ATRON METROLOGY | ADVANCE ENGINEERING | SEFC FORMATION | CERAP PREVENTION

ATRON
METROLOGY

Agenda overview

CERAP and its subsidiaries at a glance

- ✓ ATRON, a technological platform in Normandy

Irradiation services

- ✓ Calibration of radiation survey meters
- ✓ Treatment of materials
- ✓ Qualification of electronic devices for nuclear or space applications

Characteristics of our irradiation means

- ✓ Ebeam and X-rays

Example of services

- ✓ Applications on electronics
- ✓ Applications on materials
- ✓ R&D involvements

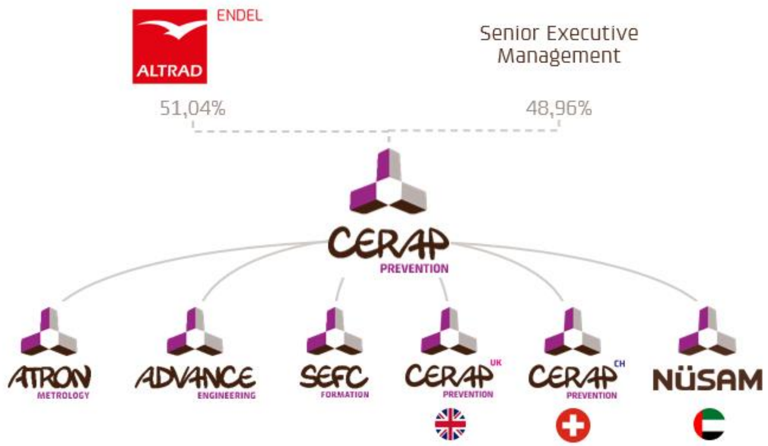
Arnaud CHAPON

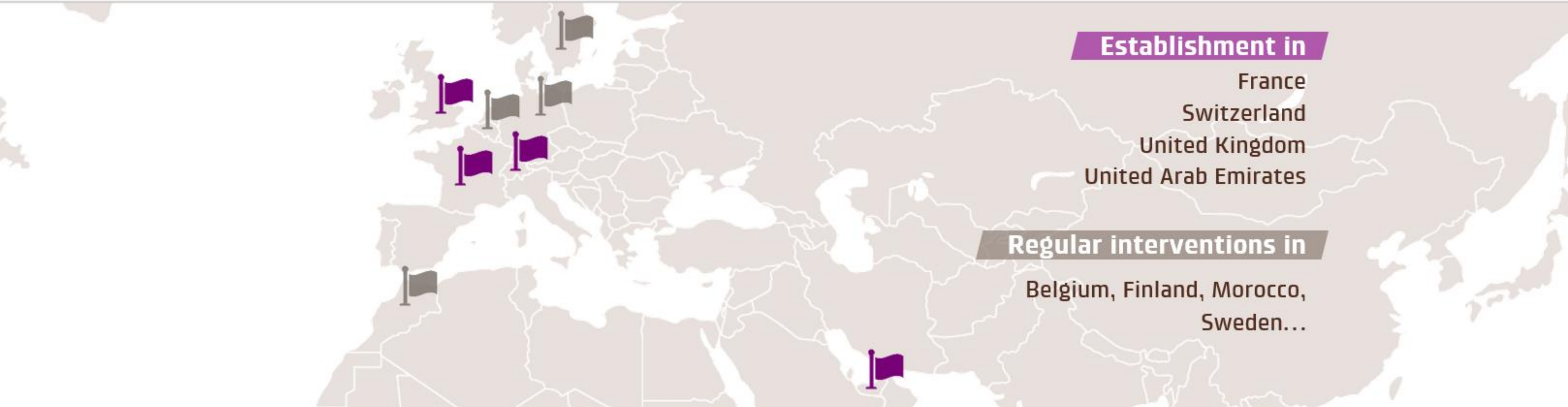
Scientific & technical manager

ATRON METROLOGY

CERAP and its subsidiaries at a glance

CERAP is 51% subsidiary of ALTRAD ENDEL,
French leader in nuclear services and industrial maintenance.





