

First characterizations of a minimum ionizing particle detector based on p⁺n junction SiC diode

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Outline

- Introduction
- Technological process
- I/V - C/V measurements and annealing effects
- CC setup and measurements
- Irradiation with 1 MeV neutrons
- Conclusions and future developments

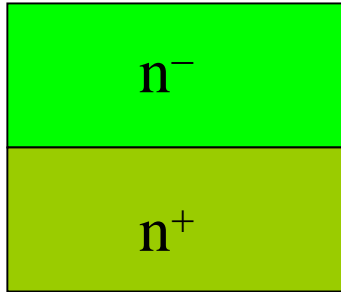


p⁺n diodes project and RD50

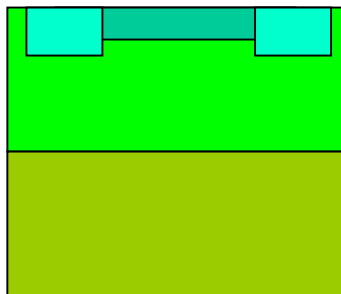
- In agreement with RD50 community
 - Prepare SiC p⁺n junctions
 - Submit a quarter of the wafer for RD50 community
- Plan of activity
 - Diodes process finished in March 2005 (done)
 - Good quality of process verified with IV, CV and CC measurements on unirradiated devices in April 2005 (done)
 - Irradiation with neutrons May 11 2005 (done)
 - Measurements on irradiated devices in June (in progress)



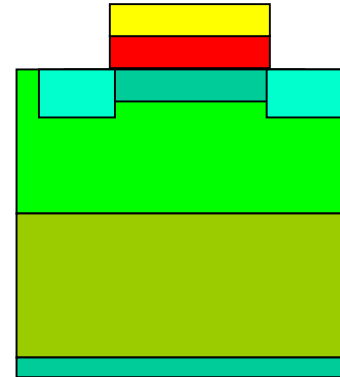
SiC Process: p⁺/n



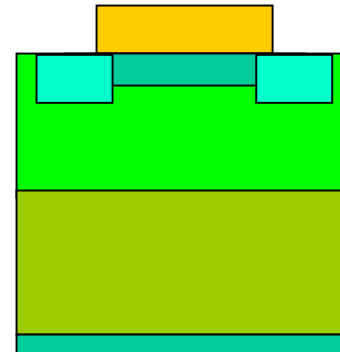
Epi (55 μm) doping:
 $2 \times 10^{14} \text{ cm}^{-3}$



Ion implantation
Al⁺ @ 300°C
p⁺ doping (0.4 μm)
 $= 4 \times 10^{19} \text{ cm}^{-3}$
p⁻ doping (0.6 μm)
 $= 5 \times 10^{17} \text{ cm}^{-3}$
Annealing 1600°C 30 min

