8th RD50 Workshop Prague June 25-28 2006

Annealing effects on p$^+$n junction 4H-SiC diodes after very high neutron irradiation

Francesco Moscatelli[1,4*], Andrea Scorzoni[2,1,4], Antonella Poggi[2], Mara Bruzzi[3], Silvio Sciortino[3], Stefano Lagomarsino[3], and Roberta Nipoti[2]

[1]CNR- IMM Sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy
[2] DIEI, University of Perugia, via G. Duranti 93, 06125 Perugia, Italy
[3]Dipartimento di Fisica, Polo Scientifico di Sesto Fiorentino,Via Sansone 1 Firenze Italy
[4]INFN Perugia, via pascoli 1 06123 Perugia, Italy

This work was partially supported by the INFN SiCPOS project and by the CERN RD50 Collaboration

Università degli Studi
di Perugia

Outline

- Introduction
- Samples: OPAL and SiCPOS
- IV and CV measurements after annealing on devices OPAL
- Summary of measurements on irradiated SiCPOS devices before annealing
- CC and I-V measurements after annealing on SiCPOS devices
- Conclusions and future developments

Introduction

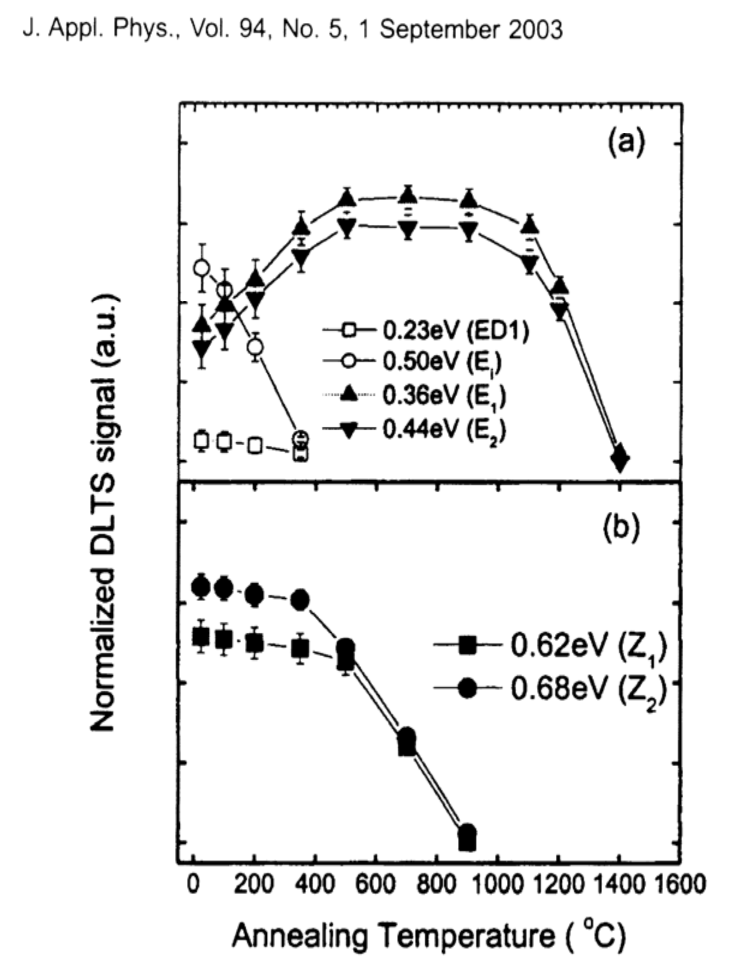
Concentration of some defects produced by neutrons decreases as a function of the annealing temperature*. In particular defects:

-E_i at E_c-0.5 eV (decreases until 400°C than expires)

-Z_1/Z_2 at E_c-0.62 /0.68 eV (decrease until 900°C than expire)

-Effects on E_c-0.82, E_c-1.16 and E_c-1.5 eV?

We want to analyze annealing effects on current, capacitance and charge collection

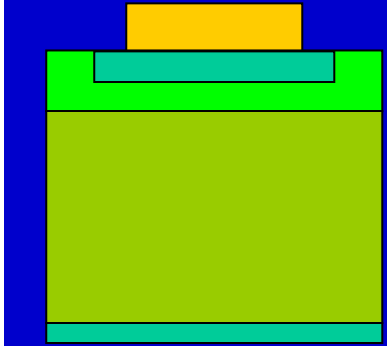


---

* X. D. Chen et al. JAP 94 (5) pp. 3004-3010, Sep 2003.

Università degli Studi
di Perugia

SiC p^+/n samples



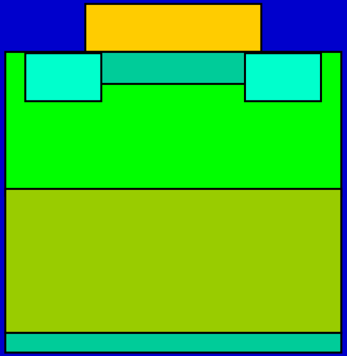
Epi CREE: 5 μm
epi doping = 3×10^{15} cm^{-3}

