Status productions of 3D at CNM

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Outline

Description of the technology

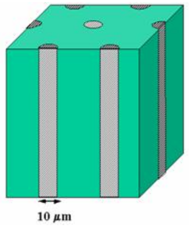
Activity on 3D detectors:

- FE-I4 Atlas pixels for IBL and atlas upgrade
- Future improvements.
- Other fabrication runs

Fabrication of 3D detectors at CNM-IMB clean room facilities

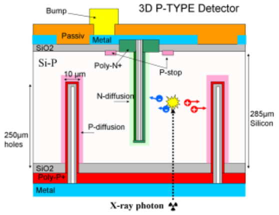
Technology:

First proposed by Parker et al.
Nucl. Instr. Meth. A, 395 (1997) 328



- 4” silicon wafer
- 285um FZ high resistivity wafers (n and p- types)
- All fabrication done in-house
  - ICP etching of the holes: Bosch process, ALCATEL 601-E
  - Holes partially filled with 3 µm LPCVD poly doped with P or B
  - Holes passivated with 2 µm TEOS SiO2
- Double side process proposed by CNM in 2006
- Fabrication of 3D double sided in 2007.
- Fabrication of ultra thin U3DTHIN in 2007.
- First fabrication of 3D single side in 2008.
- In 2010 CNM started the fabrication 235um thick wafers for the IBL.

G. Pellegrini at the Second Trento Workshop on Advanced Silicon Radiation Detectors, Trento,Italy, 2006.

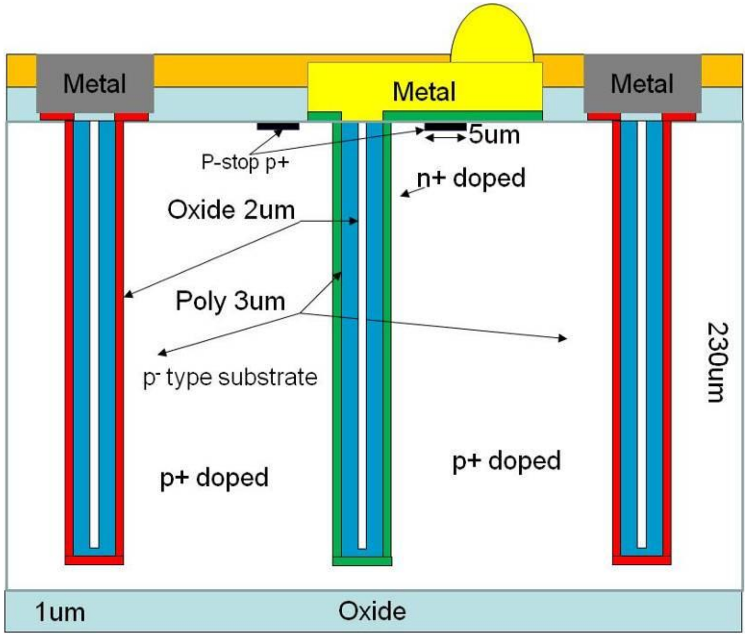


Technologies

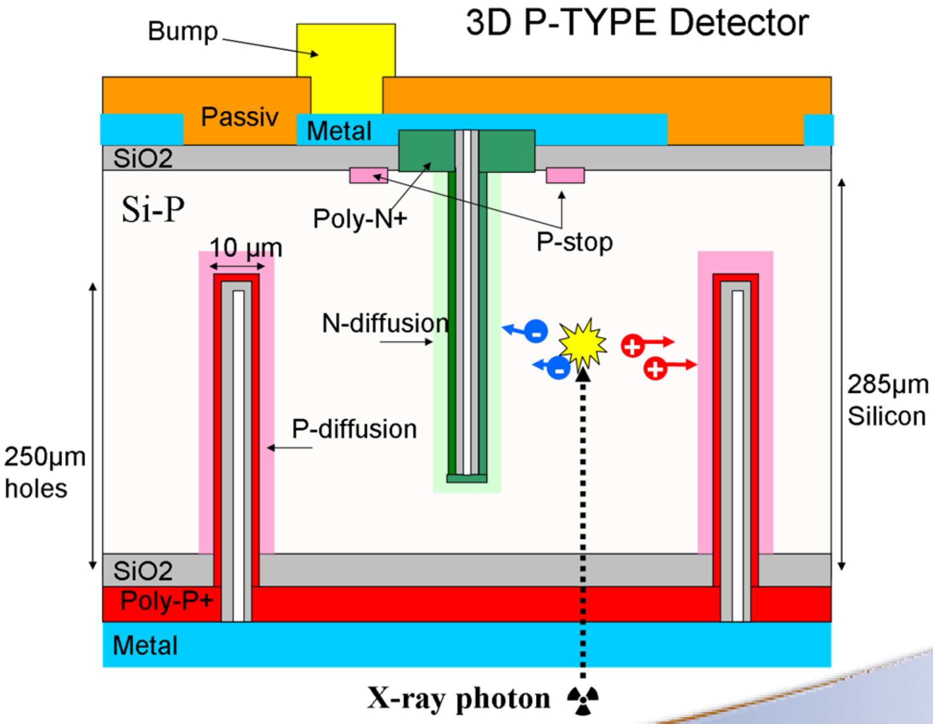
Array of electrode columns passing through substrate
Electrode spacing << wafer thickness (e.g. from 10μm to >300μm)

