Silicon On Diamond Research

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INO-CNR

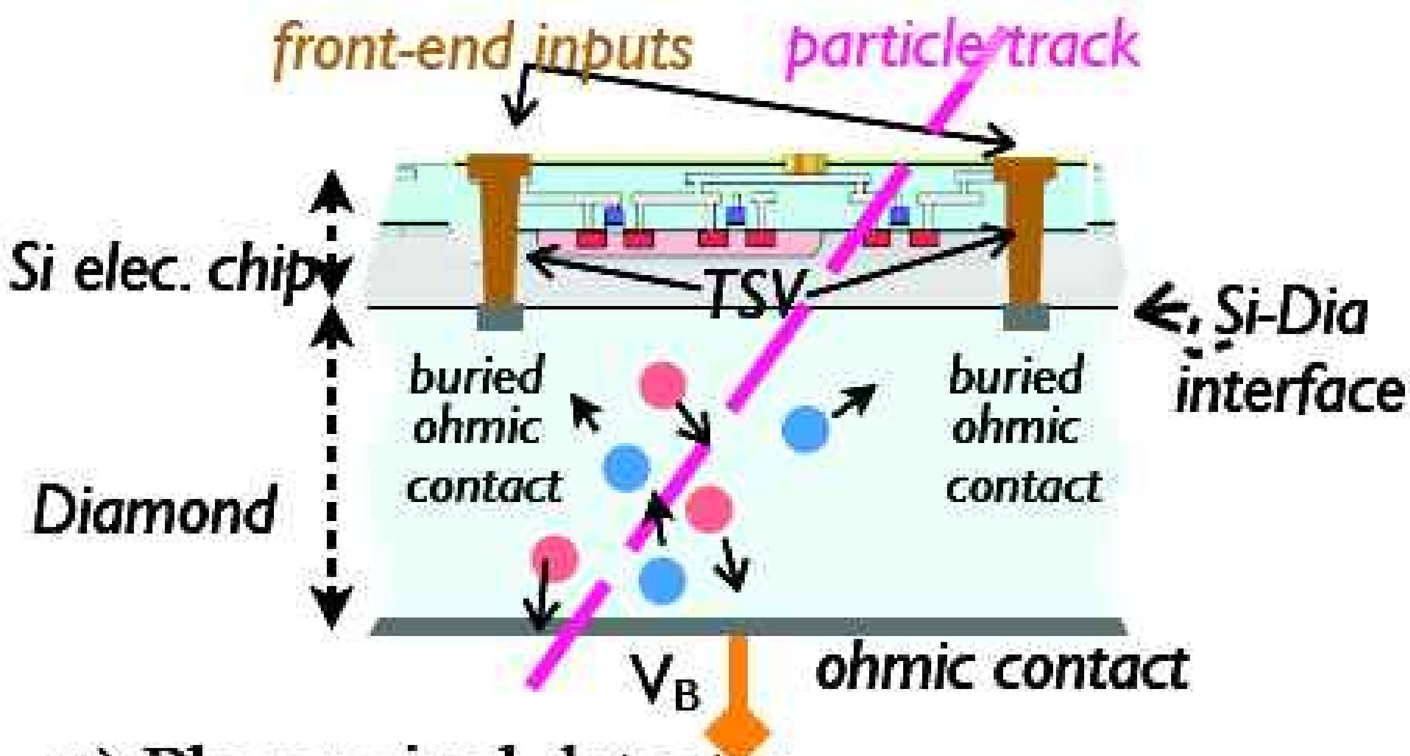
2nd ADAMAS Workshop @ GSI

December 16th, 2013

Summary

- Silicon-On-Diamond Detectors. Prototypes 0 and 1
- MAPS -On-Diamond
- 3D-diamond detectors (next talk by Stefano Lagomarsino)

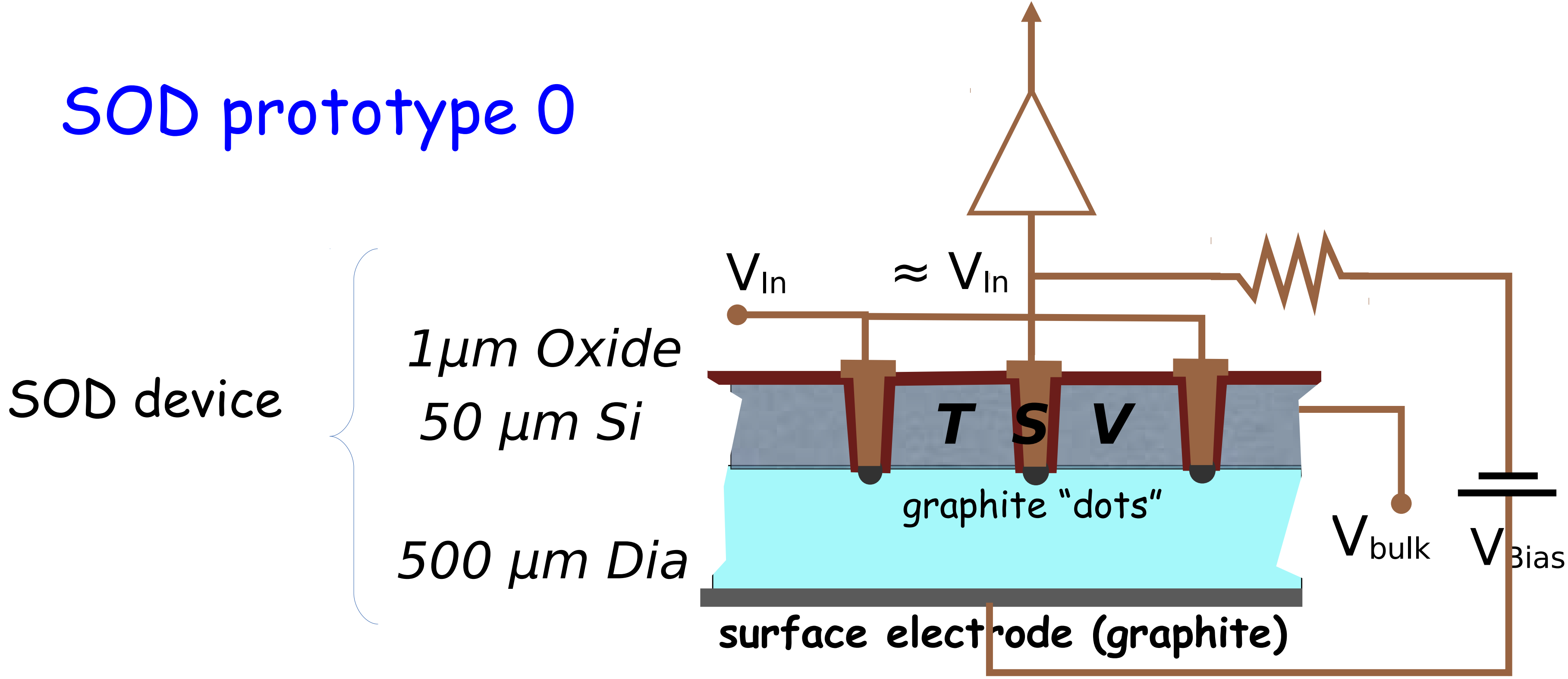
- Silicon-On-Diamond Detectors



a) Planar pixel detector

Chip-On-Diamond Sensor: diamond connected to the readout electronics by Through Silicon Vias (TSV)

SOD prototype 0



External electronics. Few TSV connected to one external preamplifier

All the other TSV are biased at V_{in} .

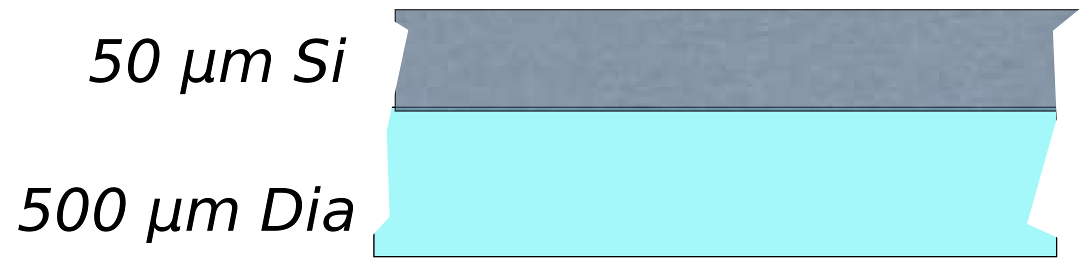
The TSV are insulated from the bulk.

The silicon bulk is biased at V_{bulk}

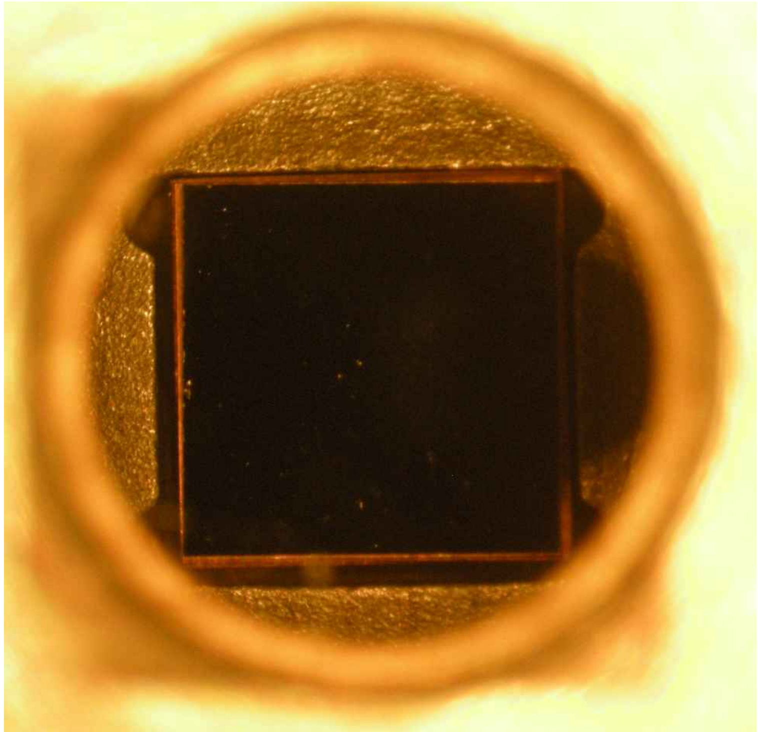
Diamond is biased at V_{bias}-V_{in}

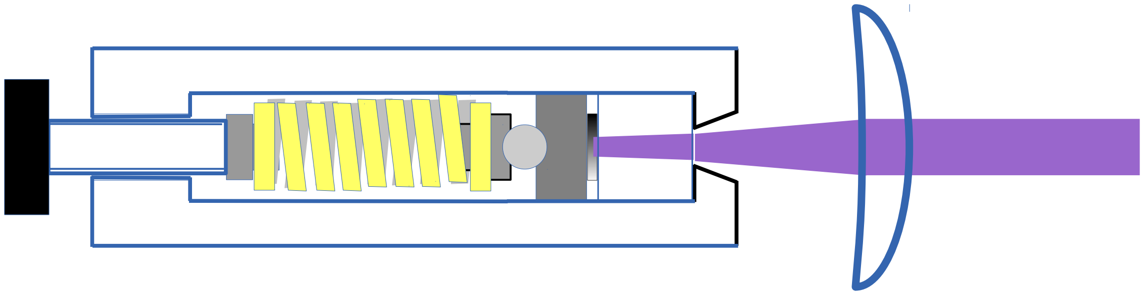
The ohmic contacts on the free diamond surface and the buried diamond surface (TSV bottom) are fabricated by laser graphitization

SOD prototype 0 (step 1)



1 silicon-diamond laser bonding of 500 μm diamond with 50 μm Si 5x5 mm^2 plates (Florence);

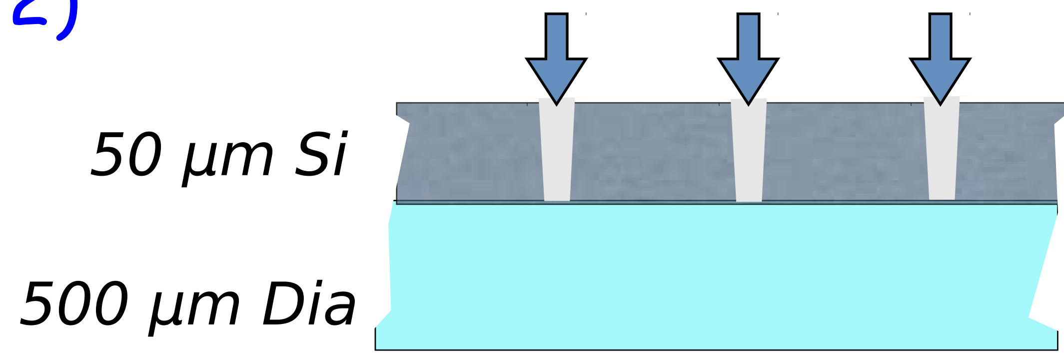




S. Lagomarsino, G. Parrini, S. Sciortino, M. Santoro, M. Citroni, M. Vannoni, A. Fossati, F. Gorelli, G. Molesini, and A. Scorzoni, Silicon-on-diamond material by pulsed laser technique, Appl. Phys. Lett. 96, 031901 (2010).

SOD prototype 0 (step 2)

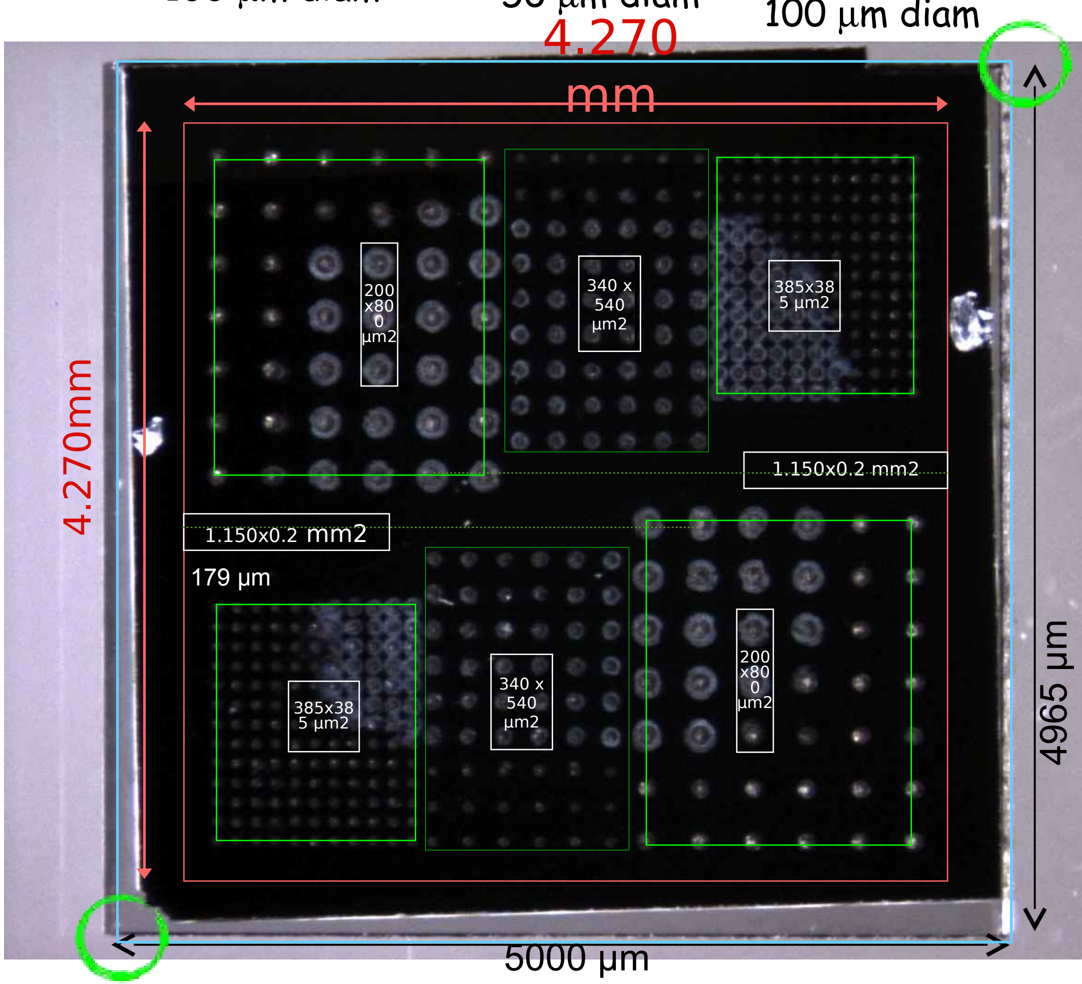
2. Laser drilling of holes (IIT)



