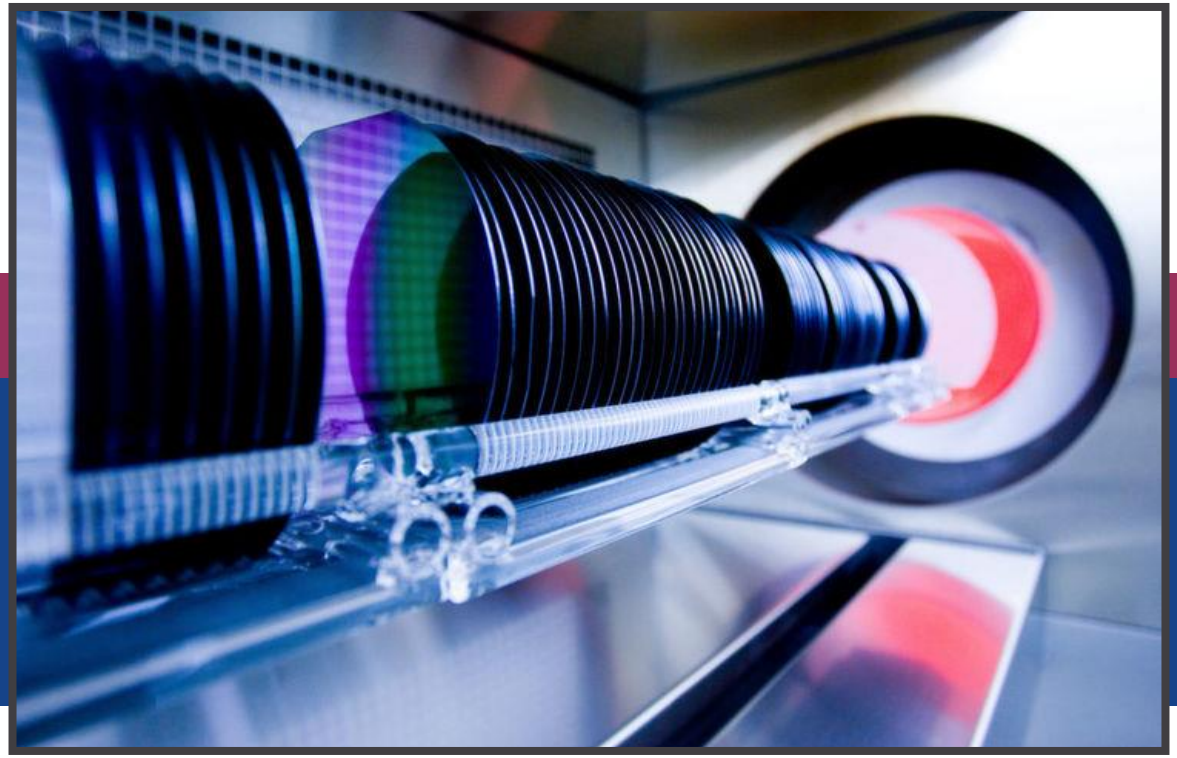


CiS Forschungsinstitut für Mikrosensorik GmbH

Competence in Silicon

Kevin Lauer, Tobias Wittig,
Alexander Lawerenz, Ralf Röder

Defect-engineering of new detector solutions

Overview

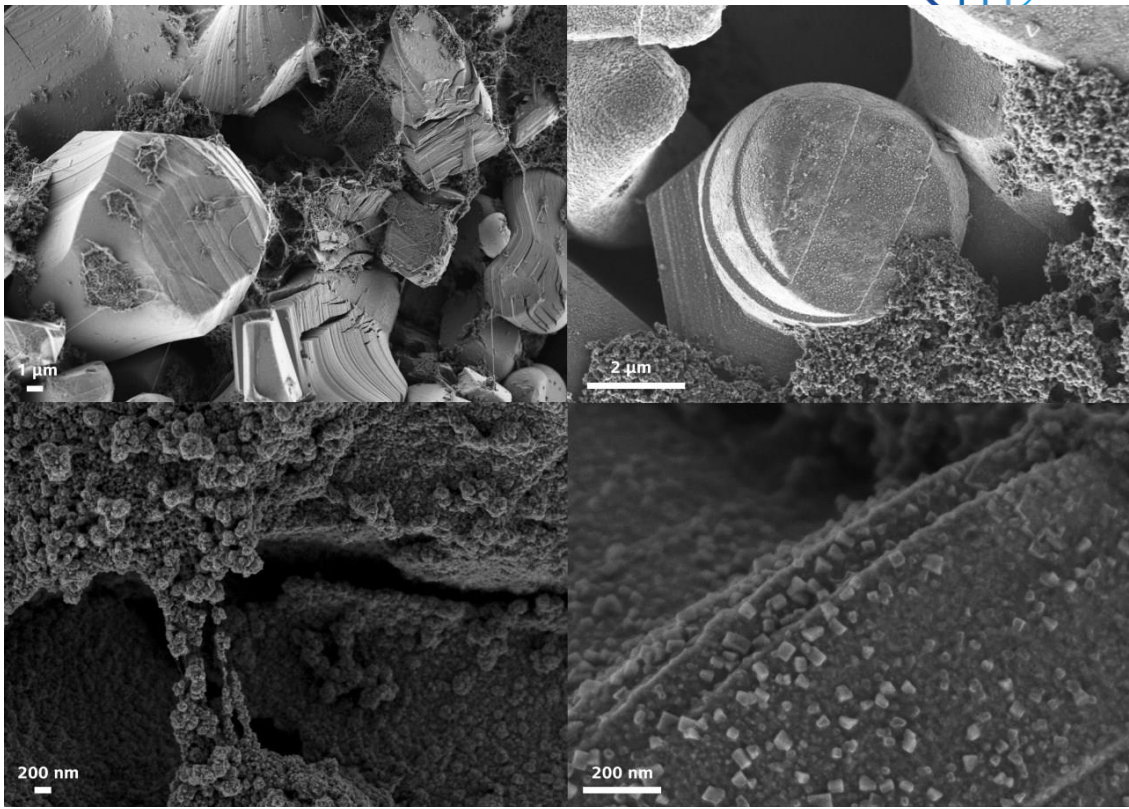
1. Motivation
2. Detectors for low energy electrons
3. Low gain avalanche detectors
4. Conclusion

Motivation

- Two projects of CiS are presented:
- I) Development of detectors for low energy electrons
