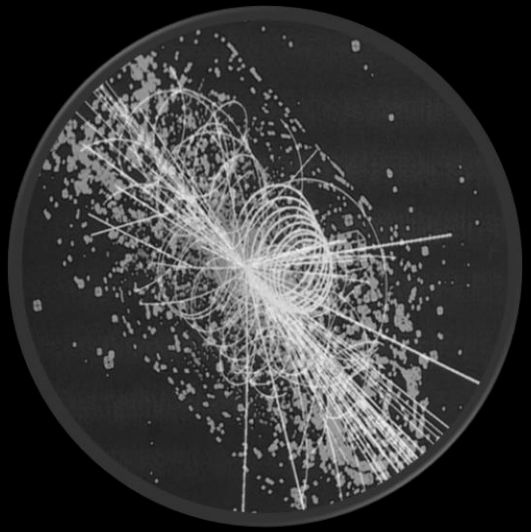
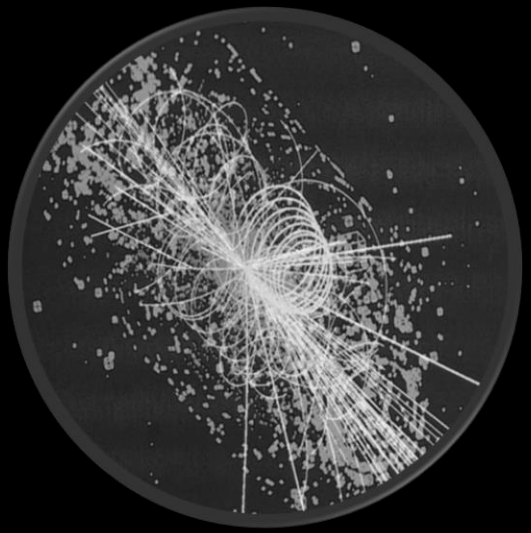

CERN



Expecting the unknown…

A preliminary characterization of 3D silicon sensors by means of IV-CV measurements

CERN Internship: April 2015

David Gruettner, ISH

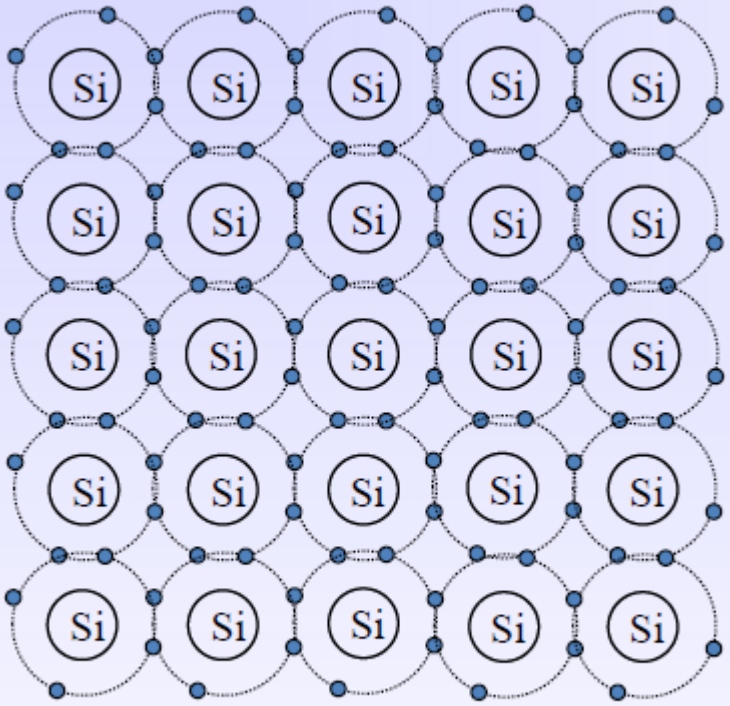
SSD/ PH-DT-DD

Outline

- **Silicon sensors**– The physics behind it
- **IV and CV** – The theoretical, ideal curve
- **My measurements** – The Setup
- **My results** – The experimental reality
- **Review on the internship** – What's left to say

The chemistry behind a semiconductor...

Silicon sensors



Silicon atoms share valence electrons to form insulator-like bonds.

Hauptgruppen

Periode	II	III	IV	V	VI
2	9,0 Be 4	10,8 B 5	12,0 C 6	14,0 N 7	16,0 O 8
3	24,3 Mg 12	27,0 Al 13	28,1 Si 14	31,0 P 15	32,1 S 16
4	40,1 Ca 20	69,7 Ga 31	72,6 Ge 32	74,9 As 33	79,0 Se 34
5	87,6 Sr 38	114,8 In 49	118,7 Sn 50	121,8 Sb 51	127,6 Te 52
6	137,3 Ba 56	204,4 Tl 81	207,2 Pb 82	209,0 Bi 83	209 Po 84

http://www.leifiphysik.de/sites/default/files/medien/periodensystem_einfelektronik_gru.gif 22.04.2015 ; 15-02-ESIPAP-School-Silicon-Radiation Damage Intro_Marcos 22.04.2015

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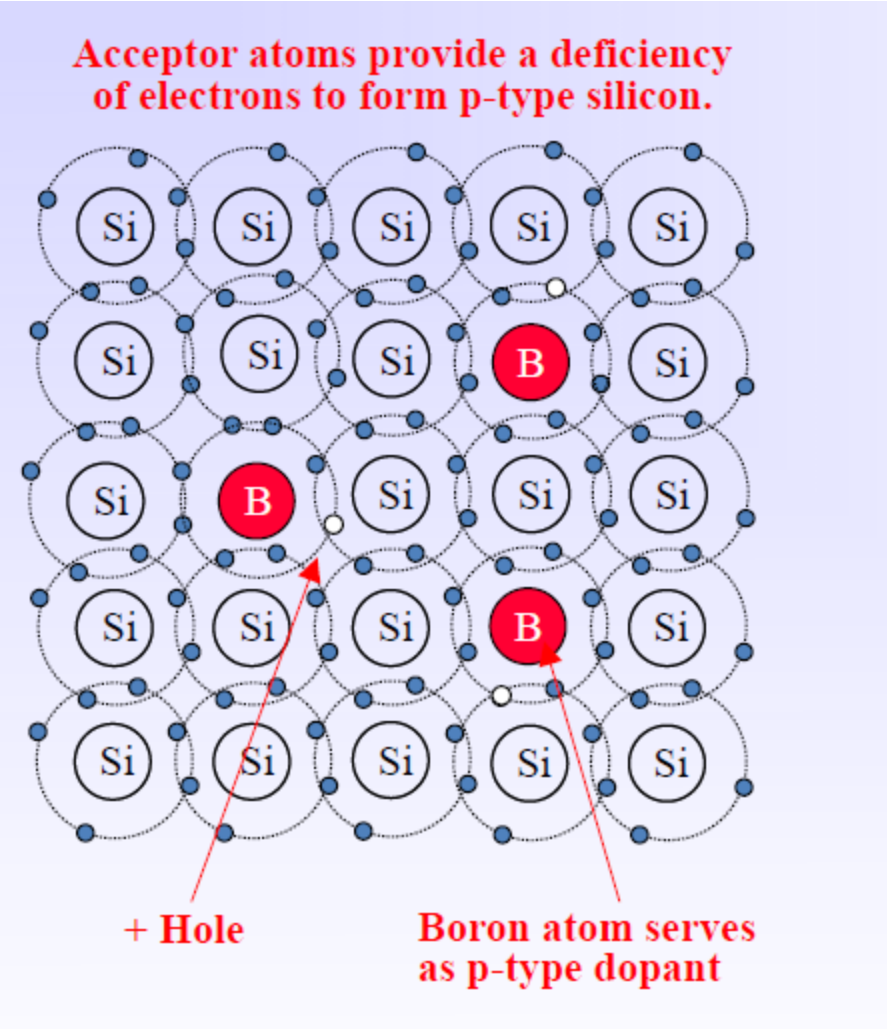

