# Silicon On Diamond Detectors Project

INO-CNR

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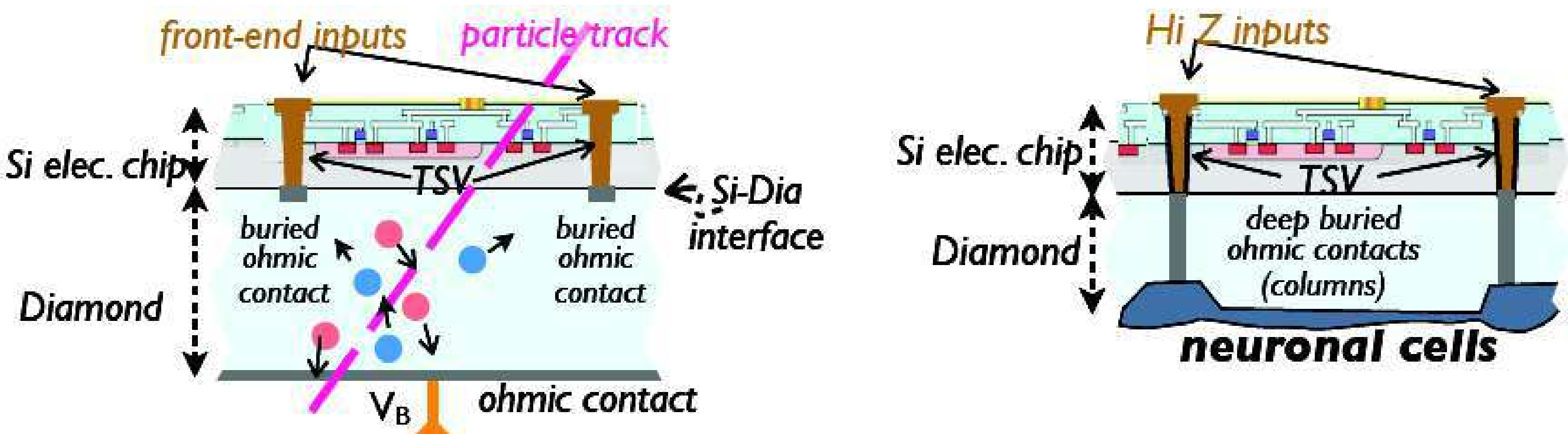
**Darmstadt, December 16-18**

