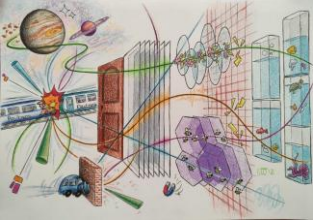
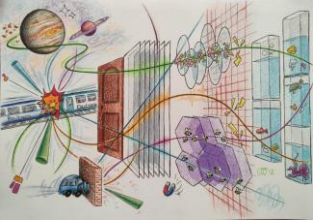


Progress of SiC and GaN as particle detector

Xin Shi & Tao Yang
On behalf of DRD3 Collobration

24 July 2026

34th International Workshop on Vertex Detectors

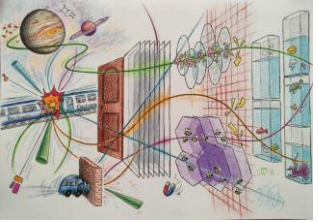


SiC and GaN in WG6

- WG6 Research goals in DRD3 Scientific Proposal

WG6 research goals <2027	
	Description
RG 6.1	Development of small cell 3D diamond detectors (cages / interconnects, base length 25 μm) and possible exploitation of impact ionization
RG 6.2	Fabrication of large area SiC and GaN detectors, improve material quality and reduce defect levels.
RG 6.3	Improve tracking and timing capabilities of WBG materials
RG 6.4	Apply graphene and/or other 2D materials in radiation detectors, understand signal formation.

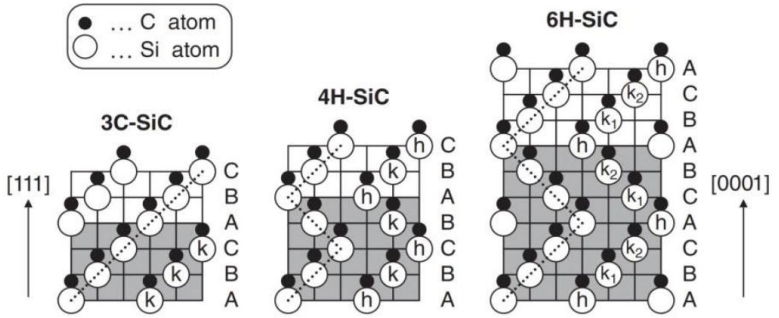
Table 11: WG6 research goals in the period 2024 - 2026

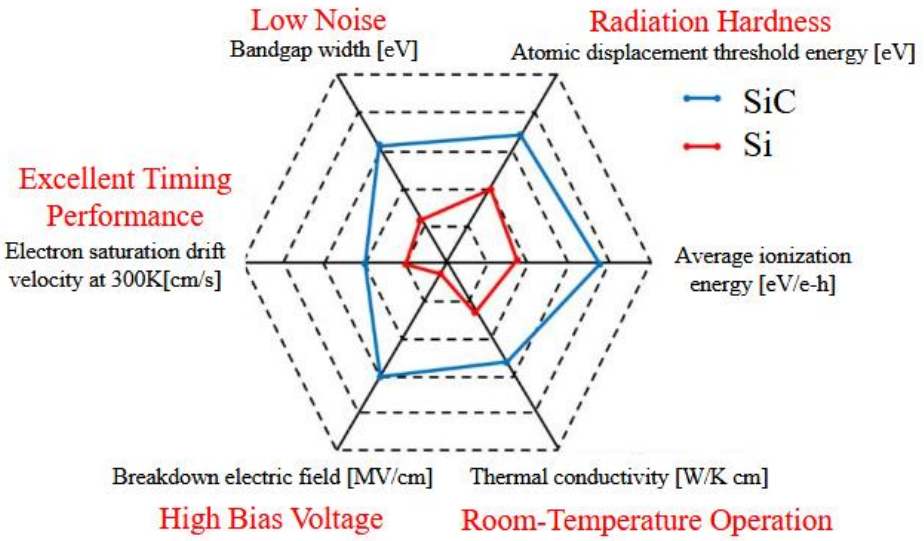


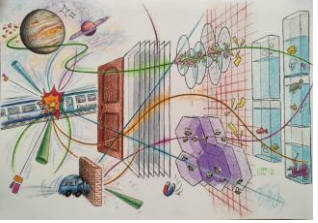
SiC as Particle Detector

- Advantages over Silicon

Physical Properties	Silicon	SiC
Bandgap width [eV]	1.12	3.26
Thermal conductivity [W/K cm]	1.5	4.9
Breakdown electric field [MV/cm]	0.3	2.0
Atomic displacement threshold energy [eV]	13	22
Average ionization energy [eV/e-h]	3.6	7.8
Electron saturation drift velocity [cm/s]	1e7	2e7
Hole saturation drift velocity [cm/s]	0.6e7	1.8e7