CERAP and its subsidiaries at a glance

created in
1988

600
employees
In 2021

€43,8M
turnover
in 2021

establishment in
France
Switzerland
United-kingdom
United Arab Emirates

10%
of payroll invested in
training

inpi
development
Of an autonomous equipment for radiological monitoring and mapping

inpi
1
particles accelerator

1
nuclear measures laboratory

ATRON, a technological platform in Normandy

FELIX: E-BEAM AND X-RAYS FACILITY

- ✓ Calibration of radiation survey meters
- ✓ Treatment of materials
- ✓ Qualification of electronic devices for nuclear or space applications

CALIBRATION OF SURVEY METERS

- ✓ 3000 devices per year
- ✓ Without radioactive source
- ✓ High metrological requirements
- ✓ In accordance with the ISO-17025 standard (COFRAC accreditation n° 2-6778)

Since 2018

2 PhDs

Turnover: 0,5 M€

Calibration of radiation survey meters

METROLOGICAL ADVANTAGE

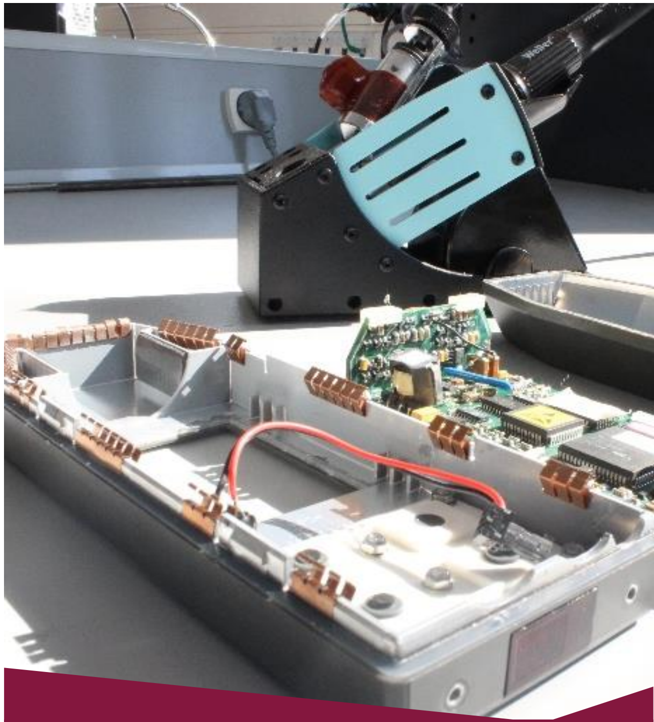
- ✓ Adaptation of the energy spectrum (1.25 MeV, 2.00 MeV, 3.00 MeV) to the measurement range of the instruments
- ✓ Adaptation of dose rates (20%, 50%, 80%) to each H*(10) range of instruments