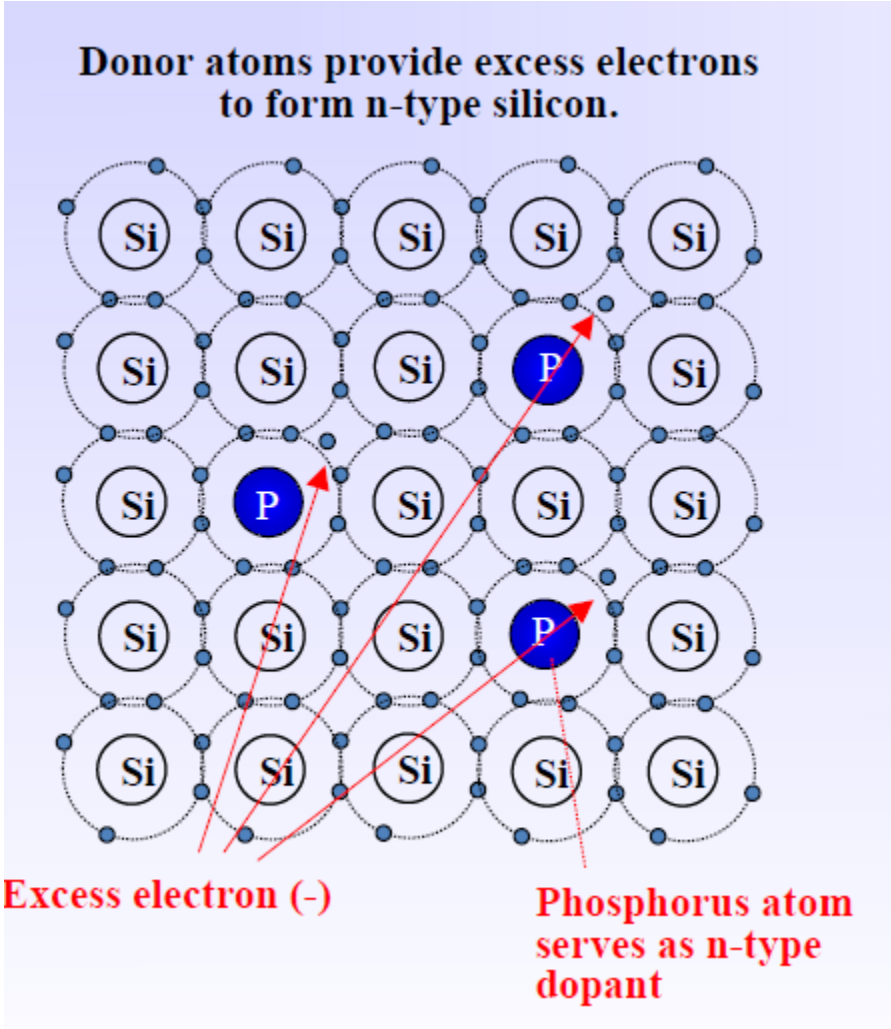

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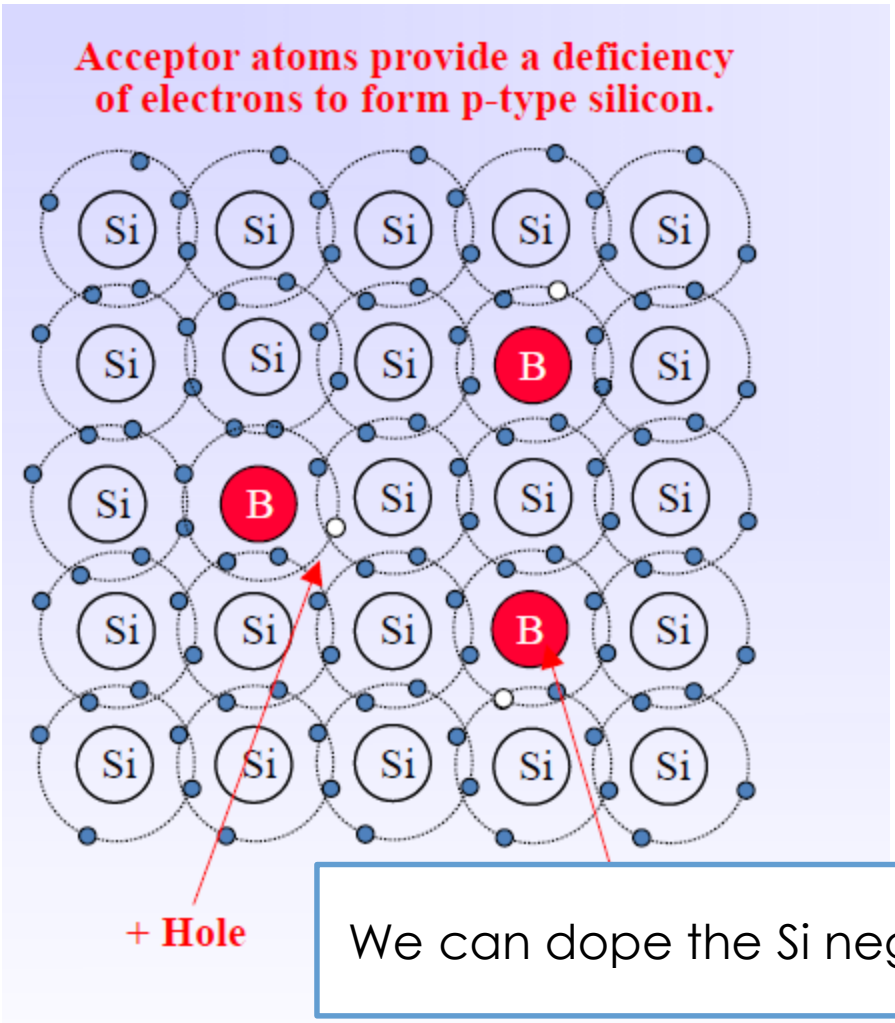
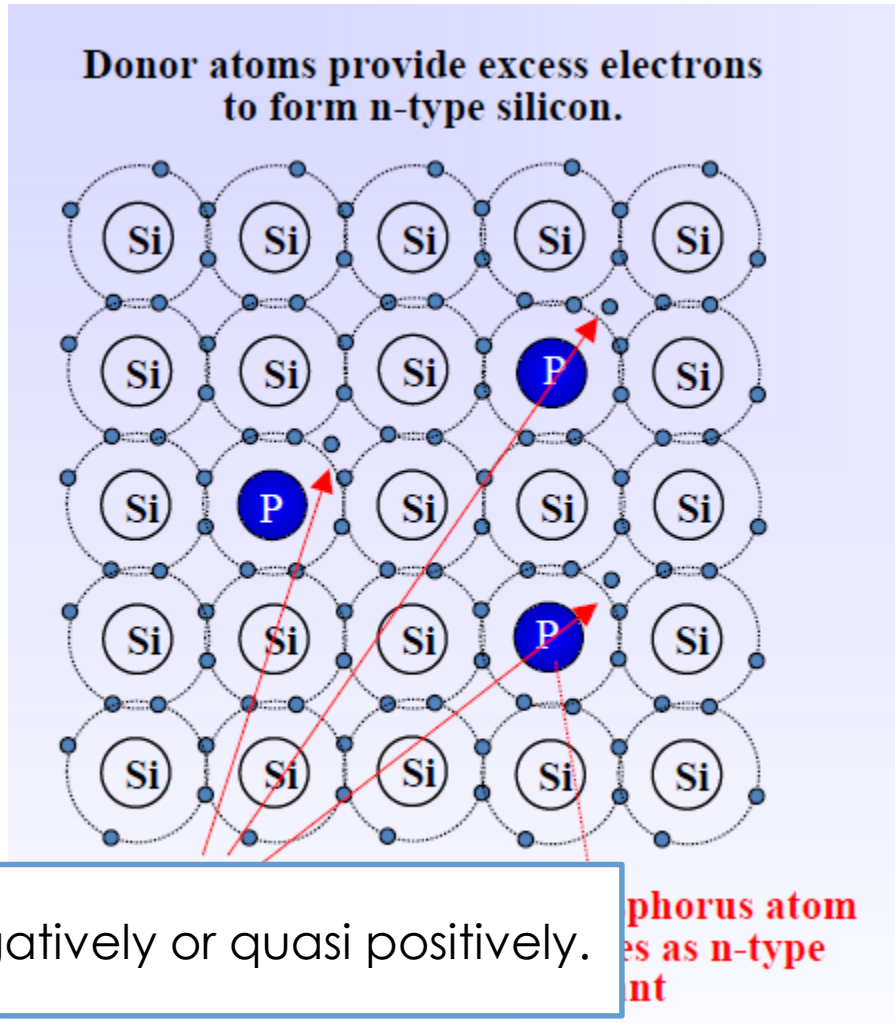


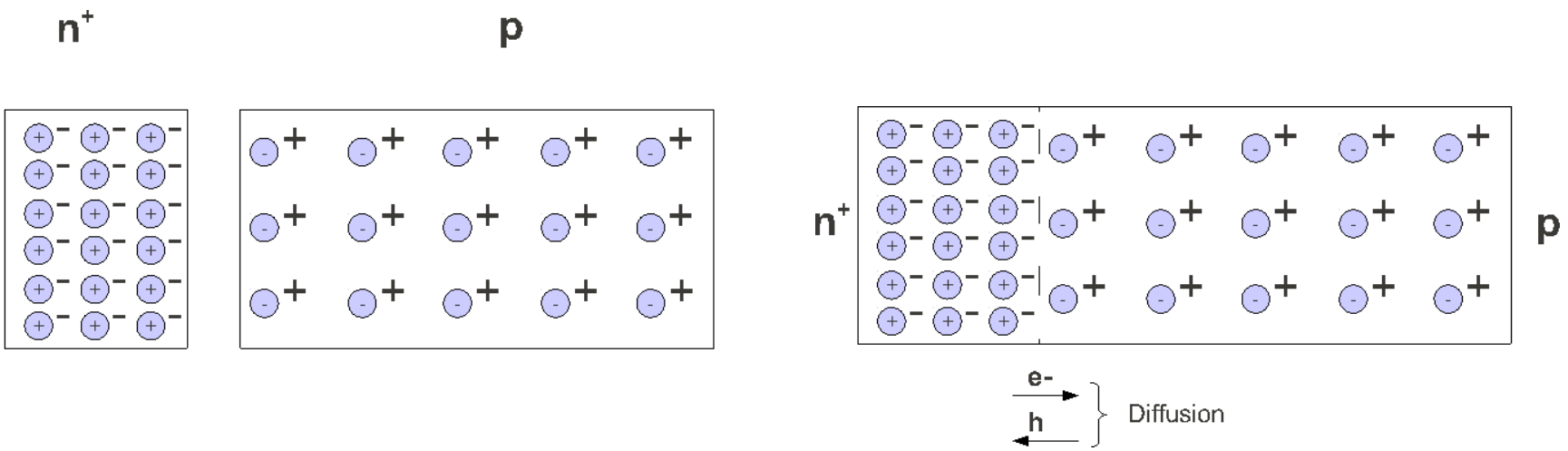


We can dope the Si negatively or quasi positively.

http://www.leifiphysik.de/sites/default/files/medien/periodensystem_einfelektronik_gru.gif 22.04.2015 ; 15-02-ESIPAP-School-Silicon-Radiation Damage Intro_Marcos 22.04.2015

The 2D physics behind a semiconductor...

Silicon sensors



The two doped materials diffuse and the electrons fill the free holes.

http://www.leifiphysik.de/sites/default/files/medien/periodensystem_einfelektronik_gru.gif 22.04.2015 ; 15-02-ESIPAP-School-Silicon-Radiation Damage Intro_Marcos 22.04.2015

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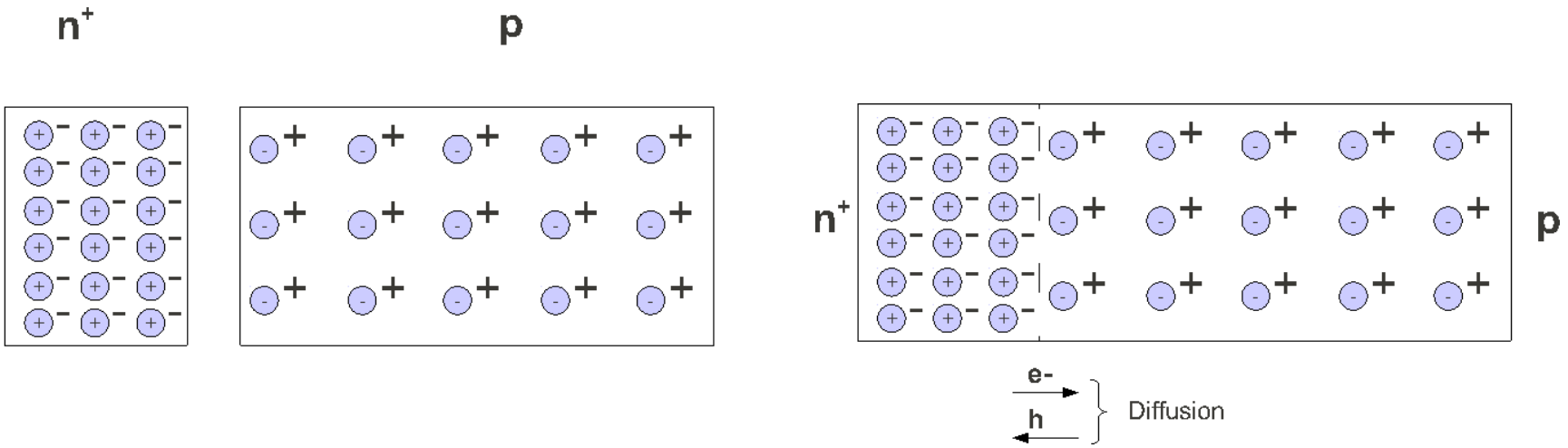
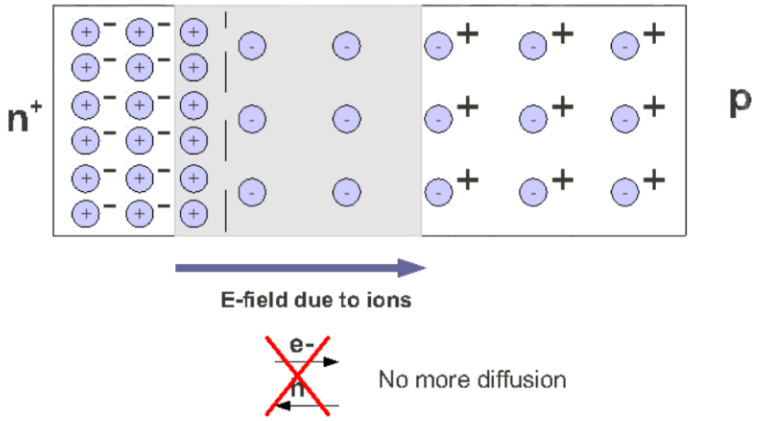
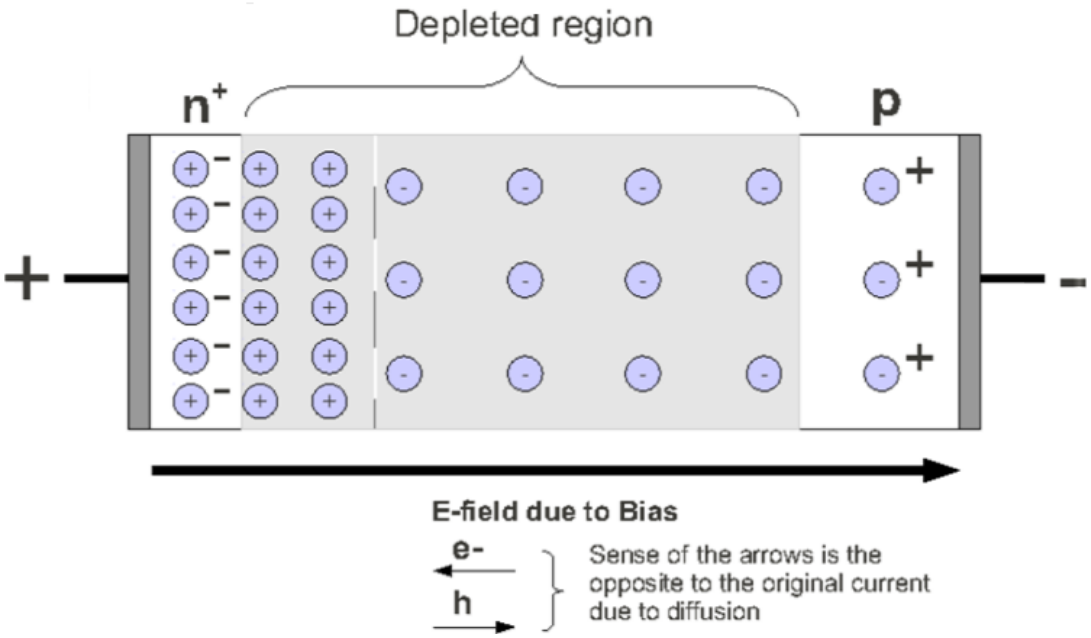




The diffusion has created an E-field, therefore the electron movement is stopped and the forces equalise each other.