p^+ doping (0.2 μm) = 6×10^{19} cm^{-3}

No JTE

Called **OPAL**

To analyze current and V_{dep}



Epi IKZ: 55 μm
epi doping = 1.6×10^{14} cm^{-3}

p^+ doping (0.4 μm) = 4×10^{19} cm^{-3}

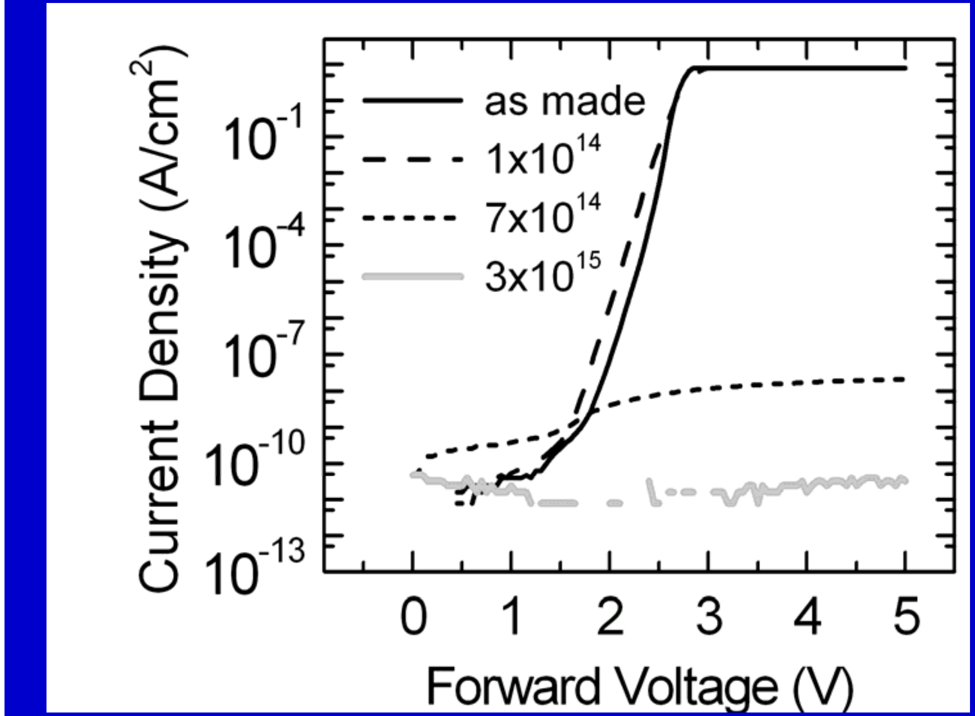
Called **SiCPOS**

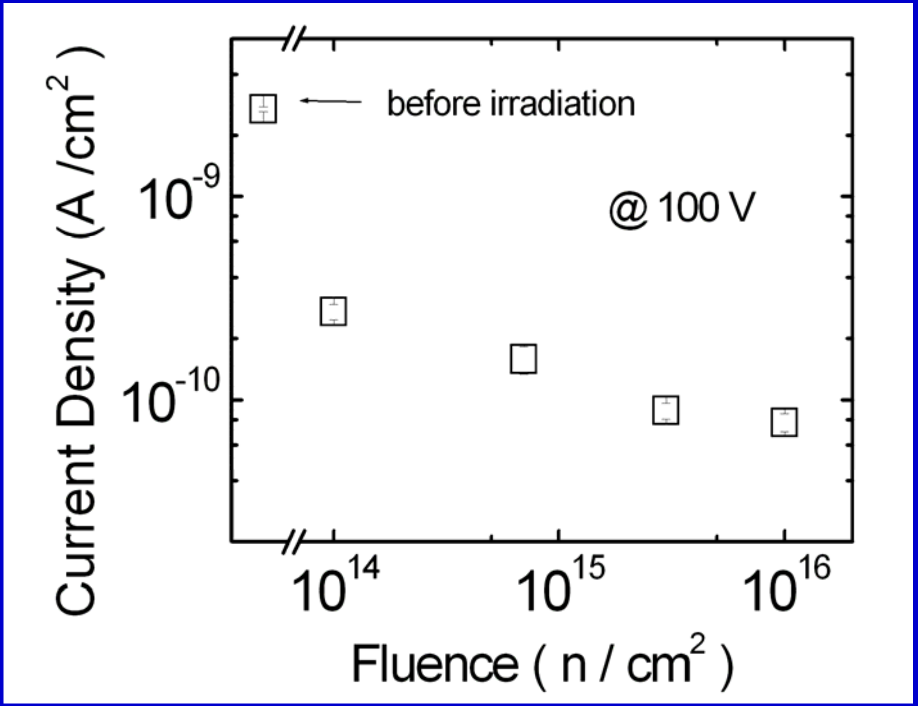
To analyze current and CC

Irradiation with neutrons

OPAL	1×10^{14} 1 MeV n/cm^2		7×10^{14} 1 MeV n/cm^2		3×10^{15} 1 MeV n/cm^2	1×10^{16} 1 MeV n/cm^2
SiCPOS	1×10^{14} 1 MeV n/cm^2	3×10^{14} 1 MeV n/cm^2	7×10^{14} 1 MeV n/cm^2	1.5×10^{15} 1 MeV n/cm^2	3×10^{15} 1 MeV n/cm^2	1×10^{16} 1 MeV n/cm^2

OPAL Diodes: IV measurements

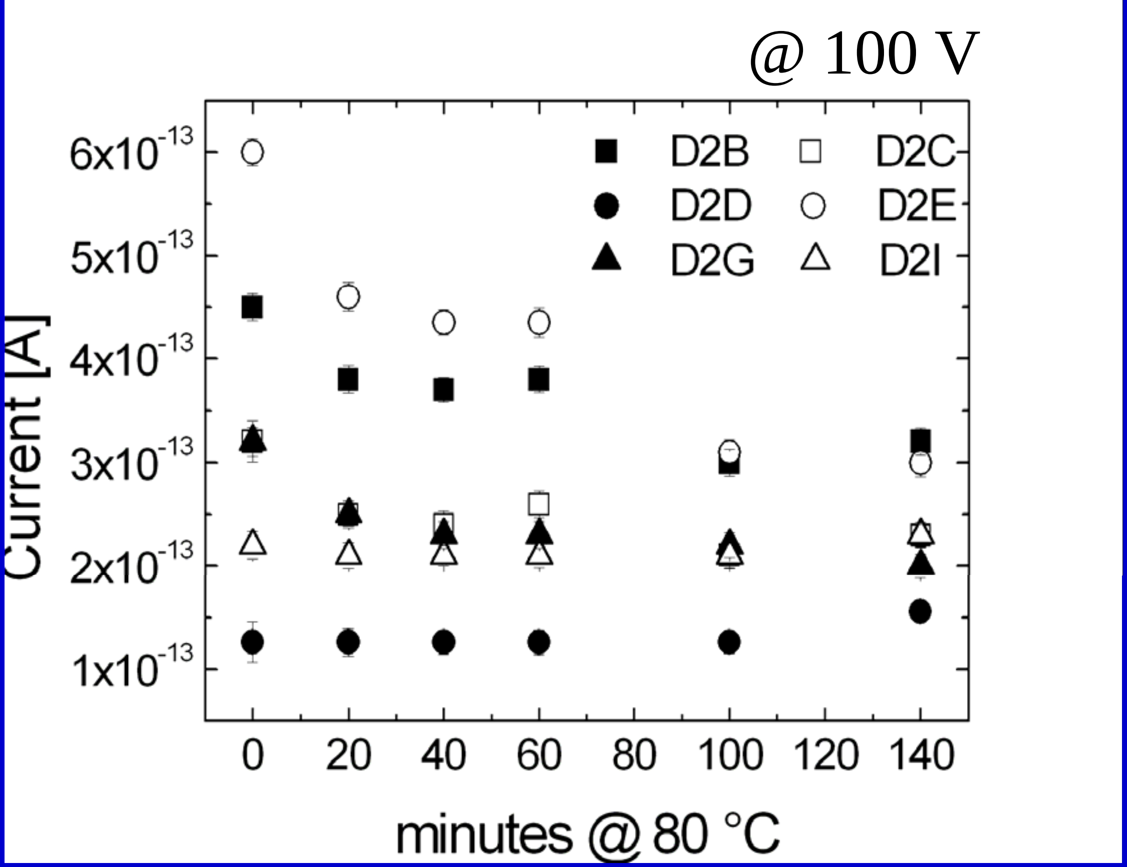




Before annealing. The samples become intrinsic after a fluence of some 10^{14} n/cm^2.