ENVIRONMENTAL ADVANTAGE

- ✓ No radioactive source

AUTOMATION OF IRRADIATION SEQUENCES

- ✓ reliability of results
- ✓ reduction of instrument downtime



On-site repair

Contaminated instruments

Instrument rental service

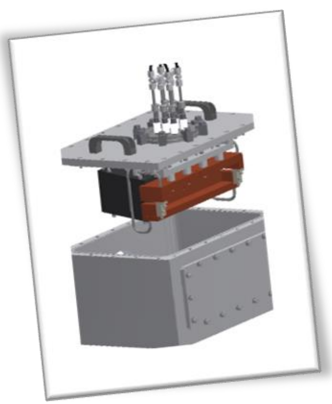
Electrons accelerator datasheet

ENERGY RANGE OF ELECTRONS

- From 0.2 to 3.5 MeV

ELECTRONS BEAM CURRENT

- From ~1 pA to 1 mA



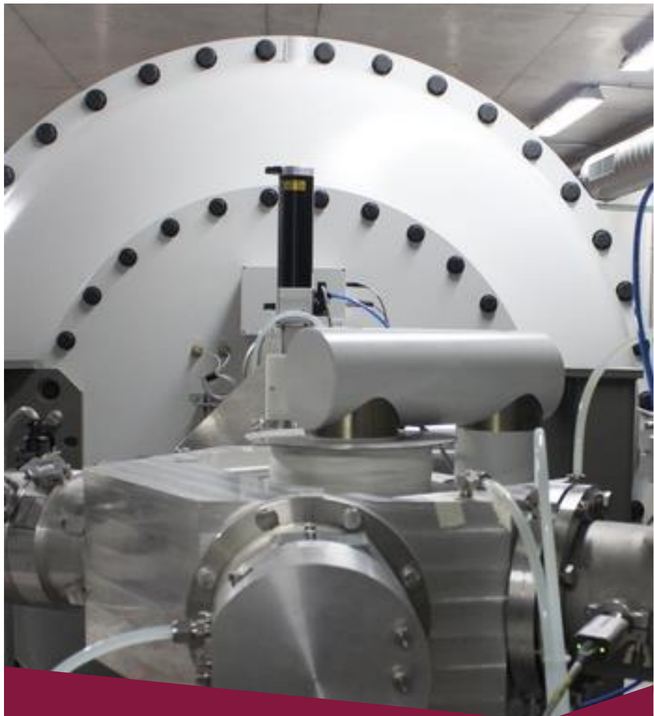
X conversion target

X-RAYS

- From 0.1 µGy/h to 500 Gy/h
  = 1 µrad/h – 50 krad/h
- Volumes up to few m^3
  (irradiation room size is 3×6 m²)

E-BEAM

- Up to 6×10^{15} e^-/s
- Beam spot size ~1 mm²

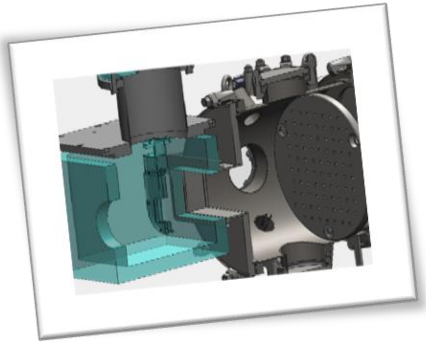


Electrostatic accelerator

Removable X-target

→ X-rays or ebeam

Irradiation chamber datasheet



internal cold plate

TEMPERATURE CONTROL

- From -200 °C to +300 °C

ATMOSPHERE CONTROL

- Under vacuum,
- In N_2, Ar, Air, etc.

VACUUM-TIGHT FEEDTHROUGHS

- Instrumentation during irradiation
- Window and camera available

EFFECTIVE SURFACE

- 300 mm in diameter for X-rays irradiations
- Up to 40×220 mm² in e-beam

Simulation of extreme environmental conditions

Irradiation services

TREATMENT OF MATERIAL BY IRRADIATION

- ✓ Innovation capabilities, scientific collaborations
- ✓ Extreme environmental conditions

ACCELERATED AGEING OF MATERIALS UNDER RADIATION

- ✓ Various applications in space or nuclear domains
- ✓ From coating (ebeam) to whole system (X-rays)

EQUIPMENT QUALIFICATION UNDER RADIATION

- ✓ TID effects on components and systems
- ✓ Continuity of service during equipment lifetime

Easy availability

Strong reactivity

Confidentiality culture

Effects of radiative environments on components

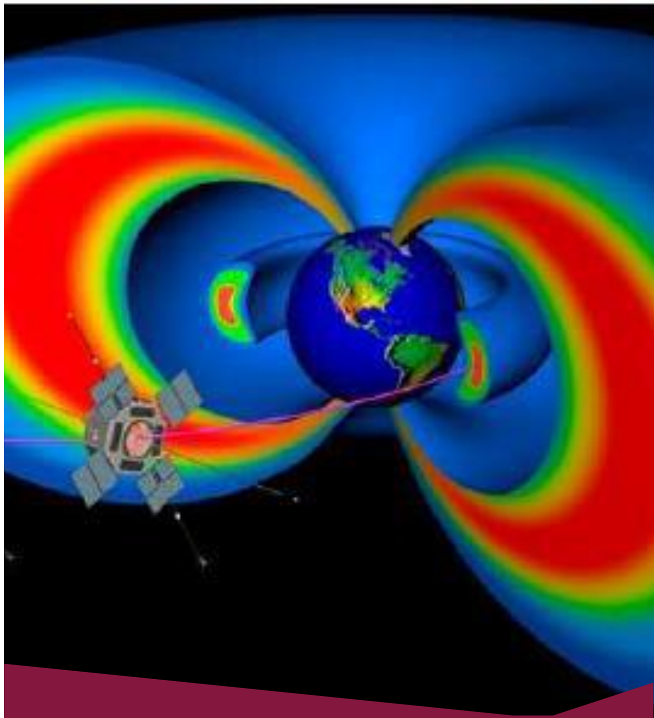
Effects of radiation on electronic devices and materials depends on:

- ✓ Type of radiation (photon, electron, proton, etc.)
- ✓ Rate of interaction
- ✓ Type of material (Silicon, GaAs)
- ✓ Component characteristics (process, structure, etc.)

CONSEQUENCES

- ✓ Single Events Effects (SEE)
- ✓ Displacement Damages (DD or TNID)
- ✓ Total Ionizing Dose (TID)

RADIATION EXECUTIVE TESTS



Electrons and protons trapped in Earth magnetic field (Lorentz force)

Single Events Effects

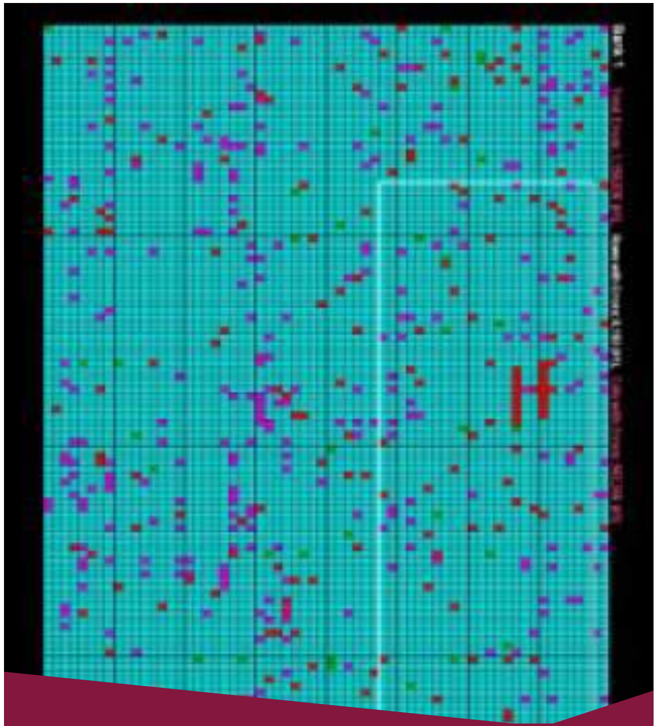
- ✓ SEEs are Random Events:
  1. Charge generation (direct orindirect ionization)
  2. Charge Collection and Recombination
  3. Circuit Response

- ✓ Many types of SEEs: SET, SEU, MCU, SEFI, ISB, SEL, SEB, SEGR/SEDR, etc.

- ✓ Single Events Effects (SEE) → LET ($MeV.cm^2/mg$)
  - ✓ Heavy ions

Ion	Total Energy (MeV)	Range in Si (µm)
^{84}Kr	1260	170
^{129}Xe	1935	156
^{165}Ho	2475	112

15MeV beams

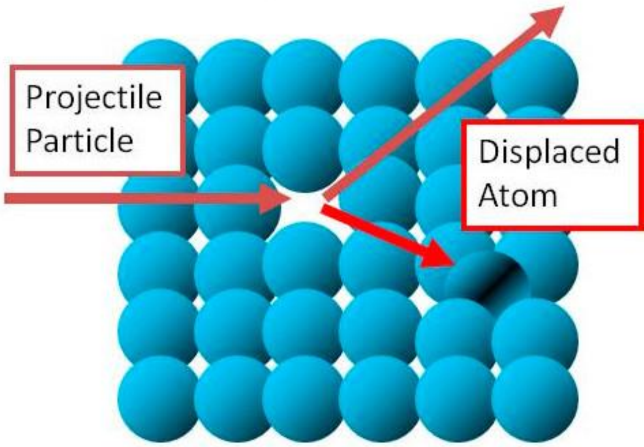


A SEE with a low probability of occurrence can occur the first day of a mission

Displacement Damages

- ✓ Sensor degradation is a significant constraint for payloads and star trackers (CCDs)
  - ✓ Increase of dark current (overall)
  - ✓ Hot pixels (→ reduction at low temperatures)
  - ✓ Charge Transfer Efficiency (CTE) degradation