The 2D physics behind a semiconductor...

Silicon sensors

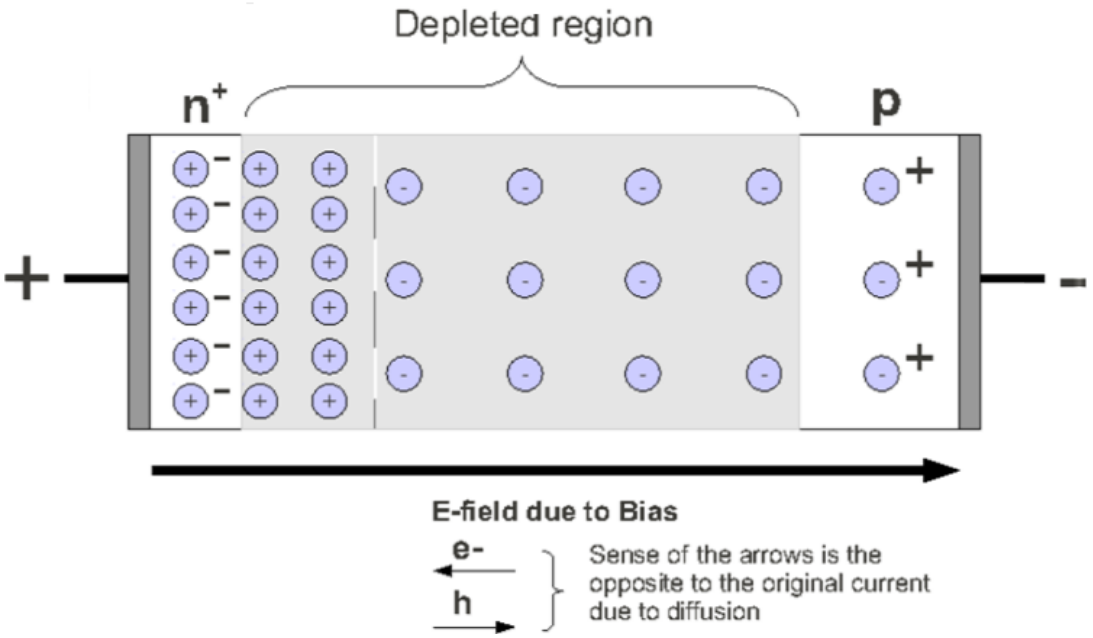


By applying a voltage we can increase the E-field and thus increase the width of the depletion to a fixed maximum.

http://www.leifiphysik.de/sites/default/files/medien/periodensystem_einfelektronik_gru.gif 22.04.2015 ; 15-02-ESIPAP-School-Silicon-Radiation Damage Intro_Marcos 22.04.2015

The 2D physics behind a semiconductor...

Silicon sensors



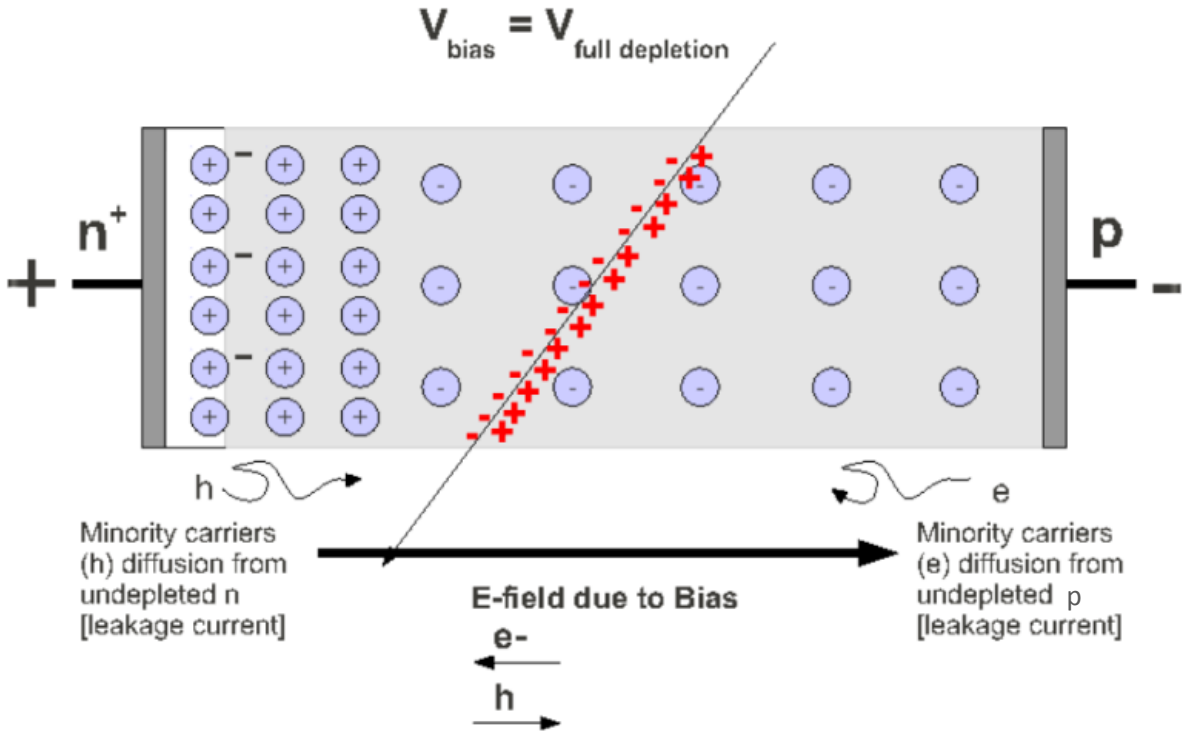
By applying a voltage we can increase the E-field and thus increase the width of the depletion to a fixed maximum.

1) The sensors can also be seen as a **capacitor** of variable thickness (as a function of V).

2) And a silicon sensor also is a diode.

The 2D physics behind a semiconductor...

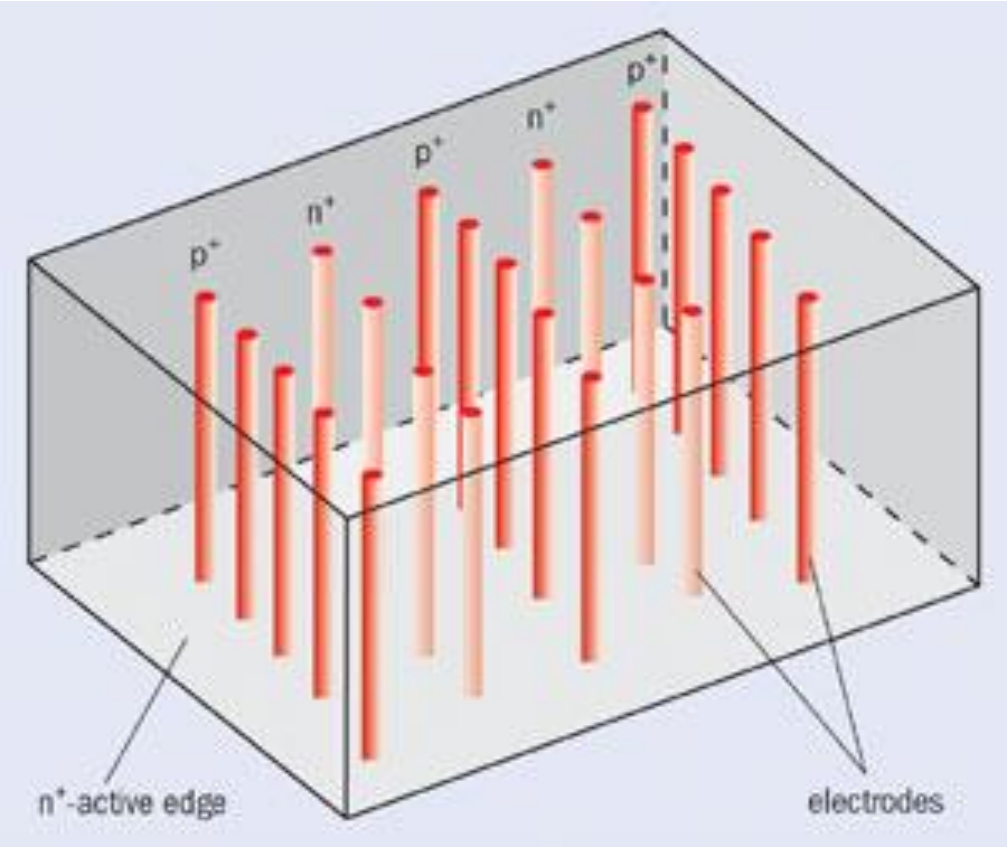
Silicon sensors



An ionising particle that passes the silicon sensor can be detected by the current it creates.

The aim is to keep the leakage current low.

The 3D visualisation
Silicon sensors

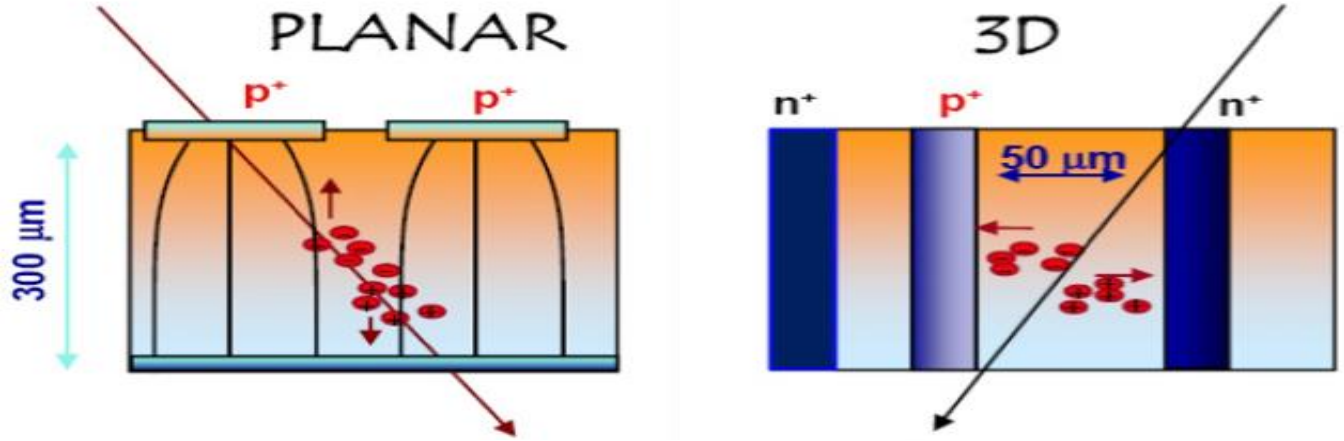


A 3D-sensor shows the same attributes as the 2D.

http://images.iop.org/objects/ccr/cern/43/1/16/cernrad1_1-03.jpg 23.04.2015

What dimension should it be?

