SiC Discussion

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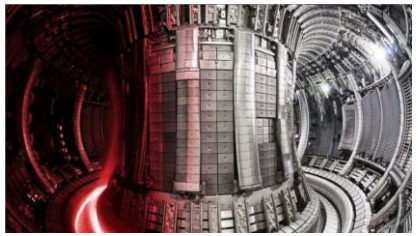
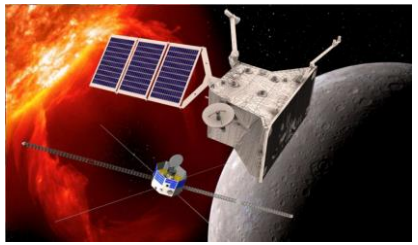
Silicon Carbide Detectors

- Wide bandgap semiconductor (3.26 eV) : Low leakage currents, insensitivity to visible light
- Renewed interest: High-quality wafers from power electronics industry

\+ High breakdown field and saturation velocity: timing applications
\+ Potentially higher radiation hardness (displacement energy), no cooling is needed after irradiation
\- Higher ionization energy (~30% less signal per µm) [1]
\- Limitations in wafer thickness and resistivity

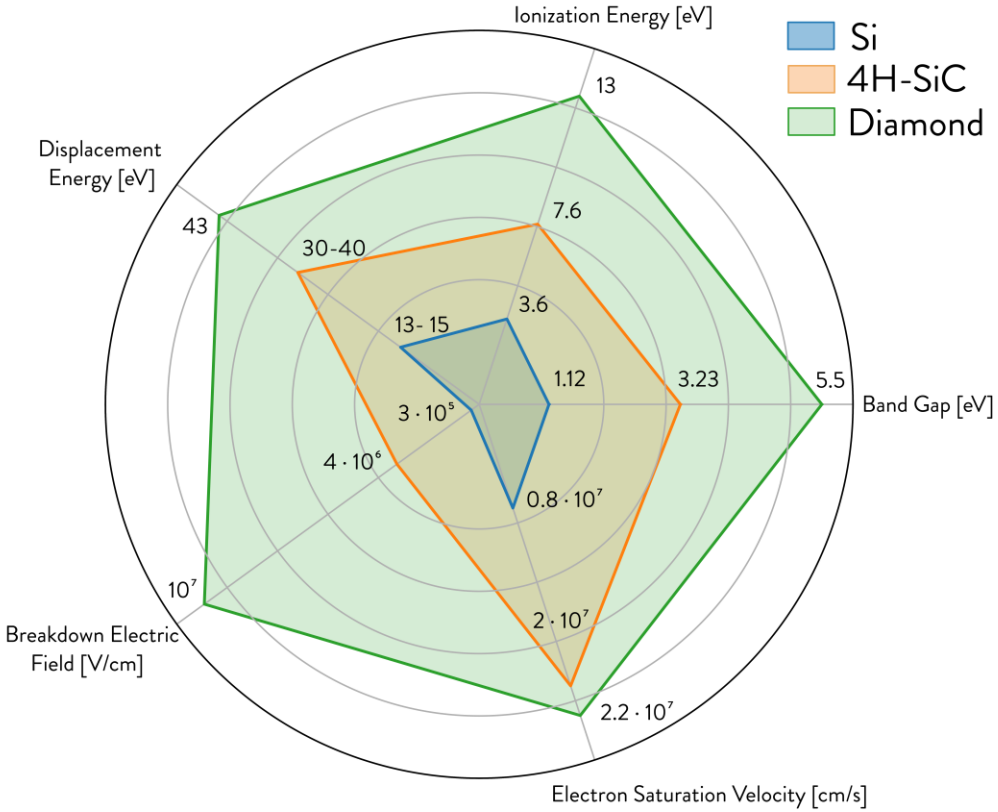
Dosimetry: µDOS, FLASH





Space, harsh environments (fusion)