- II) Development of defect-engineering processes to avoid gain layer disappearance in LGAD devices

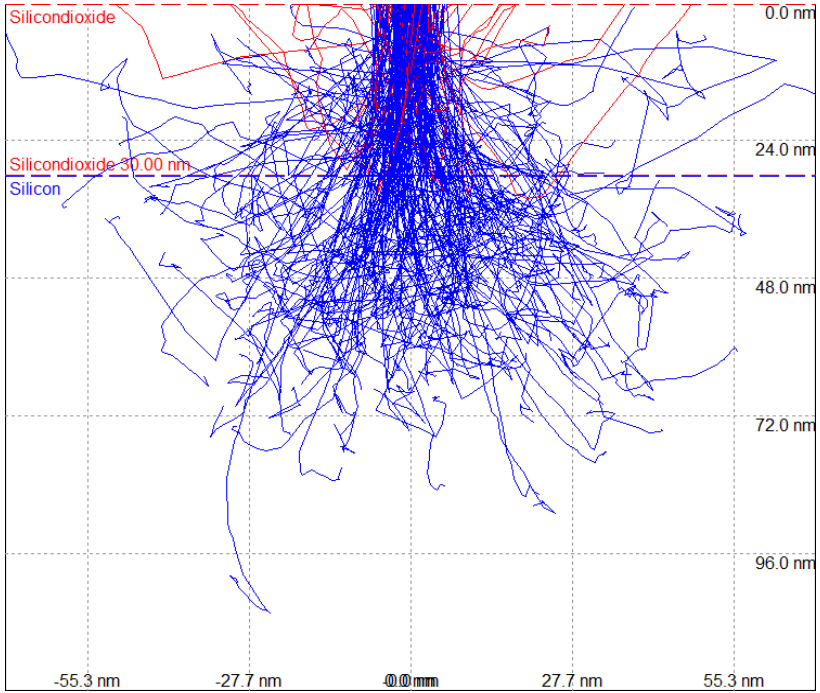
Motivation

- Detection of
  low energy electrons
  needed for investigation of
  sensitive nano structured
  materials
  e.g. for lithium-ion-battery research)
- Low energy electrons
  increase due to their
  low penetration depth the
  surface sensitivity
- Reduction of charging
  effects