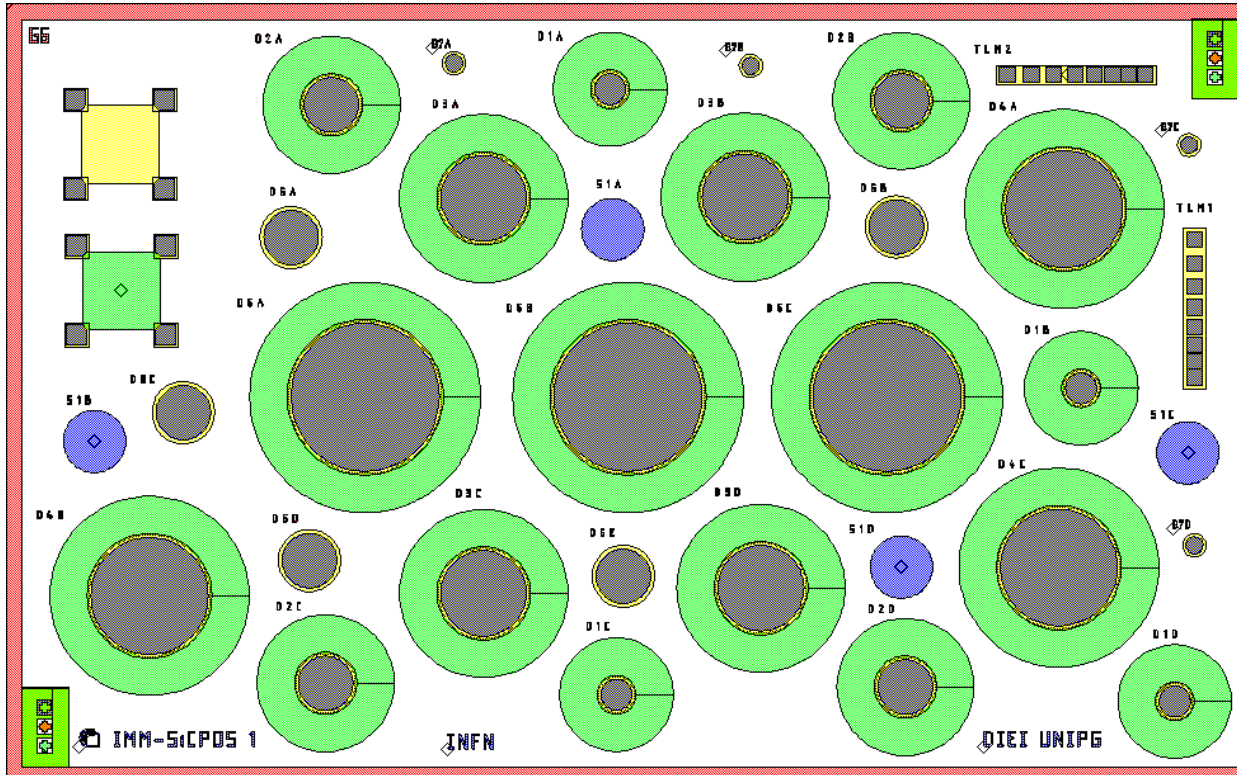


Front: Al (350 nm) / Ti (80 nm)
deposition
Back: Ni



Annealing 1000°C
in vacuum 2 min

Mask design



Diode	Diameter (μm)	JTE (μm)
D1	250	200
D2	400	200
D3	600	200
D4	800	200
D5	1000	200
D6	400	No
D7	150	No
S1	400	No

