

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

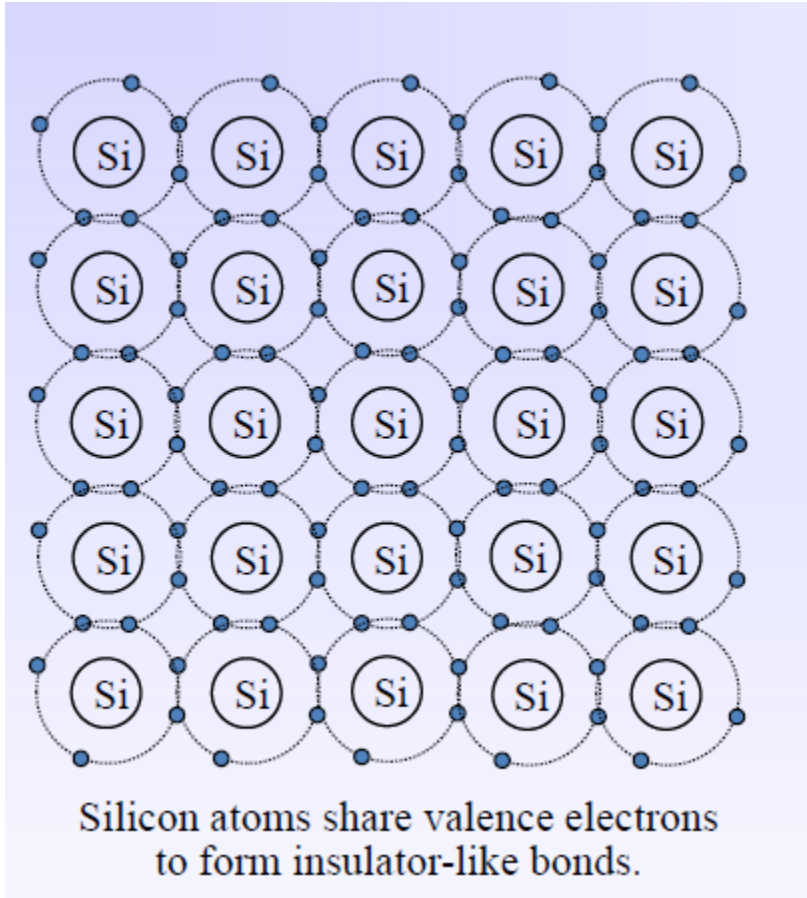




- **Silicon sensors**– The physics behind it
- **IV and CV** – The theoretical, ideal curve
- **My measurements** – The Setup
- **My results** – The experimental reality
- **Review on the internship** – What's left to say

The chemistry behind a semiconductor...

Silicon sensors



Hauptgruppen

	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

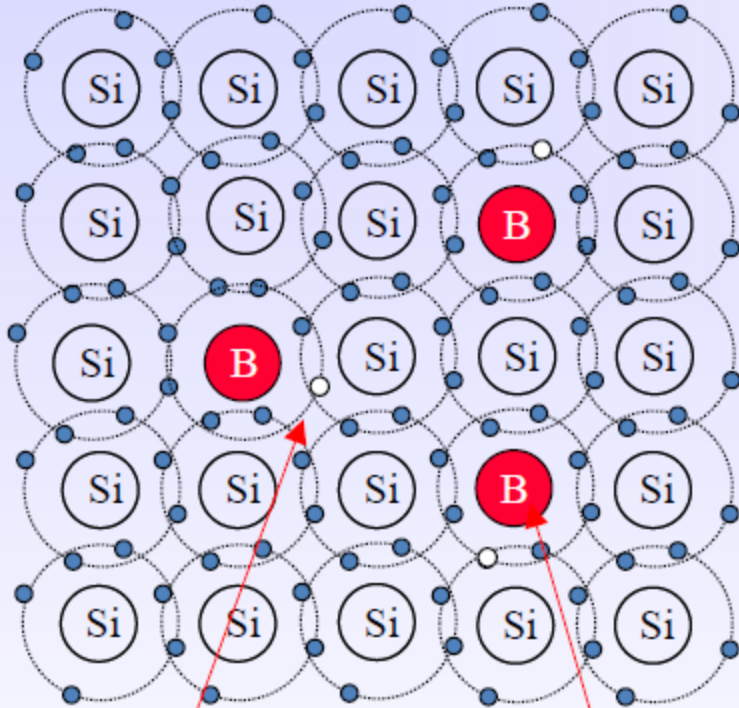
Periode

The chemistry behind a semiconductor...

Silicon sensors



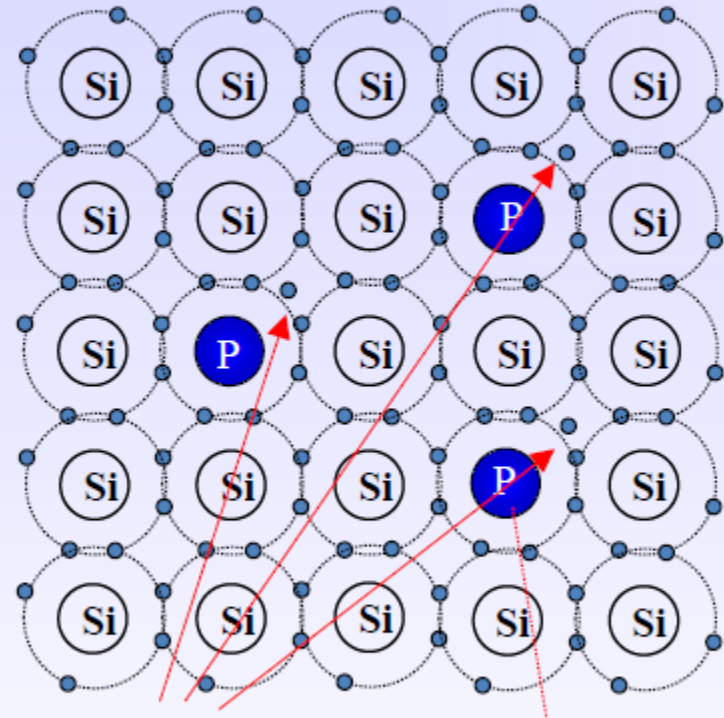
Acceptor atoms provide a deficiency of electrons to form p-type silicon.



+ Hole

Boron atom serves as p-type dopant

Donor atoms provide excess electrons to form n-type silicon.



Excess electron (-)

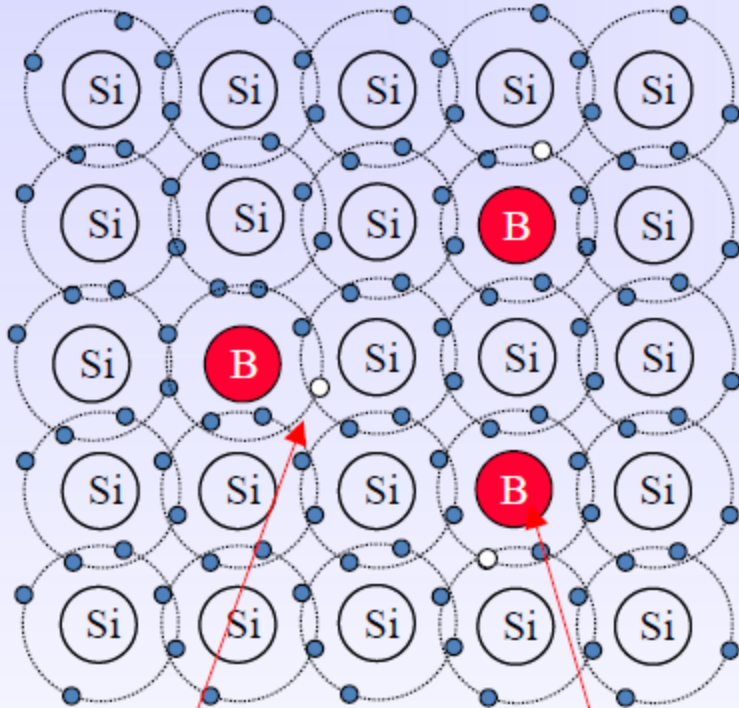
Phosphorus atom serves as n-type dopant

The chemistry behind a semiconductor...

Silicon sensors

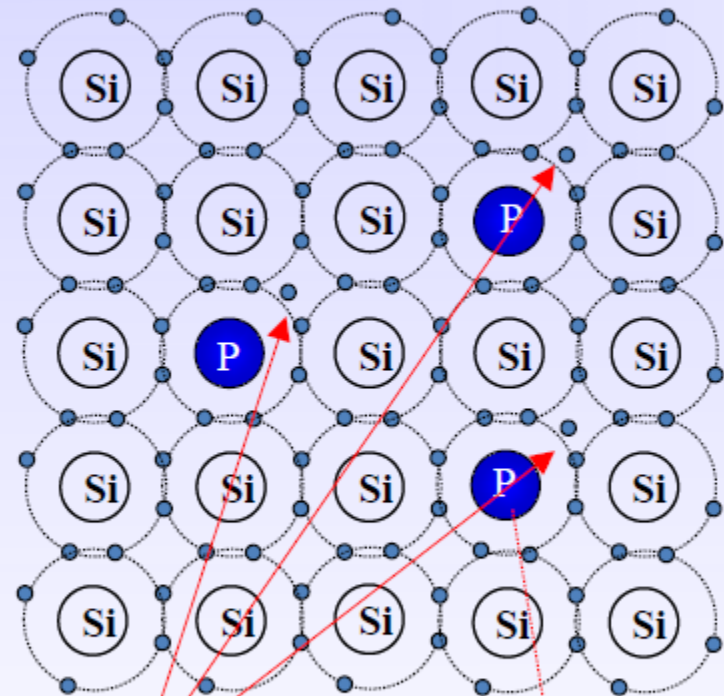


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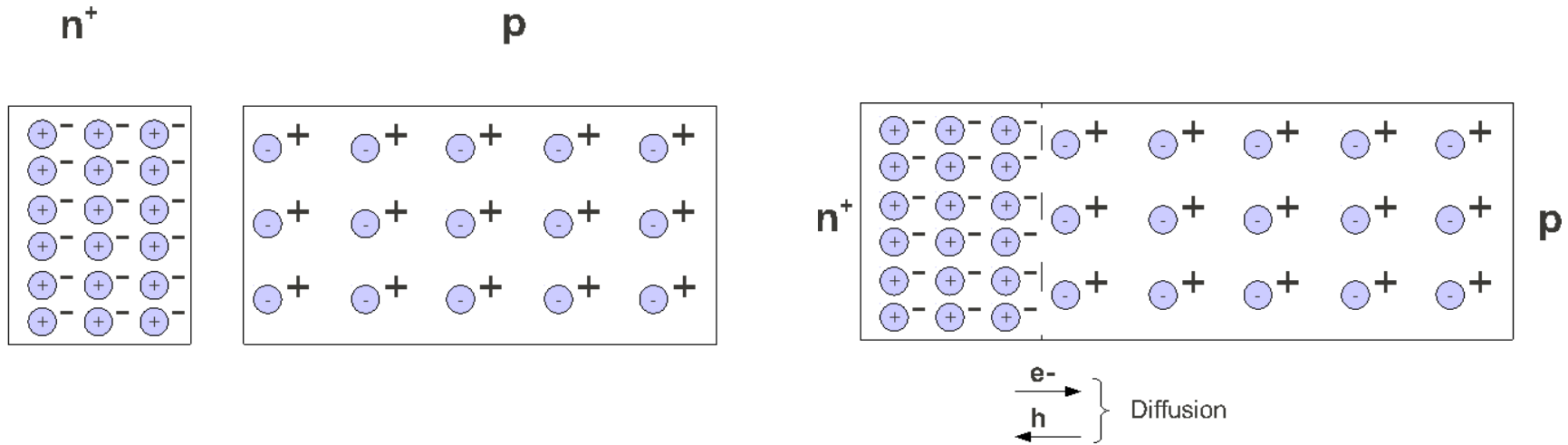


We can dope the Si negatively or quasi positively.

phorus atom
es as n-type
nt

The 2D physics behind a semiconductor...

