

WP07-JRA3 Cumulative radiation effects on electronics - Overview of WP7

Jerome BOCH

RADNEXT 3rd Annual Meeting – 10-11 June 2024

<https://indico.cern.ch/event/1348465/>



WP7 members

-  Université de Montpellier
-  ISAE-SUPAERO
-  Université de Liège
-  Université Jean Monnet Saint-Etienne
-  ATRON
-  Airbus Defence & Space



Jérôme Boch
WPL



Vincent Gailion
Deputy WPL



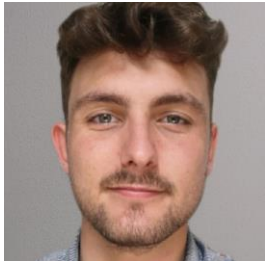
Alexandre LE ROCH
Deputy WPL

WP7 structure

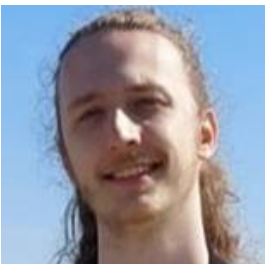
The main objective is to understand the physical mechanisms behind the damage caused by TID and TNID and to propose test methodologies adapted to the use of electronic components and systems in radiative environment.

Two main technical tasks are studied:

- **Task 7.1: Coordination and communication**
- **Task 7.2: The effects of ionizing dose (TID = Total Ionizing Dose)**
PhD recruitment from October 2021 (36 months) at UM
↳ end in October 2024
- **Task 7.3: The effects of non-ionizing dose (TNID = Total Non-Ionizing Dose)**
Postdoc recruitment from October 2022 (12 months) at ISAE-SUPAERO
↳ finished



Vincent GIRONES

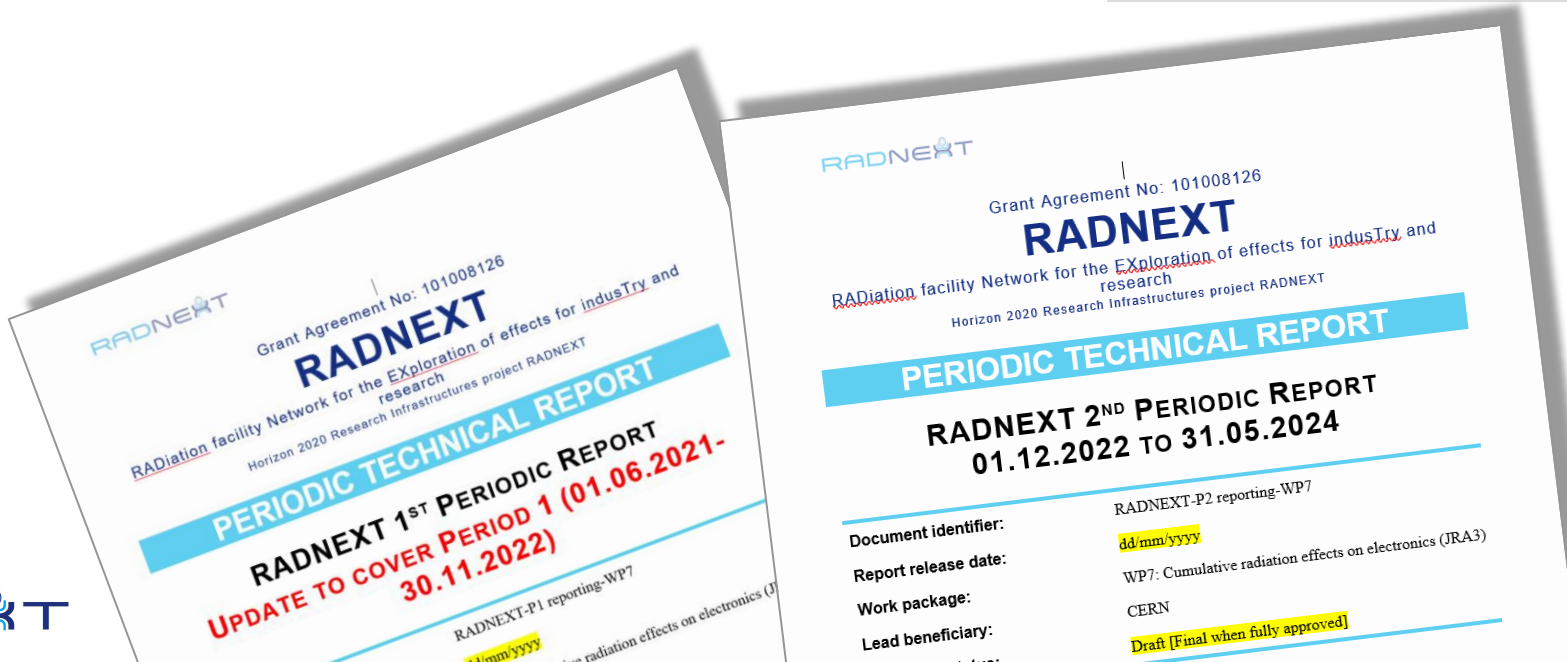


Maxence GUENIN

WP7 milestones, deliverables and reports

✓ MS24	X-ray ATRON Facility modelling	2023/05/31
✓ MS25	Comparison of X-ray / cobalt experimental data	2024/05/31
✓ MS30	Beginning of TNID irradiation campaign	2024/05/31