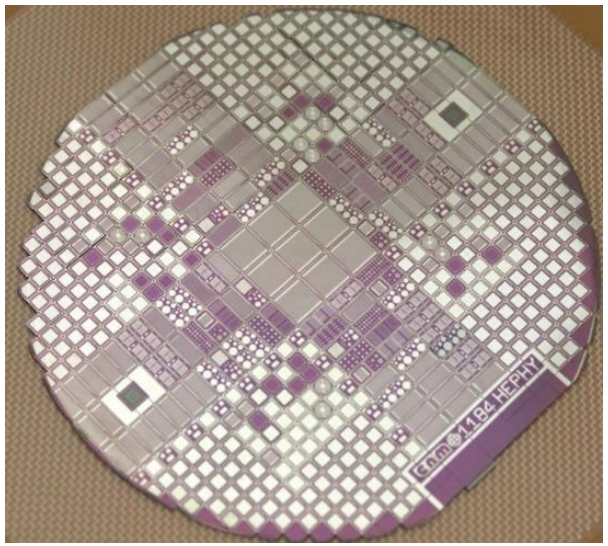


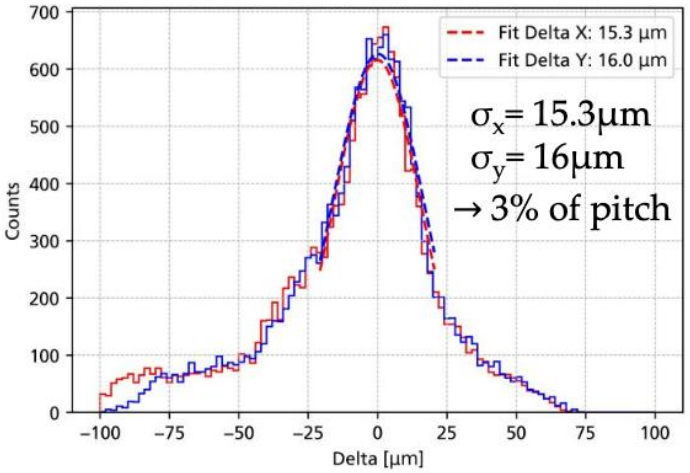




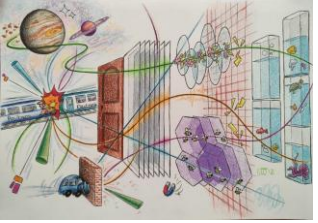
SiC-LGAD from HEPHY/CNM

- RD50 SiC-LGAD Common Project
  - 2 PiN + 1 LGAD run
  - design by HEPHY, production at CNM
- 2 wafers: 1x50µm and 1x 100µm epi thickness
- PAD diode yield increased over first produciton
- Strip sensnors show excessive leakage (>1nA below 20V bias)
- 500 µm pitch resistive devices measured with spatial res. ~15µm



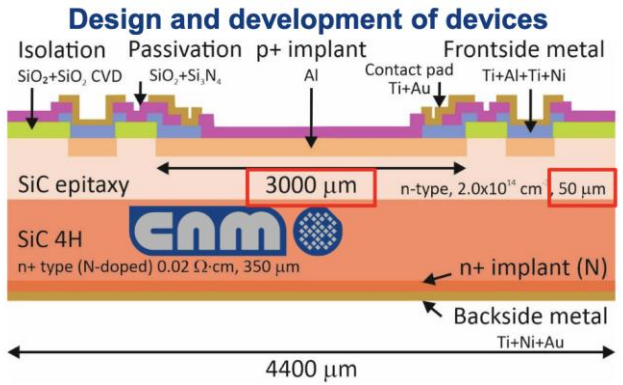


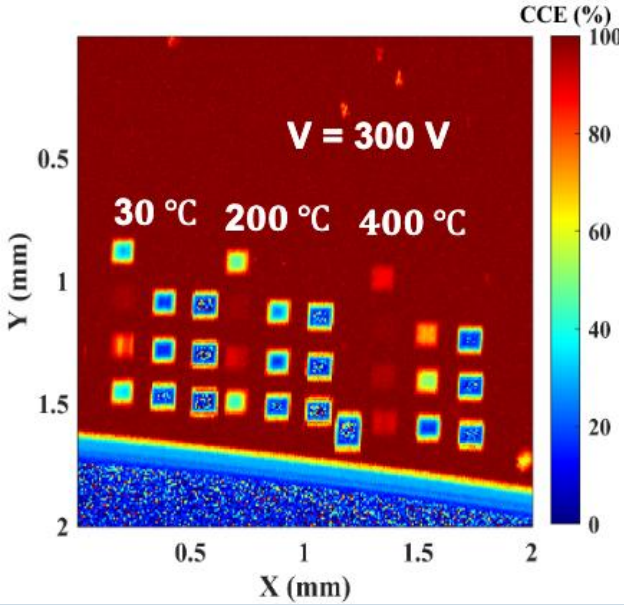
S. Onder talk on 4th DRD3 Week



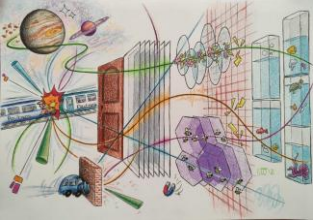
SiC for alpha particle detection

- Development of SiC detector for alpha particle detection in plasma diagnostics
- Detector response improves when irradiated at higher temperatures
- Operating the device in high-temperature environments results in less spectrometric degradation compared to room temperature, effectively extending the device's lifetime



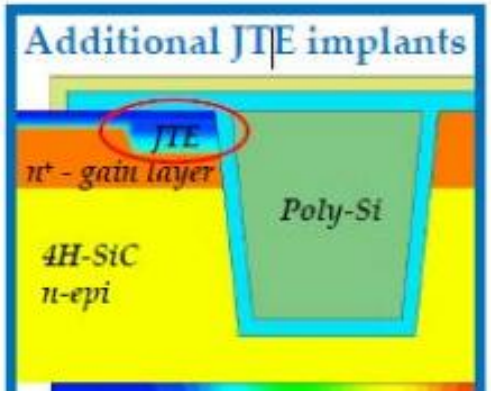


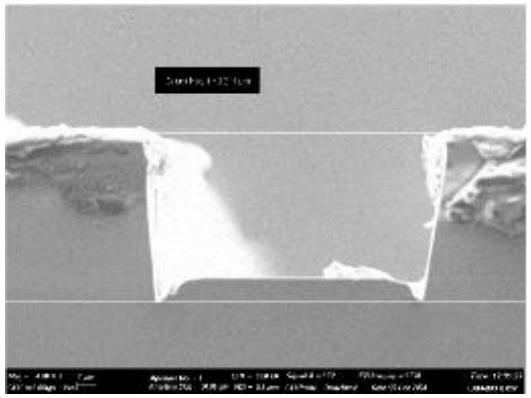
C. Torres-Munoz et. al. talk on the 3rd DRD3 week.