CNM-IMB has developed both technologies

Single sided

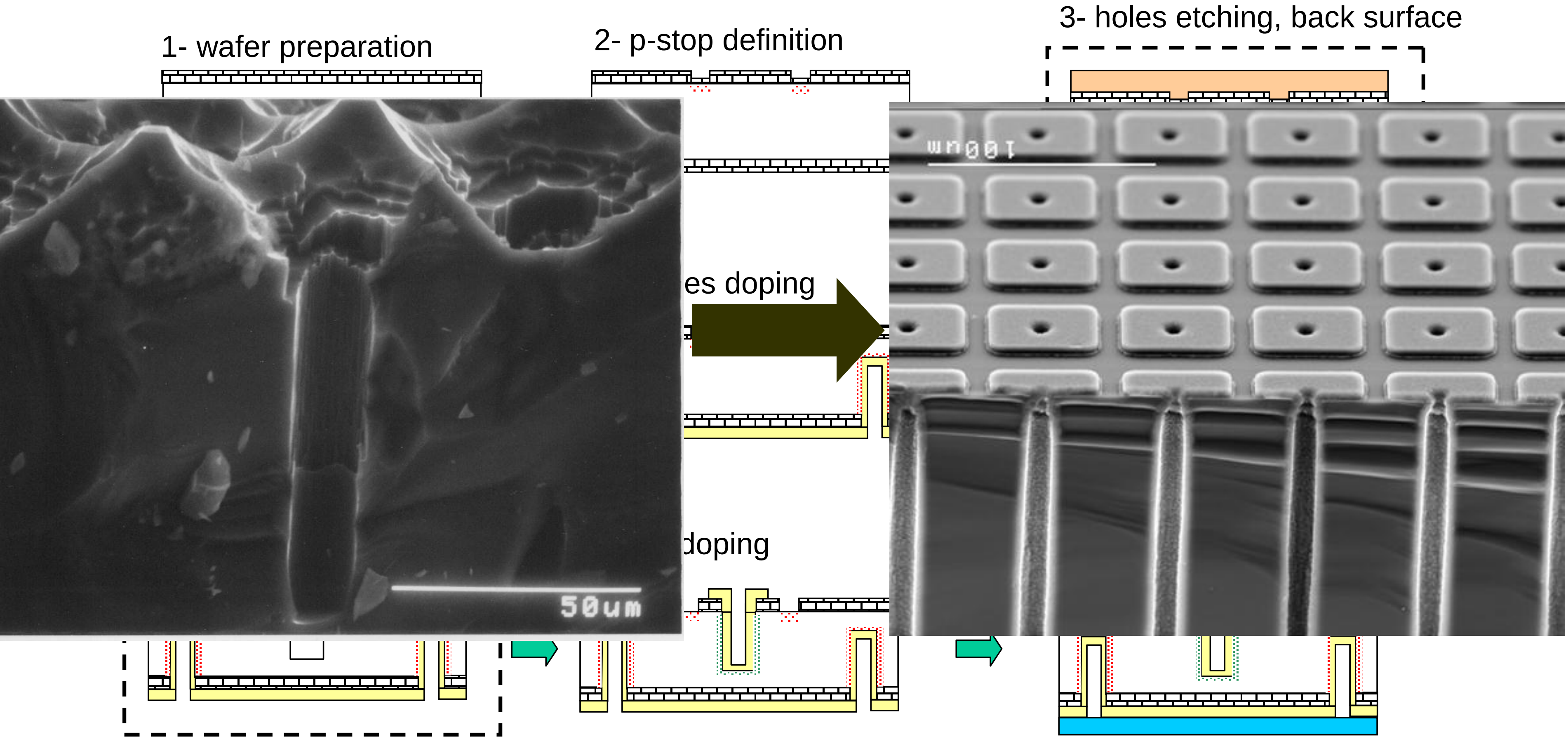


Double sided 3D



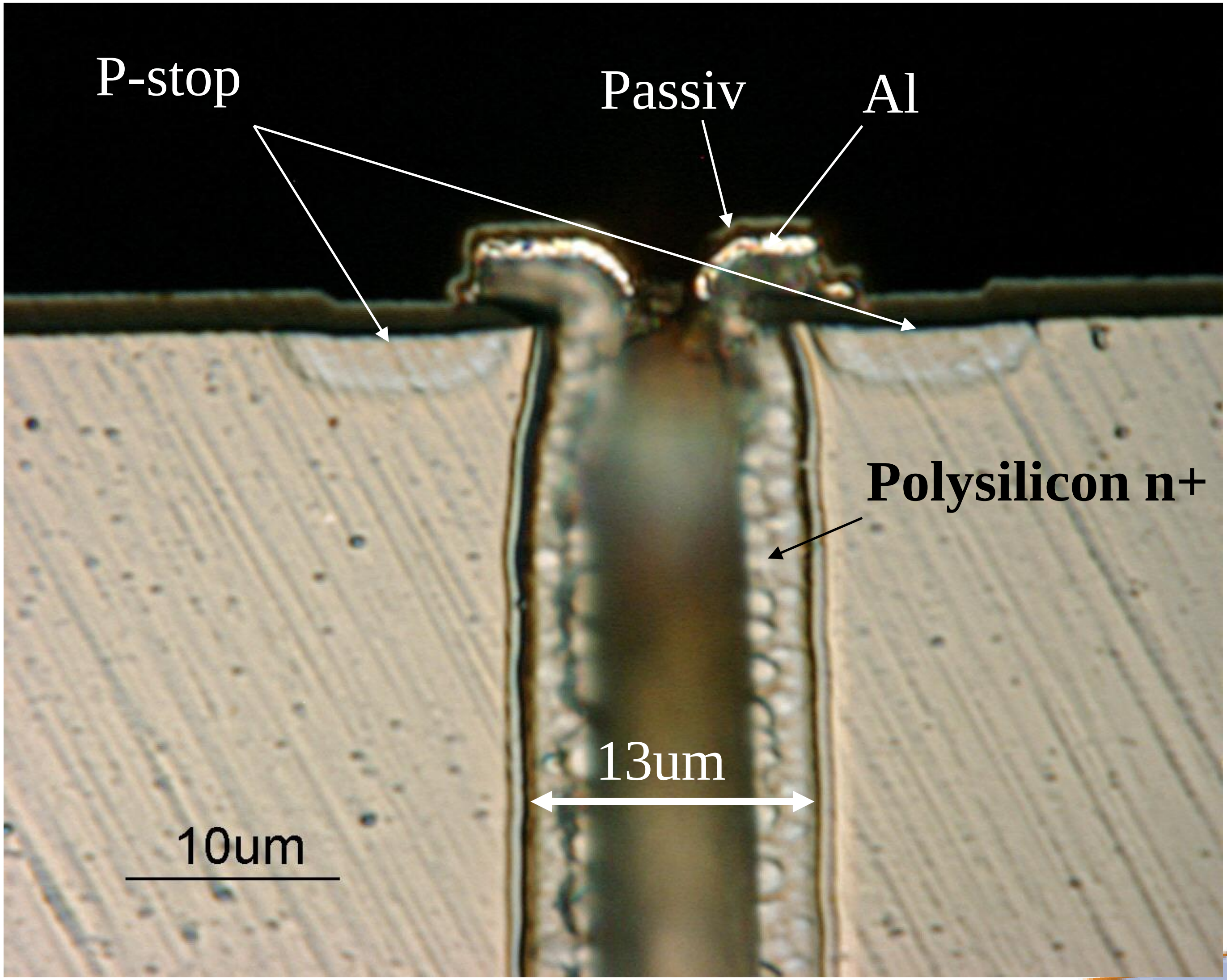
Technology

Few years of technology development: double sided

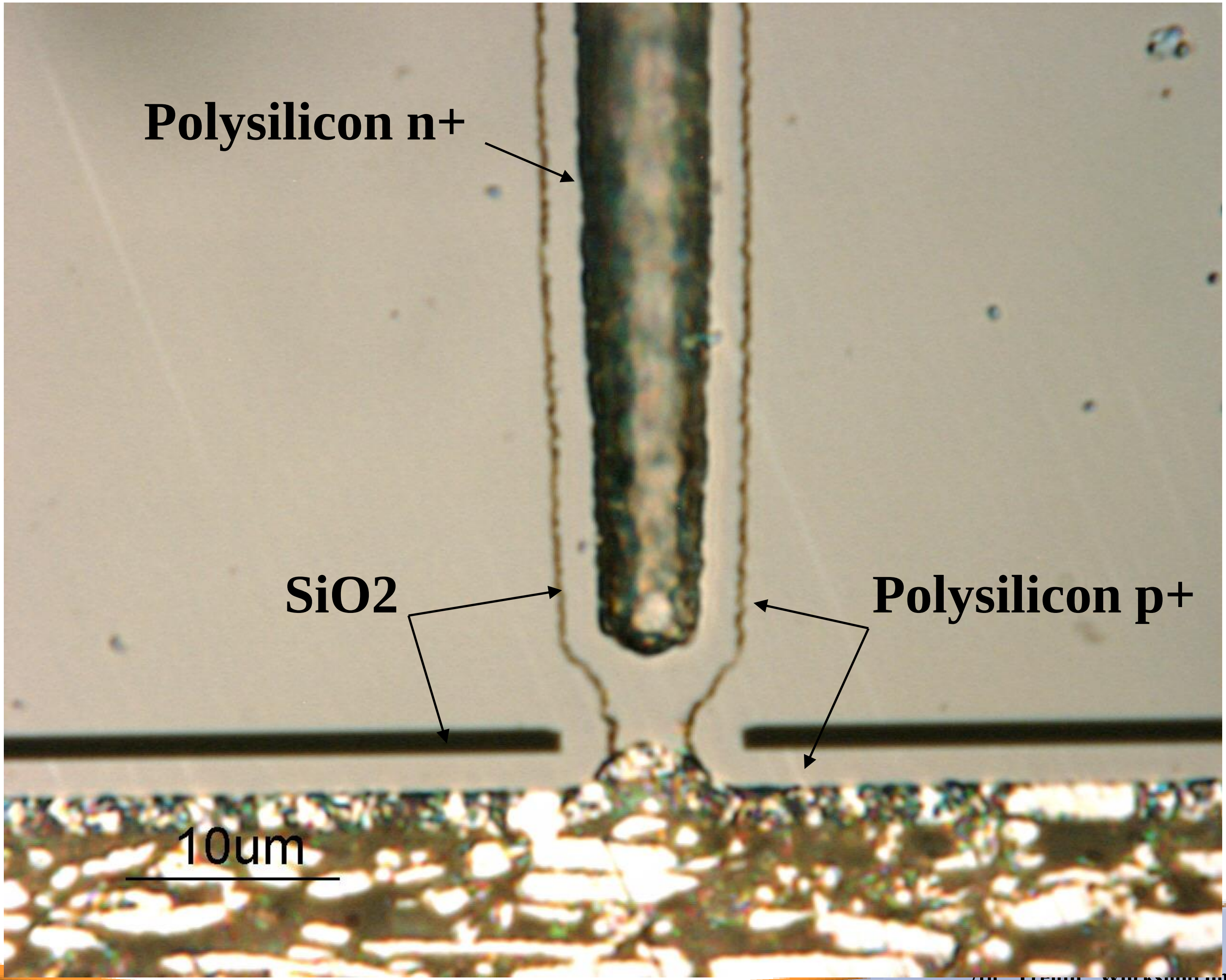


☐: Silicon ▦: Oxide ▨: Si p^+ 🟧: Resist 🟦: Aluminun 🟨:Polysilicon ▩: Si n^+ ▧: Pasivation