31 diodes in each die

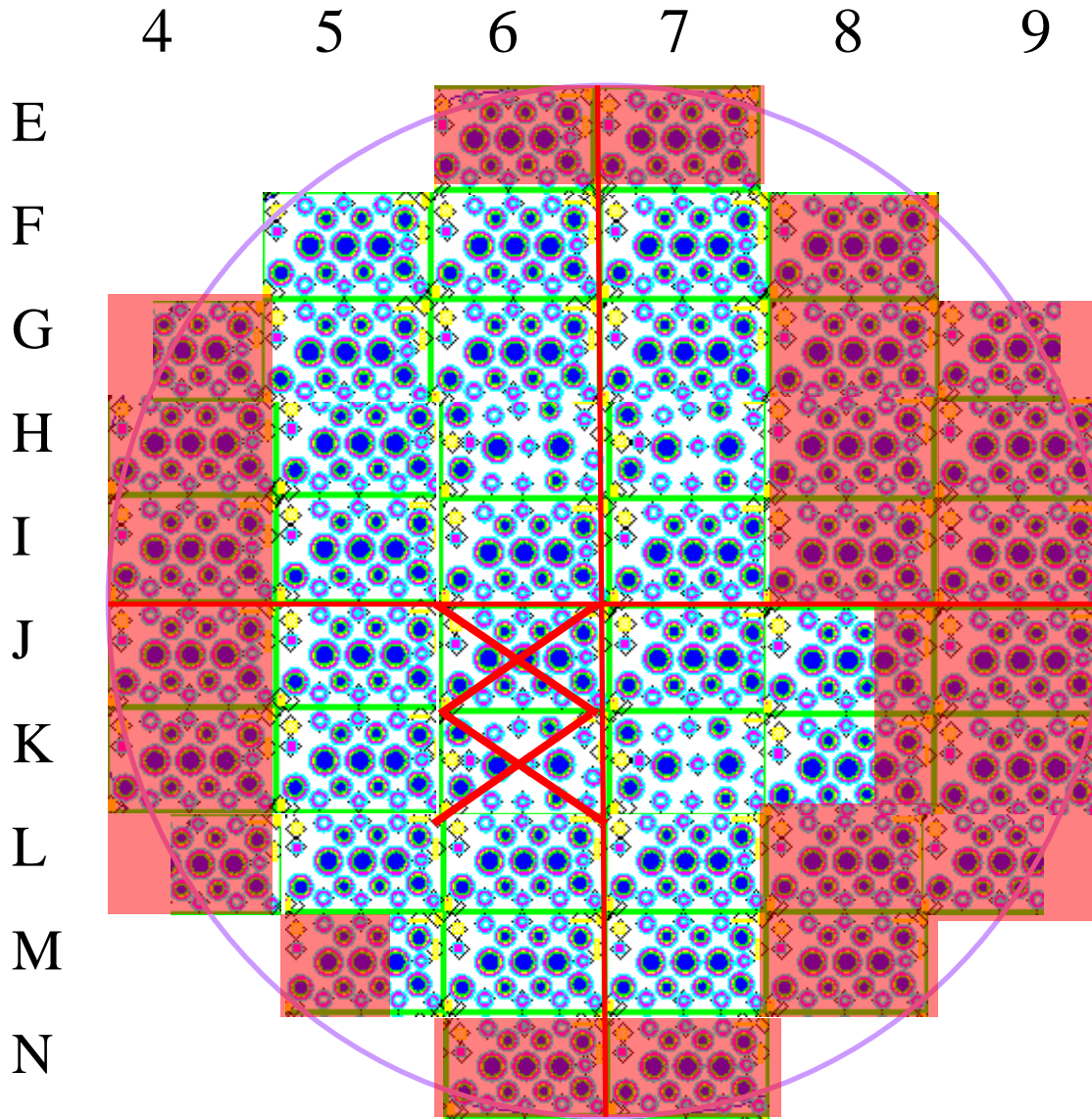


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Wafer



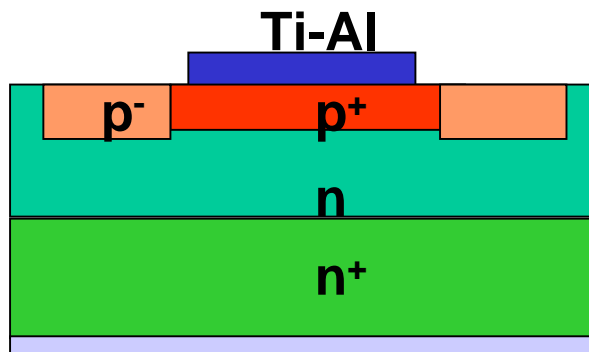
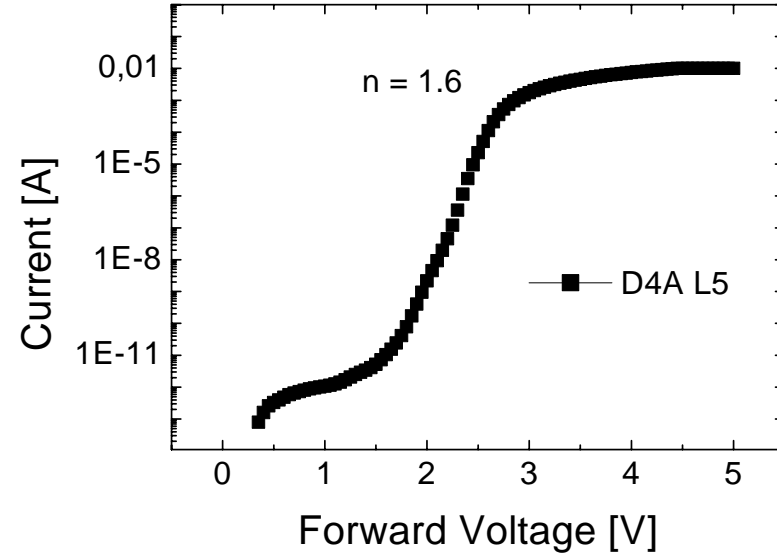
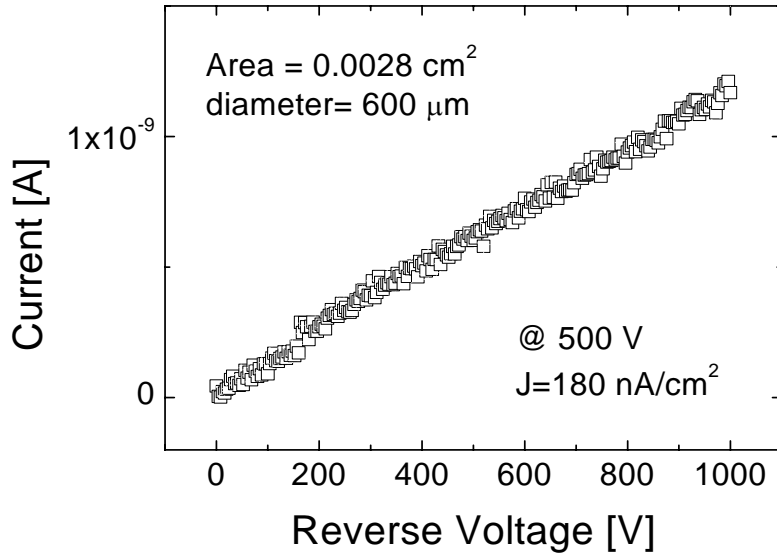
4 quarters. Rows from E to N

Columns from 4 to 9

Columns 4, 8 (no J8 and k8) and 9 present p-type layer under the Schottky contacts