Silicon sensors



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

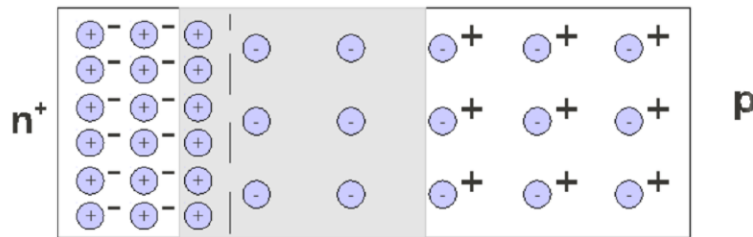
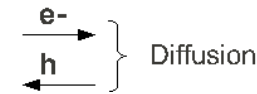
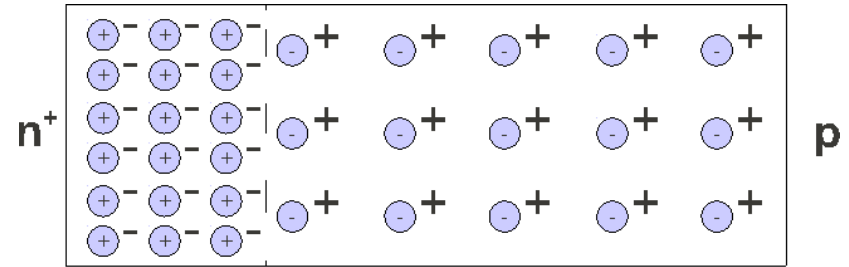
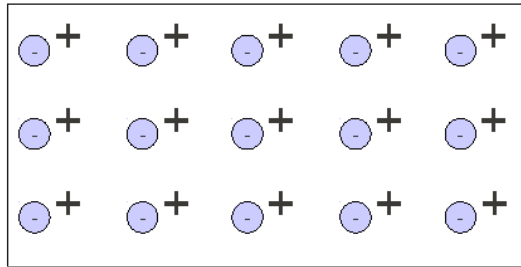
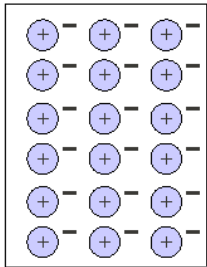
The 2D physics behind a semiconductor...

Silicon sensors

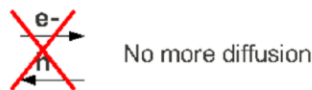


n^+

p



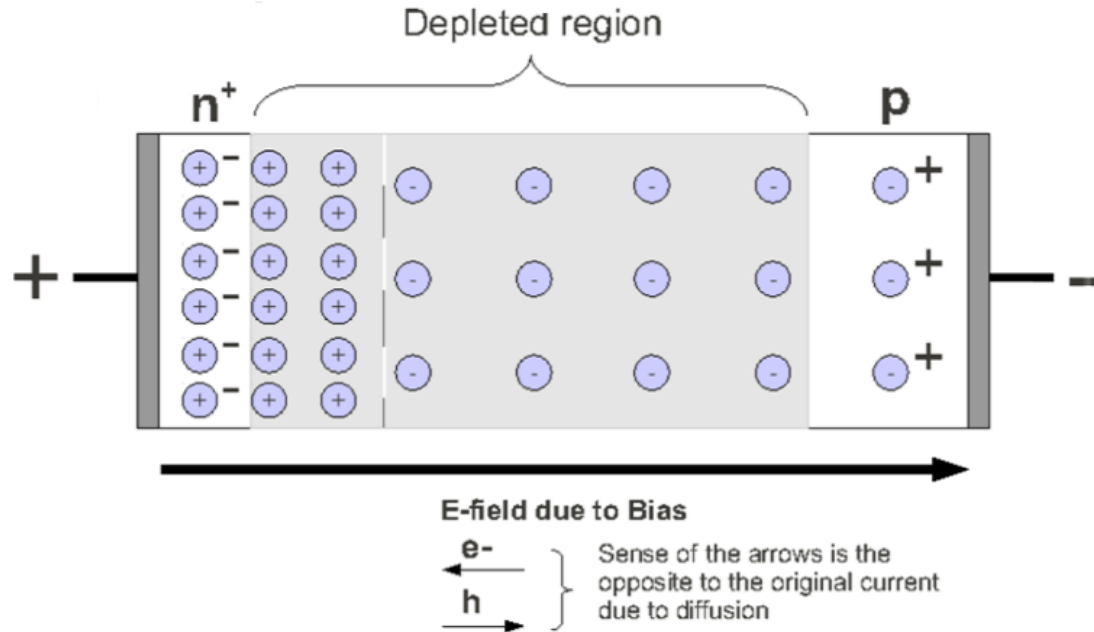
E-field due to ions



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...

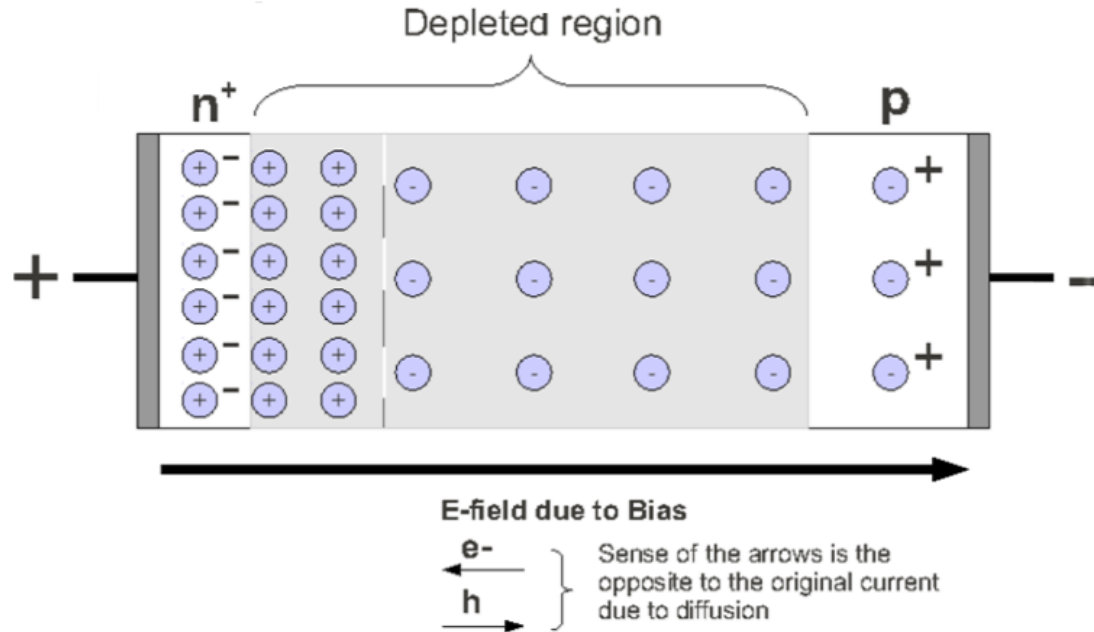
Silicon sensors



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

The 2D physics behind a semiconductor...

Silicon sensors



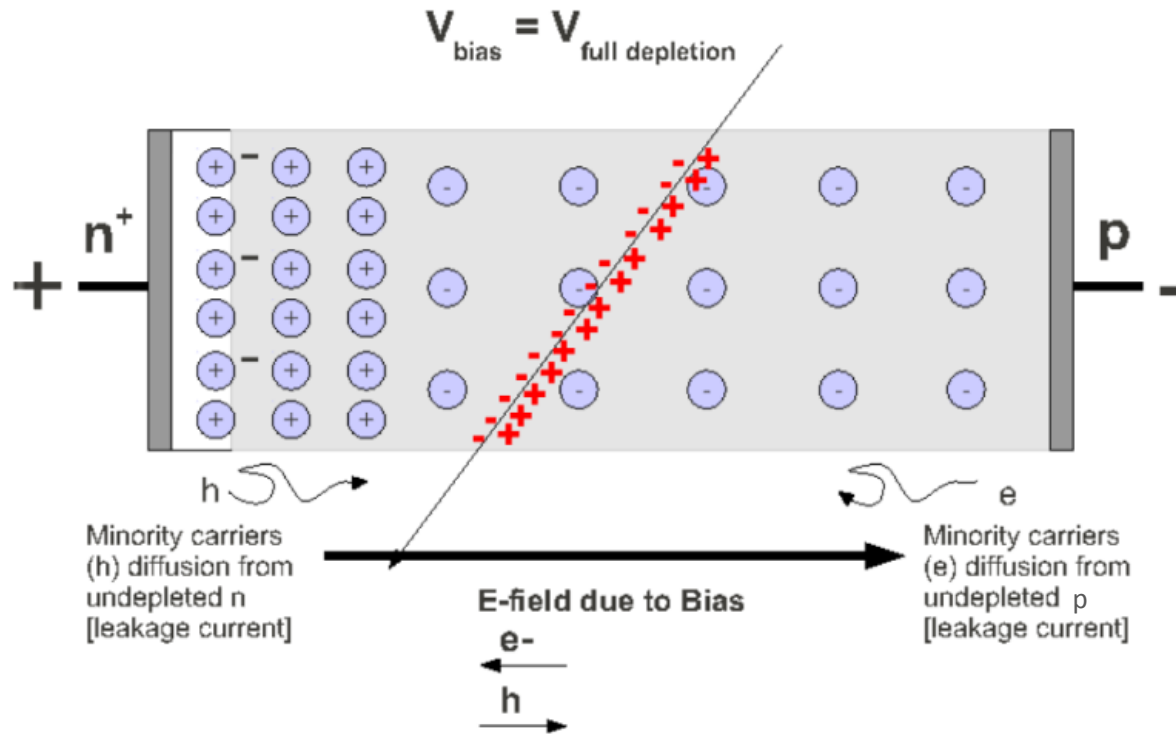
By applying a voltage we can increase the E-field and thus increase the width of the depletion to a fixed maximum.