Cross section

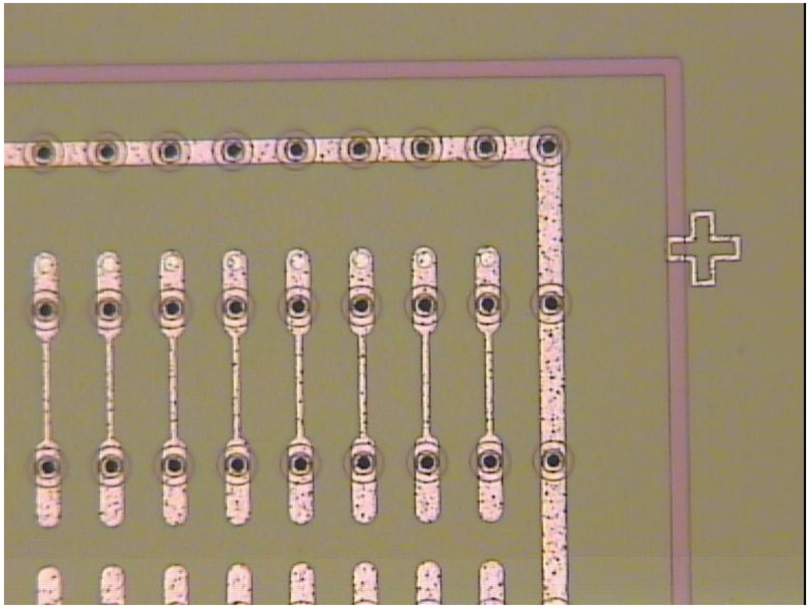


P-type holes



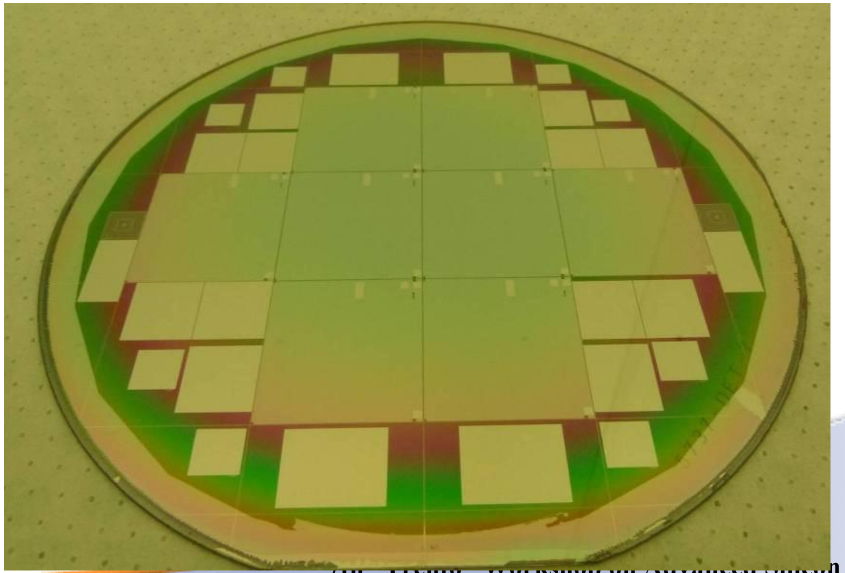
3D FE-I4 Atlas pixels for IBL

Atlas pixels, FE-I3 and new FE-I4 fabrication and irradiation for Insertable B-Layer and testbeam. In the framework of the Atlas 3D collaboration (http://test-3dsensor.web.cern.ch/test-3dsensor/).



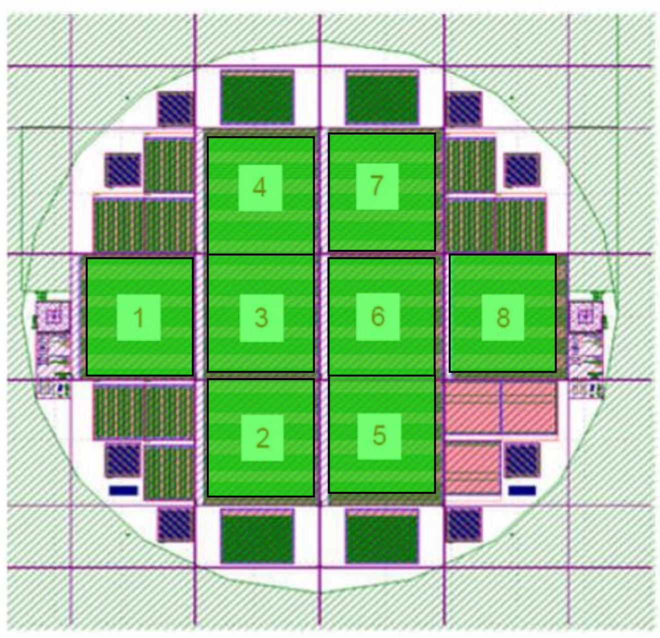
Common layout designed in the framework Atlas 3D collaboration (CNM,FBK,SINTEF, Stanford).
New FE-I4 design (2x2 cm^2).

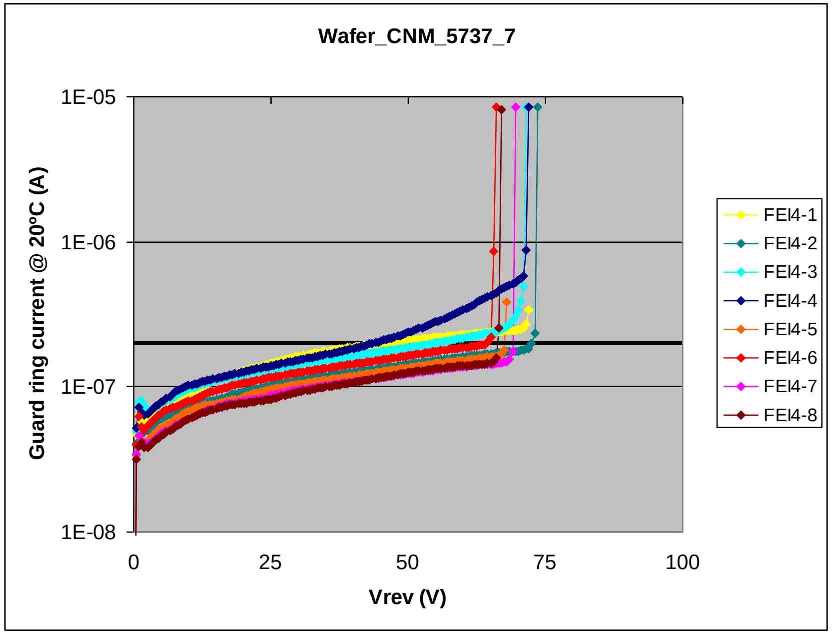
Qualification run finished and tested (please see next talk)