7 x 6
300 µm pitch
100 µm diam

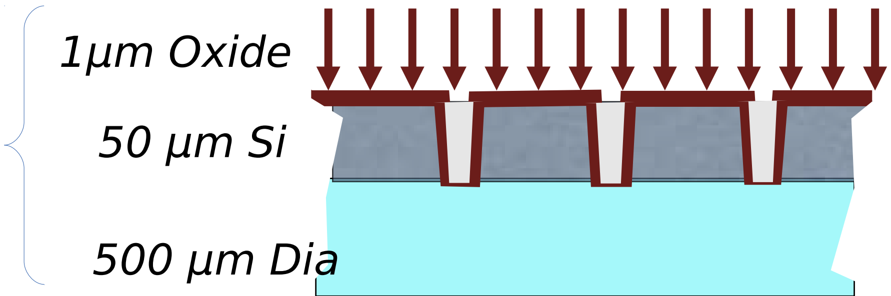
9 x 6
200 µm pitch
50 µm diam

7 x 6
300 µm pitch
100 µm diam



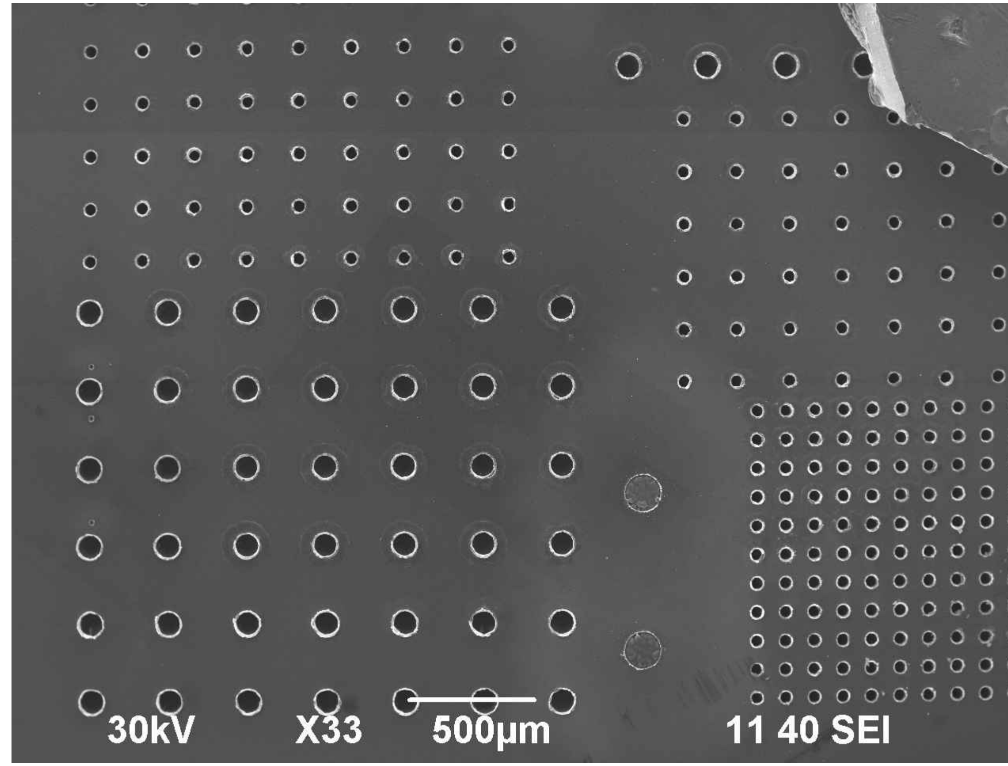
TSV matrices have been implemented. They differ for TSV diameters, pitches and diamond contact techniques.
At the center of each matrix the cluster of TSVs to be connected to the external preamplifier.
TSVs are connected together by metal masks (not visible)

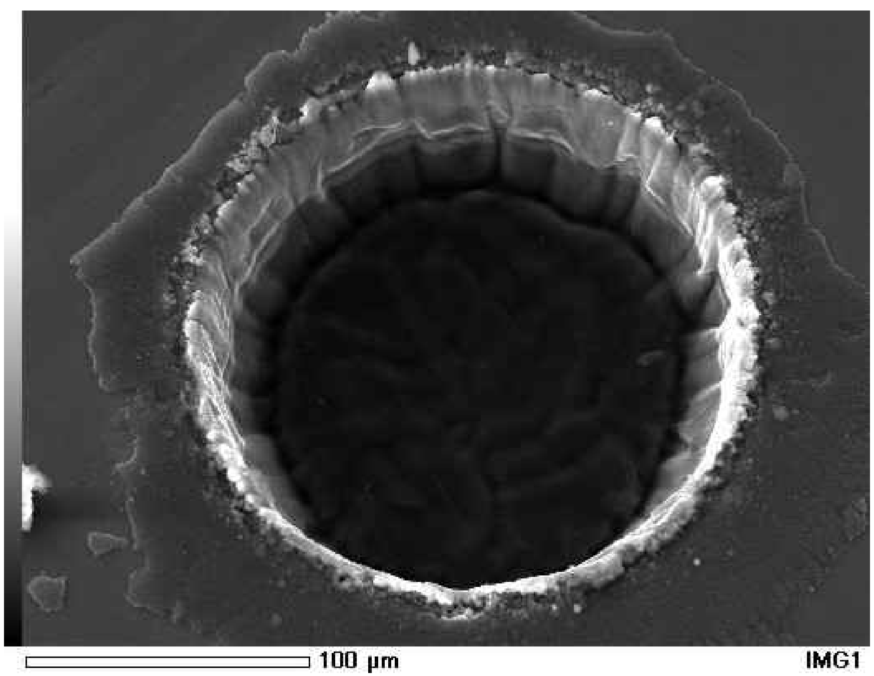
SOD prototype 0 (step 3)

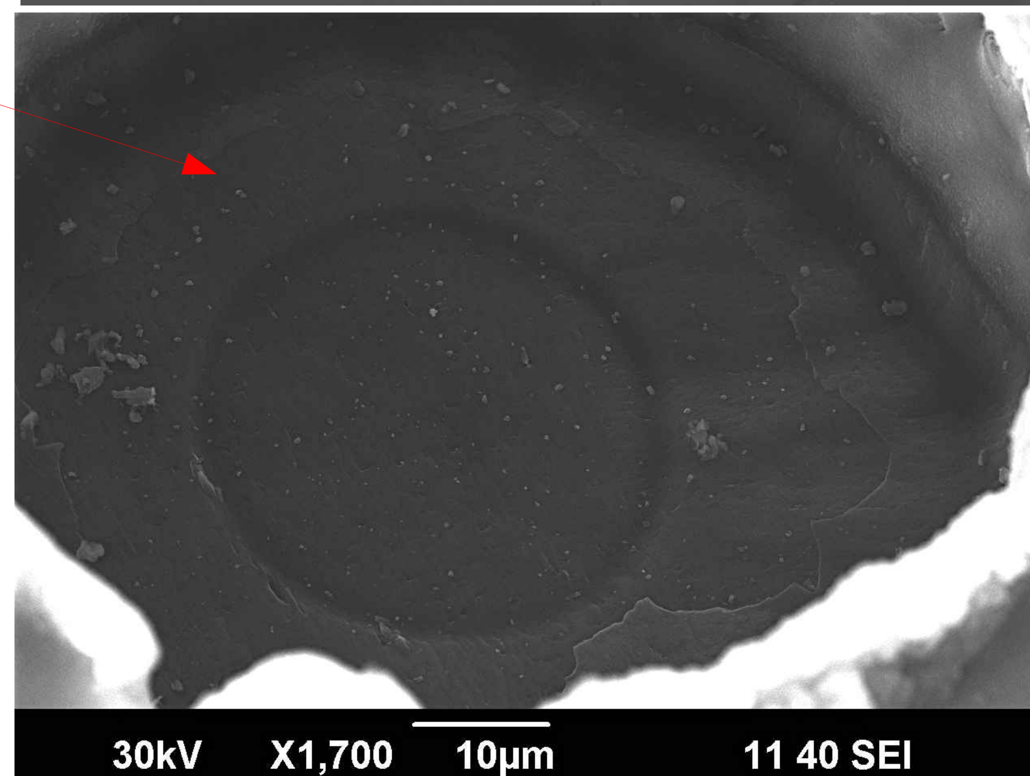


3. PECVD formation of a 1 µm SiO_2 layer

& removal of the oxide film at the bottom of the TSV (IIT)

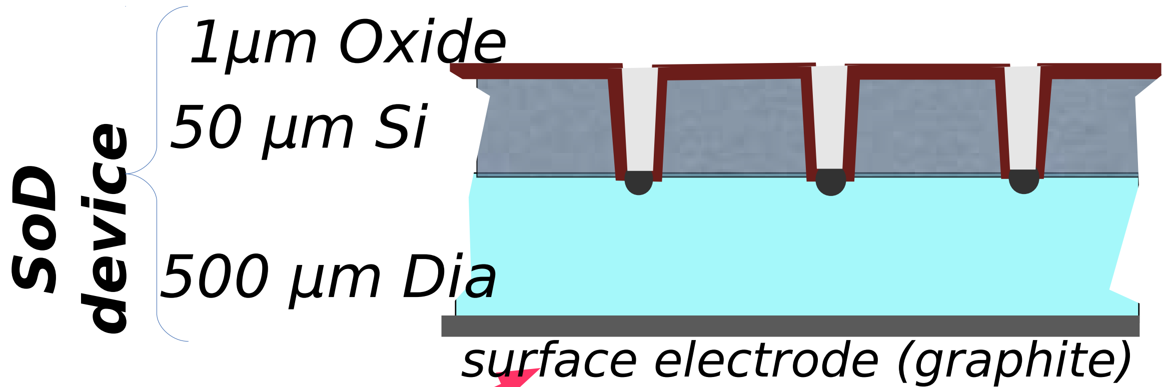


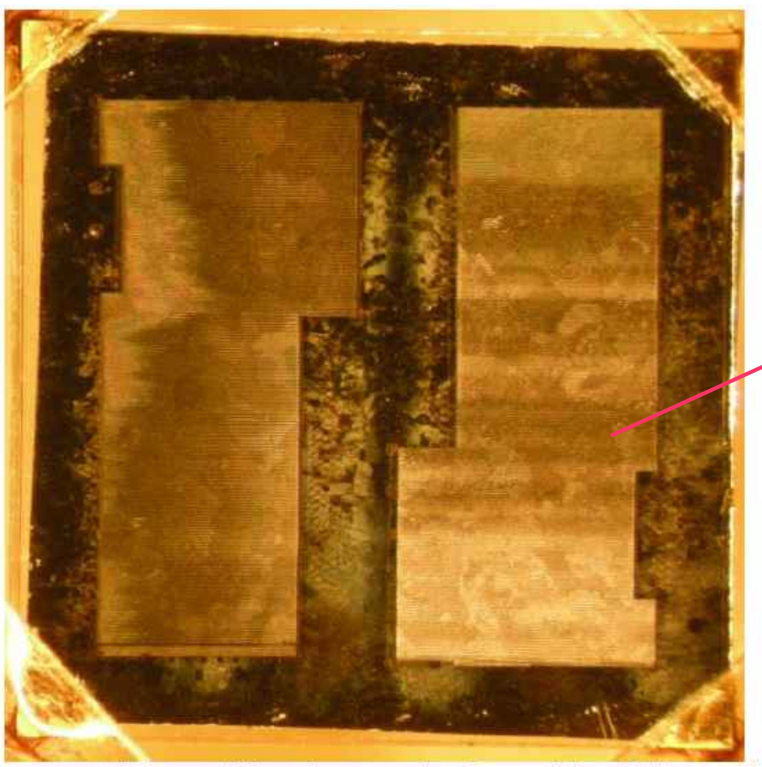




SOD prototype 0 (step 4)

4 Growth of ohmic contacts by nanosecond laser irradiation at the bottom of the TSV holes and on the diamond side (Florence)