Reverse voltage: the current decreases as a function of the fluence

OPAL:I-V after 80°C annealing

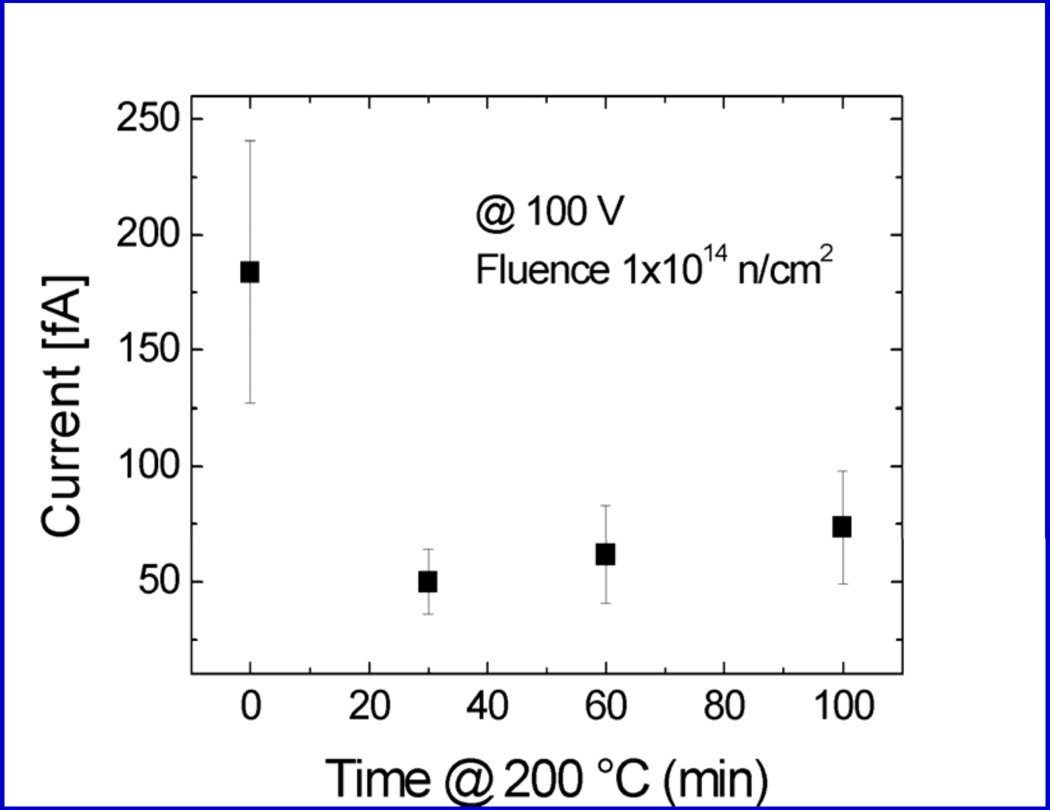


Current density or decreases or is constant as a function of the annealing time even at 80°C.

Fluence 1×10^{14} n/cm^2

Epi: 5 µm
Diameter: 350 µm

I-V after annealing at 200°C

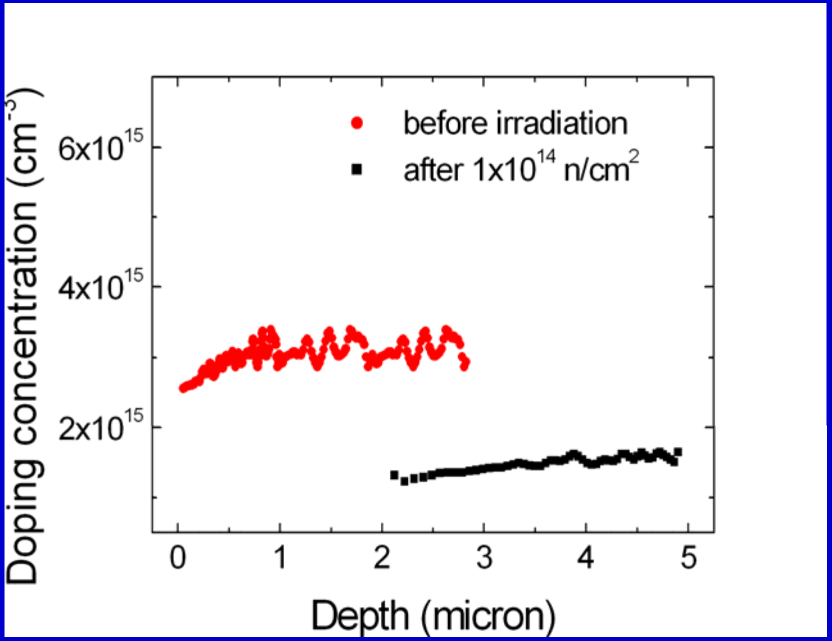


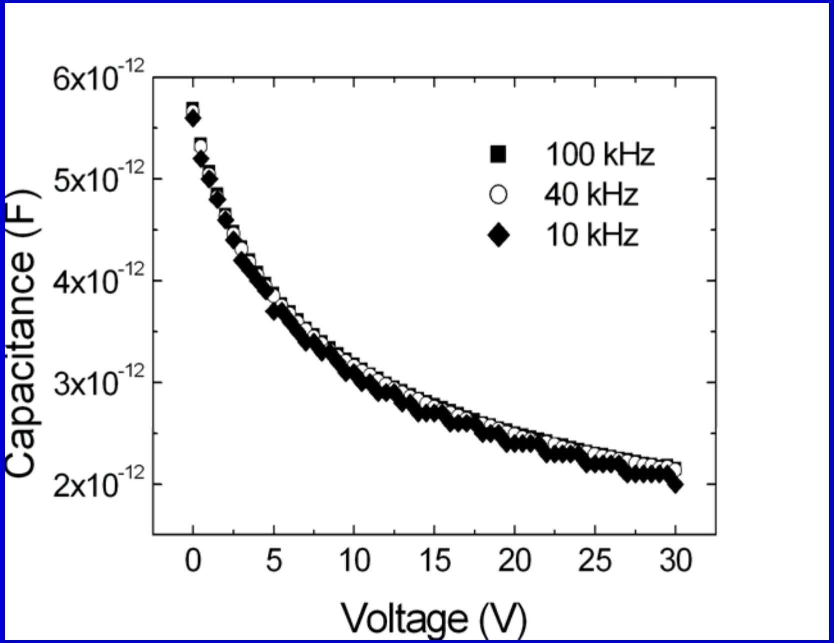
Average current decreases after an annealing at 200°C for 30 minutes and then remain almost constant.