# CHIPSODIA aims at two prototypes



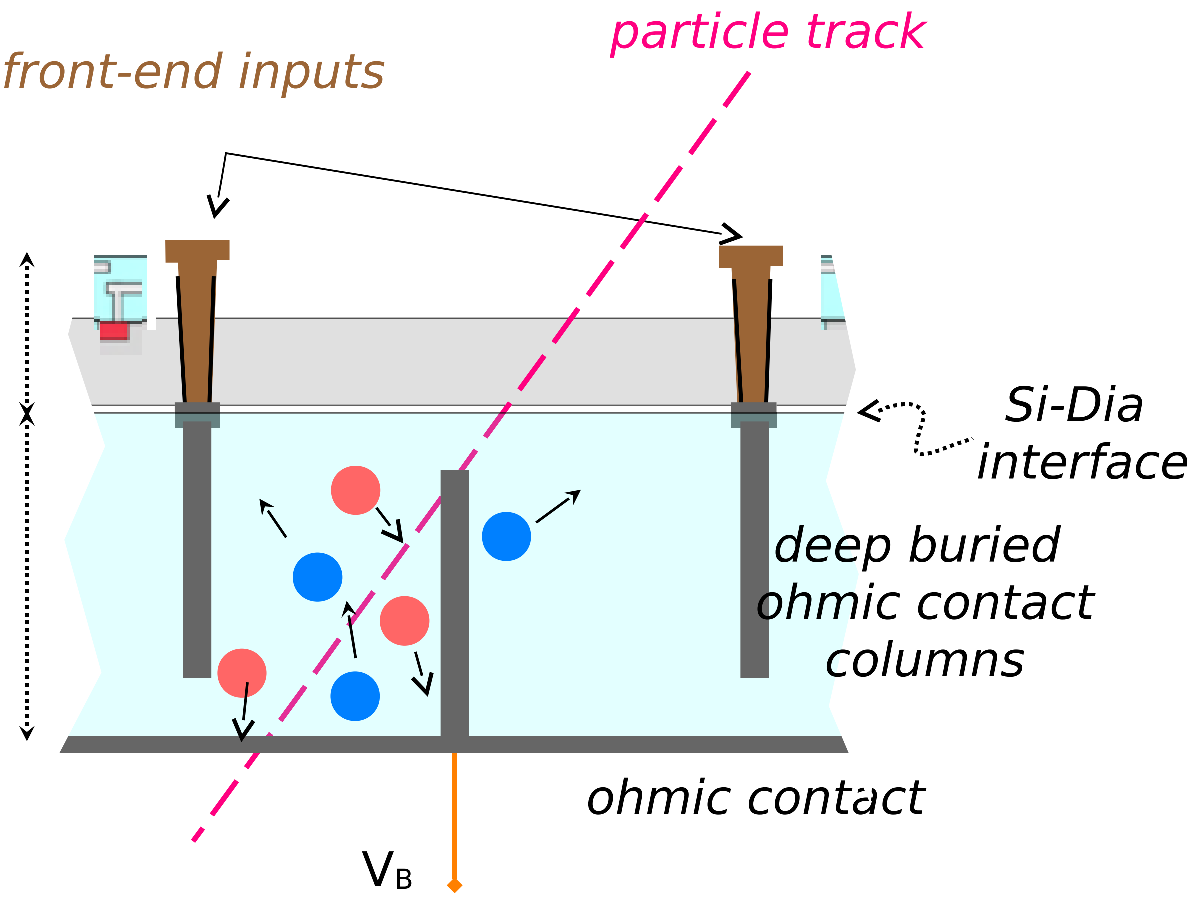

a) Planar pixel detector

b) MEA

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

b) SOD Micro-Electrode Array (MEA): diamond hosting neural tissue connected to the R/W electronics by conductive channels and TSVs