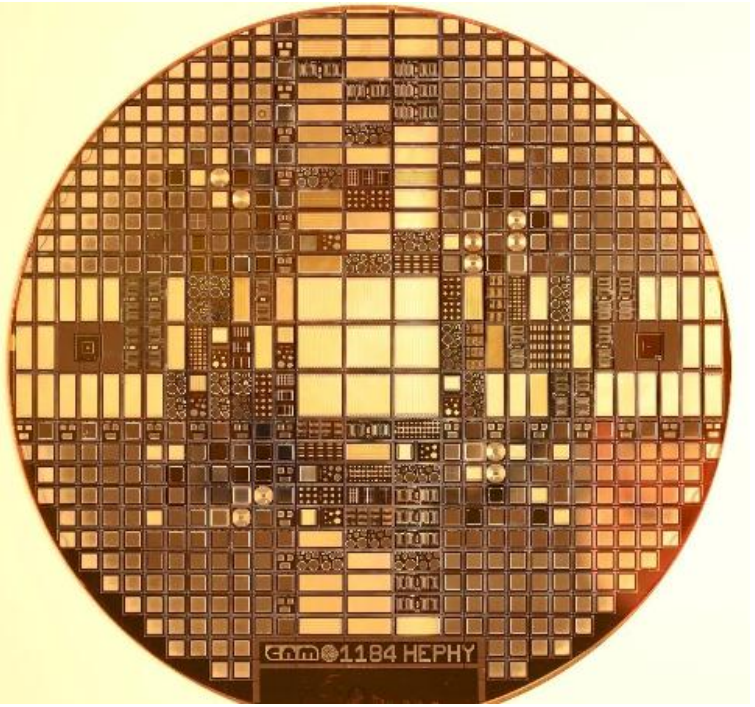


SiC for harsh environments

- Development of SiC detectors for harsh evnironments
- Fabricated three wafers: 50µm, 100µm epi, high doped substrate dummy
- SiC-LGAD with ultra deep implantation and deep reactive ion etching, up to 10µm

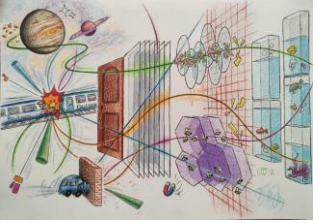






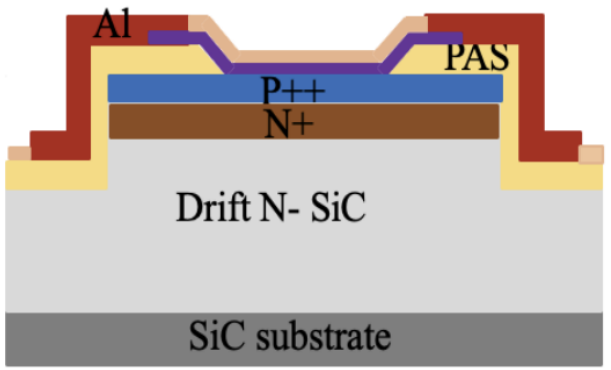
Full depletion voltages:
- 50um ≈ 300V
- 100um ≈ 2200V

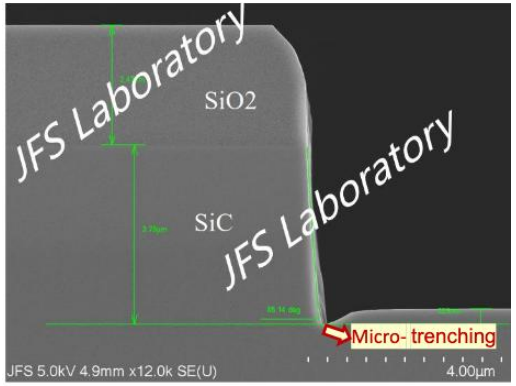
G. Pellegrini, et. al. 3rd DRD3 week

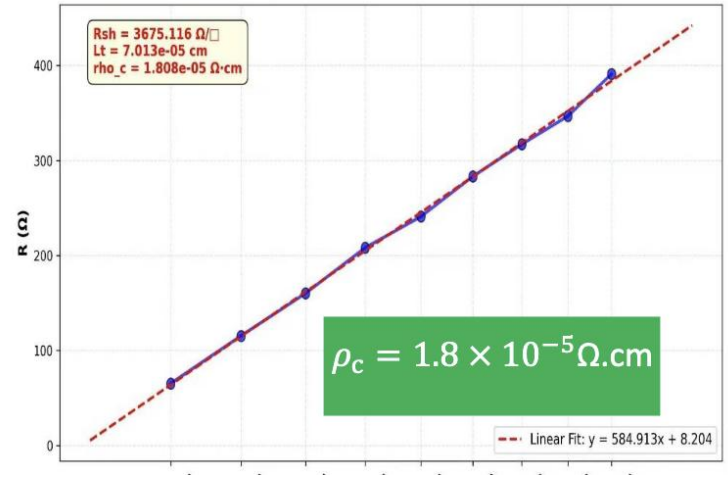


SICAR1/2 by IHEP

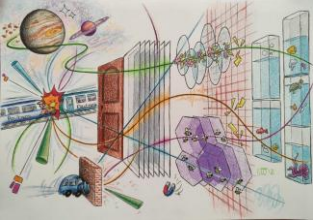
- SICAR 1.2 PIN:
  - Low yield due to photoresist residue
  - Promising X-ray radiation hardness
- SICAR2 LGAD (2025.11~ ongoing)
  - 350 nm MOSFET Process with Stepper Lithography
  - Single Reticle Field : 2cm x 2cm
  - 6-inch epi wafer / 98.2% yield
  - Ohmic contact optimization completed
  - Problems discovered in the Etch Termination structure
  - Delayed due to deep etch termination & Metal etch issues