Epi: 5 μm

Università degli Studi
di Perugia

OPAL: C-V measurements

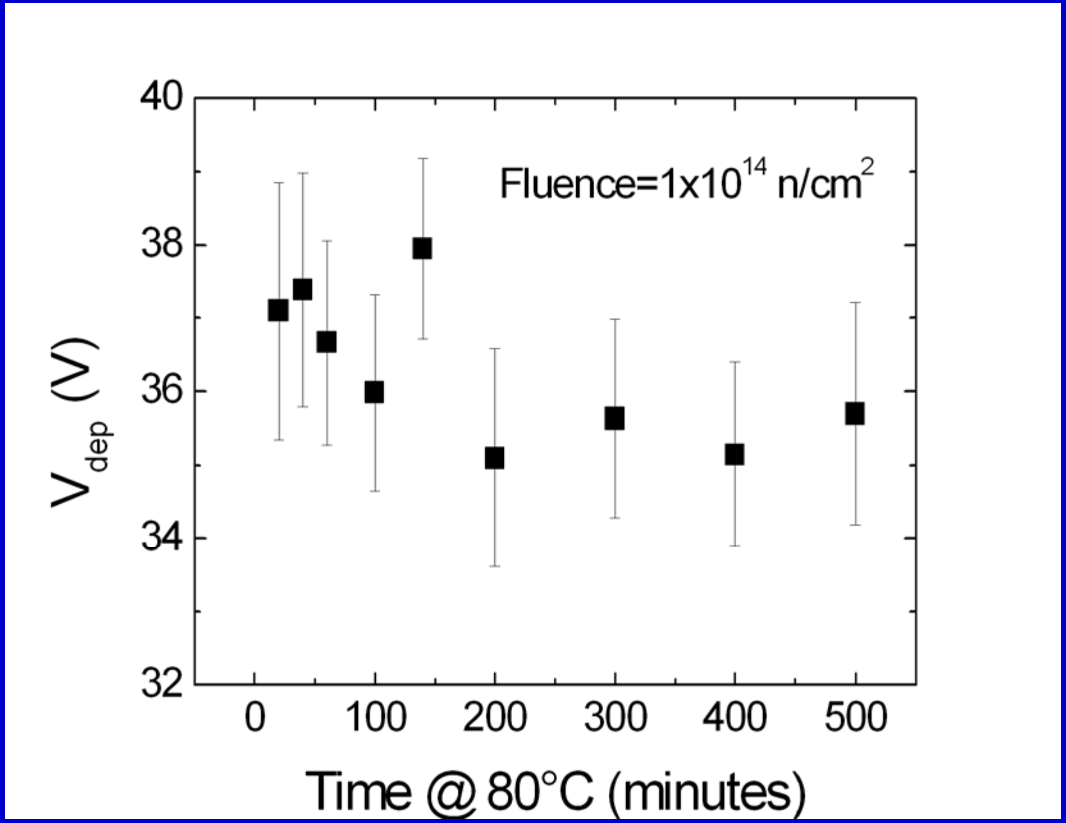




- After a fluence of 1×10^{14} n/cm^{2} the doping decreases at 1.5×10^{15} cm^{-3}.
- Capacitance is constant as a function of the frequency. Fluence = 1×10^{14} n/cm^{2} .