# Feasibility of a 3D structure is also investigated

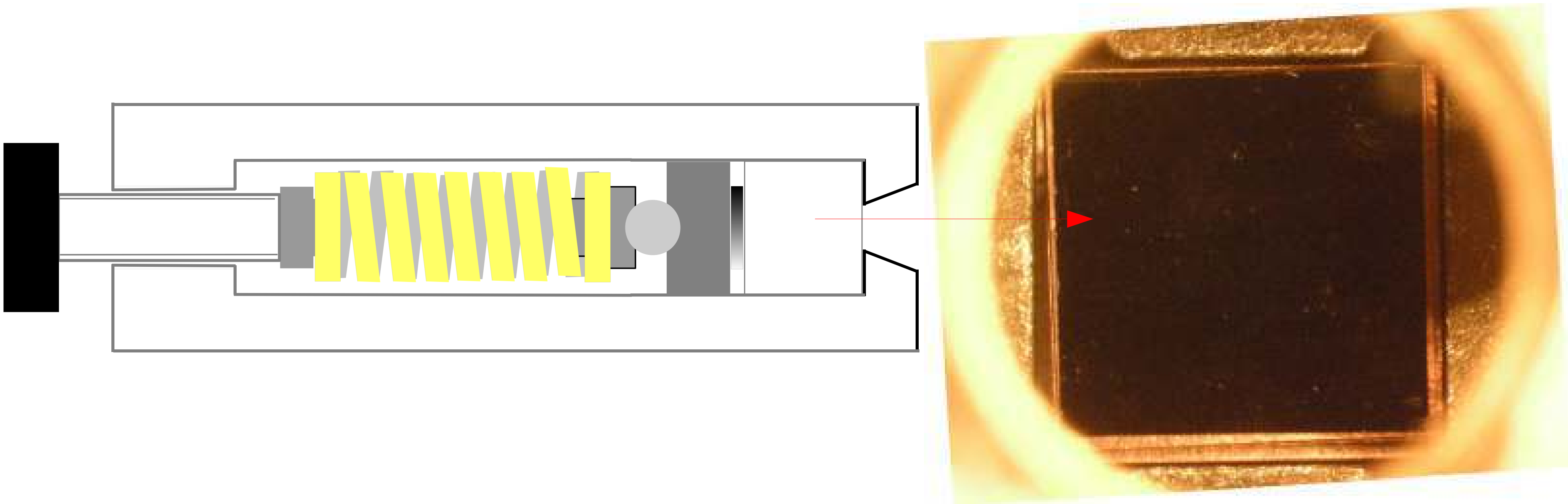



3D detector

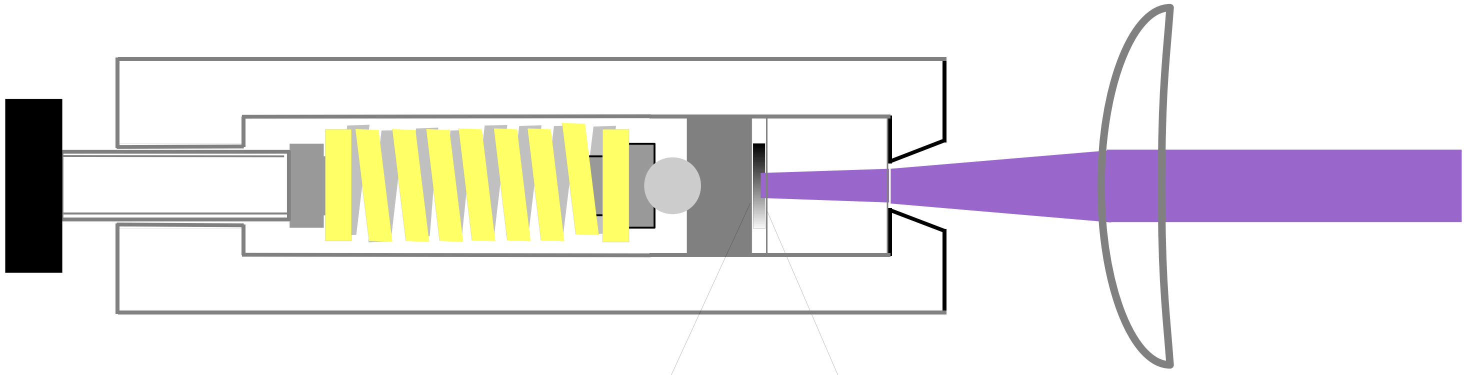
# Silicon On Diamond Fabrication: Cleaning and mounting

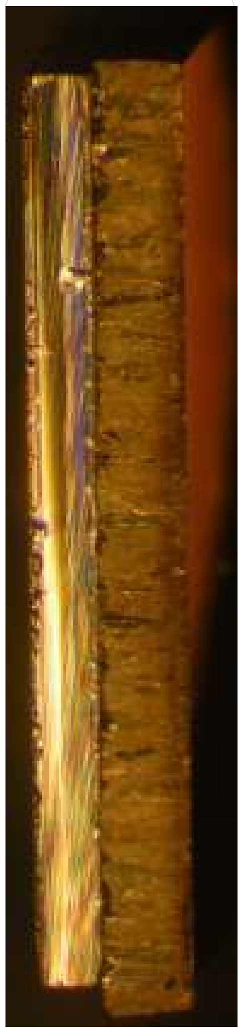
Si & D plates are cleaned in a white chamber in ultrasonic bath assembled in a laminar flow hood