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

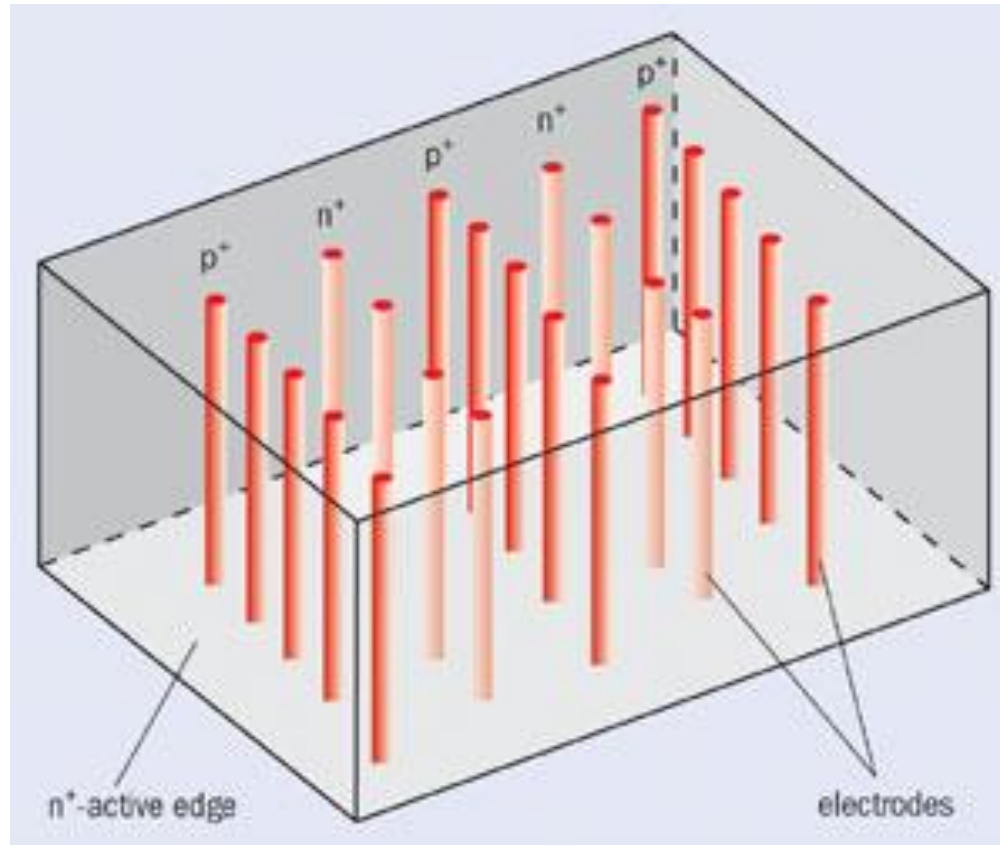


An ionising particle that passes the silicon sensor can be detected by the current it creates.

The aim is to keep the leakage current low.

The 3D visualisation

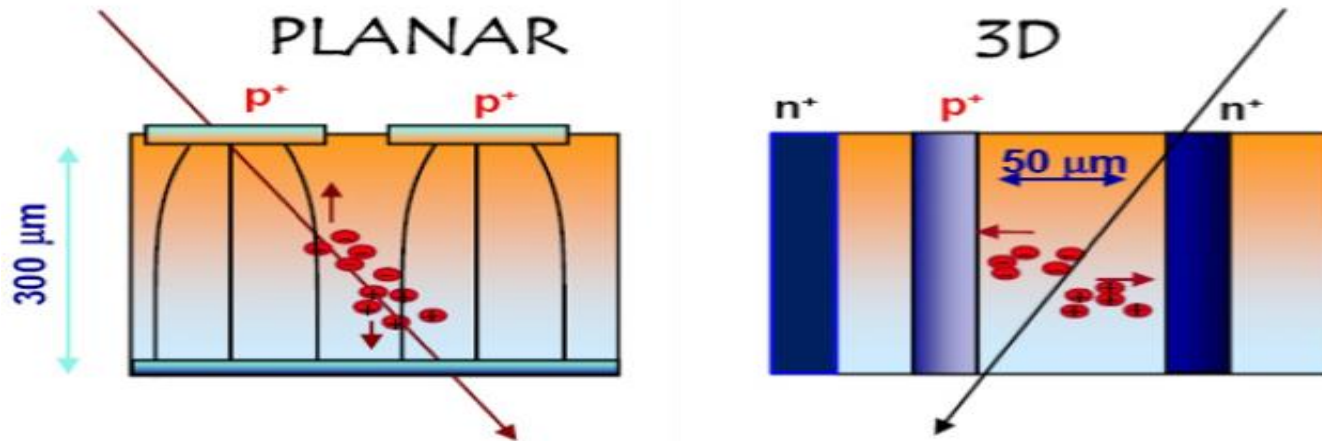
Silicon sensors



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

What dimension should it be?

Silicon sensors



3Ds offer a faster charge collection

Smaller depletion voltage

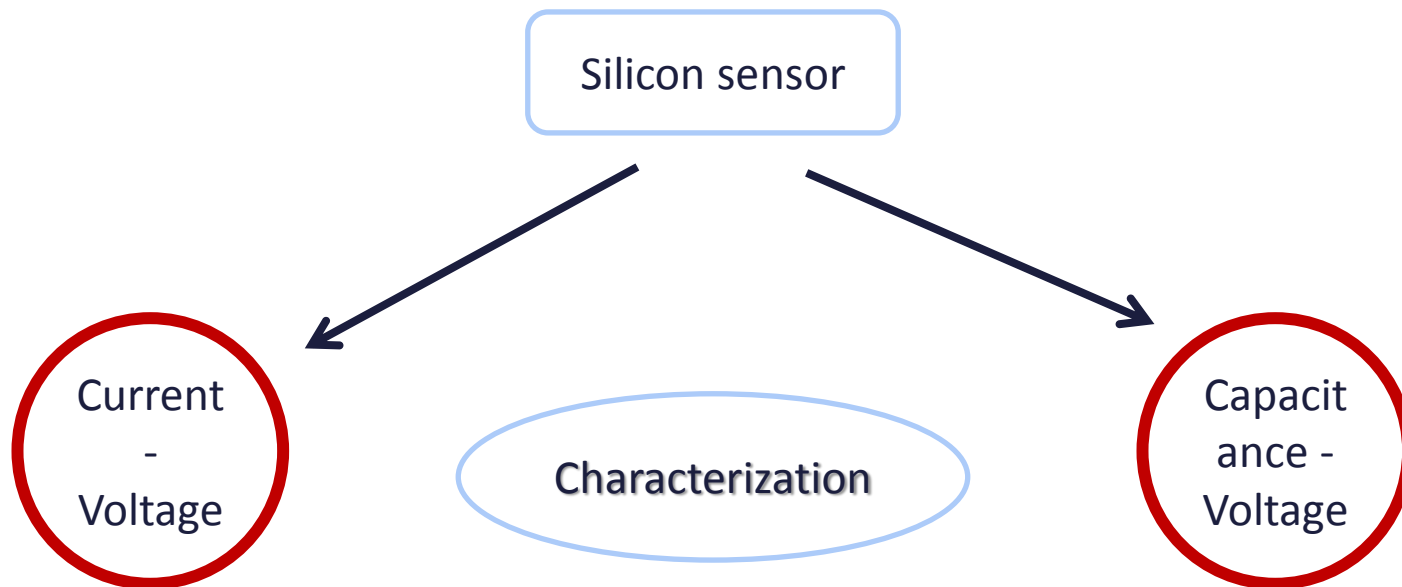
& are radiation harder

BUT planar technology is the more consolidated

Both sensors show reasonable advantages.

