Functional characterization and functionalization of materials by ion beams.

Ettore Vittone

Physics Department

University of Torino (I)

Functional characterization of semiconductor materials and devices

Measurement of the their electronic properties and performances

Main physical observable: current
Current = F(carrier density; carrier transport)

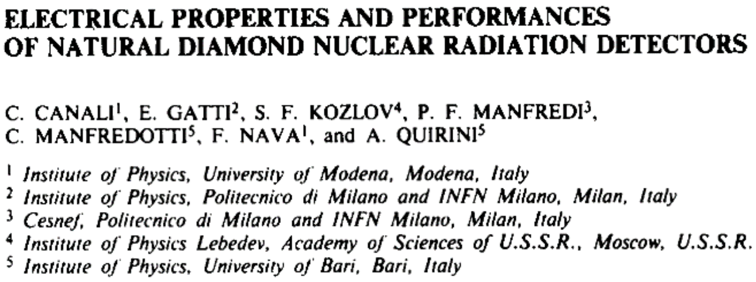
Carrier (electron-hole) generation
Recombination/trapping

Carrier lifetime τ

Free carriers (electron/hole) transport
Two mechanisms:

Drift ⇒ electric field $v=\mu\cdot E$
Diffusion ⇒ concentration gradient

NIMB 93 (1979) 160, 73



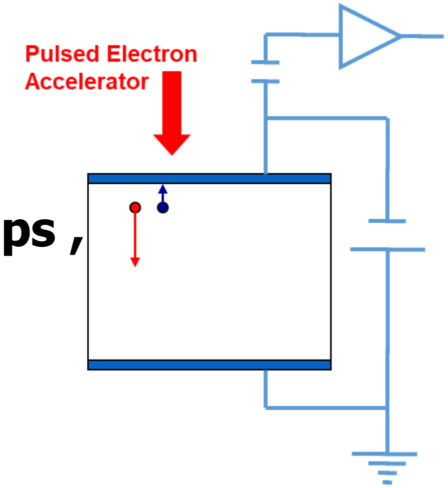
ELECTRICAL PROPERTIES AND PERFORMANCES
OF NATURAL DIAMOND NUCLEAR RADIATION DETECTORS

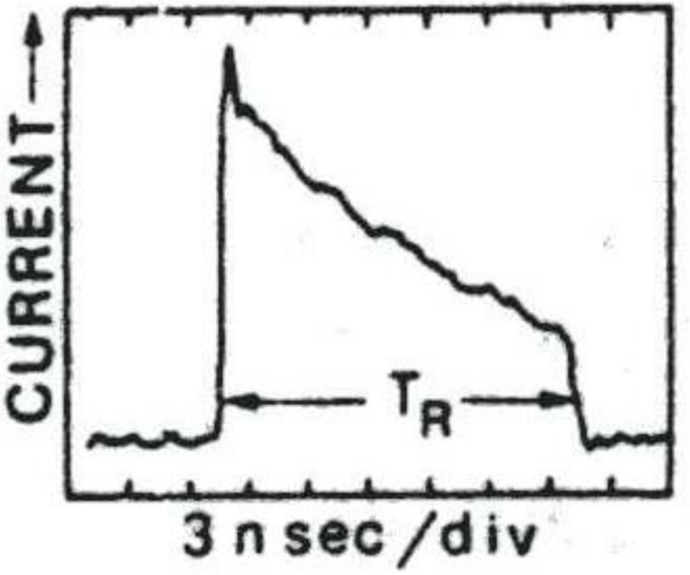
C. CANALI[1], E. GATTI[2], S. F. KOZLOV[4], P. F. MANFREDI[3],
C. MANFREDOTTI[5], F. NAVA[1], and A. QUIRINI[5]

[1] *Institute of Physics, University of Modena, Modena, Italy*
[2] *Institute of Physics, Politecnico di Milano and INFN Milano, Milan, Italy*
[3] *Cesnef, Politecnico di Milano and INFN Milano, Milan, Italy*
[4] *Institute of Physics Lebedev, Academy of Sciences of U.S.S.R., Moscow, U.S.S.R.*
[5] *Institute of Physics, University of Bari, Bari, Italy*

40 keV pulsed electron accelerator, 70 ps ,

RevScInstr 41, 1205 (1970)





Natural IIa diamond from Yakutia (Siberia USSR)

400 µm thick

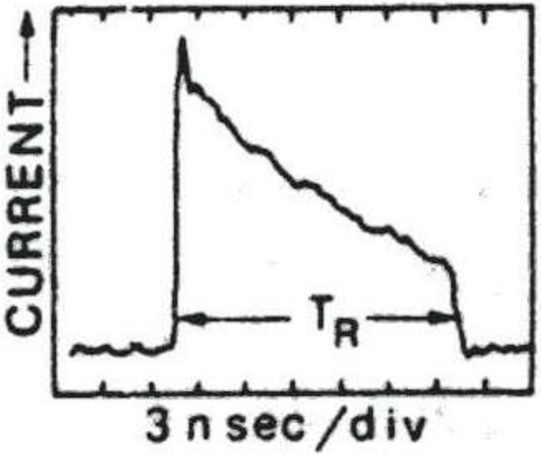
$\rho \approx 10^{15}$ Ω·cm; ε=0.5 pF/cm;

Dielectric relaxation time = 500 s.

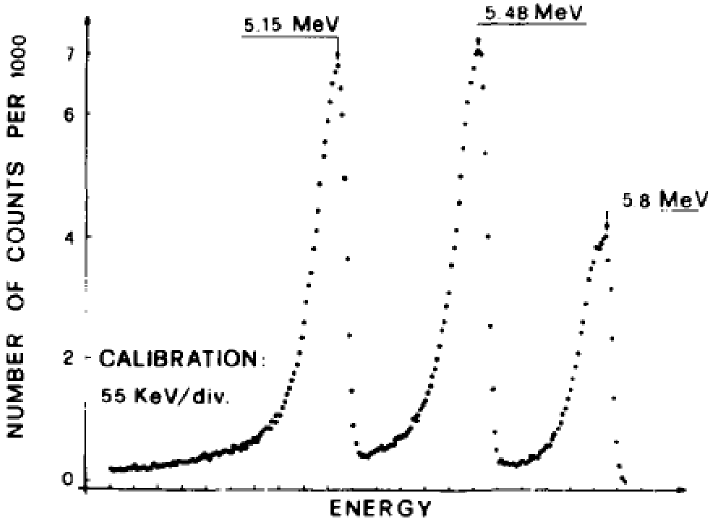
Charge neutrality not maintained

T_R → drift velocity → mobility
Current decay → carrier lifetime

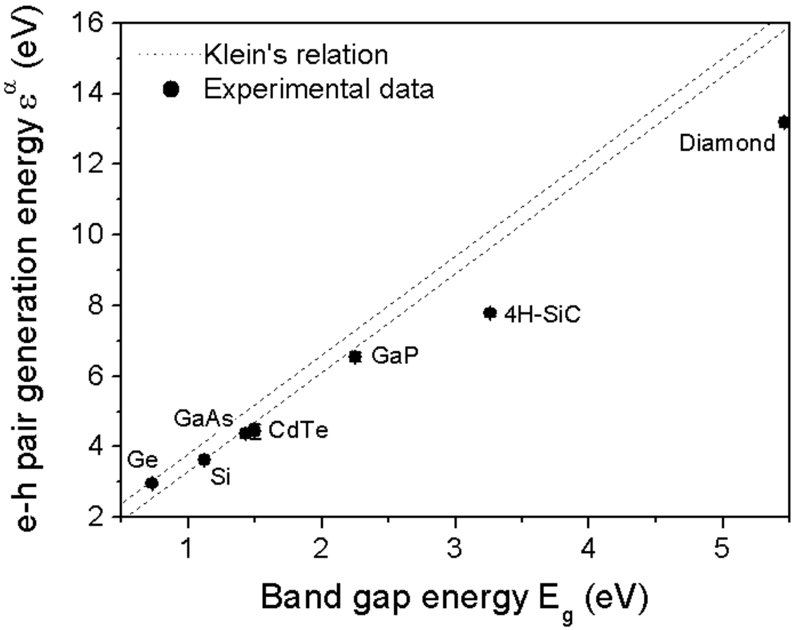
Electron beam induced current



Ion beam induced charge



Alpha spectra from a source containing a mixture of ^{231}Am, ^{239}Pu and ^{244}Cm.



$$N_{eh} = \frac{E_{ion}}{\varepsilon_{eh}}$$

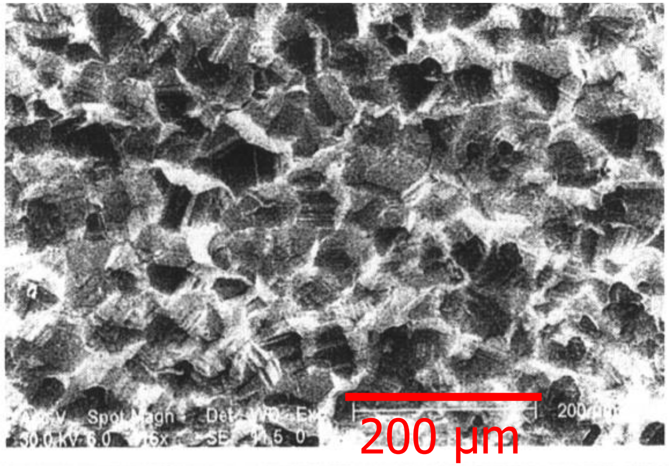
1 MeV alpha in Diamond generates about 78000 e/h pairs

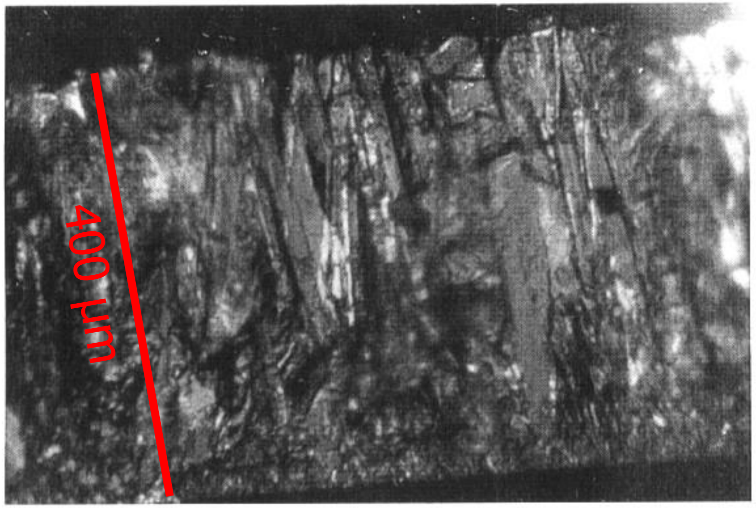
Single ion detection

NIMB 93 (1994) 516

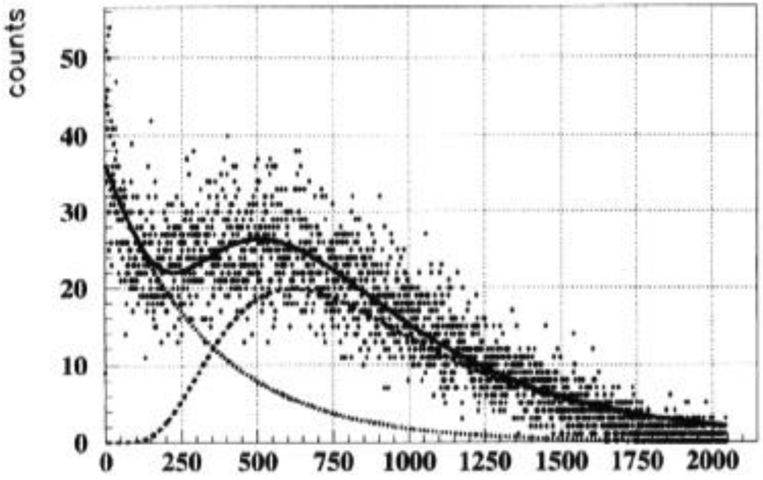
Grain size effects in CVD diamond detectors

C. Manfredotti *, F. Fizzotti, E. Vittone, S. Bistolfi, M. Boero, P. Polesello
Experimental Physics Dept., University of Torino, Via Giuria 1, Torino, Italy and National Institute for Nuclear Physics (INFN), Sez. of Torino, Italy





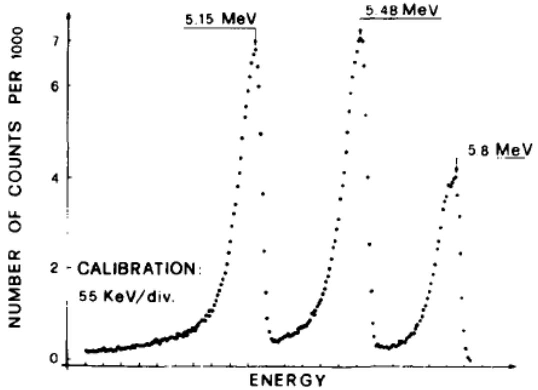
microscope image showing the first 200 µm of thickness of a CVD diamond sample from the



Polycristalline diamond

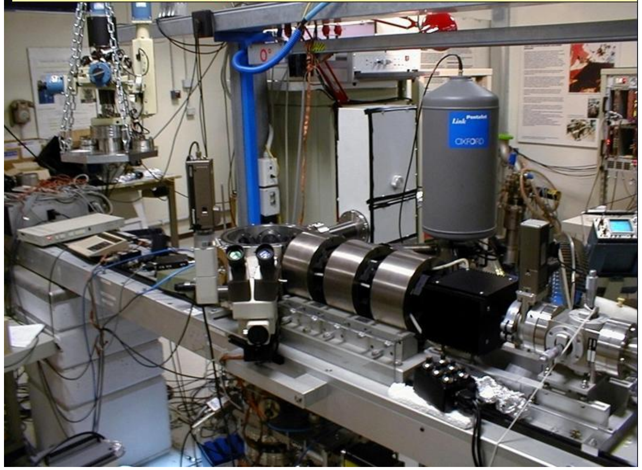
Alpha particle spectrum

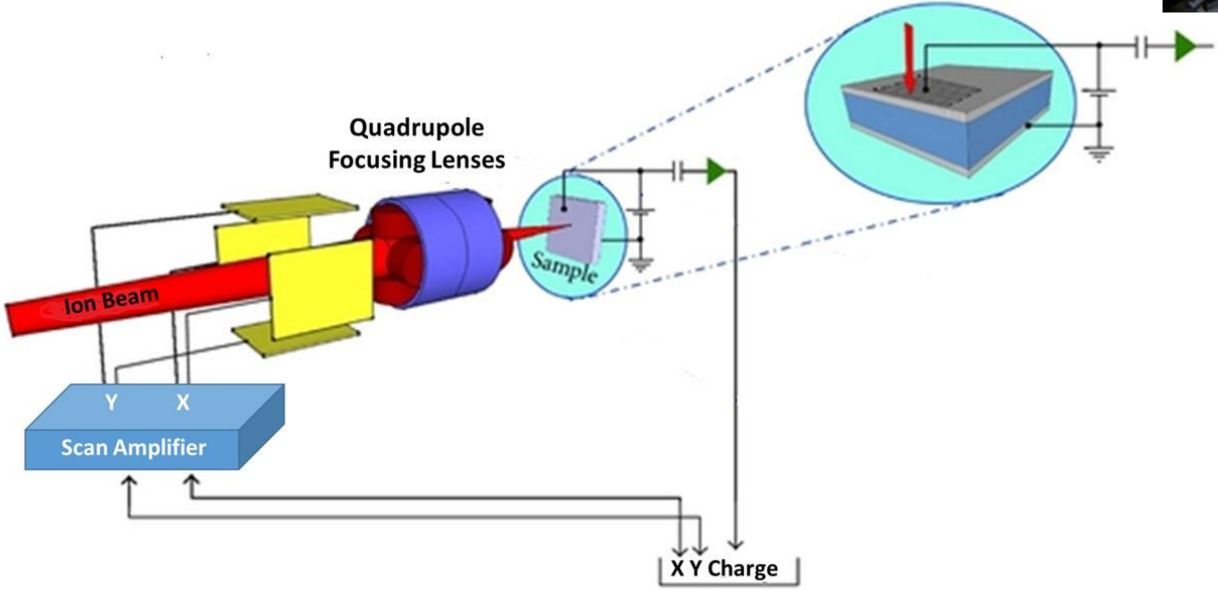
Monocrystalline diamond



Ion Beam Induced Charge
IBIC

National Legnaro Labs. microbeam line



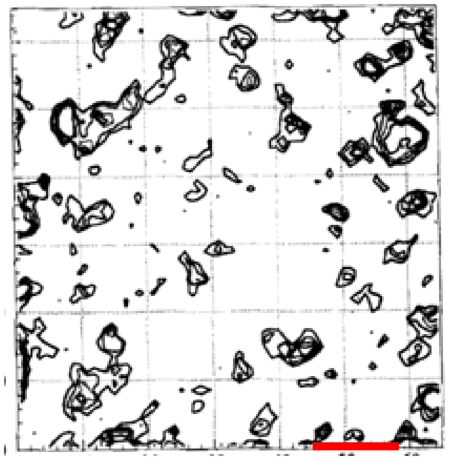


Nuclear microprobe facility @ Ruđer Bošković Institute (Zagreb, Croatia)

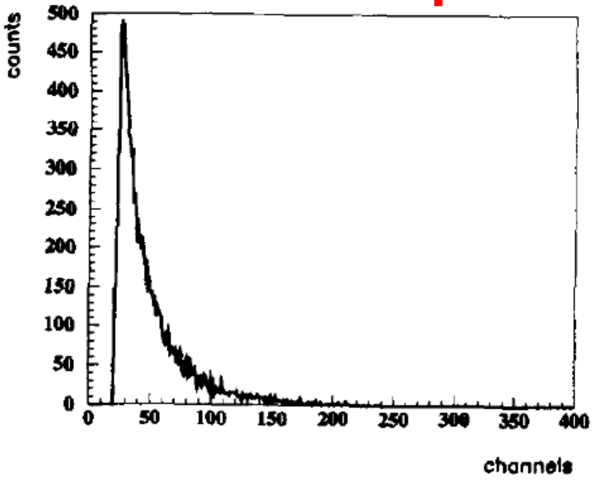
NIMB 100 (1995) 133

IBIC investigations on CVD diamond

C. Manfredotti [a,b,*], F. Fizzotti [a,b], E. Vittone [a,b], M. Boero [a,b], P. Polesello [a,]
S. Galassini [c,d], M. Jaksic [e], S. Fazinic [e], I. Bogdanovic [e]



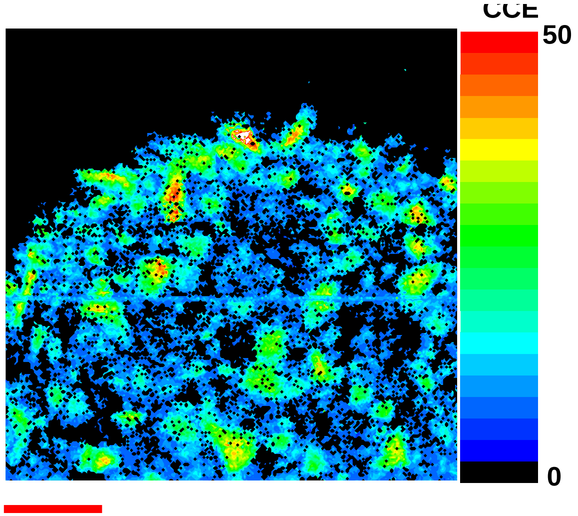
100 µm



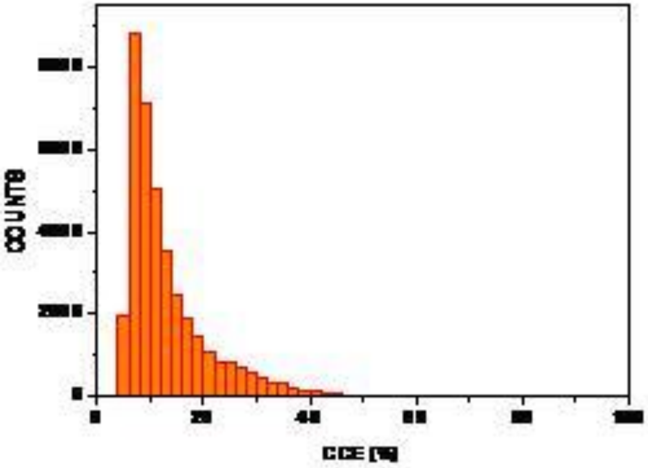
DiamRelMat 12 (2003) 662

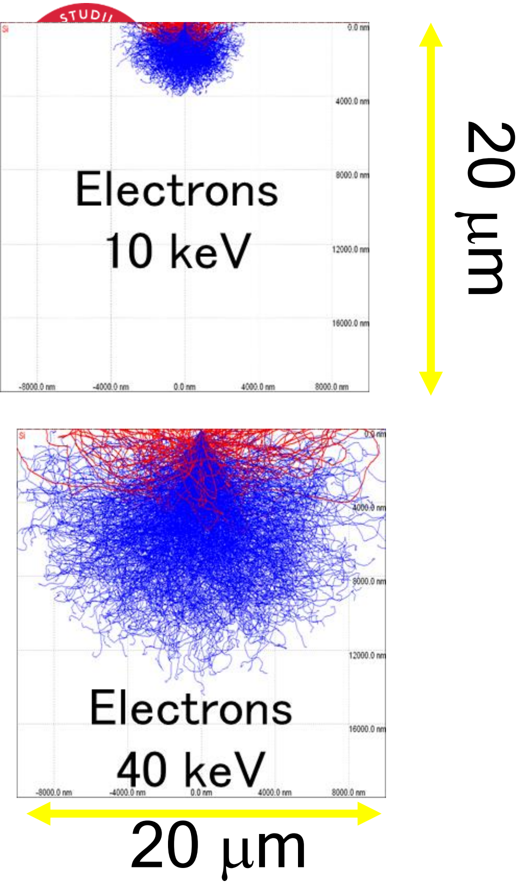
Blue light sensitization of CVD diamond detectors

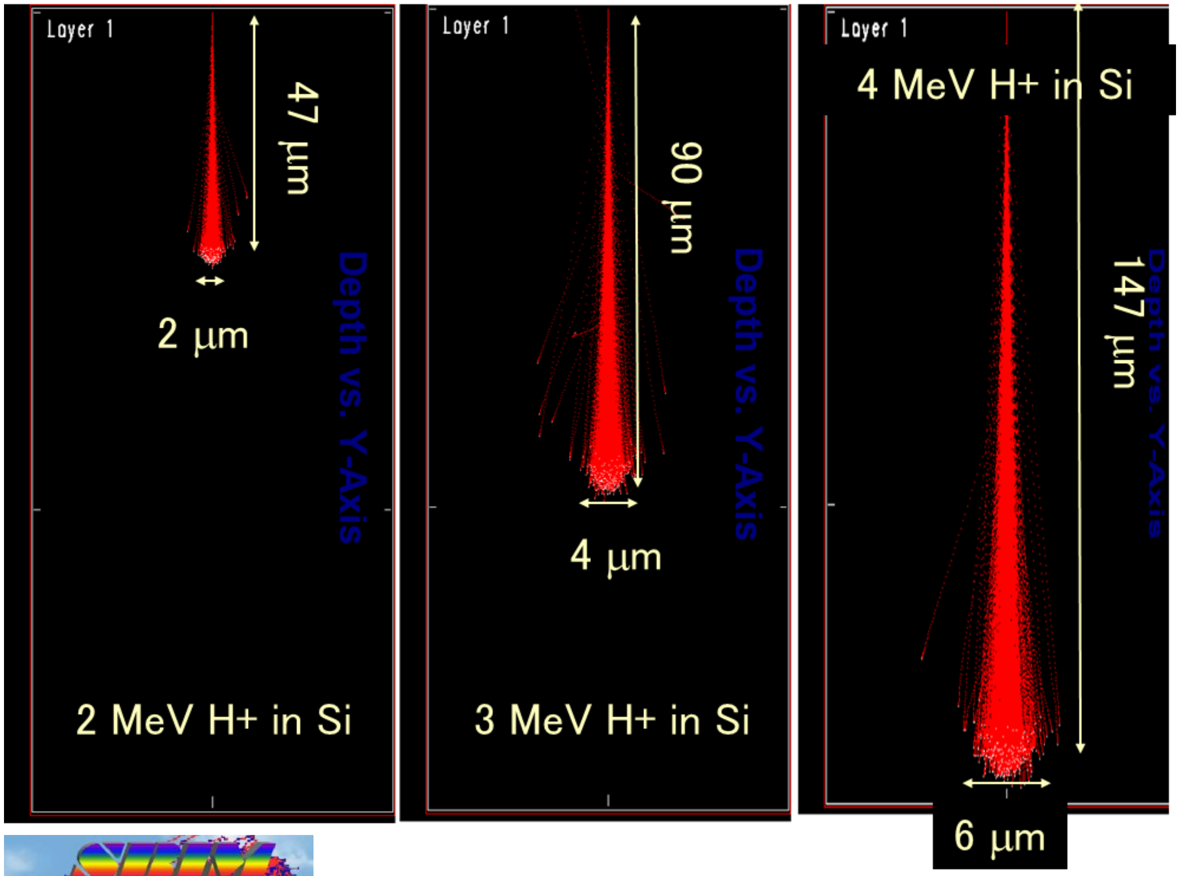
C. Manfredotti [a,b,*], E. Vittone [a,b], C. Paolini [a,b], P. Olivero [a,b], A. Lo Giudice [b]



300 µm







SRIM
The Stopping and Range of Ions in Matter

With respect to OBIC, XBIC, EBIC

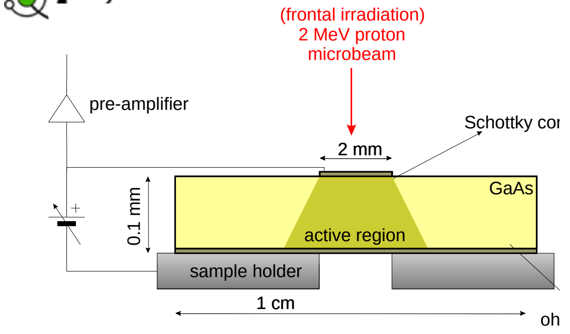
- larger analytical depth
- lower scattering through the surface layers
- flexibility due to the possibility of using ions with different mass and energy

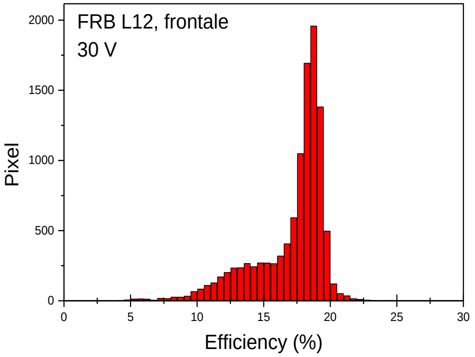
Higher spatial resolution in buried layers
Depth profiling

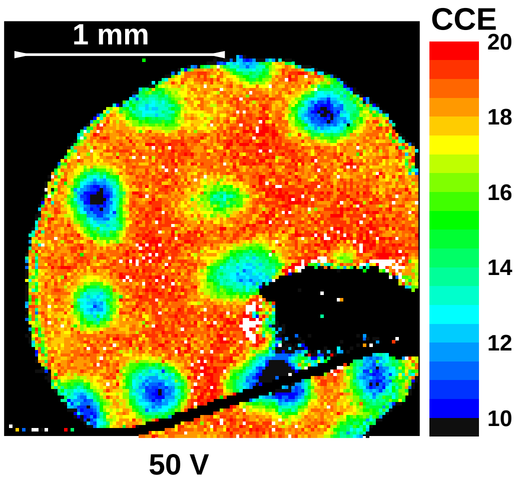
NIMB 158 (1999) 470

IBIC analysis of gallium arsenide Schottky diodes

E. Vittone [a,b,*], F. Fizzotti [a,b], K. Mirri [a], E. Gargioni [a,b], P. Polesello [a,b],
A. LoGiudice [a,b], C. Manfredotti [a,b], S. Galassini [c], P. Rossi [d], P. Vanni [c], F. Nava [e]