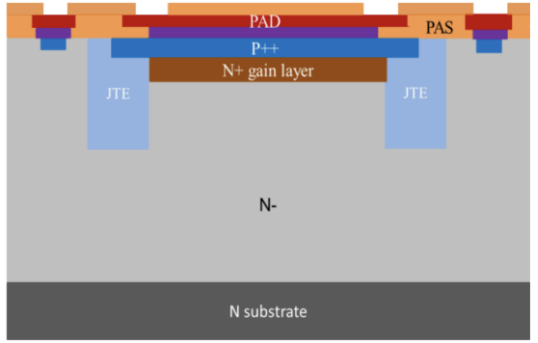


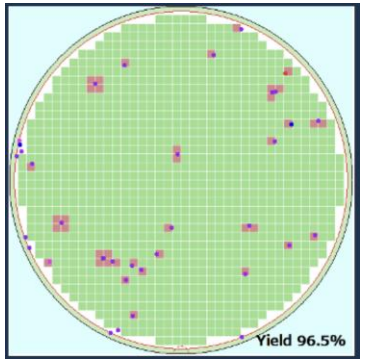
X. Zhang 4th/5th DRD3 week

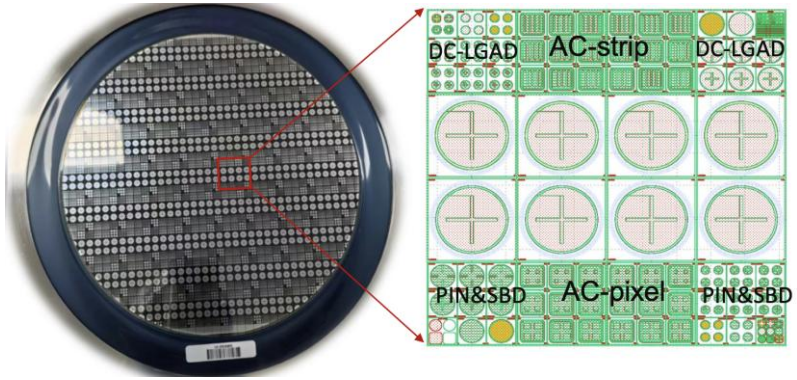


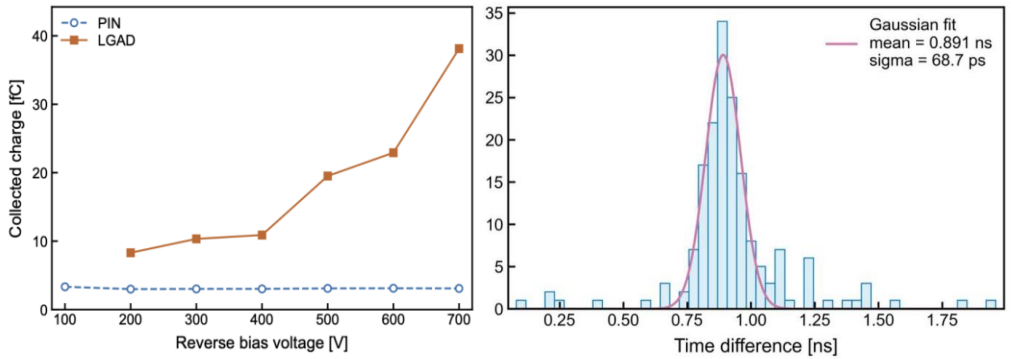
SICAR3 by IHEP

- 350nm MOSFET Process Platform
- High-energy ion implantation & High-temperature post-implantation annealing
  - N+ gain layer / P++ layer / JTE Termination
- 8-inch epi wafer / 96.5% yield
- Leakage current reaches ~1 μA at 1000V in LGAD
- Charge collection reaches ~12× that of the PIN @ 700V;
- Time resolution of SICAR3 ~55 ps (d~1.4mm) @ 400V