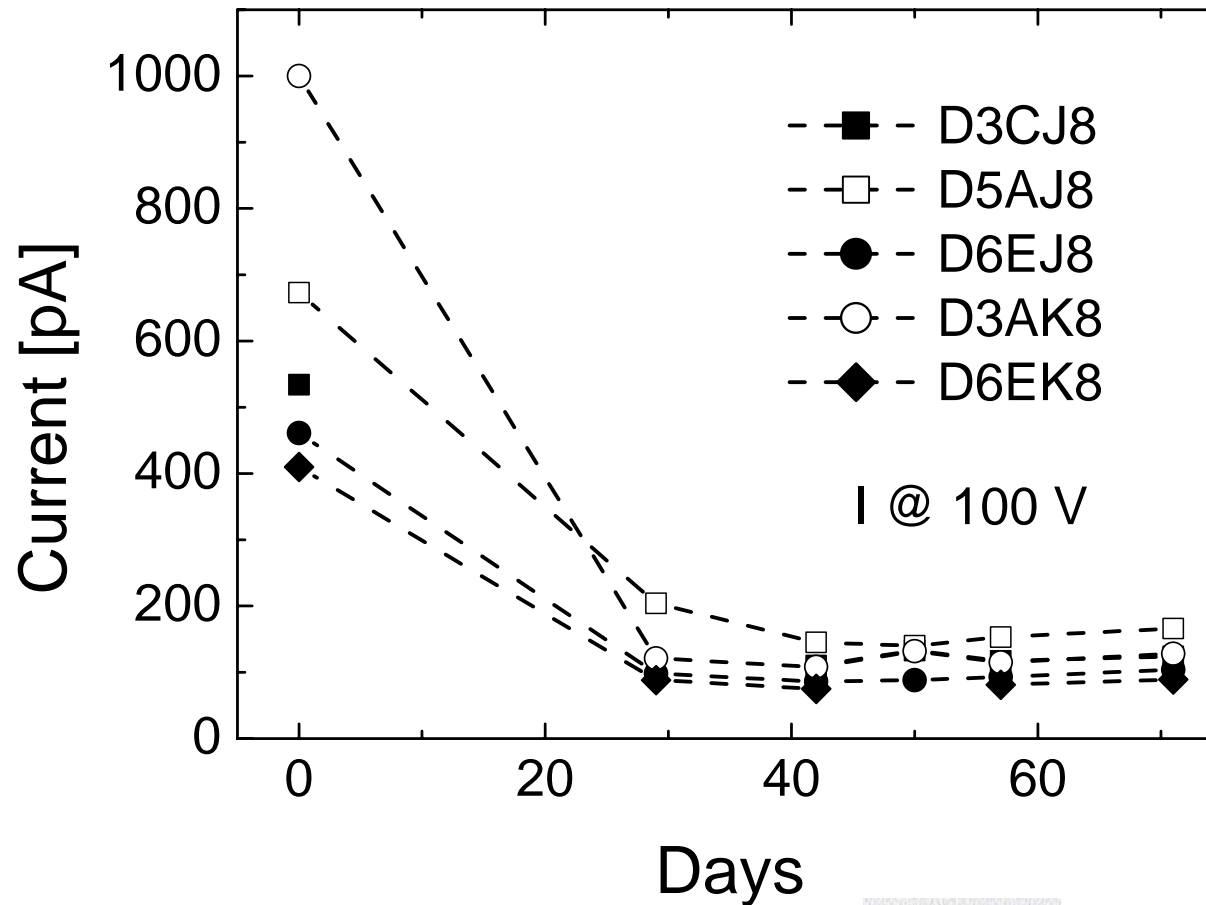


I-V measurements on p⁺/n diodes

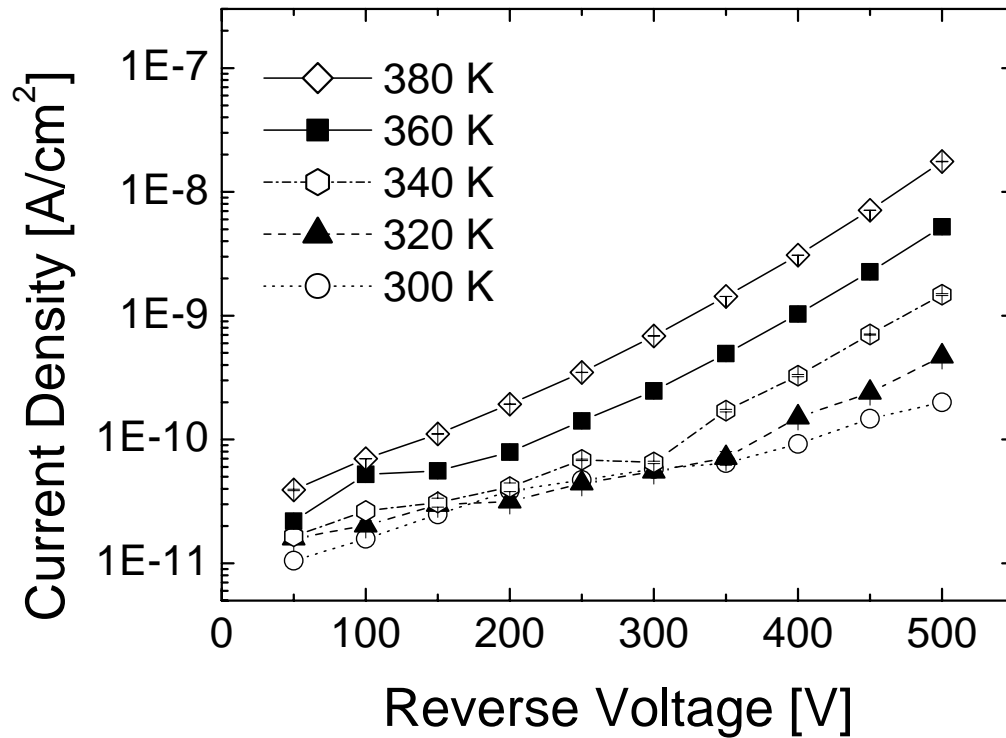


- 70 % of diodes have good I-V curves (considered columns 5, 6, 7 and dies J8 and K8)
- Theoretical limit for this device \cong 6 kV

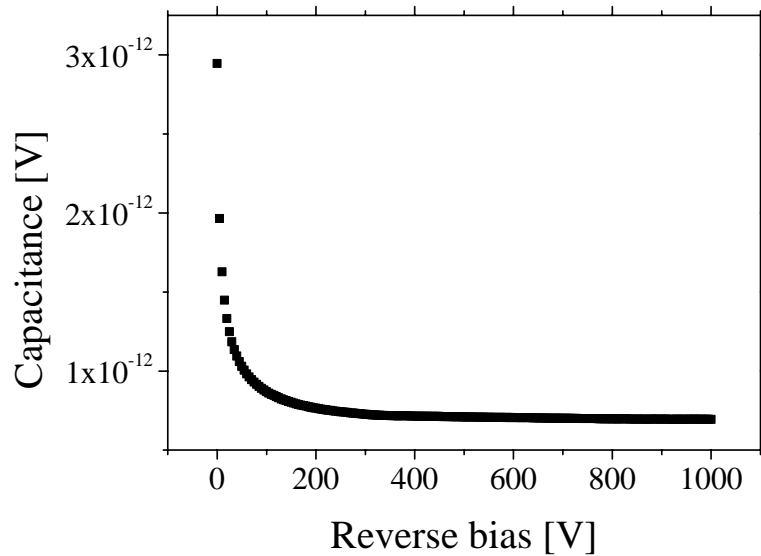
Reverse current: effect of annealing at room temperature