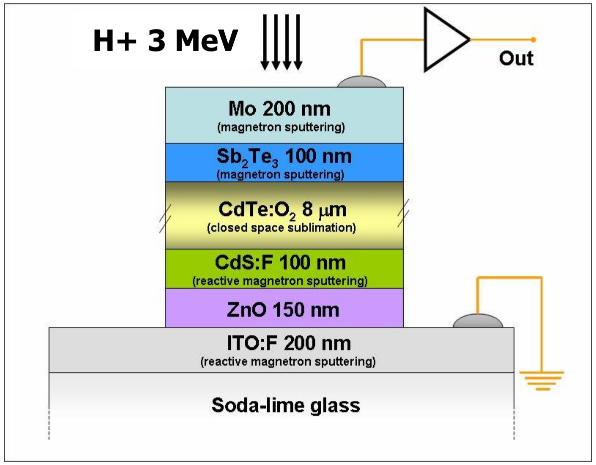


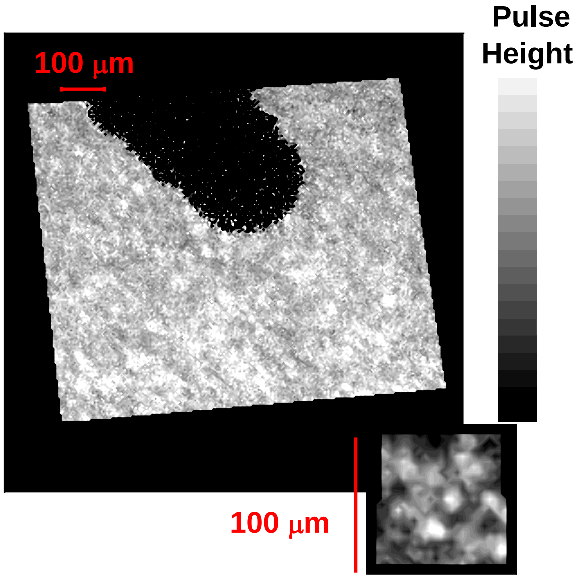
the material behaves
as a ``mixture'' of two
``electronic phases''

NIMB 267 (2009) 2181

IBIC analysis of CdTe/CdS solar cells

E. Colombo [a,b], A. Bosio [c], S. Calusi [a,d], L. Giuntini [d], A. Lo Giudice [a,b], C. Manfredotti [a,b],
M. Massi [d], P. Olivero [a,b], A. Romeo [e], N. Romeo [c], E. Vittone [a,b,*]

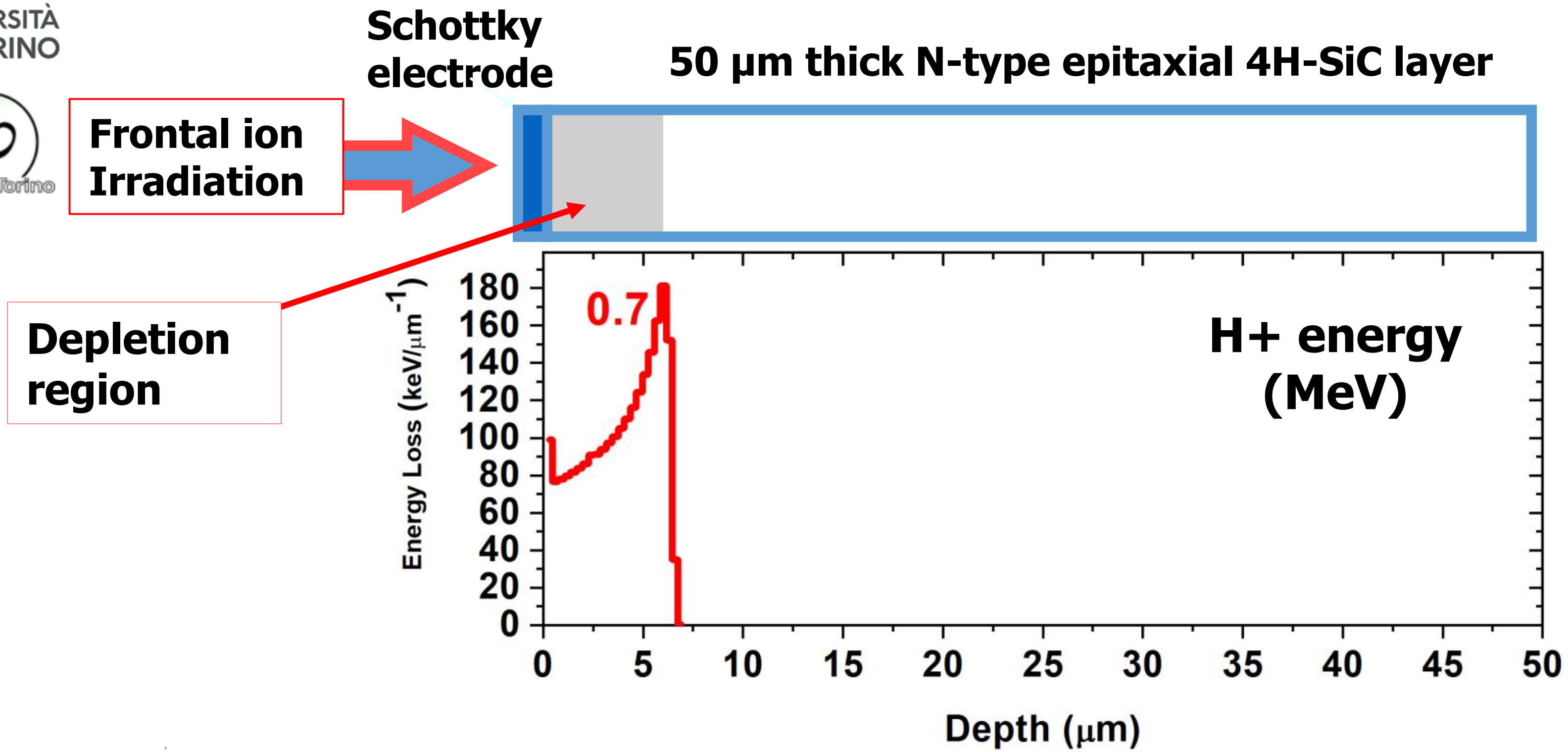




NIMB 188 (2002) 130

Characterisation of SiC by IBIC and other IBA techniques

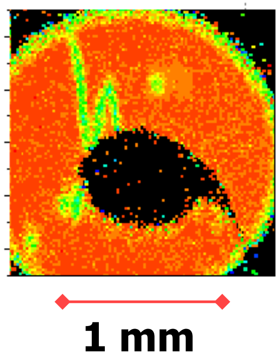
M. Jakšić [a,*], Ž. Bošnjak [a], D. Gracin [a], Z. Medunić [a], Ž. Pastuović [a],
E. Vittone [b], F. Nava [c]


Schottky electrode

50 µm thick N-type epitaxial 4H-SiC layer

Frontal ion Irradiation

Depletion region



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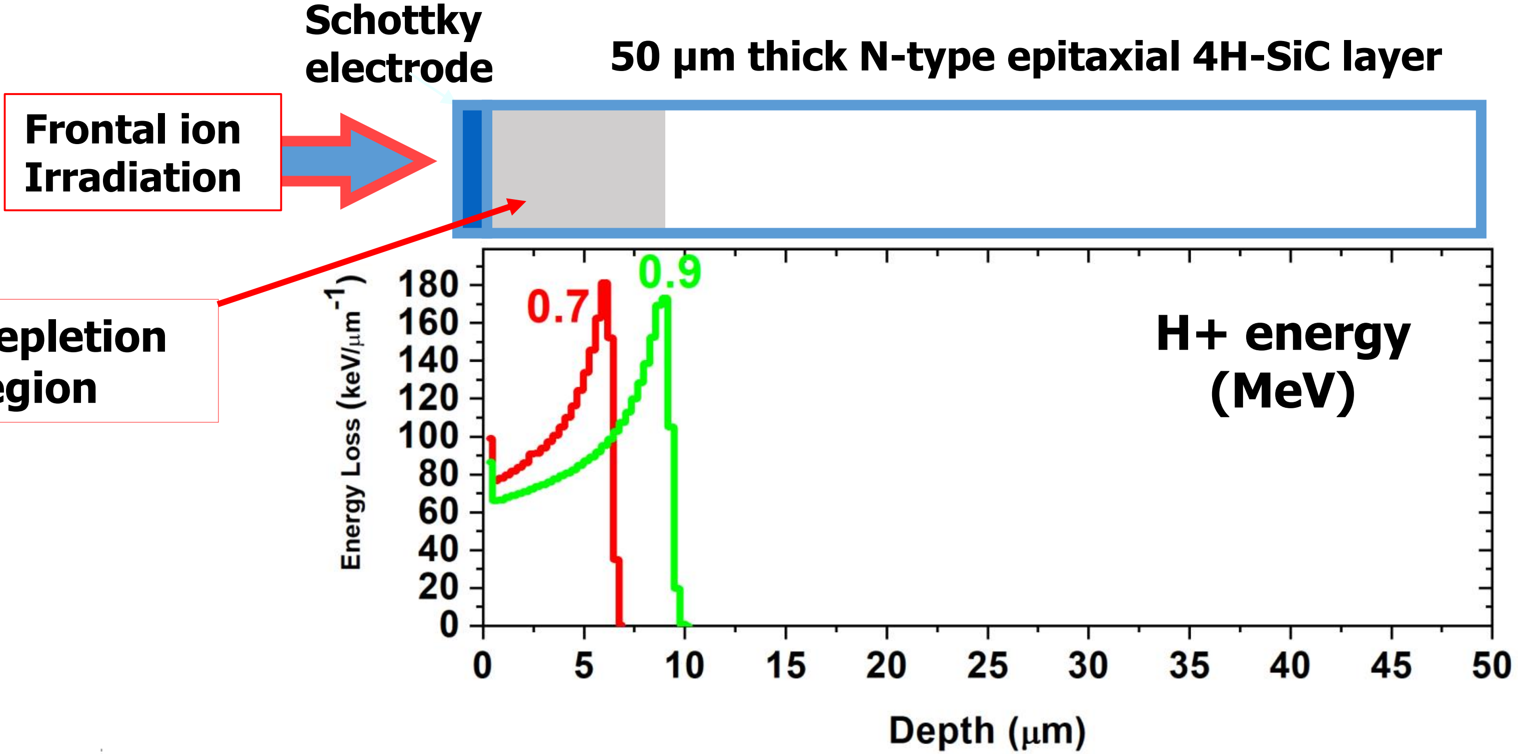

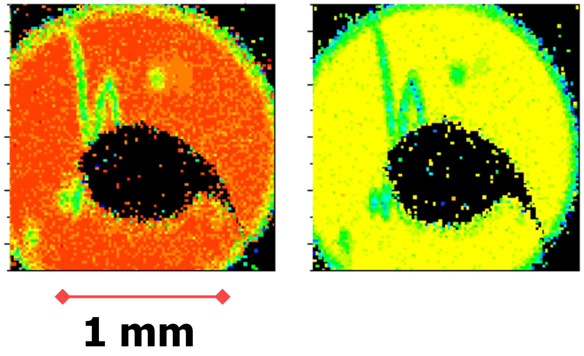

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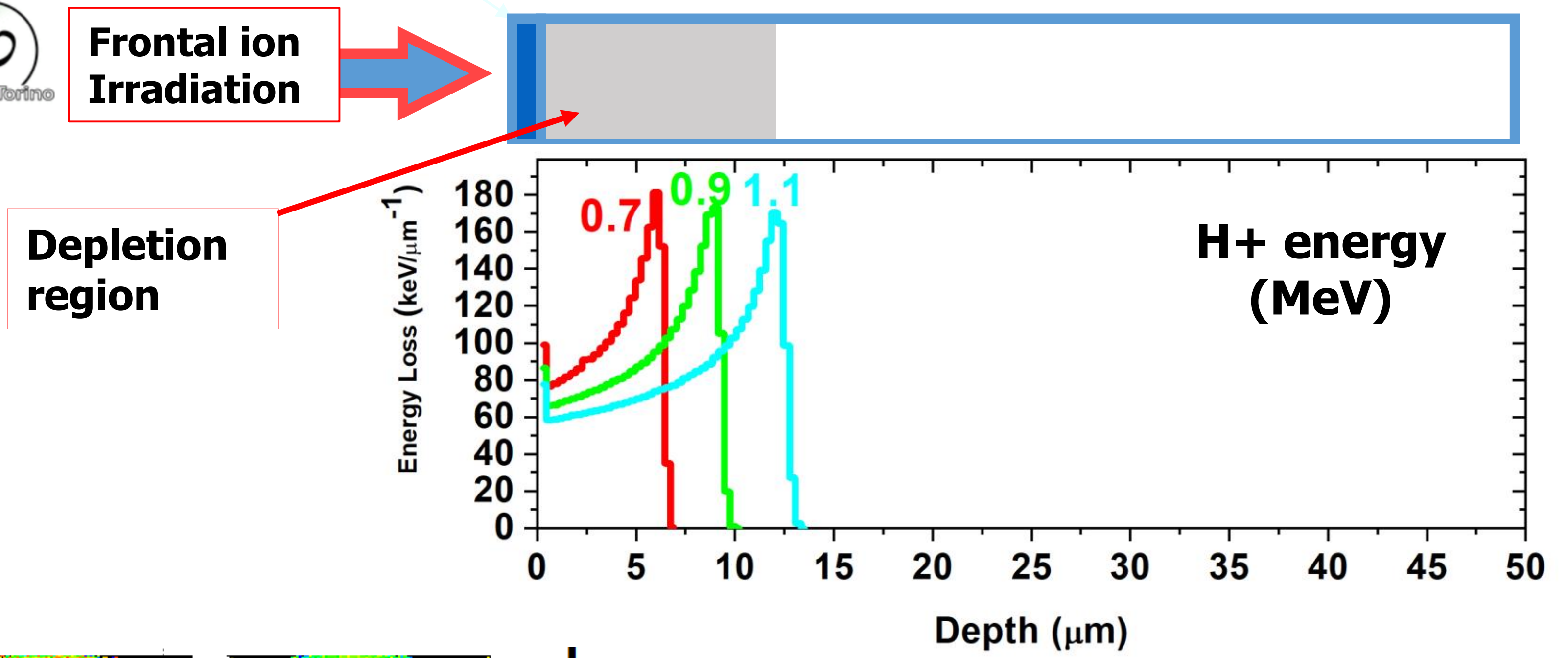
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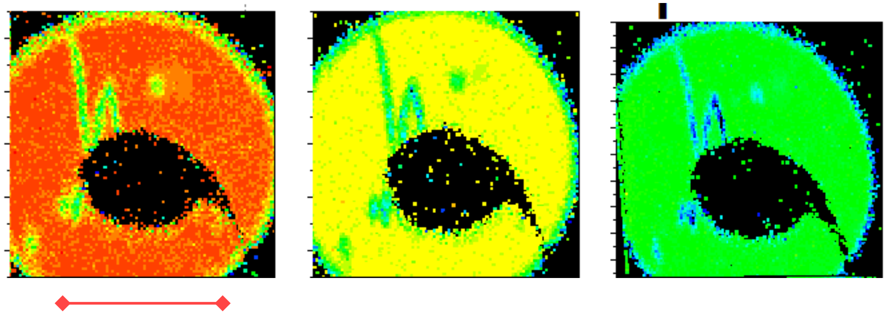
50 µm thick N-type epitaxial 4H-SiC layer

Frontal ion Irradiation

Depletion region

H+ energy (MeV)



CCE

NIMB 188 (2002) 130

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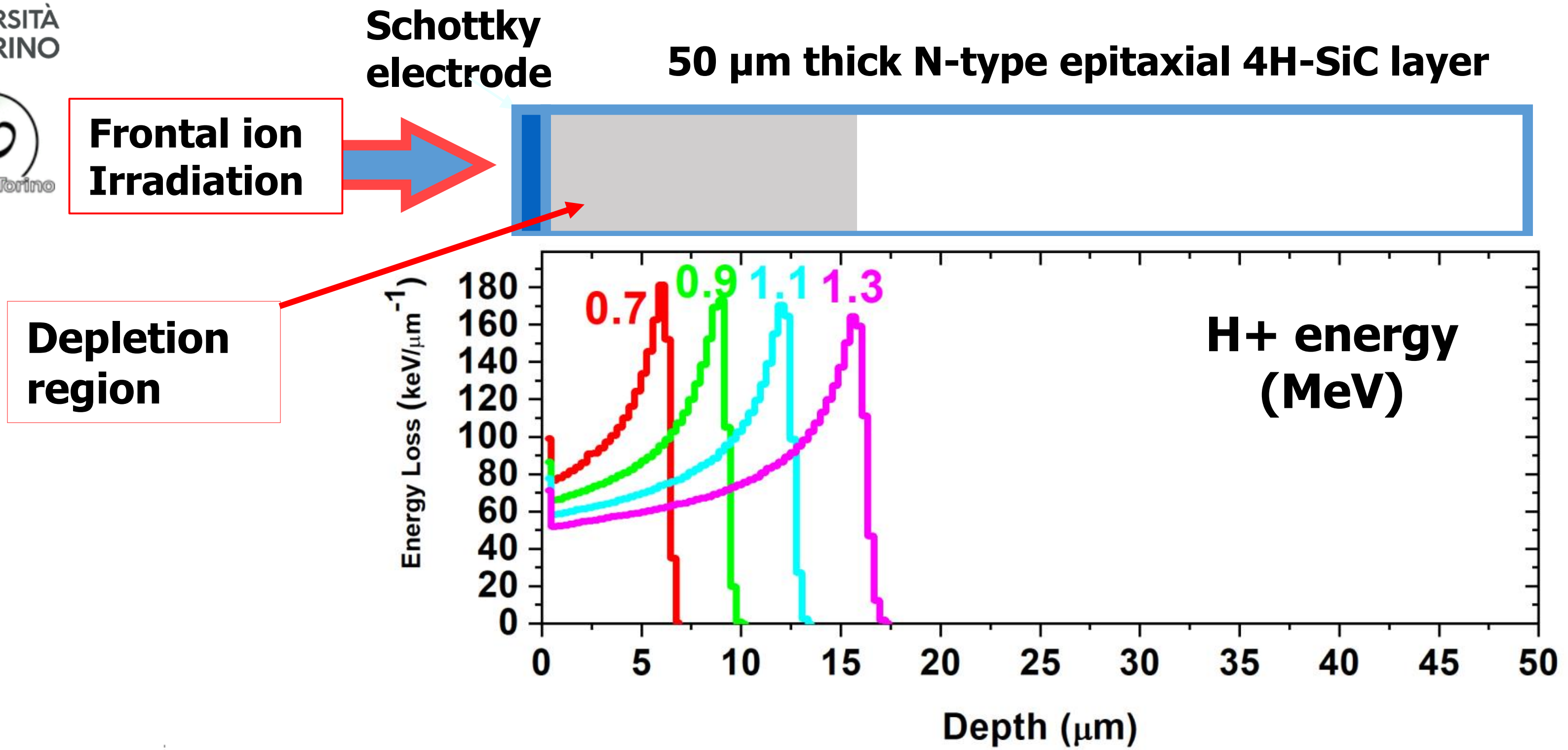
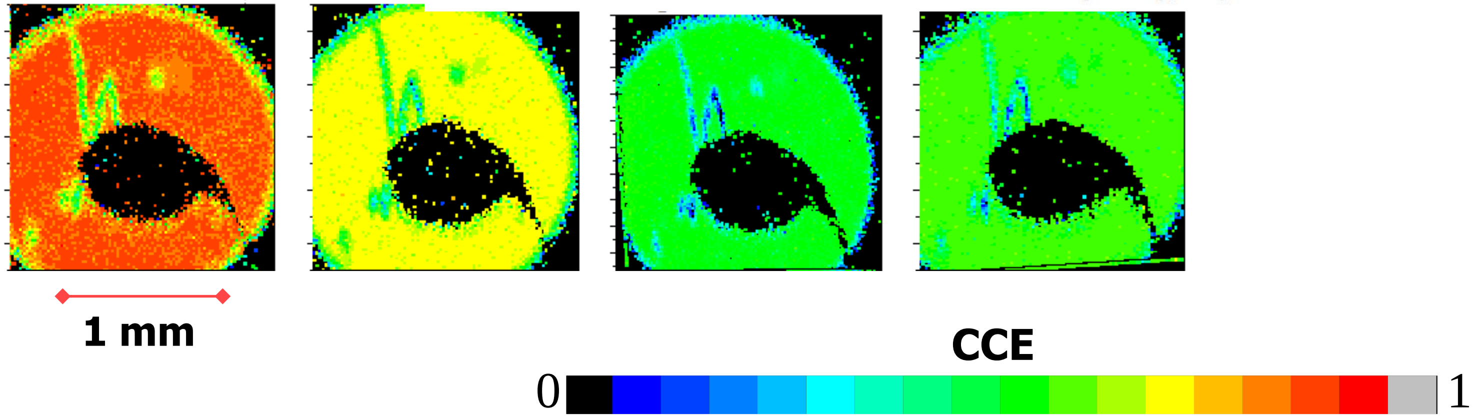


Schottky electrode

50 µm thick N-type epitaxial 4H-SiC layer

Frontal ion Irradiation

Depletion region



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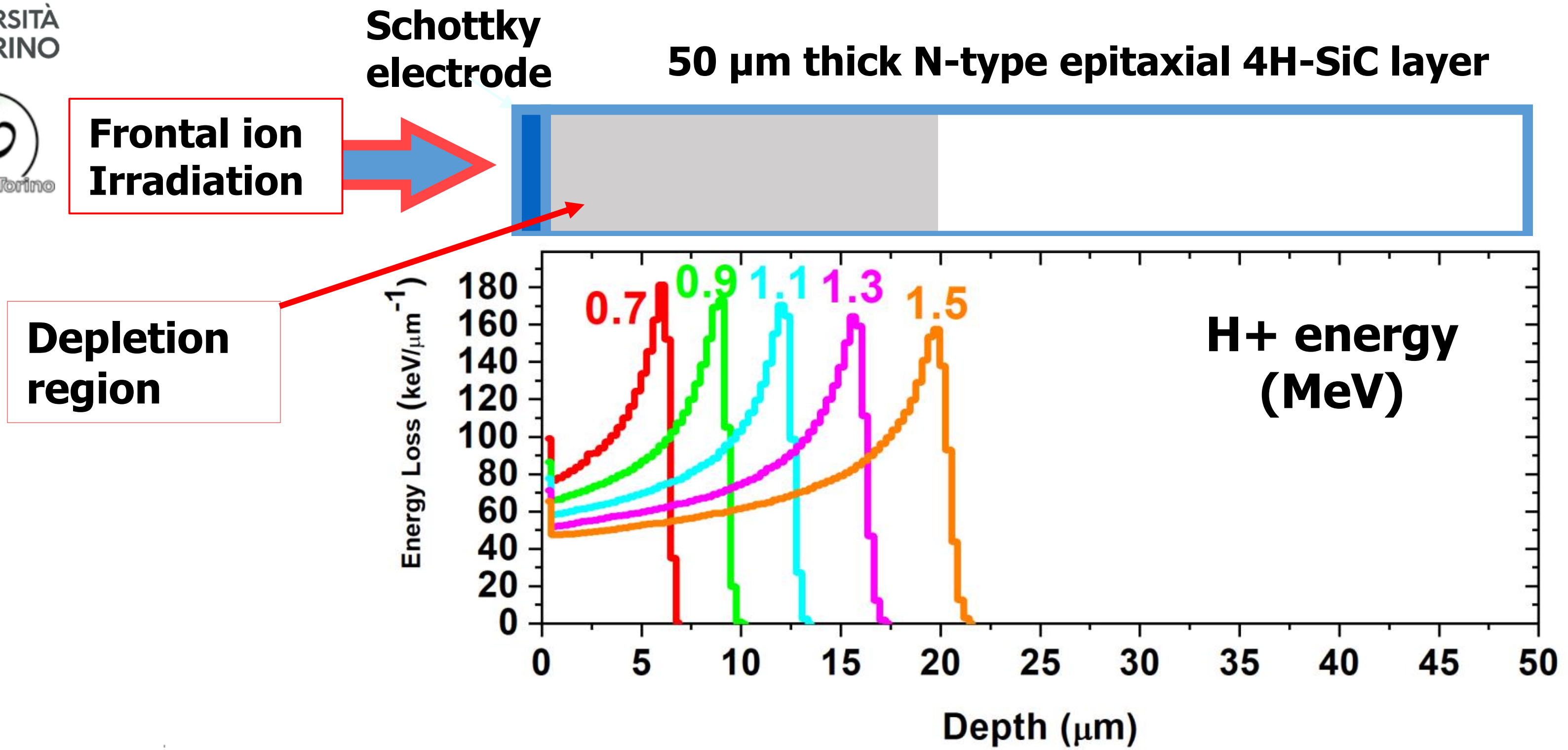