Silicon sensors



3Ds offer a faster charge collection

Smaller depletion voltage

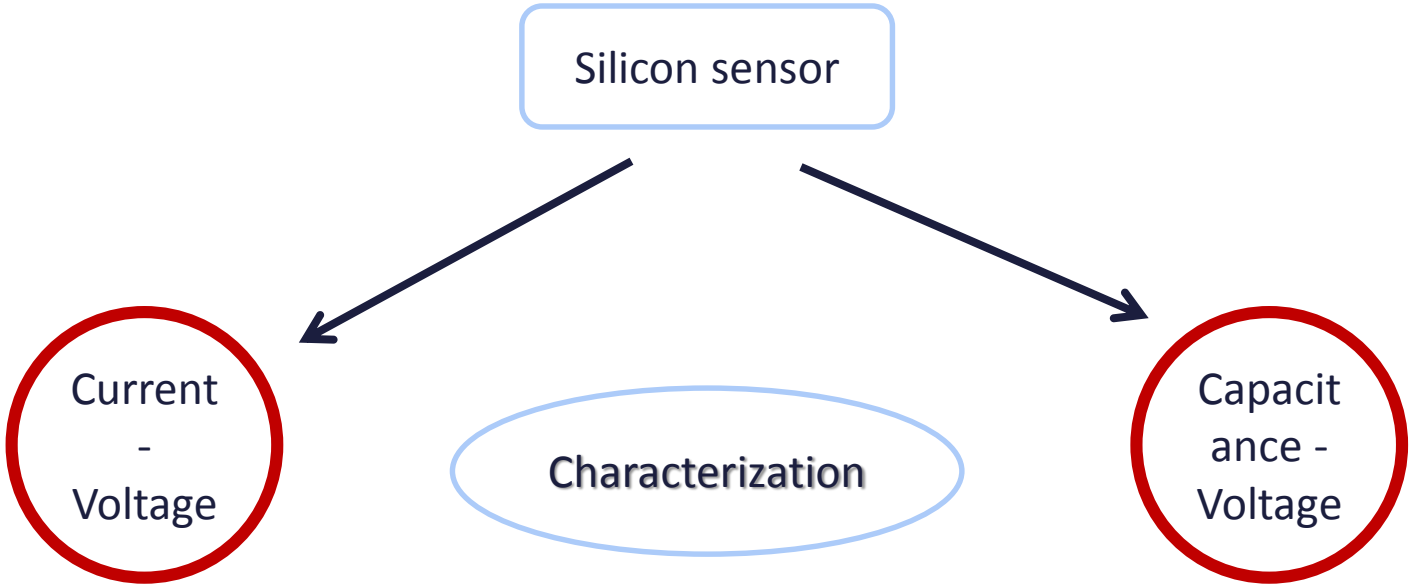
& are radiation harder

BUT planar technology is the more consolidated

Both sensors show reasonable advantages.

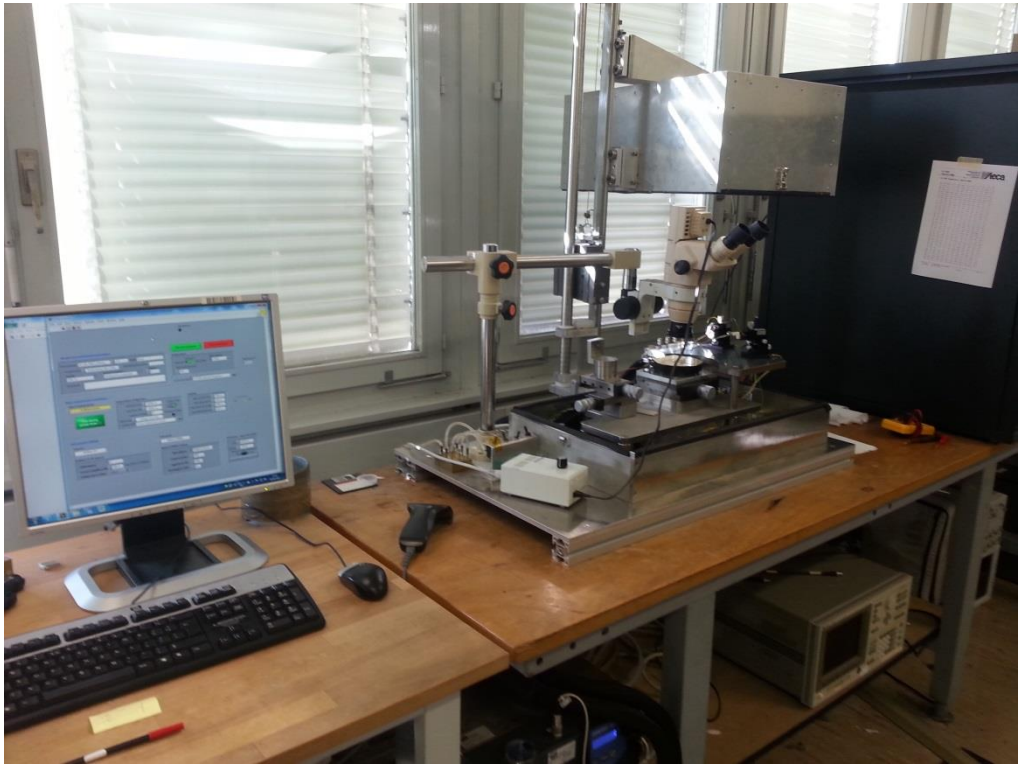
What are IV and CV measurements?

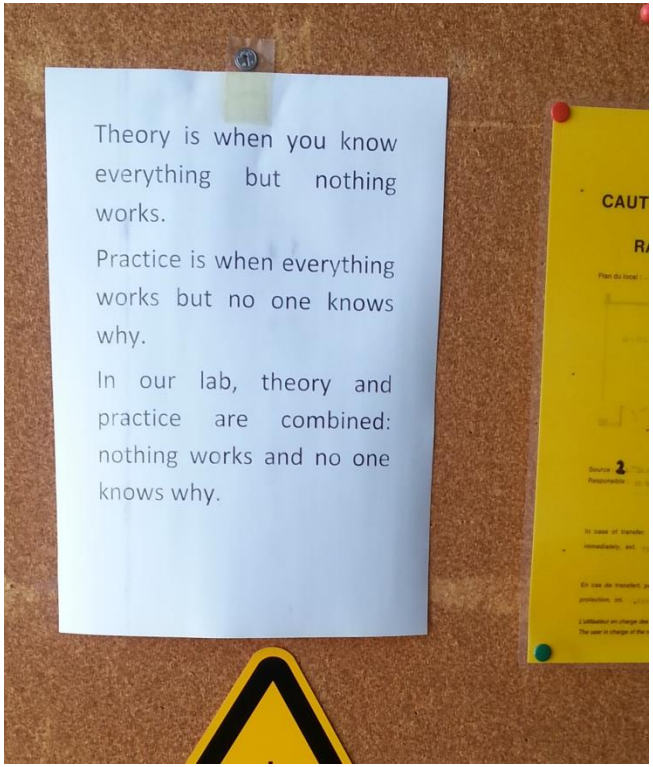
IV and CV theory



The lab: My place to be

Measurement-Set up





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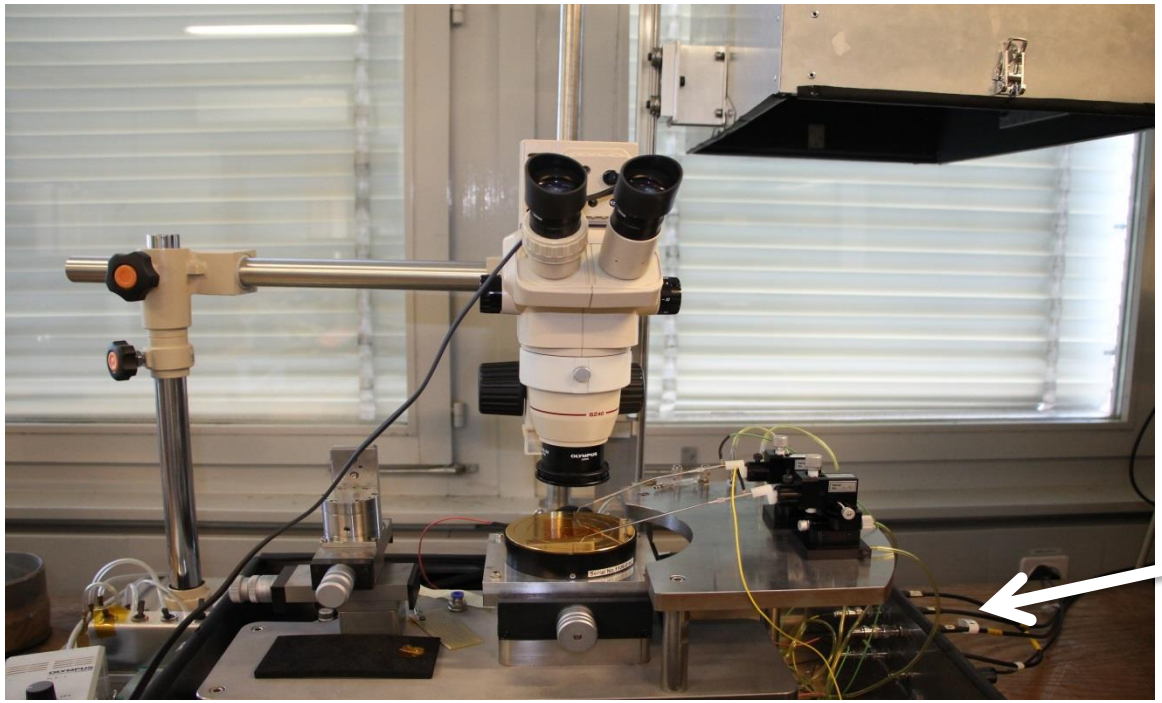
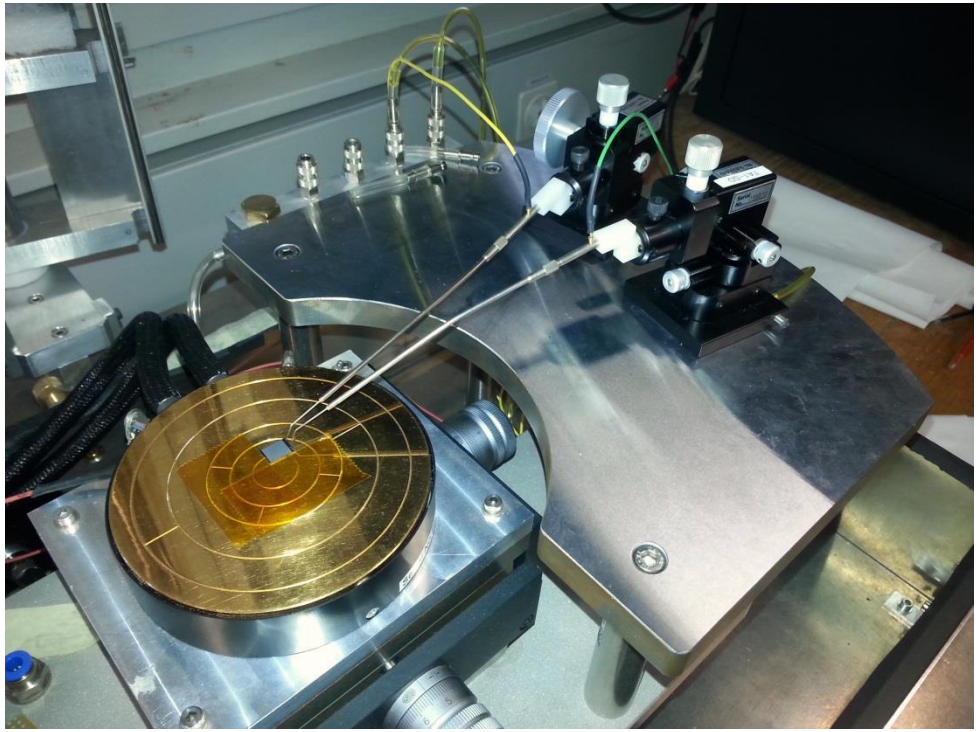
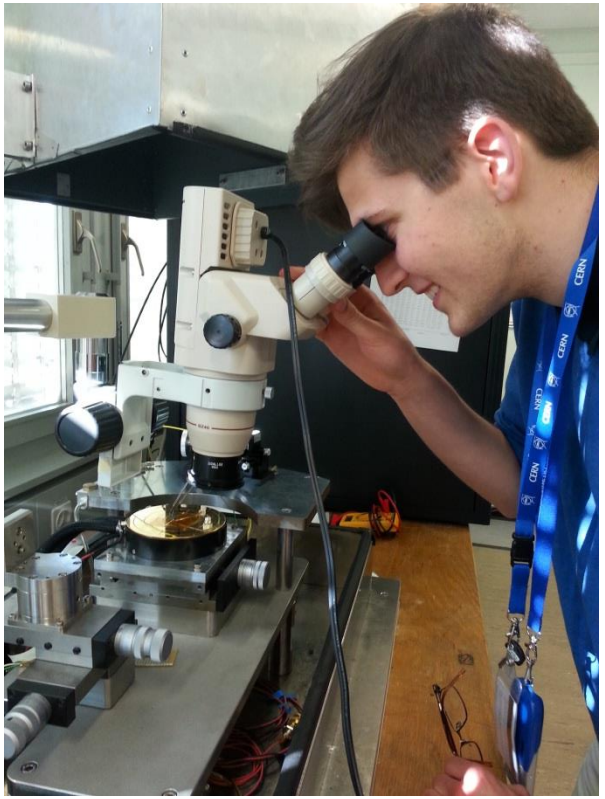


We apply a voltage and measure I or C.