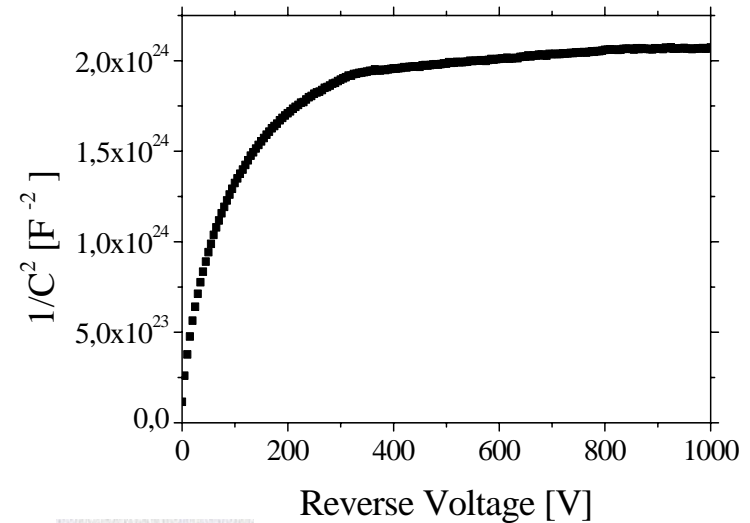
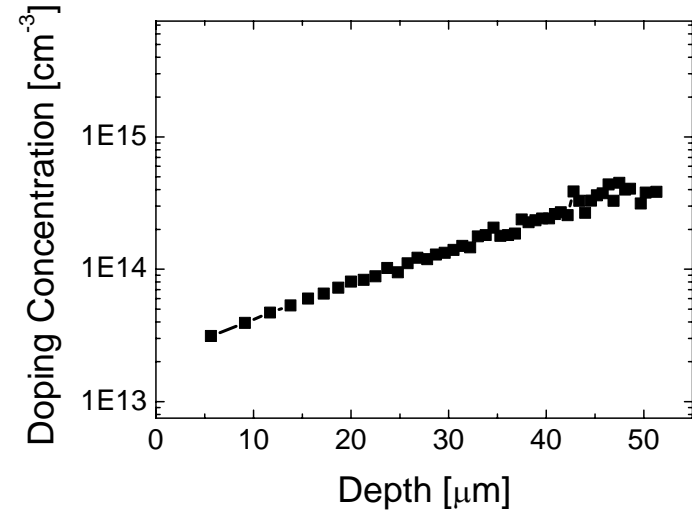
Comparison with recent process



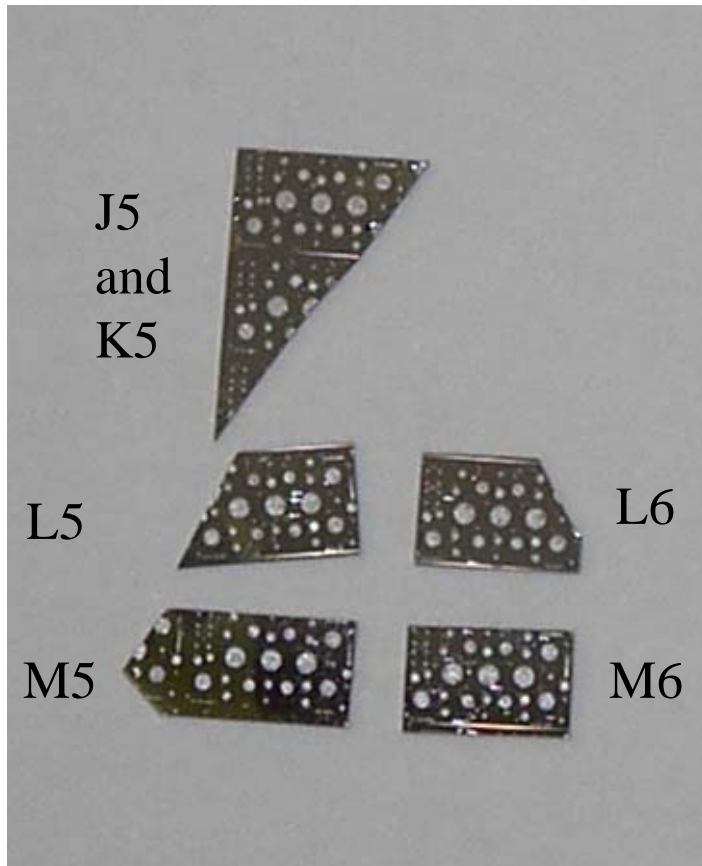
CV measurements



- Epi doping not uniform (average value $2 \times 10^{14} \text{ cm}^{-3}$)
- The depletion voltage is near 220-250 V



