(x) * dx = LET_{EQ} * (x_2 - x_1) * k$$

Then, we can use classical tools for reliability calculation . . .

- CRÈME – OMERE (same hypothesis)

. . . for devices with deep active zone

Proposal for Reliability Calculation

We agree that . . .

- It is a *raw / pragmatic / industrial* approach !
- This method need to be *refined / validated / tested*

. . . that is why . . .

- We have initiated a thesis in partnership with IXL Bordeaux / CNES / AAS
- It is part of CNES R&D Study 2006/2007

Conclusions

This practical experience show :

- Basically, LET is not the key parameter for SEE assessment,
  it is the collected charge or more practically, the deposited charge

- For devices with deep active zone,
  the use of LET as a key parameter can end to a failure !
  we have to consider the range

- As the LET calculation is not normalized,
  check the model used by the cyclotron administrator
  and the reliability calculation tool

- A method, based on deposited charge, for reliability calculation is proposed

Alcatel Alenia Space

B R O A D E N   Y O U R   L I F E