Diamond 5 ×5 $mm^2$ plate over silicon seen through the fused silica viewport



# Silicon On Diamond Fabrication: Laser bonding



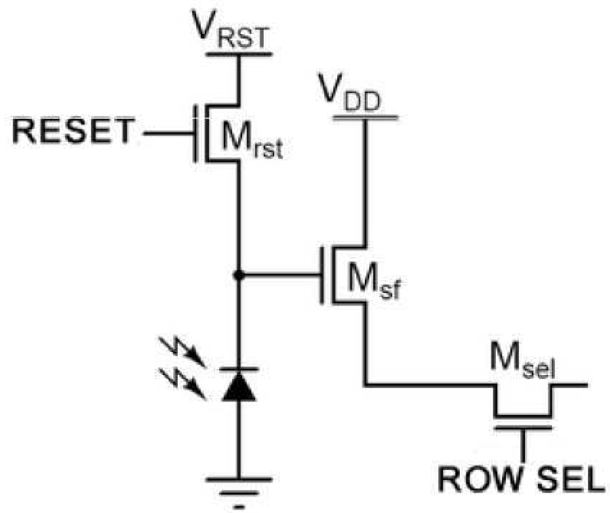


The diamond silicon interface is irradiated by UV laser pulses
$\lambda$=355 nm
$\tau$=20 ps
Energy density = 2-0.5 J/cm$^2$

Uniaxial stress: 800 atm needed* for 90 % adhesion with the present $R_a$~5 nm

*Stefano Lagomarsino Ph,D Thesis http://hep.fi.infn.it/sciortino/Research/dissertation_Lagomarsino.pdf