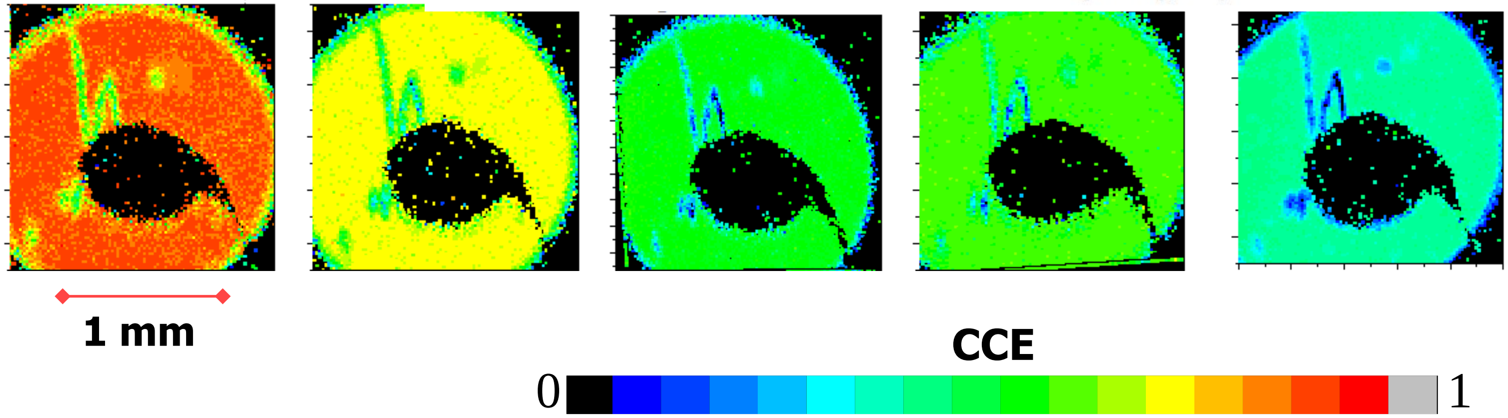

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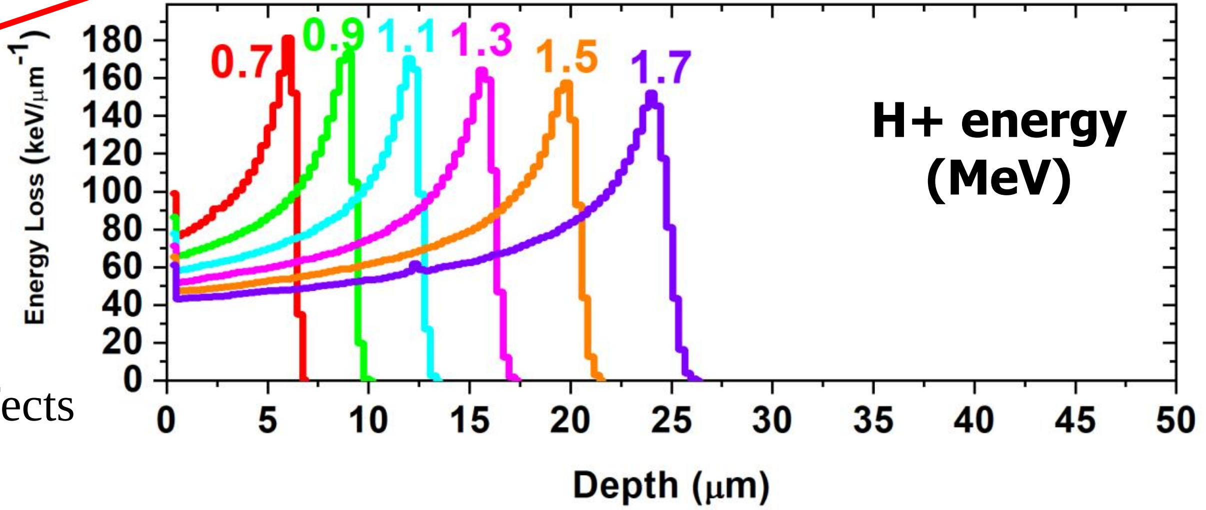
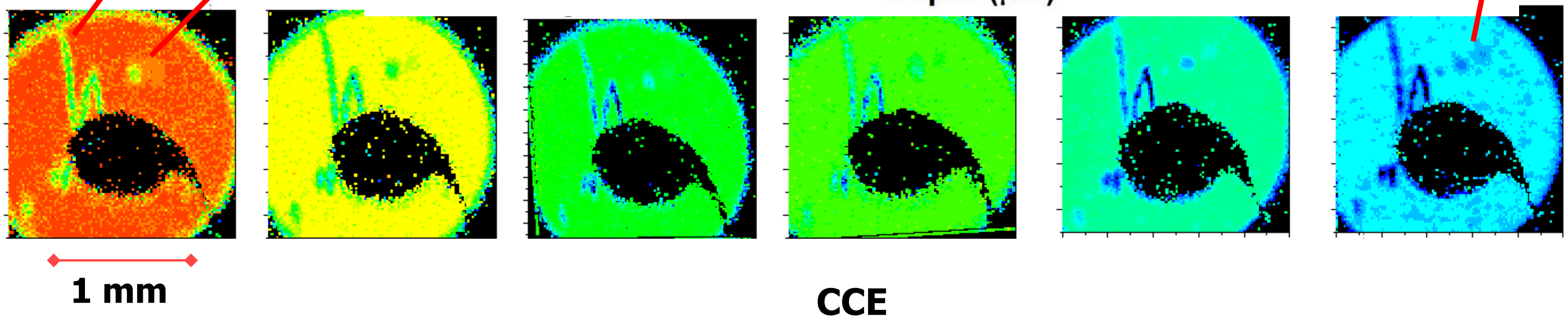
Frontal ion Irradiation

Depletion region





Scratch

Surface defects

Bulk defects

CCE

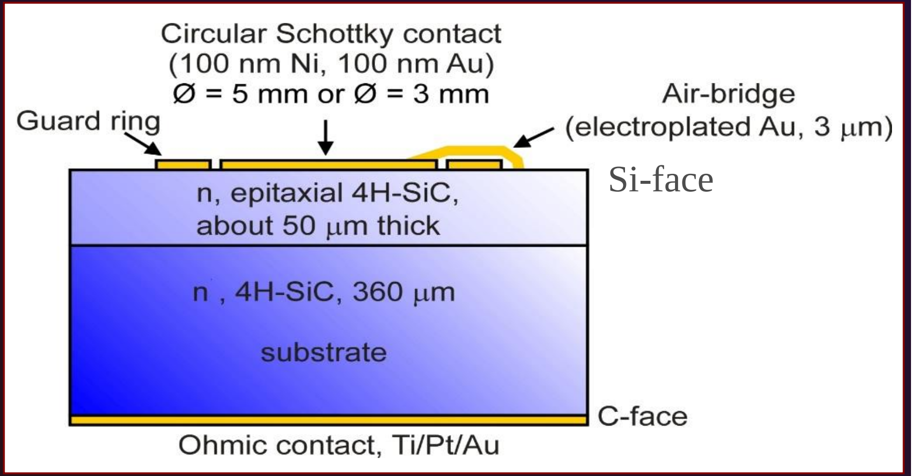
4H-SiC Schottky diode

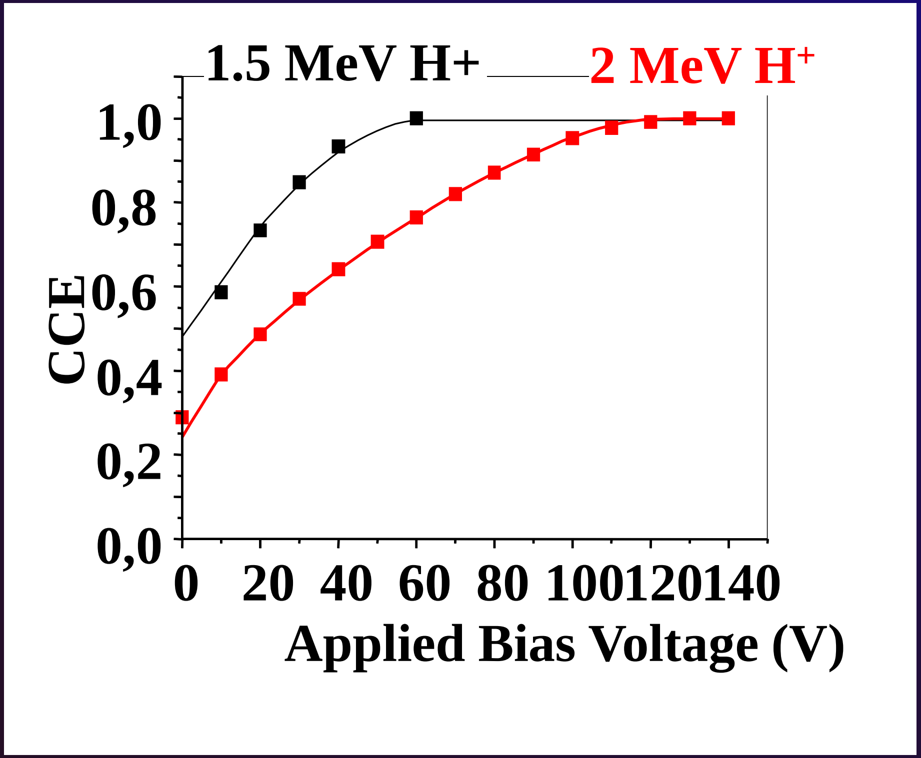
Starting Material: 360 μm n-type 4H-SiC by CREE (USA)
Epitaxial layer from Institute of Crystal Growth (IKZ), Berlin, Germany
Devices from Alenia Marconi System

CCE=Charge Collection Efficiency
=
(Charge collected)/(Charge generated)

1.5 or 2.0

MeV H+





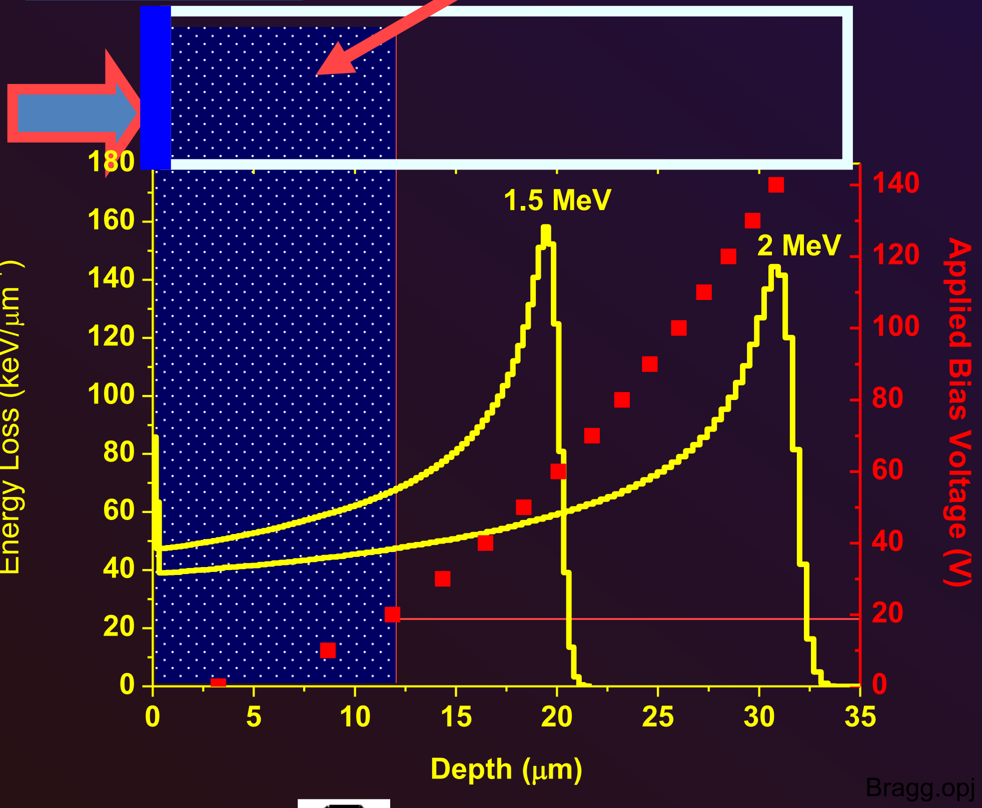
Zagreb 10.12.2013

Contribution from the neutral region

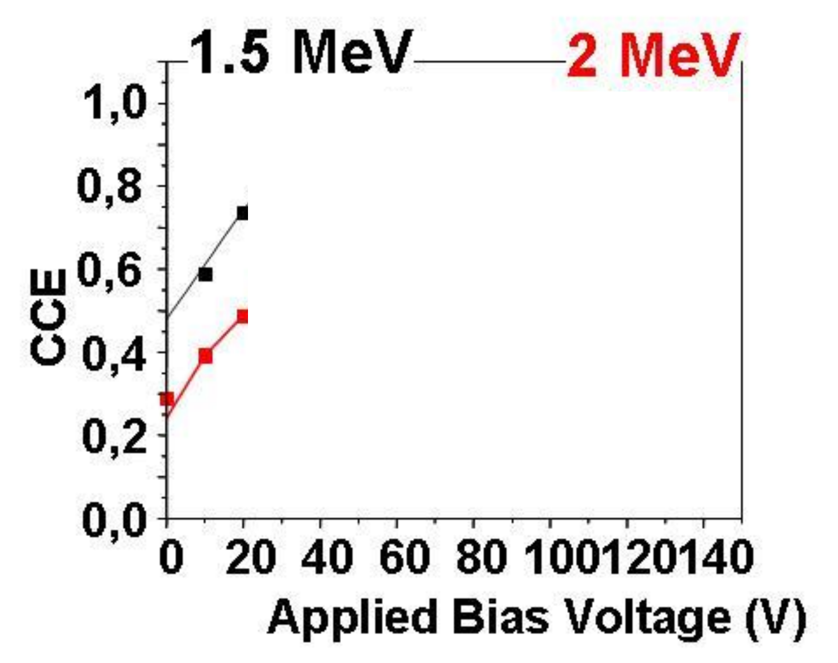
Contribution from the depletion layer

$$Q = Q_{Depl} + Q_{Neutr} \propto \left[\int_0^W \left(\frac{dE}{dx}\right)\cdot dx\right] + \left[\int_W^d \left(\frac{dE}{dx}\right)\cdot \exp\left[-\frac{x-W}{L_p}\right]\cdot dx\right]$$

Frontal ion Irradiation



4H-SiC Schottky diode

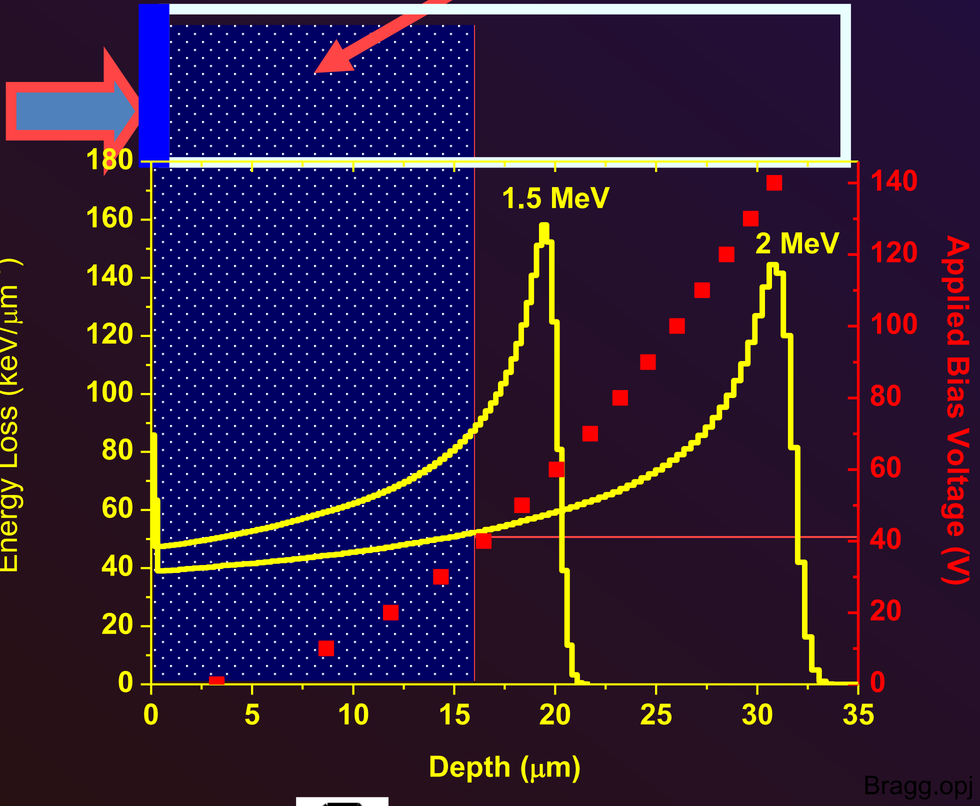


Contribution from the neutral region

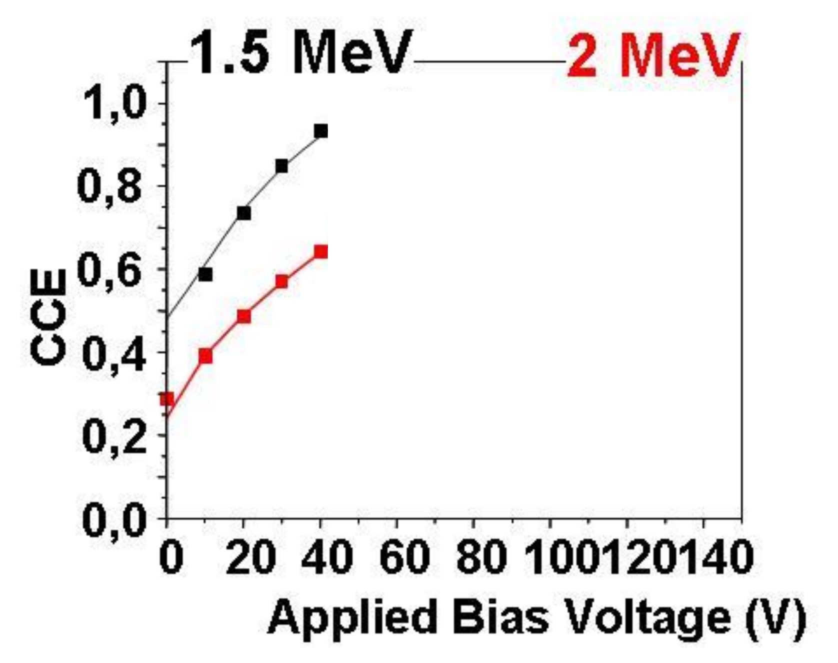
Contribution from the depletion layer

$$Q = Q_{Depl} + Q_{Neutr} \propto \left[\int_0^W \left(\frac{dE}{dx}\right)\cdot dx\right] + \left[\int_W^d \left(\frac{dE}{dx}\right)\cdot \exp\left[-\frac{x-W}{L_p}\right]\cdot dx\right]$$

Frontal ion Irradiation



4H-SiC Schottky diode

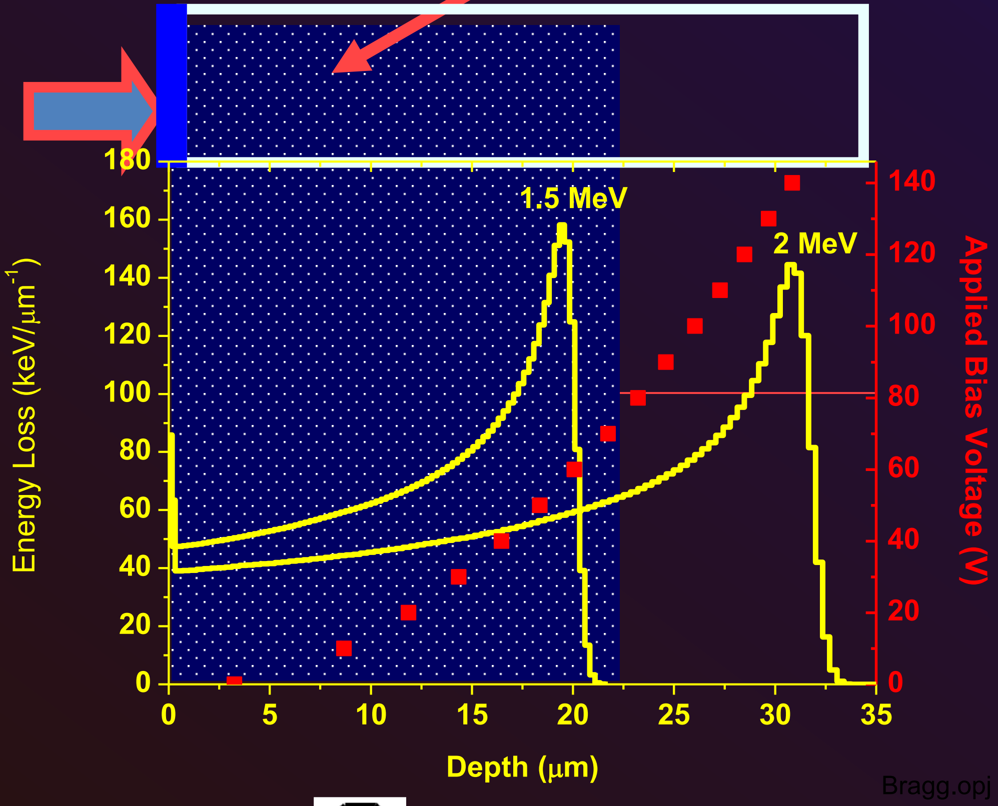


Contribution from the neutral region

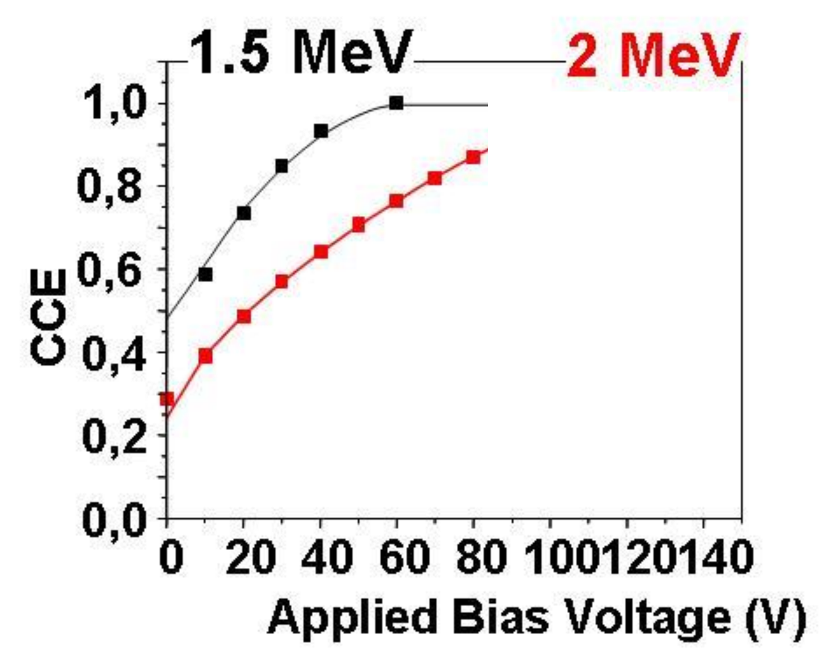
Contribution from the depletion layer

$$Q = Q_{Depl} + Q_{Neutr} \propto \left[\int_0^W \left(\frac{dE}{dx}\right) \cdot dx\right] + \left[\int_W^d \left(\frac{dE}{dx}\right) \cdot \exp\left[-\frac{x-W}{L_p}\right] \cdot dx\right]$$

Frontal ion Irradiation



4H-SiC Schottky diode

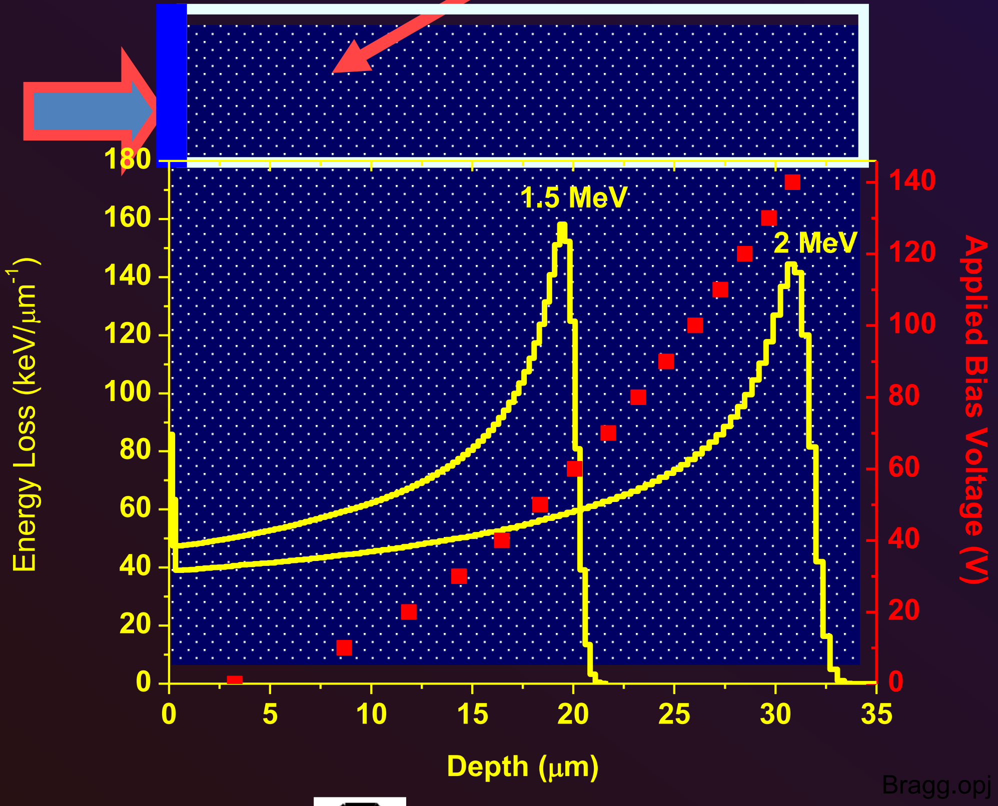


Contribution from the neutral region

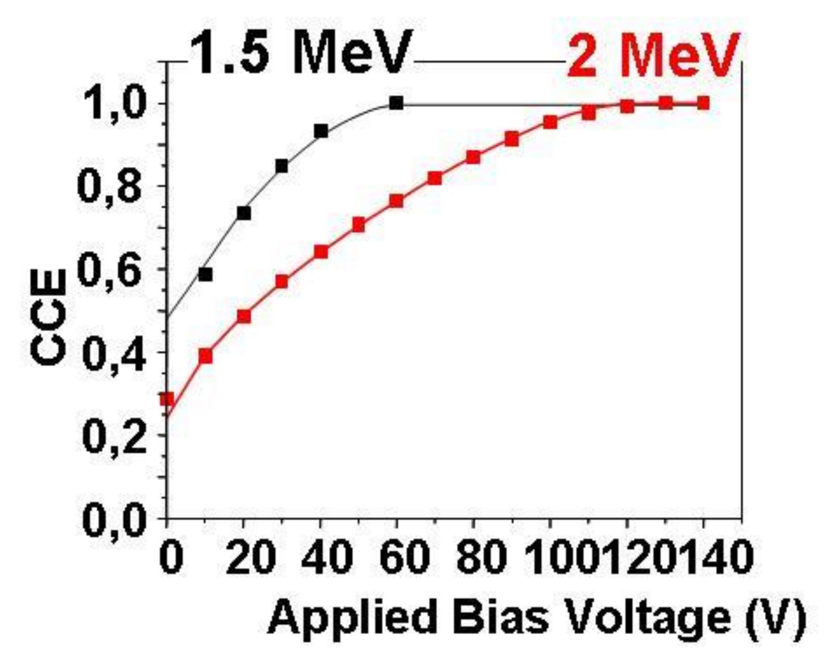
Contribution from the depletion layer

$$Q = Q_{Depl} + Q_{Neutr} \propto \left[\int_0^W \left(\frac{dE}{dx}\right)\cdot dx\right] + \left[\int_W^d \left(\frac{dE}{dx}\right)\cdot \exp\left[-\frac{x-W}{L_p}\right]\cdot dx\right]$$

Frontal ion Irradiation



4H-SiC Schottky diode



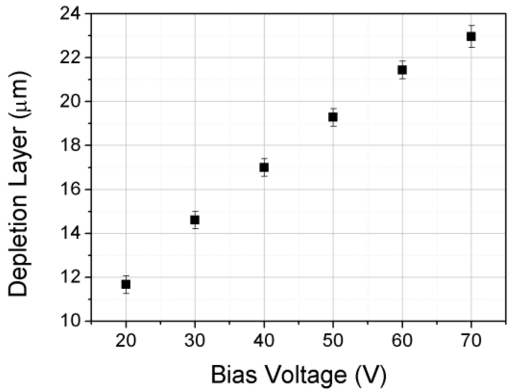
Contribution from the neutral region

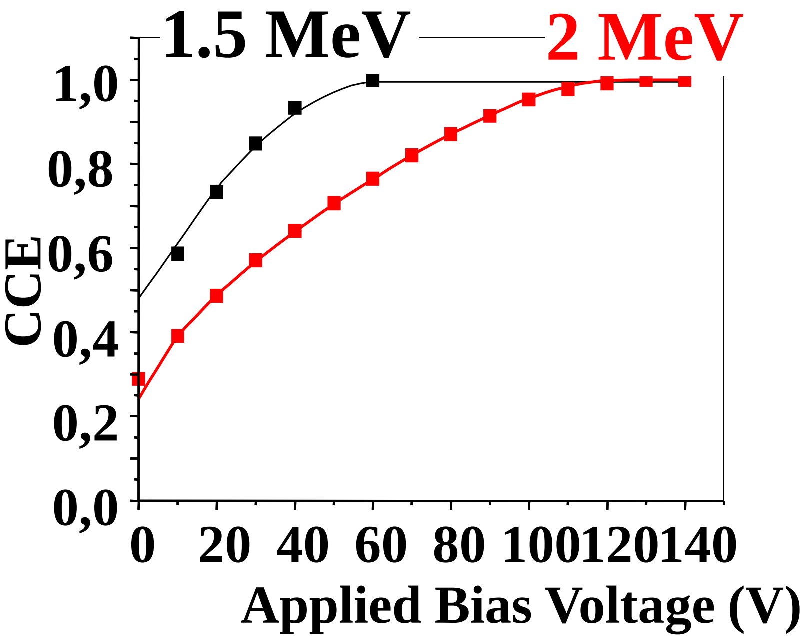
Contribution from the depletion layer

$$Q = Q_{Depl} + Q_{Neutr} \propto \left[\int_0^w \left(\frac{dE}{dx}\right)\cdot dx\right] + \left[\int_w^d \left(\frac{dE}{dx}\right)\cdot \exp\left[-\frac{x-W}{L_p}\right]\cdot dx\right]$$