✓ D1	Comparison of X-ray / cobalt experimental data	2024/05/31
✓ D2	Published list of tested components against cumulative effects	2024/05/31
D3	Final TID results and guidelines for dose testing with X-ray facilities	2025/03/31
D4	Final TID results and guidelines for dose testing with X-ray facilities	2025/03/31



The report on the second period is currently being written

WP7 publications

- Journals: 2 IEEE TNS (2023, 2024)
- Conferences:
 - ✓ 2 poster presentations in RADECS (2022, 2023)
 - ✓ 1 poster presentation SERESSA 2022
 - ✓ 1 poster presentation DEM2024

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

Vincent Girones, Jérôme Boch, Alain Carapelle, Arnaud Chapon, Tadee Maraine, Timothee Labau, Frédéric Saigné, Rubén García Alía

Abstract— A high energy X-ray generator is studied in order to perform dose tests on electronic components. The main idea is to reduce the photoelectric effect in order to get closer to the Compton scattering. For this, the spectrum of the X-ray generator is filtered in order to cut on the low energy photons. Experimental results and simulations show that it is possible to filter the spectrum from this result, the filtered X-ray generator is used to study the dose response of the Cobalt 60 irradiation. The obtained data are analyzed and discussed. This work provides a first demonstration of the use of a filtered high energy X-ray generator for TID testing.

Index Terms— Total Ionizing Dose, X-ray, Cobalt-60, Dose testing, MOS, BJT.

1. INTRODUCTION

Electronic devices used in many space, military, accelerator and nuclear power plants systems may be exposed to Total Ionizing Dose (TID). For the use of these devices, it is essential to have test methods to determine the hardness in a radiative environment. A number of different standards and guidelines exist for testing TID effects. The most common are MIL-STD-883 test method (TM) 1019 for TID qualification and Radiation Let Acceptance Testing (RLAT) [1]. ESA ESCC Basic Specification No. 22900 [2], and ASTM F 1892 Standard Guide for Ionizing Radiation (Total Dose) Testing of Semiconductor Devices [3]. These standards specify dose testing using irradiation from ⁶⁰Co gamma sources, electron beams, or ⁶⁰Co or Cesium-137 (¹³⁷Cs) irradiators. X-ray generators (approximately 10 keV) X-ray generators and low energy (approximately 10 keV) X-ray generators are used for total ionizing dose testing of electronic devices and systems. MIL-STD-883 TM 1019 and ESA ESCC No. 22900 specify 60Co for total ionizing dose testing of electronic devices and systems. It is usually considered as the reference irradiation source to perform TID tests on electronic devices and systems. Although ESA ESCC No. 22900 allows the use of Cesium-137 irradiators, ASTM F 1892 allows the use of X-ray generator. It is recommended to use X-ray generators for TID testing of electronic devices.

Comparison of High Energy X-ray and Cobalt 60 irradiations on MOS capacitors

Vincent Girones, Jérôme Boch, Frédéric Saigné, Alain Carapelle, Arnaud Chapon, Tadee Maraine, Rubén García Alía

Abstract— The use of a high energy X-ray generator for Total Ionizing Dose testing is studied on MOS capacitors. Several conditions were studied for the high energy X-ray irradiation (with aluminum and lead filters) and the experimental results are compared to Co-60 irradiations. The effects of annealing and dose rate are also studied. All the results are presented and discussed. It is shown that the simple BEOL stack (only one thin aluminum layer) has no effect on dose deposition in the oxide of MOS capacitors.

Index Terms— Total Ionizing Dose, high energy X-ray, Cobalt-60, Dose testing, MOS Capacitor.

1. INTRODUCTION

Over the past decade, efforts have been made to reduce the world's dependence on high-level radioactive sources, particularly Cobalt 60 (⁶⁰Co) and Cesium 137 (¹³⁷Cs). These sources are used in commercial, medical, and research applications throughout the world. The main objective of this work is to replace high-risk radioactive sources with less risky alternatives in order to enhance radiological security strategy, to reduce the environmental impact of these sources, and to foster an act of radiological security. Total Ionizing Dose (TID) testing of electronic components and systems for reliability, accelerator and nuclear power plants applications, such as radiation testing standards such as MIL-STD-883 test method (TM) 1019 for TID qualification and Radiation Let Acceptance Testing (RLAT) [4], ESA ESCC Basic Specification No. 22900 [5], and ASTM F 1892 Standard Guide for Ionizing Radiation (Total Dose) Testing of Semiconductor Devices [6]. These standards specify electronic devices and systems to be tested with ⁶⁰Co gamma sources, electron beams, or ⁶⁰Co or Cesium-137 (¹³⁷Cs) irradiators. X-ray generators are used for total ionizing dose testing of electronic devices and systems. MIL-STD-883 TM 1019 and ESA ESCC No. 22900 specify 60Co for total ionizing dose testing of electronic devices and systems. It is usually considered as the reference irradiation source to perform TID tests on electronic devices and systems. Although ESA ESCC No. 22900 allows the use of Cesium-137 irradiators, ASTM F 1892 allows the use of X-ray generator. It is recommended to use X-ray generators for TID testing of electronic devices.