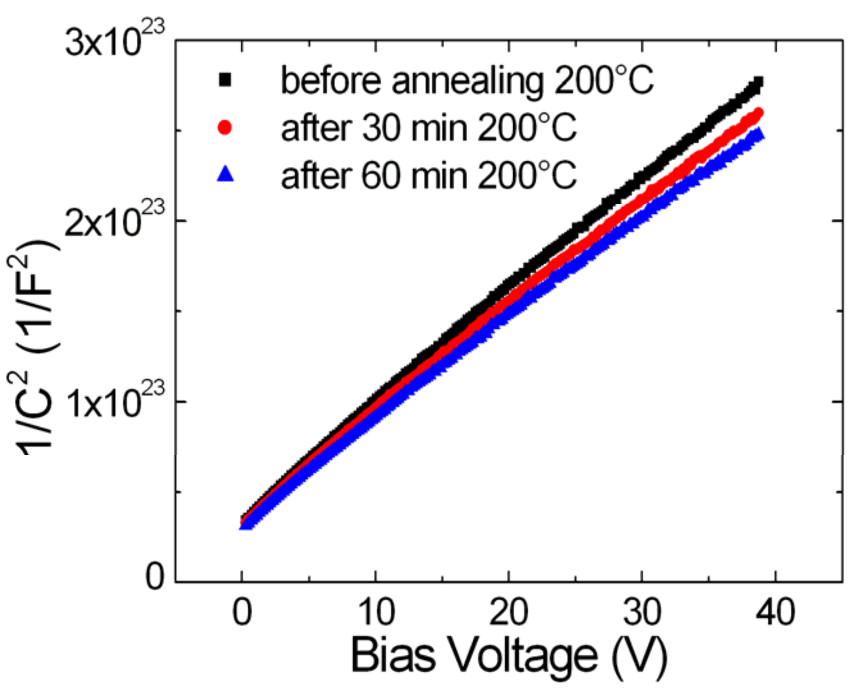
Università degli Studi
di Perugia

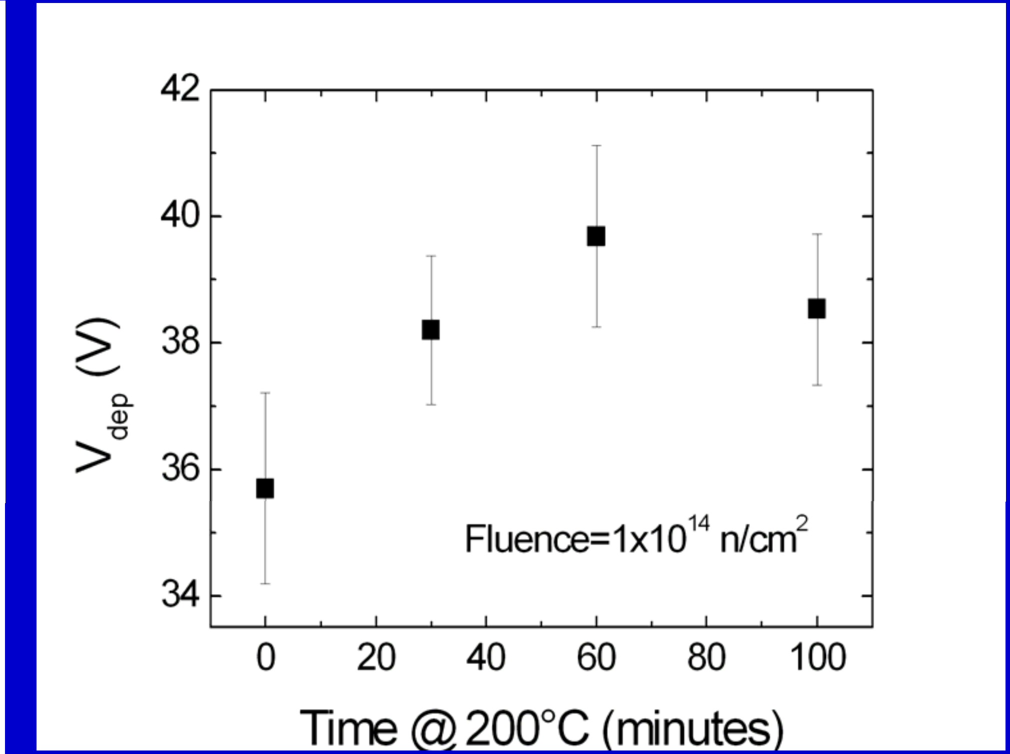
OPAL: CV after annealing 80°C



- Depletion voltage is almost constant as a function of the annealing time at 80°C.
- Average value considering 6 diodes

CV after annealing at 200°C





- After annealing at 200°C V_{dep} increases slightly.