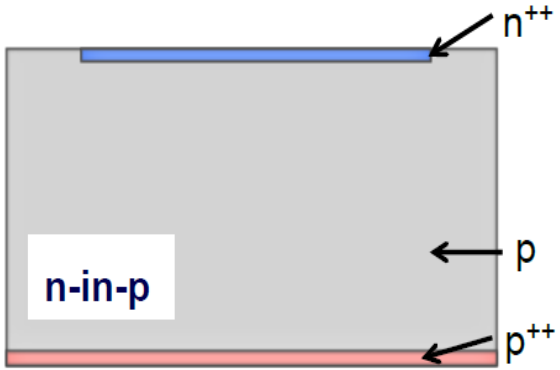
Detection of low energy electrons

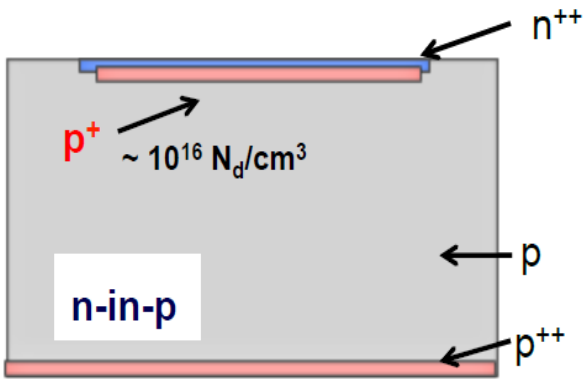
- Simulation of 2keV electron beam by SREM
- Penetration depth of low energy electrons in the range of several 10nm
- Development of shallow p-n-junction
- Development of thin entrance window (dead layer)



http://www.gel.usherbrooke.ca/casino/

Low gain avalanche detector

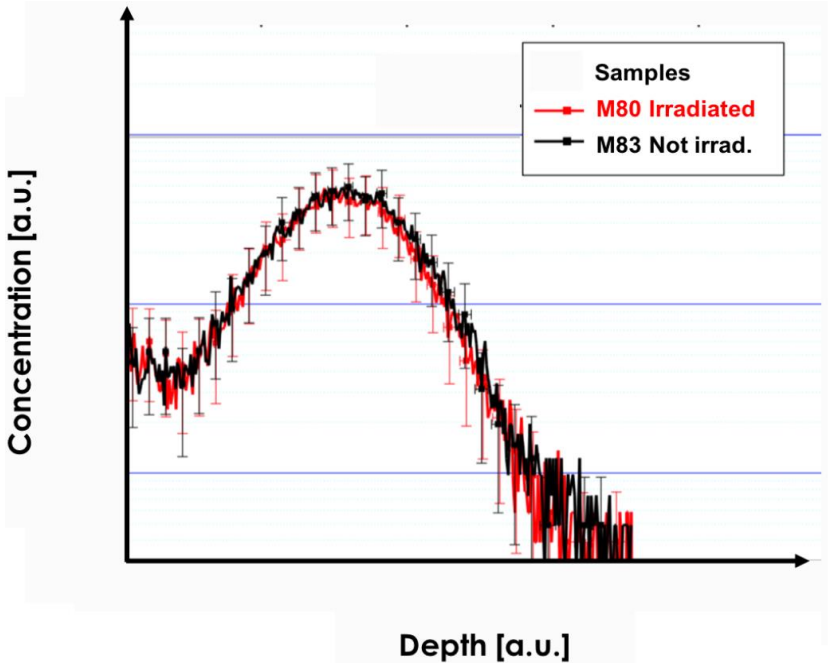




N. Cartiglia *et al*, " Tracking in 4 dimensions", NIMA 845 (2017) 47-51

- p^+ gain layer below n^{++} region
- p^+ gain layer adjusted to generate gain of about 20 (10 … 30) compared to standard n-in-p detector
- Problem: gain layer disappears under irradiation and hence gain disappears