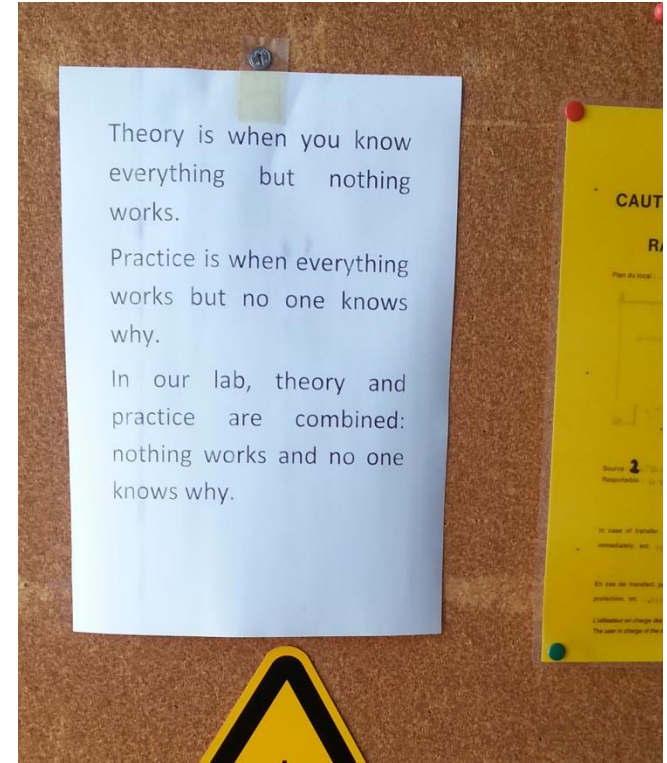
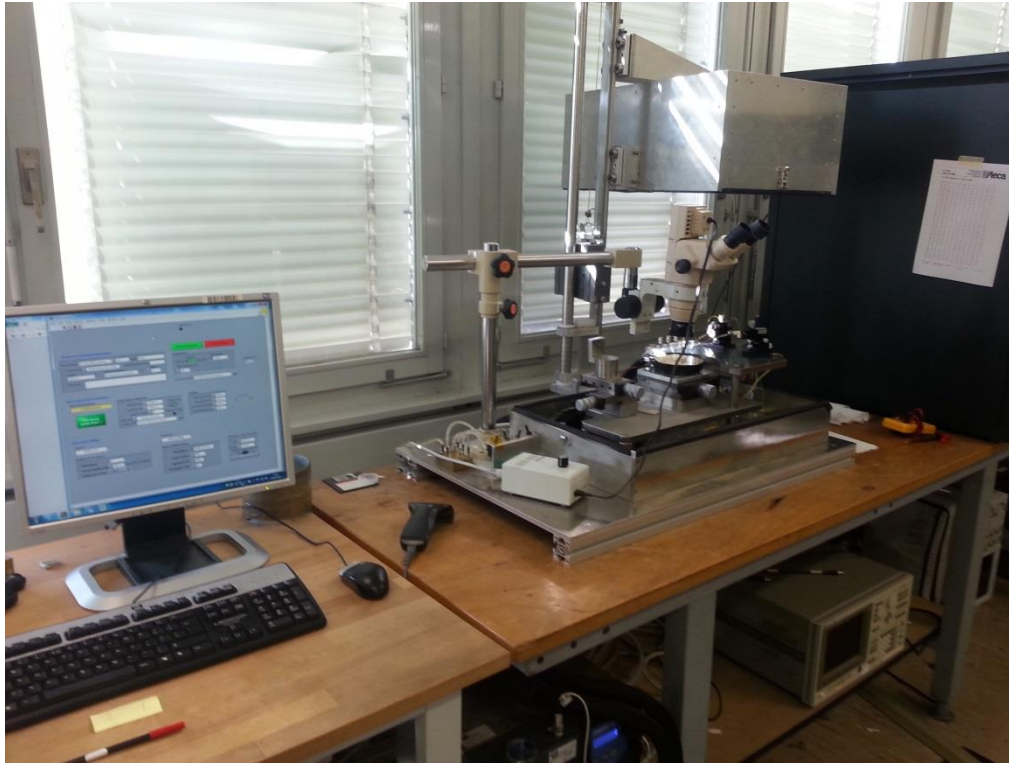
What are IV and CV measurements?

IV and CV theory



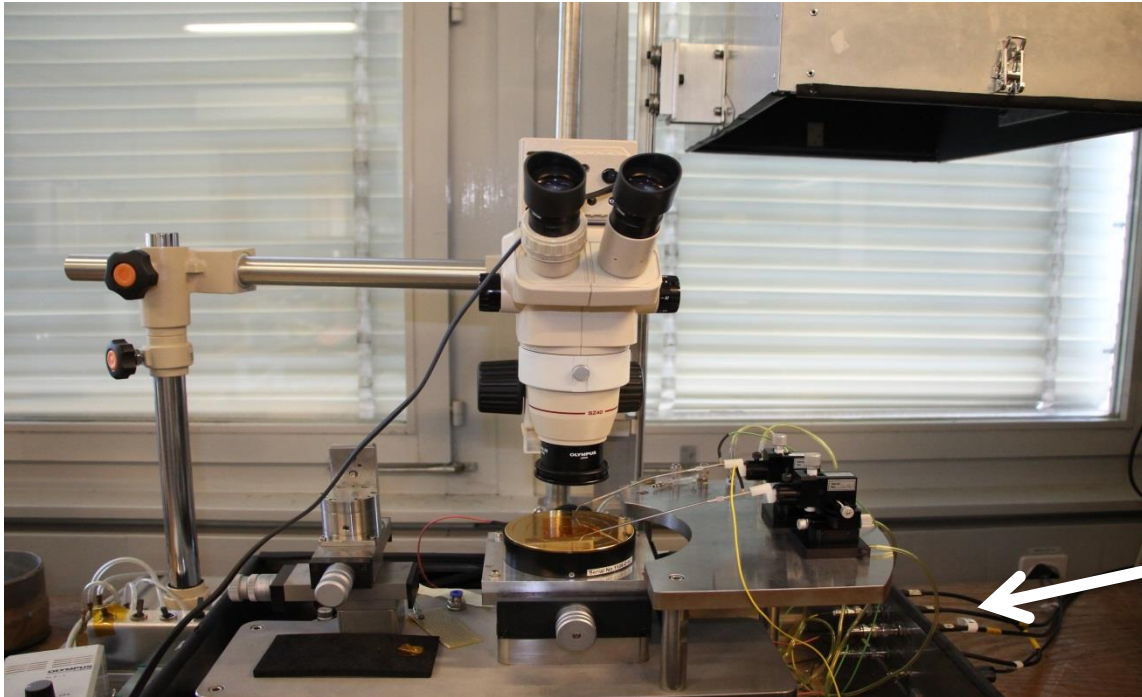
The lab: My place to be

Measurement-Set up



The lab: My place to be

Measurement-Set up



We apply a voltage and measure I or C.

Introduction

Silicon sensors

Measurement Setup

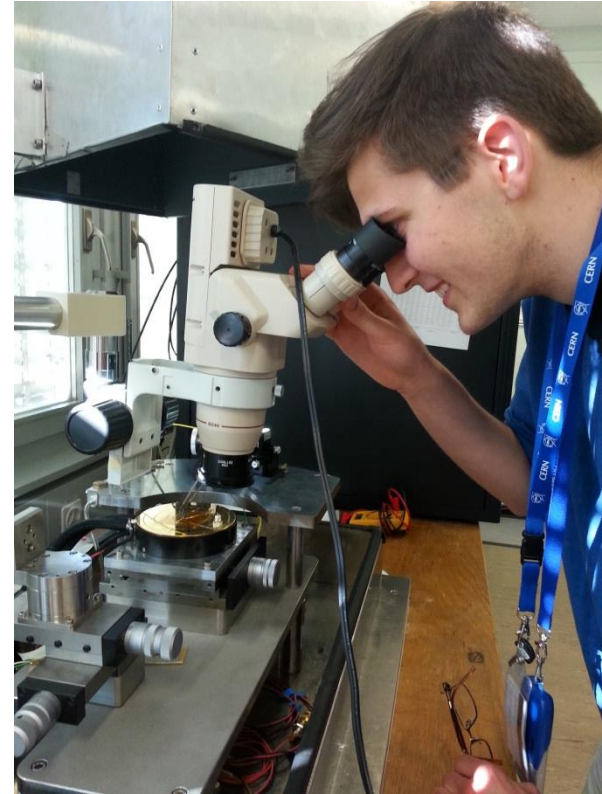
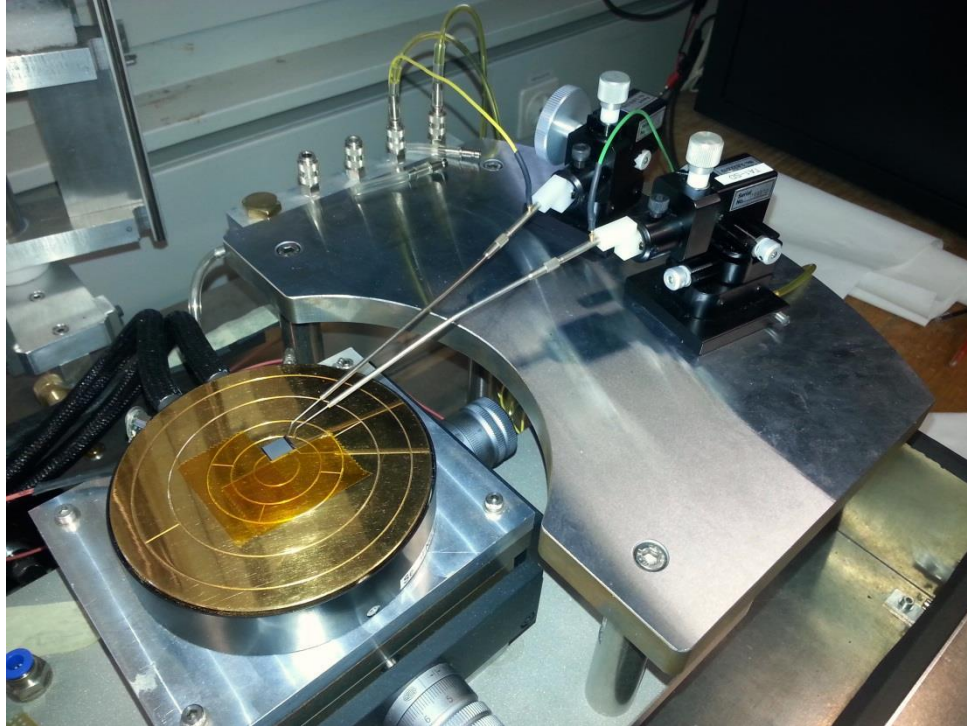
IV and CV theory

Measurement results

Review

Close-up: Microscope & sensitivity needed

Measurement-Set up



Introduction

Silicon sensors

Measurement Setup

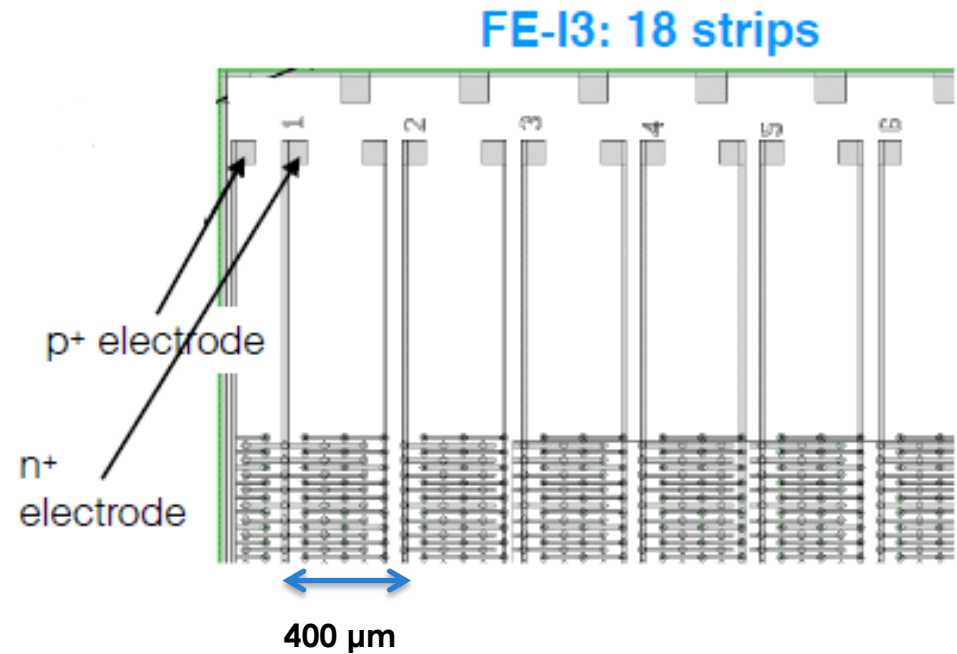
IV and CV theory

Measurement results

Review

Close-up: Microscope & sensitivity needed

Measurement-Set up



Connecting both needles is precision work.