# RAPS on DIAMOND: succesfully tested by INFN Perugia

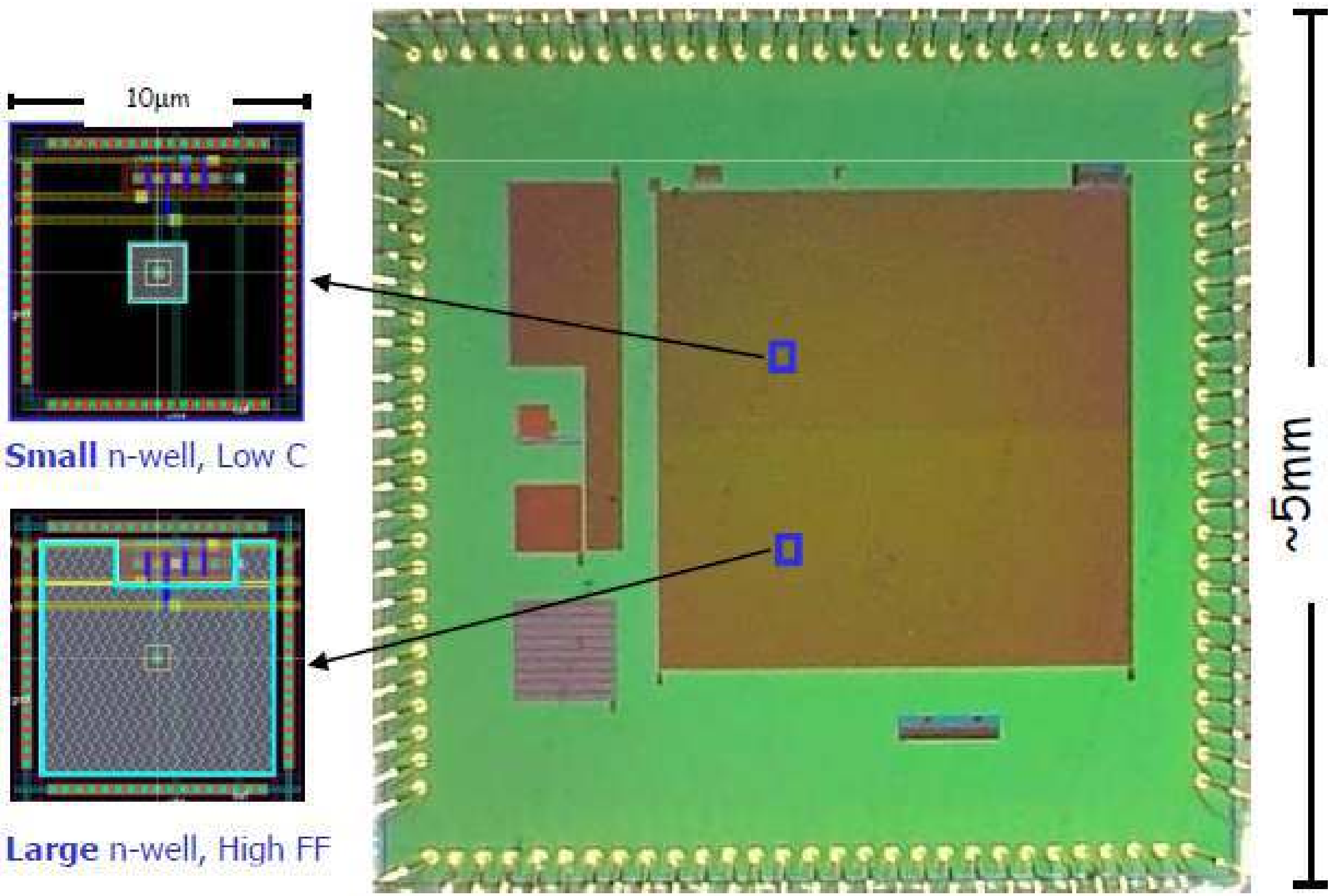



GOAL:

To test the functionality of a real chip

After ⇒ thinning (down to 40 μm)