Diodes for the RD50 community

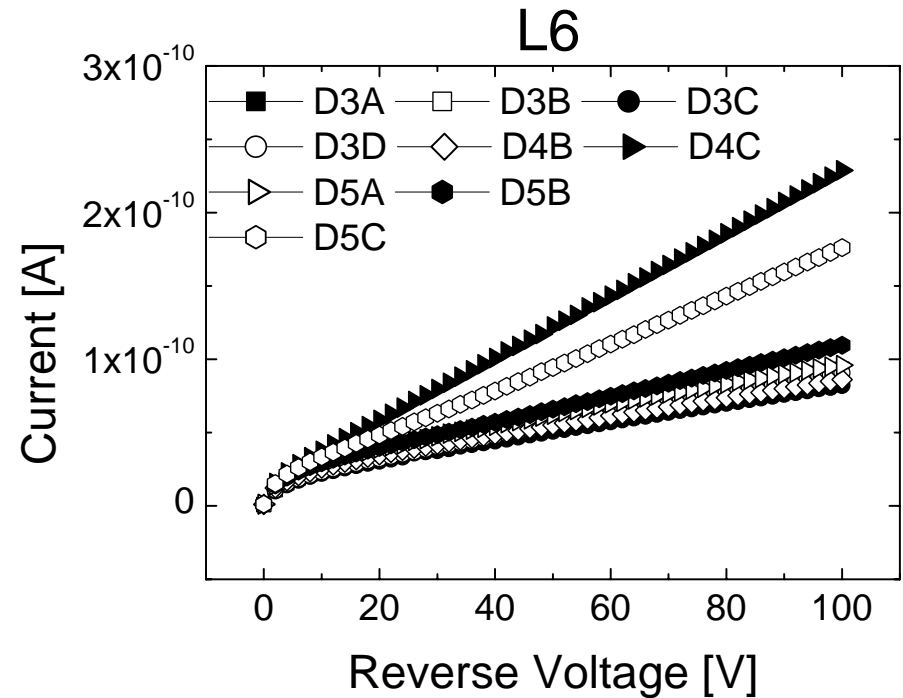
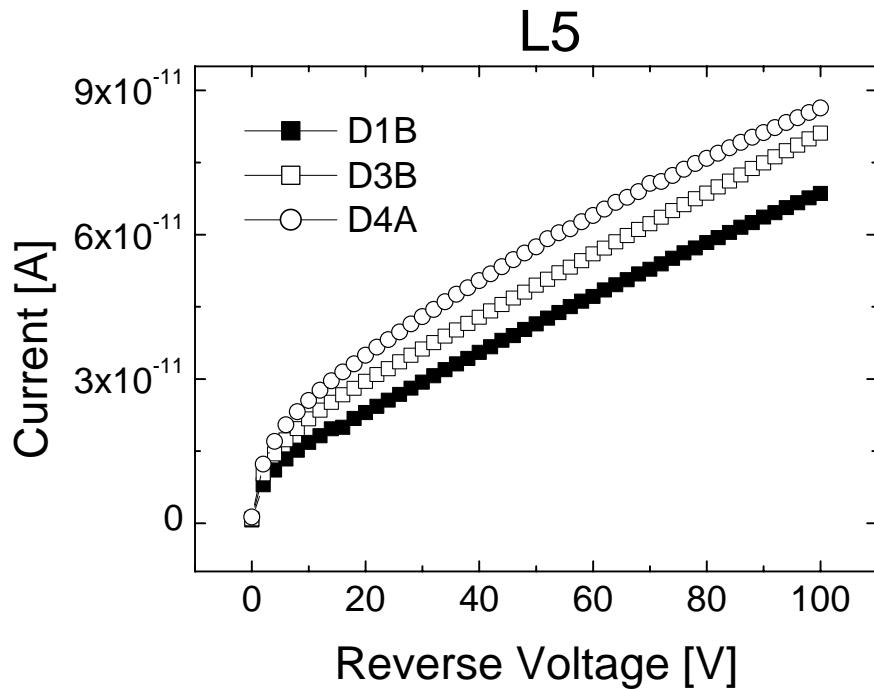


- A “virgin” quarter of the SiCPOS wafer is going to be made available to the RD50 community
- RD50 funded this activity with a financial support

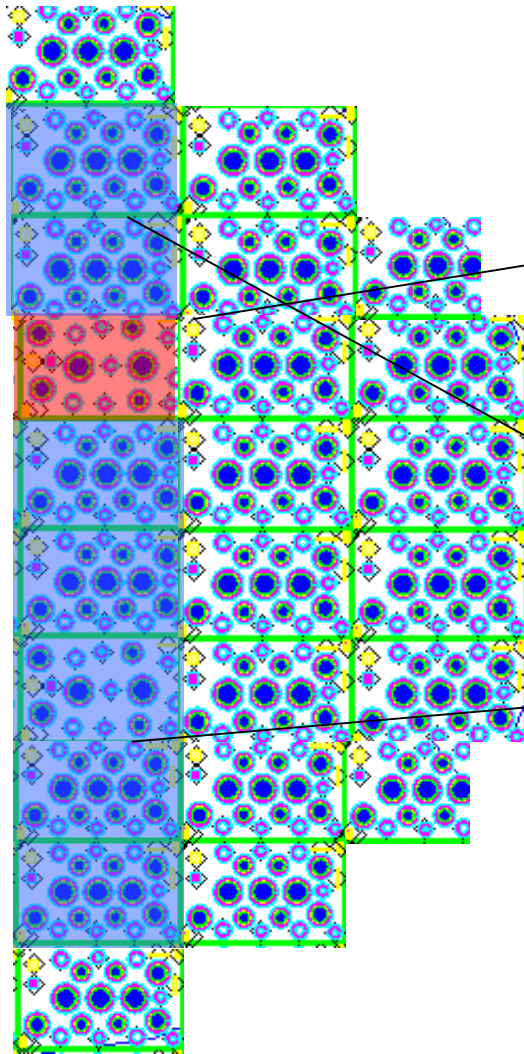
Publications related to measurements these samples:

- will need an official approval from the Univ. of Perugia and IMM Bologna;
- will include, as authors, the people involved in the design of the process;
- will acknowledge the SiCPOS project (together with RD50).

