DRD3

WG3 - Discussion on radiation damage

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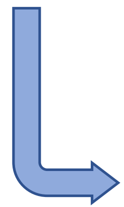
WG3 projects

Title	Contact person
1) **RD50-2023-05: PAB -** Partial Activation of Boron to enhance the radiation tolerance of the gain implant	Valentina Sola, INFN Torino
2) **RD50-2023-06: Impact ionization parameterization at extreme fluences**	Gregor Kramberger, JSI
3) **RD50-2023-07: PIN sensors for dosimetry & NIEL studies**	Michael Moll, CERN
4) **RD50–2022-01:** Defect engineering in PAD diodes mimicking the gain layer in LGADs	Ioana Pintilie, NIMP



The base for a wider project proposal for WP3, DRD3-2024-05:
Radiation damage in Boron-doped Silicon diodes and LGAD sensors

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Project proposal: Radiation damage in Boron-doped Silicon diodes and LGAD sensors

Description

The project address both, **experimental and theoretical aspects related to radiation induced damage in Silicon**, ***covering the full range from low to high and extreme fluences beyond 2x10^{16} n$_{eq}$/cm^{2}*** and contributes to some of the research goals of **WG3 & WG4** (RG 3.2, RG3.3, RG3.4, RG4.2, RG 4.3, RG 4.4).

The **final goal** of the project is to ***achieve a fundamental scientific understanding of radiation damage processes in Si detector material at low, high, and extreme radiation levels and find ways to increase the radiation hardness of Silicon sensors***

For this, several ***specific objectives*** has to be reached:

O1*) Understand the gain loss in Silicon LGADs exposed to irradiation fluences above 10^{15} n$_{eq}$/cm^{2};*

O2*) Establish the role of B, C, O and P in the formation of electrically active defects in Si PiN diodes exposed to irradiation fluences above 10^{15} n$_{eq}$/cm^{2} and find ways to improve the Si based devices*;

O3*) Model the defects formation, dynamics and metastabilities in connection with doping and extrinsic impurities;*

O4*) Device modeling and parametrization of radiation effects in Si over a large fluence range and in connection with doping and extrinsic impurities;*

O5*) Fabricate LGADs with optimized defect engineered gain layers*

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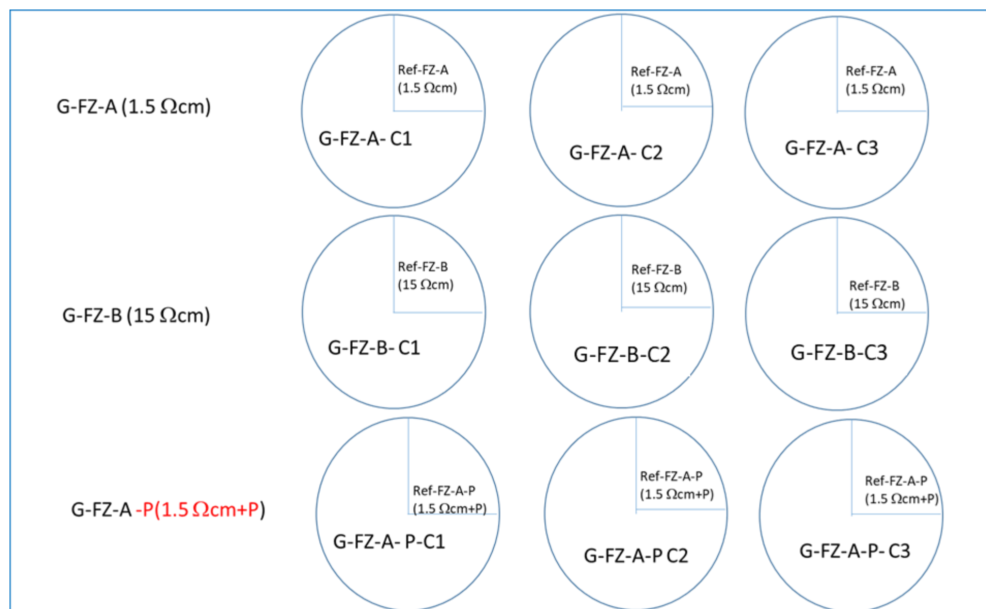
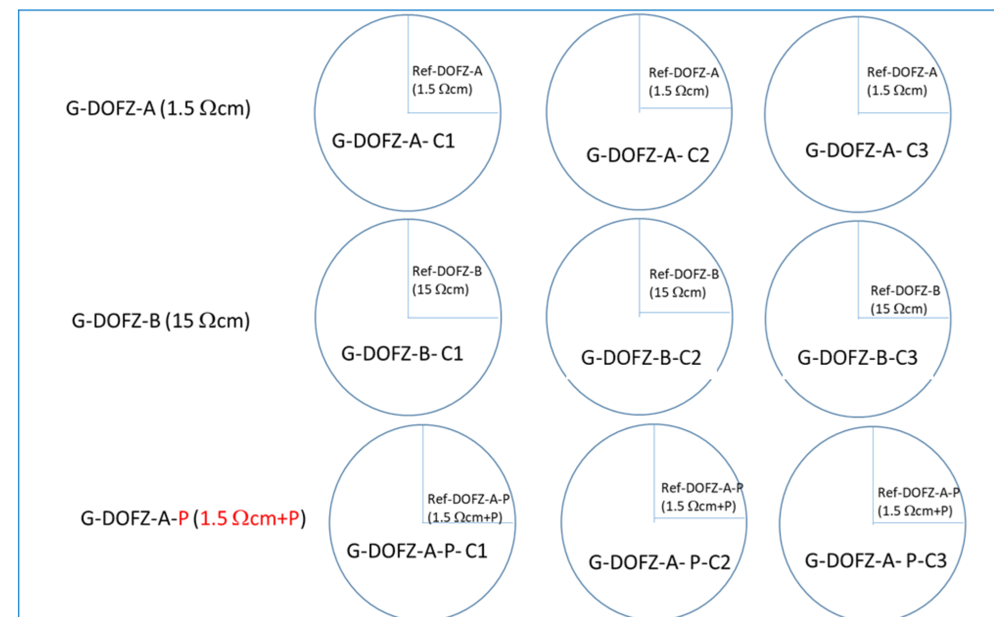
1) Fabrication of PiN samples mimicking the gain layer in LGADs (G-type diodes, RD50 – 2022 -01 project)