- ✓ Displacement Damage (TNID) → NIEL (MeV.cm²/g)
  - ✓ Protons (most often in 40-60 MeV range)
  - ✓ Flux generally in the range of 10^7 to 10^8 p/cm²/s
  - ✓ Up to a fluence based on NIEL:
    - ✓ target material,
    - ✓ particle type and energy.



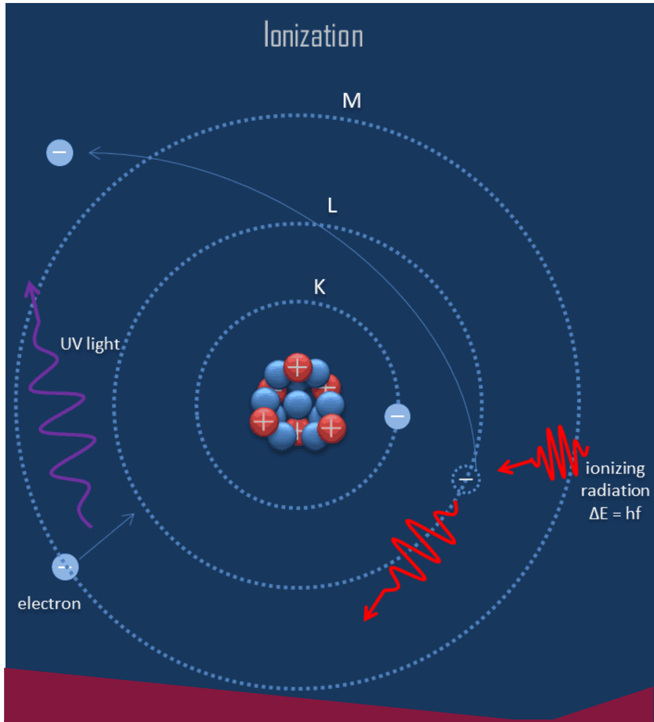
Frenkel pair after stable migration of vacancies and interstitials

Total Ionizing Dose

- ✓ Component degradation is very much dependent on a device technology, process and bias conditions

- ✓ TID is mainly a semiconductor oxide effect → $E_{EH}(SiO_2)$ = ~17 eV

- ✓ Total Ionizing Dose (TID) → D (Gy)
  - ✓ Dose rates most often higher than the actual operation dose rates
  - ✓ Co-60 Gamma rays
  - ✓ X-rays from ebeam



Excited electrons are freed from their bound state and create electron-hole pairs

Example of applications on electronics

CHARACTERIZATION OF RADIATION DETECTORS

- ✓ RADFETs components
- ✓ 3.5 MeV X-rays at 500 Gy/h (50 krad/h) for 20 hours to reach a total dose of 10 kGy (1 Mrad)

QUALIFICATION OF LED LUMINAIRES IN NUCLEAR ENVIRONMENT

- ✓ Equipment powered during irradiation, camera monitoring
- ✓ X-ray irradiation up to 9 kGy in air (Red Zone)

QUALIFICATION OF RF CABLES

- ✓ 240 keV ebeam scanned on a 160×160 mm² area for 10 hours at 80 nA/cm²

Representative spectrum

Large irradiation areas

(system / subsystem scale)