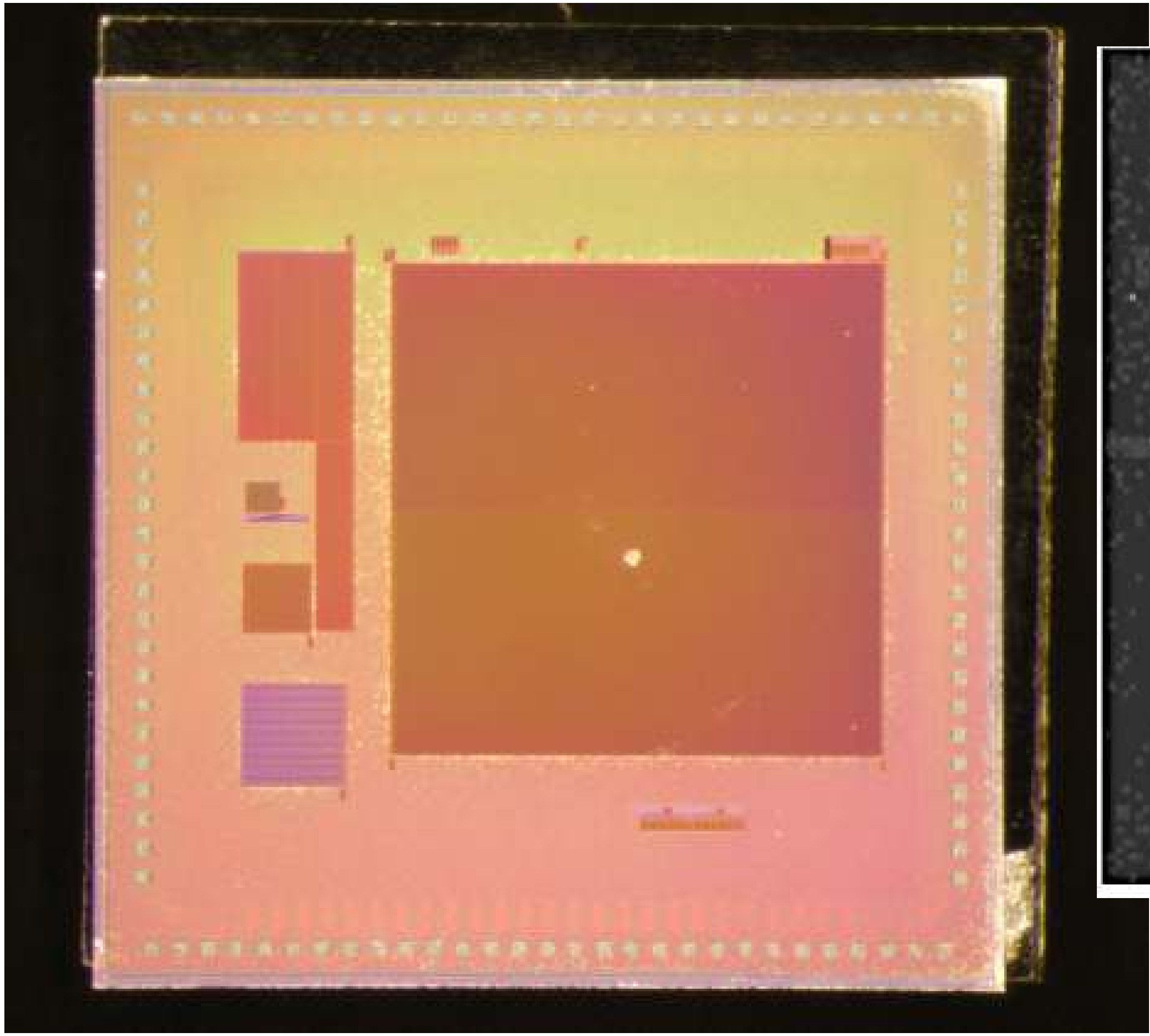
and⇒ bonding to diamond

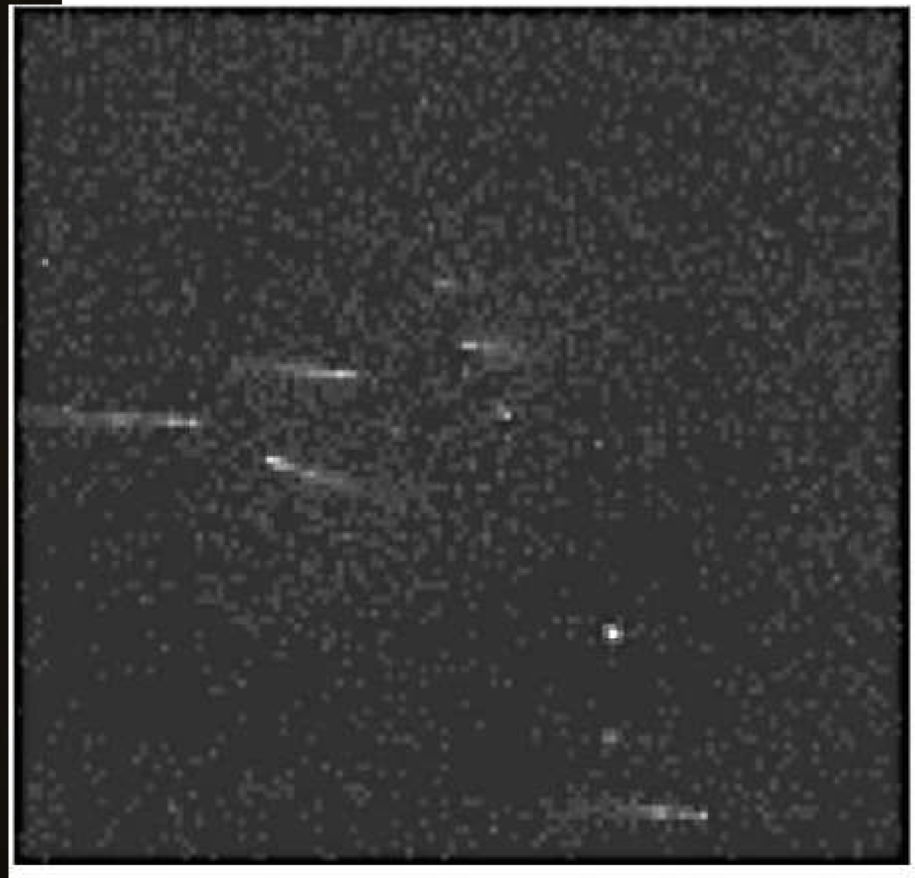



CMOS Active Pixel Sensors

256 × 256 matrix

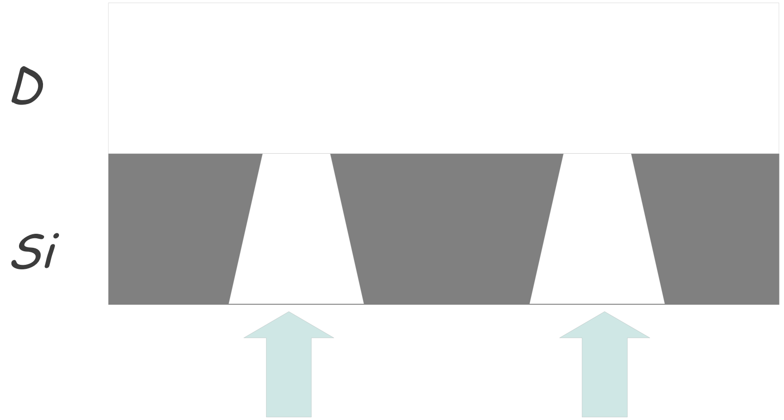