Epi: 5 μm

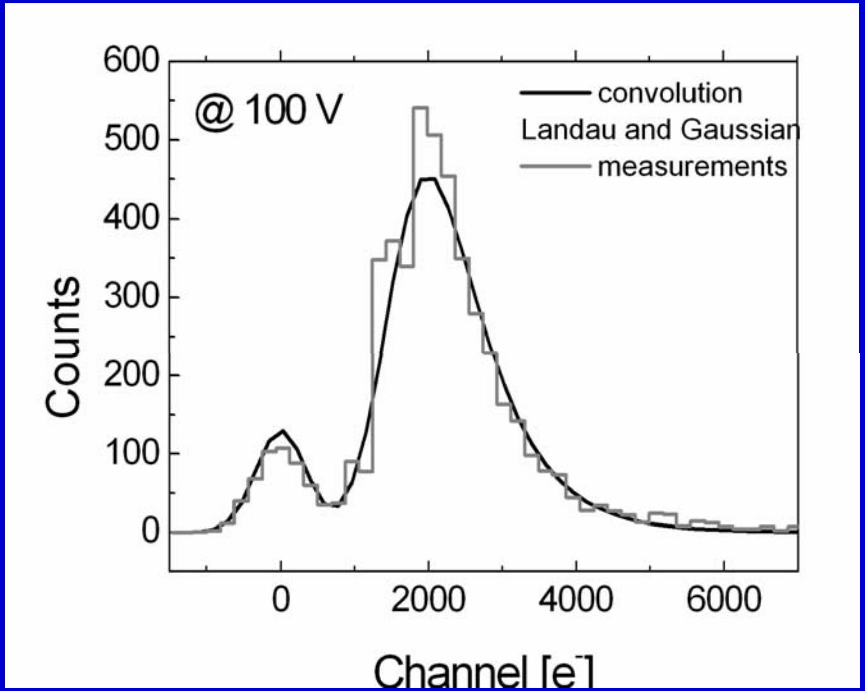
Università degli Studi
di Perugia

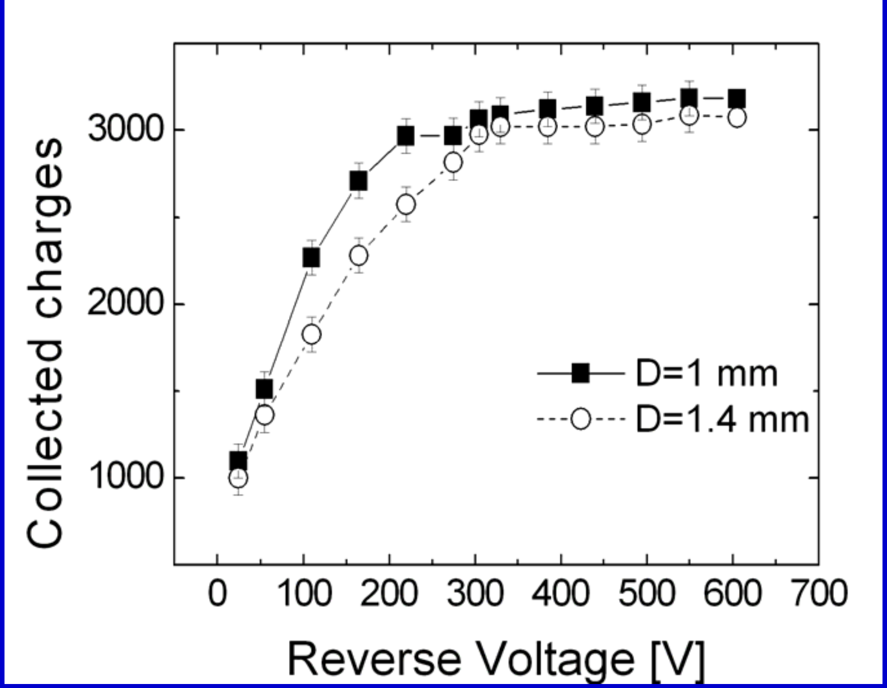
Measurements on SiCPOS samples

Epi: 55 μm

epi doping = 1.6×10^{14} cm^{-3}

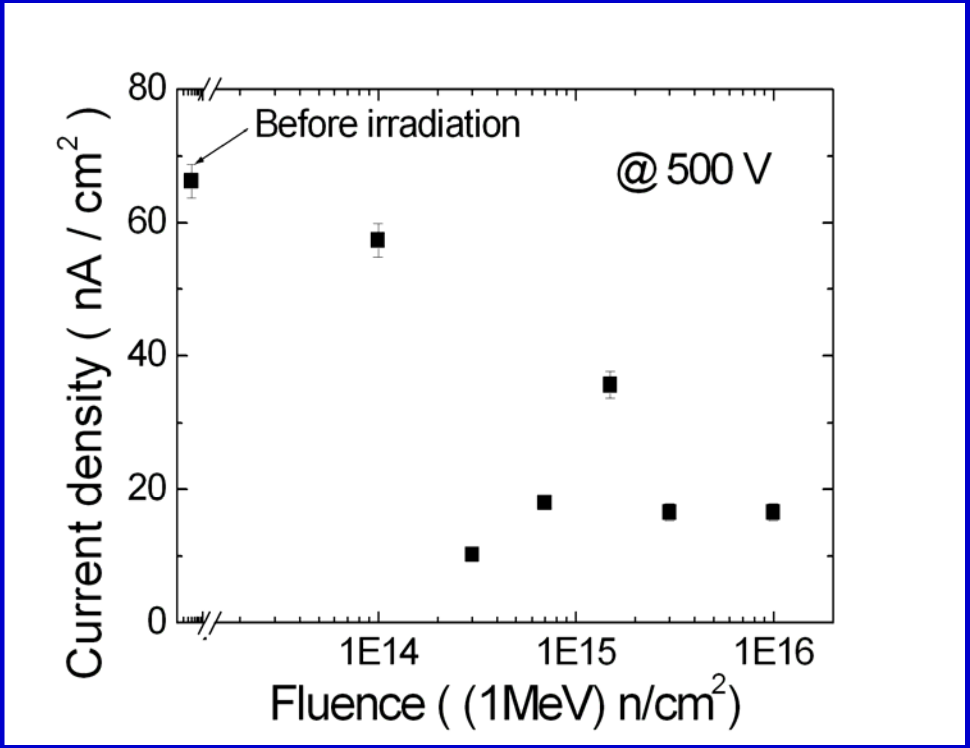
CC measurements on reference





3000 e- @ 200 V and 3100 e- @ 600 V for diode with D=1 mm

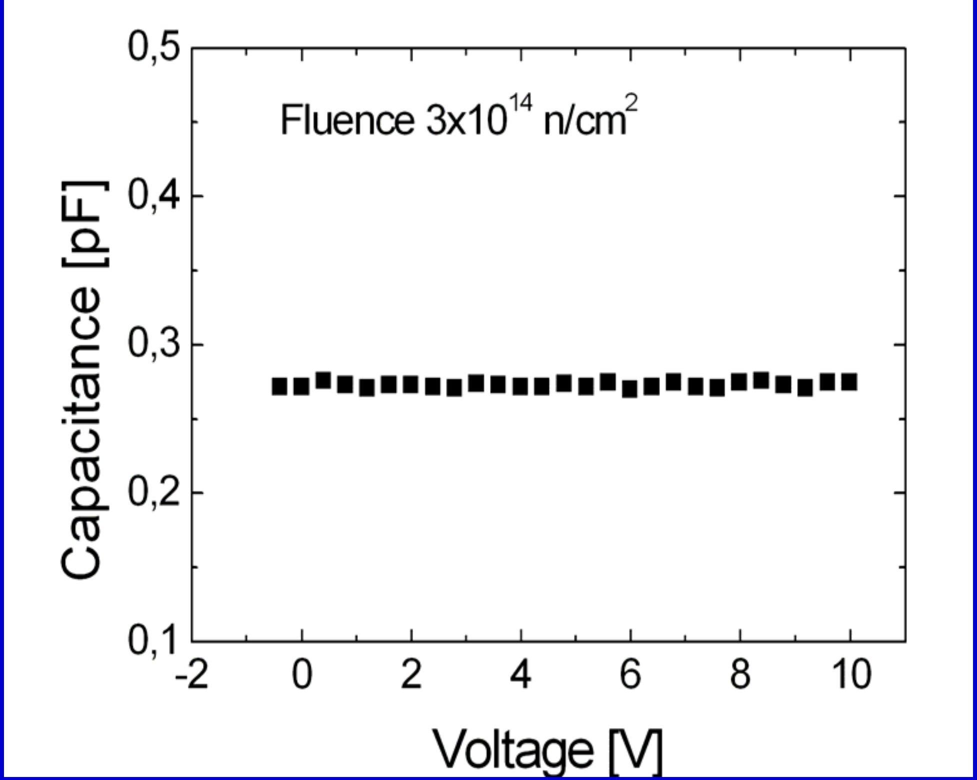
I- V after irradiation



Reverse current density decreases after irradiation!