Beam monitoring, radiation hard large area detectors



Advantages and disadvantages of 4H-SiC compared to Si

SiC Session

09:00	**Four-quadrant Si and SiC Photodiodes for Beam Position and Monitor Applications** *6/2-024 - BE Auditorium Meyrin, CERN*	*Dr Joan Marc Rafí* 09:00 - 09:20
	Thermal Annealing of Electron, Neutron and Proton Irradiation Effects on SiC Radiation Detectors *6/2-024 - BE Auditorium Meyrin, CERN*	*Dr Joan Marc Rafí* 09:20 - 09:40
	Defect Spectroscopy on Proton Irradiated 4H Silicon Carbide Devices *6/2-024 - BE Auditorium Meyrin, CERN*	*Niels Sorgenfrei* 09:40 - 10:00
10:00	**TCAD simulation of 4H silicon carbide LGADs** *6/2-024 - BE Auditorium Meyrin, CERN*	*Philipp Gaggl* 10:00 - 10:20
	Coffee break *6/2-024 - BE Auditorium Meyrin, CERN*	10:20 - 10:50
	Charge Collection Study of SiC-LGAD - SICAR1 *6/2-024 - BE Auditorium Meyrin, CERN*	*Xin Shi* 10:50 - 11:10
11:00	**Discussion: SiC** *6/2-024 - BE Auditorium Meyrin, CERN*	*Thomas Bergauer* 11:10 - 11:30

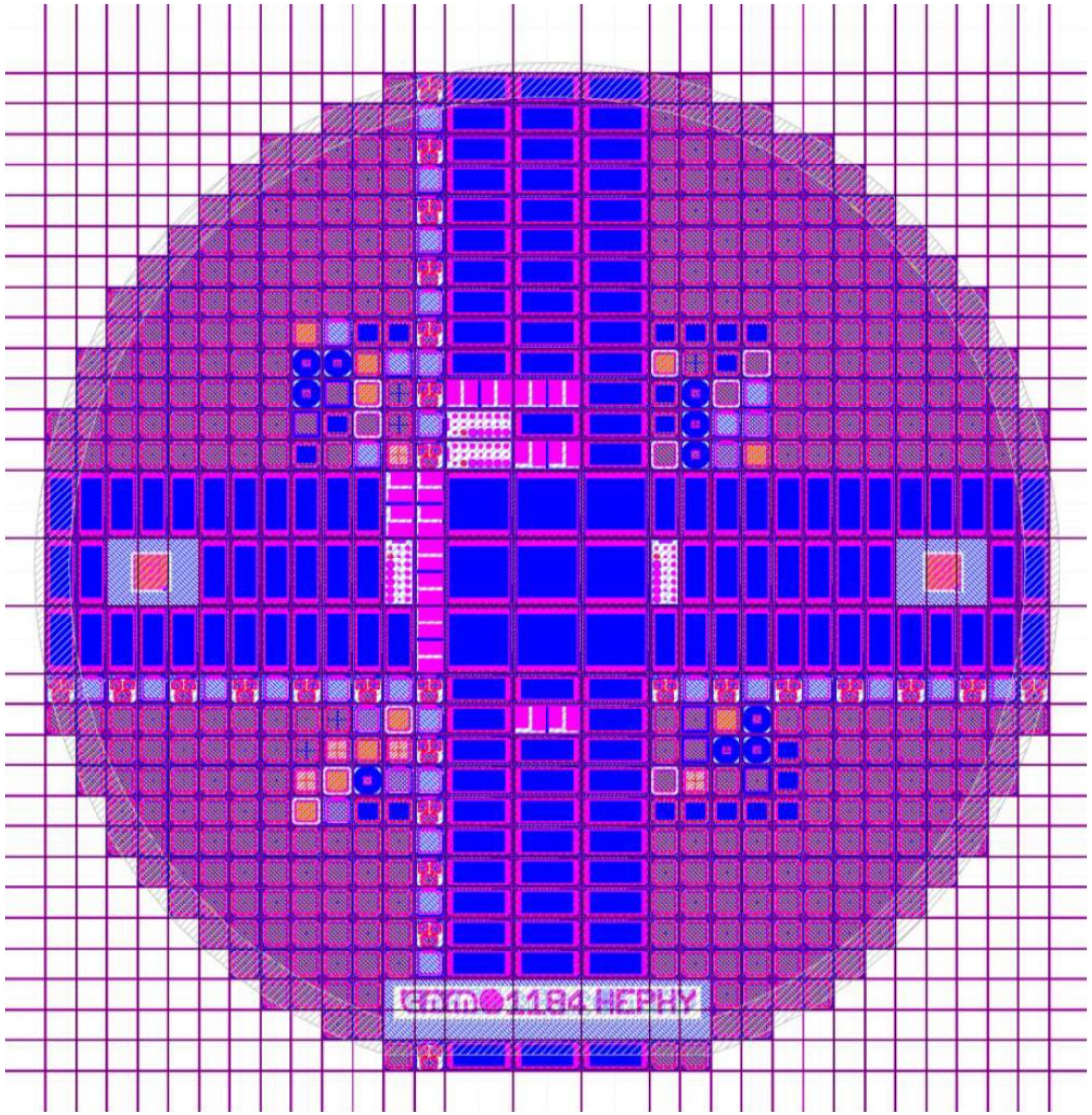
RD50 common project

- RD50 project “SiC-LGAD” (RD50-2023-01) approved in March 2023
- Institutes: **HEPHY**, CNM, CERN, Perugia, Santander, NIKHEF
- RD50 fund requested : 30k€ , Total project cost: 110k€