Active region width

minority carrier diffusion length





L_p=(9.0±0.3) µm

D_p = 3 cm^2/s

τ_p = 270 ns

4H-SiC Schottky diode

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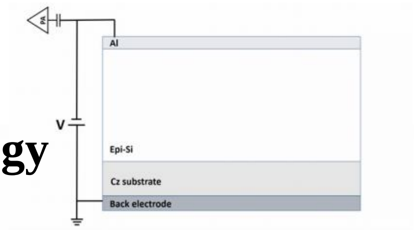
NIMB 488 (2020) 50

Polychromatic angle resolved IBIC analysis of silicon power diodes

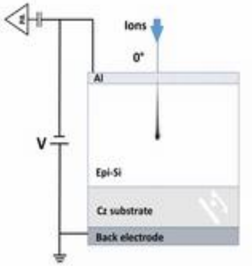
M. Pezzarossa [a], E. Cepparrone [b], D. Cosic [d], M. Jakšić [d], G. Provatas [d], M. Vićentijević [d], E. Vittone [b,c,*]

Parameter space: (E,θ,V)

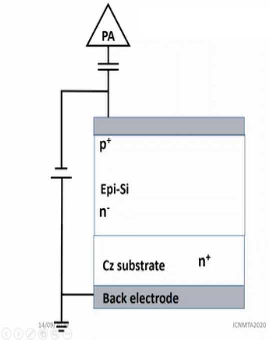
E
ion energy



θ
Tilting angle



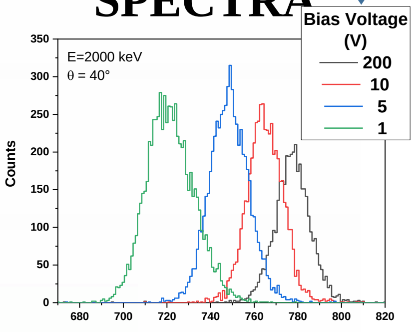
V
Bias voltage

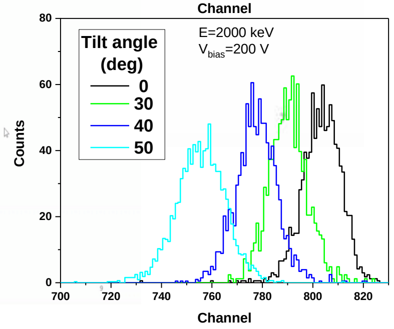


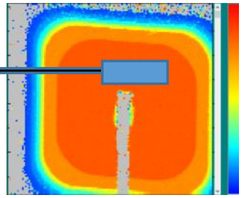
For each (E)

Selecting a region

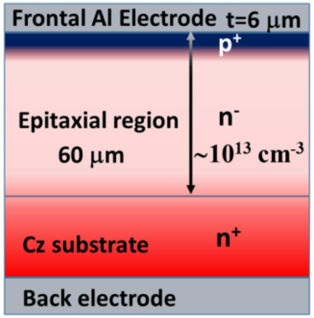
IBIC SPECTRA

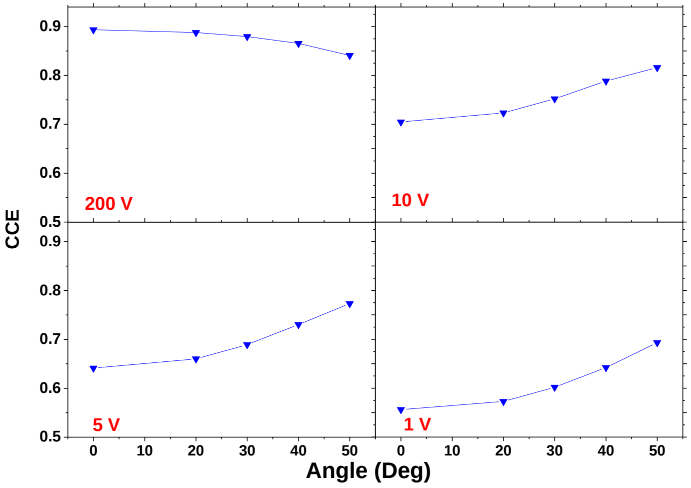






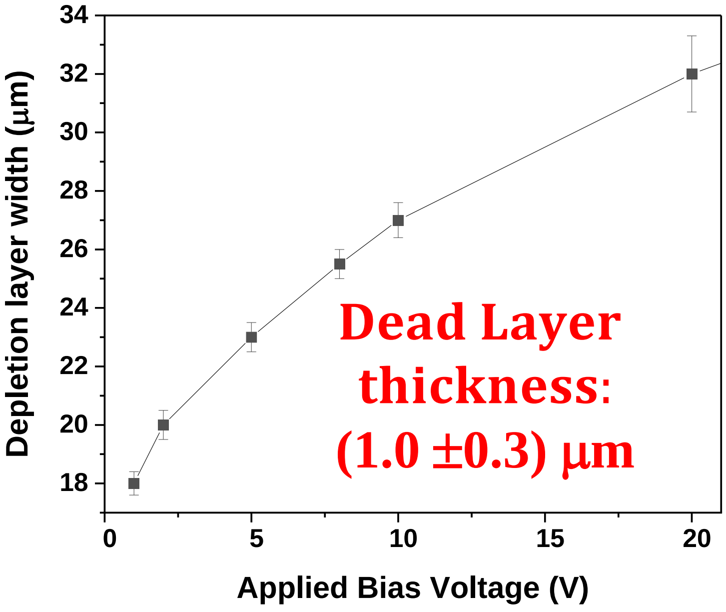
IBIC Map





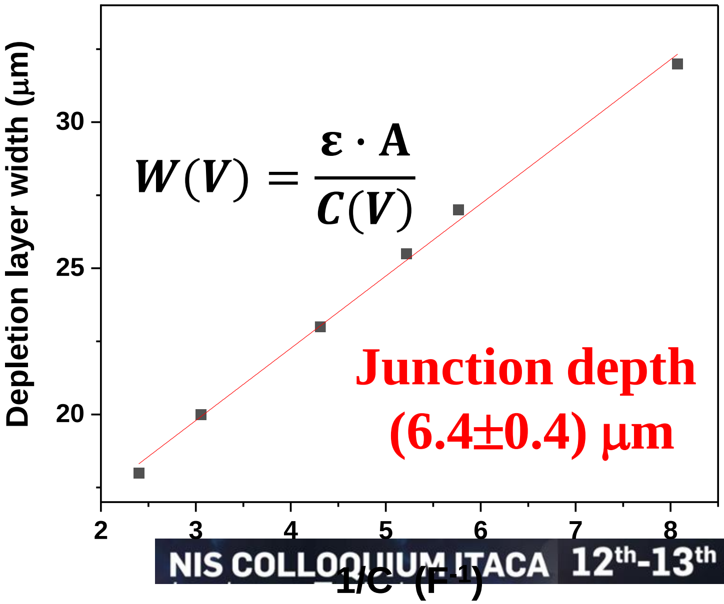
Model based on the Diffusion-drift model

Behavior of the depletion layer width as function of the applied bias voltage



Dead Layer thickness: (1.0 ±0.3) µm

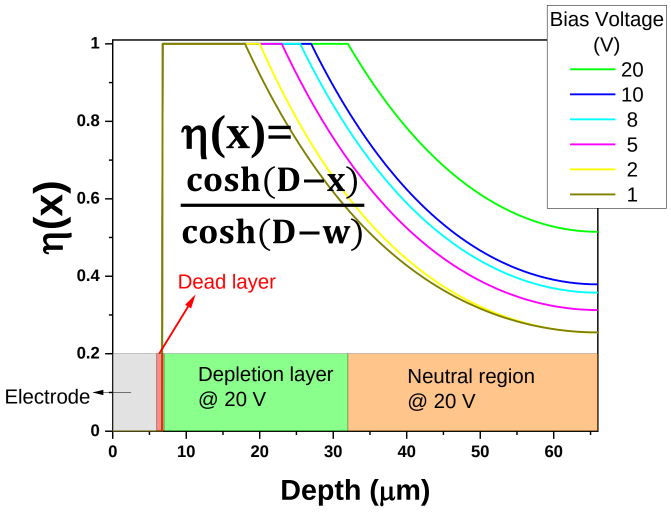
Linear relationship between inverse of capacitance and the depletion layer width



$$W(V) = \frac{\varepsilon \cdot A}{C(V)}$$

Junction depth (6.4±0.4) µm

Charge collection efficiency profiles at different bias voltages



$$\eta(x) = \frac{\cosh(D-x)}{\cosh(D-w)}$$

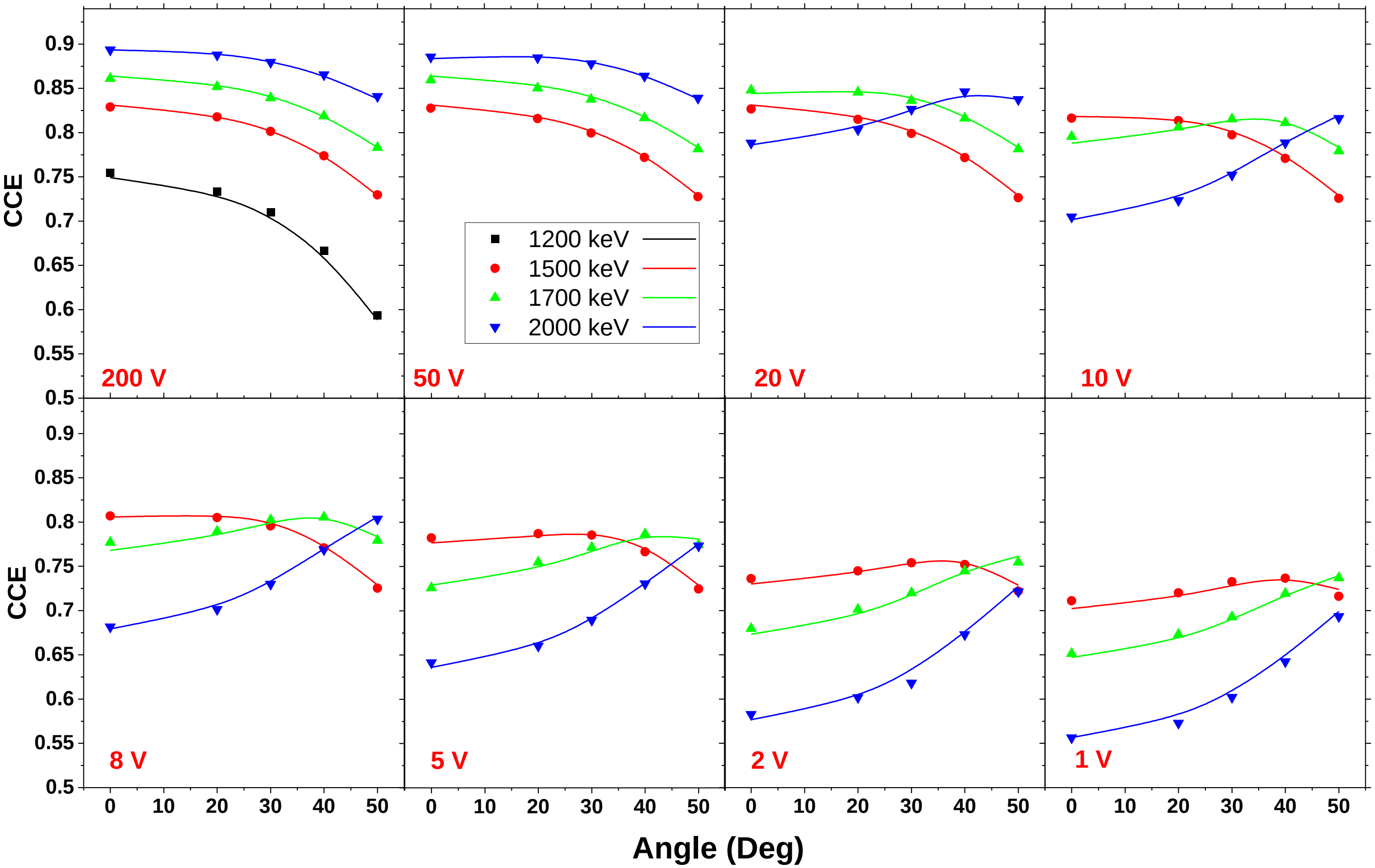
Minority carriers (holes) diffusion length:

L_h = (24.0±1.3) µm

Results: Model

Solid lines are fitting curves

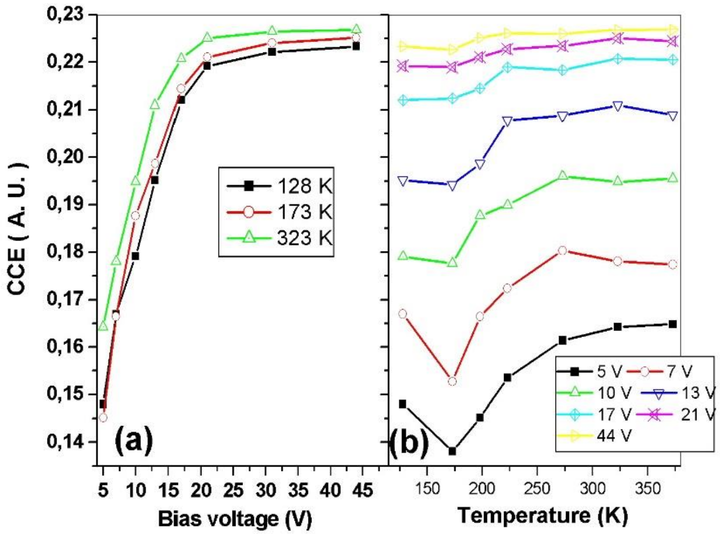
Experimental and fitting CCE as function of Tilting angle θ @ different V Parametrized by E

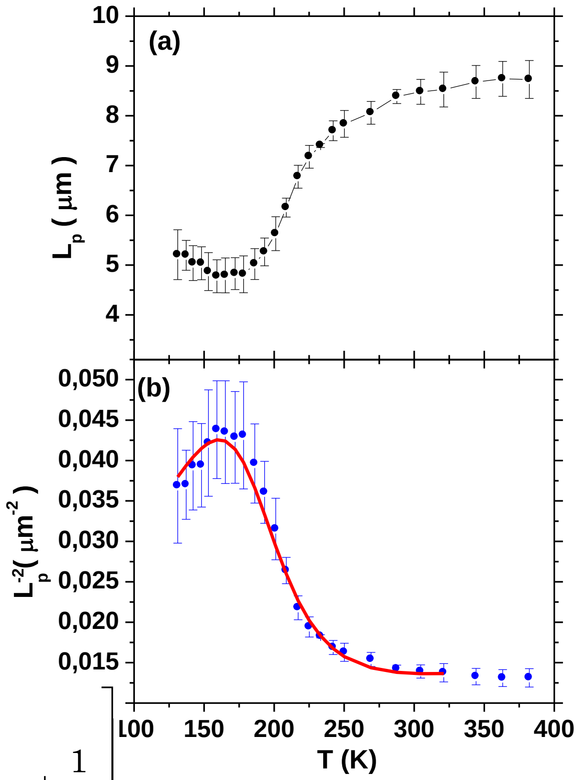


NIMB 231 (2005) 491

Temperature dependent IBIC study of 4H–SiC Schottky diodes

E. Vittone [a,b,*], V. Rigato [c], P. Olivero [a,1], F. Nava [d], C. Manfredotti [a,b],
A. LoGiudice [b], Y. Garino [a,b], F. Fizzotti [b]



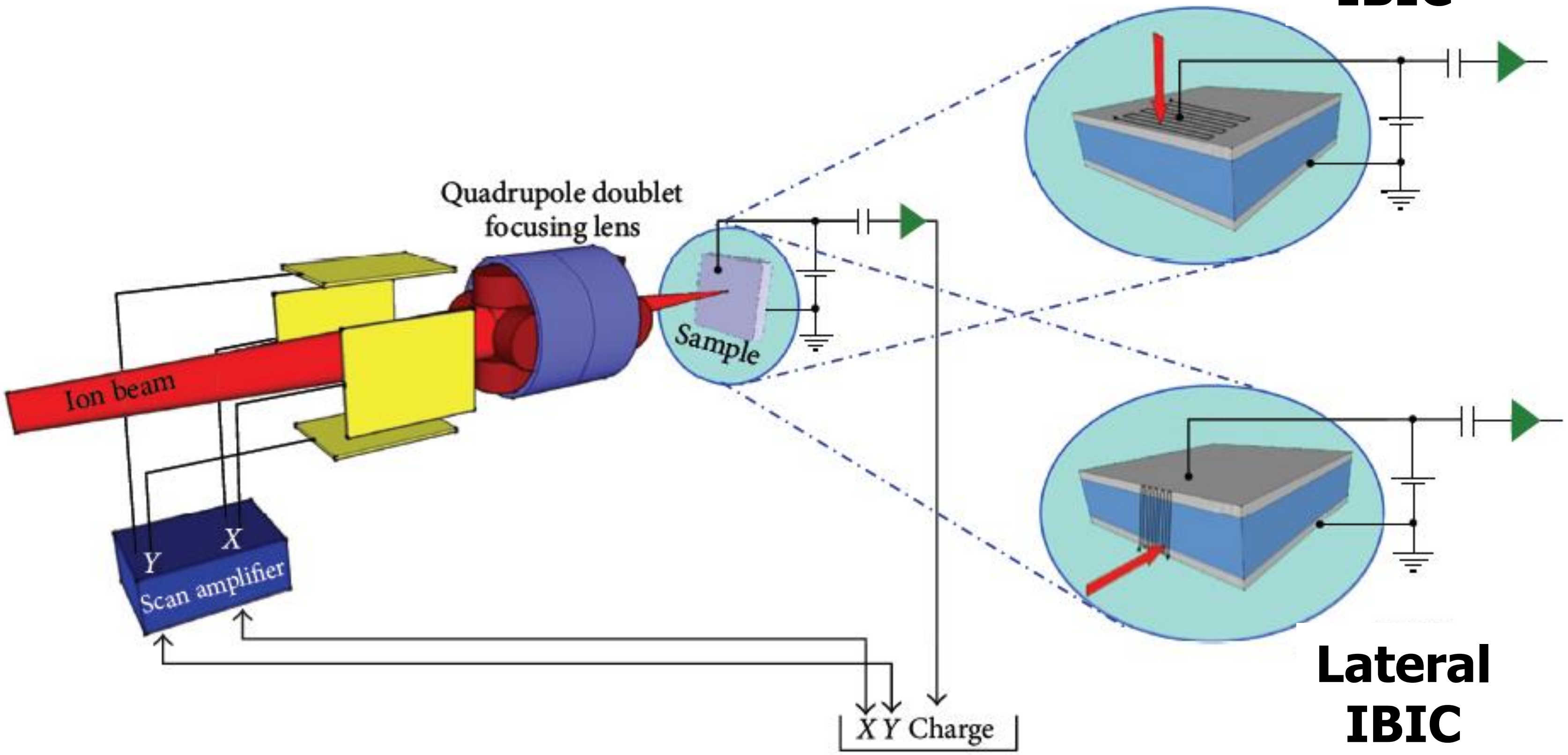


Two trapping levels

SRH recombination model

$$\frac{1}{L_p^2}=\frac{1}{D_p\cdot\tau}=\frac{1}{D_p}\cdot\left(\frac{1}{\tau(T)}+\frac{1}{\tau_B}\right)=A\cdot\frac{1}{T^{-0.5}}\cdot\left[\frac{1}{T^{-0.5}+\frac{B}{N_D}\cdot T\cdot\exp\left(-\frac{E_t}{k_B T}\right)}+\frac{1}{\tau_B}\right]$$

The fitting procedure provides a trapping level of about 0.163 eV which is close to the value found in similar 4H SiC Schottky diodes by DLTS technique (S1 level).



Frontal IBIC

Lateral IBIC

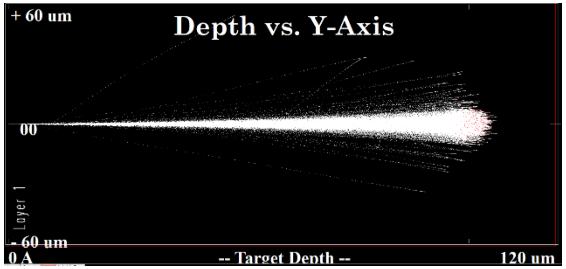
NIMB 537 (2023) 14

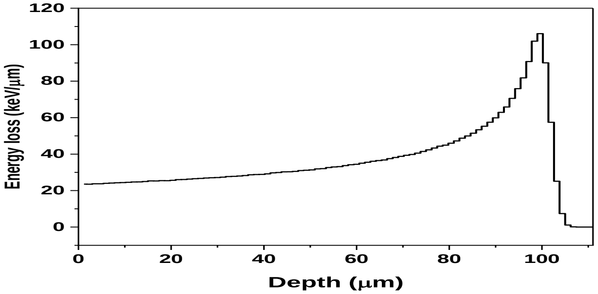
4H-SiC Schottky diode radiation hardness assessment by IBIC microscopy

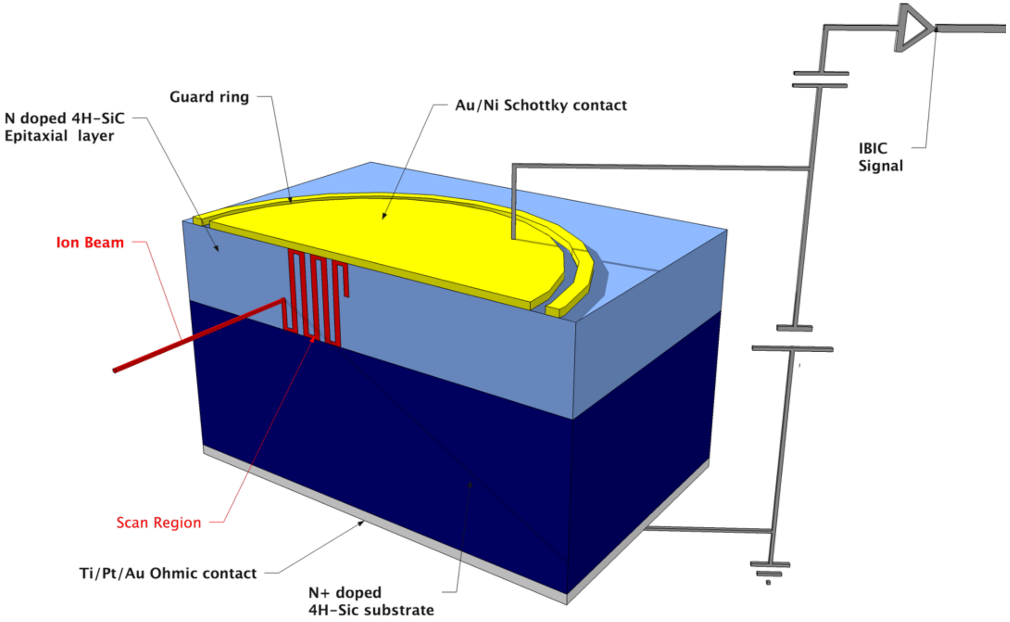
Ettore Vittone [a,*], Paolo Olivero [a], Milko Jakšic [b], Željko Pastuović [c]

Laboratory for Ion Beam Interactions, Ruder Boškovic Institute, Zagreb, Croatia

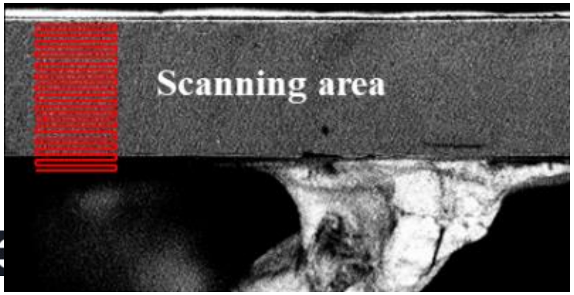
4 MeV protons
2 µm beam spot size (FWHM)
Charge sensitivity 1800 electrons/channel -> 14 keV in SiC
Spectral resolution: 12000 electrons (FWHM) ->94 keV in SiC