9 STFZ (O ~10^{16} cm^{-3}) and 9 DOFZ (O ~ $5x10^{17}$ cm^{-3})

- 3 of 1.5 Ω cm with different C implantations
- 3 of 15 Ω cm with different C implantations
- 3 of 15 Ω cm resulted from compensation with P of 1.5 Ω cm wafers





Samples will be available for characterization in January-February 2025

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2) Characterization of as processed G-type diodes and LGAD sensors (WG2) (2025)

- *Structural and chemical characterization (e.g. SIMS, **FTIR**, **PL**) – determine real concentration of impurities*
- *Electrical characterization* (e.g. IV/CV, DLTS, TCS, carrier lifetime, **Hall**)
- LGAD sensors fabricated in **PAB** project (RD50-2023-05) and in **WG2** would also fit very well in this common project

3) Irradiation - *up to 1×10^{17} n_{eq}/cm^2* (2025-2026)

4) Experimental studies of irradiated G-type diodes and LGAD sensors (2025-2027)

- *Electrical characterization (IV/CV, TCT, CCE, lifetime, Hall)*
- *Detection and characterization of radiation induced defects (DLTS, TSC, FTIR, PL) – annealing studies*

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5) Assessment of the role played by O, C and P impurities in the formation of defects in low resistivity Boron doped Si after irradiation fluences above 10^{16} n_{eq}/cm^2 (2025-2027)

- *Defect kinetics experimental studies, establish the dependencies of the defects introduction rates in the gain layer of LGADs on the impurity content*
- *Parametrization of radiation damage in Silicon devices on large range of fluences and with respect to impurity content*
- *Model defect' distribution, configuration, metastabilities and electronic properties (Geant4&TRIM , molecular dynamics and ab initio calculations), calibration of computational models with the experimental results*
- *Device modelling of PiN and LGAD devices with radiation defects by COMSOL, TCAD*

→ ***Elaboration of the further strategy for fabricating optimized defect engineered LGADS***

6) Fabrication of optimized defect engineered LGADs (2027-2028)

Fabrication of LGADs with gain layers optimized with respect to C, O, B and P content