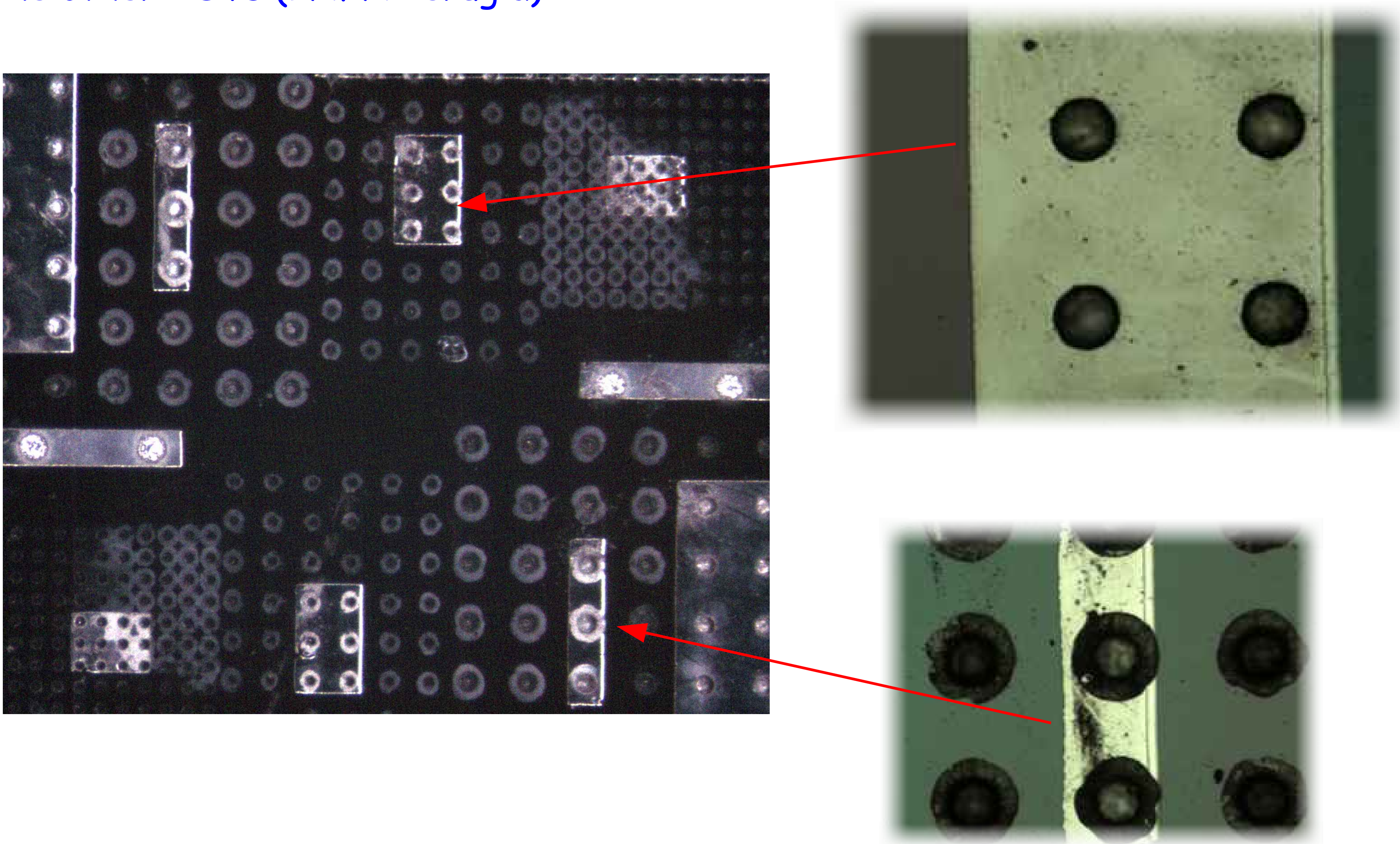




Graphitic surface contacts

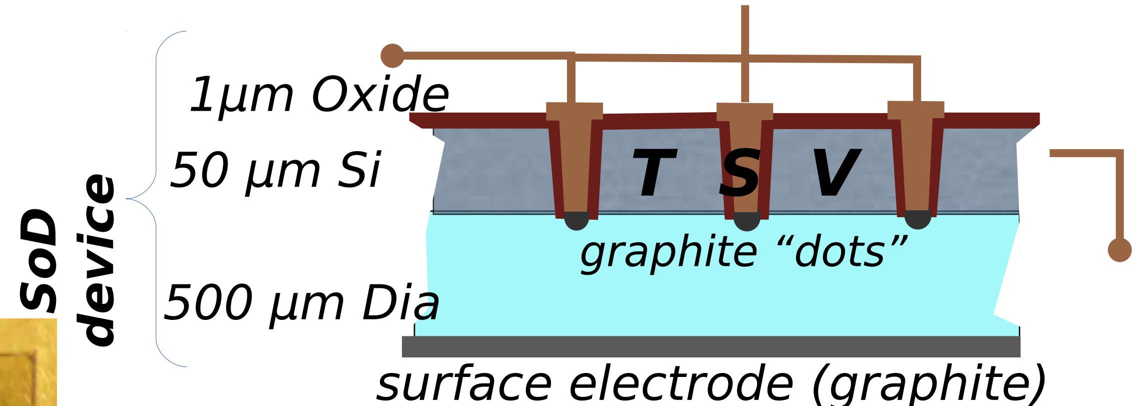
SOD prototype 0 (step 5)

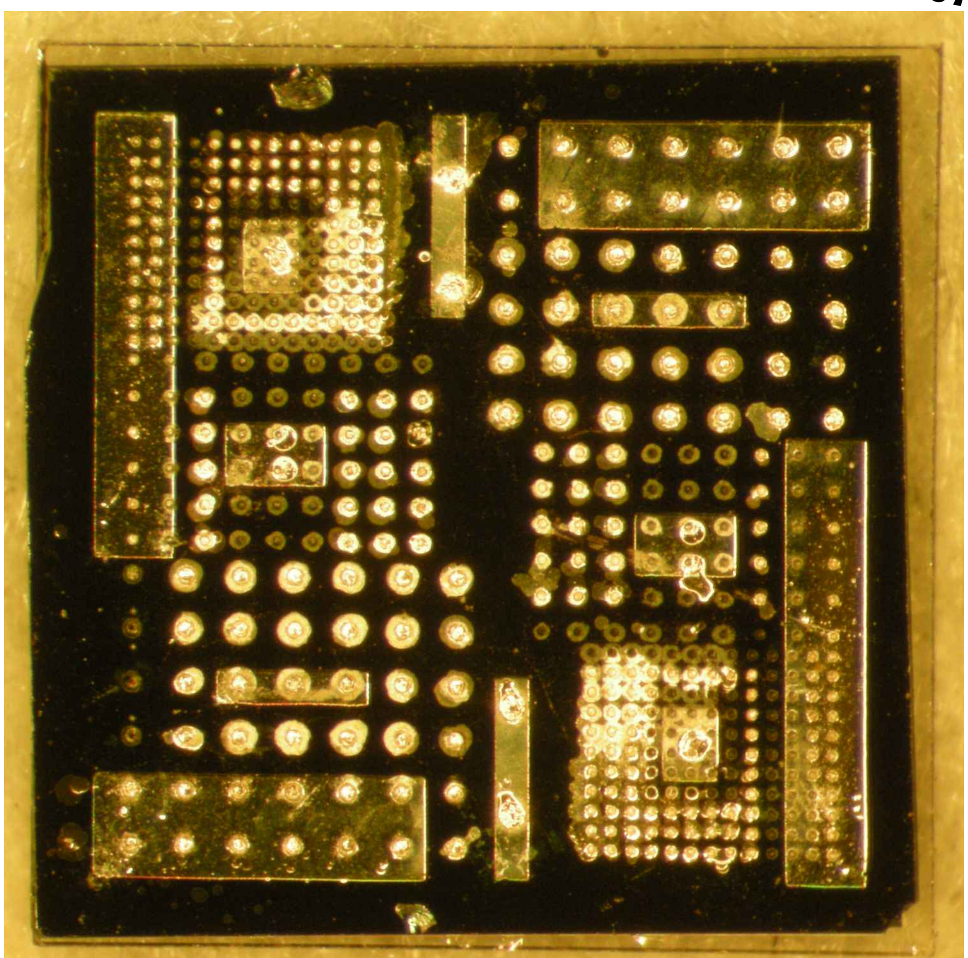
5 Al metallization of the TSV cluster to be connected to the PA and all the other TSVs (INFN Perugia)



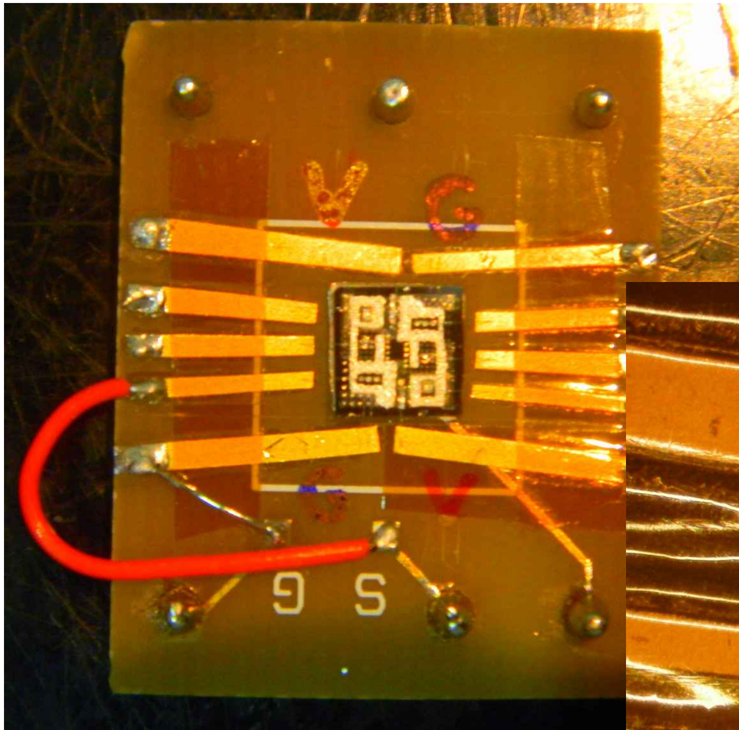
SOD prototype 0 (step 6)