Close-up: Microscope & sensitivity needed

Measurement-Set up





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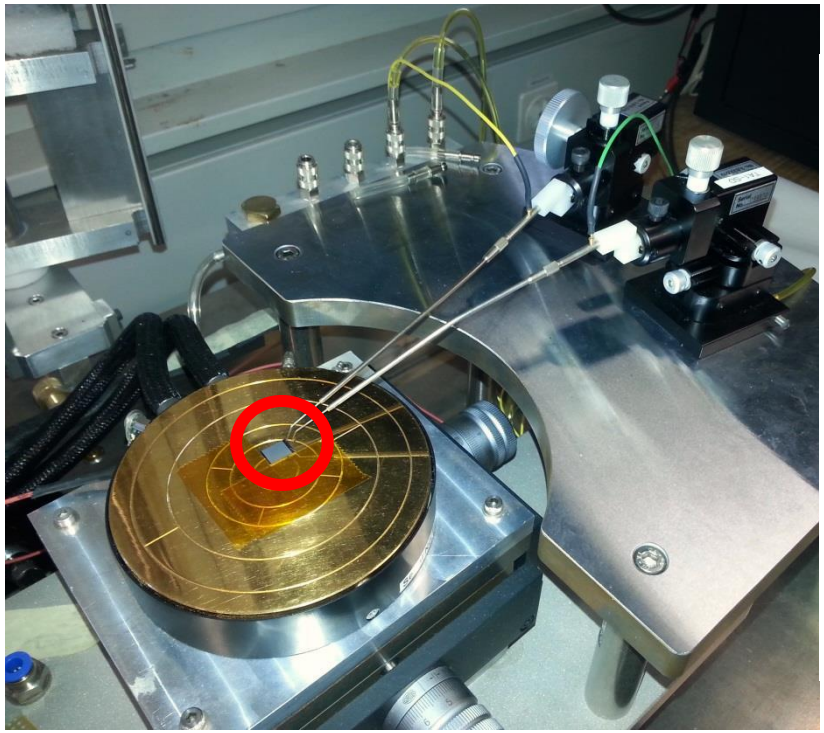
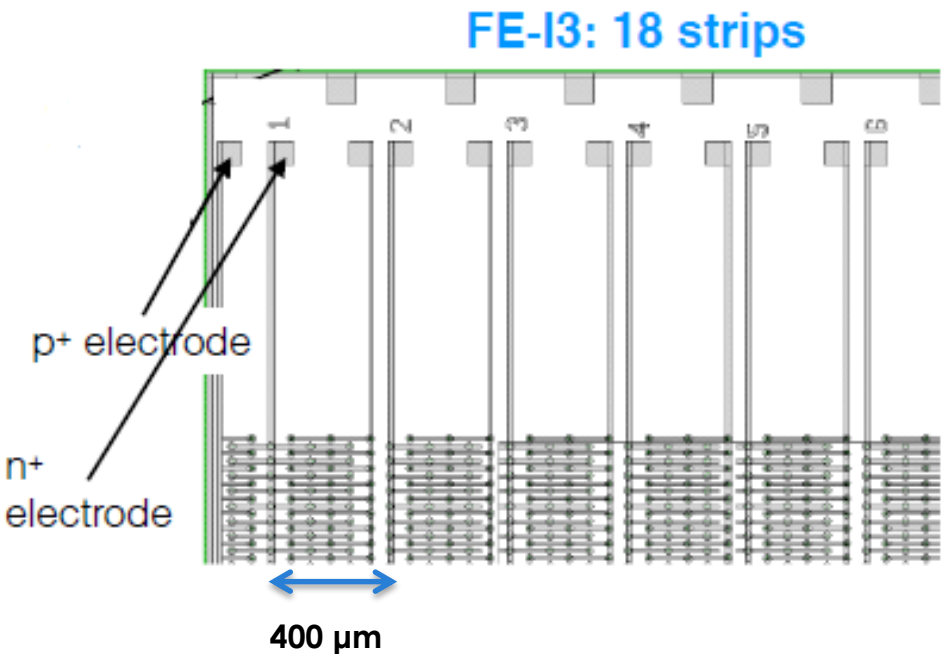


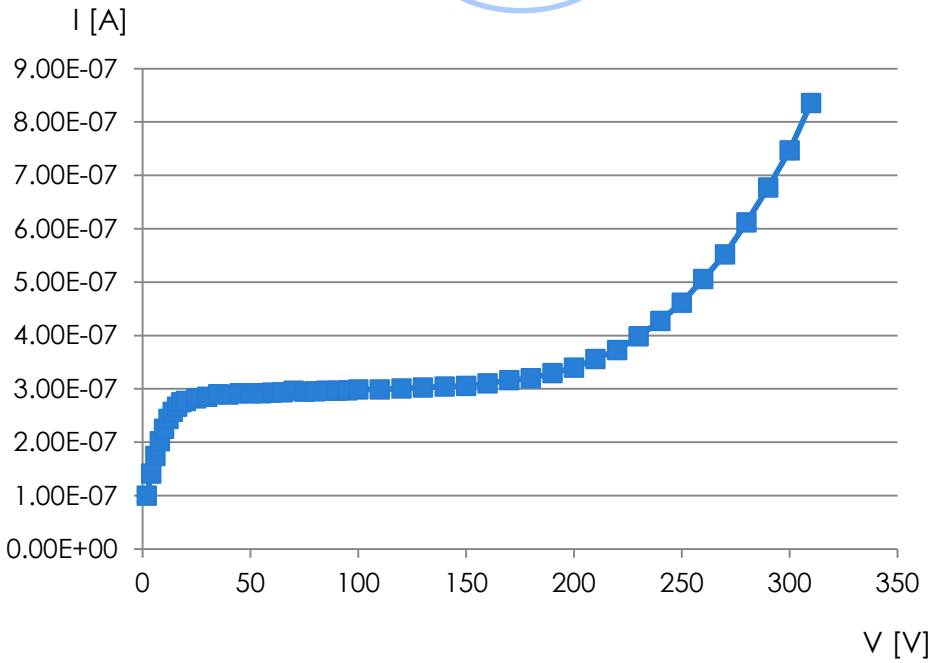


Connecting both needles is precision work.

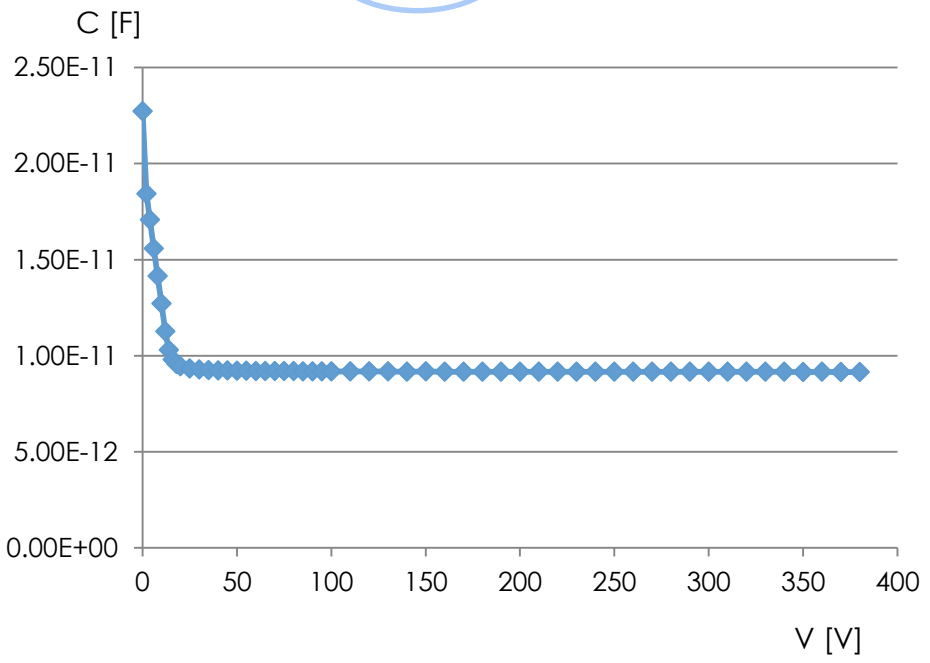
What are IV and CV measurements?

IV and CV theory

IV



CV



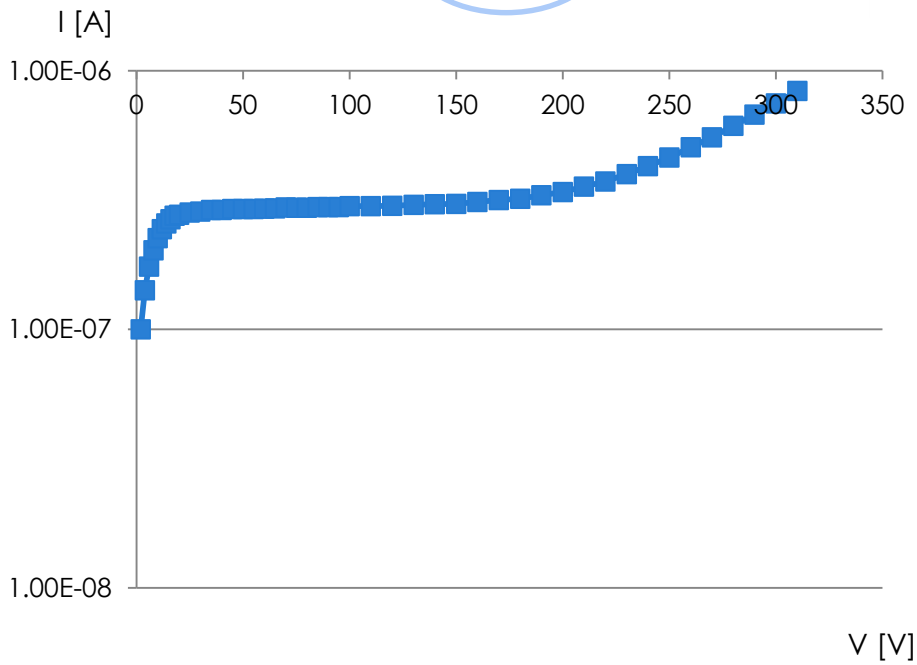
What are IV and CV measurements?