Diameter = 1 mm

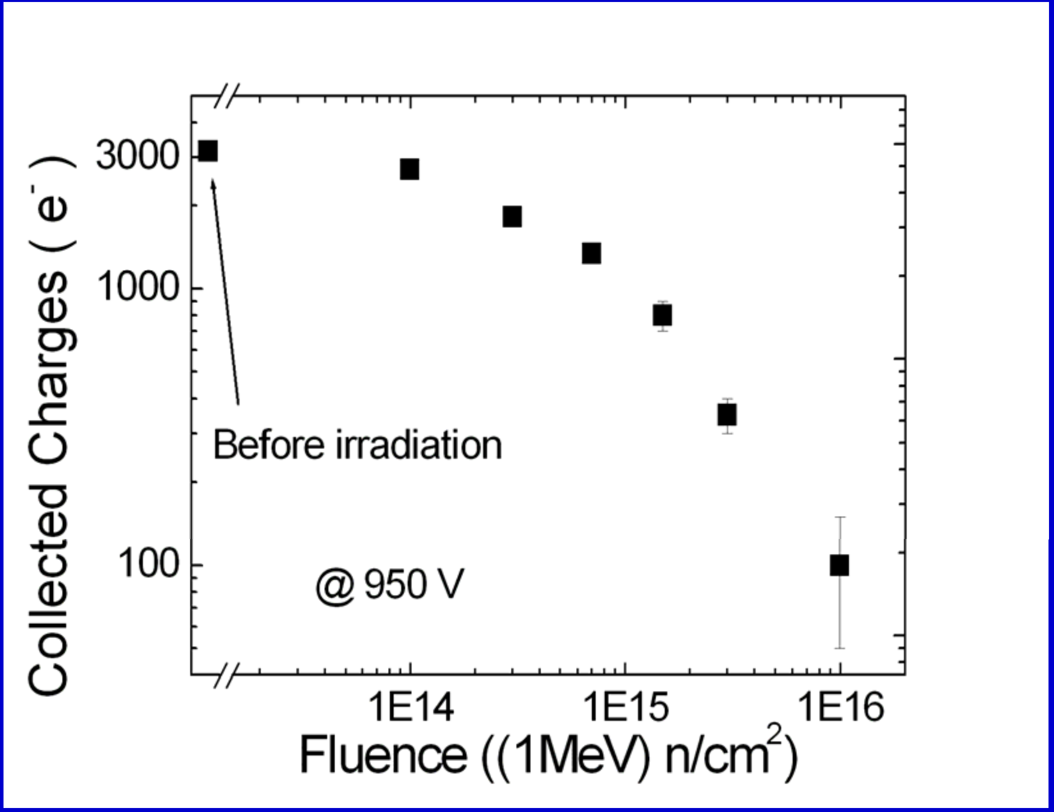
C-V after irradiation



Capacitance is constant. The material turns to intrinsic

Diameter = 0.4 mm

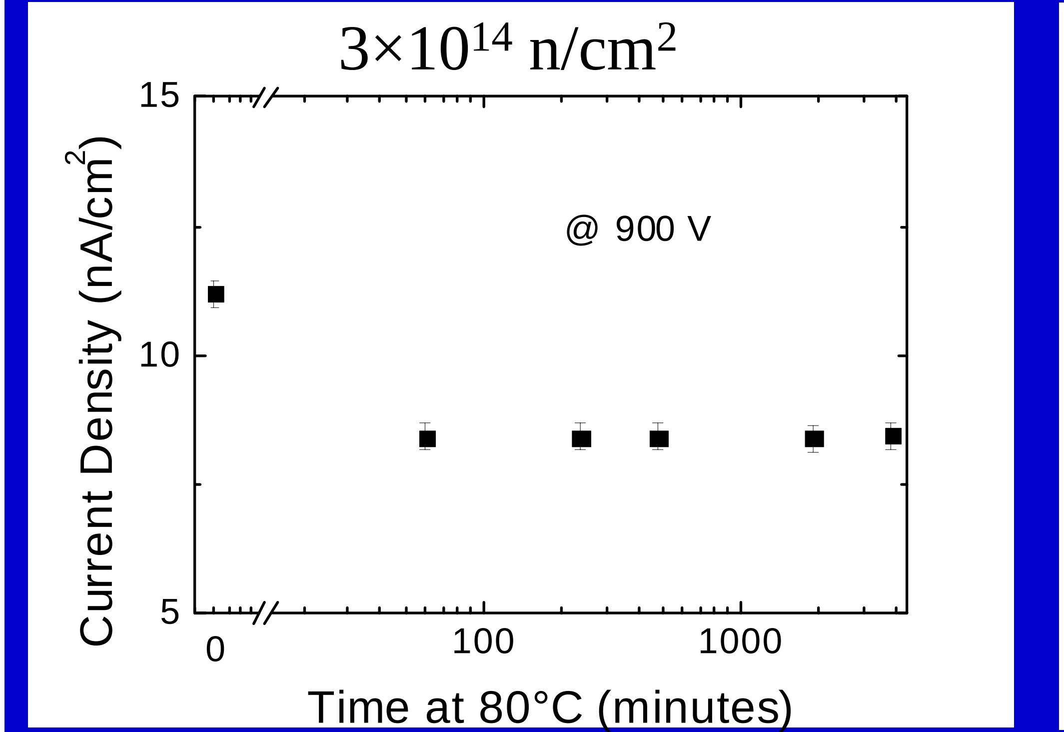
CC vs fluence

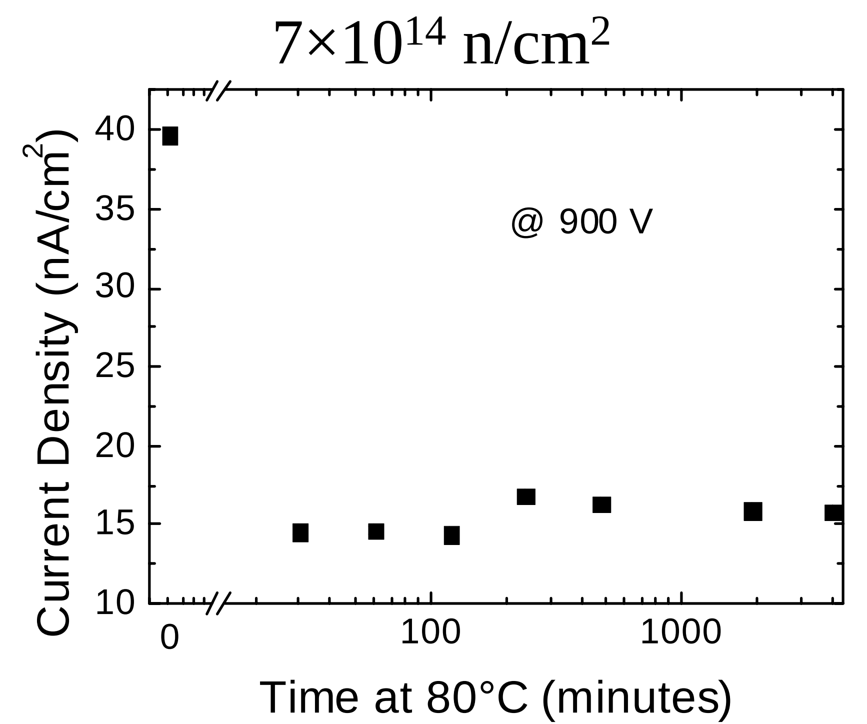


Diameter = 1 mm

- CC is high until some 10^{14} n/cm^2
- CC decreases sharply after 10^{15} n/cm^2. Only 130 e$^-$ after 10^{16} n/cm^2
- Presently SiC is not radiation hard as we thought of!