6 Final step: filling of the TSV with Ag nanopowder and sintering at 220 °C, @ IIT

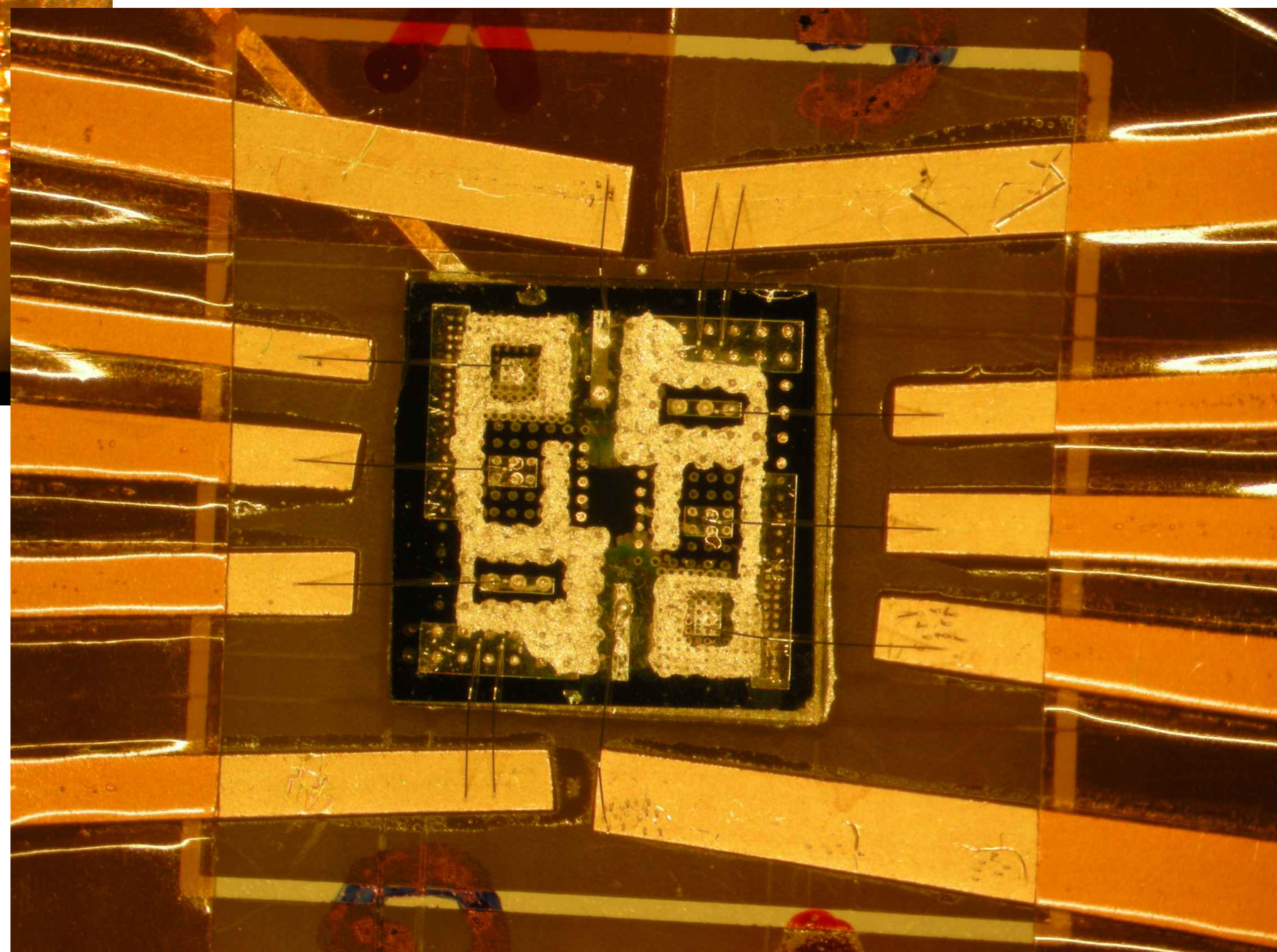


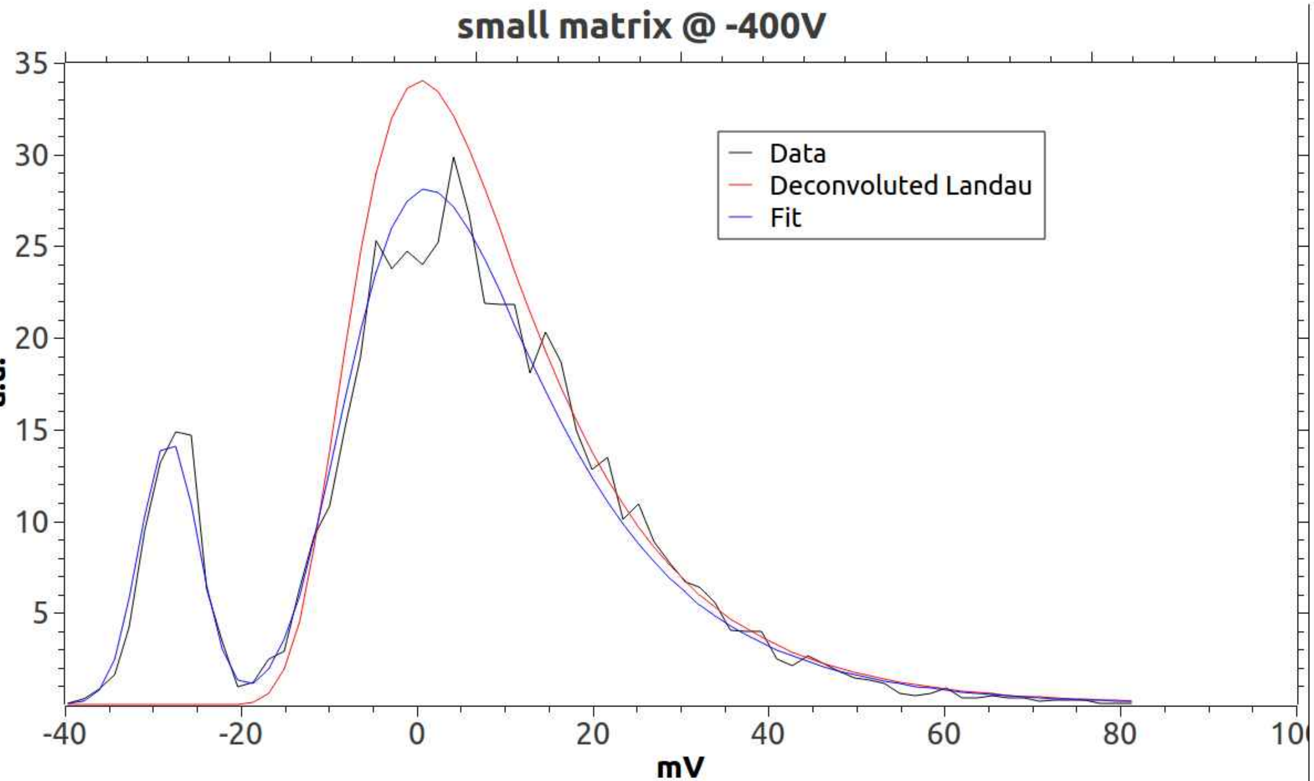


SOD prototype 0 Test with beta source



Test board

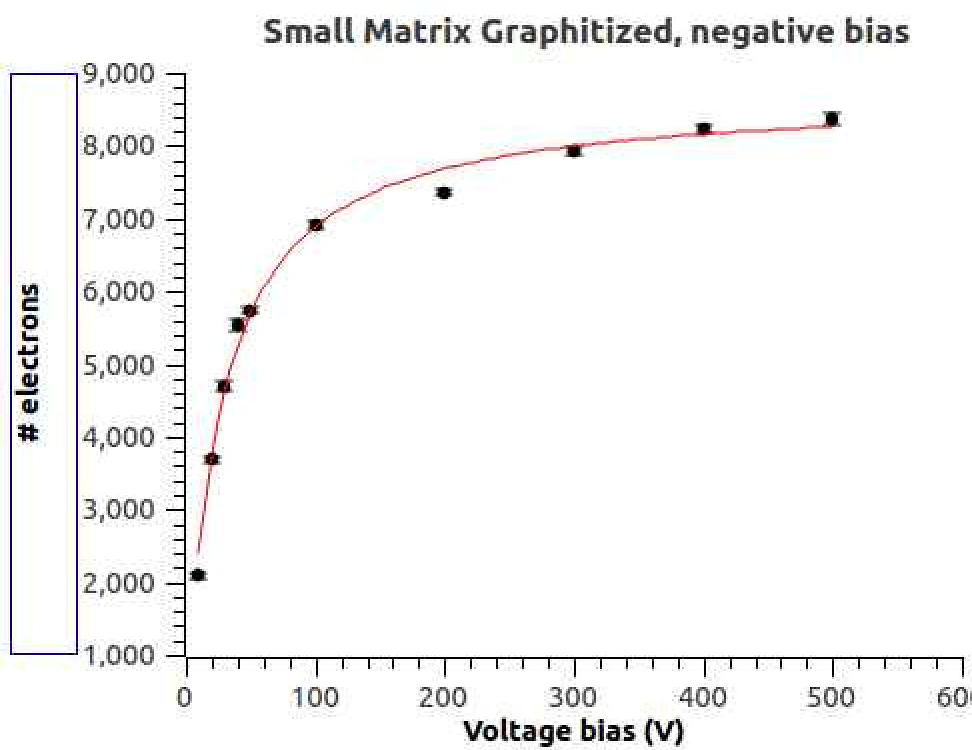


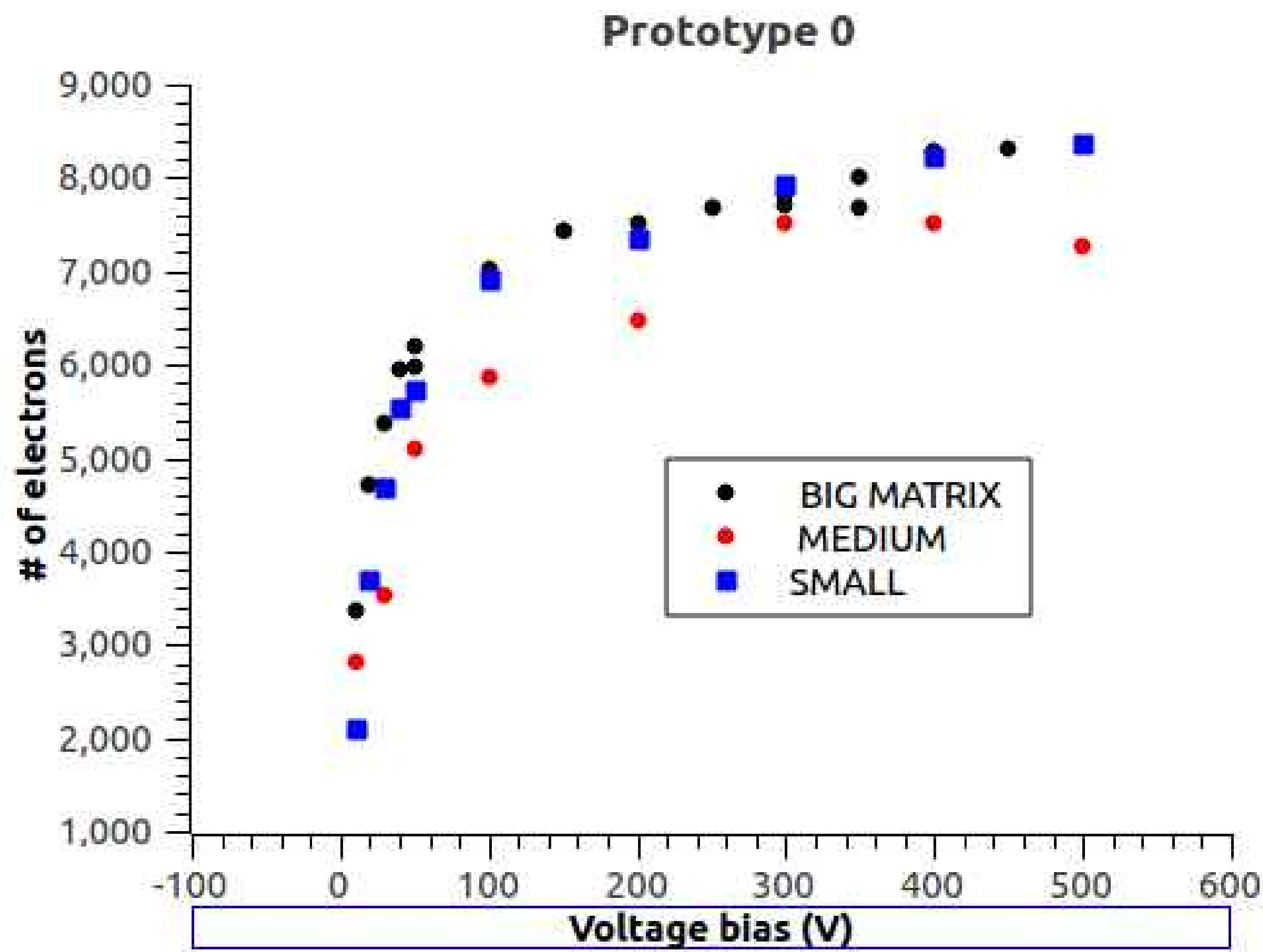


$$Q = A\frac{bV}{1+bV}$$

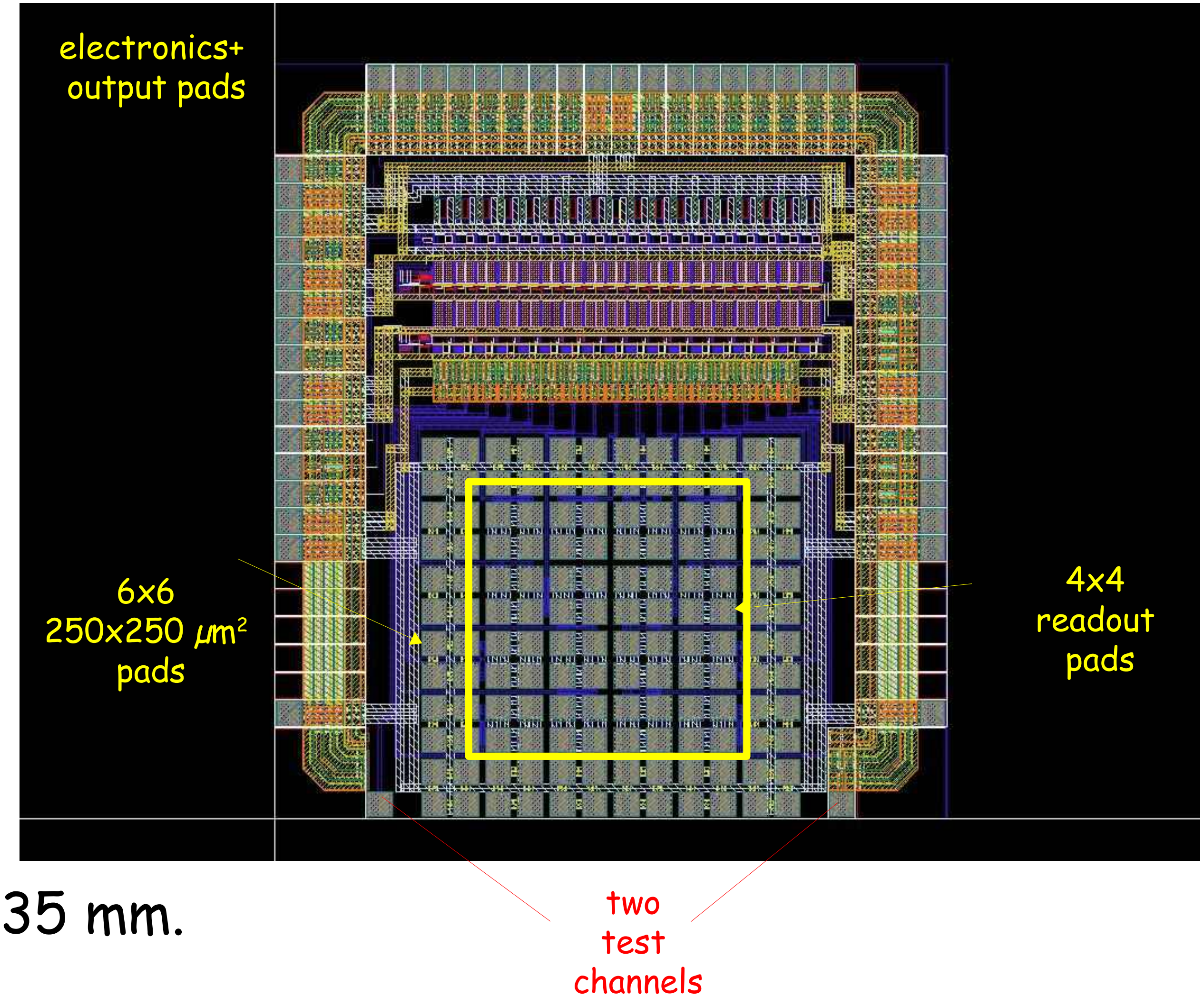
$$A = 8700 \pm 130 \quad e$$

$$b = 0.038 \pm 0.002$$




Prototype 0
# of electrons
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-100
0
100
200
300
400
500
600
Voltage bias (V)
BIG MATRIX
MEDIUM
SMALL

SOD prototype 1



Technology: CMOS 0.35 mm.

Size: 2.9 x 3.1 mm^2 .

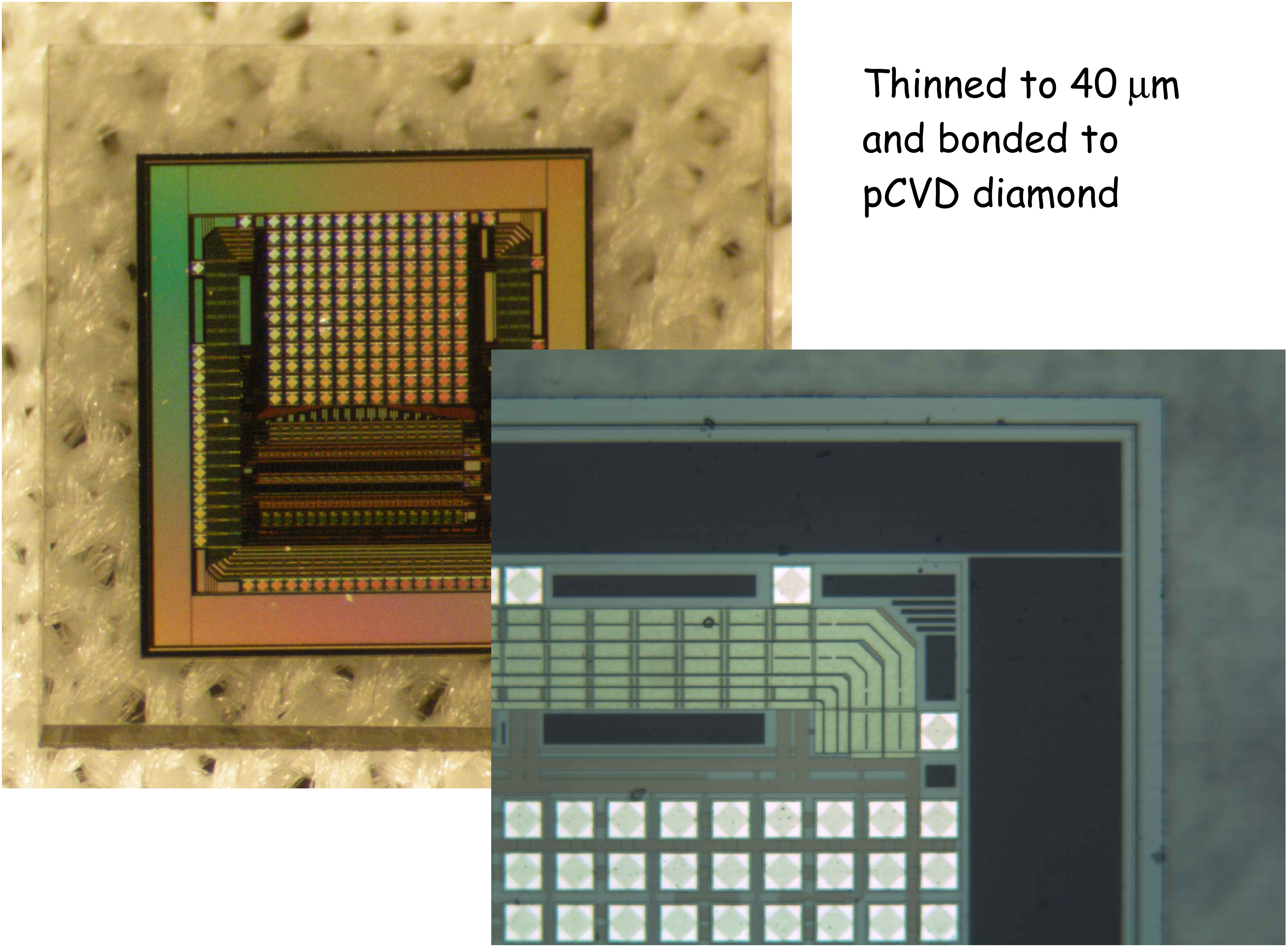
18 channels. 16 are to be connected to diamond by TSV and the remaining two are for test purpose