# RAPS bonded on diamond (SOD_34) successfully tested



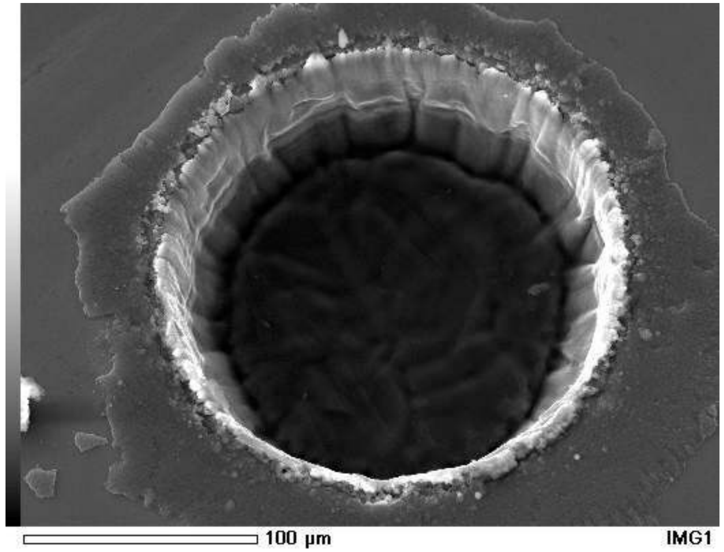


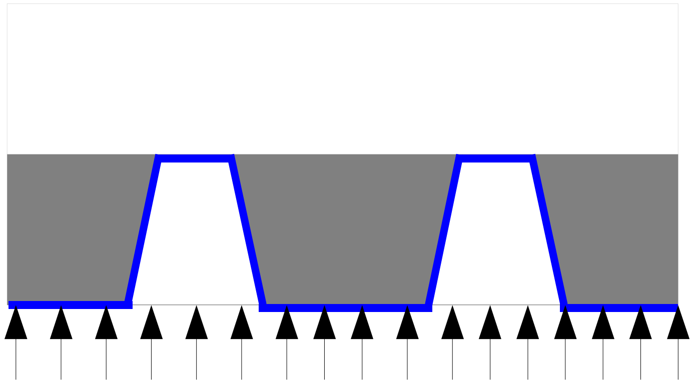
Display of the response to MIPs at grazing incidence