First and second fabrication runs finished
Third run ongoing + backups

Electrical characterization





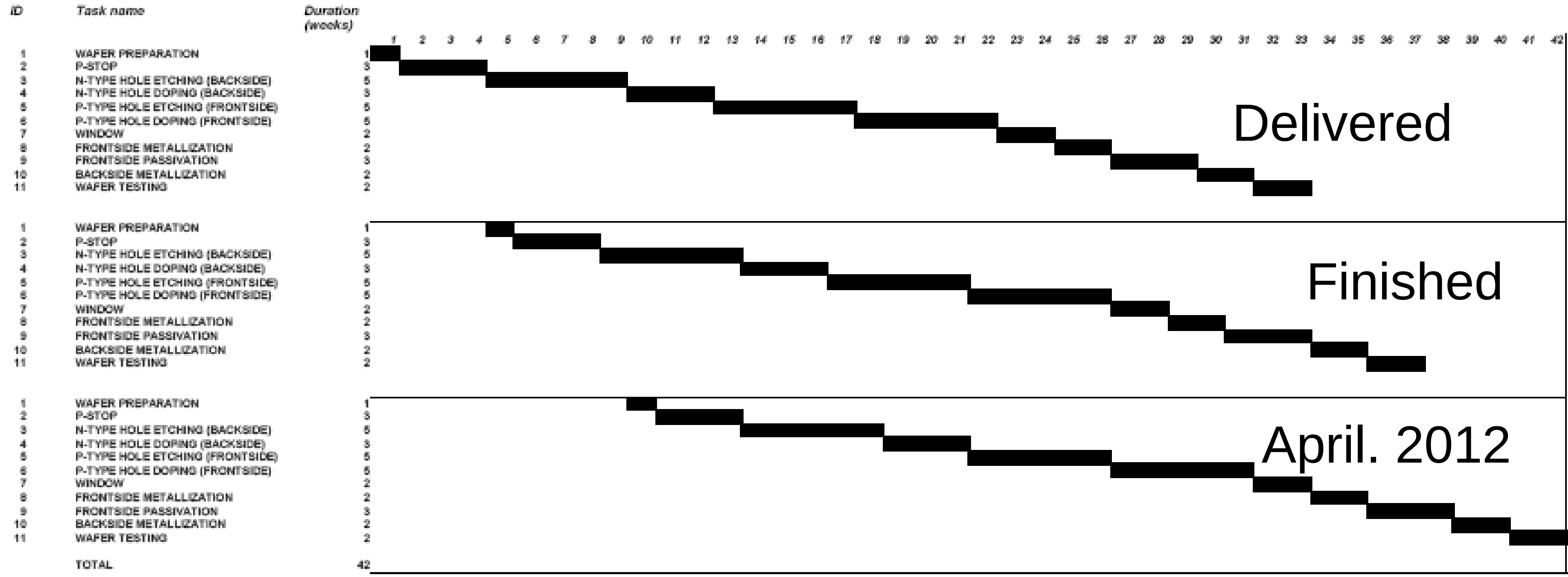
	Class	GR current @ 25 V (nA)	I(25V) / I(20V)	Breakdown V (V)
S1	A	145.18	1.13	71
S2	A	102.12	1.10	72
S3	A	132.70	1.09	69
S4	A	139.88	1.10	71
S5	A	96.12	1.14	67
S6	A	116.11	1.09	65
S7	A	86.76	1.09	69
S8	A	82.57	1.07	66

Bow: 60.8µm

class A detectors: 8
class B detectors: 0
class C detectors: 0

Status of production run

Worplan for 3d double side detectors (p-type) - 3 batches of 24 wafers



ID	*Task name*	*Duration (weeks)*
1	WAFER PREPARATION	1
2	P-STOP	3
3	N-TYPE HOLE ETCHING (BACKSIDE)	5
4	N-TYPE HOLE DOPING (BACKSIDE)	3
5	P-TYPE HOLE ETCHING (FRONTSIDE)	5
6	P-TYPE HOLE DOPING (FRONTSIDE)	5
7	WINDOW	2
8	FRONTSIDE METALLIZATION	2
9	FRONTSIDE PASSIVATION	3
10	BACKSIDE METALLIZATION	2
11	WAFER TESTING	2
1	WAFER PREPARATION	1
2	P-STOP	3
3	N-TYPE HOLE ETCHING (BACKSIDE)	5
4	N-TYPE HOLE DOPING (BACKSIDE)	3
5	P-TYPE HOLE ETCHING (FRONTSIDE)	5
6	P-TYPE HOLE DOPING (FRONTSIDE)	5
7	WINDOW	2
8	FRONTSIDE METALLIZATION	2
9	FRONTSIDE PASSIVATION	3
10	BACKSIDE METALLIZATION	2
11	WAFER TESTING	2
1	WAFER PREPARATION	1
2	P-STOP	3
3	N-TYPE HOLE ETCHING (BACKSIDE)	5
4	N-TYPE HOLE DOPING (BACKSIDE)	3
5	P-TYPE HOLE ETCHING (FRONTSIDE)	5
6	P-TYPE HOLE DOPING (FRONTSIDE)	5
7	WINDOW	2
8	FRONTSIDE METALLIZATION	2
9	FRONTSIDE PASSIVATION	3
10	BACKSIDE METALLIZATION	2
11	WAFER TESTING	2
	TOTAL	42

Delivered

Finished

April. 2012

+ back up

Total A: 171

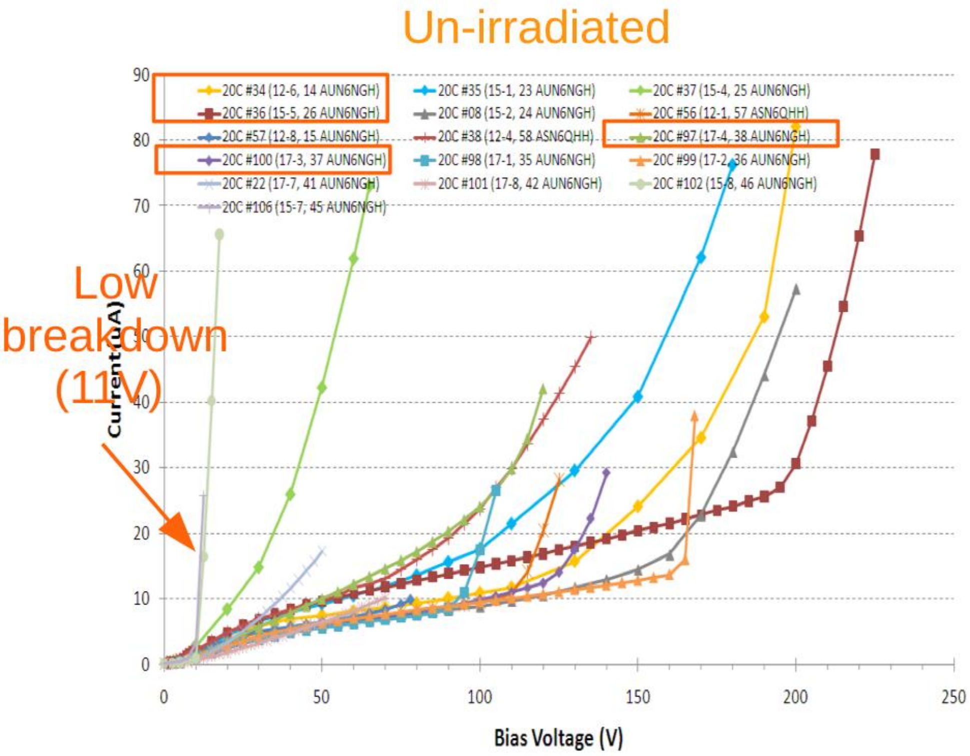
Total B: 17

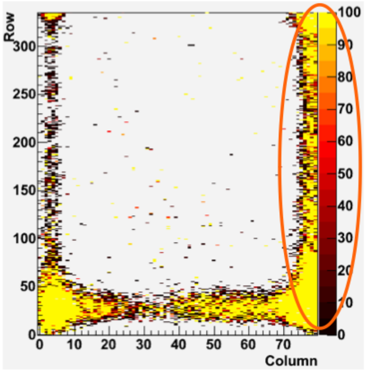
Total C: 100

Overall yield: 60%

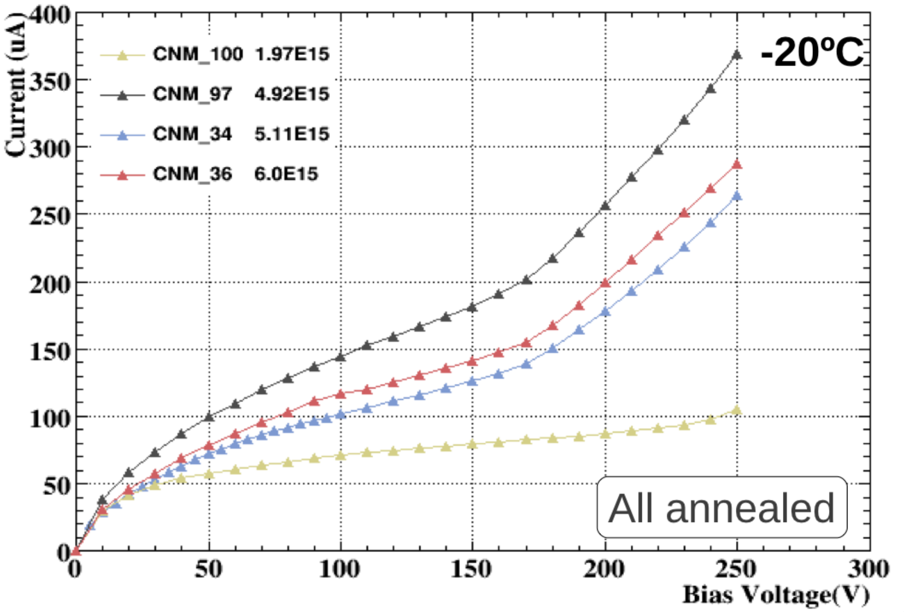
Characterization of p-irradiated devices