Overall gain: 150 mV/fC

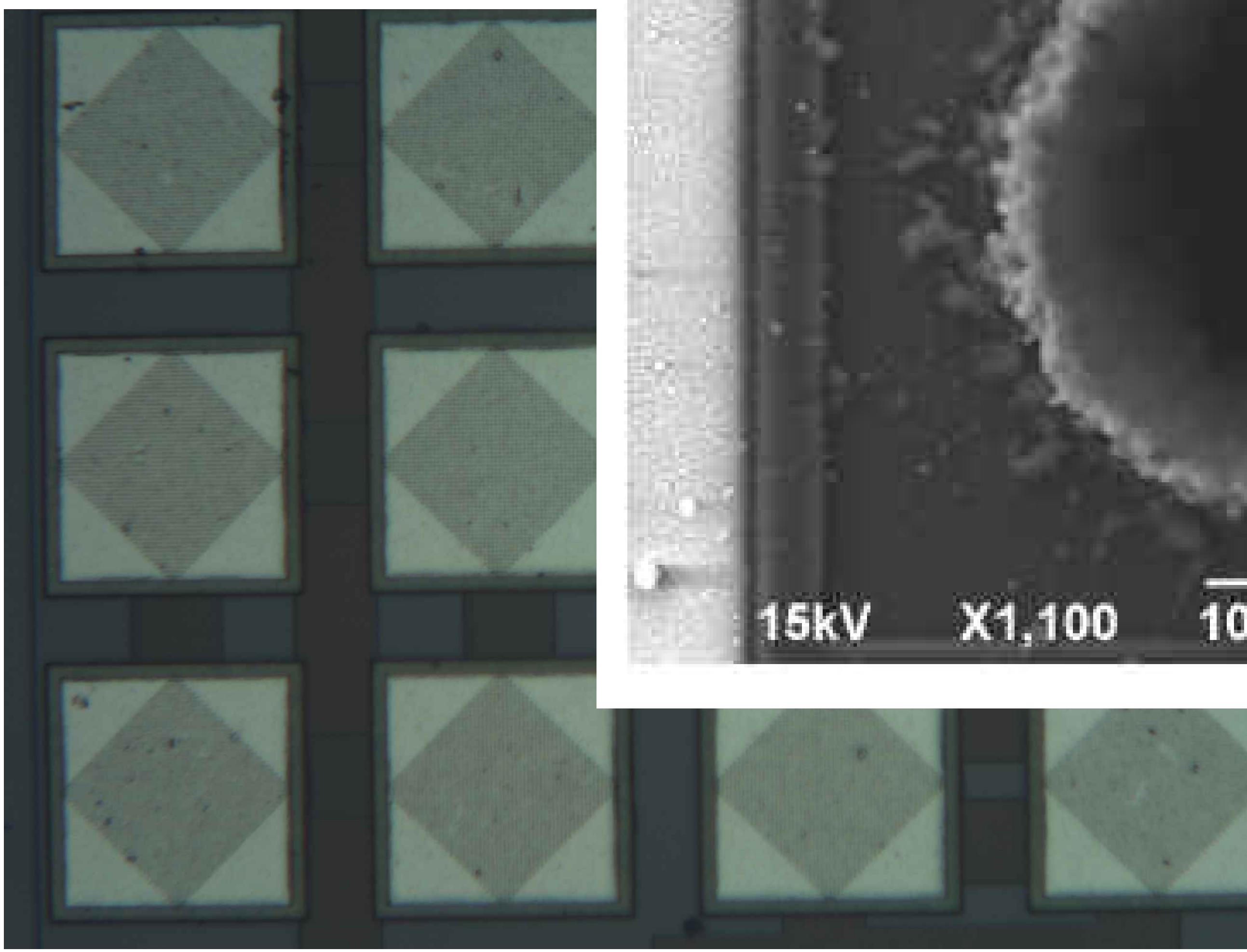
Peaking time: 500 ns

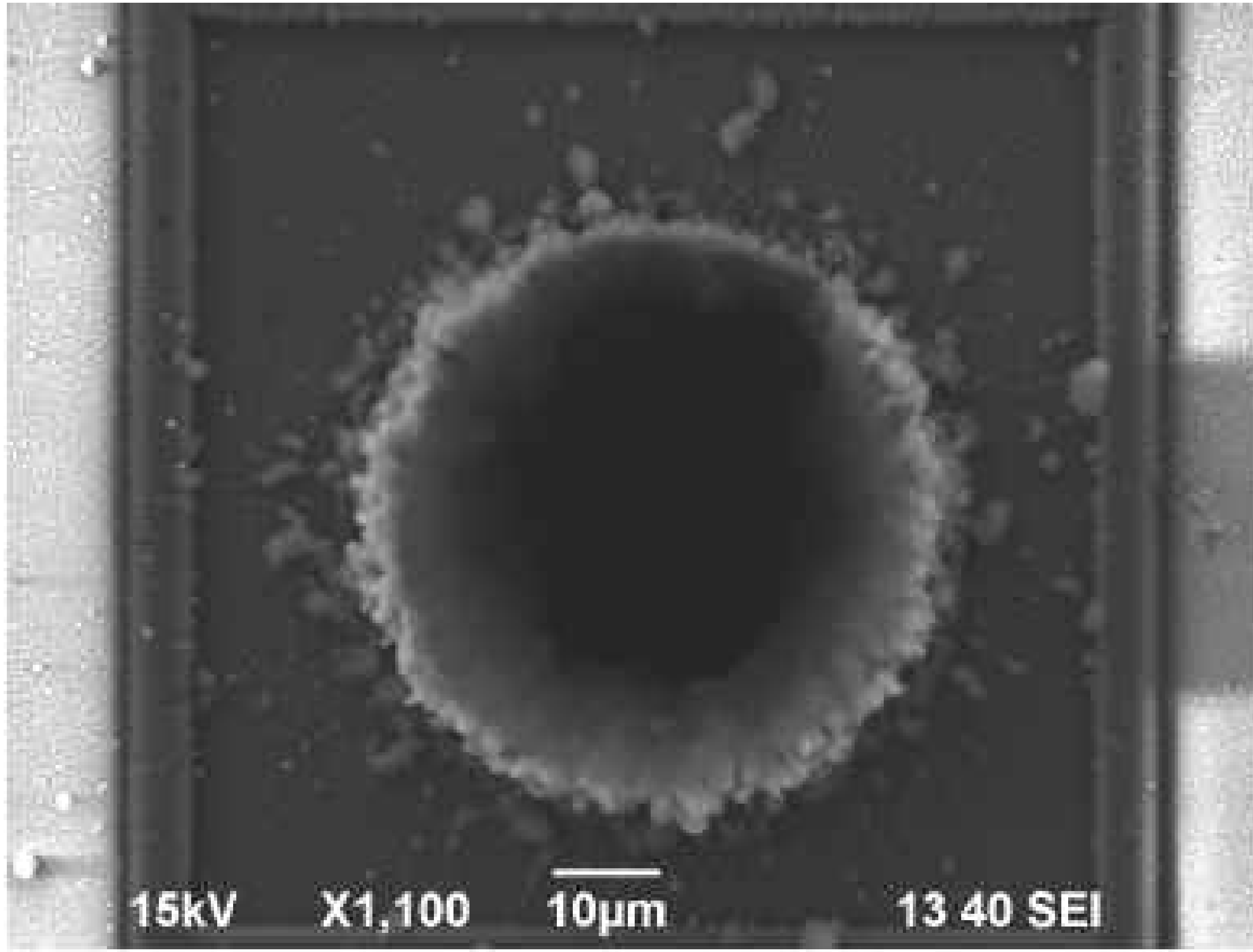
ENC= 135 e+ 33 e/pF

Thinned to 40 μm
and bonded to
pCVD diamond



TSV are underway @ iit

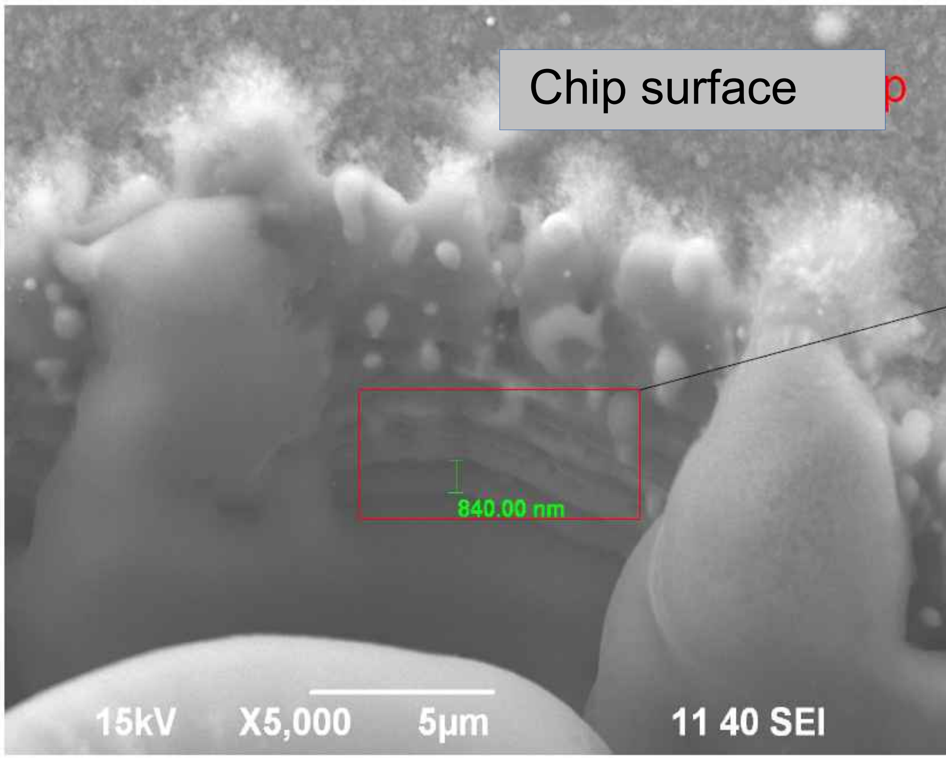


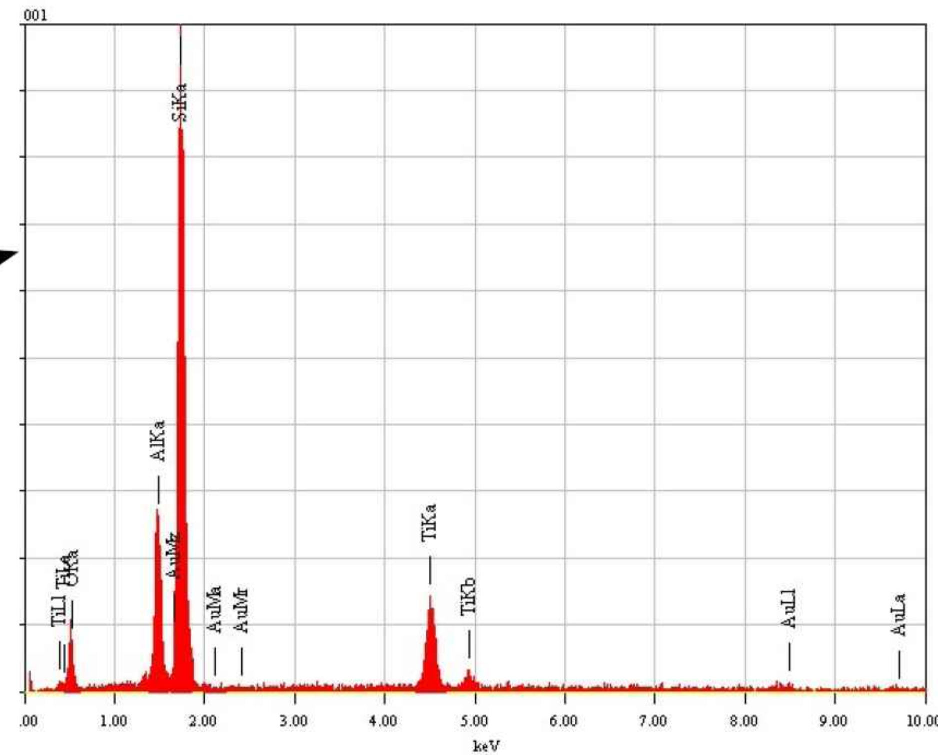


iit
istituto italiano di tecnologia

Each pad has 4 metal layers
ASIC 350 nm architecture

COMPOSITIONAL ANALYSIS





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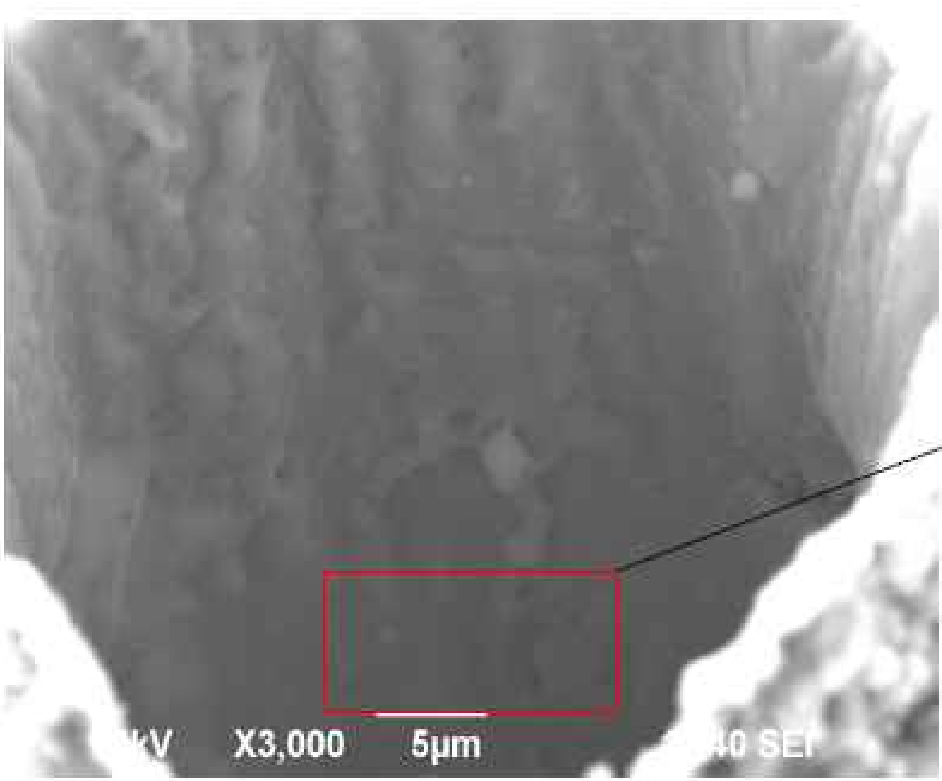
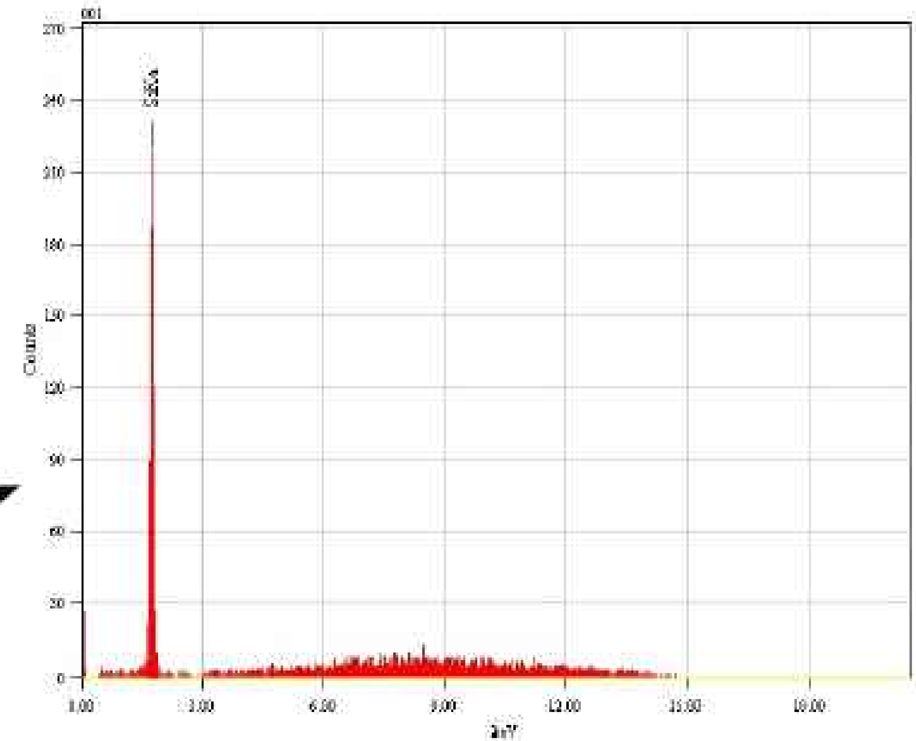
Only silicon at the bottom of the drilled hole