Activity	Institute	Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
TCAD simulations	*HEPHY, CNM*	Planar							LGAD run1				
Wafer layout	*HEPHY, CNM*												
Production	*CNM*												
IV, CV characterization	*HEPHY, CNM, Perugia, NIKHEF*												
UV-TCT Measurements	*HEPHY, CNM*												
TPA-TCT Measurements	*Santander*												
Alibava	*CERN*												
Neutron Irradiations	*HEPHY*												
X-Ray irradiations	*Perugia*												

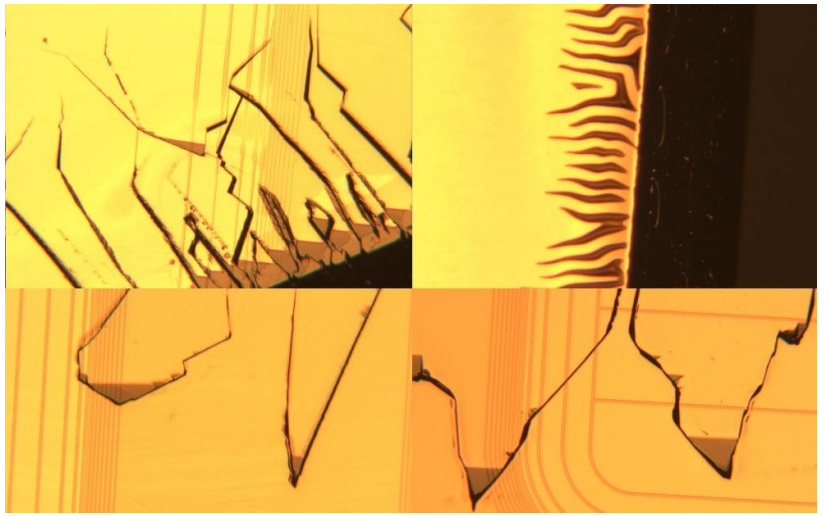
Planar SiC Wafer-run @ CNM

- 4H-SiC wafers in collaboration with CNM
- 3 x 50 µm & 2 x 100 µm epi, 6’’
- Design at HEPHY, processing at CNM
- Structures:
  - Pad & strip detectors, resistive detectors
  - Diodes for edge-TCT
  - Pixel array
  - MOSCAPs (various forms and sizes)
  - MOSFETs (various forms and sizes)
  - Gate controlled diodes
  - Test structures (van der Pauw, Kelvin-bridge, …)

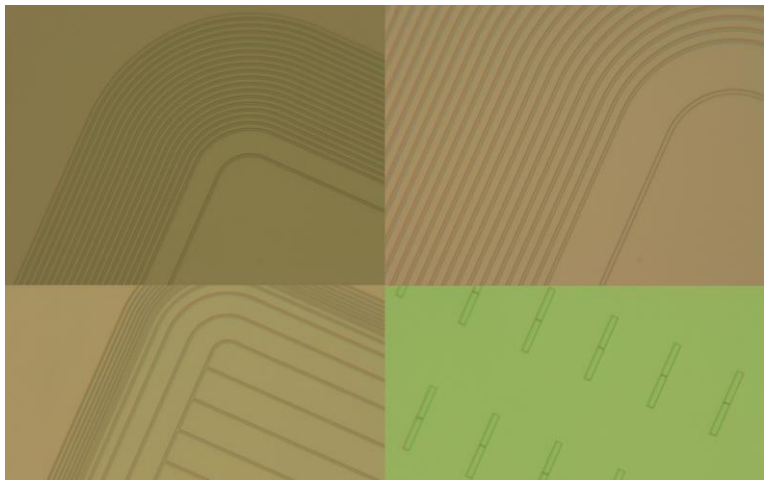


Planar SiC Wafer-run: Status

- Completed: 25 / 58 stages
  - Photolithography P-DIFF
  - Ion Implantation: large delay accumulated for the implantation, by IBS (external company)
  - Thermal Oxidation
  - Dry Etching
  - Oxide Deposition
- To do:
  - Windows opening
  - Metallization
  - Passivation
- **Completion expected mid-February 2024**



Defects appeared after ion implantation and activation on all the wafers. They are mainly localized at the edge of the wafers.