Leakage current of CNM devices is along the guard ring



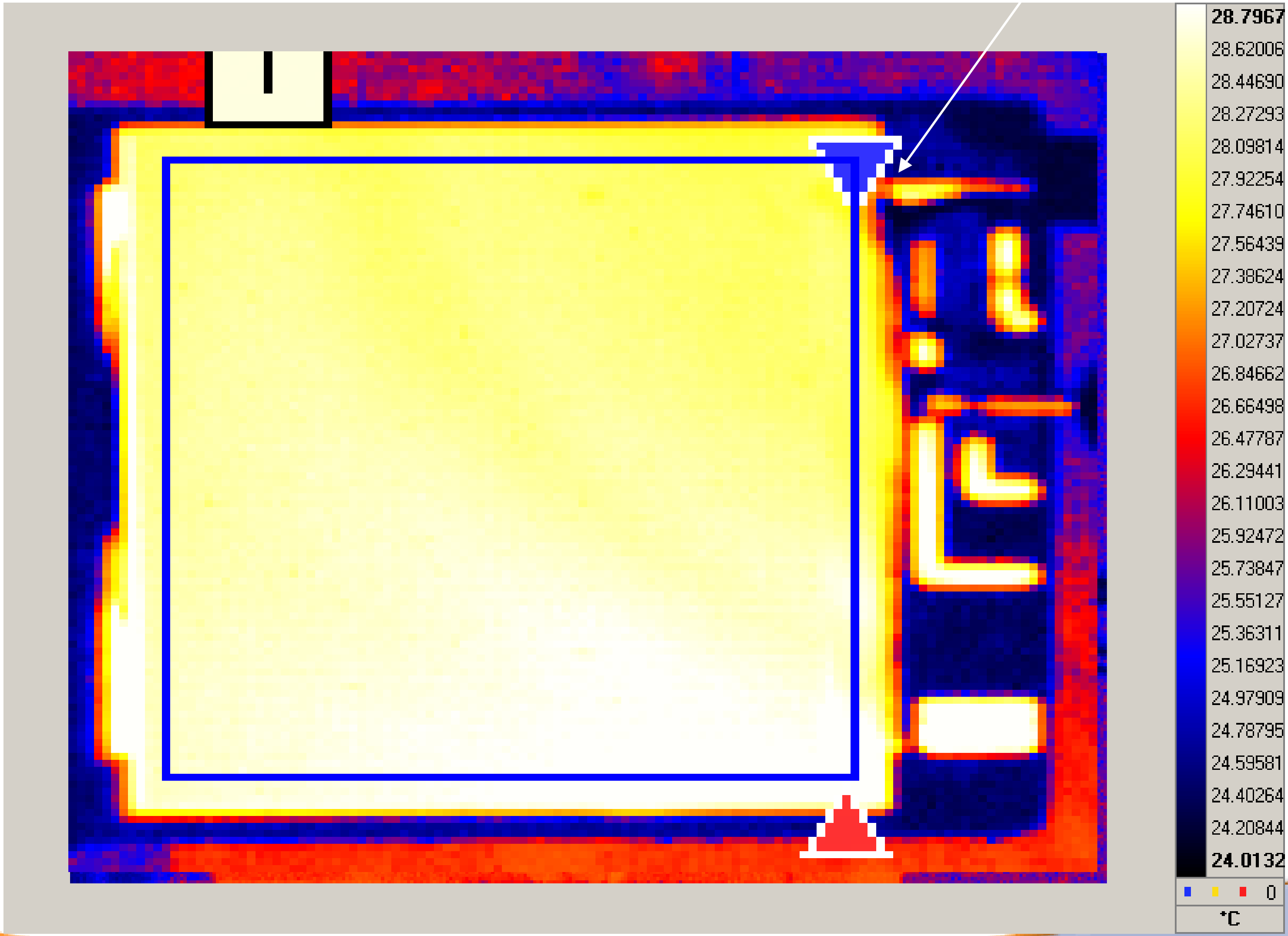


Proton



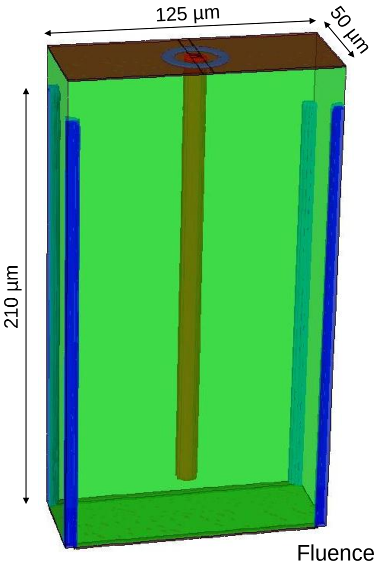
Thermal Image

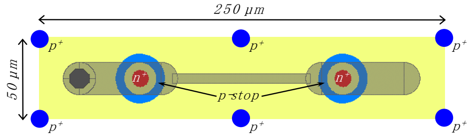
V=50V



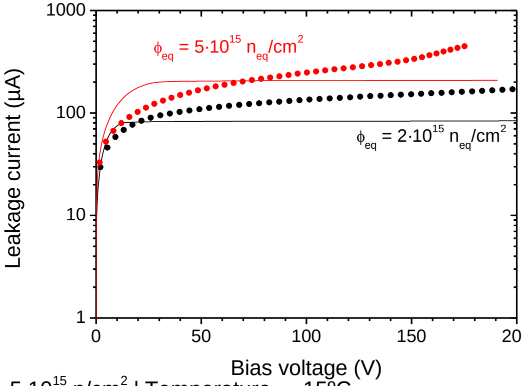
Wire bond

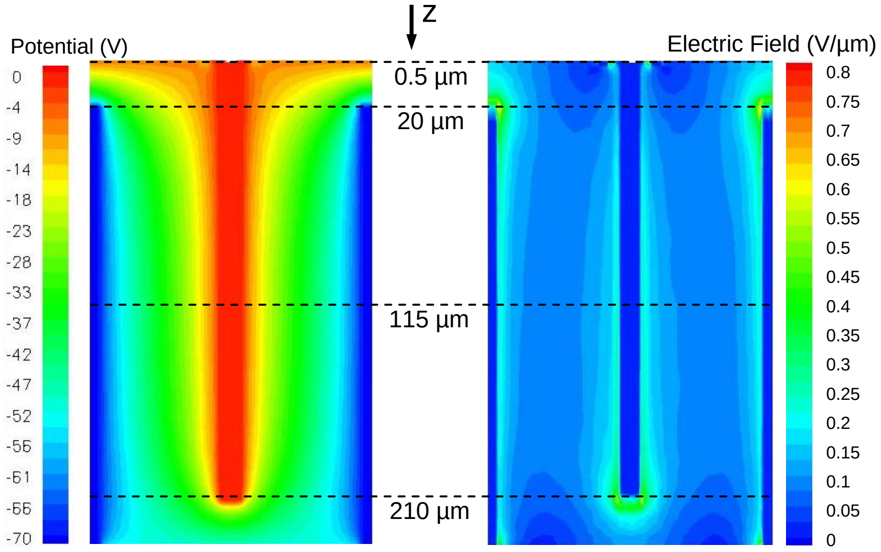
Simulation



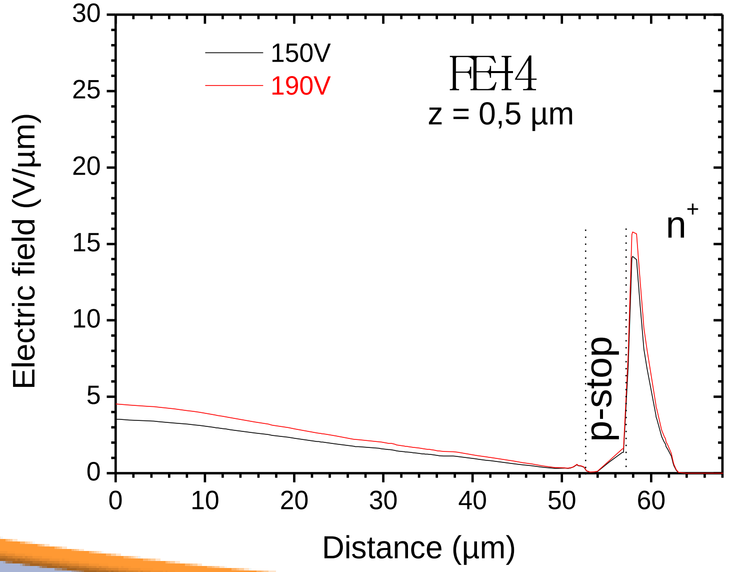


Irradiated | Temperature = -15ºC

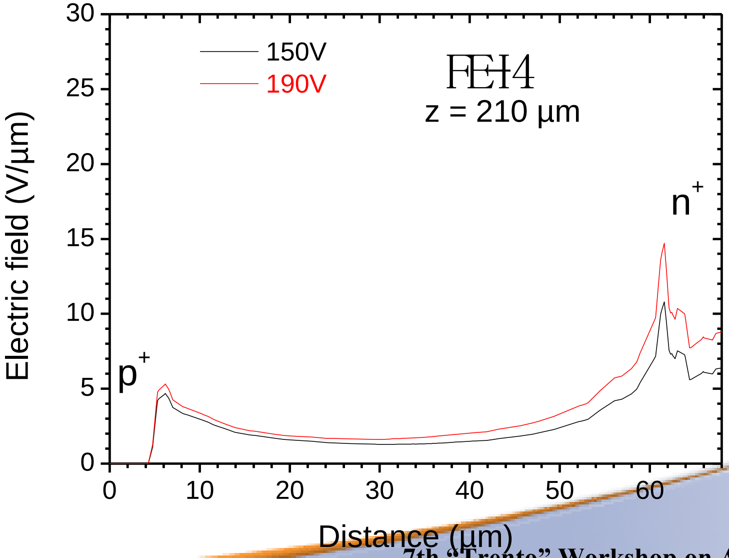




Fluence = 5·10^{15} n/cm^2 | Temperature = -15ºC

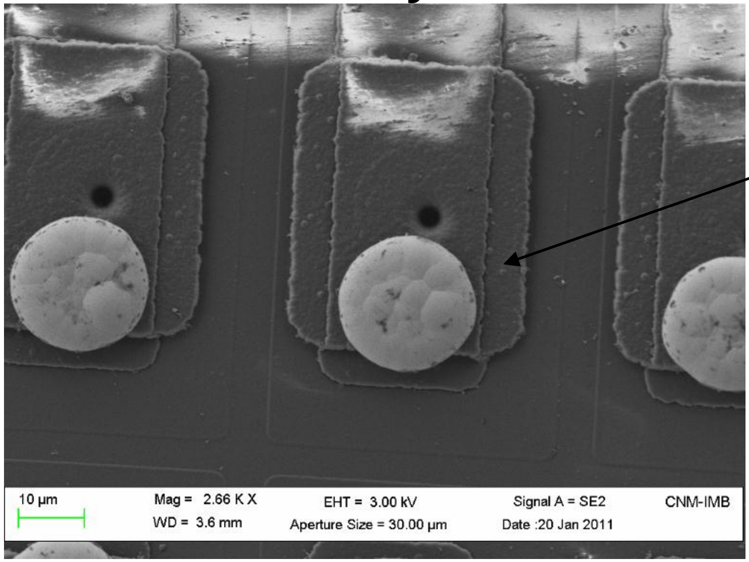


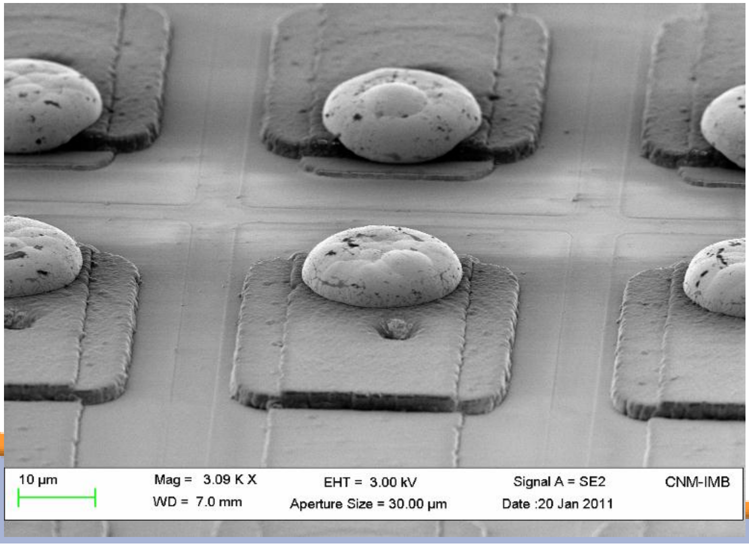