COMPOSITIONAL ANALYSIS

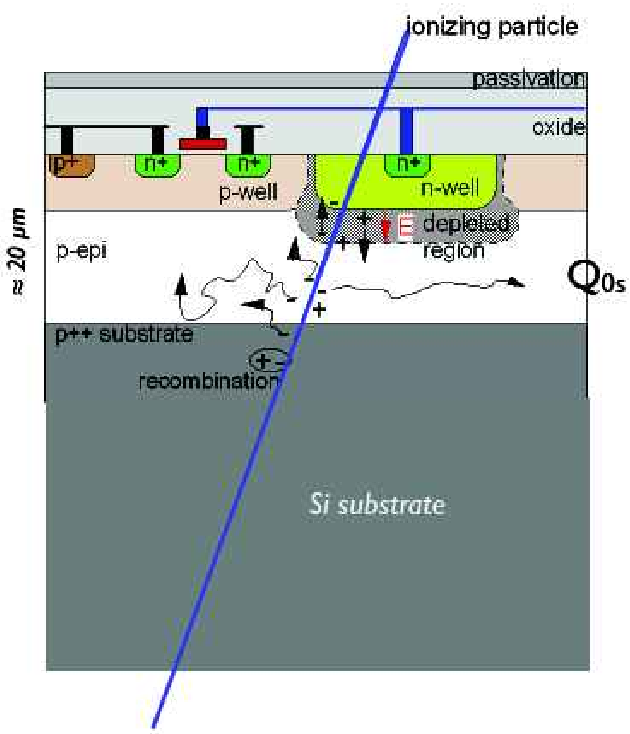




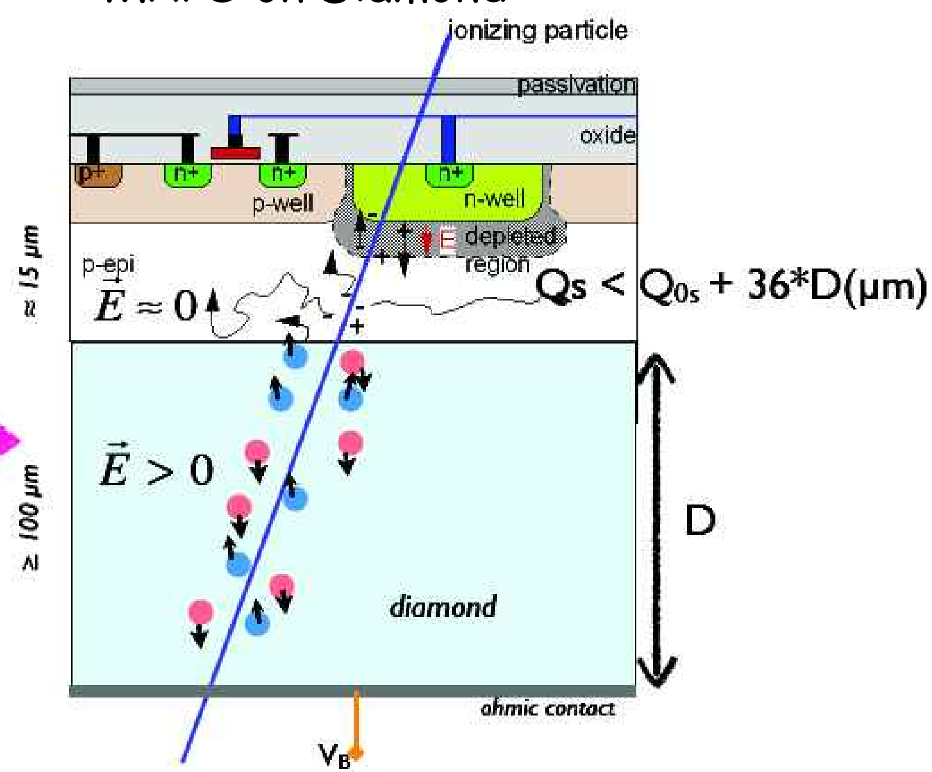
Monolithic Active Pixel Sensor On Diamond ?

In order to increase the MIP signal we are thinning RAPS03 chips down to about 25 μm in order to bond them to a diamond substrate, which when electrically biased can inject charges in proximity of the potential well

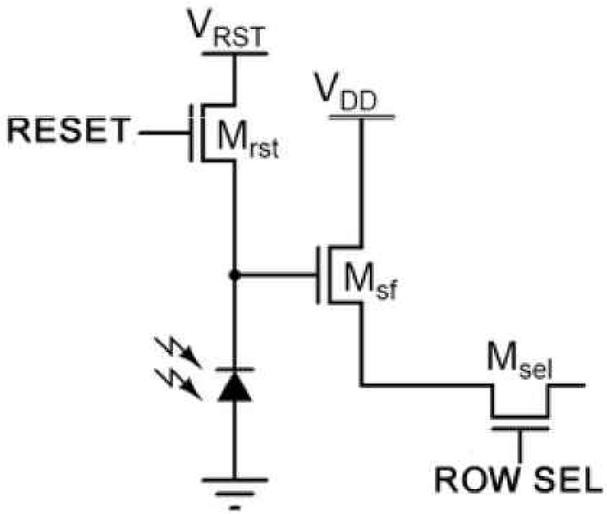
Monolithic Active Pixel Sensor (MAPS)

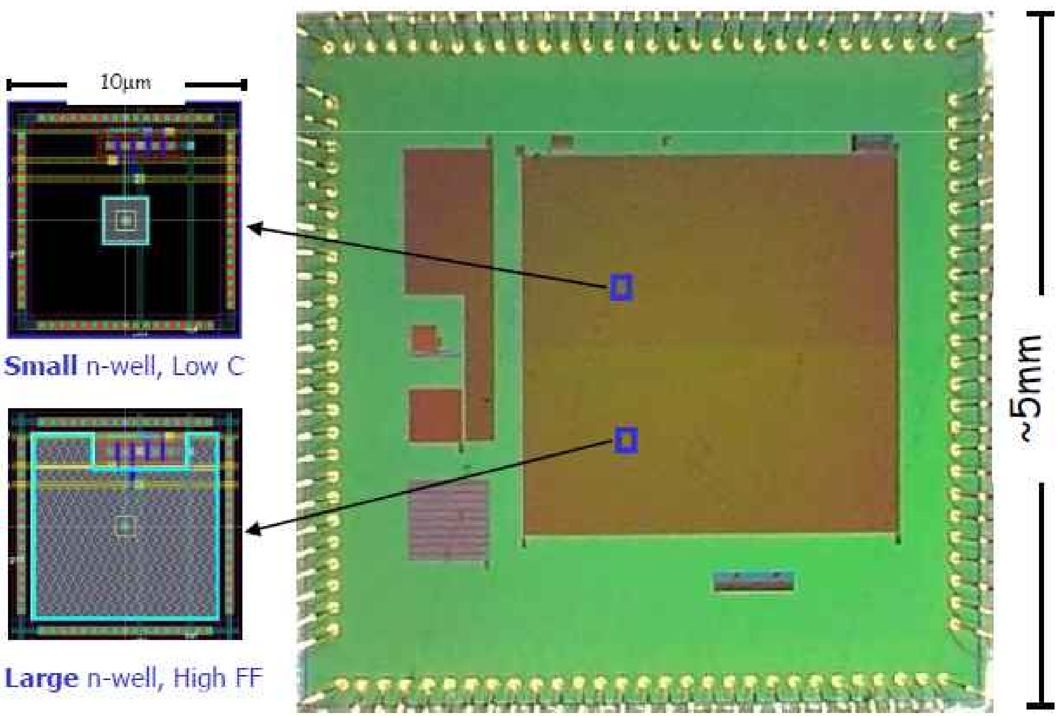


MAPS on Diamond



RAPS03 Monolithic Active Pixel Sensor On Diamond





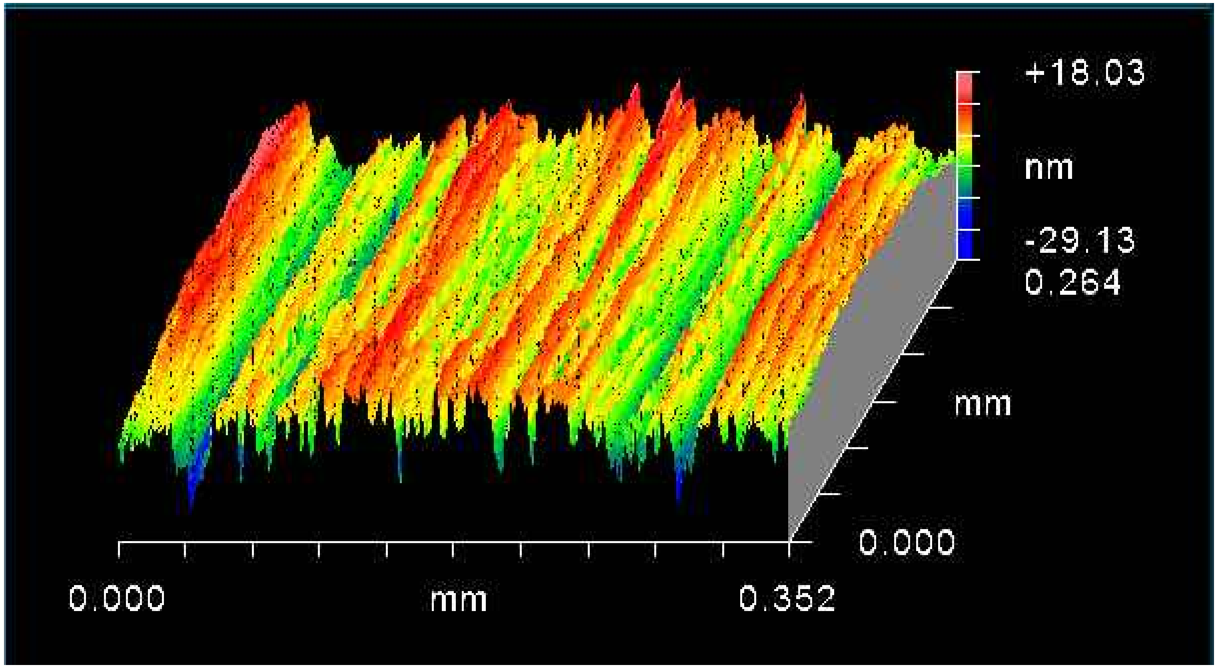
256x256 pixel matrix (10x10 μm)

Four 128x128 submatrices.

Two submatrices have a small Photodiode: 4% of pixel surface) to minimize the sensing capacitance

The other two have a large photodiode (77% of the pixel surface) to maximize the sensing area.

The estimated effctive diffusion region is below 30 μm;