Example of applications on materials

ATRON METROLOGY ADVANCE ENGINEERING SEFC FORMATION CERAP RADIOPROTECTION

COATING TESTS

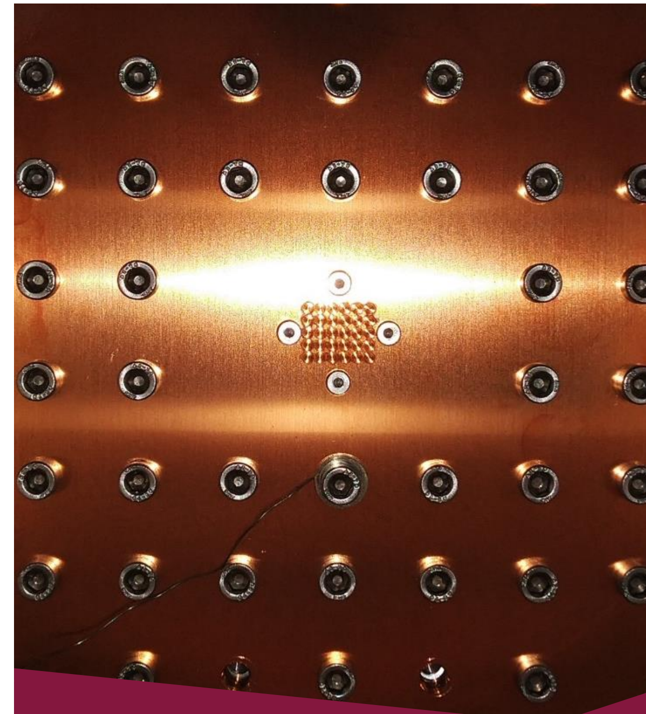
- ✓ Qualification for space applications
- ✓ 400 keV ebeam scanned on a 40×150 mm² area for 1 hour at 1 µA

CHARACTERIZATION OF PROTECTION SCREENS

- ✓ X-ray irradiation on various energy spectra
- ✓ Attenuation measurements

QUALIFICATION OF NUCLEAR STEELS

- ✓ 30 samples → nuclear ageing modelling
- ✓ 2 MeV ebeam scanned on a 20×20 mm² area for 15 days at 1 mA



Wide ranges of energy

Wide ranges of dose-rate

Temperature control

Example of R&D involvements

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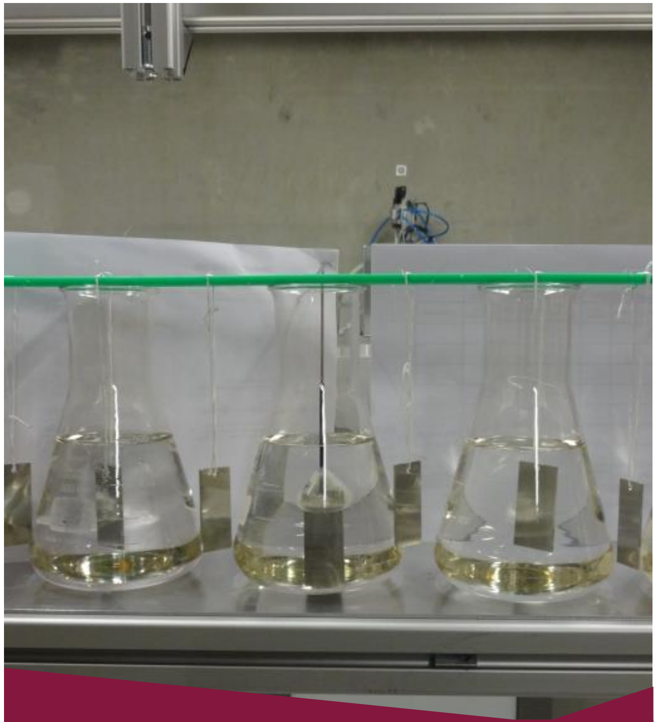
STUDY OF CORROSION/BIOCORROSION UNDER RADIATION

- ✓ Water radiolysis
- ✓ Nature of the sample and its representative medium

RADNEXT CONTRIBUTOR (H2020 PROGRAM)

- ✓ WP7-JRA3: cumulative radiation effects on electronics:
  - ✓ Determination of Co-60 / X-ray comparison
  - ✓ Provision of expertise for Monte-Carlo simulations (Geant4)