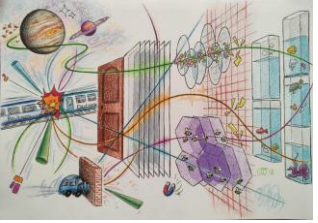






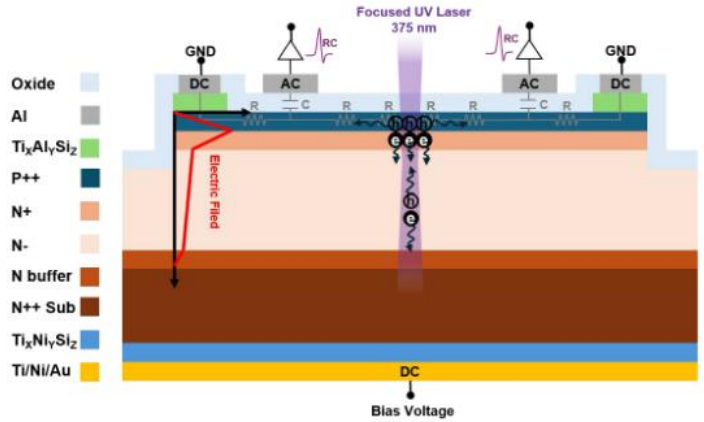


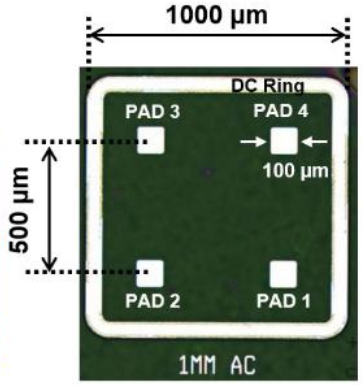
X. Zhang talk on 5th DRD3 week

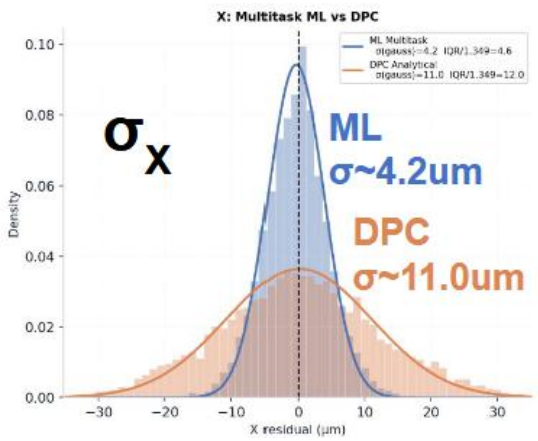


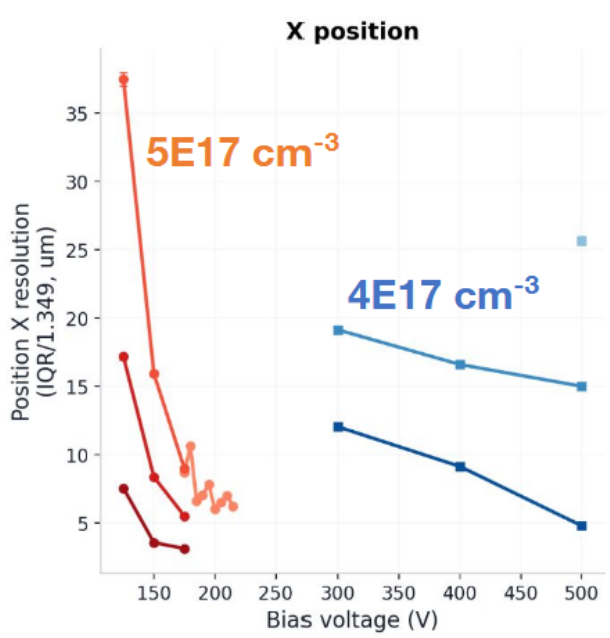
SiC-LGAD by LBL/NCSU

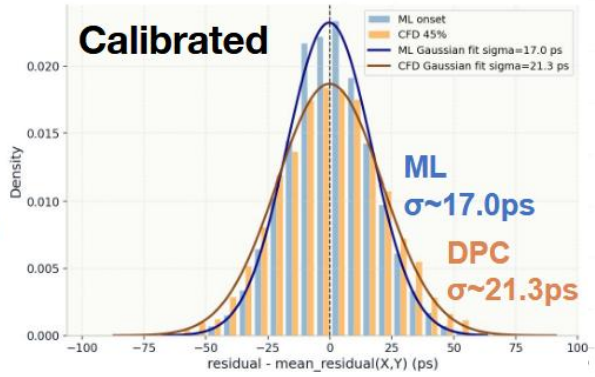
- Gain layer: 0.5 um
- Gain layer doping: 4E17 cm-3 and 5E17 cm-3
- Gain factor: 2~10 and 10~100

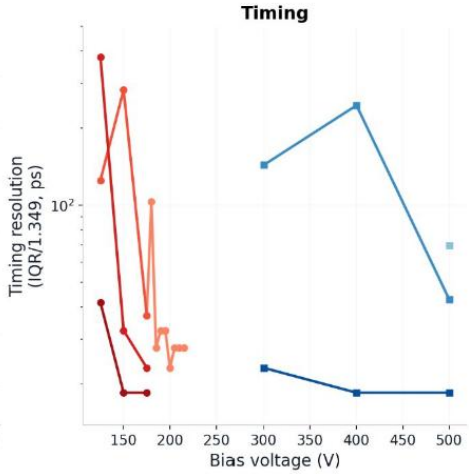




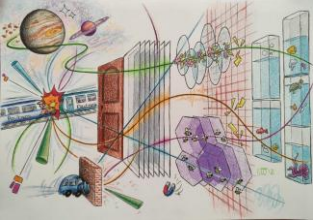








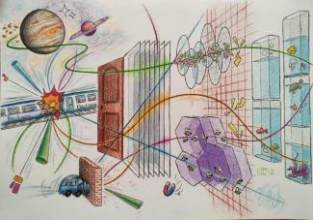
C. Yang 5th DRD3 Week



GaN proposal status

WG6 research goals <2027	
	Description
RG 6.1	Development of small cell 3D diamond detectors (cages / interconnects, base length 25 μm) and possible exploitation of impact ionization
RG 6.2	Fabrication of large area SiC and GaN detectors, improve material quality and reduce defect levels.
RG 6.3	Improve tracking and timing capabilities of WBG materials

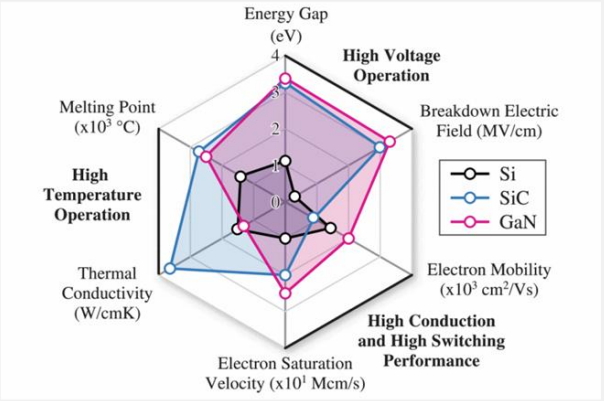
- Proposal in CDS:
  - CERN-DRD3-PROJECT-2024-001
- Deliverables:
  - D1 : Improve material quality [STARTED]
  - D2 : Establish radiation hardness at >10^{16} neq/cm^2 [STARTED]
  - D3 : Develop device simulation
  - D4 : High-temperature operation [STARTED]
  - D5 : Ageing effects
  - D6 : Monolithically integrate transistors and sensors on same substrate