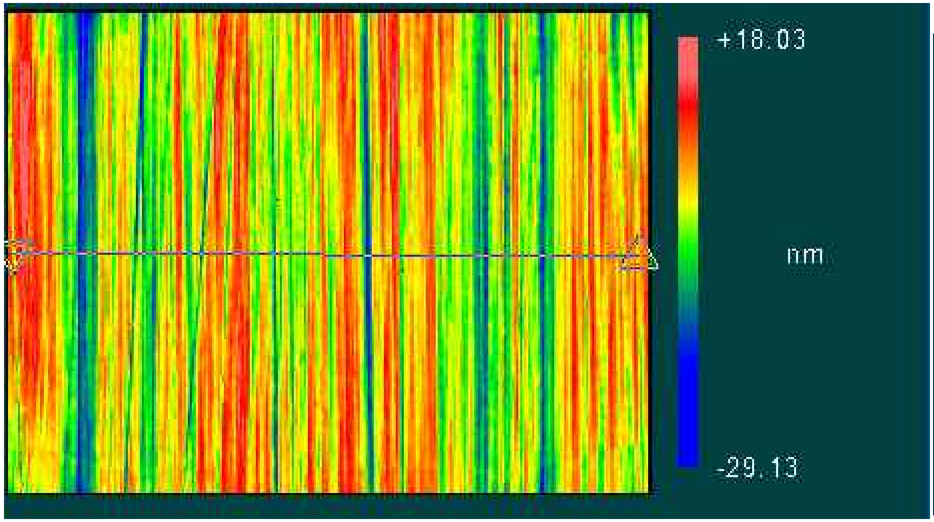


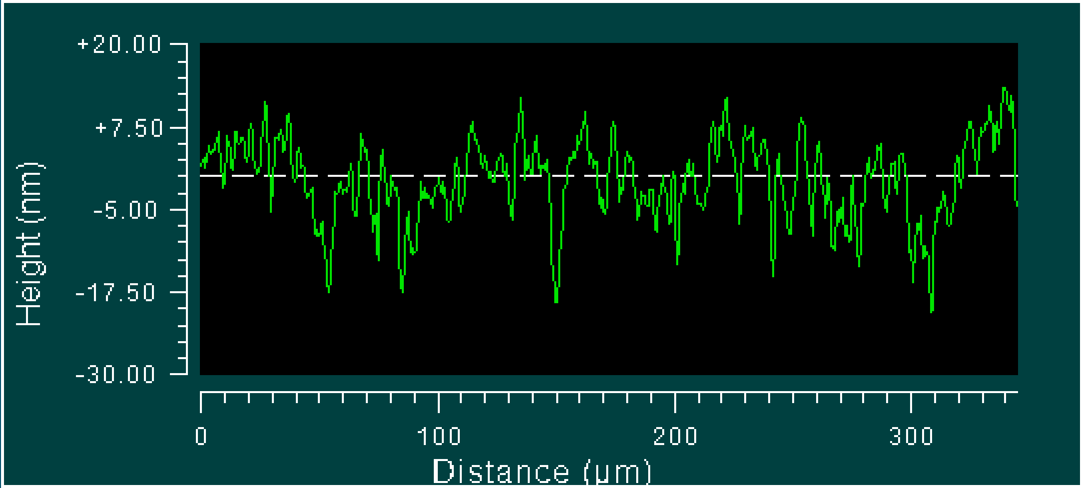
RAPS thinned @ 25 & 20 μm

Backside profilometry

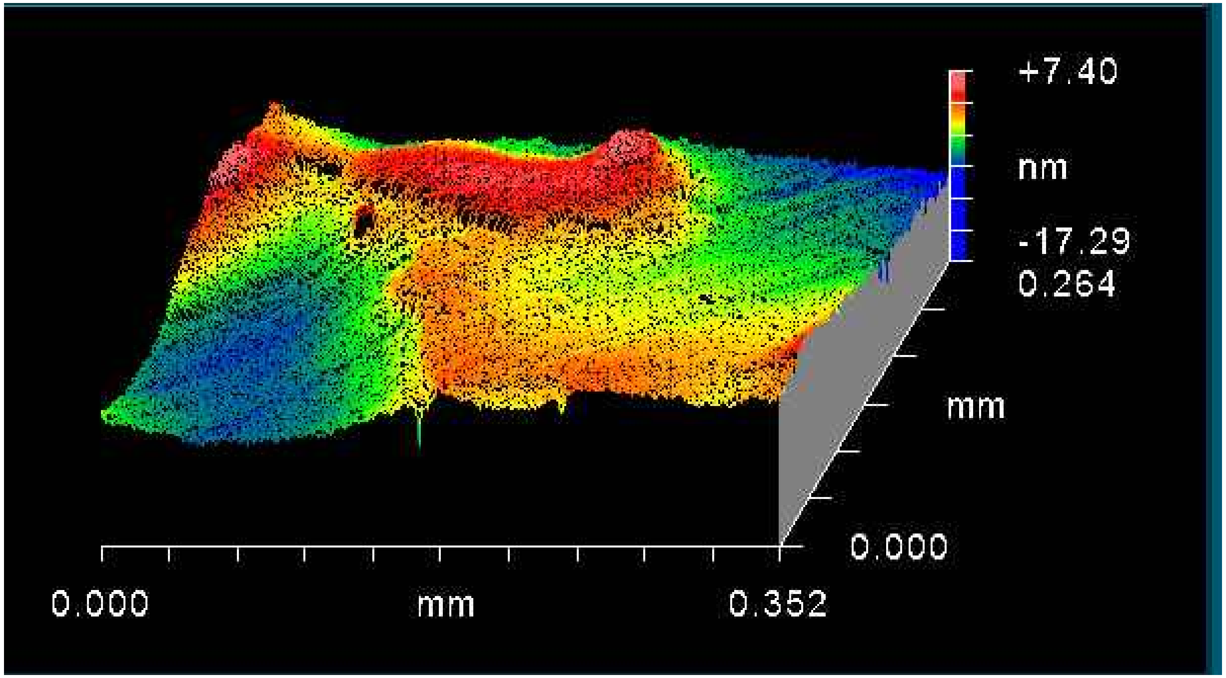
R_a ~4 nm

Peaktopeak~50 nm

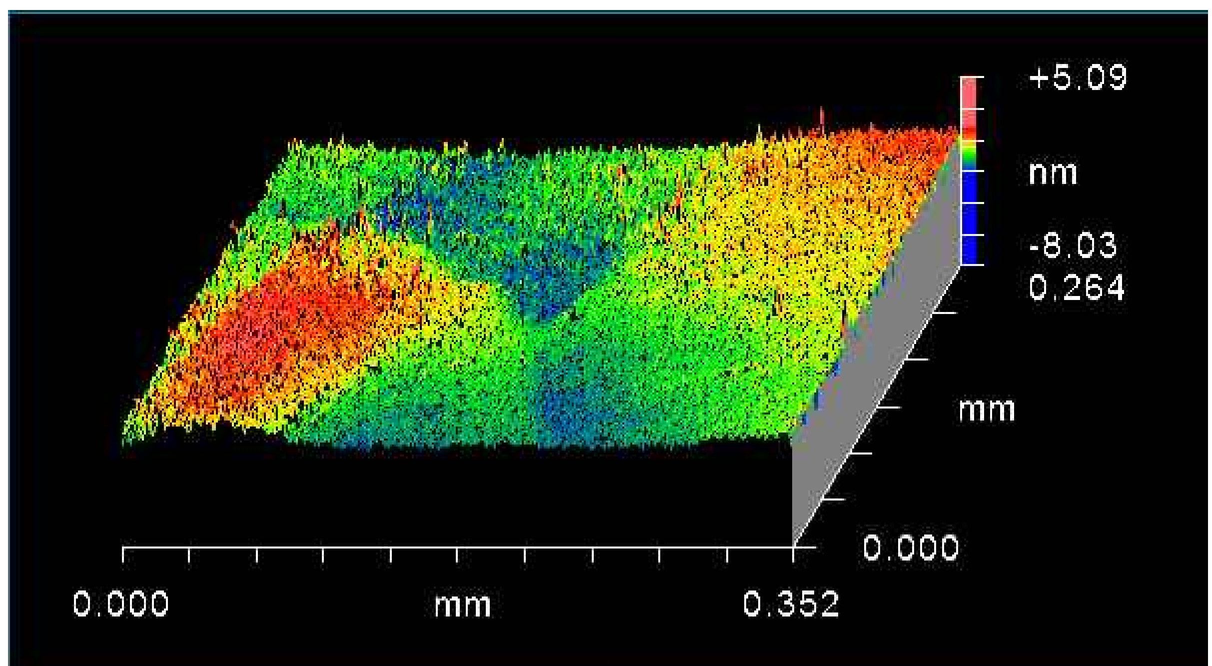




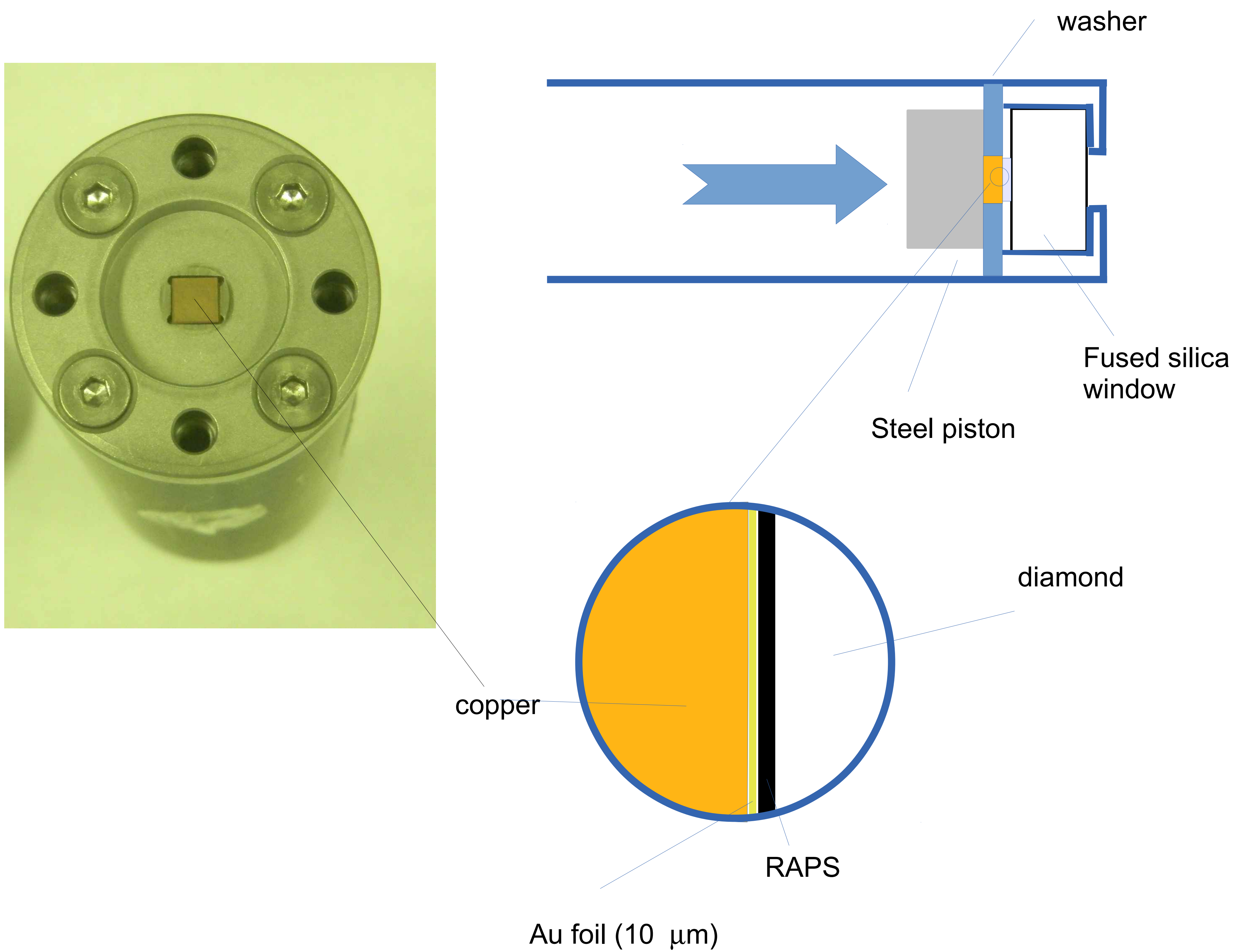
Choose the best polished pCVD diamond



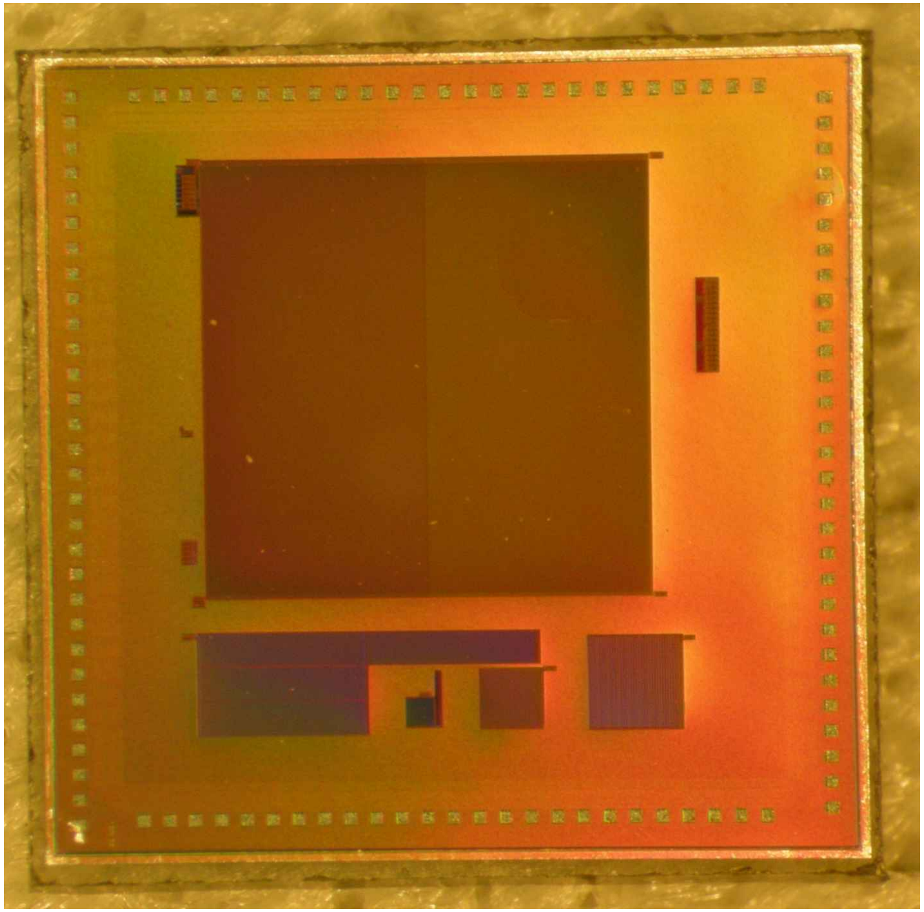
Good



Very Good



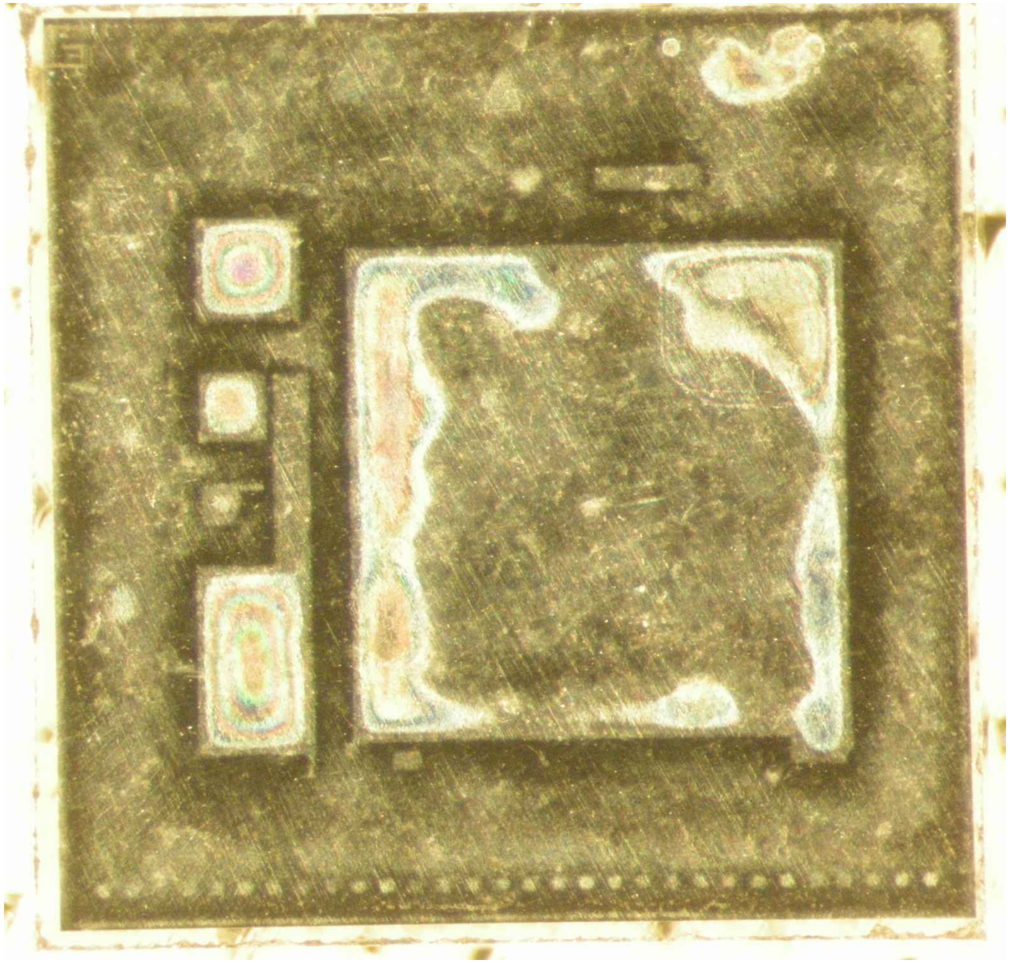
washer
Fused silica
window
Steel piston
diamond
copper
RAPS
Au foil (10 µm)



RAPS thinned @ 25 μm bonded on diamond (SOD_40)