Fluence = 5·10^{15} n/cm^2 | Temperature = -15ºC



UBM deposition

- For IBL the UBM is deposited on all wafers at IZM in Germany before the flip chip.





Under bump metallization

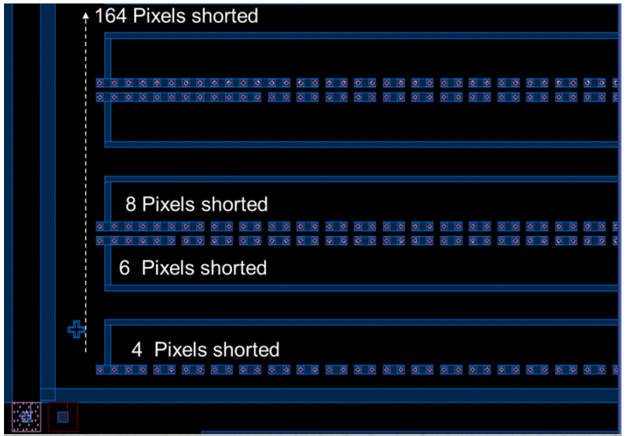
CMN and IFAE have developed the technology for UBM deposition Ni/Au and Cu and the flip chip process with SnPb and SnAg bumps.

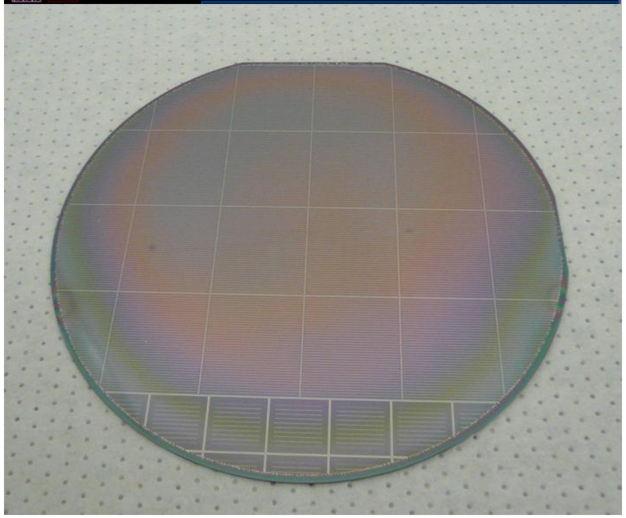
Electroplating for 50µm-pitch

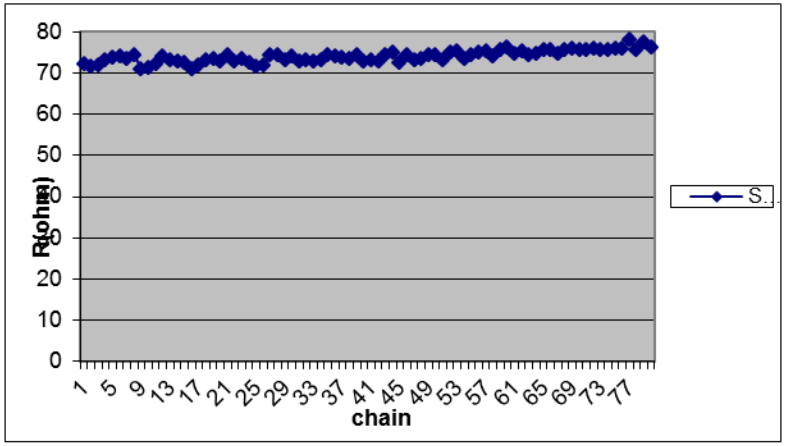
Indium: Under development: FlipChip

We have bought 4 FE-I4 wafers to start doing flip chip also at CNM.