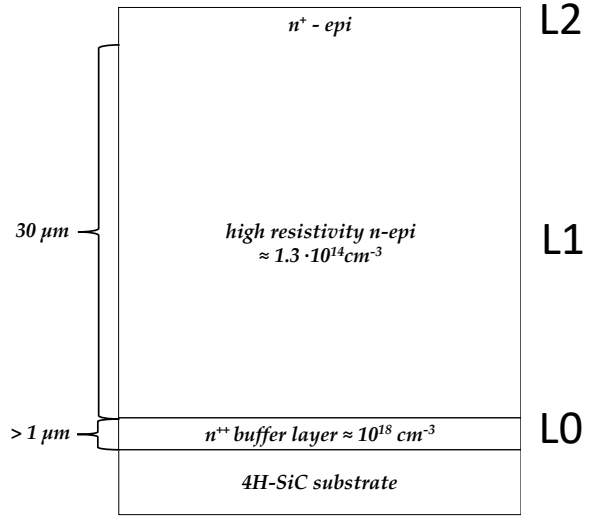


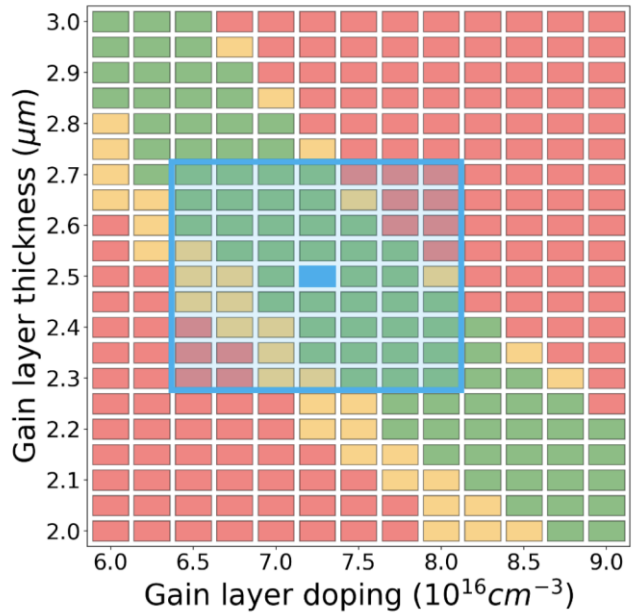
Status of the wafers

Wafers for SiC-LGAD

- Simulations results in Vienna show that gain can be reached by one single gain layer from top surface down to 2.5µm (no buried layer)

- Offer from Coherent (II-VI) for 150 mm SiC Epi-Wafer with additional epi layer doping L2:
  - L0=Coherent standard buffer n ≥1e18/cm^3,
  - L1= 30µm n = 1-3e14/cm^3,
  - L2= 2.5µm ±10% n = 7e16-8e16/cm^3.
  - Volume: 5-10 pcs., Price: USD 3.850/pcs, estimated lead-time: ~16-20 weeks
- Target a doping range 7-8e16/cm3 for L2 with stepwise concentration approximation and provide CnCV measurement data. Meeting exact values as specified by you cannot be guaranteed. Epi is done on best effort terms.
- They do not have statistics for 2-3µm. 10µm target tolerances are: Thickness deviation ±6% mean, uniformity 4% sigma/mean. N 1e16/cm3 doping deviation ±12% mean, uniformity 10% sigma/mean.





Summary

- SiC Planar Run
  - Ongoing
  - Estimated finish February 2024

- SiC LGAD
  - TCAD simulations ongoing
  - Offer exists; not too expensive
  - Unclear if epi gain layer can be doped to the necessary precision
  - TCAD simulations show that gain is only in a very small range

Discussions

RD50 common project SiC-LGAD

Activity cost	cost/piece	pieces	total costs	comment
Bare wafers	5.000,00 €	15	75.000,00 €	5 wafers per run, 3 runs
Mask set	8.000,00 €	2	16.000,00 €	planar + LGAD
Implantation service	3.000,00 €	3	9.000,00 €	three runs
Wafer processing			5.000,00 €	at CNM
SIMS measurements			2.000,00 €	
Irradiations			3.000,00 €	
Total project costs			110.000,00 €	

Funds	cost/piece	pieces	costs	comment
RD50 common fund			30.000,00 €	
CNM			5.000,00 €	in-kind
HEPHY			50.000,00 €	through HEPHY-CNM contract
Perugia			5.000,00 €	
CERN			10.000,00 €	
Santander			5.000,00 €	
NIKHEF			5.000,00 €	
Total income			110.000,00 €	