Tailor-made tests

R&D programs

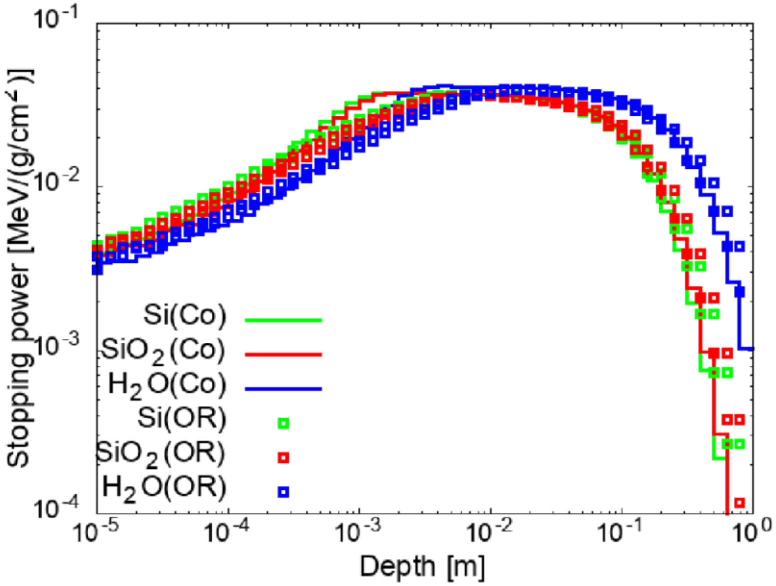
Flexibility

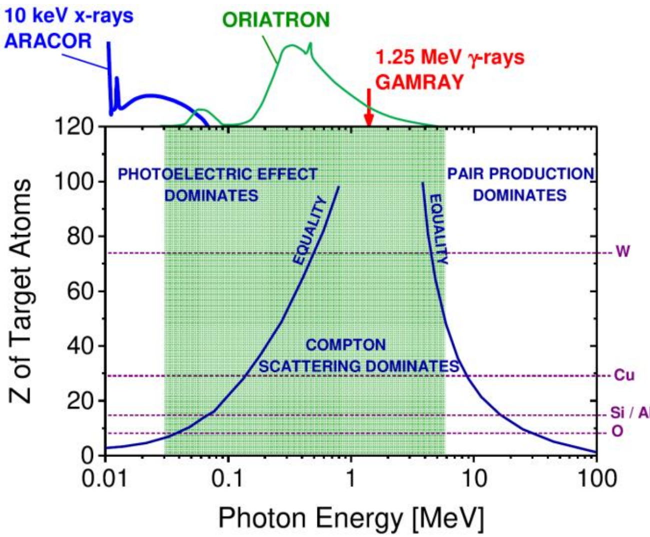
Innovation in regulations and standards

“The Use of High Energy X-Ray Generators for TID Testing of Electronic Devices”

RADECS conference, oct. 2022, V. Girones et al.

- ✓ Stopping power of photons from Co-60 and Mev-scale X-rays are the same, whatever is the material





IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 68, NO. 5, MAY 2021

Investigations on Spectral Photon Radiation Sources to Perform TID Experiments in Micro- and Nano-Electronic Devices, M. Gaillardin et al.

TID Effects Induced by ARACOR, 60Co, and ORIATRON Photon Sources in MOS Devices: Impact of Geometry and Materials, D. Lambert et al.

Innovation in regulations and standards

RCC-E CODE (AFCEN)

“Design and construction rules for electrical equipment of nuclear islands”

- ✓ **Gamma radiation from cobalt-60 shall be used, the radiation takes place in air**

WHAT ABOUT ASME, KTA, NIKIET, ETC.?

CLIENT BENEFITS

- ✓ Alternative solution to radiation qualification
- ✓ Higher representativity of a wide spectrum compared to gamma of cobalt-60
- ✓ Safety standards improvement
- ✓ Costs reduction

Radiation sources comparison

Nuclear applications

Representativity of tests

Optimization through innovation

ATRON OFFERS ALTERNATIVE TO THE USE OF RADIOACTIVE SOURCES

- ✓ Calibration of radiation survey meters
- ✓ Treatment of materials
- ✓ Qualification of electronic devices for nuclear or space applications

STRONG R&D INVOLVEMENT

- ✓ Study of corrosion/biocorrosion under radiation
- ✓ Cumulative radiation effects on electronics
- ✓ Reduction in the use of radioactive sources

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ANY QUESTION?

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“OPTIMIZATION THROUGH INNOVATION”