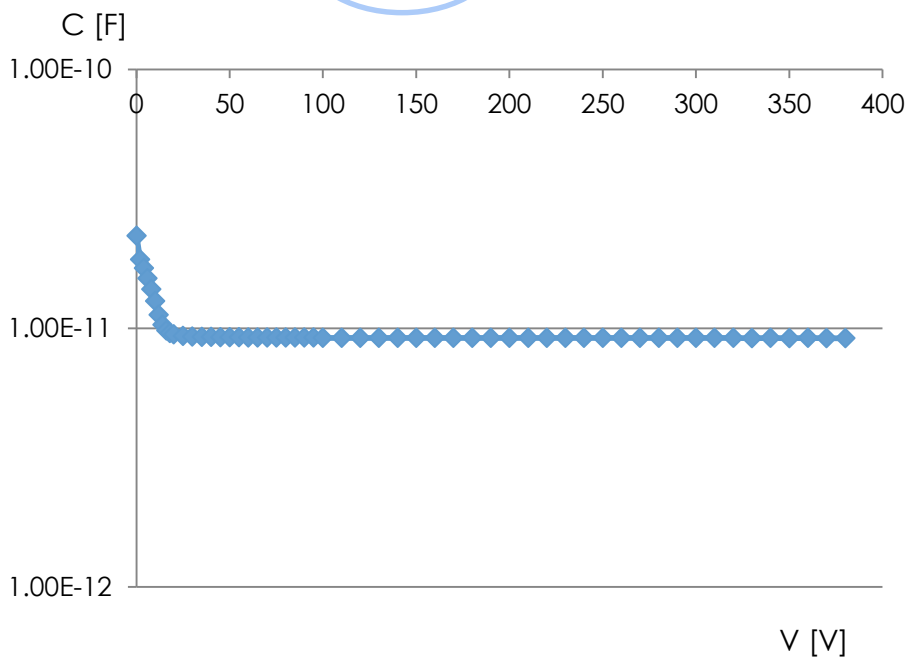
IV and CV theory

IV

log

CV

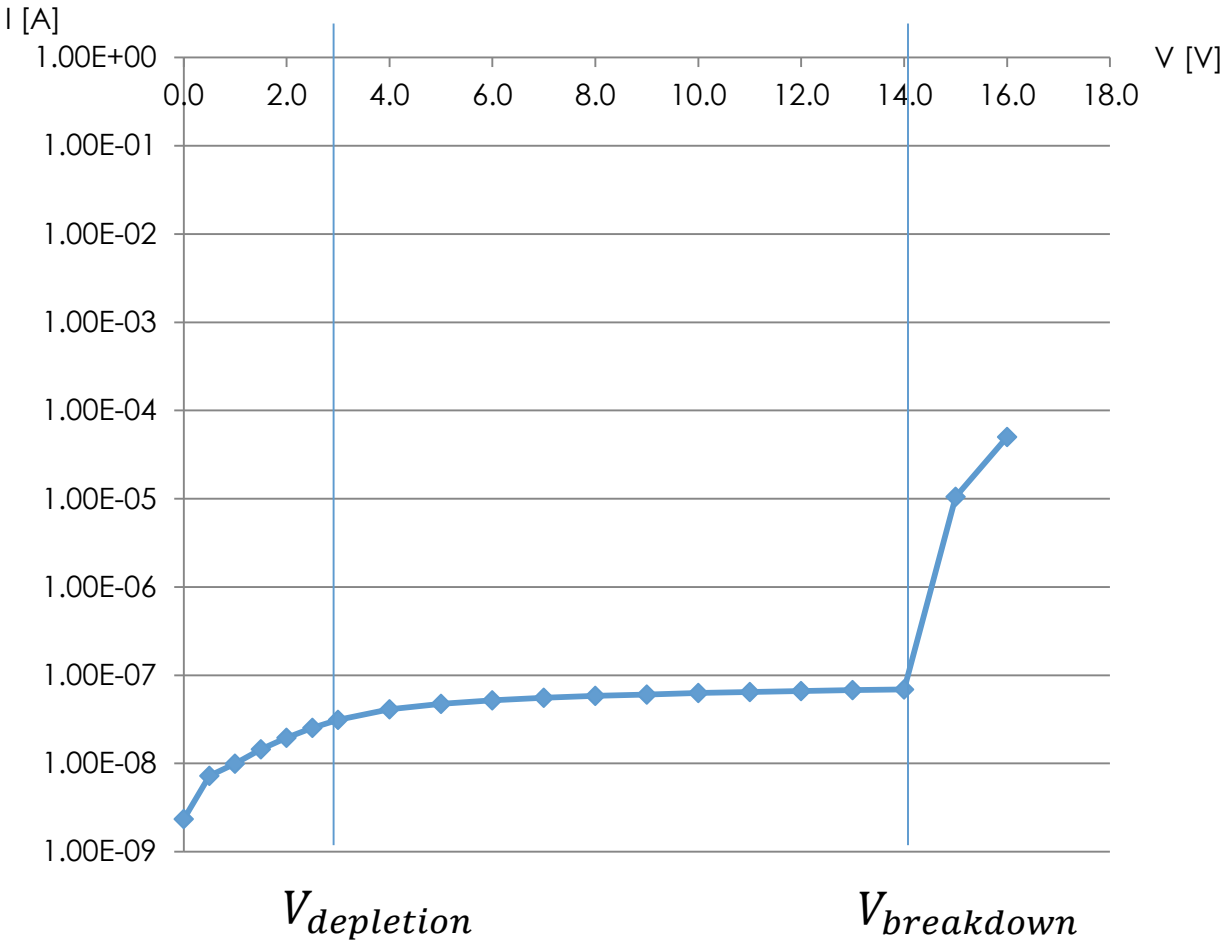




The depletion and breakdown voltages are important properties.

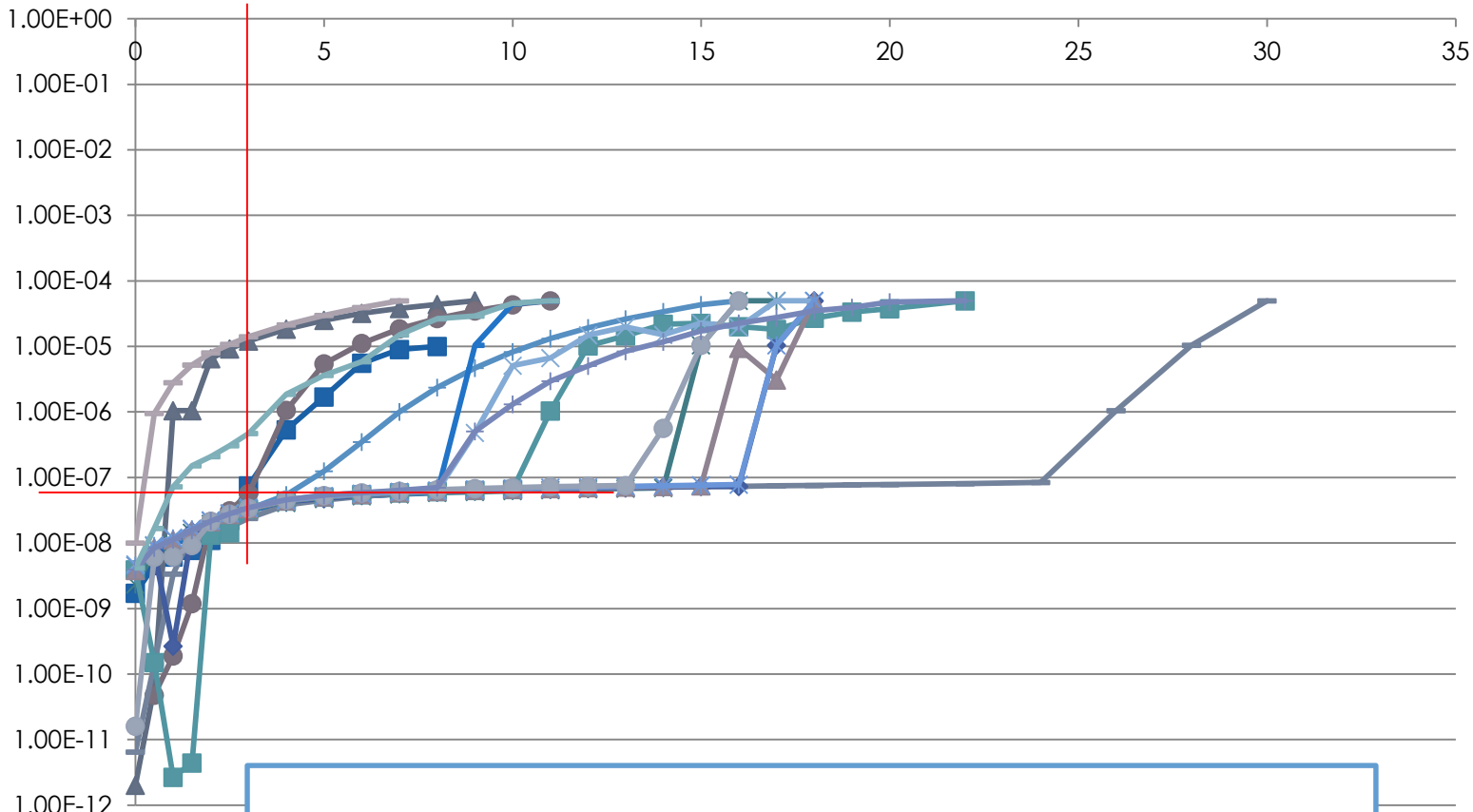
The 3D-IV result for one single strip

Measurement results



Overlapping strips create confusion

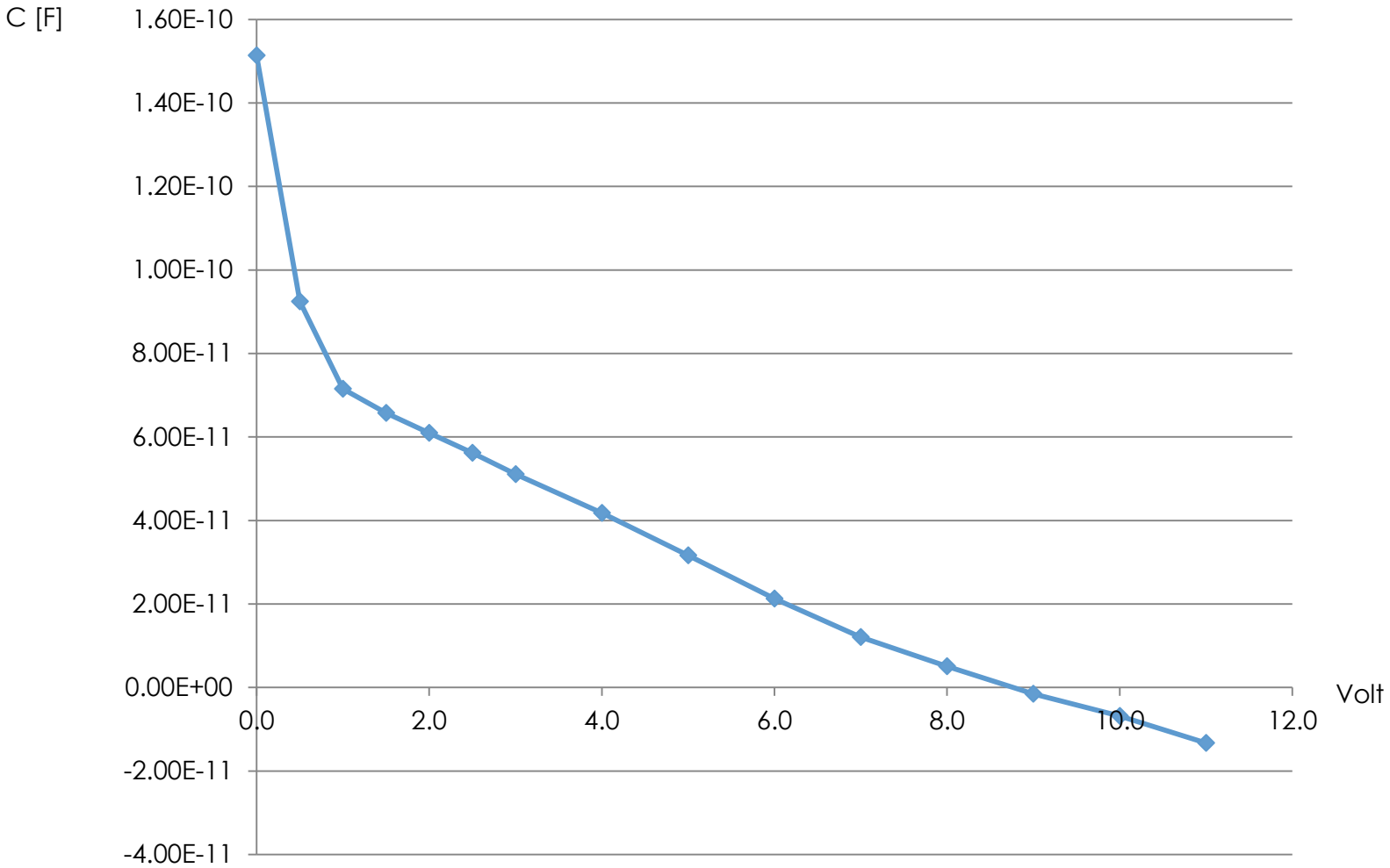
Measurement results



No uniformity makes it a rather bad sensor.