I-V characteristics of diodes for RD50

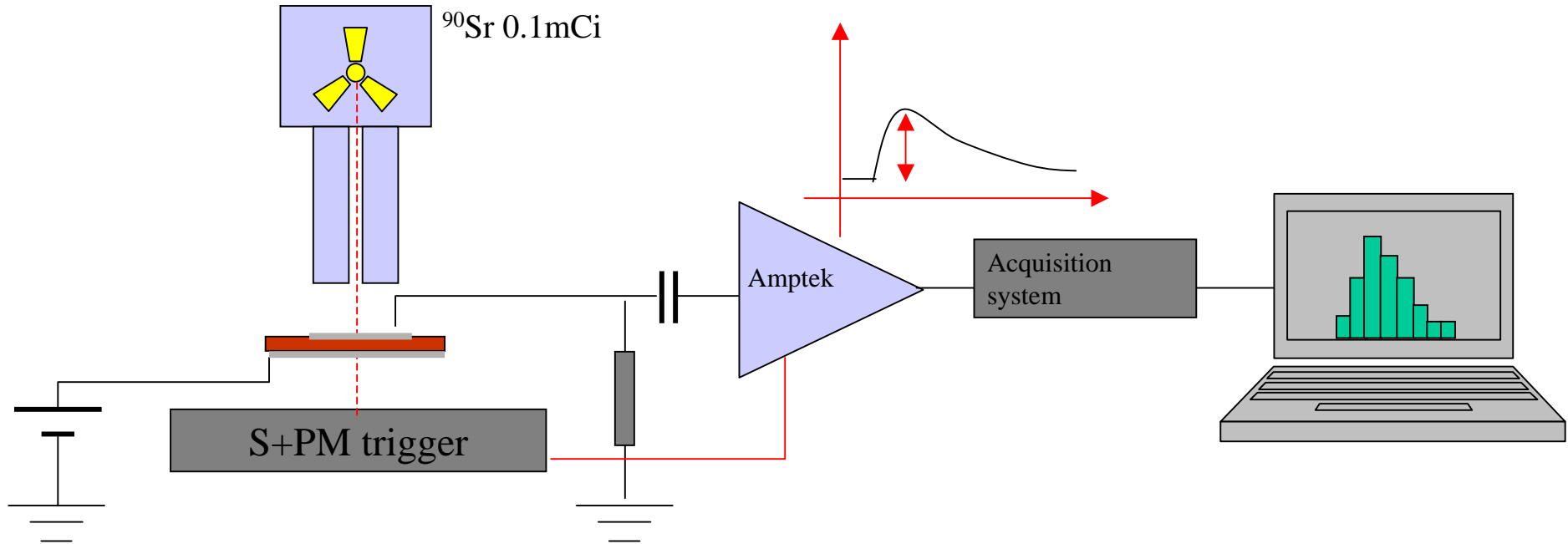


CC measurements and irradiation



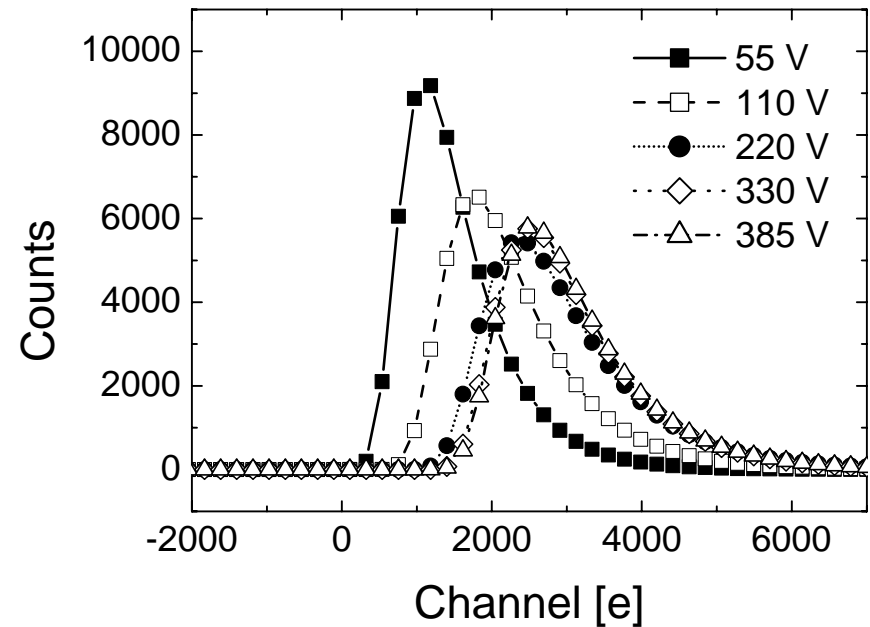
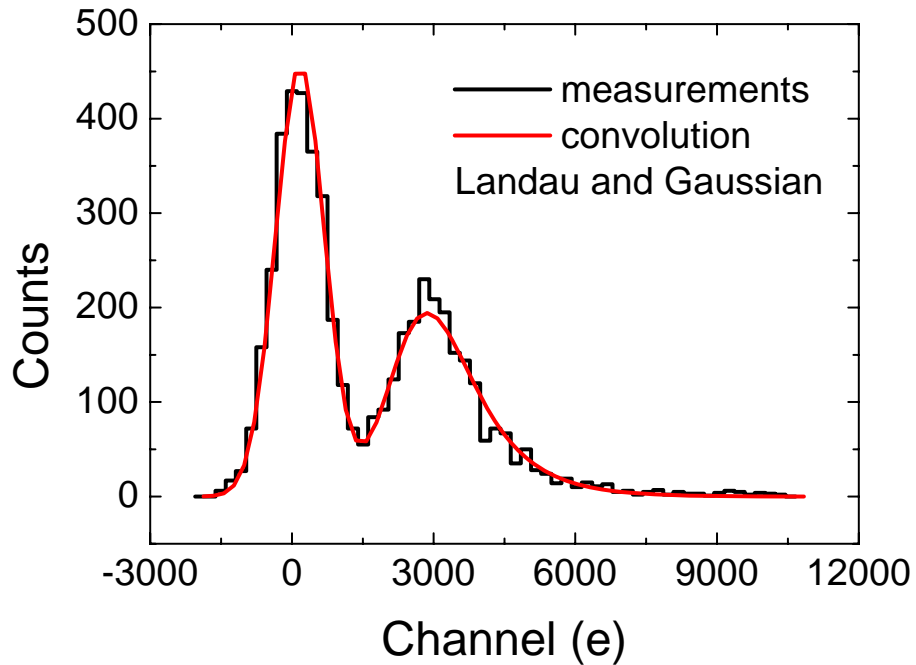
- Reference with CC measurements without irradiation
- 7 dies for irradiation with neutrons