GaN project progress

Introduction

GaN Properties

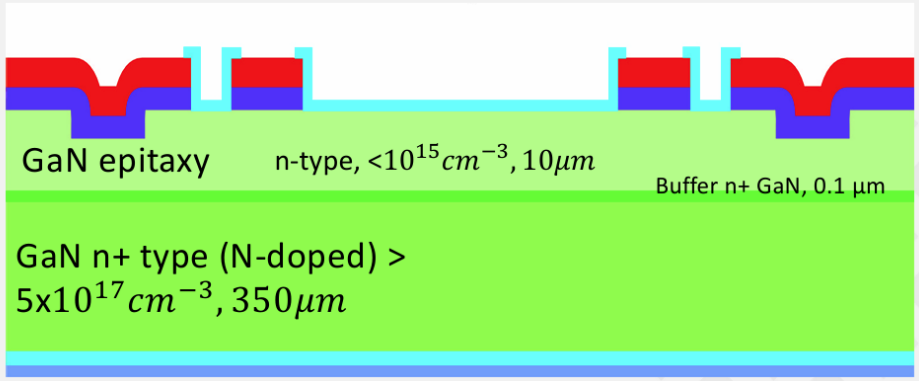


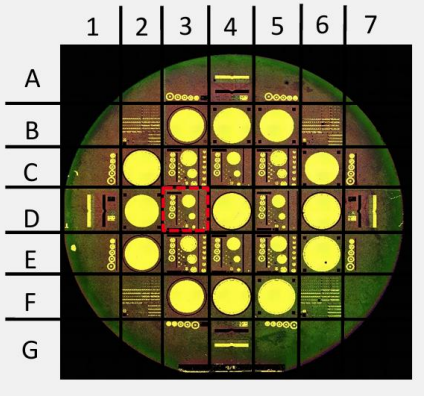
Parameter	Description	Si	SiC	GaN
E_g (eV)	Energy Gap – Band Gap	1.12	3.26	3.39
μ_n (cm^2/Vs)	Electron Mobility	1430	900	2000
v_n (Mcm/s)	Electron Saturation Velocity	10	20	25
E_b (MV/cm)	Breakdown Electric Field	0.3	3.0	3.3
λ_{th} (W/cmK)	Thermal Conductivity	1.5	3.7	1.3
T_m (°C)	Melting Point	1414	2730	2500

D. Cittanti, et al., IEEE Access, v. 10, 51693 - 51707, 2022

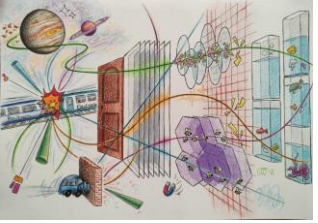
CERN RD50 collaborative funded project (fabrication, characterization & evaluation of GaN devices

- 2 GaN bulk n-type + n- epilayer 2-inch wafers received at **NRC-CNRC**
- 2 GaN bulk n-type + n- epilayer 2-inch wafers received at **IMB-CNM**
- GaN Schottky diodes fabrication at NRC-CNRC
- GaN Schottky diodes fabrication at IMB-CNM





[4th DRD3 week : Temperature-Dependent Electrical Characterization of GaN Homoepitaxial Schottky Diodes for Radiation Detection]

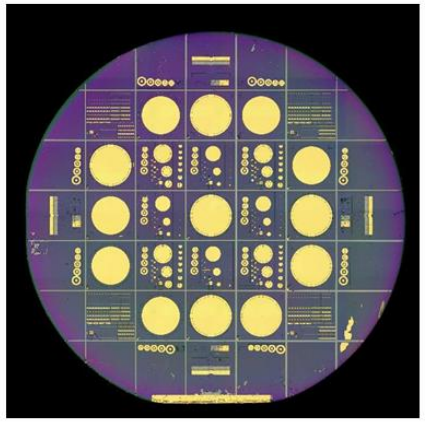


GaN project progress

Status of GaN Schottky diodes fabrication at IMB-CNM

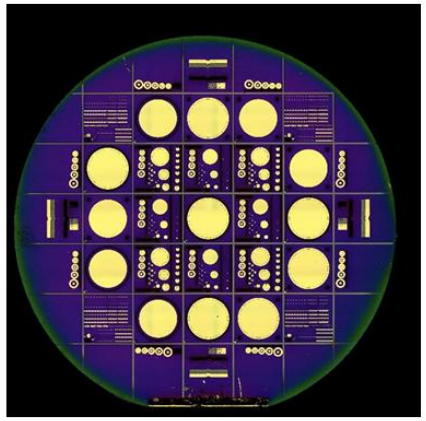
- Preliminary electrical characterization before Schottky metal RTA
- Reasonable I-V and C-V area dependence and extracted parameters