The 3D-CV result for one single strip

Measurement results



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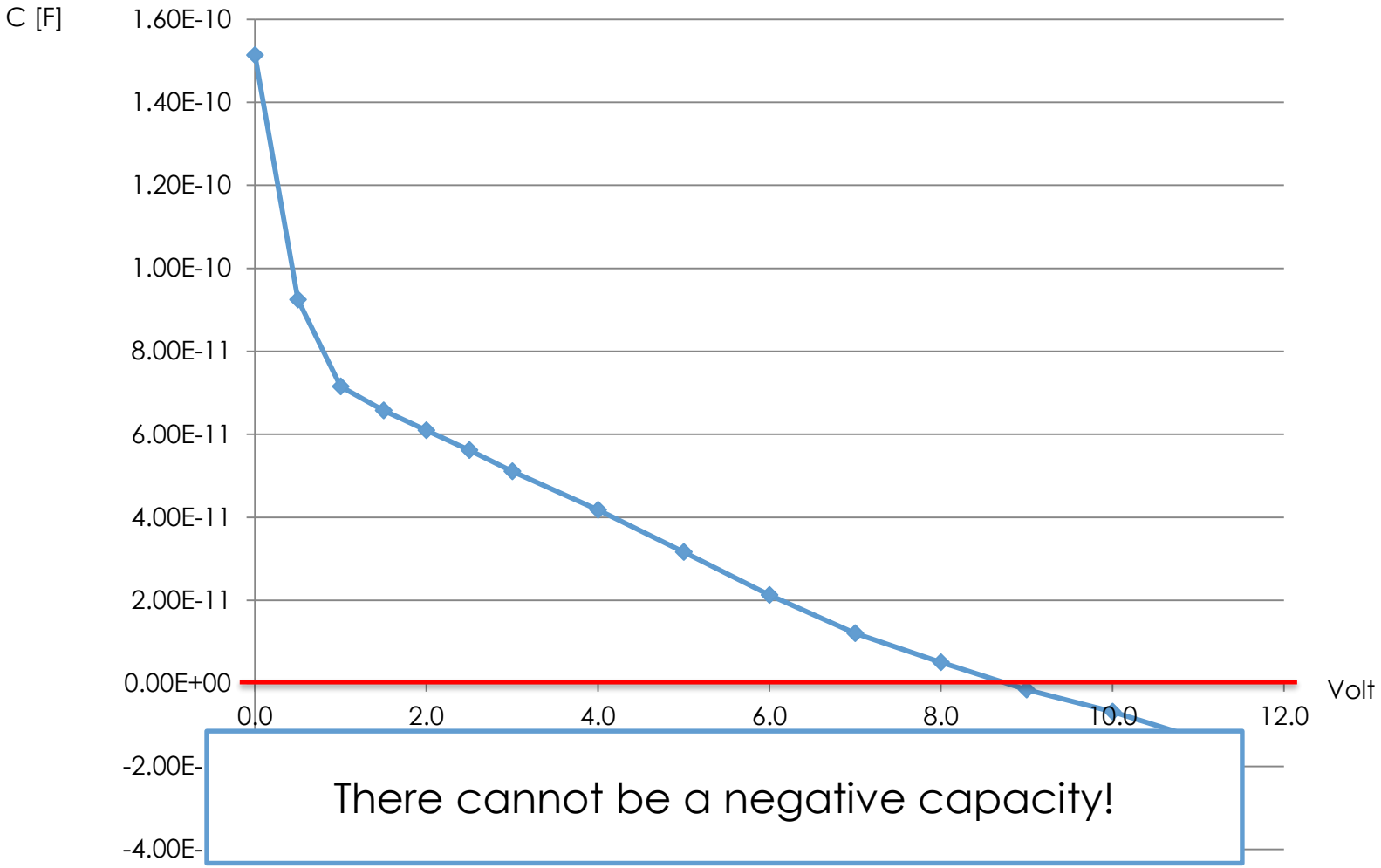

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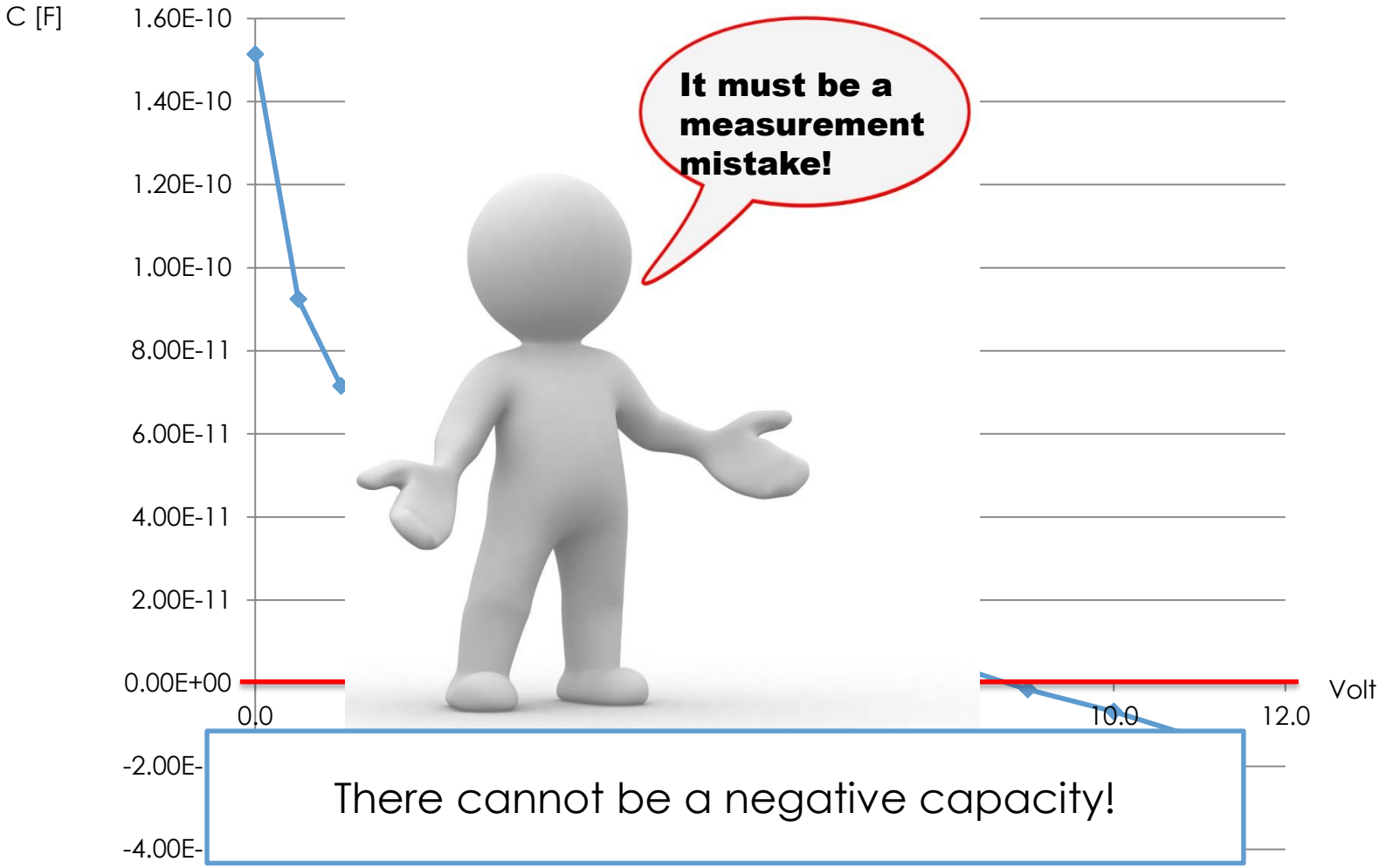