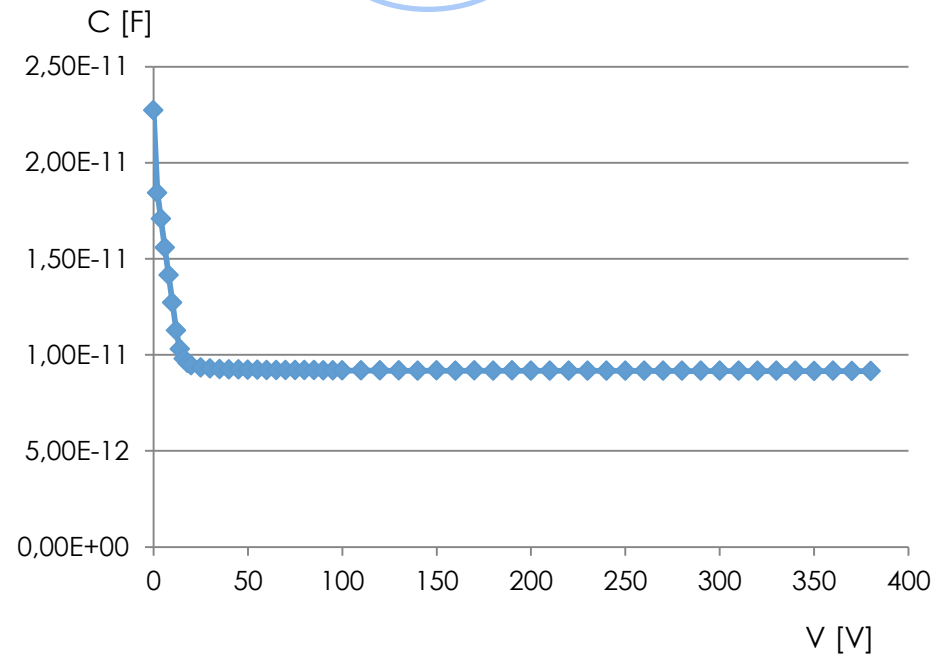
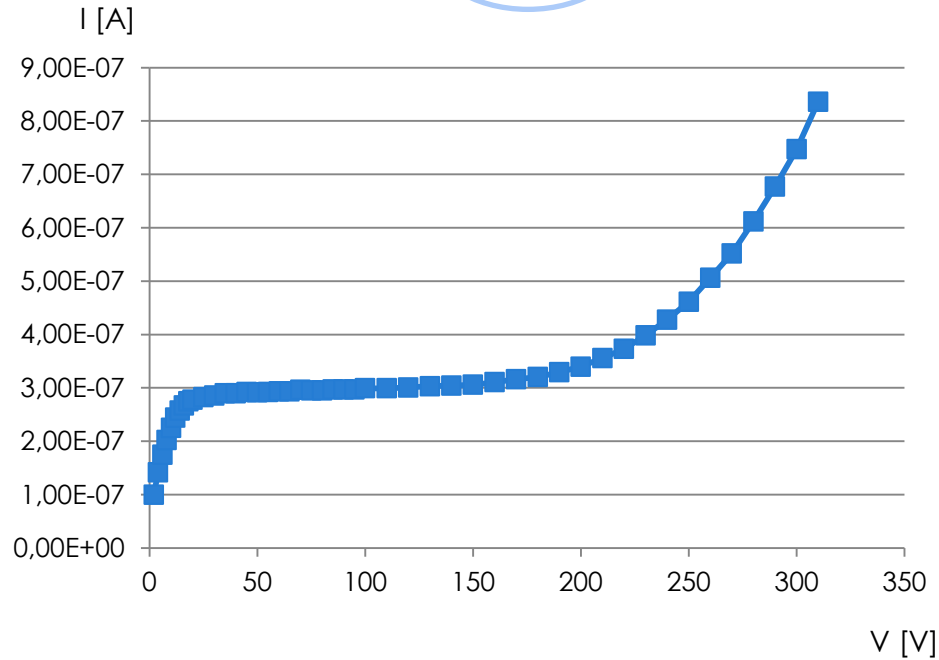
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IV and CV theory



IV

CV



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Silicon sensors

Measurement Setup

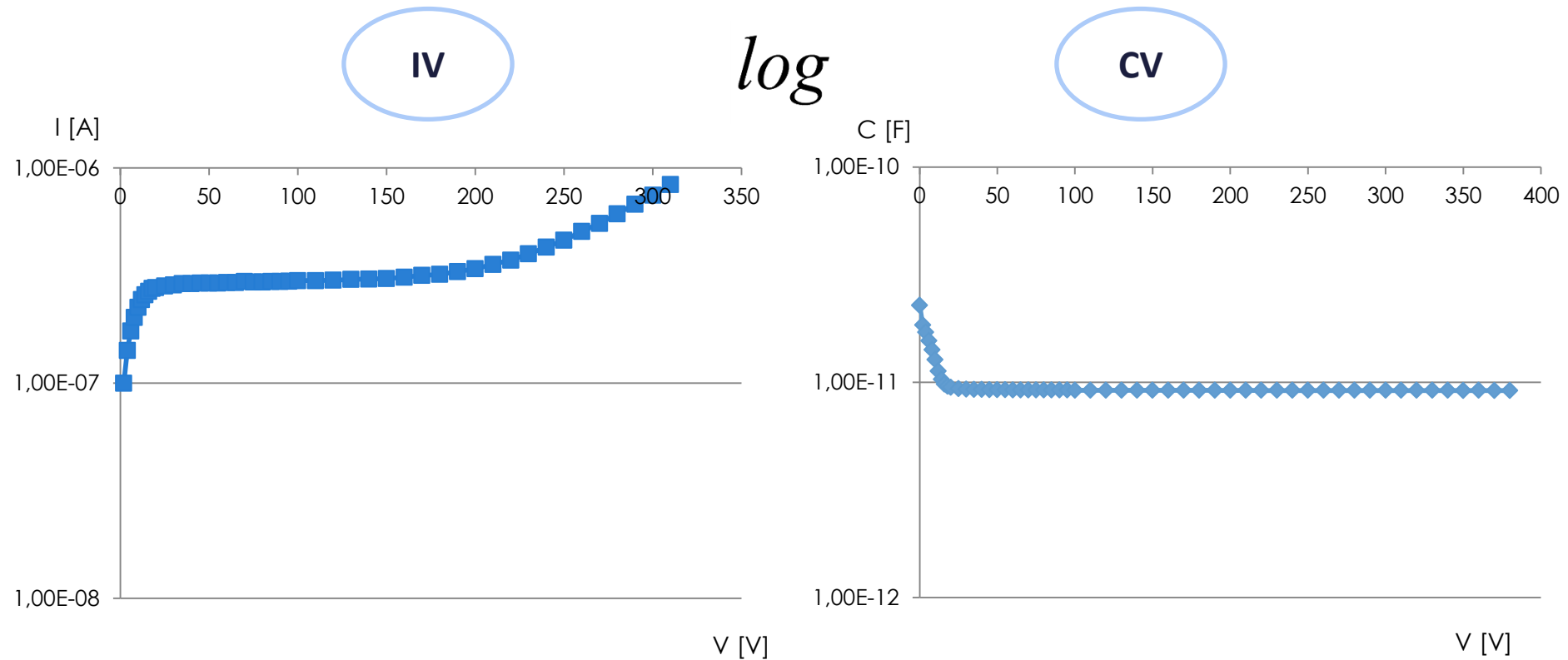
IV and CV theory

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What are IV and CV measurements?

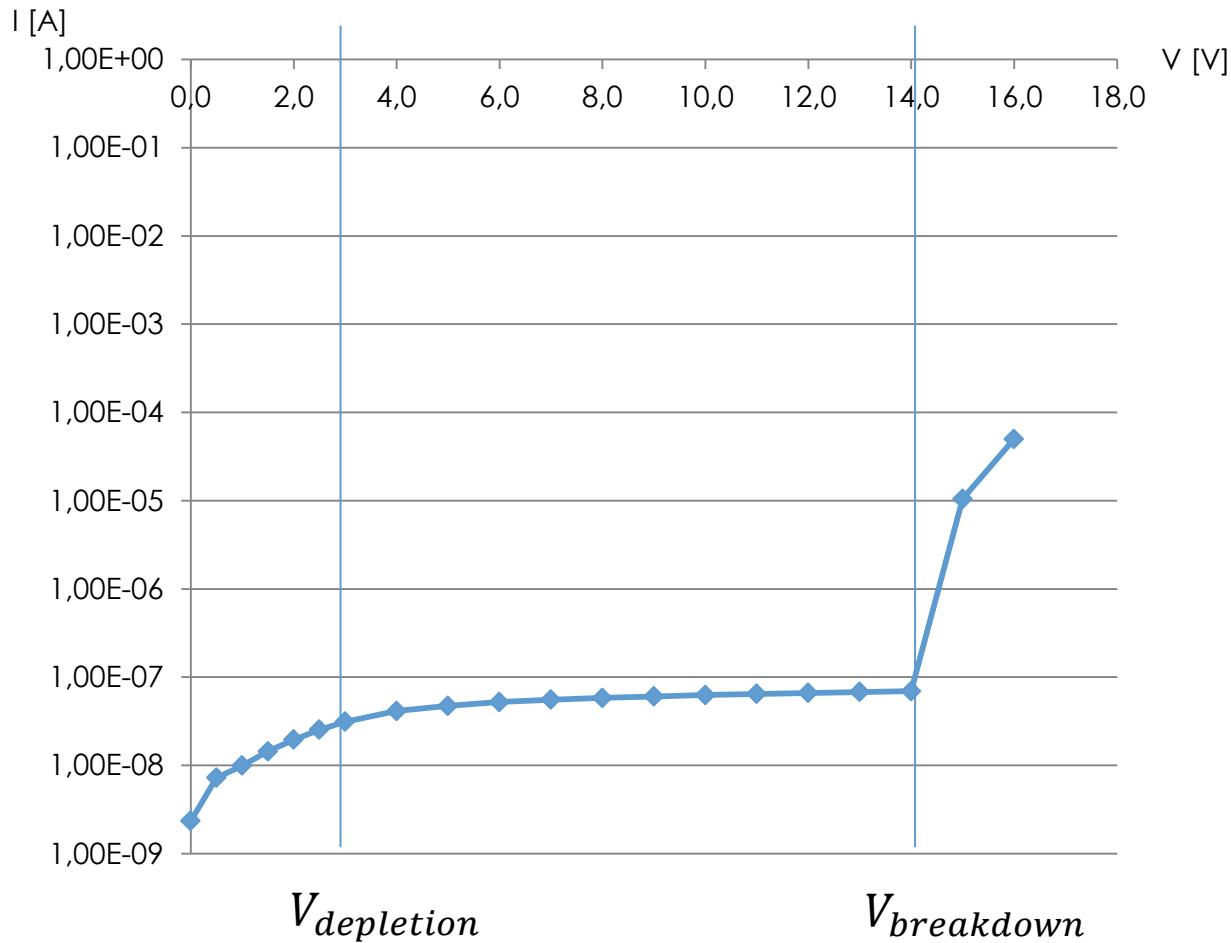
IV and CV theory



The depletion and breakdown voltages are important properties.