Wafer 1
Si bulk p-type



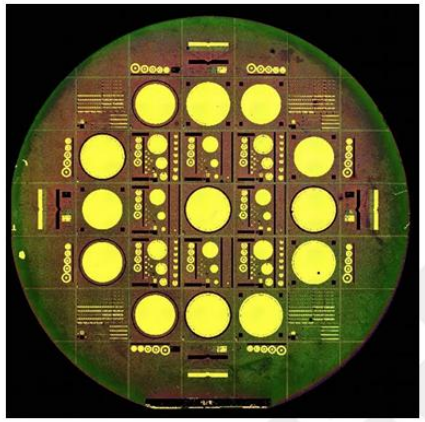
Currently @step #48
RTA already done

Wafer 2
GaN bulk n-type



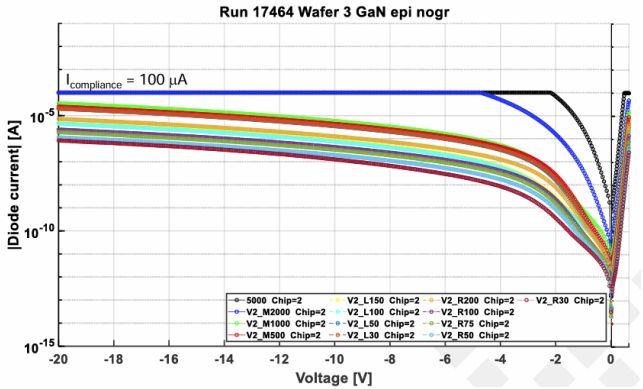
Currently @step #47
RTA still not done

Wafer 3
GaN bulk n-type + n⁻ epilayer
Kyma RD50 wafer

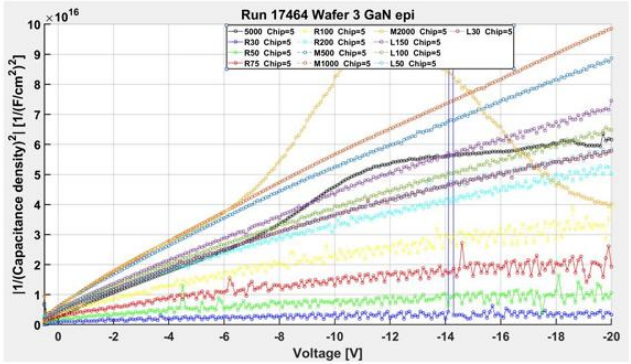


Currently @step #47
RTA still not done

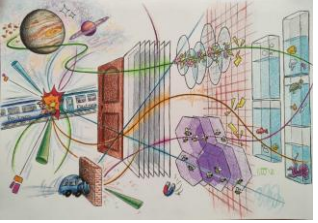
I-V



C-V



[2nd DRD3 week : GaN Schottky Diodes Fabrication at IMB-CNM - Preliminary Results]



GaN project progress

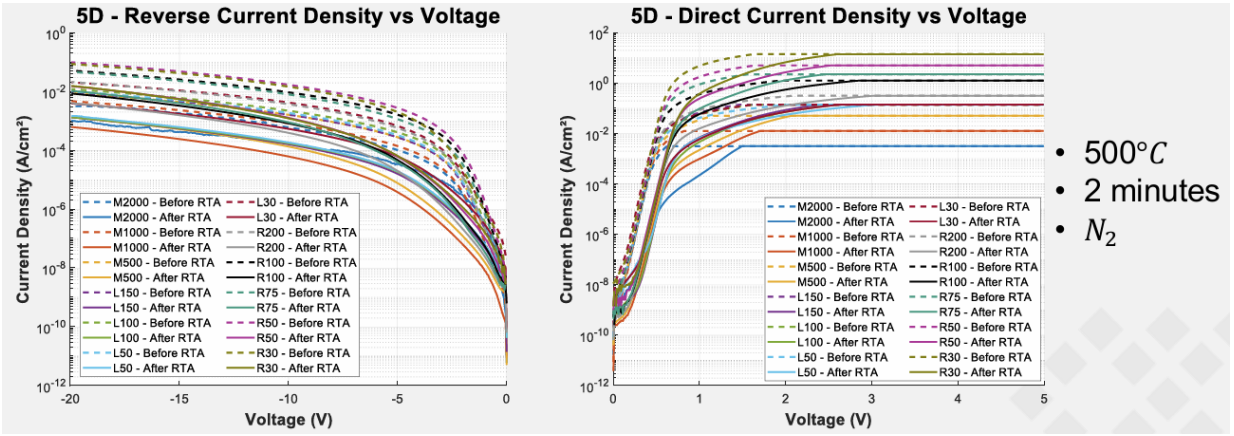
Status of RD50 GaN Schottky diodes fabrication at IMB-CNM

Works focused on GaN bulk n type + n- epilayer Kyma RD50 wafer.

- After rapid thermal annealing leakage current decreased
- I-V-T and C-V-T measurements have been carried out.
- Some analysis has been done to try to explain the trends (Ongoing).

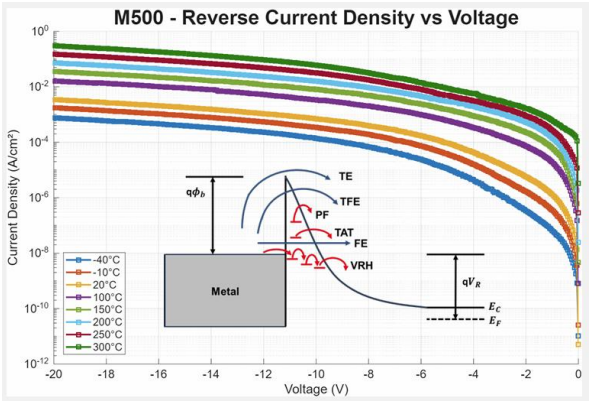
[4th DRD3 week : Temperature-Dependent Electrical Characterization of GaN Homoepitaxial Schottky Diodes for Radiation Detection]

Initial Measurements (Before and After Schottky Metal RTA)