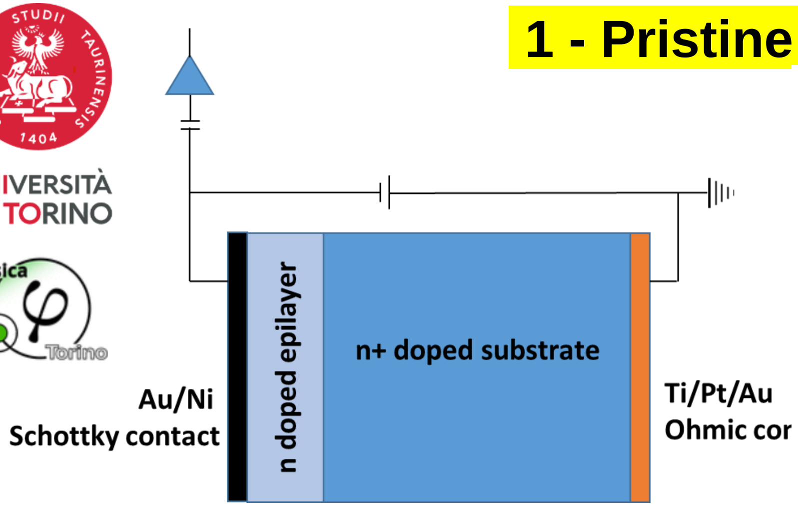


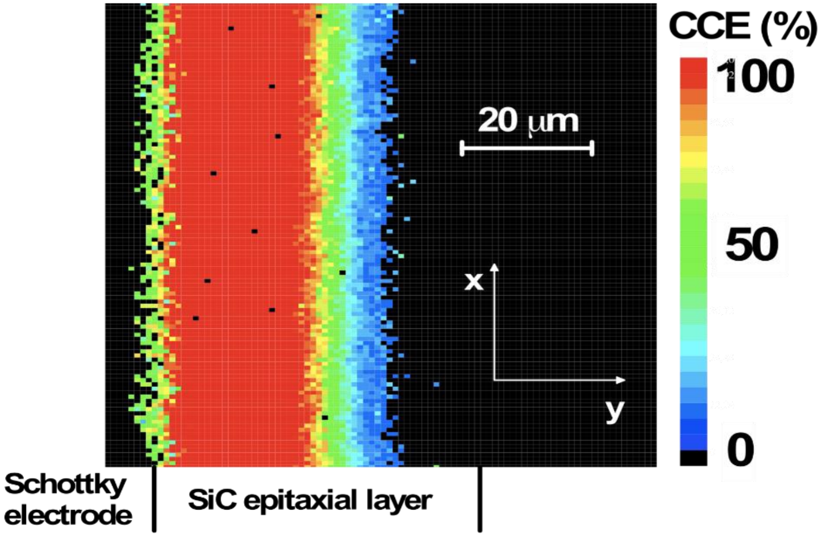


Range
Longitudinal: 100 µm
Lateral: 2.6 µm

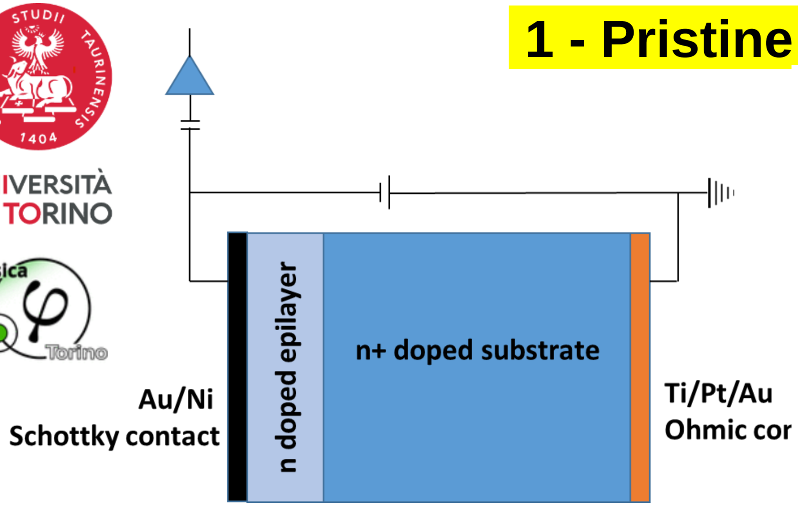


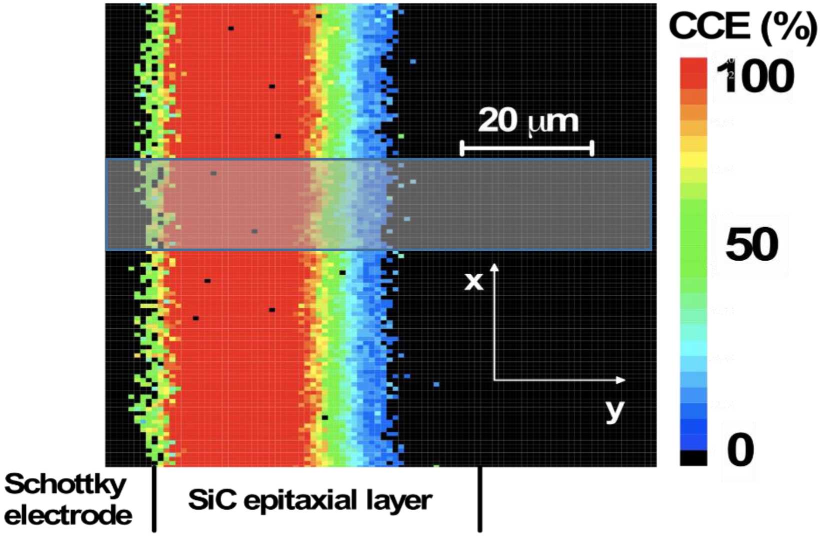
1 - Pristine diode: Lateral IBIC

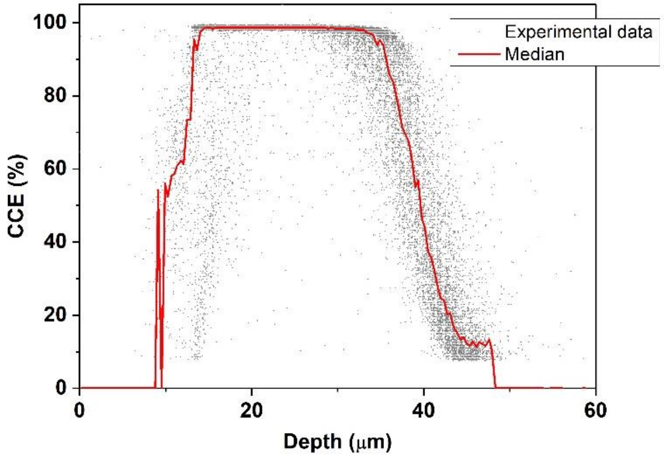




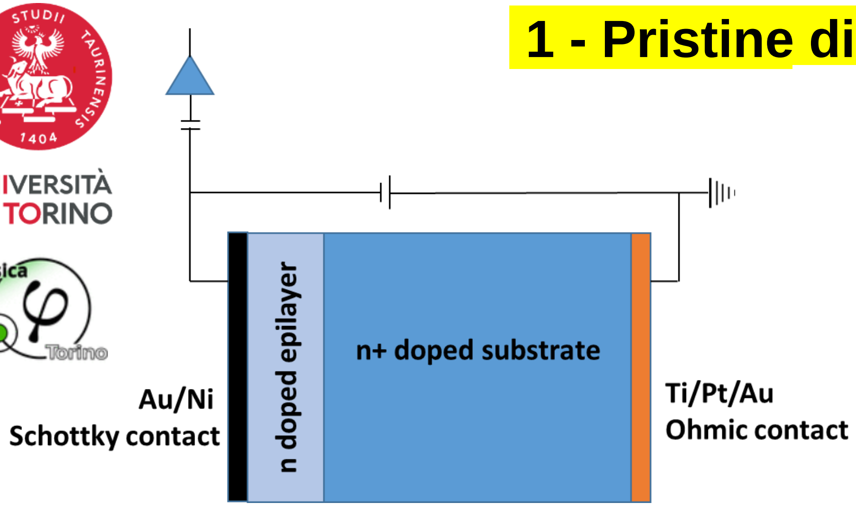
1 - Pristine diode: Lateral IBIC

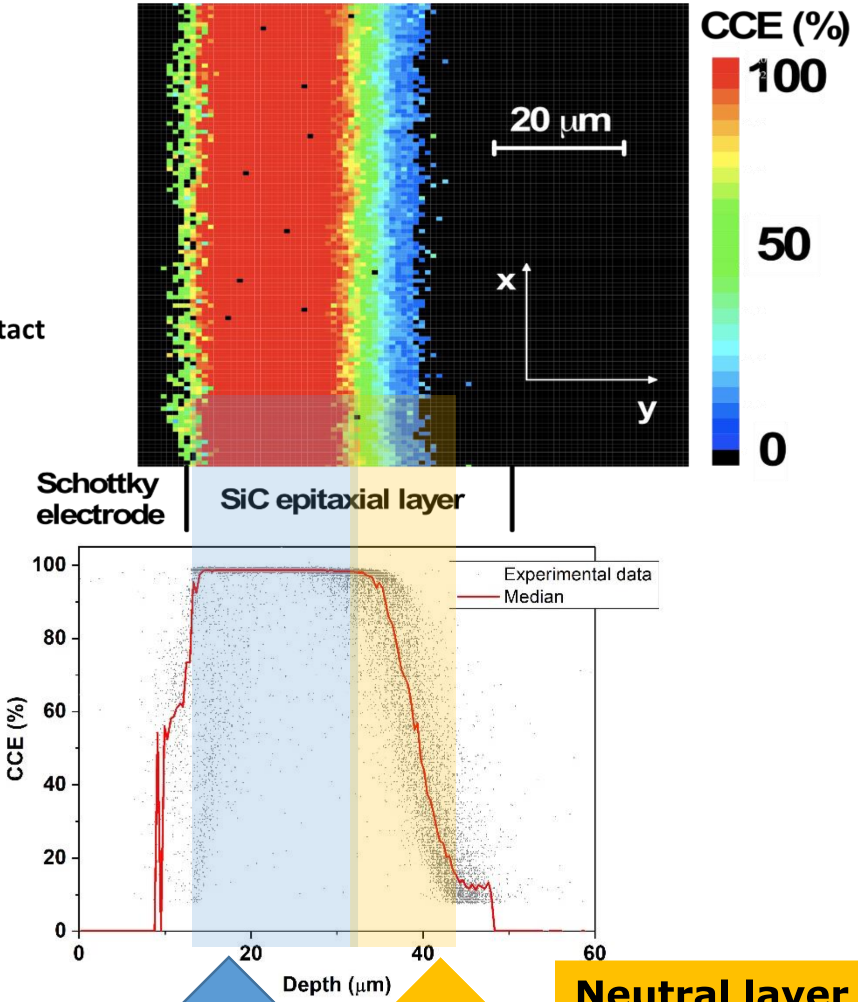






1 - Pristine diode: Lateral IBIC





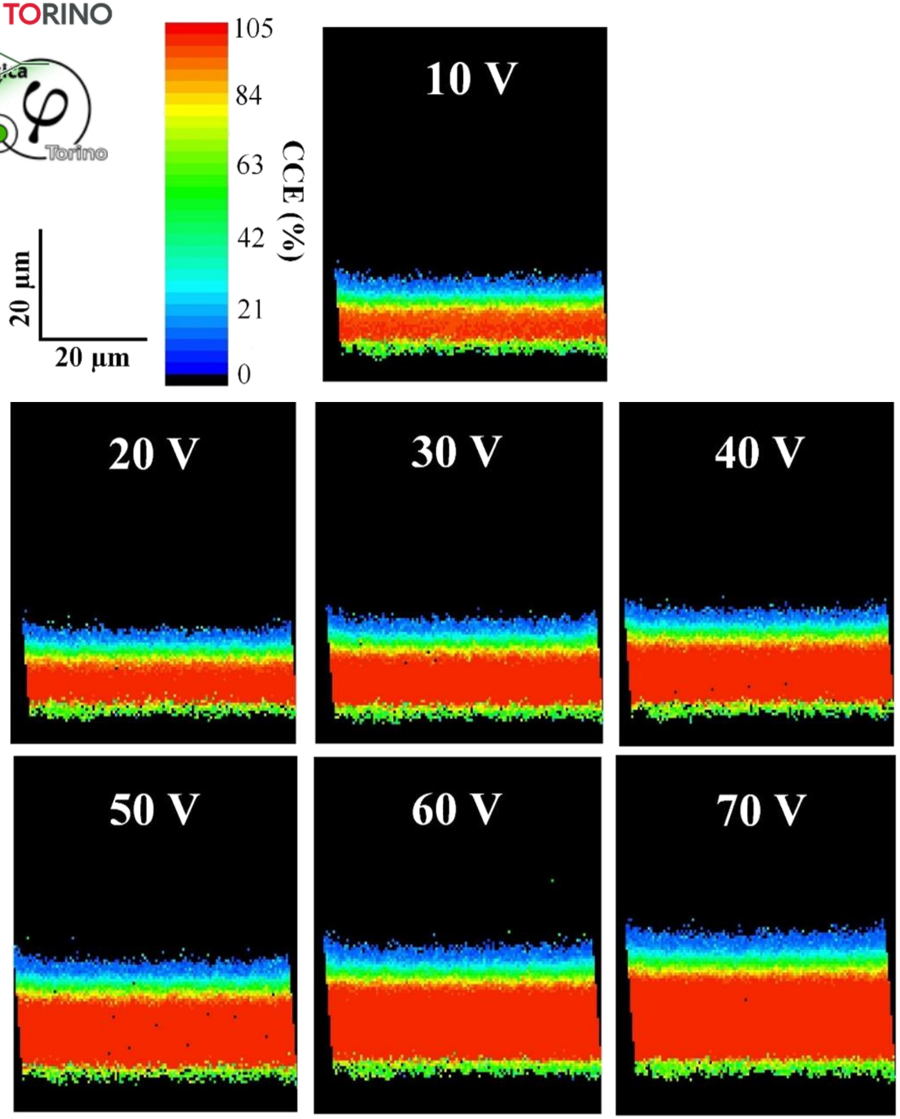
Drift-Diffusion model

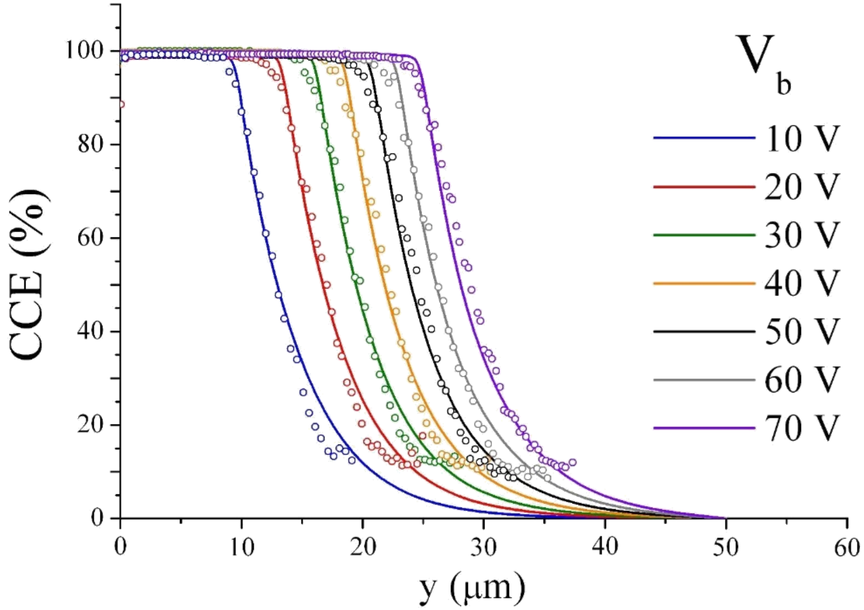
Depletion layer
↓
high electric field/drift velocity
↓
Complete induced charge collection (Ramo theorem)

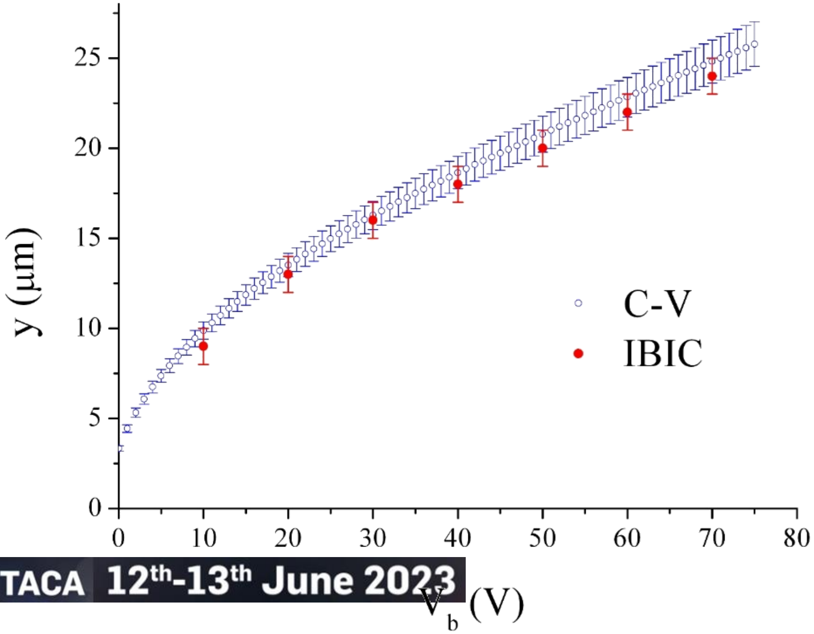
Neutral layer
↓
Minority carrier diffusion
↓
CCE exponential decay

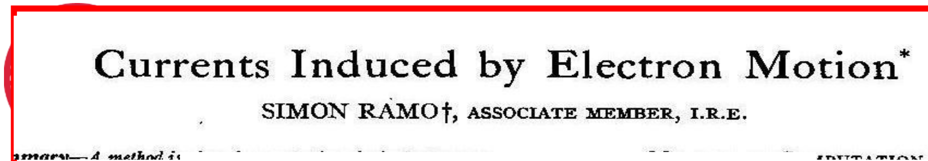
Drift-diffusion model Simulation

$L_p = (4{,}9 \pm 0{,}3)\mu m$ $\tau_p \approx 80\,ns$



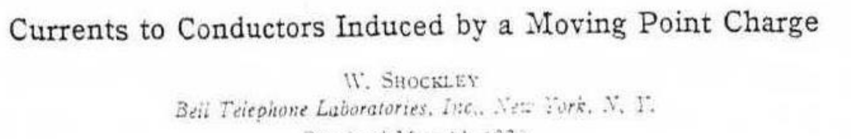






Currents Induced by Electron Motion*

SIMON RAMO†, ASSOCIATE MEMBER, I.R.E.



Currents to Conductors Induced by a Moving Point Charge

W. SHOCKLEY
Bell Telephone Laboratories, Inc., New York, N. Y.

Proc. of the IRE (1939), 584

Journ. Appl. Phys. 9,(1938), 635

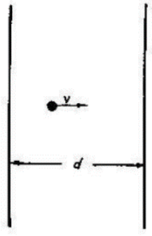


Fig. 1

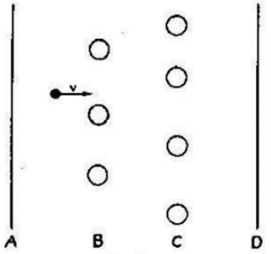
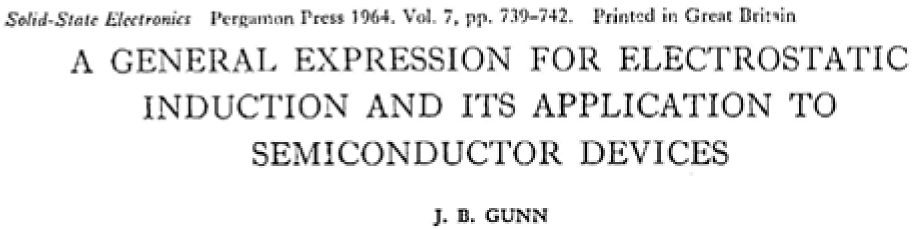


Fig. 2

$$i = evE_v = \frac{ev}{d}.$$

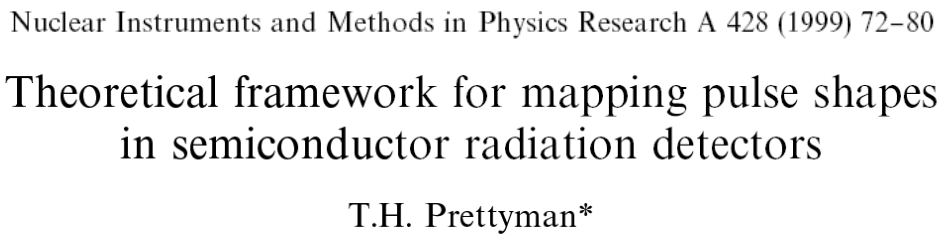


Solid-State Electronics Pergamon Press 1964. Vol. 7, pp. 739–742. Printed in Great Britain

A GENERAL EXPRESSION FOR ELECTROSTATIC INDUCTION AND ITS APPLICATION TO SEMICONDUCTOR DEVICES

J. B. GUNN

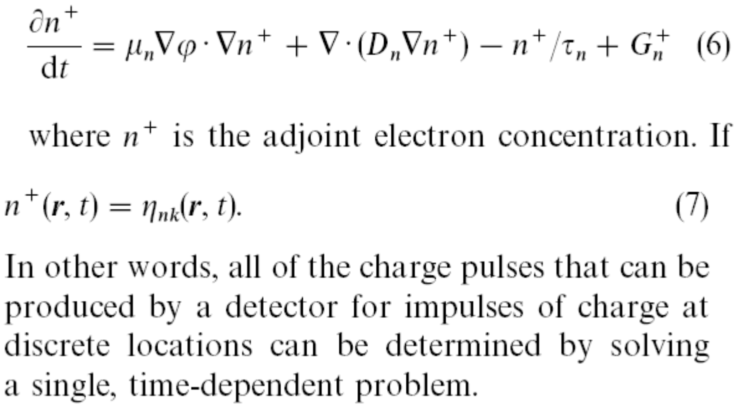
$$\nabla_r Q_i = -q\{(\partial E/\partial V_i)_r\}. \tag{7}$$



Nuclear Instruments and Methods in Physics Research A 428 (1999) 72–80

Theoretical framework for mapping pulse shapes in semiconductor radiation detectors

T.H. Prettyman*

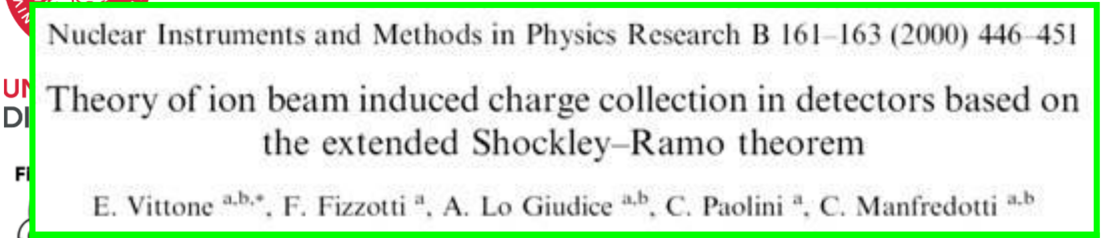


$$\frac{\partial n^+}{dt} = \mu_n \nabla\varphi \cdot \nabla n^+ + \nabla\cdot(D_n \nabla n^+) - n^+/\tau_n + G_n^+ \tag{6}$$

where n^+ is the adjoint electron concentration. If

$$n^+(\mathbf{r}, t) = \eta_{nk}(\mathbf{r}, t). \tag{7}$$

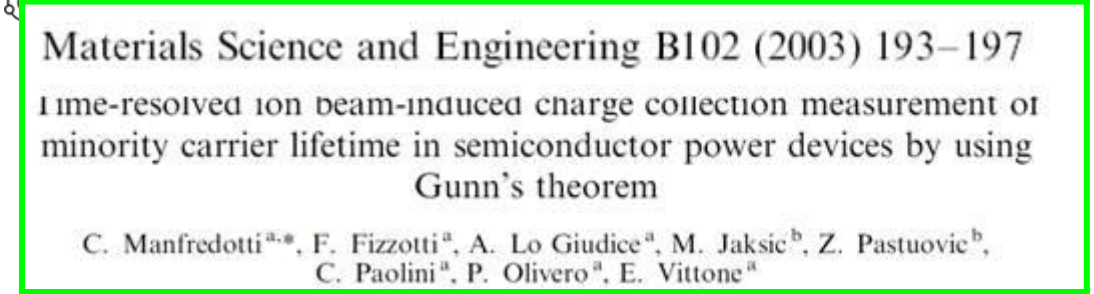
In other words, all of the charge pulses that can be produced by a detector for impulses of charge at discrete locations can be determined by solving a single, time-dependent problem.



Nuclear Instruments and Methods in Physics Research B 161–163 (2000) 446–451

Theory of ion beam induced charge collection in detectors based on the extended Shockley–Ramo theorem

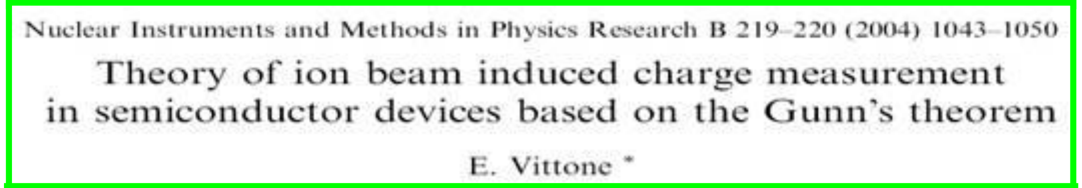
E. Vittone [a,b,*], F. Fizzotti [a], A. Lo Giudice [a,b], C. Paolini [a], C. Manfredotti [a,b]



Materials Science and Engineering B102 (2003) 193–197

Time-resolved ion beam-induced charge collection measurement of minority carrier lifetime in semiconductor power devices by using Gunn's theorem

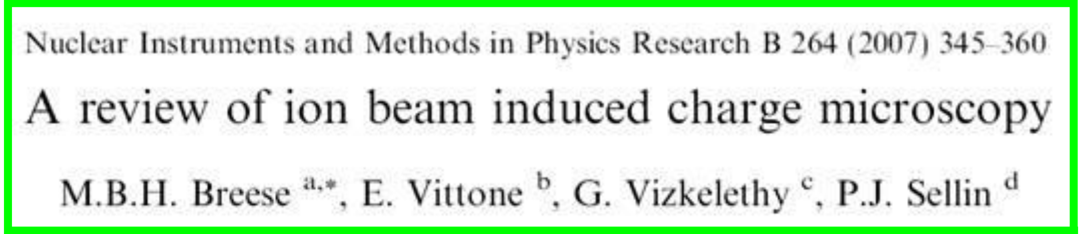
C. Manfredotti [a,*], F. Fizzotti [a], A. Lo Giudice [a], M. Jaksic [b], Z. Pastuovic [b],
C. Paolini [a], P. Olivero [a], E. Vittone [a]



Nuclear Instruments and Methods in Physics Research B 219–220 (2004) 1043–1050

Theory of ion beam induced charge measurement in semiconductor devices based on the Gunn's theorem

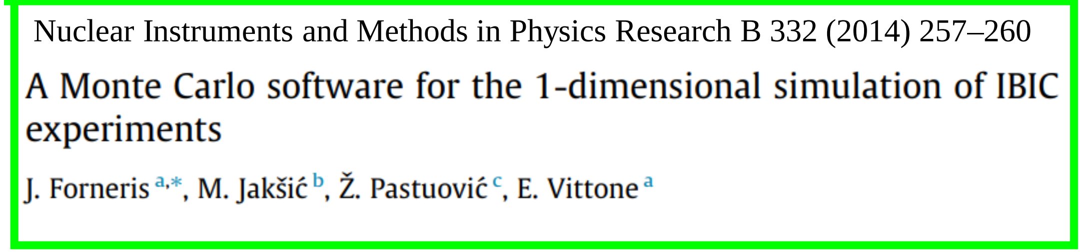
E. Vittone *



Nuclear Instruments and Methods in Physics Research B 264 (2007) 345–360

A review of ion beam induced charge microscopy

M.B.H. Breese [a,*], E. Vittone [b], G. Vizkelethy [c], P.J. Sellin [d]



Nuclear Instruments and Methods in Physics Research B 332 (2014) 257–260

A Monte Carlo software for the 1-dimensional simulation of IBIC experiments

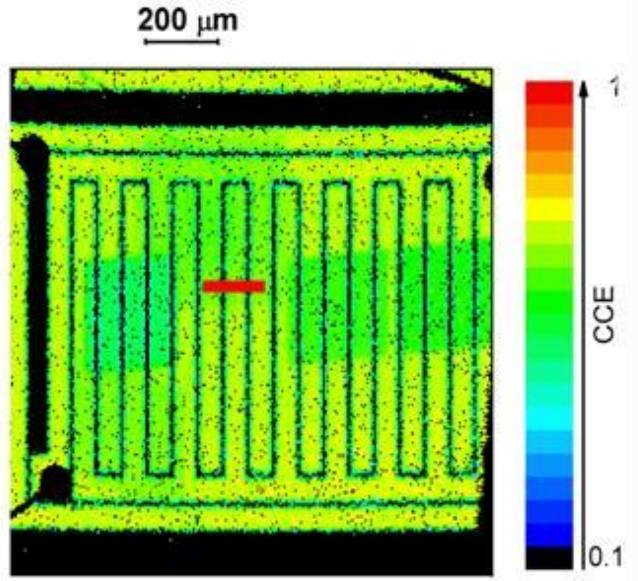
J. Forneris [a,*], M. Jakšić [b], Ž. Pastuović [c], E. Vittone [a]

NIMB 266 (2008)1312

Semiconductor characterization by scanning ion beam induced charge (IBIC) microscopy

E. Vittone [a,b,*], Z. Pastuovic [c], P. Olivero [b], C. Manfredotti [a,b], M. Jaksic [c], A. Lo Giudice [b], F. Fizzotti [b], E. Colombo [a,b]

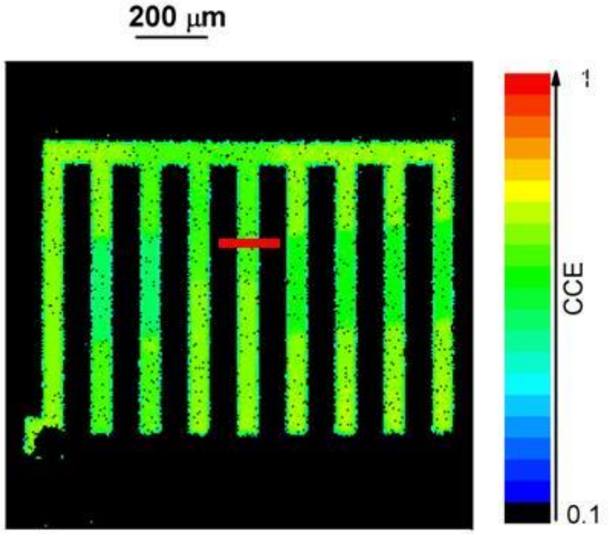
Experiments to validate the theoretical model



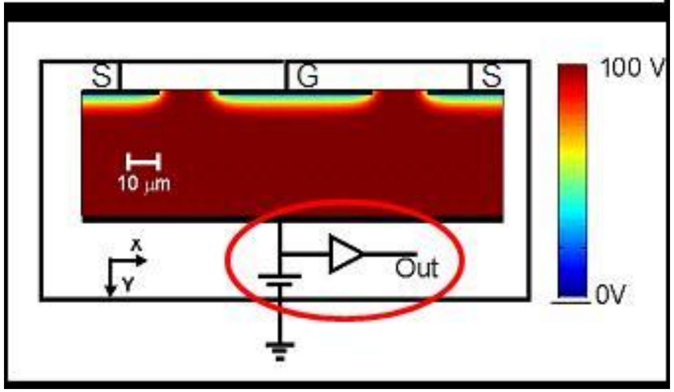
4H-SiC Schottky diode

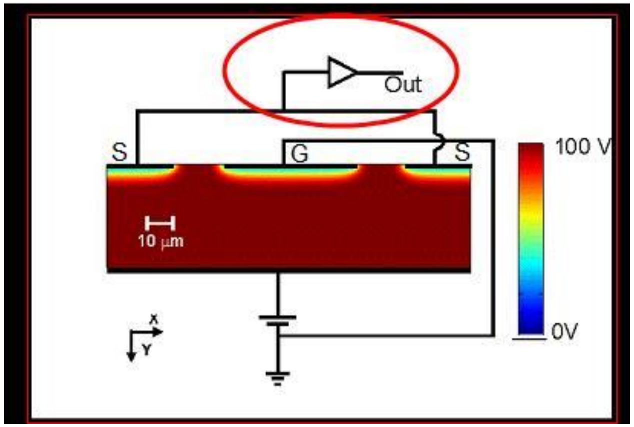
Inter-digitated frontal electrodes

- Finger width: 50 μm
- Finger length: 700 μm
- Finger-finger gap = 20 μm;
- Finger-guard ring = 70 μm.