Dummies FE-I4 bonded at CNM-IFAE



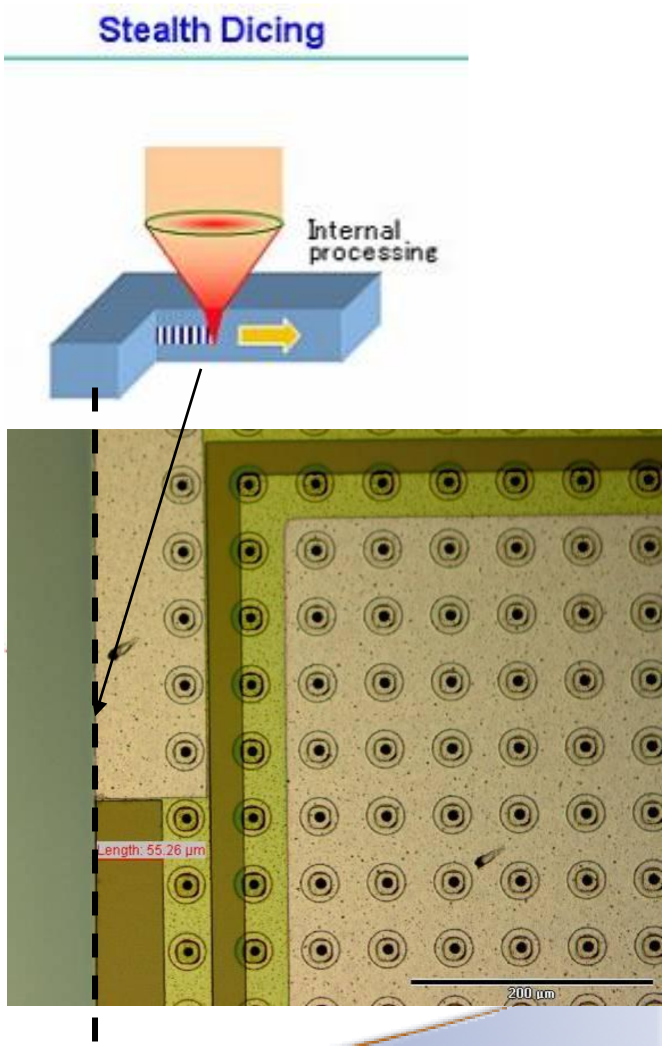




Work done in collaboration with University of Genova

Total wafer fabricated: 24 6” wafers (12 sent to IZM for UBM)
8 4” wafers sent to Selex

What can be improved for HEP?

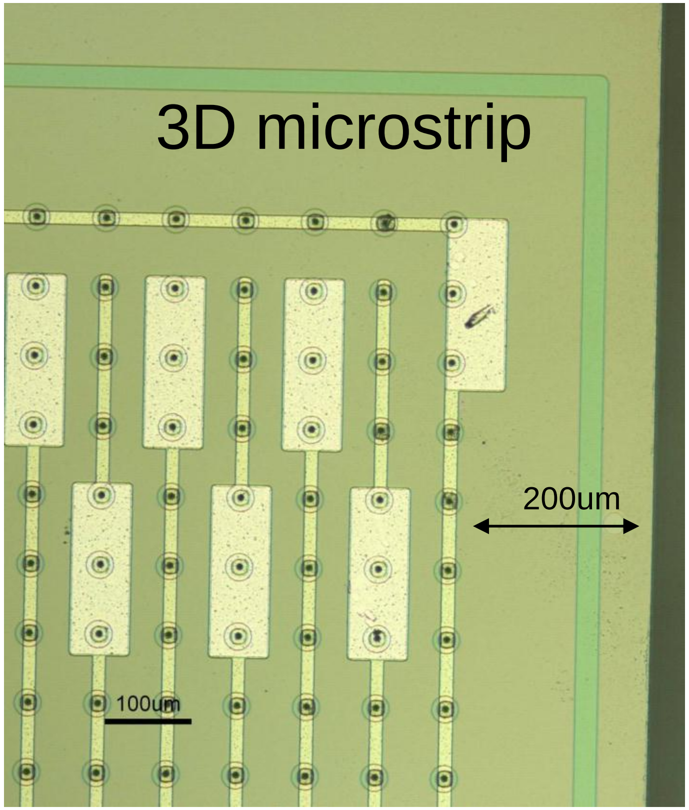


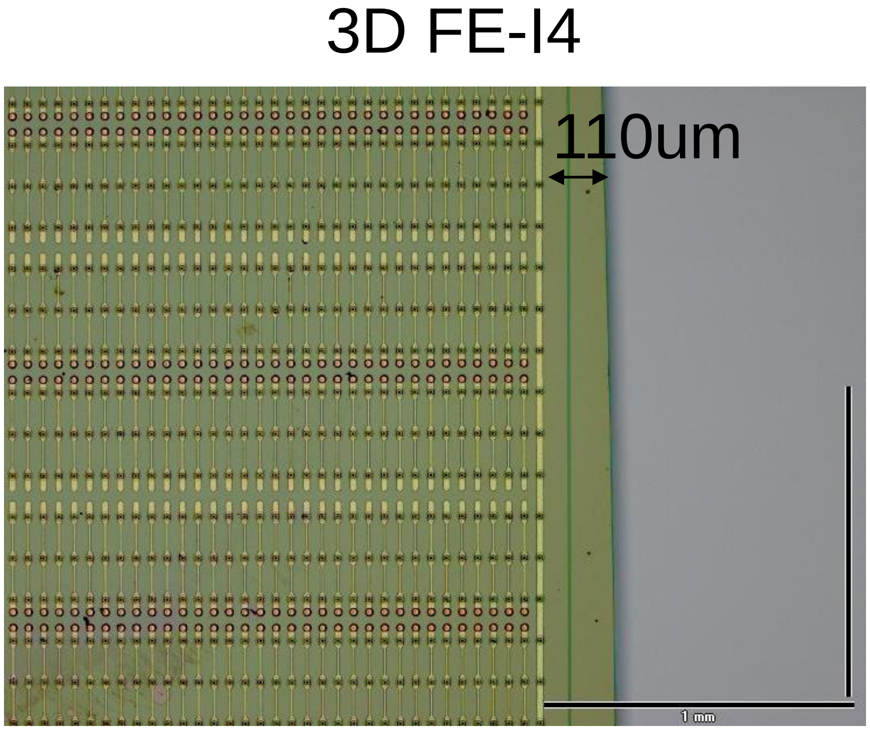
Reduce the dead area at the detector edges. **Laser-Scribing and Al2O3 Sidewall Passivation of P-Type Sensors** : **(M. Christophersen´s)**

Negative charges induced by Al_2O_3 deposited by ALD process, isolate the sidewall surface cut in p-type wafers reducing surface current.

See: Vitaliy Fadeev´s talk.