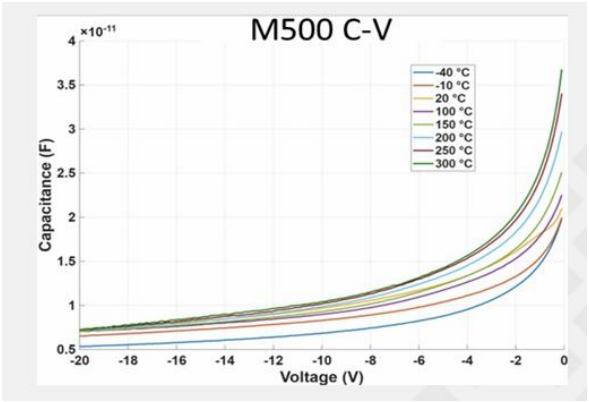


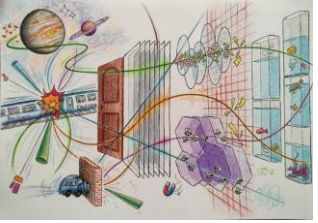
- $500°C$
- 2 minutes
- N_2

I-V-T



C-V-T

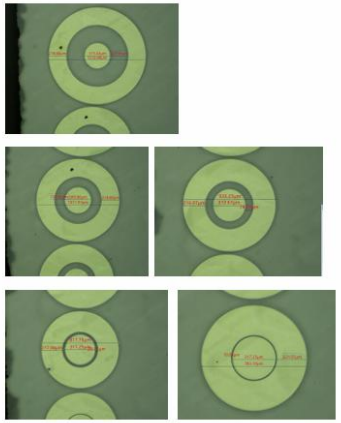




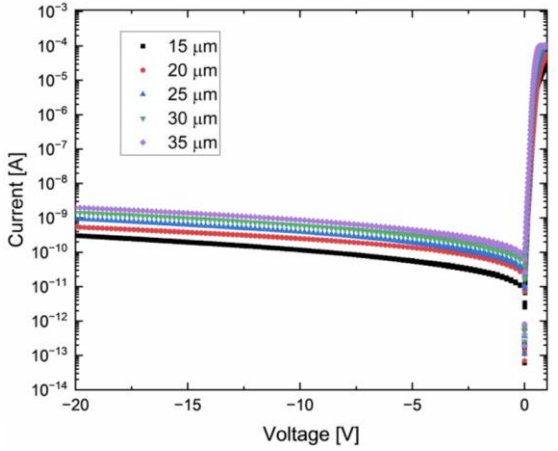
GaN project progress

Status of GaN Schottky diodes fabrication at NRC Advanced Technology Facility

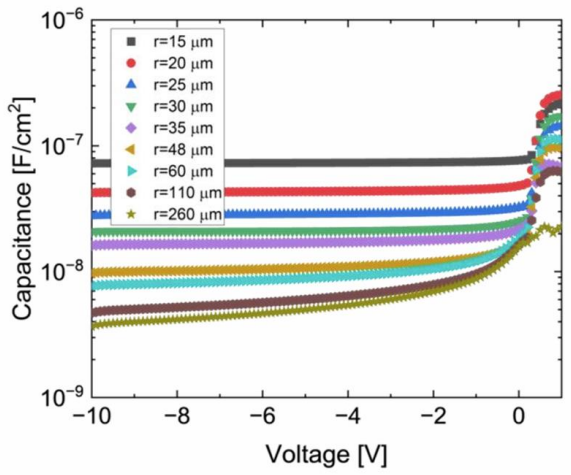
- GaN Schottky devices based on epi-layers grown on native substrates have demonstrated low leakage with no soft breakdown behavior
- low doping of 8µm epi-layer
- trap parameters are in good agreement with observations in unirradiated GaN sample



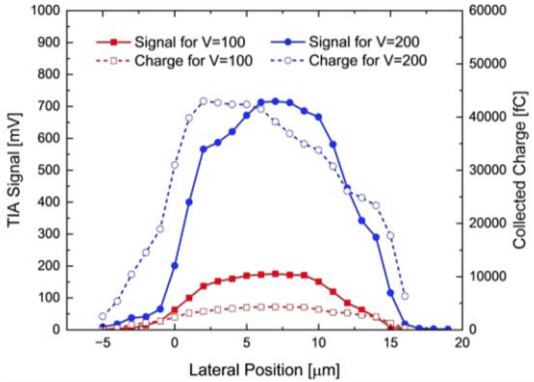
I-V



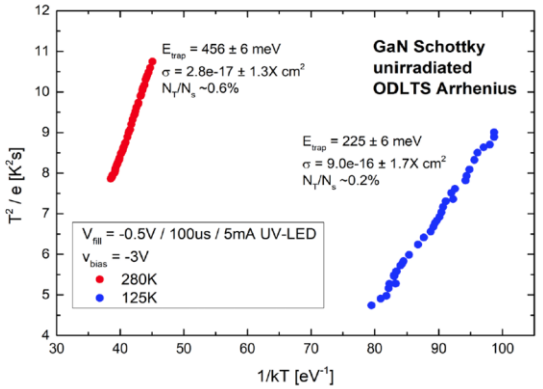
C-V



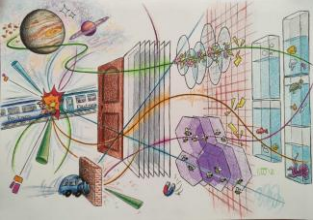
Optical response



DLTS



3rd DRD3 week: Gallium Nitride Schottky Devices for Sensing Applications



Summary

- SiC and GaN as wide bandgap material have potential to be used as particle detector
- Active progress within the WG6 group in DRD3
  - Device fabrication by many groups
  - Promising spatial and temporal resolution performance
- Large area device fabrication and radiation tolerance are still challenging