I-V measurements after 80°C annealing

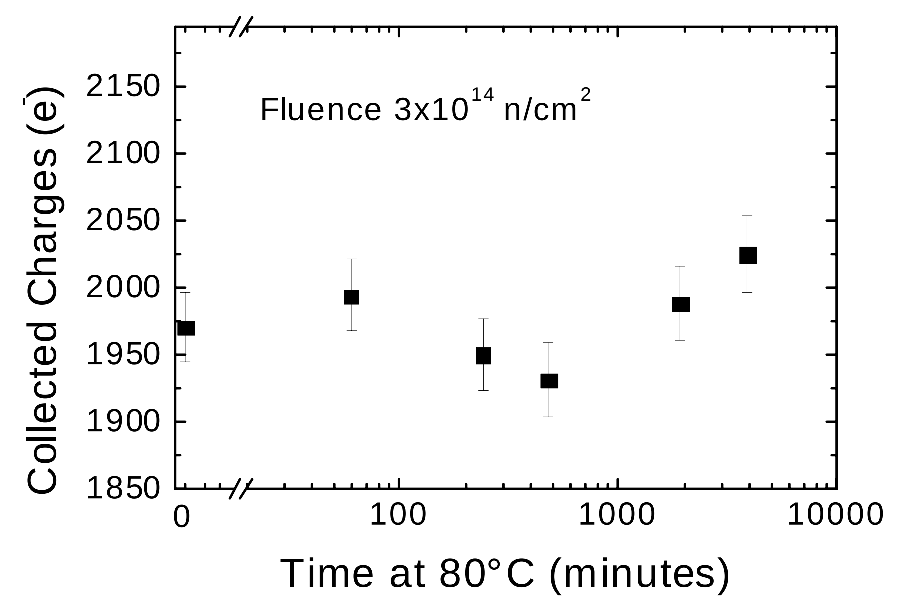


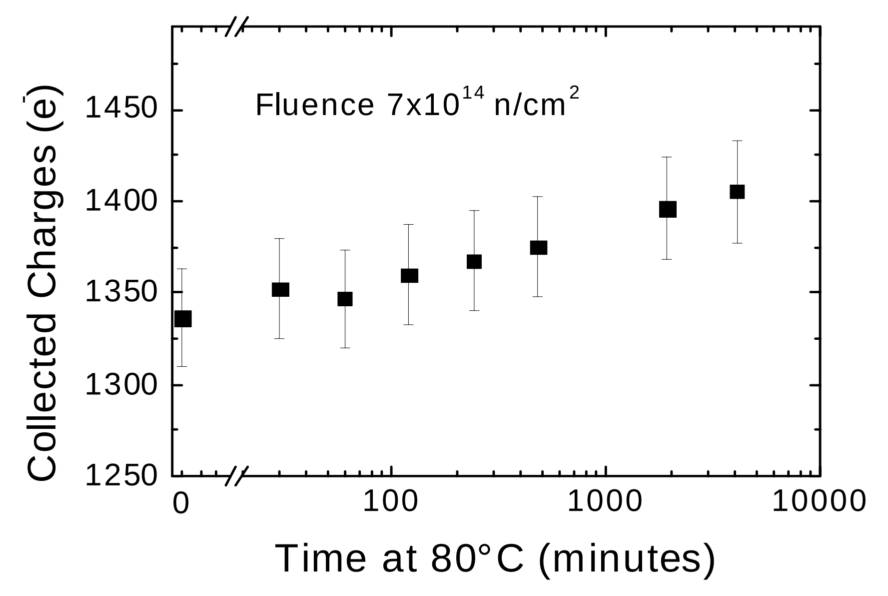


Average current decreases after an annealing at 80°C for 30 minutes and then remain almost constant.

Università degli Studi
di Perugia

CC measurements after 80°C annealing

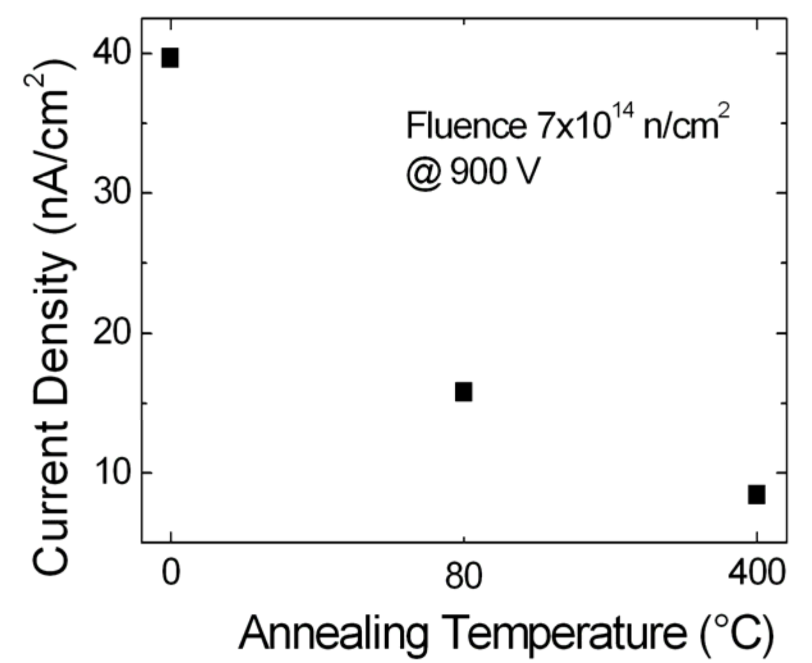


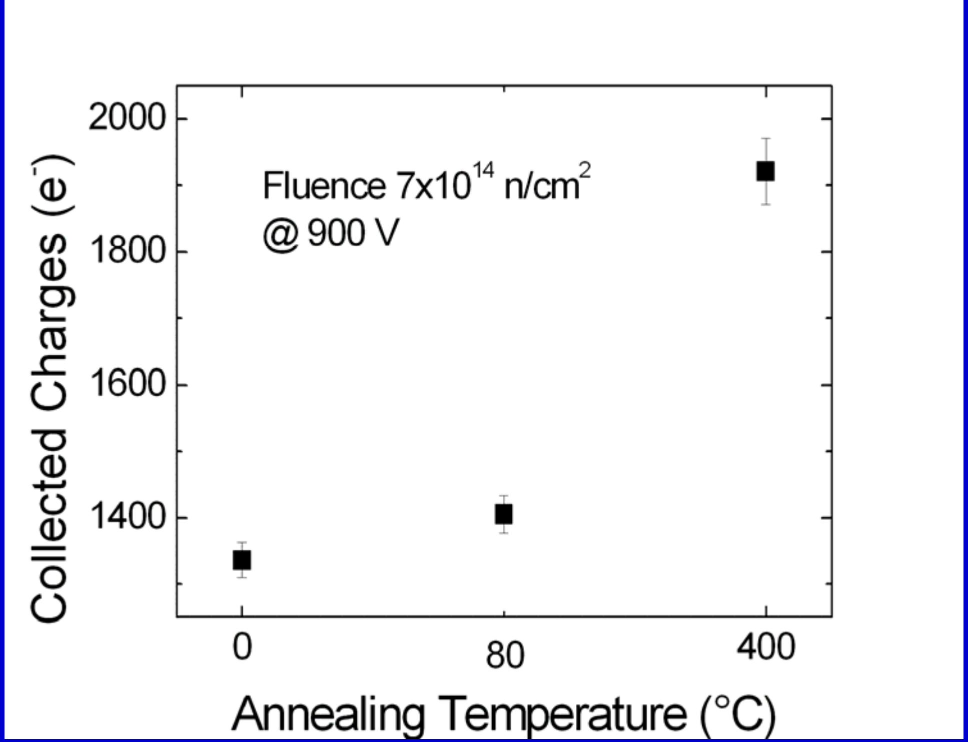


After annealing at 80°C we observe a slight increase of the collected charge, in the range of the experimental error.

No recovery of the damage at 80°C and then at RT!

I-V and CC after annealing at 400°C





After 30 min at 400°C the current furtherly decreases and the CC increases of 500 e^- (from 1400 e^- to 1900 e^-).

Conclusions

- Current
  - Currents @ 500 V are very low even after fluences of the order of 10^{16} n/cm^2.
  - Currents decrease after annealing at 80°C, 200°C and 400°C.
- Depletion voltage
  - remain almost constant as a function of the annealing at 80°C. There is a slight increase after an annealing at 200°C
- CC
  - is good until fluences of the order of some 10^{14} n/cm^2. Before annealing , for fluences of the order of 10^{15}-10^{16} n/cm^2 the CC is very low.
  - After annealing at 80°C we observe a slight increase of the collected charge, in the range of the experimental error. No recovery of the damage!
  - After annealing at 400°C for 30 min we obtain an increase of the CC of the order of 500 e^- for the sample irradiated with 7×10^{14} n/cm^2.

CC and I-V after annealing at 200°C