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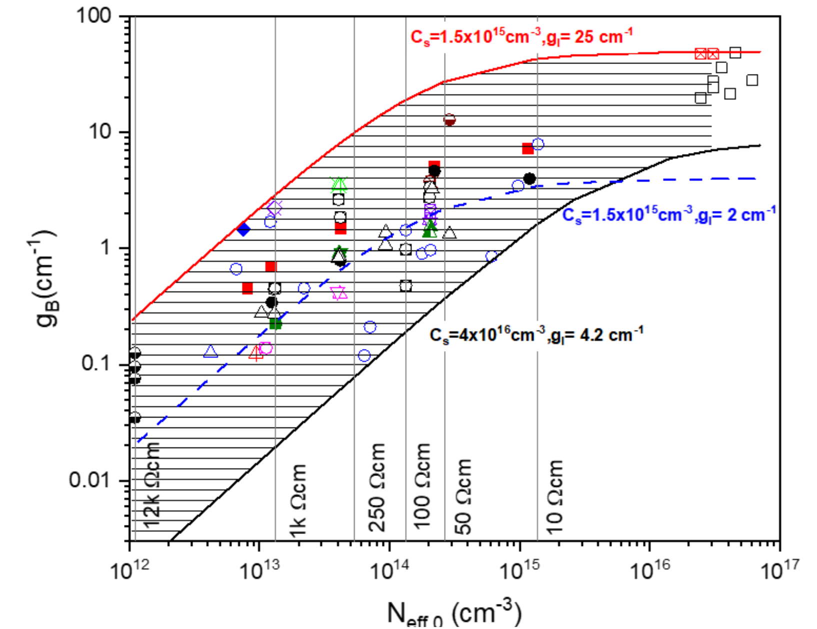
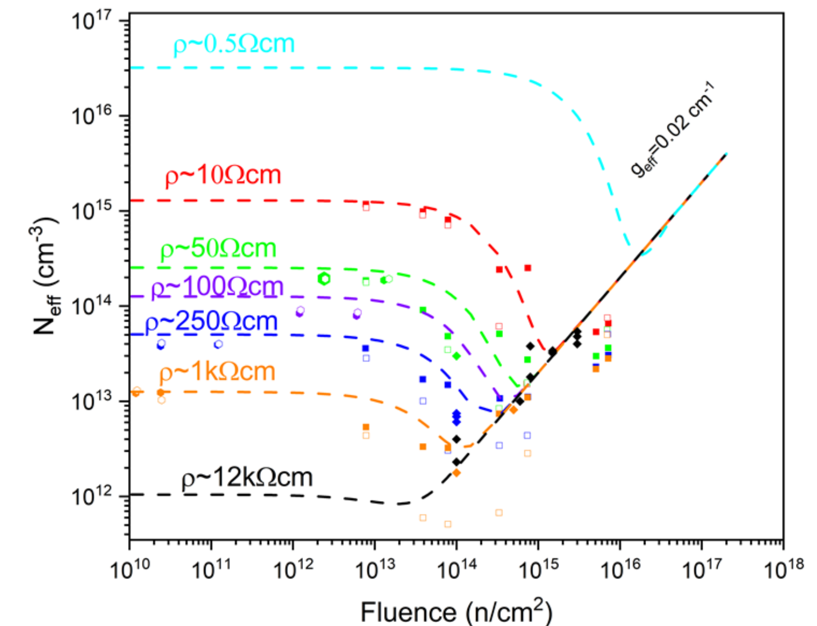
What we expect from investigations of G-type diodes?

- Reveal all the electrically active defects induced by irradiation over a large range of fluences, from low to extreme (generated via a 1st and 2nd order processes) providing real inputs for simulations

- Determine g_B c_a and g_I values for different O, C and P impurity content in highly doped gain layers of LGADs, understand the gain loss in LGADs and find defect engineered solutions to minimize this effect

- By accounting also, the existing results on more the resistive Silicon diodes it become possible to develop knowledge-based parametrization models for differently defect engineered Silicon sensors and over a large range of fluences, from low to extreme





Project proposal: Radiation damage in Boron-doped Silicon diodes and LGAD sensors

Institutions involved so far (already from RD50 and from DRD3)

Country	Collaborating Institution	Town	Institution Code	Contact
Germany	CiS Forschungsinstitut für Mikrosensorik GmbH	Erfurt	CiS	Kevin Lauer
Germany	Institute for Experimental Physics, University of Hamburg	Hamburg	UHH	Jörn Schwandt
Italy	INFN Torino	Torino	Torino	Valentina Sola
Lithuania	Vilnius University	Vilnius	VU	Tomas Ceponis
Romania	National Institute of Materials Physics	Magurele	NIMP	Ioana Pintilie
Romania	Horia Hulubei National Institute for R\&D in Physics and Nuclear Engineering	Magurele	NIPNE	George Alexandru Nemnes
Romania	Institute of Space Science - INFLPR Subsidiary	Magurele	ISS	Alexandru Florin Dobrin
Slovenia	Jožef Stefan Institute	Ljubljana	JSI	Gregor Kramberger
Switzerland	CERN	Geneve	CERN	Michael Moll

WG3 projects proposals on WBG materials – presently missing

However,

- Defect investigations in n-type SiC planar PAD diodes are already started within **RD50 Common Project 4H-SiC LGADs and are foreseen in WG6 proposal on SiC LGADS** and **groups from WG3 are involved**
- Studies on **n-type SiC Schottky diodes** will also start soon (samples in hand)