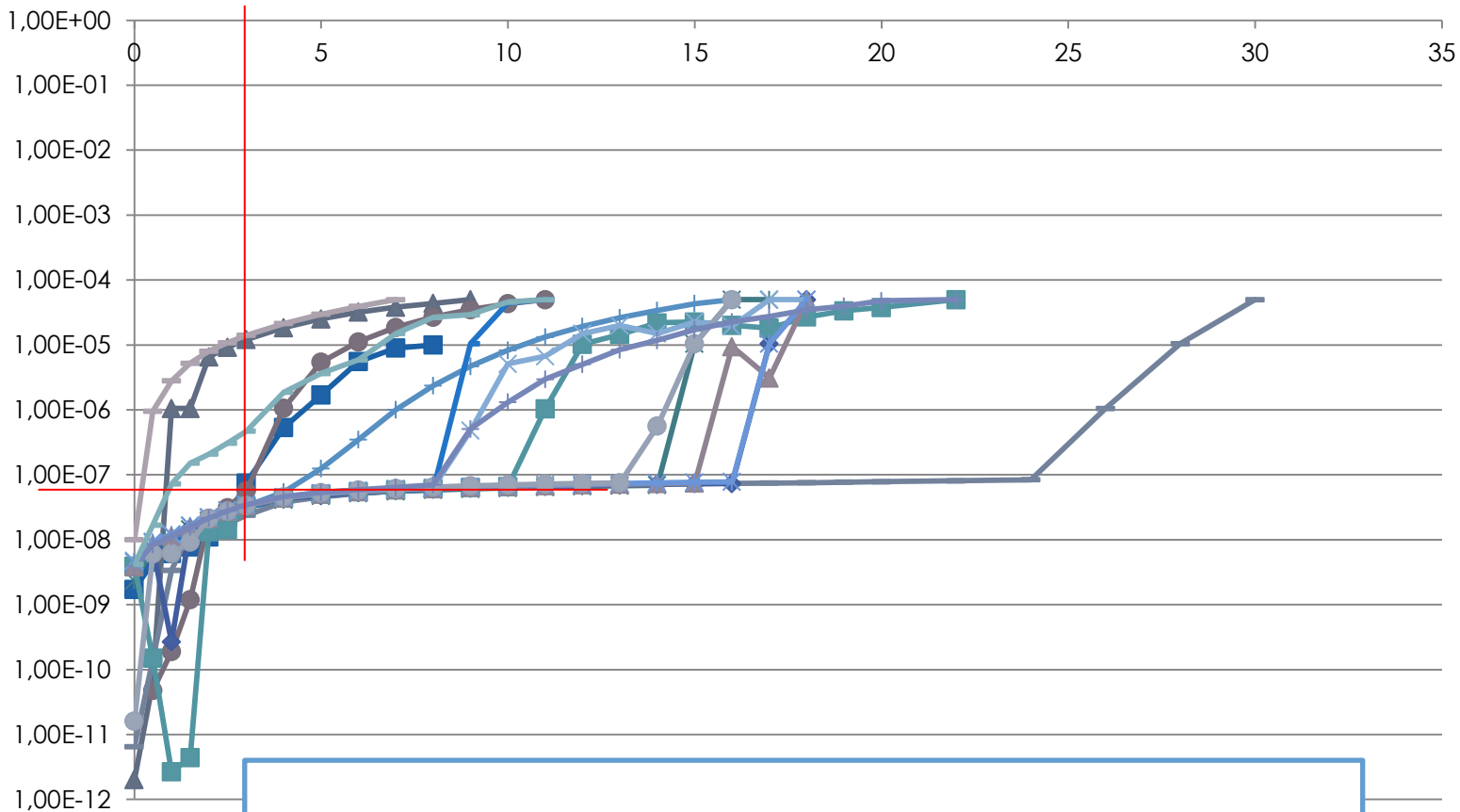
The 3D-IV result for one single strip

Measurement results



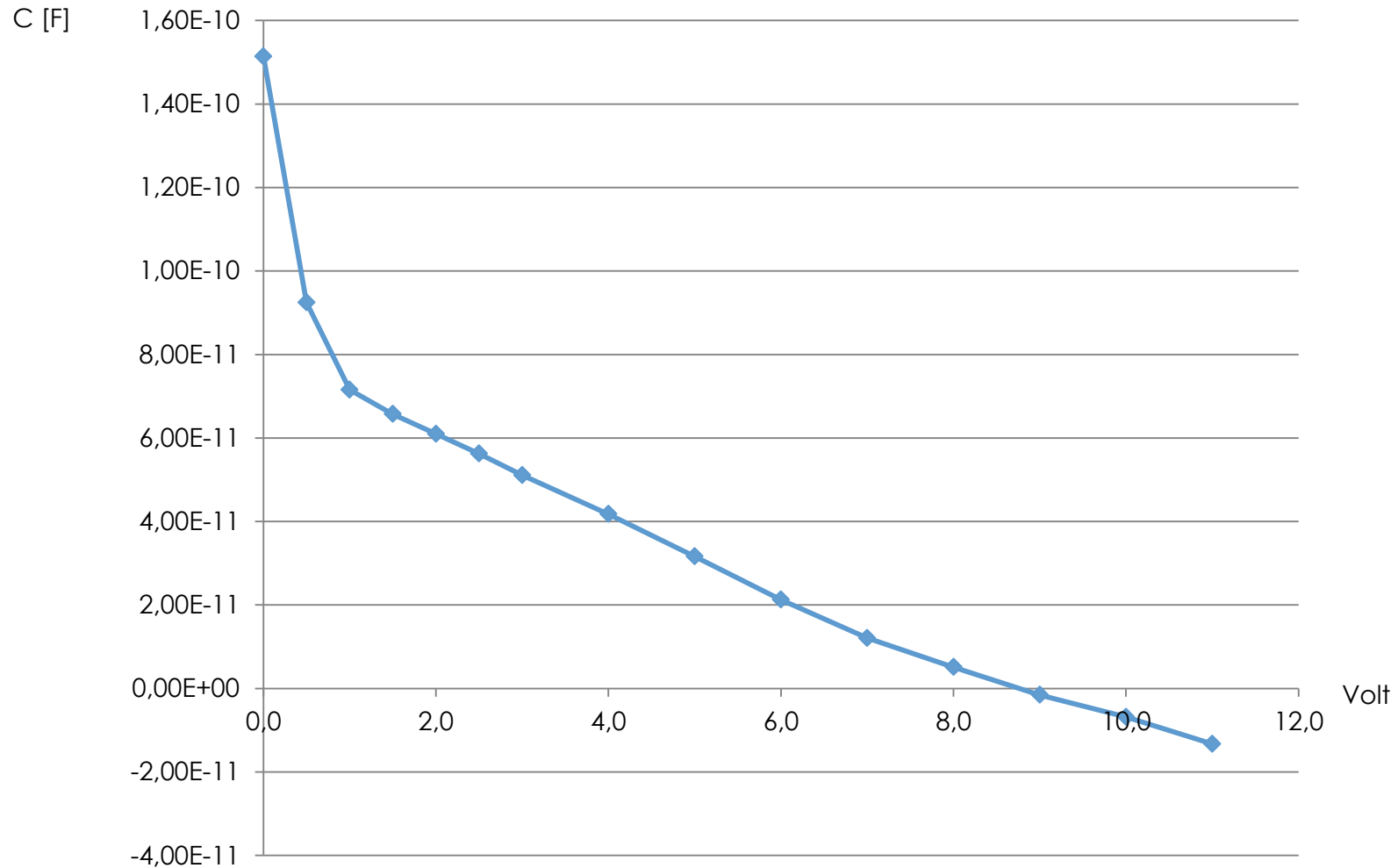
Overlapping strips create confusion

Measurement results



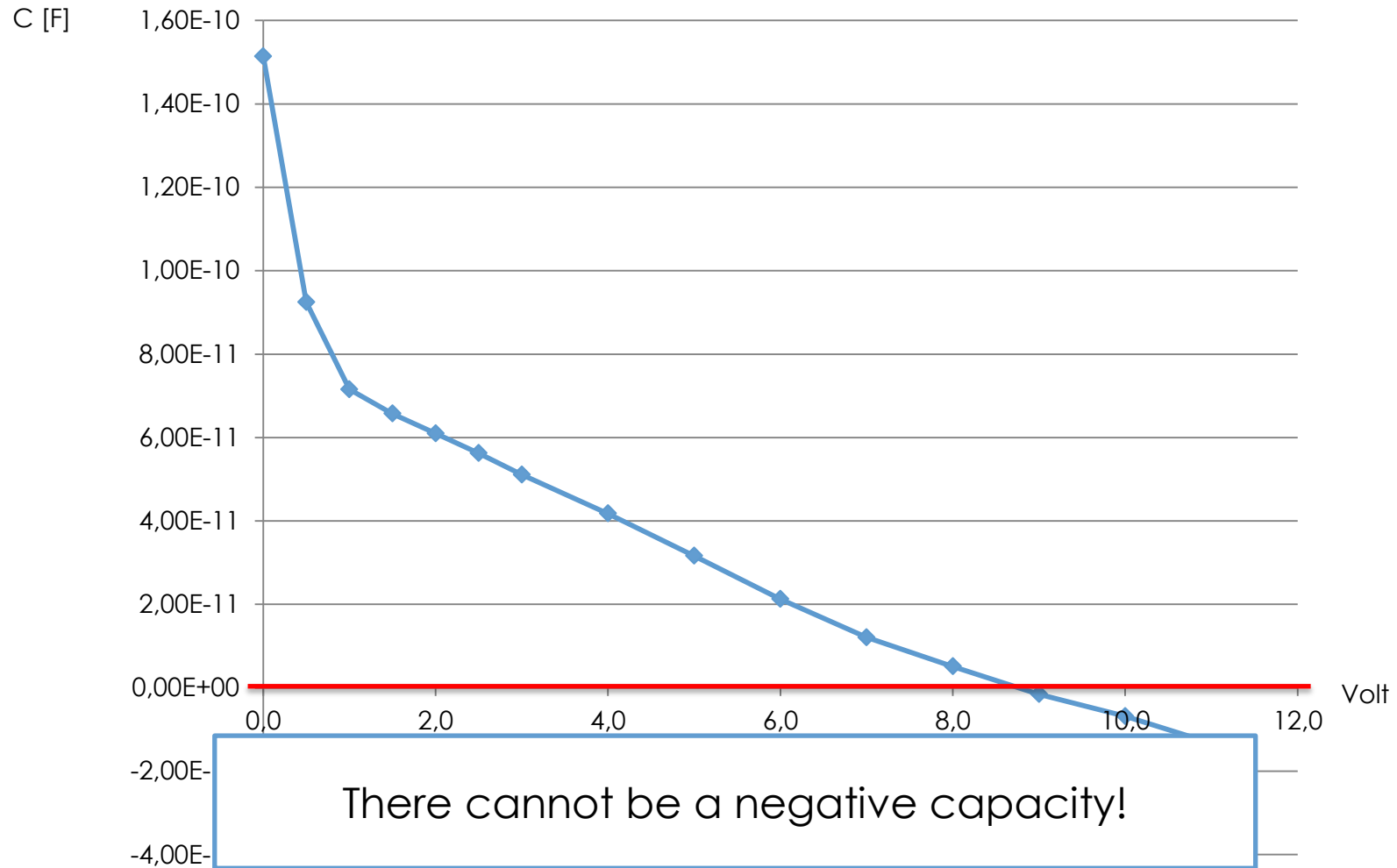
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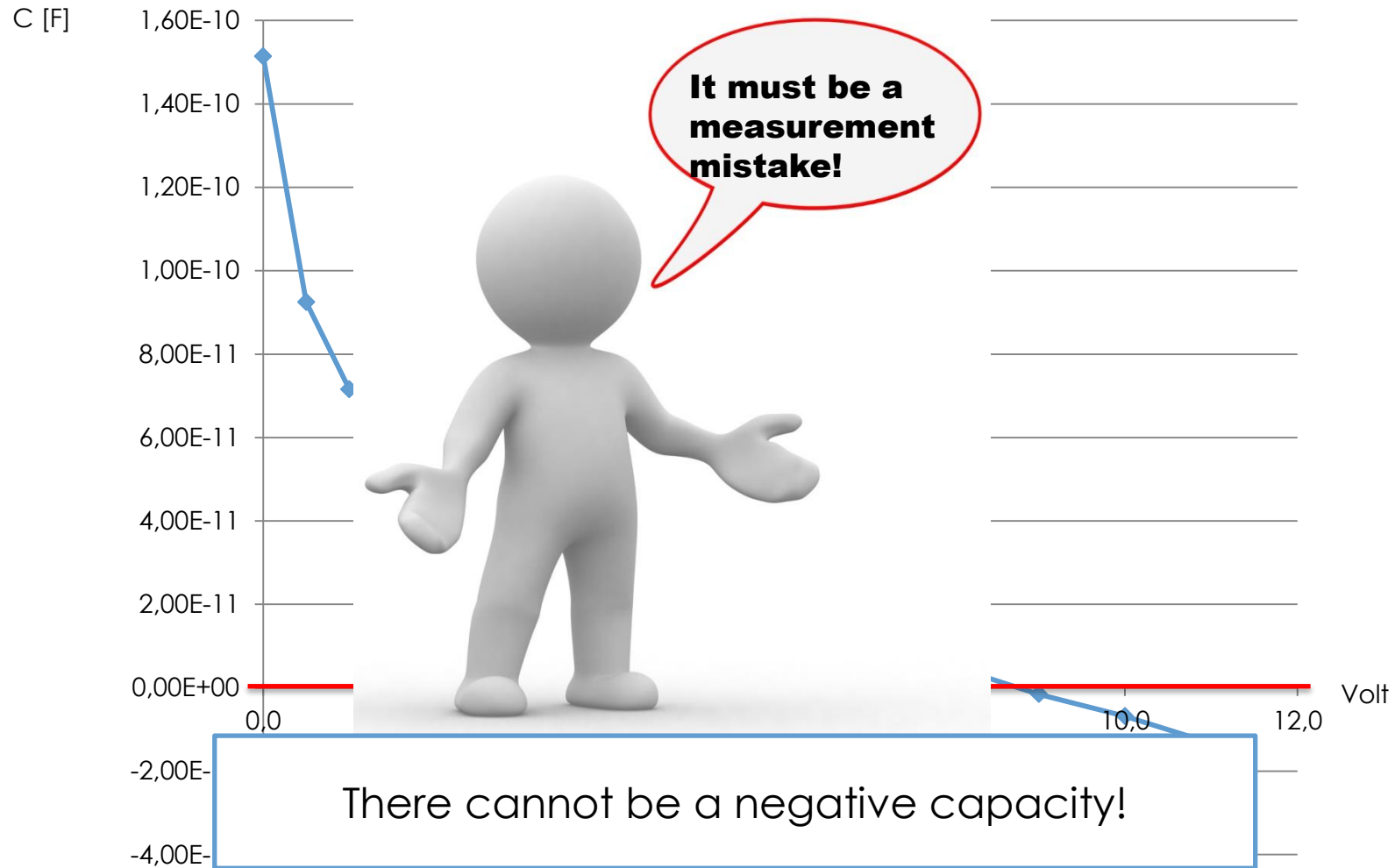
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Measurement results