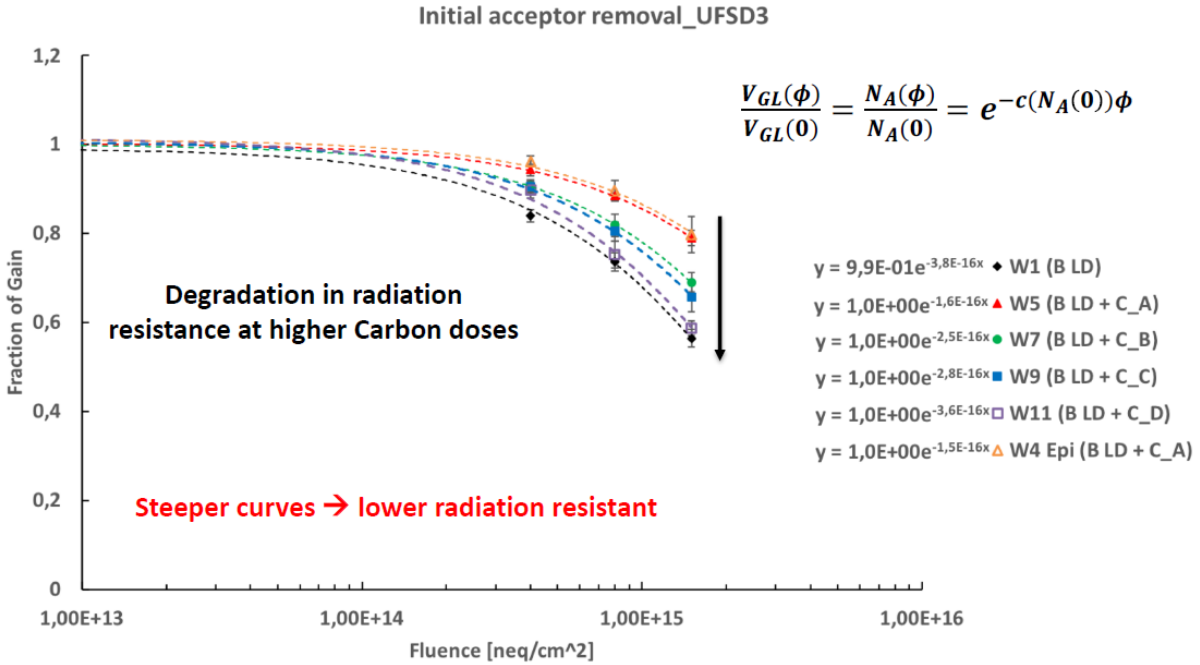
SIMS measurement of gain layer



M. Ferrero et al., NIMA **919**, 16 (2019).

- Boron atoms of p^+ gain layer still at same depth
- SIMS measurement shows no difference before and after irradiation
- But boron atoms not electrically active
- Which defect reactions take place?
- **Project goal:** Stabilizing gain factor by defect-engineering

Approaches for solution of problem



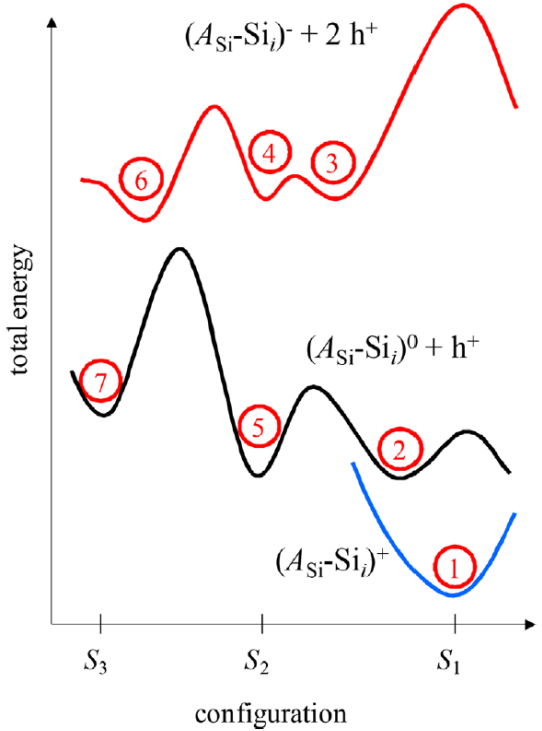
- Co-implantation of carbon, oxygen, nitrogen, …
- Implantation of alternate acceptors like Indium
- First results promising: **(DeSiD: MF140178)**
- DELGAD