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

Vincent Girones, Jérôme Boch, Frédéric Saigné, Rubén García Alía

Abstract— The use of a high energy X-ray generator is filter presented and discuss

Objective

To perform TID testing, the use of a high energy X-ray generator is filter presented and discuss. The objective is to achieve a penetration depth and an deposition on the Z of the material reason why we have a

Introduction

The use of a high energy X-ray generator has recently been proposed to performed TID testing [1] but can be filtered!

Results

The TASCiCs tool has been used to simulate irradiation conditions for the four investigated irradiation conditions.

Experimental parameters

Build condition	Area (mm²)	Area (cm²)	Area (in²)
1	252	0.039	0.015
2	400	0.062	0.024
3	400	0.062	0.024
4	345.15	0.053	0.021

Results

From each spectrum, TID can be calculated. For x-ray irradiation, the degradation obtained is higher than that obtained with Al + Pb low energy photons to that with cobalt.

Conclusion

Degradation closer to 60Co when the contribution (insulating layers) that is

Comparison of High Energy X-rays and Cobalt 60 irradiations on MOS capacitors

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Experimental parameters

Type	Filter	Dose Rate (Gy(Ar)/h)	Length Source-Target (mm)	Conditions n°
Cobalt 60	Nothing	0.52	1200	1
Cobalt 60	Nothing	0.52	1200	2
Cobalt 60	Nothing	5.28	330	3
Cobalt 60	Nothing	5.28	400	4
Cobalt 60	2mm Al	30	400	5

Results

The TASCiCs tool has been used to simulate irradiation conditions for the four investigated irradiation conditions.

Conclusion

Degradation closer to 60Co when the contribution (insulating layers) that is

An alternative to Cobalt-60 for TID testing of electronic systems with high-energy X-ray generators

Vincent Girones, Jérôme Boch, Frédéric Saigné, Tadee Maraine, Timothee Labau, Alain Carapelle, Arnaud Chapon, Rubén García Alía

1. Introduction

To perform TID testing, we study the use of a high energy X-ray generator allowing to obtain photons up to 320 keV. These conditions are far from optimal for component testing where the goal is to achieve a high penetration depth on the Z of the material. This energy photons. This cut is realized with a lead (Pb) filter.

2. X-ray

The TASCiCs tool has been used to simulate irradiation conditions for the four investigated irradiation conditions.

3. Methods

Type	Filter	Dose Rate (Gy(Ar)/h)	Length Source-Target (mm)	Conditions n°
Cobalt-60	Nothing	0.52	1200	1
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Cobalt-60	Nothing	5.28	400	4
X-ray	2mm Al + 2mm Pb	30	400	5

4. Results

Custom-Made CMOS Capacitor (100nm oxide):

Between all irradiation conditions and BEOL with low-Z materials, no gap is observed between all irradiation conditions. The addition of a high-Z material as BEOL induces dose enhancement and more degradation for irradiation with many low-energy photons (Al/Pb filtered X-rays only).

Generic commercial NMOS Transistor with unknown BEOL:

Same trend as Au metallized MOS capacitor are measured with commercial MOSFETs. Use filter and get low energies offer closer result to 60Co whatever the X-ray voltage from 320kV to 250kV.

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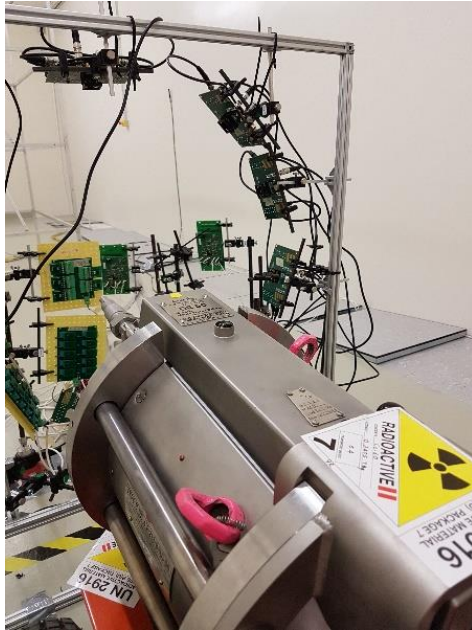
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Cobalt-60	Nothing	5.28	400	4
X-ray	2mm Al + 2mm Pb	30	400	5

5. Conclusion

We have shown that the use of a high energy X-ray generator allows to obtain photons up to 320 keV. These conditions are far from optimal for component testing where the goal is to achieve a high penetration depth on the Z of the material. This energy photons. This cut is realized with a lead (Pb) filter.

Thanks for your attention!



*Cobalt 60 Irradiator
Source: UM*



*3.5 MeV e-beam Accelerator
Source: ATRON*