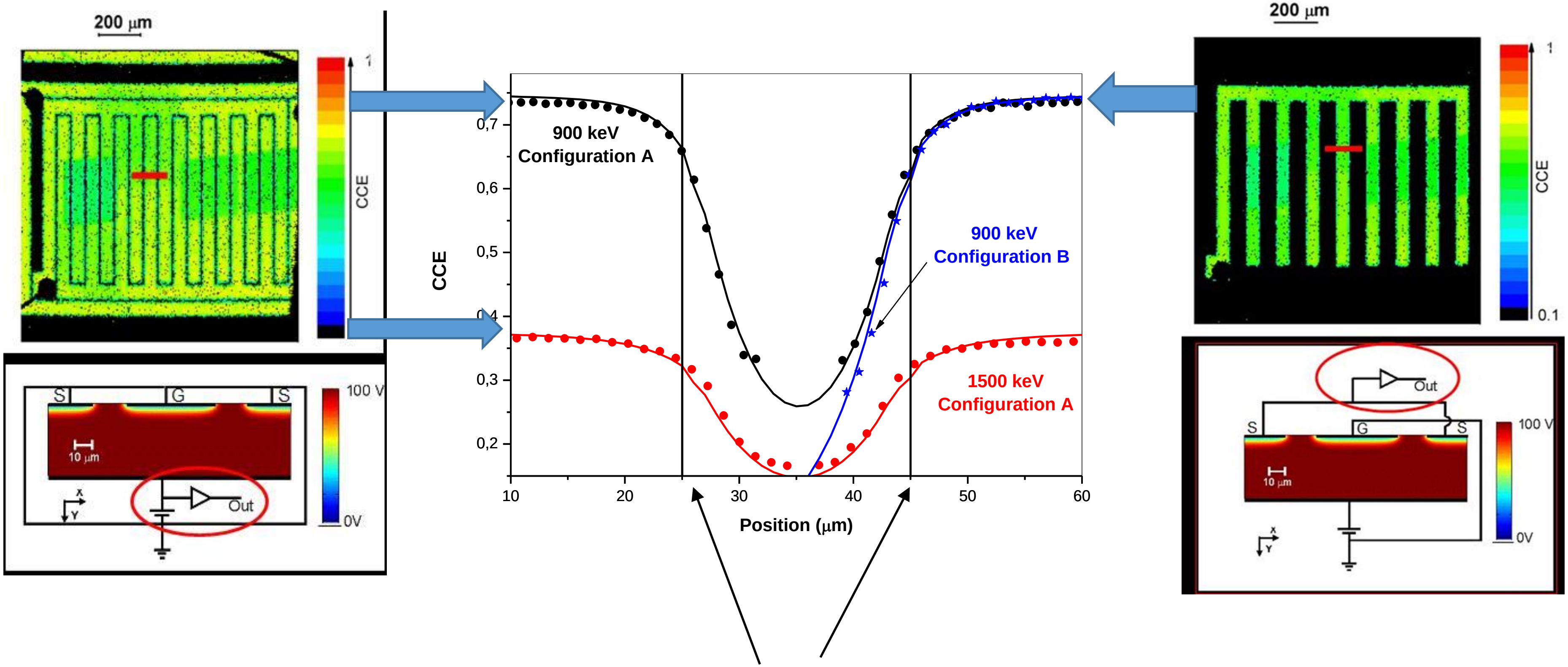


IBIC map
1.5 MeV H^+





Electrostatic
Potential map
V_{bias}=100V



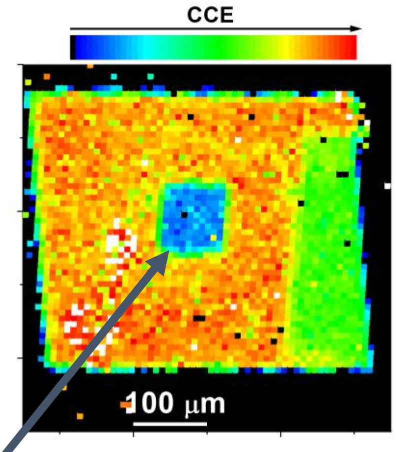
Electrode edges.

Functionalization of semiconductor materials

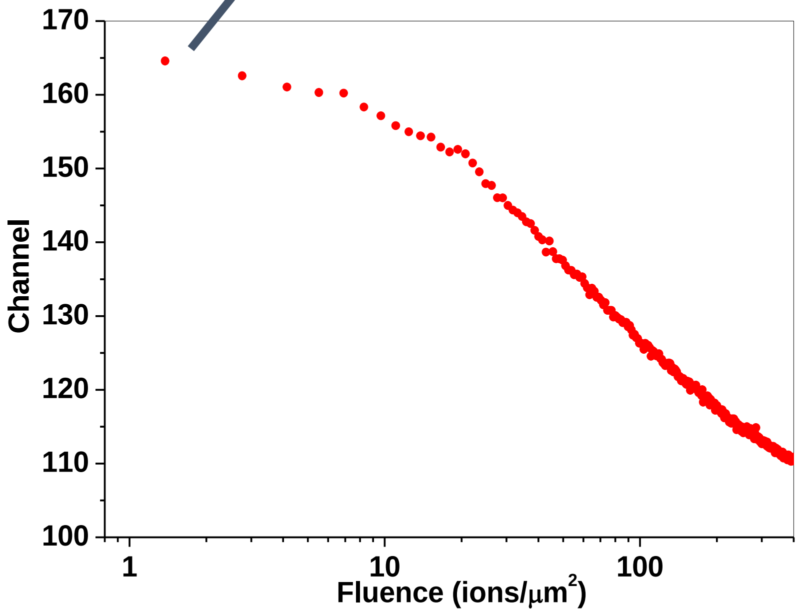
MatResForum 483-485 (2005) 389

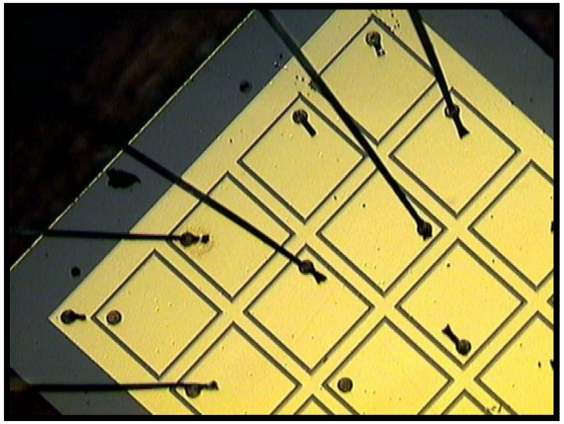
Study of ion induced damage in 4H-SiC

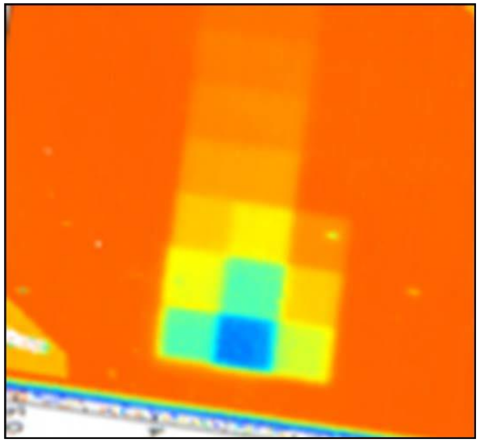
Lo Giudice A, Olivero P, Fizzotti F, Manfredotti C, Vittone E, Bianco S, Bertuccio G, Casiraghi R, Jaksic M See fewer



2 MeV H^+ IBIC Map of 400x400 μm^2 4H-SiC Schottky diode

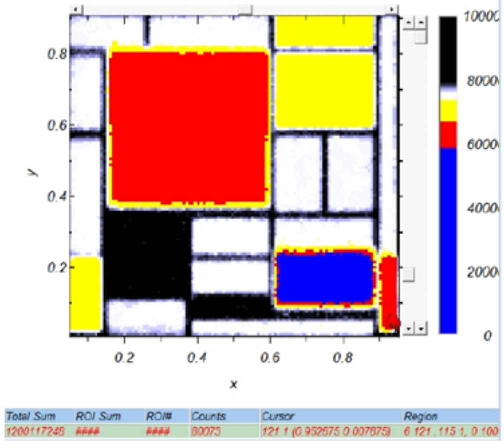






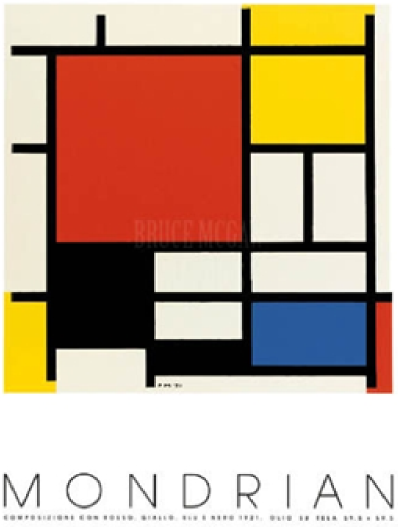
CCE map of a silicon photodiode with selected regions damaged with a) protons

IAEA – CRP, RBI Report



Total Sum	ROI Sum	ROI#	Counts	Cursor	Region
1200117246	####	####	80073	121 1 (0.952675 0.007875)	6 121 ,115 1, 0 100

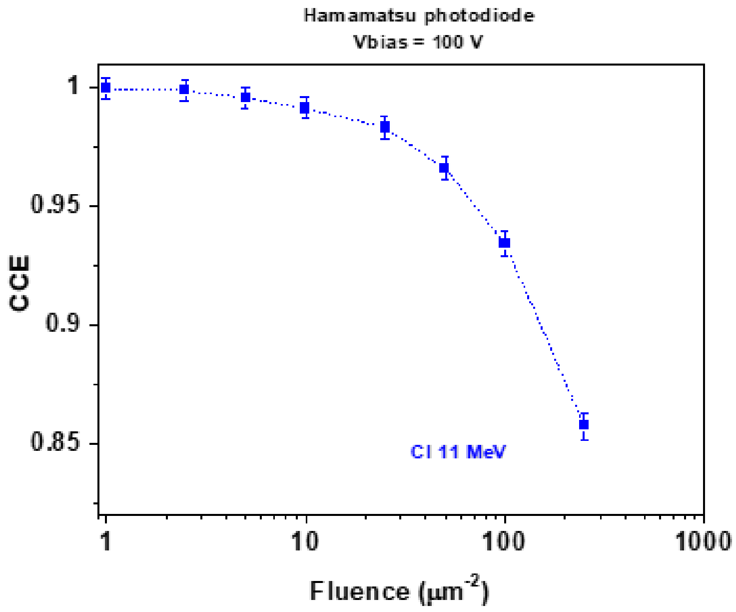
Radiation damage structures induced by 7 MeV carbon ions in Si pin diode and imaged by IBIC technique using the same ions. Scan size is 400 x 400 µm^2. Charge collection efficiency decreases according to the color scale from the highest (black) to the lowest (blue).



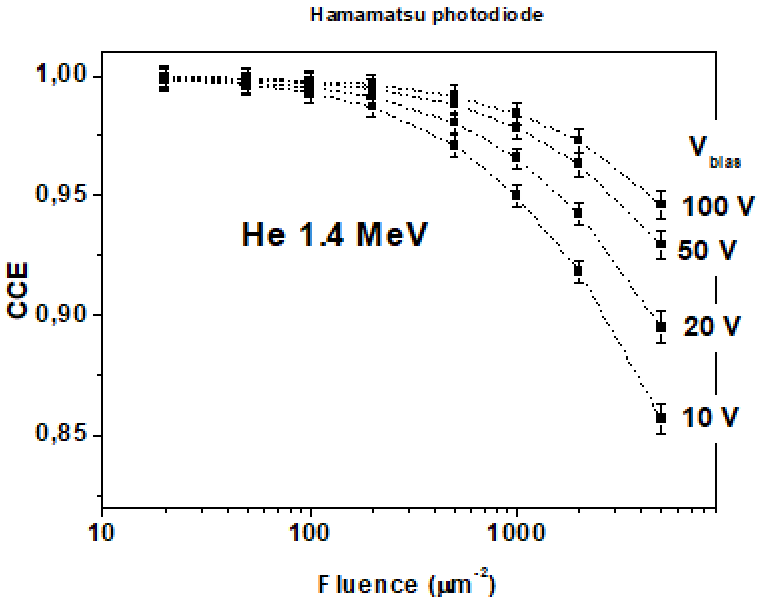
Piet Mondrian painting from 1921 (now at Gemeentemuseum, Den Haag)

CCE degradation induced by ion irradiation

Depends on the damaging ion fluence

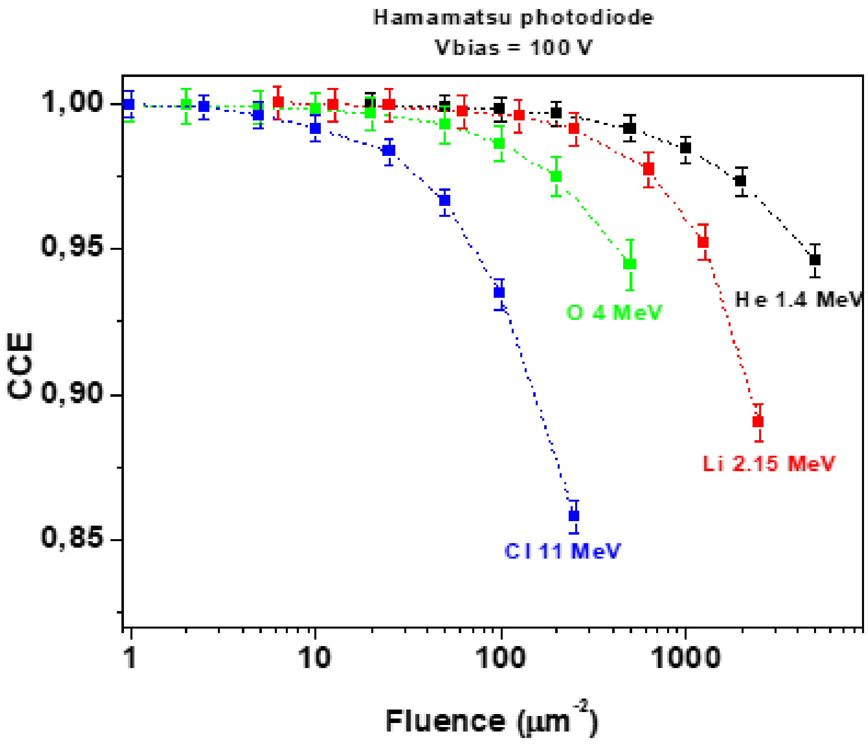


Depends on the polarization state

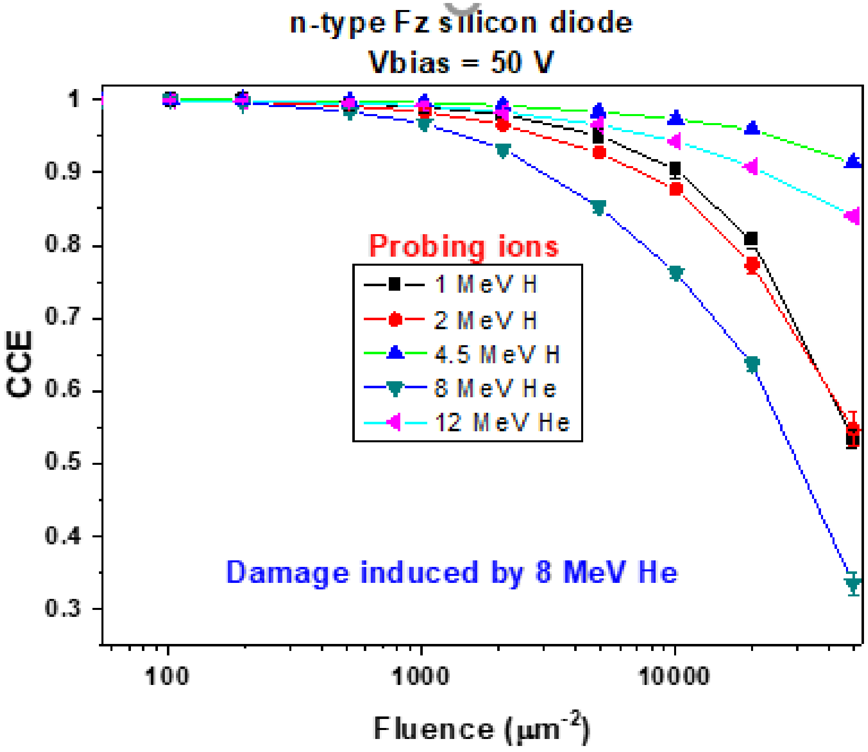


CCE degradation induced by ion irradiation

Depends on the damaging ion mass and energy



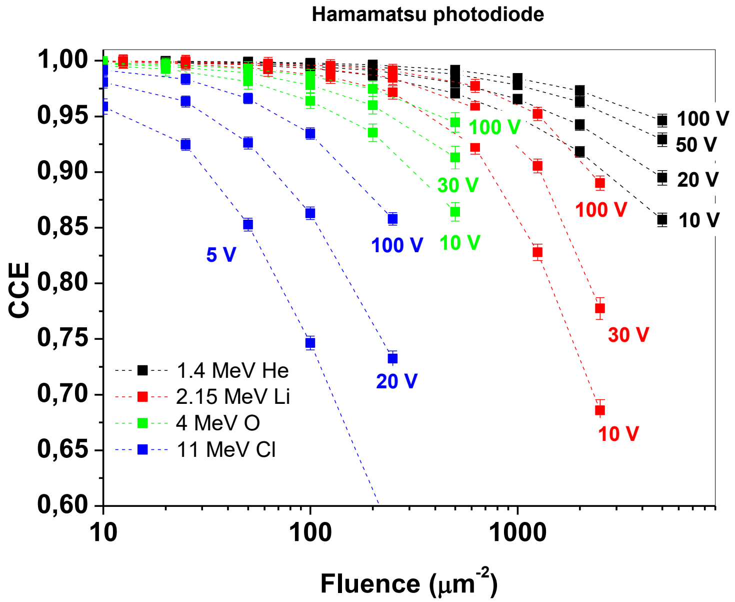
Depends on the probing ion mass and energy



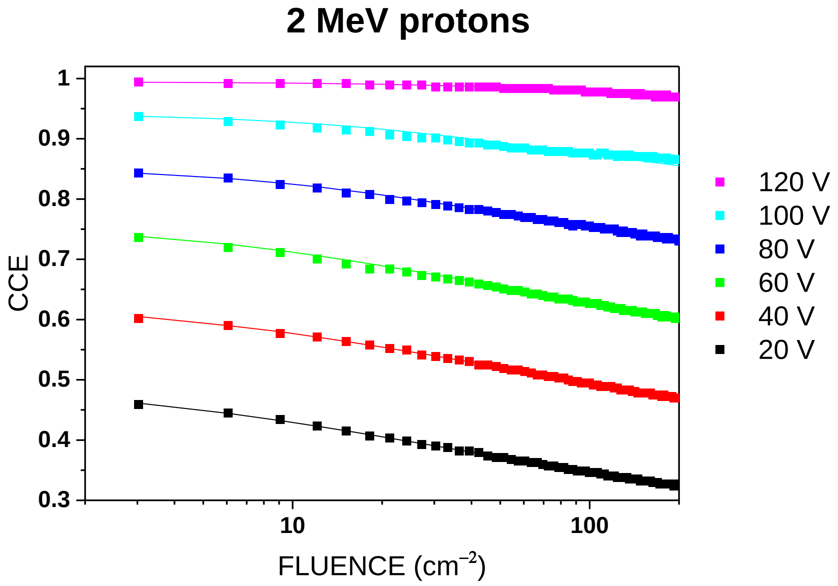
CCE degradation induced by ion irradiation

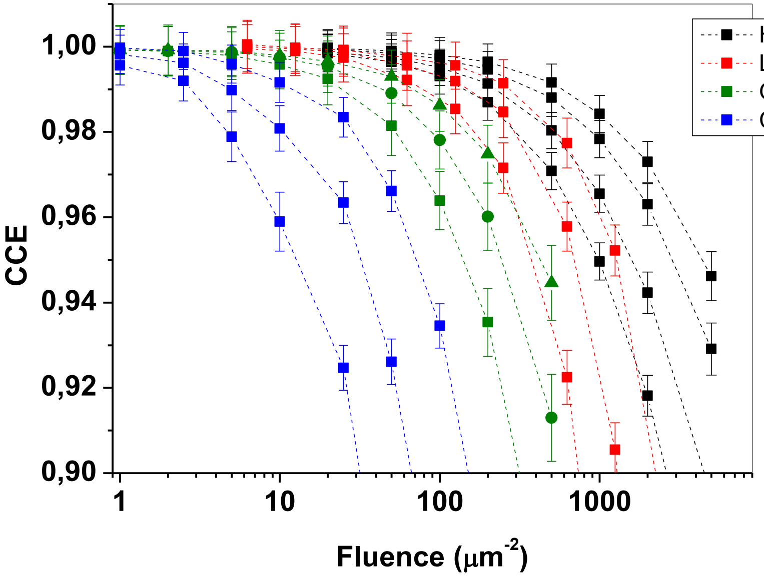
Depends on the material and/or device

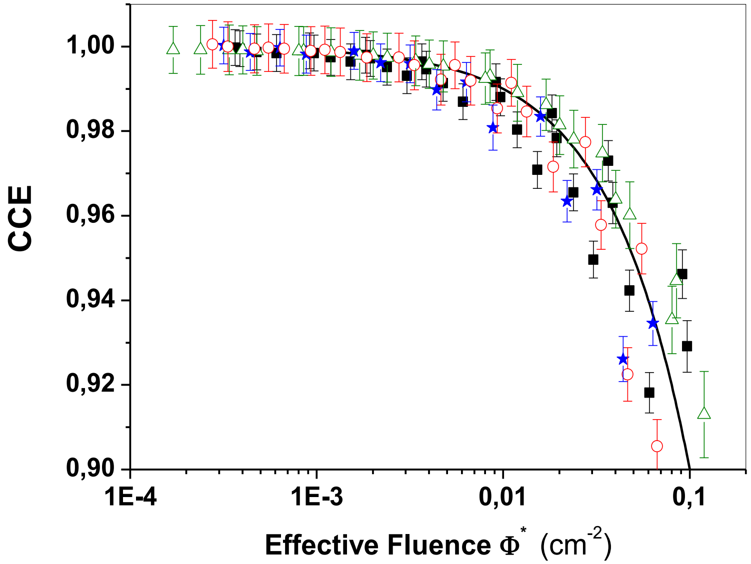
Silicon pin photodiode



4H-SiC Schottky diode







$$CCE \cong 1 - K^* \cdot \Phi *$$

$$\mathrm{From\,fit:effective\,damage\,factor\,K^* = k_e \cdot \sigma_e = (8.4 \pm 0.3) \cdot 10^{16}\,cm^2.}$$

$$\mathrm{From\,DLTS:\sigma_e = 5 \cdot 10^{-15} cm^2}$$

$$\mathrm{k_e \cong 0.17\ active\ traps/vacancy}$$

APL 98 092101 (2011)

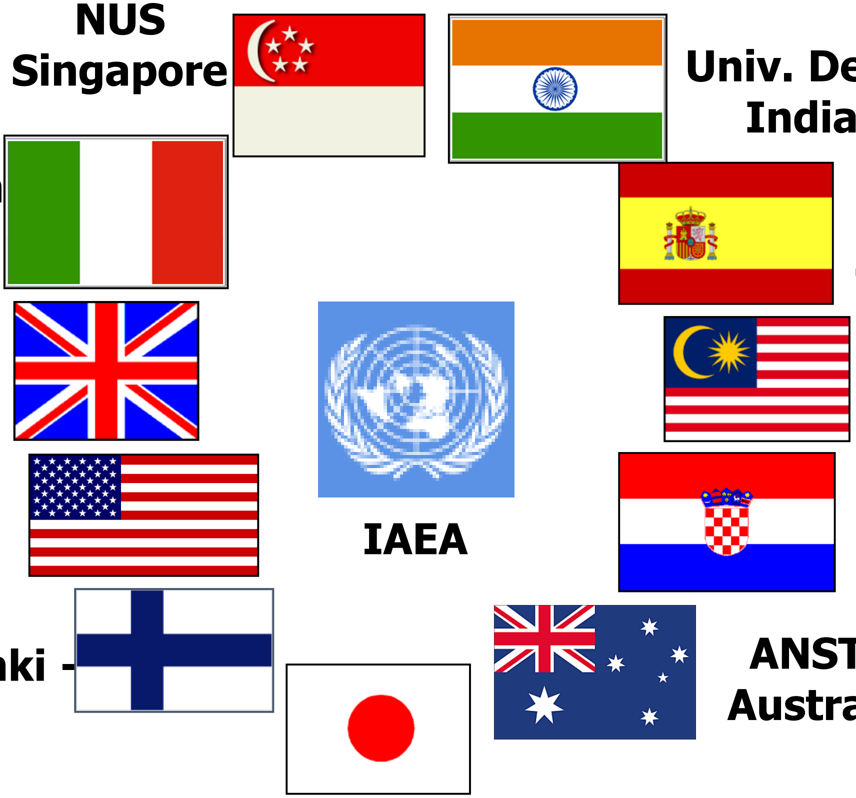
Ettore Vittone

Probability of divacancy trap production in silicon diodes exposed to focused ion beam irradiation

Željko Pastuović,[1,a)] Ettore Vittone,[2] Ivana Capan,[1] and Milko Jakšić[1]

IAEA Coordinate Research Programme (CRP) F11016
"Utilization of ion accelerators for studying and modeling of radiation induced defects in semiconductors and insulators"