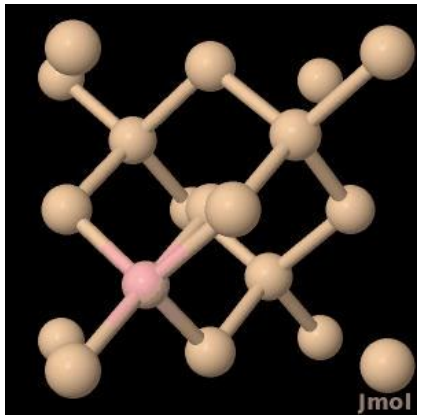
M. Ferrero et al., NIMA **919**, 16 (2019).

Multiplication layer

- Check / map
  the homogeneity of the dopant distribution

Explanation approach, A_{Si}-Si_i defect model





- Understanding of ongoing defect reactions
- A_{Si}-Si_i defect exists in three configurations
- Seven states con be occupied
- Pairing of a substitutional boron atom with an silicon interstitial atom shifts defect from acceptor to donor behavior
- Could explain disappearance of gain layer

K. Lauer et al., Physica Status Solidi (c) **14**, 1600033 (2017).

Charateization

- SIMS
- REM/FIB
- scanning acoustic microscopy (SAM)
- Raman microscopy
- transient current technique TCT
- dopant activation:
  low-temperature photoluminescence measurements TTPL

Conclusion

- Development of silicon detectors for low energy electrons
- Nescessary for enhanced surface sensitive SEM
- Low gain avalanche detectors suffer from disappearance of gain layer due to irradiation
- SIMS results show no removal of boron atoms
- Defect reactions take place
- One possible candidate: formation of A_{Si}-Si_i defect
- Defect-engineering necessary to stabilize gain layer

see also

- K. Lauer, X. Xu, D. Karolewski, U. Gohs, M. Kwestarz, P. Kaminski, R. Täschner, T. Klein, T. Wittig, R. Röder, and T. Ortlepp, „Impact of Electron Irradiation on N- and O-Enriched FZ Silicon p-in-n Pad Radiation Detectors“, Physica Status Solidi (c) **14**, 1700019 (2017).
- K. Lauer, C. Möller, C. Teßmann, D. Schulze, and N. V. Abrosimov, “Activation energies of the InSi-Sii defect transitions obtained by carrier lifetime measurements,” physica status solidi (c), vol. 14, no. 5, p. 1600033, 2017.
- Kevin Lauer, Stefan Krischok, Thomas Klein, Mario Bähr, Alexander Lawerenz, Ralf Röder, Thomas Ortlepp, and Uwe Gohs

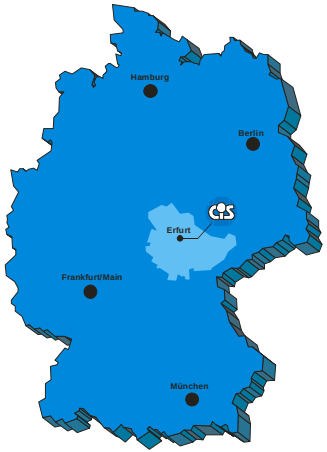
  Light-induced degradation in annealed and electron irradiated silicon: BO-LID effect

5th anniversary of CiS detector workshop

FuTuRe 2019

2th … 3th of December 2019, Erfurt, Germany

Workshop on the Future of Silicon Detector Technologies Big Science Instrumentation and New Markets



Trends in Technologies and Components

TOPs

- Technologies for Quantum photonic components
- New detector solutions for High-Energy and Heavy-Ion physics
- Modelling, Simulation and Analysis of semiconductor behavior (defects in silicon)
- Connecting and assembly techniques
  esp. UBM, alternative metal layer deposition, pillars, soldering, …
- Alternative Technology Approaches

Thank you for your kind attention!

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