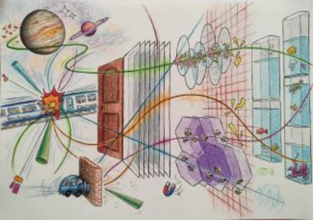

DRD3

Material and Defect Characterization

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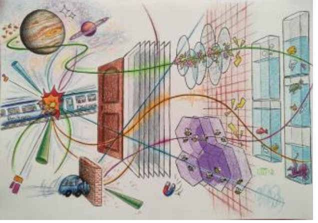
on behalf of the DRD3 proposal writing team

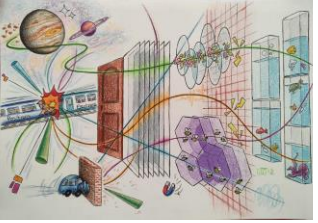


Aim

DRD3

Understand the fundamental damage processes in different type of materials and sensors, defect formation, impact of defects on device performance

- reveal and characterize the radiation induced defects and evaluate their impact on sensor properties
- provide the input defect parameters to the simulation groups to predict detector performance under various conditions.
- provide the knowledge for developing strategies for material and defect engineering



Interest

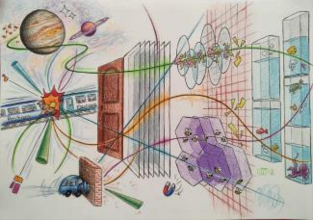
DRD3

Silicon sensors - Characterization and modelling of radiation damage effects. Enhance the radiation tolerance and understand limits of operation

- Develop and characterize Si devices for enhanced radiation tolerance after extreme fluences - $1E^{16}$ – 10^{18} n/cm^2
    - Schottky and PIN diodes, LGADs, ASGADs, 3D sensors, active and passive pixel sensors, CMOSs
- Development of radiation damage models for Silicon at extreme fluences, including NIEL scaling

Non Silicon sensors (WBG and other) - Characterization and modelling of radiation damage effects.Understand the limit of operation

- Develop **SiC** based sensors, including LGAD detectors for ultra-fast timing, fabrication and characterization, ion irradiation effects, high hadron irradiation fluence studies
- **Diamond** and **3D diamond detectors** for high radiation resilience and neutron detection, discrimination of different radiation types, detector development for niche applications in HEP and outside
- Development of a high radiation tolerant particle detector by **CIGS (CuInGaAs)**
- Explore **GaN, GaAs, GaO** and **CdTe** devices for radiation damage/detection, Thin film studies with **InP** and other materials for use as sensors in future tracking detectors
- Explore **organic semiconductor** radiation detectors for neutron/charged hadron detection/photon detection
- Understand the effects of NIEL and TID in novel materials (Silicon carbide, GaN, CIGS, etc) and provide input to TCAD models, produce radiation damage model



Techniques available in the community

DRD3

Investigation of radiation induced defects:

1) ***DLTS, TSC, TSCap, EIS, PICS, TAS*** - fluences below 5×10^{15} n_{eq}/cm^2

- provide the electric parameters and the concentration of defects induced by irradiation - inputs for modelling the radiation damage

- Extrapolation to higher fluences possible by employing both, modelling of defect generation including the higher order radiation induced defects and other techniques (see below)

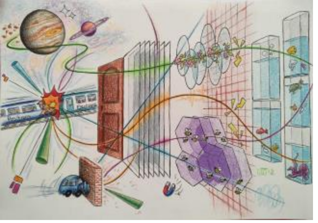
2) ***EPR, PL, FTIR, RAMAN, NMR*** – fluences above 10^{16} n_{eq}/cm^2

- Although relevant – poor expertise in the community

Most of the experimental techniques require measurements with temperature

- For Si sensors – plenty of appropriate experimental setups (10K-300K)
- For WBG sensors – only few suitable experimental setups (70K-800K)

Transport properties of charge: TCT, Hall effect, CCE, EBIC, IBIC
Impurity content: SIMS, LA-ICPMS
Microstructure: XRD, SEM, TEM
Modelling: TCAD, GEANT4, DFT



Milestones

DRD3

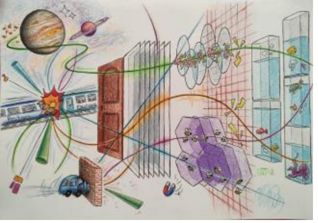
For 2026

M1) Develop radiation damage models based on microscopically measured point and cluster defects for irradiation fluences up to 10^{16} n_{eq}/cm^2

- Experimental determination of defect and transport properties in as grown and defect-engineered sensors
- Develop measurement procedures/techniques and computing models for quantitative defect analyses describing the temperature and electric field dependent measured signals in devices which cannot be fully depleted
- Parametrization of the acceptor removal process (ARP) in Silicon for various content of B, P, C and O impurities
- Develop radiation damage model for the explored WBG and other materials
- Develop defect-engineering strategies for increasing the radiation tolerance. Conclude about the role of the intentional added impurities in generation and kinetics of the radiation induced electrically active defects and identify the optimized concentrations of impurities for pads, LGADs and HVCMOSs to be next produced

M2) Characterize the defects induced by irradiation with fluences 10^{16}-10^{18} n_{eq}/cm^2

- Structural identification of defects in as grown and defect-engineered sensors after extreme fluences, annealing studies
- Work on radiation damage model, extrapolation and new developments
- Conclude about the role of the intentional added impurities in generation and kinetics of the radiation induced electrically active defects and identify the optimized concentrations of impurities for pads, LGADs and HVCMOSs to be next produced



Milestones

DRD3

For 2029

M3) Defect engineered optimized devices with increased radiation tolerance

- develop defect engineered sensors with predicted optimal concentration of impurities
- measure defect and transport properties from low irradiation fluences to up to 10^{18} n_{eq}/cm^2
- comparison prediction and experimental results
- refine the radiation models
- identify solutions for optimization of the investigated materials