The 3D-CV result for one single strip

Measurement results



Capacitance and its use...

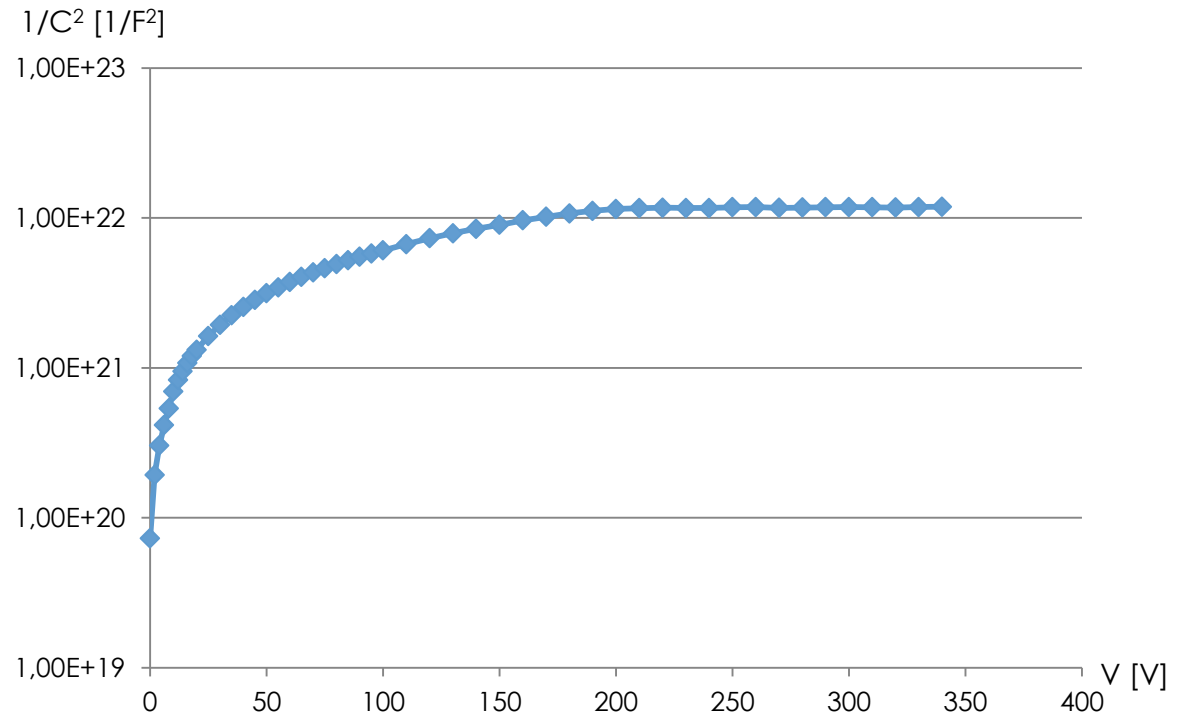
Measurement results



$$C = \frac{\epsilon_0 \epsilon_r S}{d}$$

$$w = \sqrt{\left(\frac{2\epsilon_0 \epsilon_{si}}{e|N_{eff}|} V\right)}$$

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



Capacitance and its use...