COOPERATION AND MUTUAL UNDERSTANDING LEAD TO GROWTH AND GLOBAL ENRICHMENT



NUS
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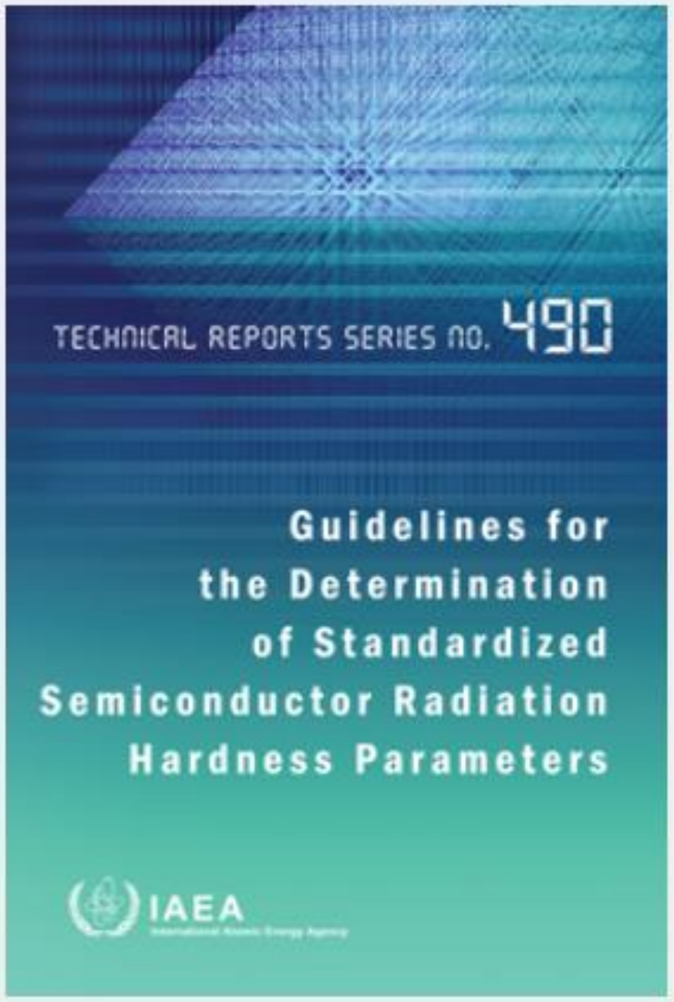
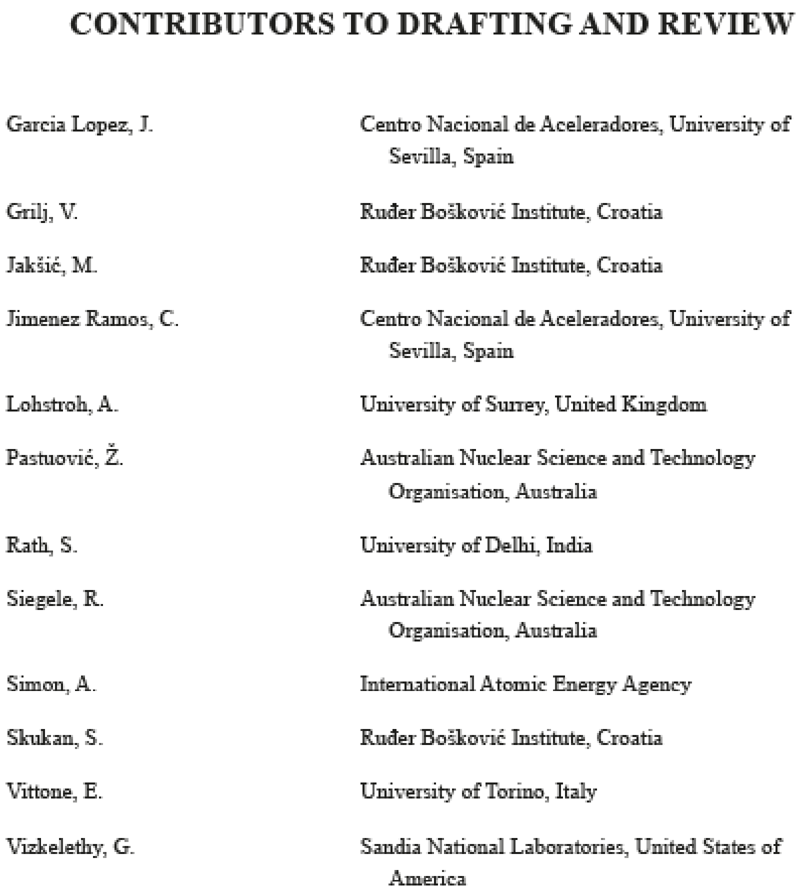
JAPAN



TECHNICAL REPORTS SERIES NO. 490

Guidelines for the Determination of Standardized Semiconductor Radiation Hardness Parameters

IAEA
International Atomic Energy Agency



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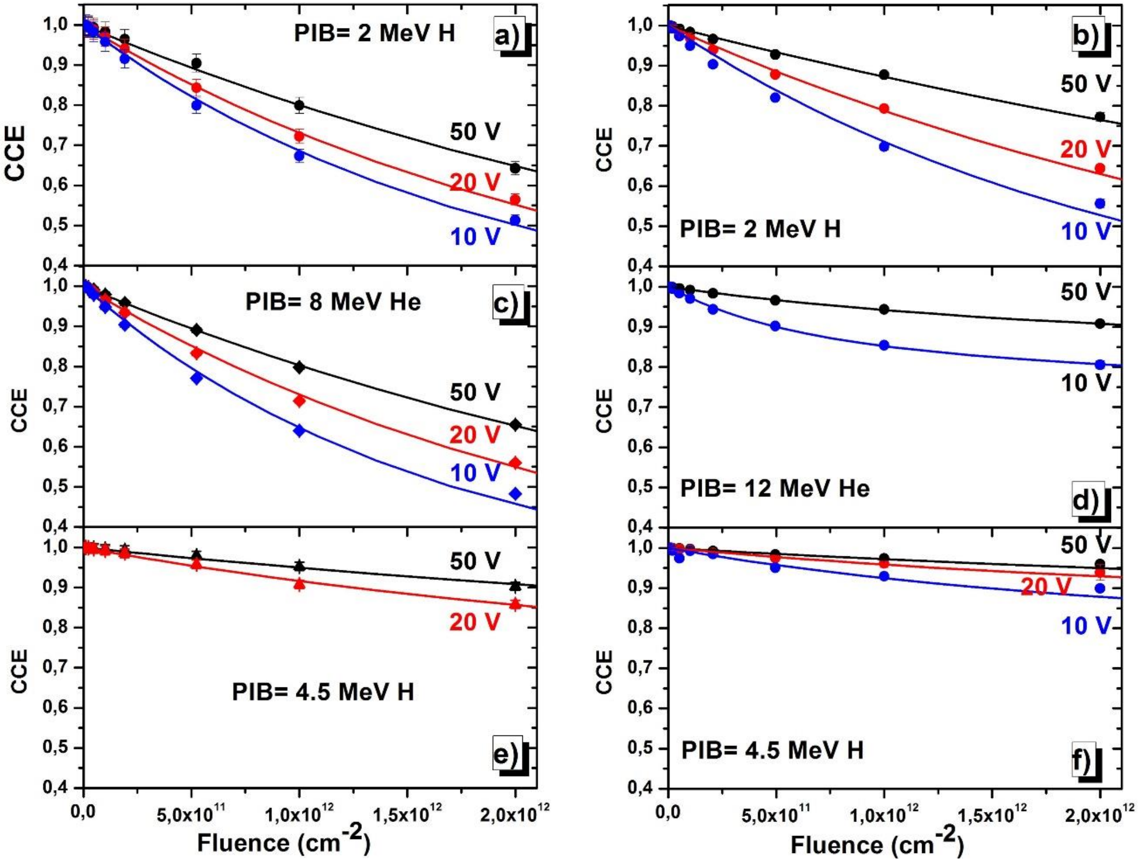
89 pages ¦ 42 figures

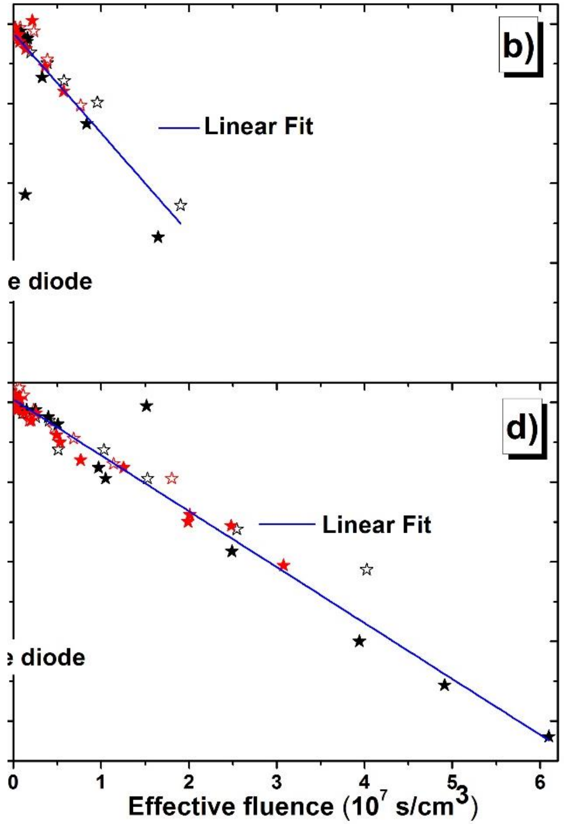
Date published: 2023

https://www.iaea.org/publications/12356/guidelines-for-the-determination-of-standardized-semiconductor-radiation-hardness-parameters

DIB: 8 MeV He



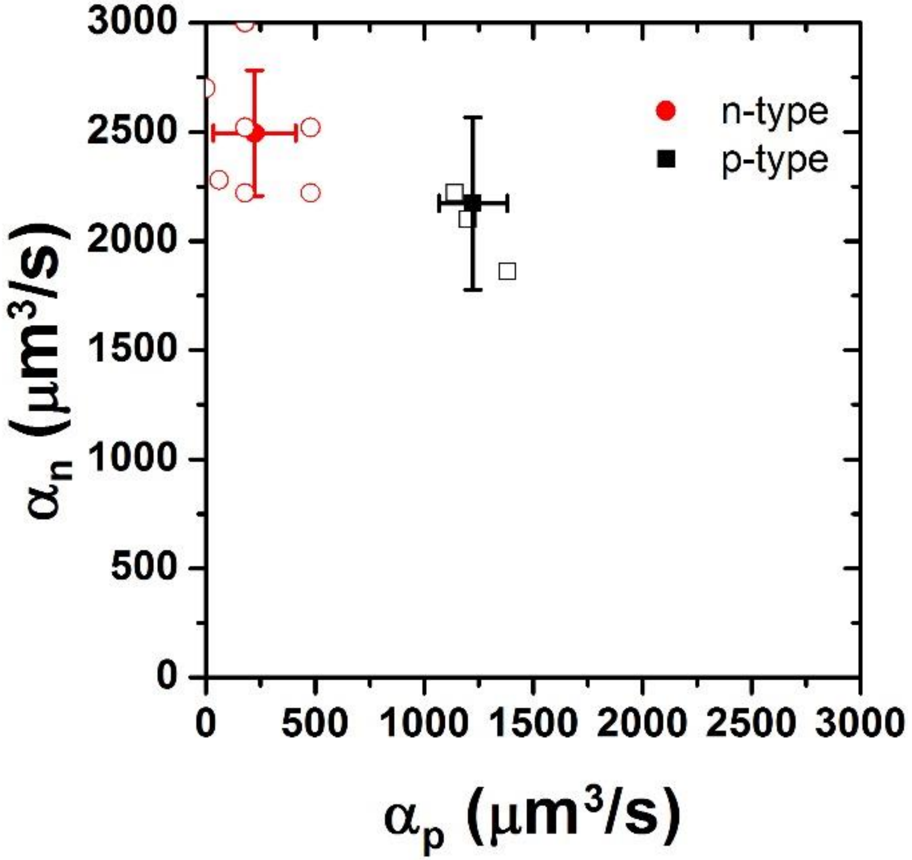
DIB: 4 MeV He



CCE degradation depends from

- **Damaging ion energy and mass**
- **Probing ion energy and mass**
- **Polarization**

The solid lines are the best fits obtained by means of our model considering
Different PIBs
Different DIBs (8 MeV, 4 MeV)
Different polarizations (10,20,50 V)



Recombination coefficient

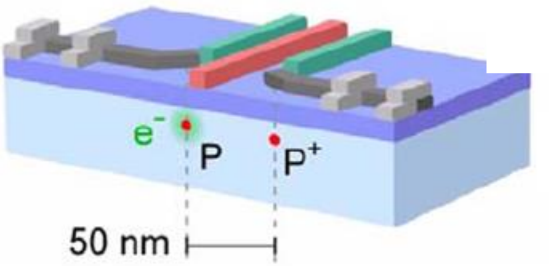
$\alpha = k \cdot \sigma \cdot v_{th}$

Final measurement of the recombination coefficients;
n-type diode: $\alpha_p = (210 \pm 160) \mu m^3/s$; $\alpha_n = (2500 \pm 300) \mu m^3/s$;
p-type diode: $\alpha_n = (2200 \pm 300) \mu m^3/s$; $\alpha_p = (1310 \pm 90) \mu m^3/s$;
Open marks: dispersion of the combination of the fitting parameters.

Ion beam characterization
by functionalized devices (by ion beams)

David N. Jamieson
School of Physics
University of Melbourne

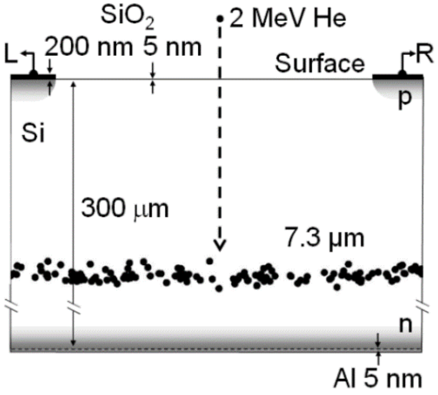
The two atom device

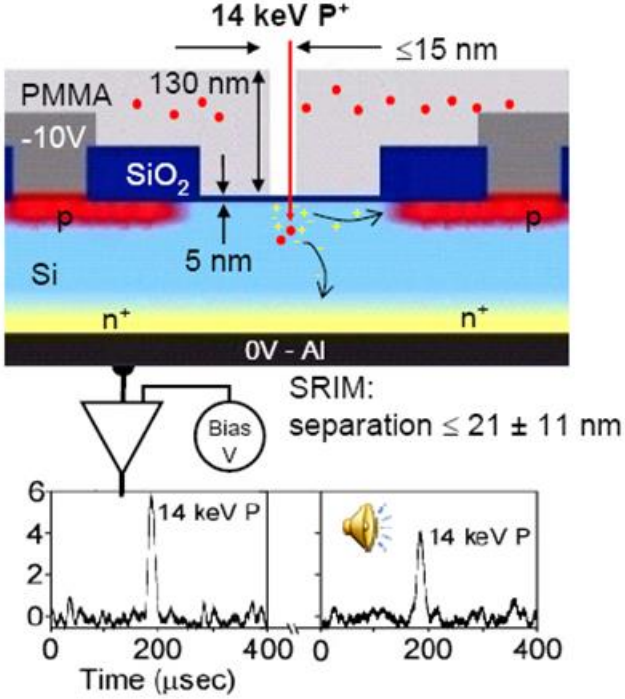


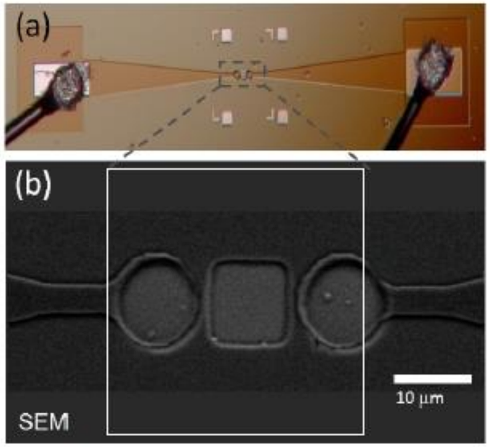
CENTRE FOR
QUANTUM COMPUTER
TECHNOLOGY
AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE

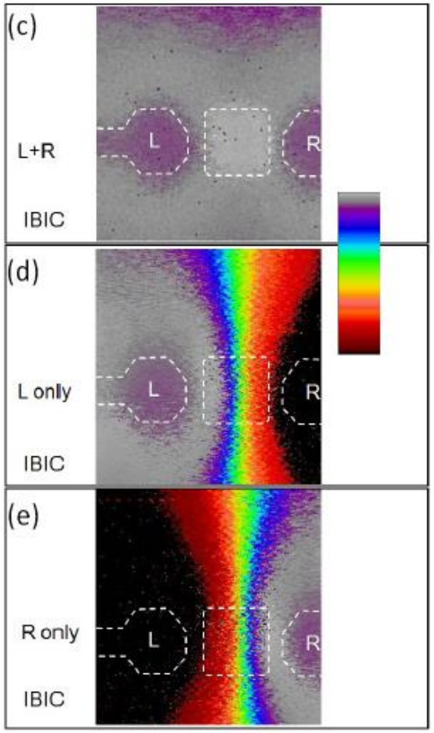
Position sensitivity - proof of concept: three-electrodes test device

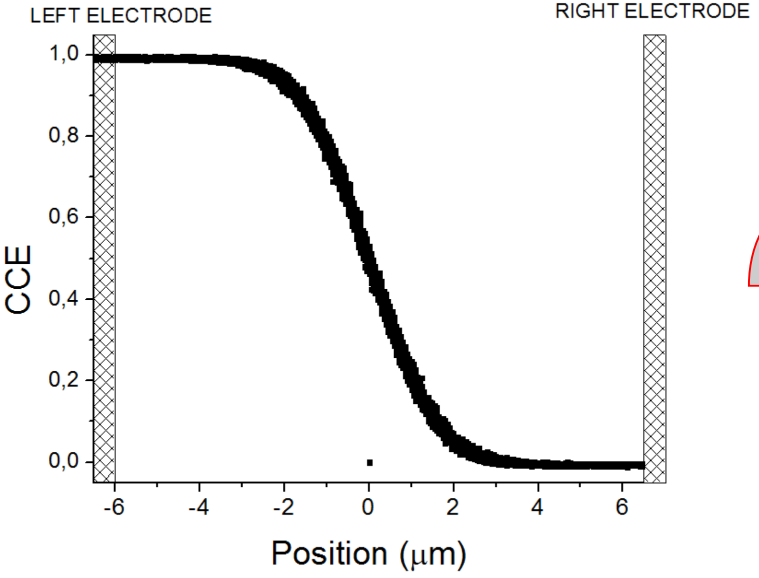
L.M. Jong et al., Nuclear Instr. Meth. B 269 (2011) 2336



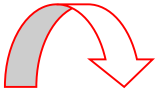


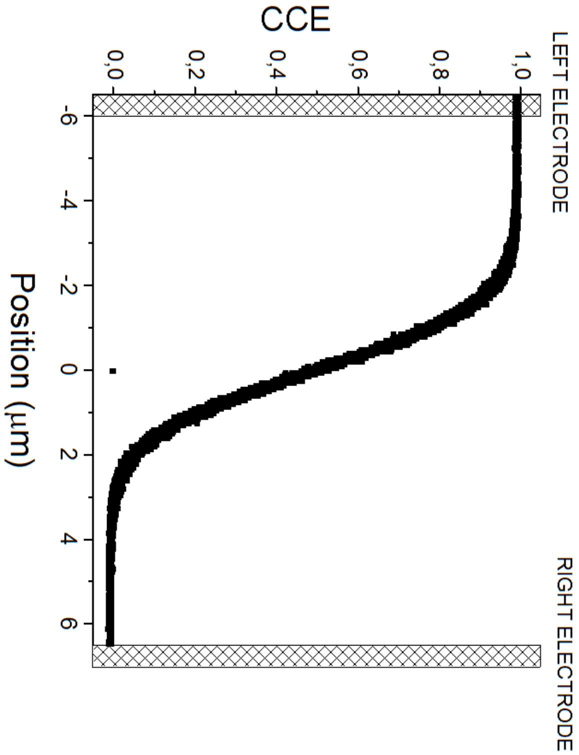






CCE AS FUNCTION OF ION STRIKE POSITION





ION STRIKE POSITION AS FUNCTION OF CCE

⇩

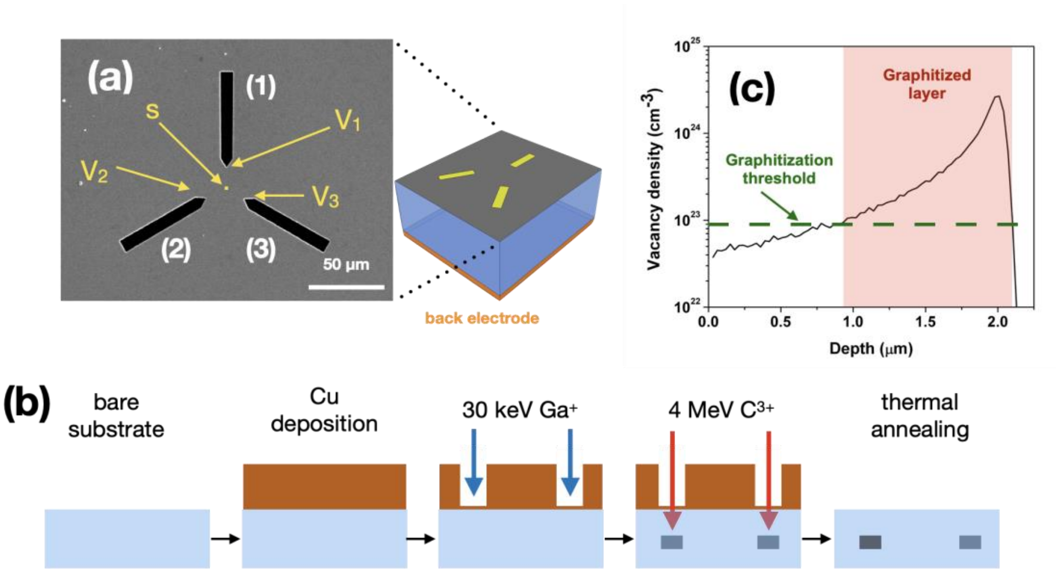
POSITION SENSITIVE DETECTOR

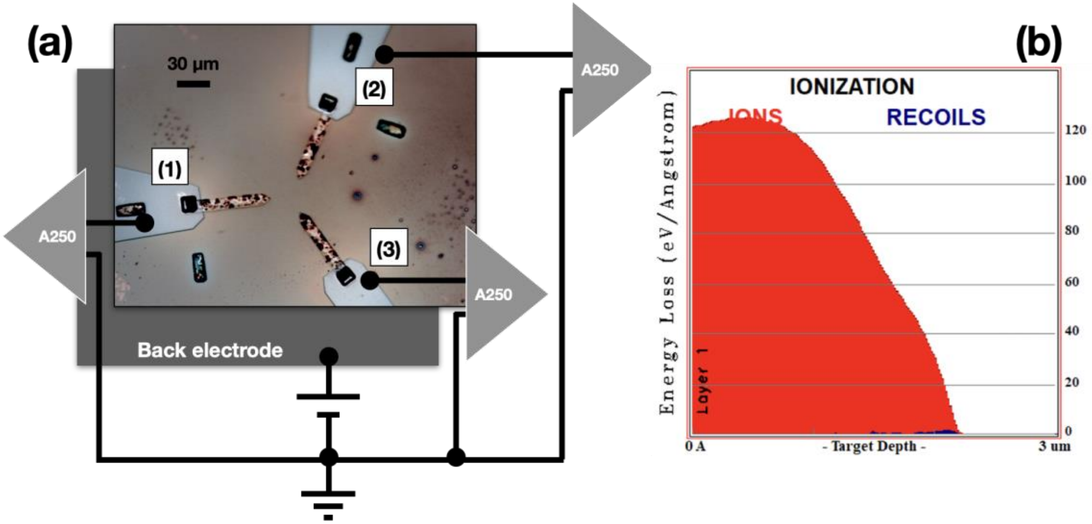
NIMB 306 (2013) 169

Modeling of ion beam induced charge sharing experiments for the design of high resolution position sensitive detectors

J. Forneris[a,*], D.N. Jamieson[b], G. Giacomini[c], C. Yang[b], E. Vittone[a]

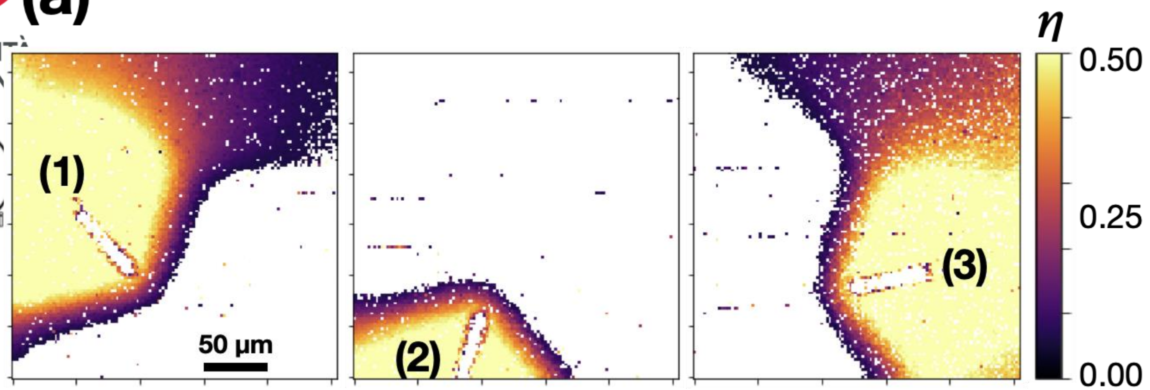
A two-dimensional position sensitive diamond detector based on the multi-electrode charge sharing effect



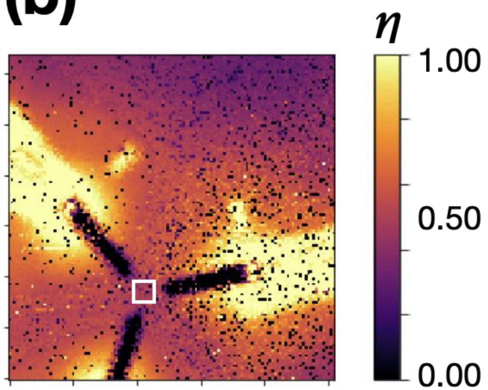


2 MeV Li

(a)