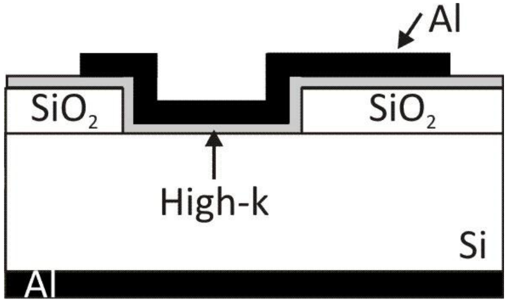
New samples with slim edges

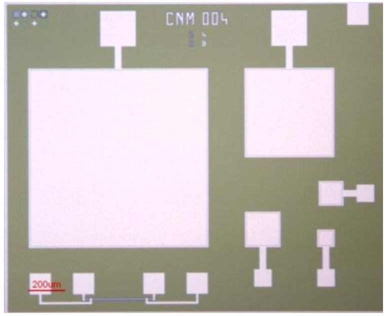


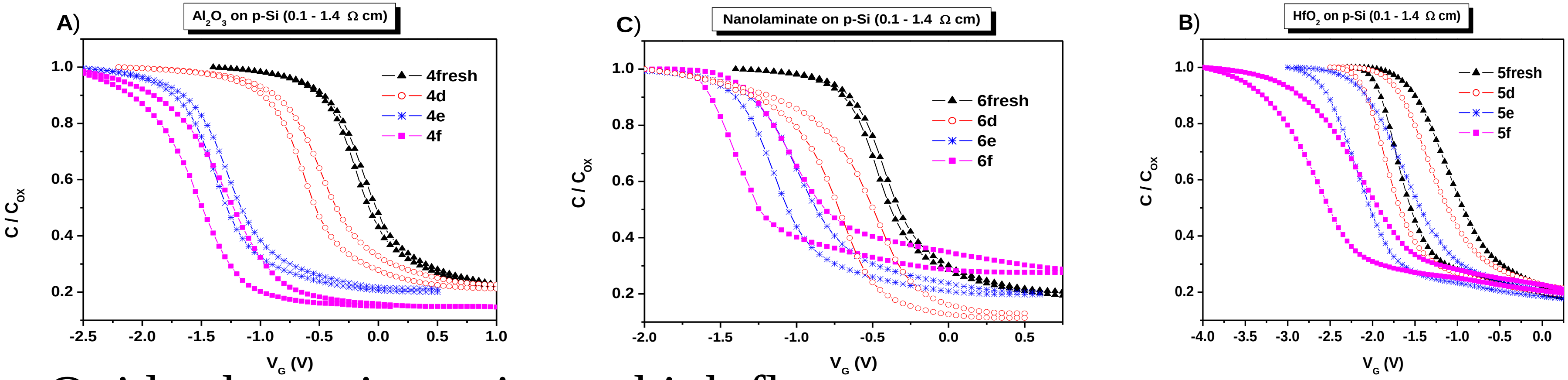


In collaboration with M. Christophersen´s, under RD 50 Common Project

Previous work at CNM with high-k dielectrics







Oxide charge inversion at high fluences

H. Garcia et al., 220th ECS Meeting ***Physics and Technology of High-k Materials 9*** *- October 9 - October 14, 2011 , Boston, MA*
ECS Transactions, v. 41, no. 3, 2010, pp. 349-359

Irradiations were performed at Takasaki-JAERI in Japan
2 MeV electrons for three different fluences: $\phi = 1\times10^{14}$ e/cm^2, 1×10^{15} e/cm^2 and 1×10^{16} e/cm^2
The total ionizing doses were about 2.5 Mrad-Si, 25 Mrad-Si and 250 Mrad-Si
Irradiation was performed at room temperature and capacitors not biased.

Plans for slim edge CNM devices

Until the IBL is assembled we will have very few available sensors and FE-I4 chips

However, we need to test that the sensors are not degraded after irradiation

We have started with 3D strip sensors done up to 200 µm from the active area in collaboration with Glasgow and Freiburg.

- Electrical tests successfully done
- Being connected to the proper electronics for further testing
- Irradiation tests thereafter

FE-I3 and FE-I4 (from the IBL pre-production) sensors have been cut with this procedure (waiting for shipping to CNM)

- Further tests will depend on availability of readout chips

As soon as we can have FE-I4 sensors and chips from the IBL production, we will also continue testing.

A small production of FE-I4 sensors (in addition to the IBL one) can also be done at CNM with a small modification (2-3 masks) to help guiding the cleavage.

CMS 3D sensors

Run is almost finished, due by middle of March 2012.

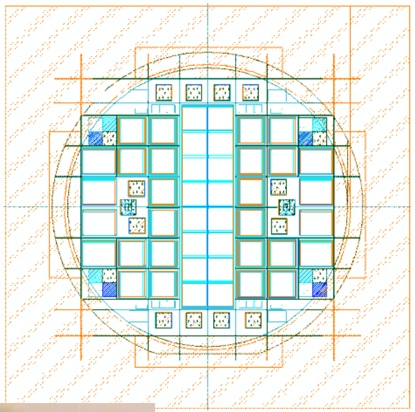
IV tests will be done at CNM and flip chip at PSI.

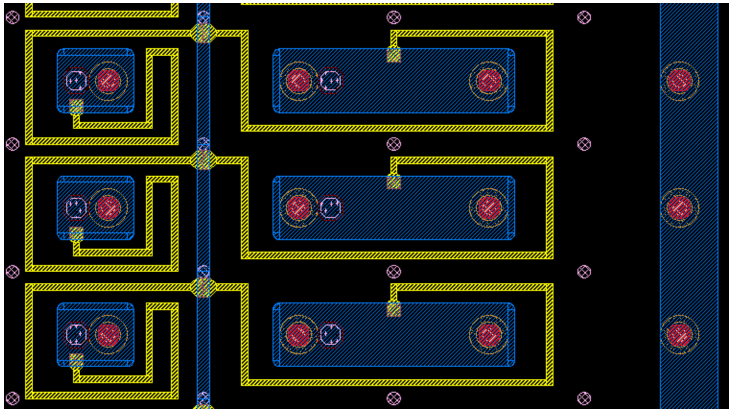
Polysilicon bias resistor to test all the pixels toghter before flip chip.

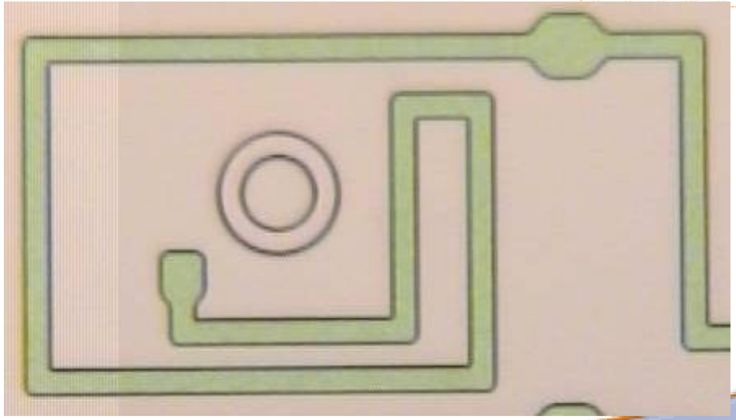
Wafers are 285um thick, p-type

Different densities of “p-holes”.

One 8x2 CMS single chip module







Summary

•IBL production was finished on time.

•More sensors will arrive soon.

•Sensors for the IBL perform as specified after being irradiated

•At Barcelona we have the full chain for sensor production, assembly and testing available

    IFAE will have also an automatic wire-bonding machine operational during this year

•We are investigating a safe procedure to safely cut the sensors as close a possible from the first active pixel

•A production of special sensors for AFP or other experiments interested (TOTEM or LHCb) in the technology can be started at CNM once the full IBL production is finished

Thanks for your attention

References of 3D detectors

1. Comparative measurements of highly irradiated n-in-p and p-in-n 3D silicon strip detectors, Nuc. Instr. Meth. A, Vol 659, Issue 1, 11 December 2011, Pages 272-281.
2. Precision scans of the Pixel cell response of double sided 3D Pixel detectors to pion and X-ray beams, Journal of Instrumentation (JINST), 6 P05002, 2011. (doi:10.1088/1748-0221/6/05/P05002).
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4. 3D Medipix2 detector characterization with a micro-focused X-ray beam: NIM A In Press, Corrected Proof, Available online 7 July 2010.
5. Synchrotron Tests of a 3D Medipix2 X-Ray Detector: TNS IEEE Volume: 57 , Issue: 1 , Part: 2 , Publication Year: 2010 , Page(s): 387 – 394.
6. Beam Test Measurements With 3D-DDTC Silicon Strip Detectors on n-Type Substrate : TNS IEEE Volume: 57 , Issue: 5 , Part: 3 , Publication Year: 2010 , Page: 2987 – 2994.
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17. A New Dimension to Semiconductor Detectors in High Energy Physics and Medical Imaging", Nucl. Instr. and Meth. 2003, A Volume 513, Issues 1-2, Pages 345-349.
18. Technology Development of 3D Detectors for Medical Imaging", Nucl. Instr. and Meth. 2003 A Volume 504, Issues 1-3, Pages 149-153.
19. Study of Irradiated 3D Detectors" Nucl. Instr. and Meth., 2003, A Volume 509, Issues 1-3, pp 132-137.
20. "Technology Development of 3D Detectors for High Energy Physics and Imaging", Nucl. Instr. and Meth., 2002, A Volume 487, pp. 19-26.

The work on 3D detectors has been done in collaboration with different high energies institutes expert in device characterization: Glasgow University, Diamond light source, Freiburg University, Brookhaven National Lab, IFIC Valencia, IFAE Barcelona.