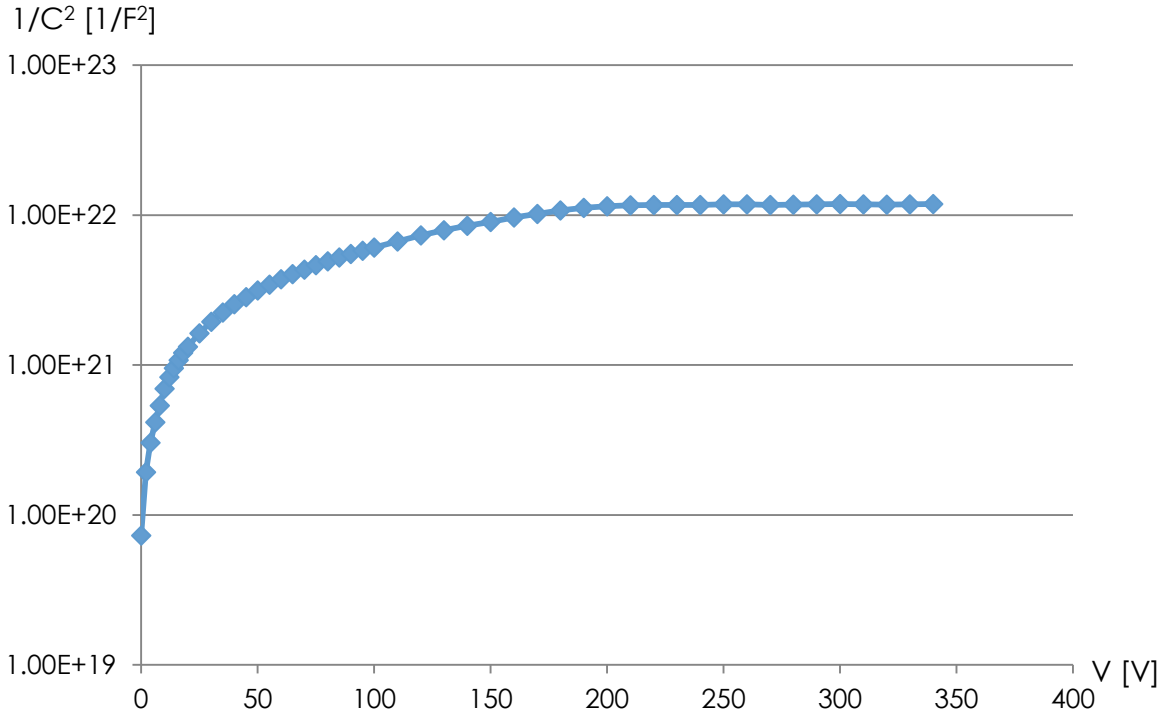
Capacitance and its use…

Measurement results

$$C = \frac{\varepsilon_0 \, \varepsilon_r \, S}{d}$$

$$w = \sqrt{\left(\frac{2\varepsilon_0 \varepsilon_{si}}{e|N_{eff}|} V\right)}$$

If $V = V_{depl}$ then $w = d$



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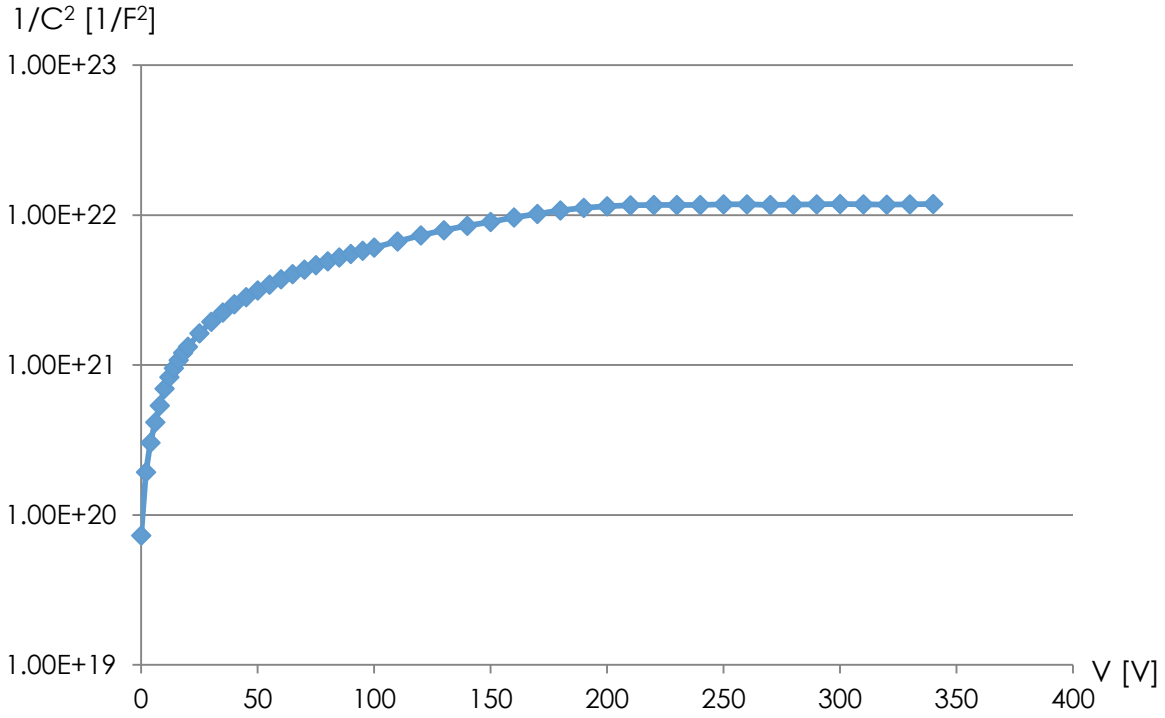
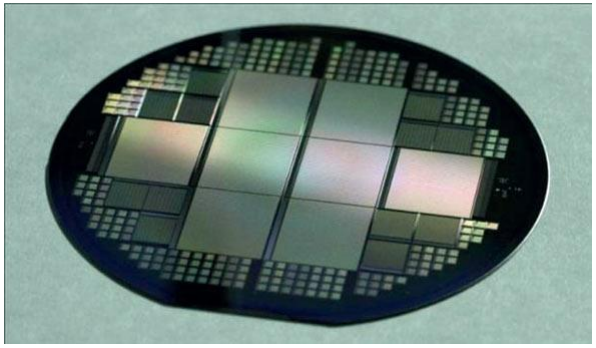


N_{eff} (effective doping concentration) can be obtained by the depletion voltage.

The dicing process changes the sensor

Measurement results



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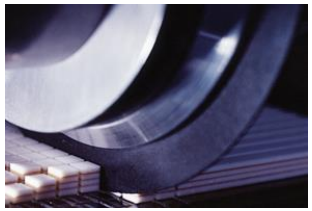

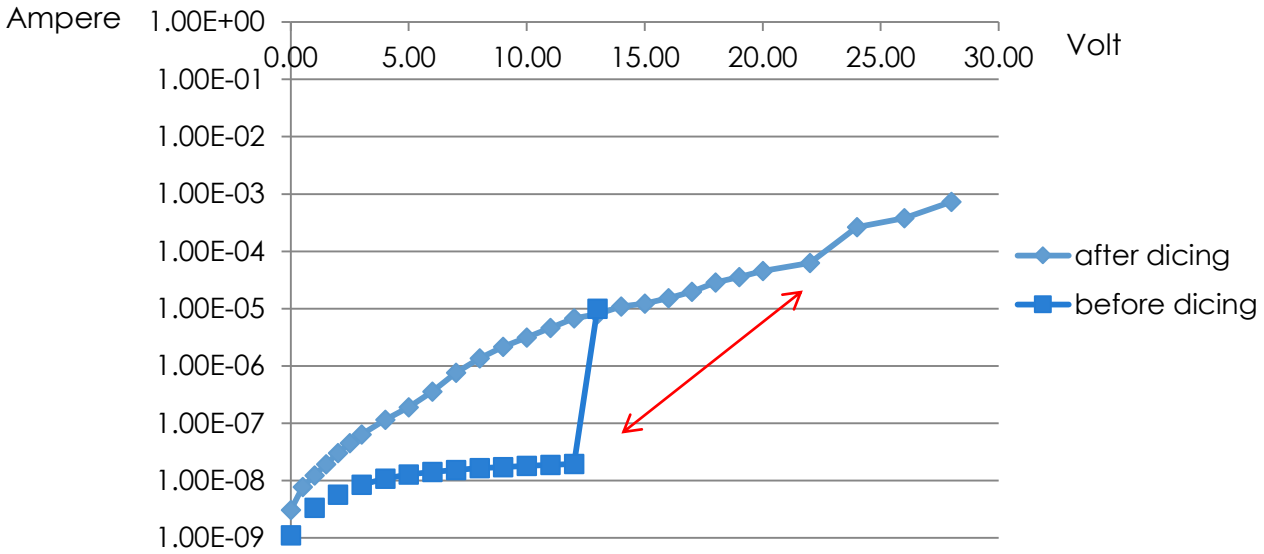

http://images.iop.org/objects/ccr/cern/52/5/17/CCsil4_05_12.jpg ; http://www.dicing.com/images/headerpsd_02.jpg 23.04.2015

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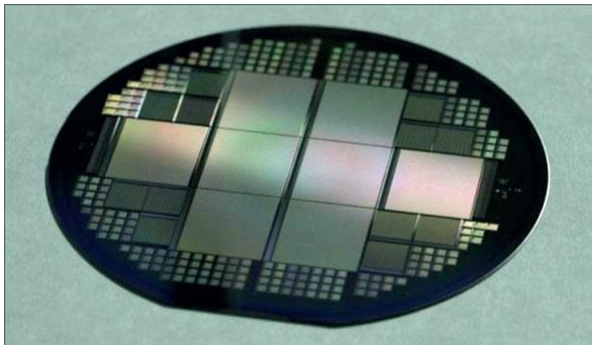

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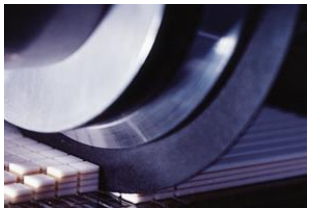
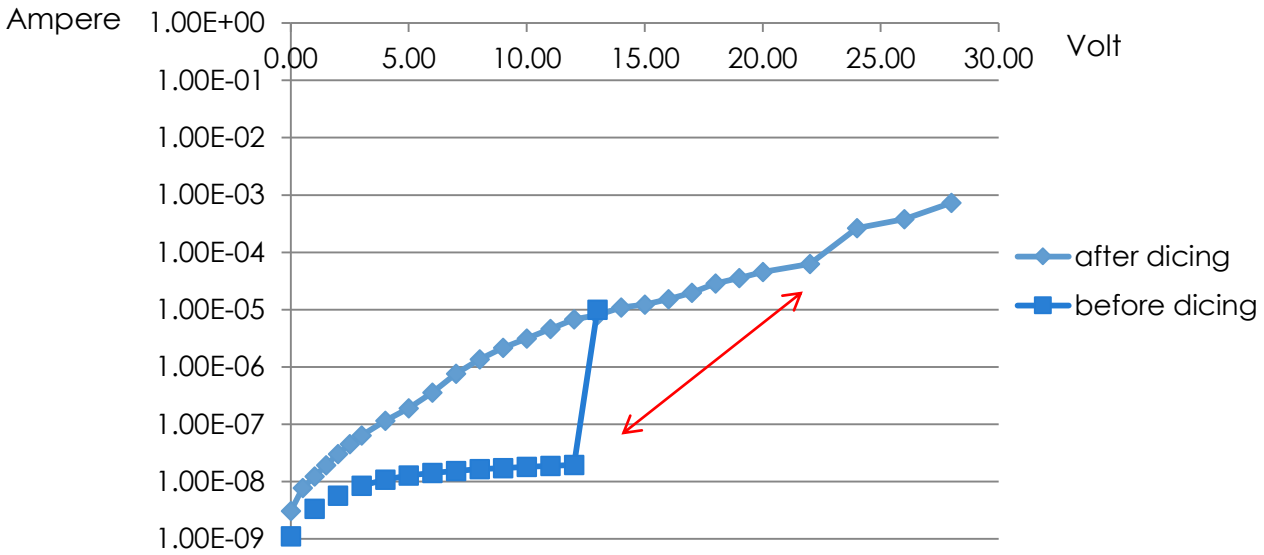




The mechanical process has changed the characteristics of the sensor.

http://images.iop.org/objects/ccr/cern/52/5/17/CCsil4_05_12.jpg ; http://www.dicing.com/images/headerpsd_02.jpg 23.04.2015

What's left to say
Review

Internship:

Warm atmosphere

CV/IV measurements
→ Slightly monotone

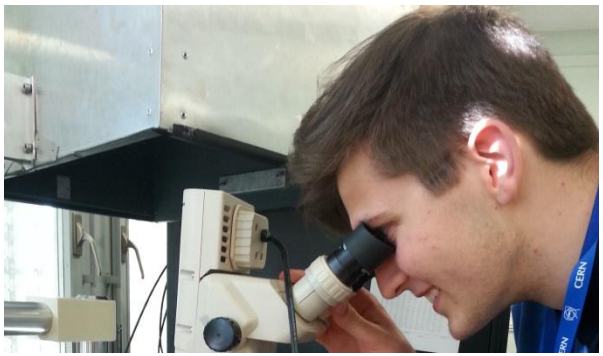
Interest working field

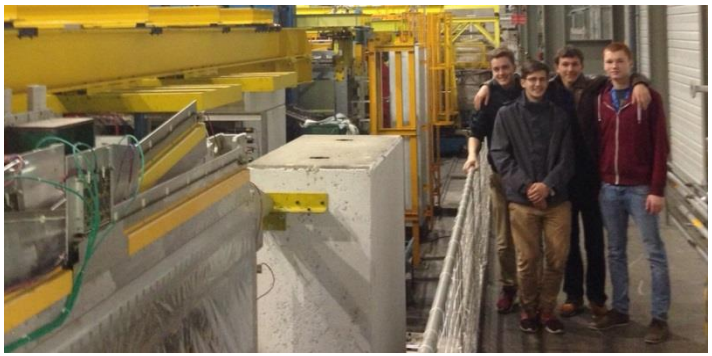
Visits:

Right number

Interesting tours

Good view into CERN





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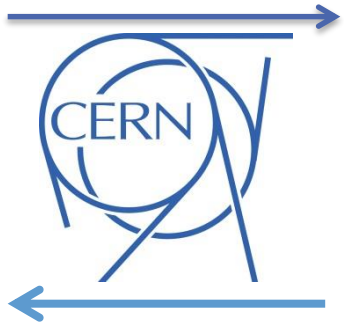

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A special thanks to the SSD-Team incl. Christian
Laura Franconi for the CV/IV measurements &
Sascha Schmeling for making everything possible