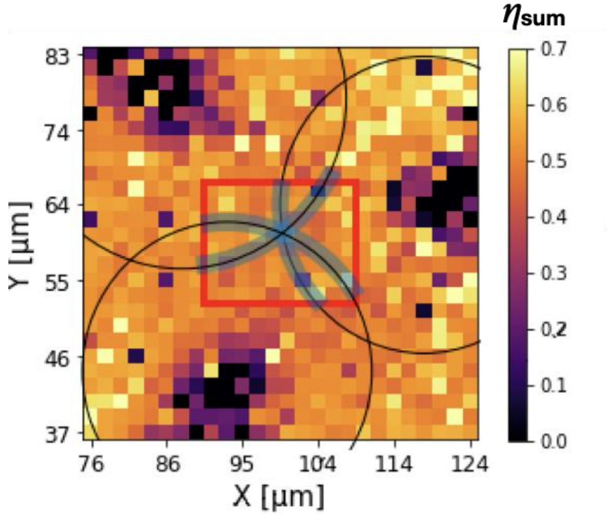


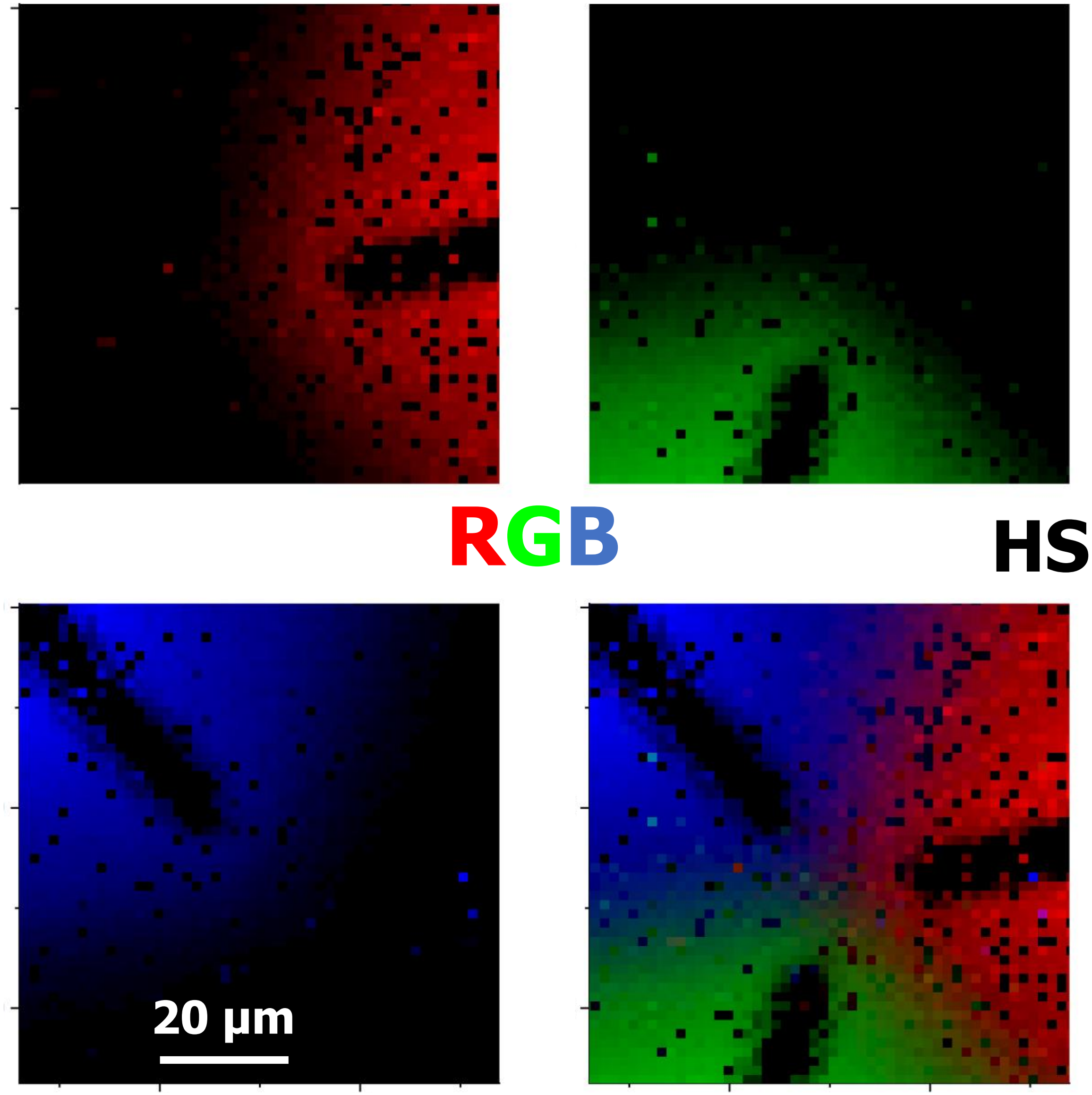
(b)



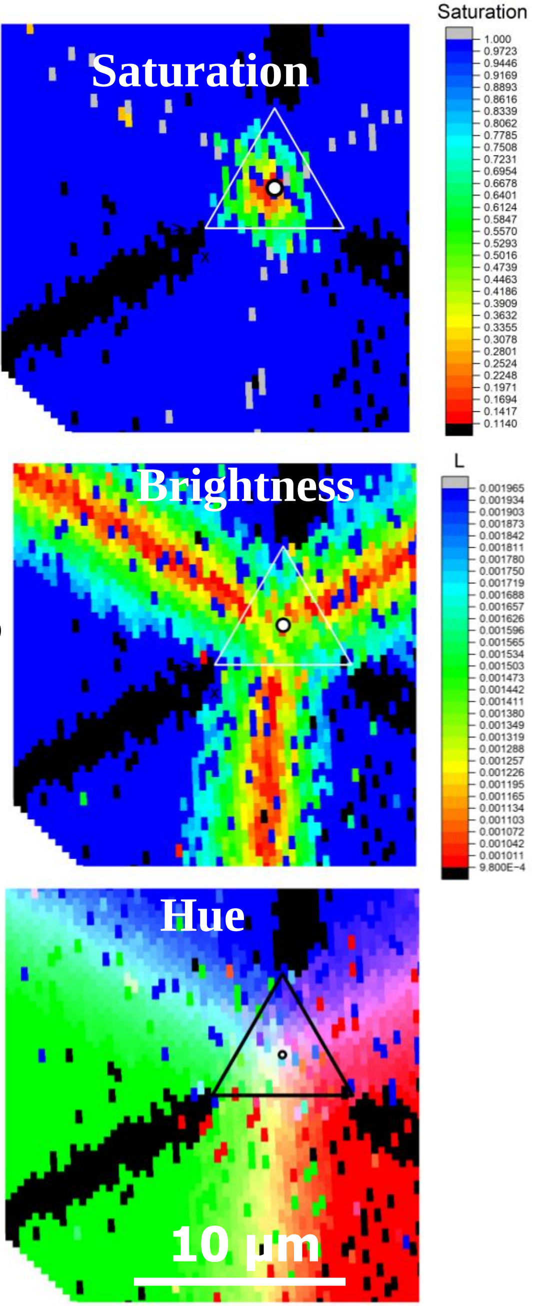
The proposed triangulation approach has demonstrated the potential to retrieve the 2-dimensional position of impact of each ion by a with a spatial uncertainty of **0.9 µm** on each spatial coordinate over a region denoted by **12 µm** length scale.

l)

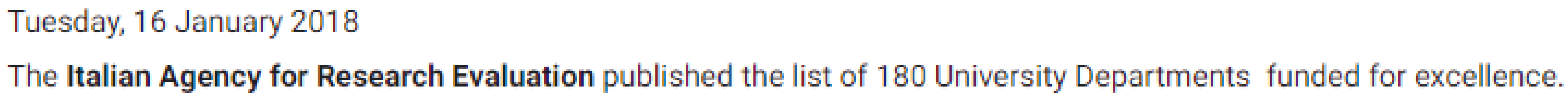



RGB
20 µm

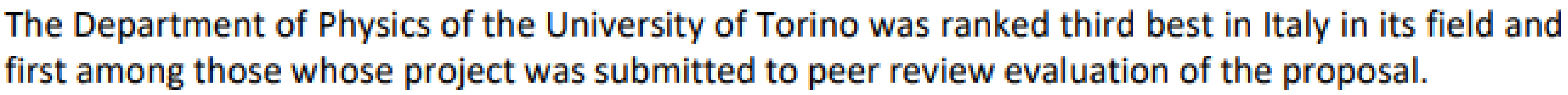
HSB


Saturation
Saturation
1.000
0.9723
0.9446
0.9169
0.8893
0.8616
0.8339
0.8062
0.7785
0.7508
0.7231
0.6954
0.6678
0.6401
0.6124
0.5847
0.5570
0.5293
0.5016
0.4739
0.4463
0.4186
0.3909
0.3632
0.3355
0.3078
0.2801
0.2524
0.2248
0.1971
0.1694
0.1417
0.1140
Brightness
L
0.001965
0.001934
0.001903
0.001873
0.001842
0.001811
0.001780
0.001750
0.001719
0.001688
0.001657
0.001626
0.001596
0.001565
0.001534
0.001503
0.001473
0.001442
0.001411
0.001380
0.001349
0.001319
0.001288
0.001257
0.001226
0.001195
0.001165
0.001134
0.001103
0.001072
0.001042
0.001011
9.800E-4
Hue
10 µm

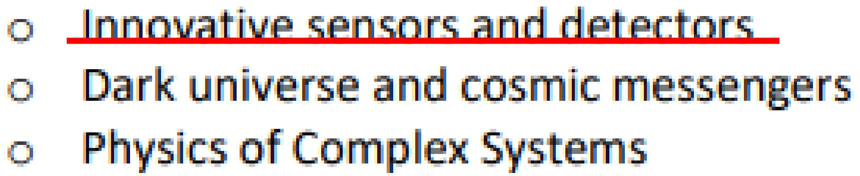
What next

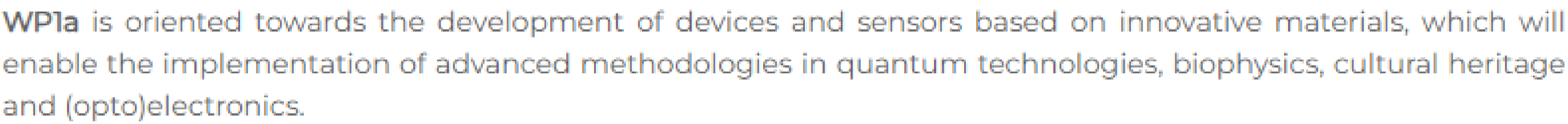

Tuesday, 16 January 2018

The **Italian Agency for Research Evaluation** published the list of 180 University Departments funded for excellence.


The Department of Physics of the University of Torino was ranked third best in Italy in its field and first among those whose project was submitted to peer review evaluation of the proposal.

WP


- Innovative sensors and detectors
- Dark universe and cosmic messengers
- Physics of Complex Systems


WP1a is oriented towards the development of devices and sensors based on innovative materials, which will enable the implementation of advanced methodologies in quantum technologies, biophysics, cultural heritage and (opto)electronics.

In the field of quantum technologies, a state-of-the-art multi-elemental ion implanter is going to be installed at the Solid State Physics laboratory, which will allow the multi-parametric defect engineering of wide-bandgap semiconductors (diamond, SiC, GaN, etc.) for the development of innovative single photon sources and quantum sensors. The ion implanter will operate in synergy with the recently established class 10’000 cleanroom

Leipzig,
January-June 2018

UNIVERSITÀ DEGLI STUDI DI TORINO

Direzione Bilancio e Contratti
Area Appalti e Contratti

Ref no. 195976 dated 29/05/2019

University of Leipzig
Ritterstraße 26
04109 Leipzig
Germany

We hereby inform you that, by Executive Decree no. 2065 of 29/5/2019, your Institution has been assigned the above contract,

100 kV Implanter - University Torino

Design Document

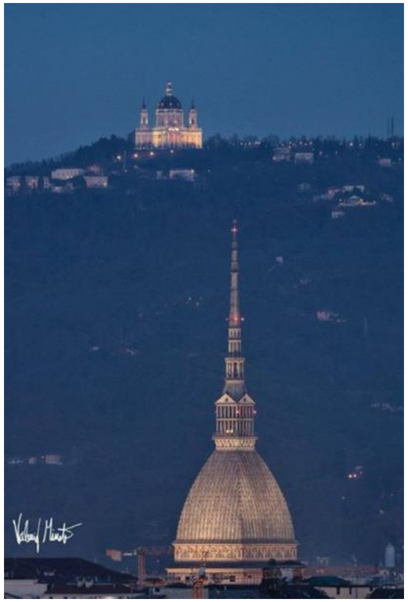
16 December 2019

Prepared by University Leipzig

9 march 2020

Italy is in total lockdown

11 march 2020



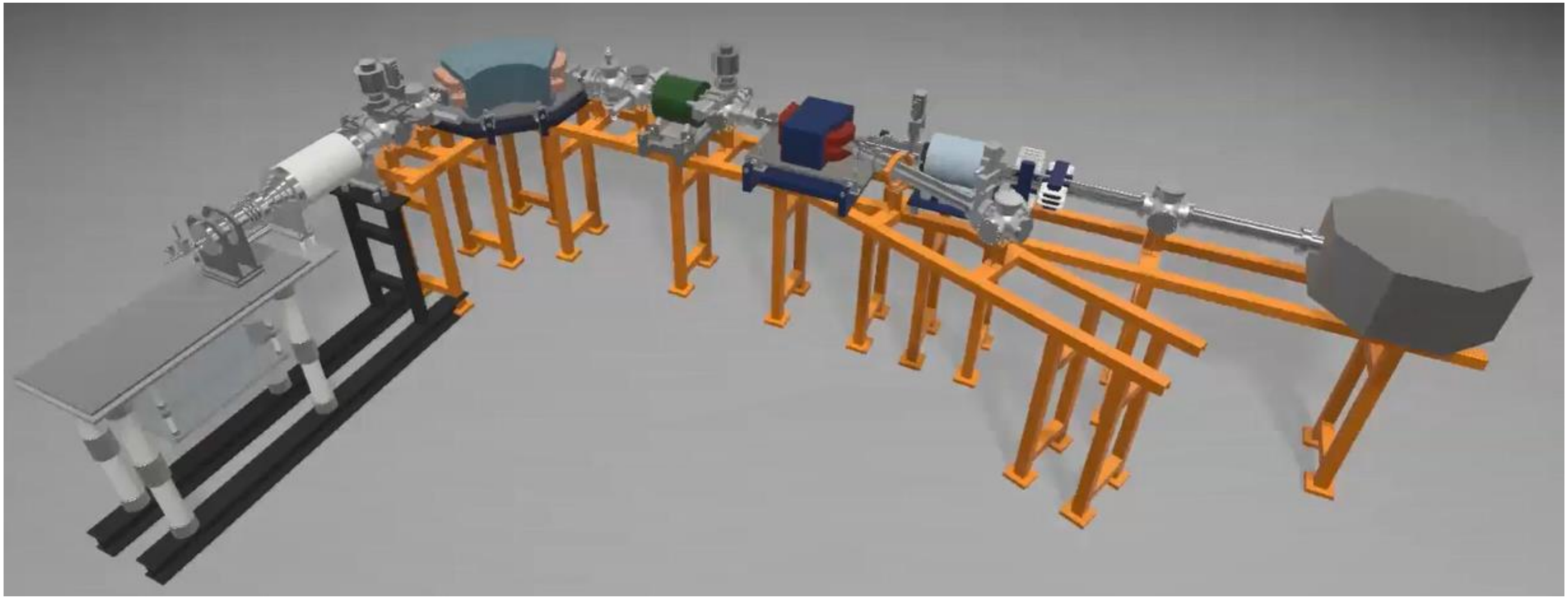
UNIVERSITÀ DI TORINO

Universität Stuttgart

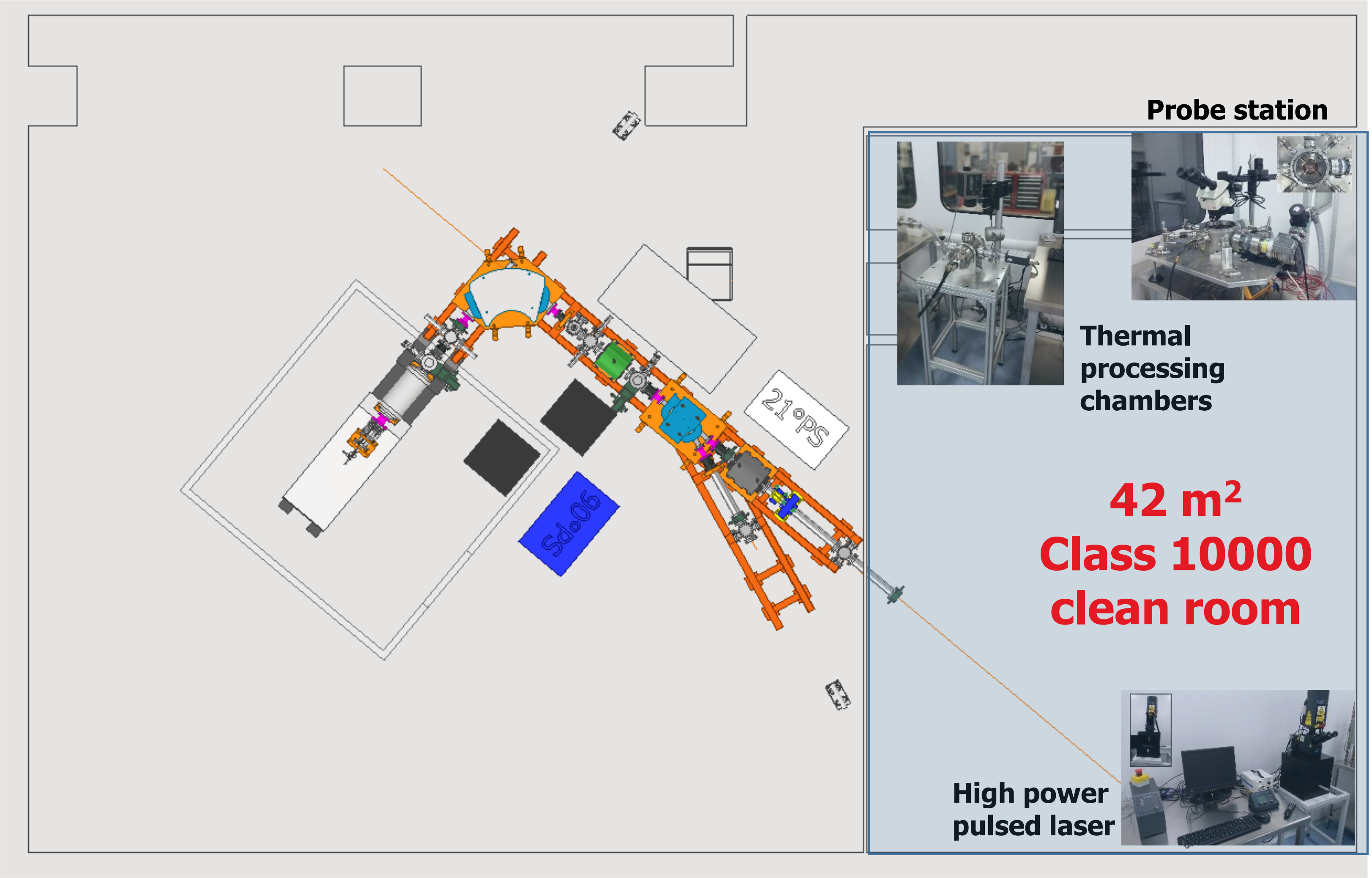
14 July 2021


09-05-2022 – FC1
10-05-2022 – FC2
13-05-2022 – FC3

Max terminal potential: 100 kV
Ion source: NEC – SNICS II
2 beamlines (one currently operational)
Typical ion beam current range: 1 pA – 1 μA
Irradiation chamber localized within the cleanroom facility



The multi-elemental ion implanter
Solid State Physics Laboratory
Physics Department, University of Torino



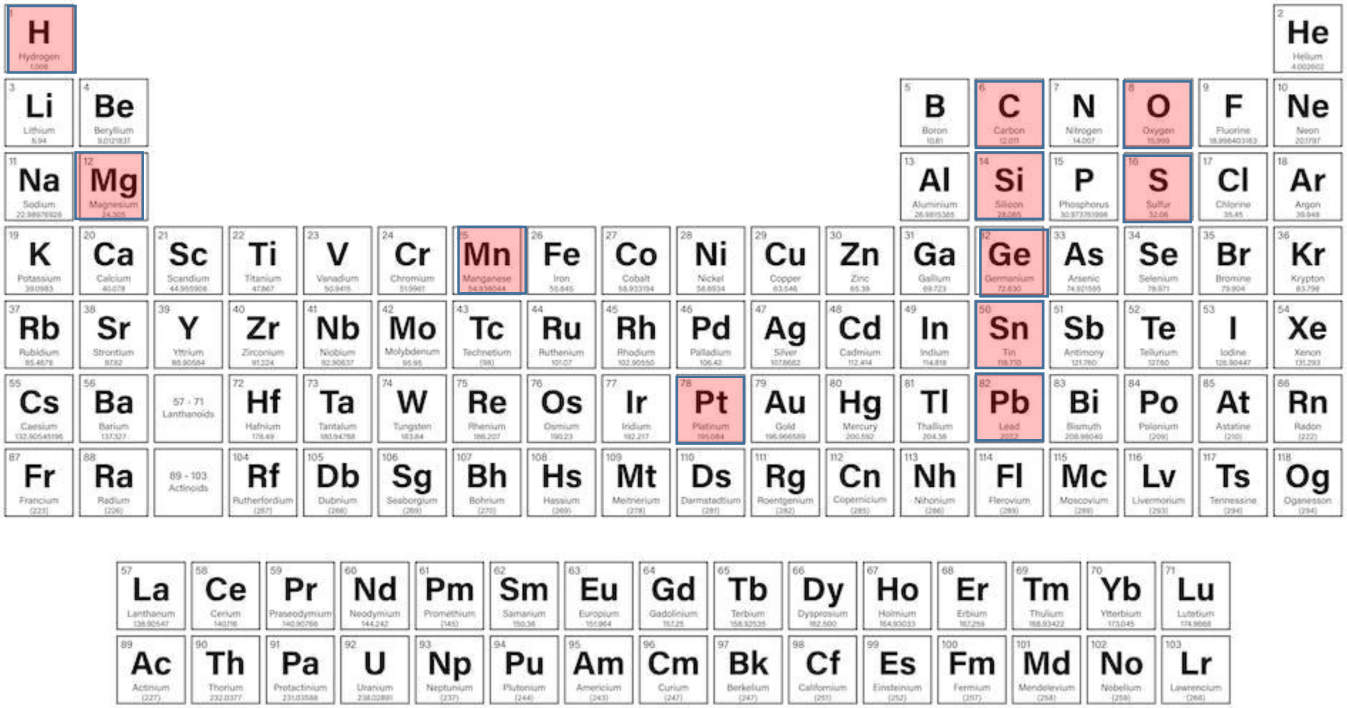
Probe station

Thermal processing chambers

42 m^2
Class 10000 clean room

High power pulsed laser

Periodic Table of the Elements



1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	**6 C Carbon**	7 N Nitrogen	**8 O Oxygen**	9 F Fluorine	10 Ne Neon
11 Na Sodium	**12 Mg Magnesium**											13 Al Aluminium	**14 Si Silicon**	15 P Phosphorus	**16 S Sulfur**	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	**25 Mn Manganese**	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	**32 Ge Germanium**	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	**50 Sn Tin**	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium	57 - 71 Lanthanoids	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	**78 Pt Platinum**	79 Au Gold	80 Hg Mercury	81 Tl Thallium	**82 Pb Lead**	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89 - 103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

From 27/10/2022 to 11/05/2023
370 operating hours

Targets: diamond, Si, SiC, Ti, Metal Oxides

Conclusions

The Solid State Physics group of the Physics Department of the University of Torino has been committed since 90’s in IBT

Main contributions

To the development of the IBIC technique for the electronic characterization of semiconductor materials and devices.

To formulate an experimental protocol, supported by a theoretical model, for the assessment of the radiation hardness of semiconductors.

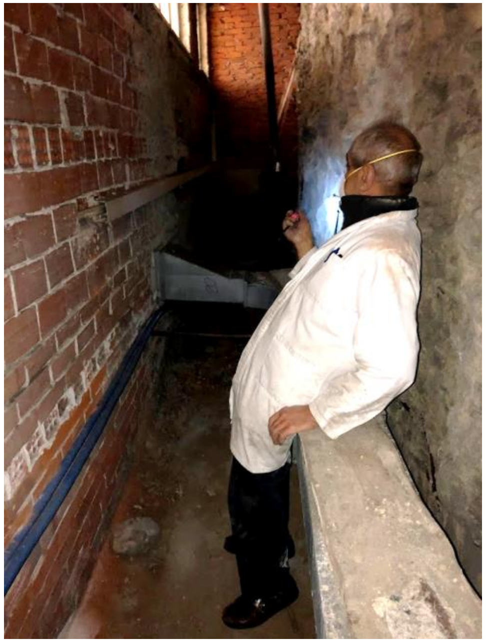
To the development of new position sensitive detectors based on the sharing of the induced charge in multiple electrode systems.

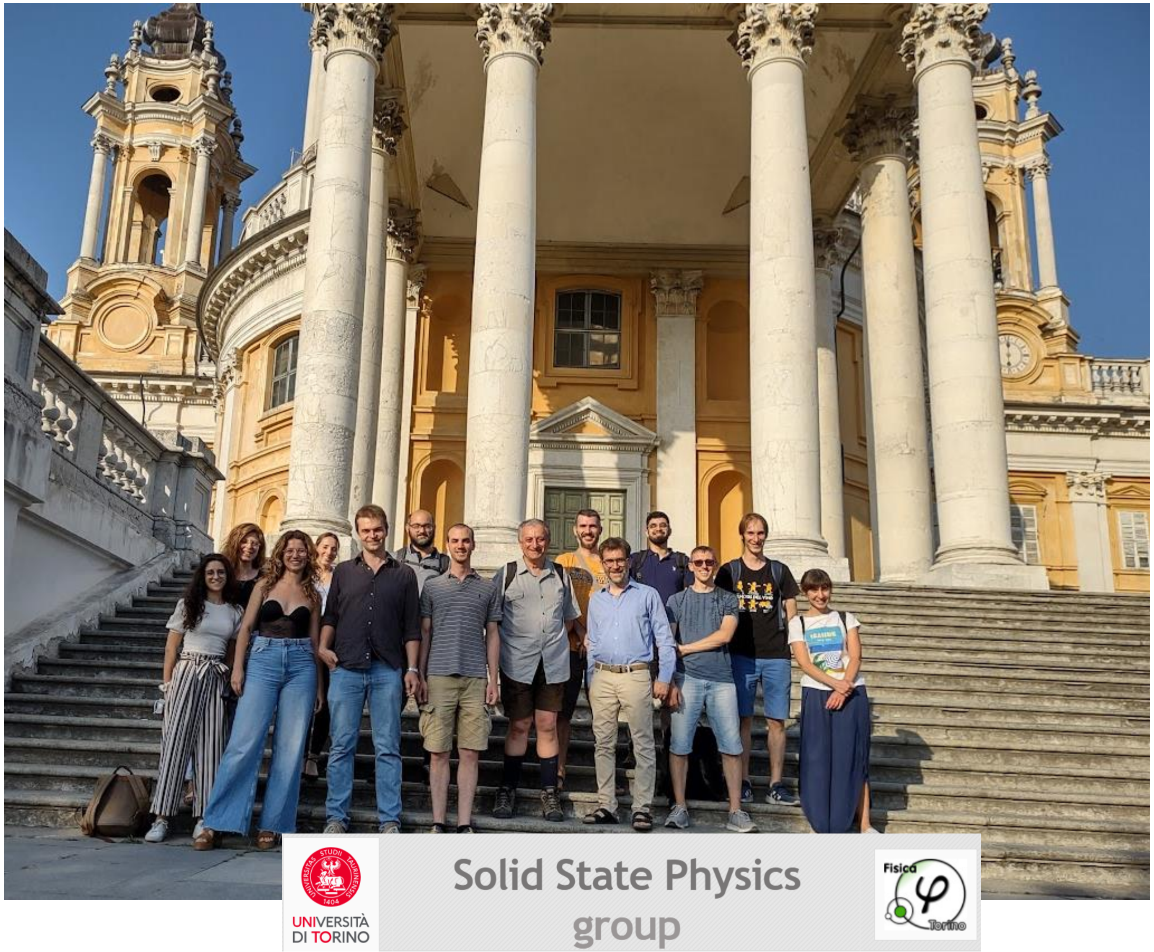
To the functionalization of materials by ion beams

Acknowledgements

- The administrative staff of UniTo
- The Department of Physics: former and current directors
- The Radioprotection Service
- The University of Leipzig

- Mr. Nunzio Dibiase





Solid State Physics group