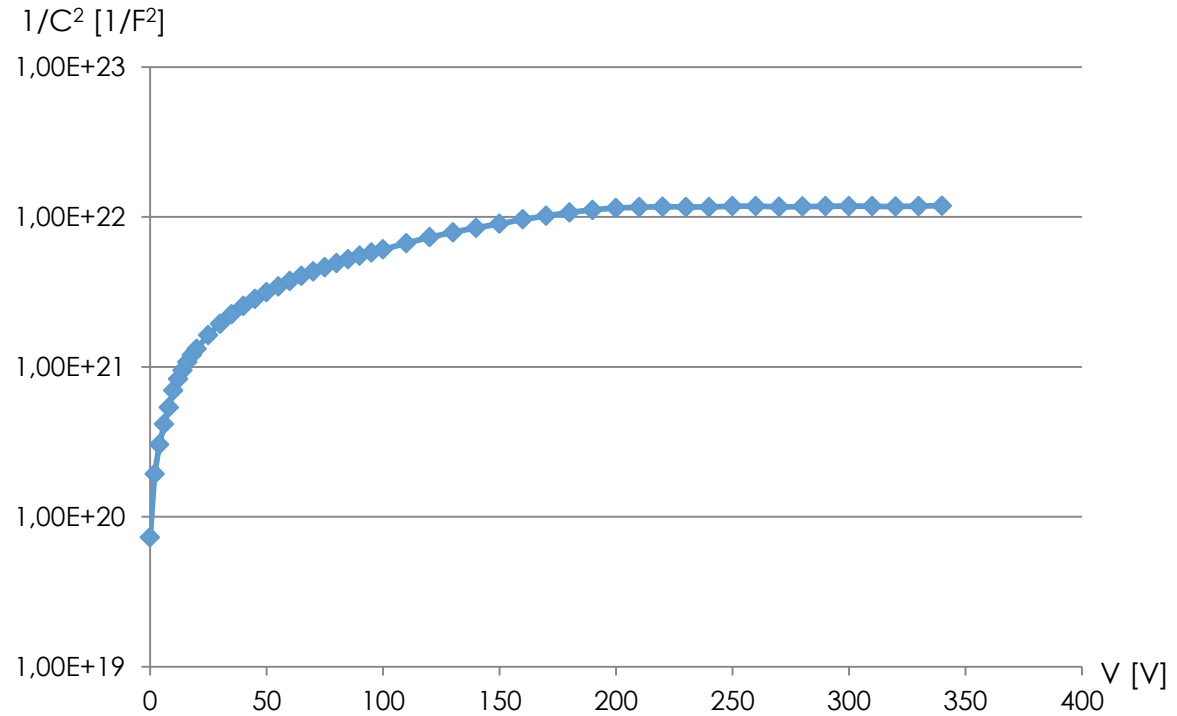
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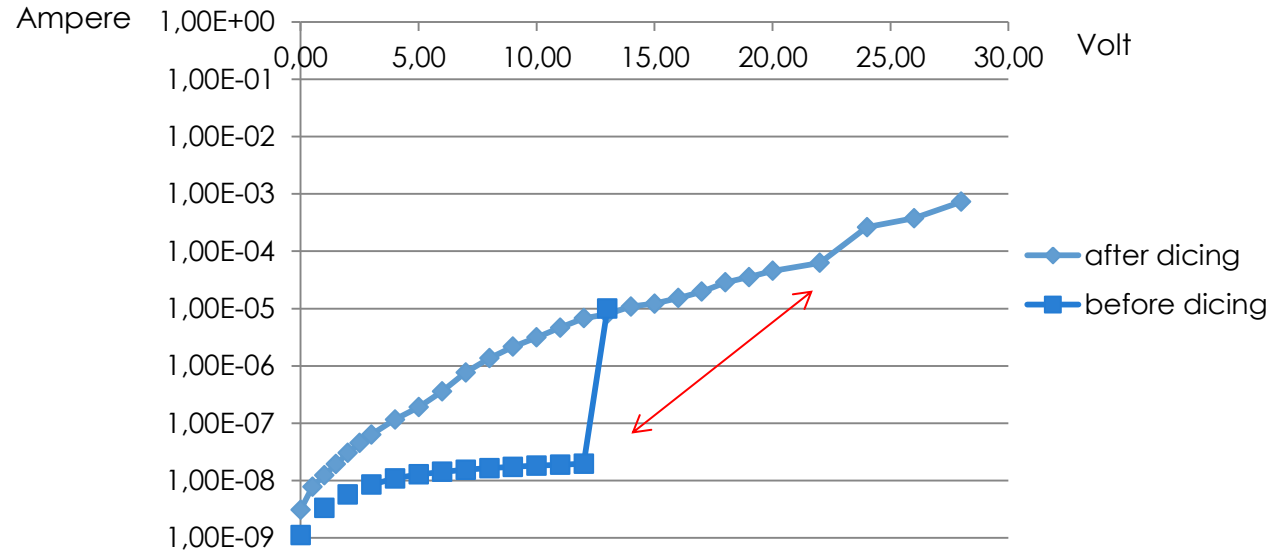
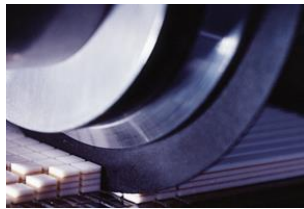
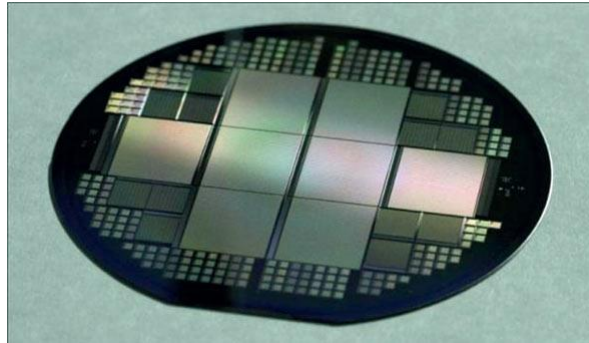
If $V = V_{depl}$ then $w = d$



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

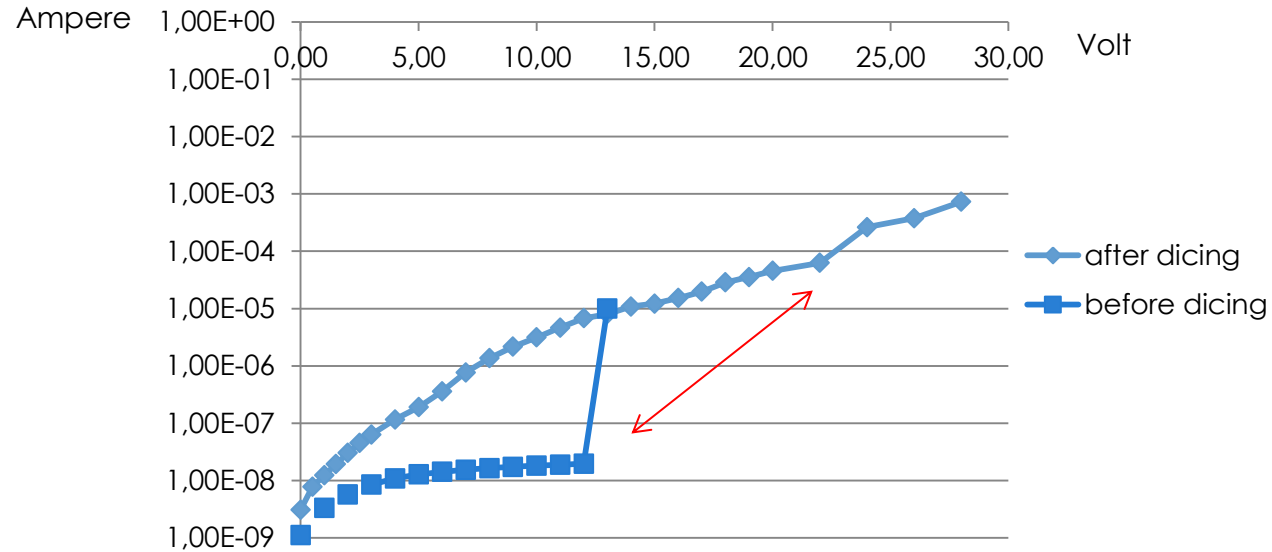
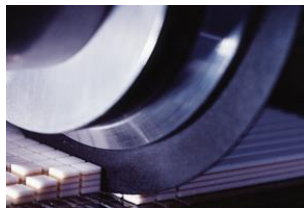
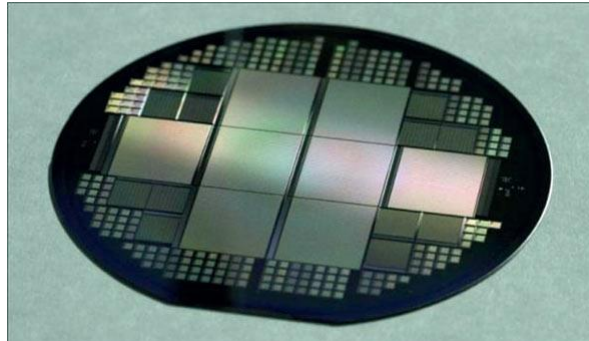
The dicing process changes the sensor

Measurement results



The dicing process changes the sensor

Measurement results



The mechanical process has changed the characteristics of the sensor.

What's left to say

Review

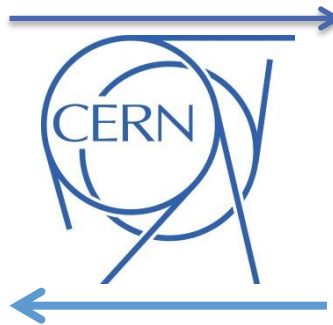


Internship:

Warm atmosphere

CV/IV measurements
→ Slightly monotone

Interest working field

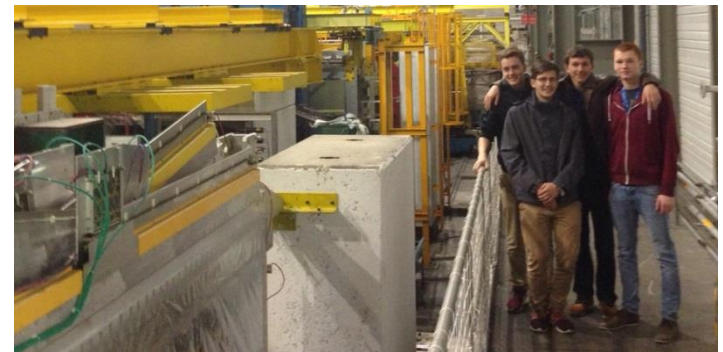
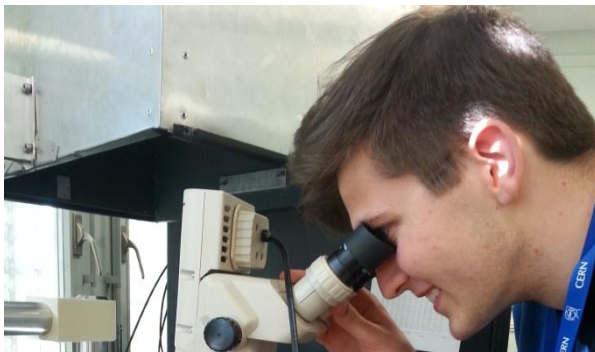


Visits:

Right number

Interesting tours

Good view into CERN



What's left to say

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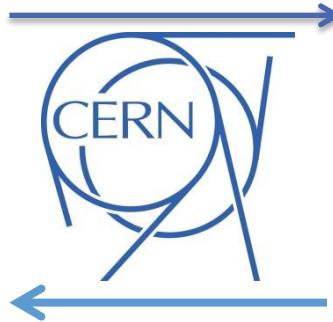


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A special thanks to the SSD-Team incl. Christian
Laura Franconi for the CV/IV measurements &
Sascha Schmeling for making everything possible