CCE measurement setup

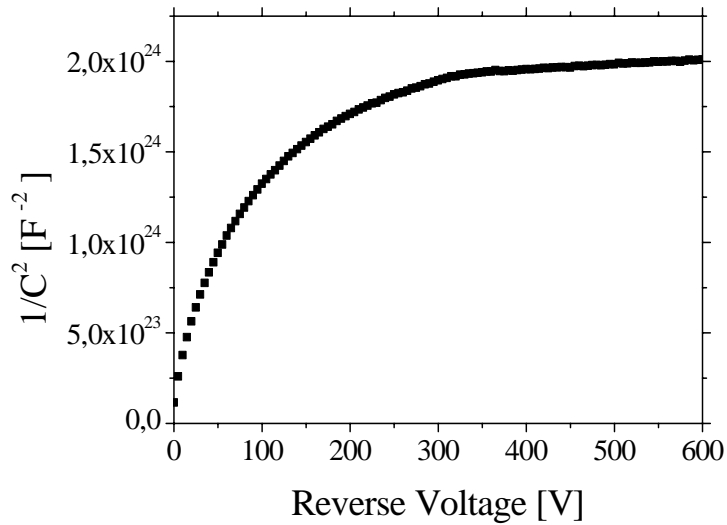
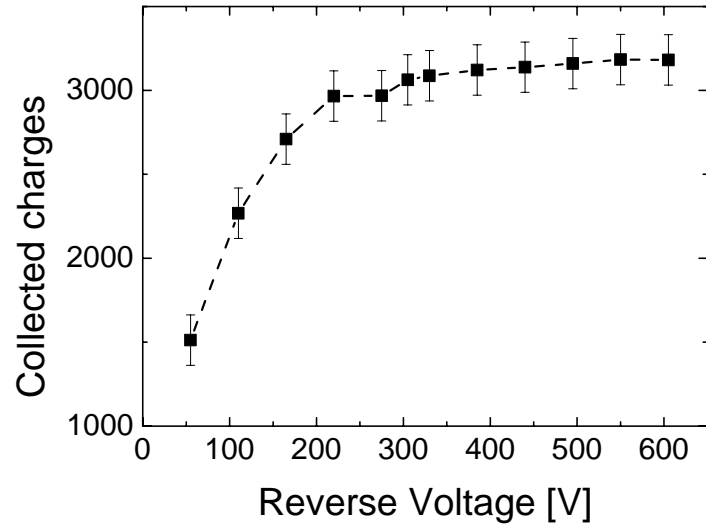


The noise of the charge collection setup is linearly proportional to the capacitance of the detector and is given by $\text{ENC} = 200e + 4.6e/pF$

CC measurements



CC vs V



Around 200-250 V the signal saturates, in good agreement with CV results.



Irradiation with neutrons

- Irradiation with 7 different fluences in the range 10^{14} - 10^{16} 1 MeV neutrons/cm² carried out May 11 in Ljubiana
- Fluences: 1×10^{14} n/cm², 4×10^{14} n/cm², 8×10^{14} n/cm², 1.5×10^{15} n/cm², 3×10^{15} n/cm², 5×10^{15} n/cm², 1×10^{16} n/cm².
- Diodes are presently at -5°C in order to make possible the analysis of annealing effects at RT.



Conclusions

- p⁺/n junctions have been realized and electrically characterized. Good characteristics have been obtained
- 25% of good diodes are today available for the RD50 community
- CC experimental results on SiC pn junctions: 3000 e⁻ at 200 V
- Irradiation with 7 different fluences in the range 10¹⁴-10¹⁶ 1 MeV neutrons/cm²

Future developments

- Measurements on irradiated samples