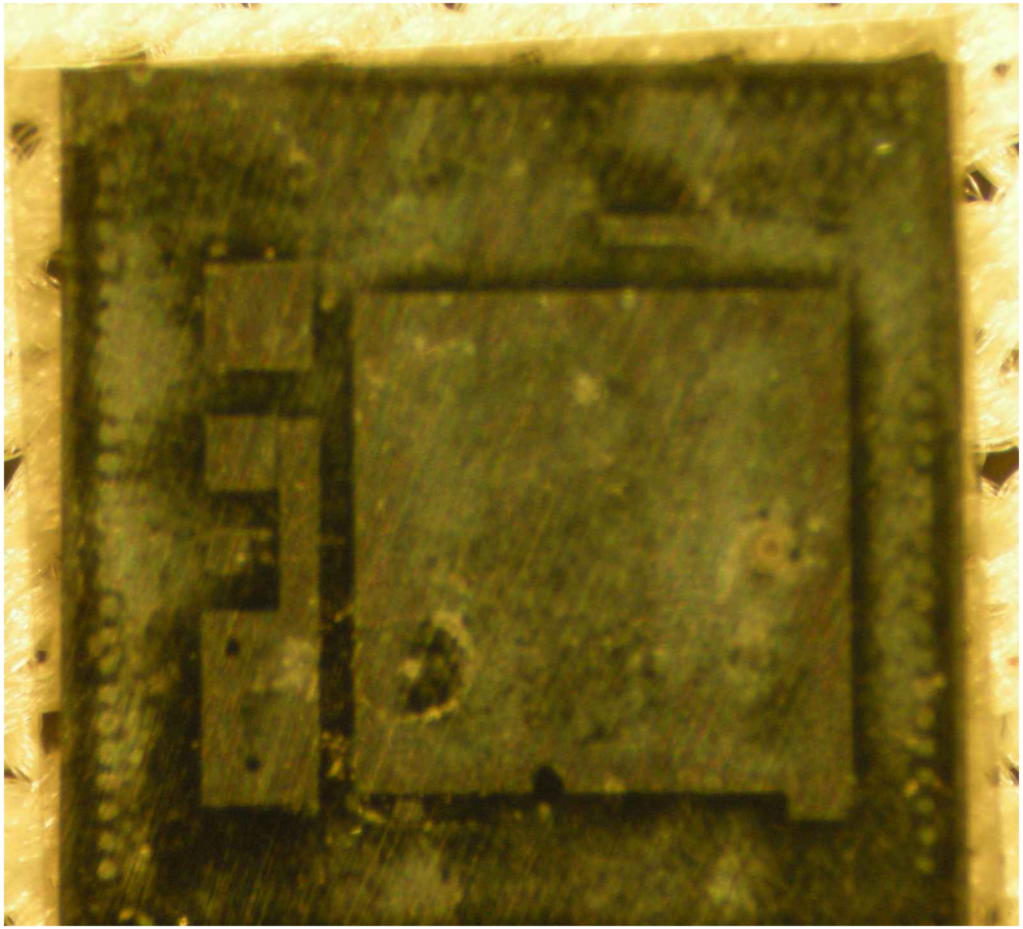
Adhesion

SOD_40



Without Au buffer

SOD_41

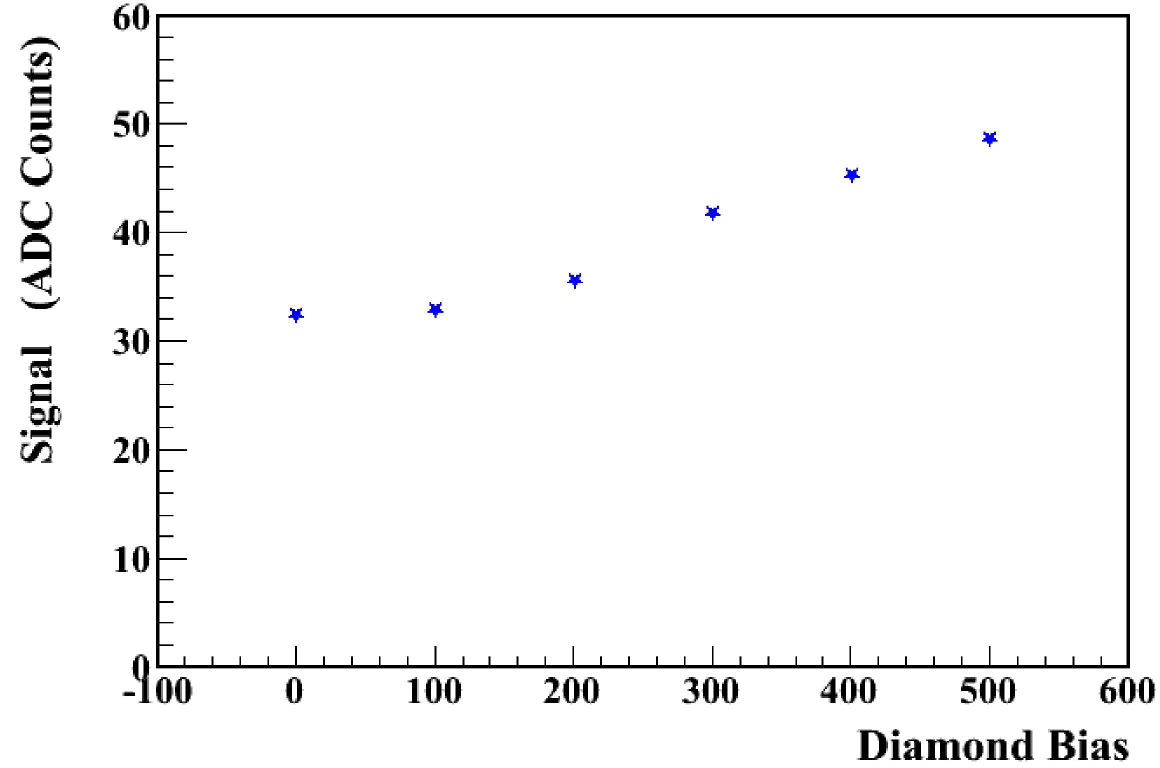


Au buffer

TESTS ON SOD_40

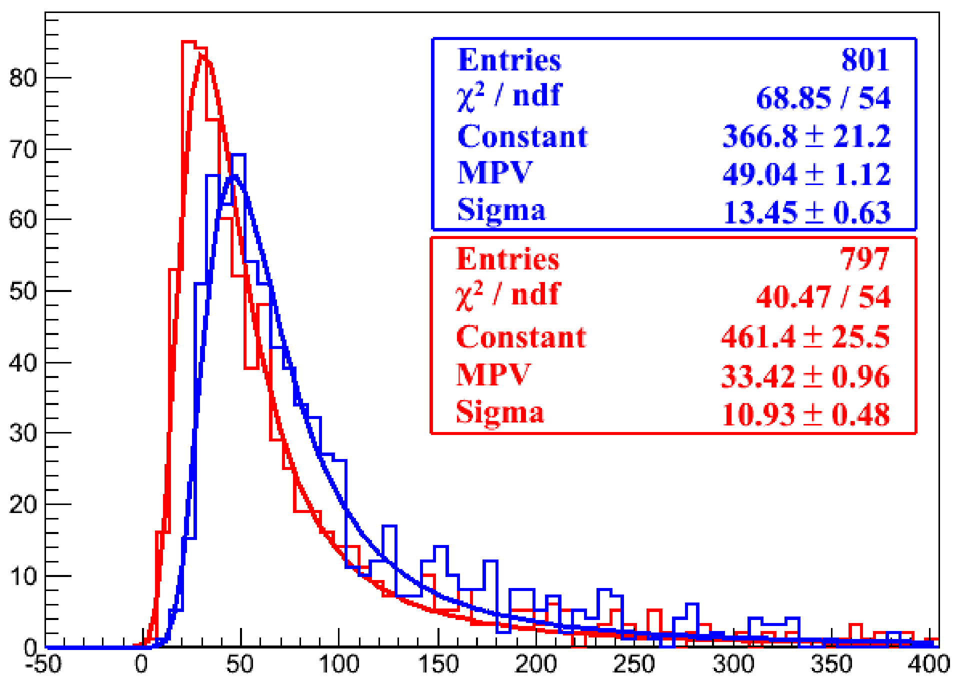
^{90}Sr beta irradiation

3x3 pixel matrix



Response to beta

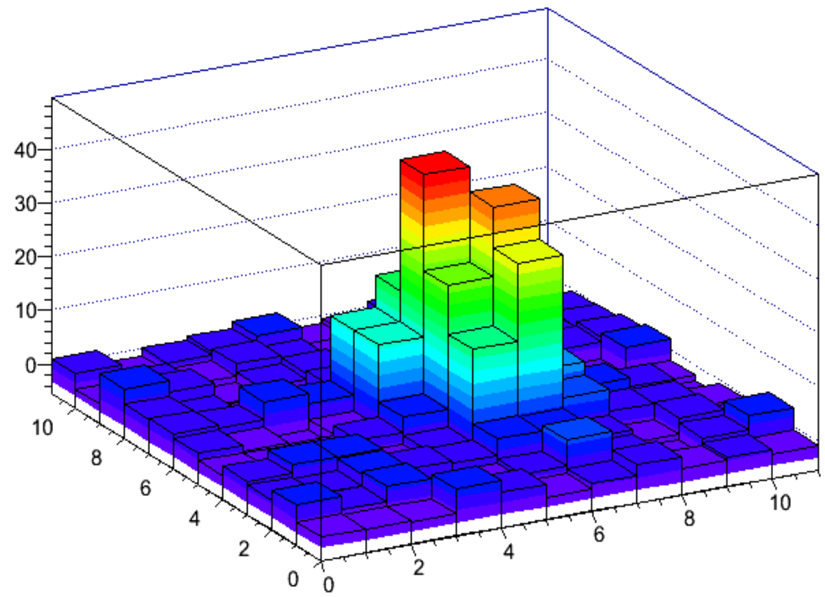
@ 0V (red) & 500 V (blue)

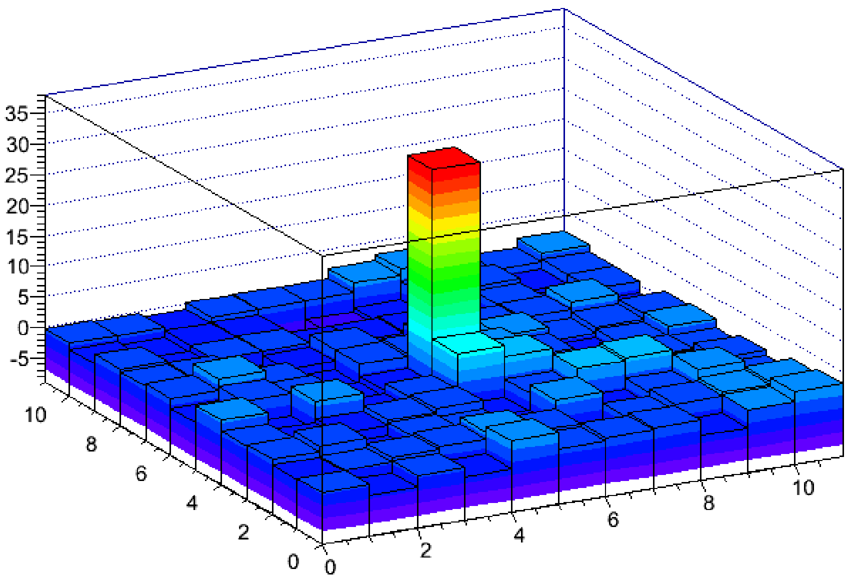


Response to beta vs. bias voltage

TESTS ON SOD_40

^{90}Sr beta irradiation



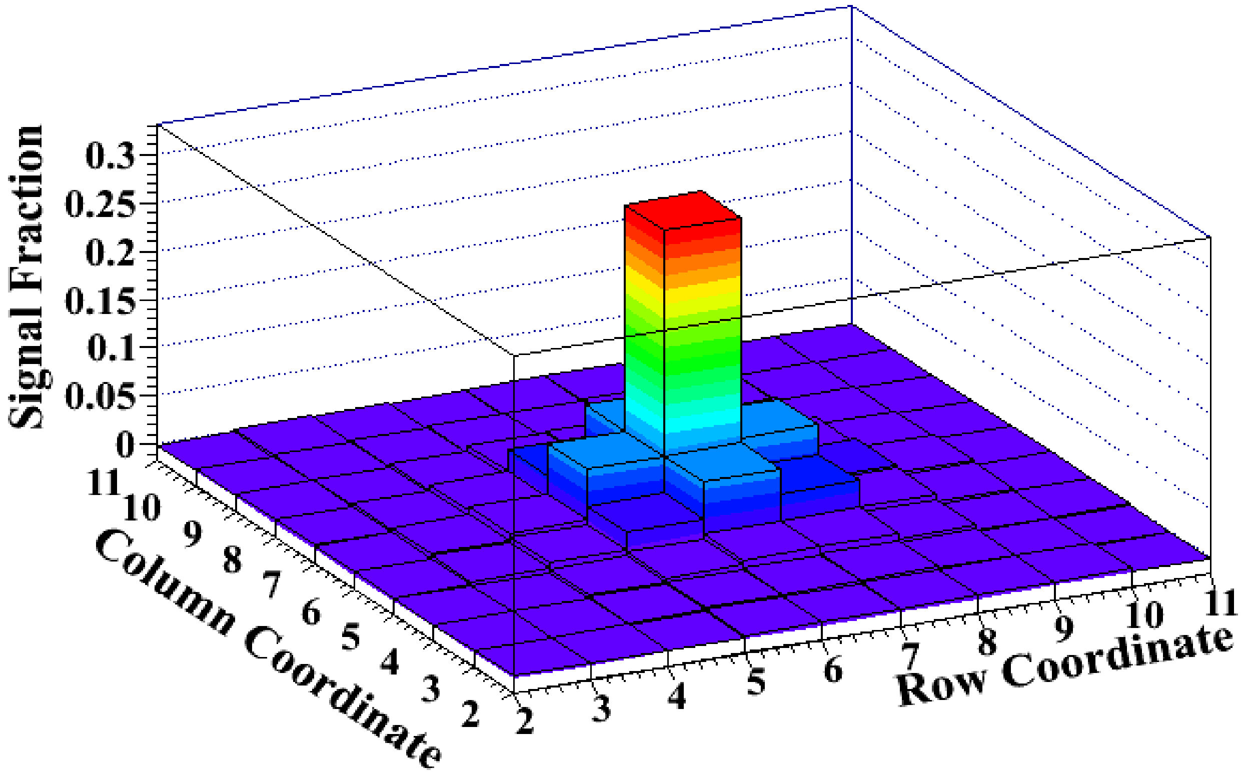


SOD_40: Two events @ 0V,
one with only one pixel and one with several pixels

TESTS ON SOD_40

^{90}Sr beta irradiation

@ 0 V



Fraction of signal @ 0 V for a 9 x9 matrix around the pixel more hit (30 %) .

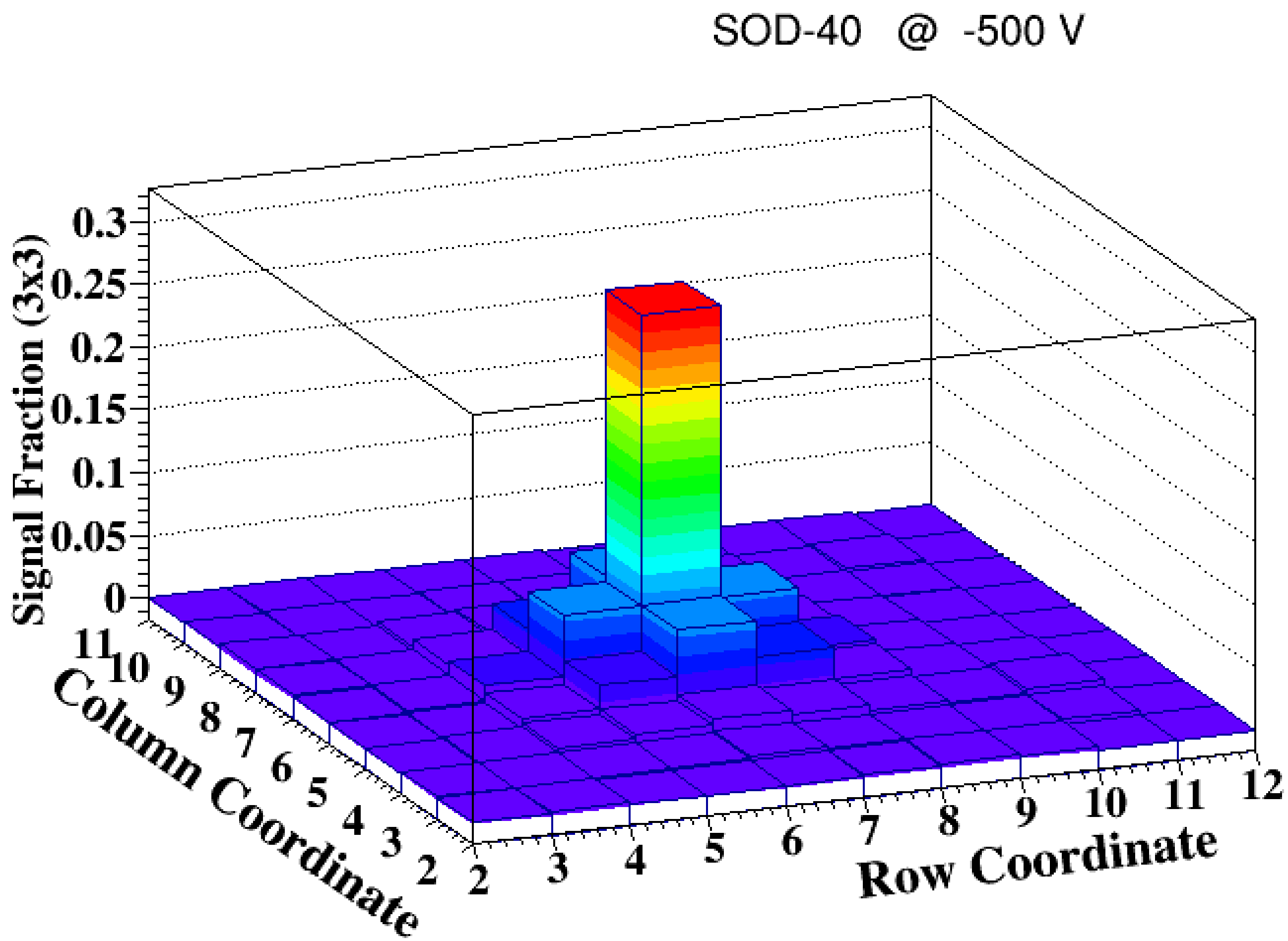
In practise, the 7x7 sum yields most of the signal

This shows that a limited amount of pixel is needed to obtain the total collected charge

TESTS ON SOD_40

^{90}Sr beta irradiation

@ -500 V



Fraction of signal @ 500 V for a 9 x9 matrix around the pixel more hit (30 %) .

Silicon On Diamond Research

Thank you for your attention!

INO-CNR

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