# Through Silicon Vias Preparation

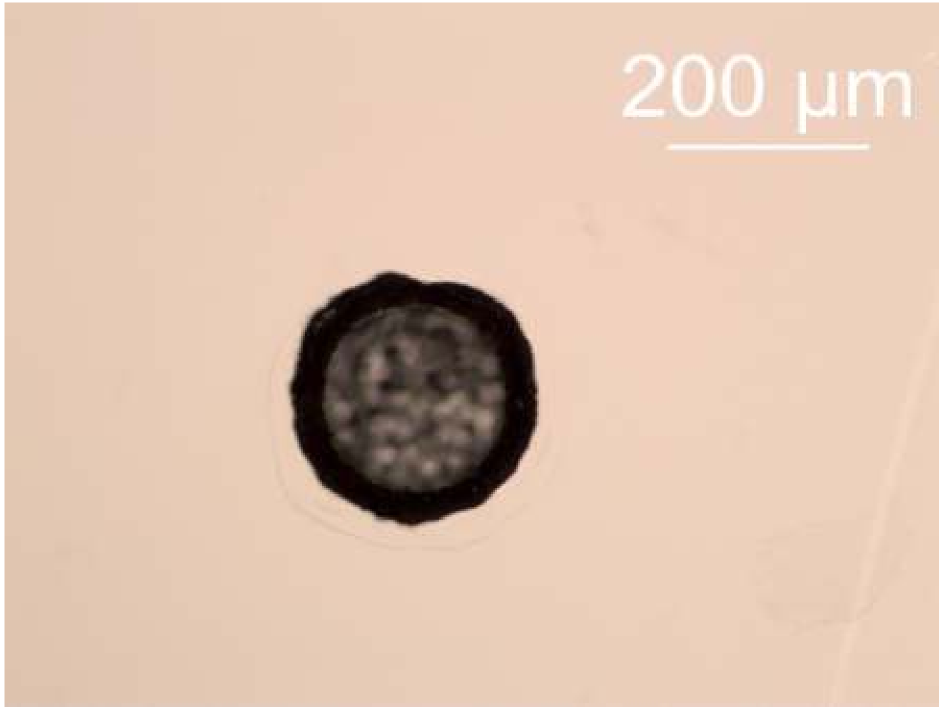



Laser drilling of holes

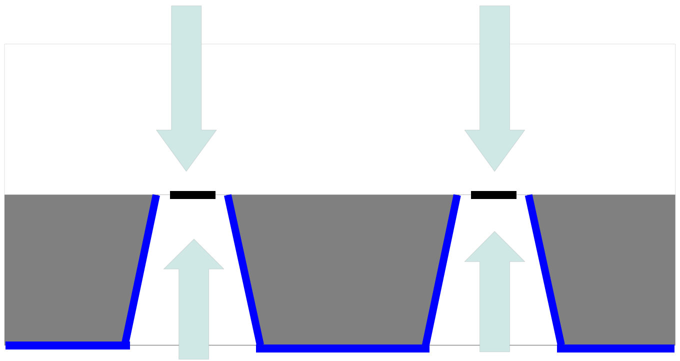


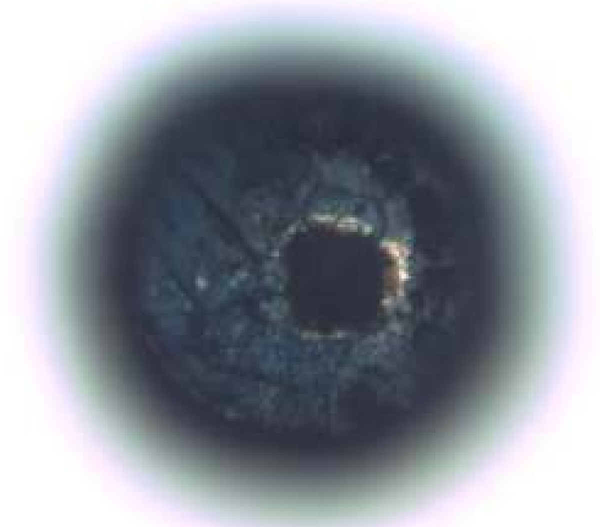
PECVD formation of $SiO_2$

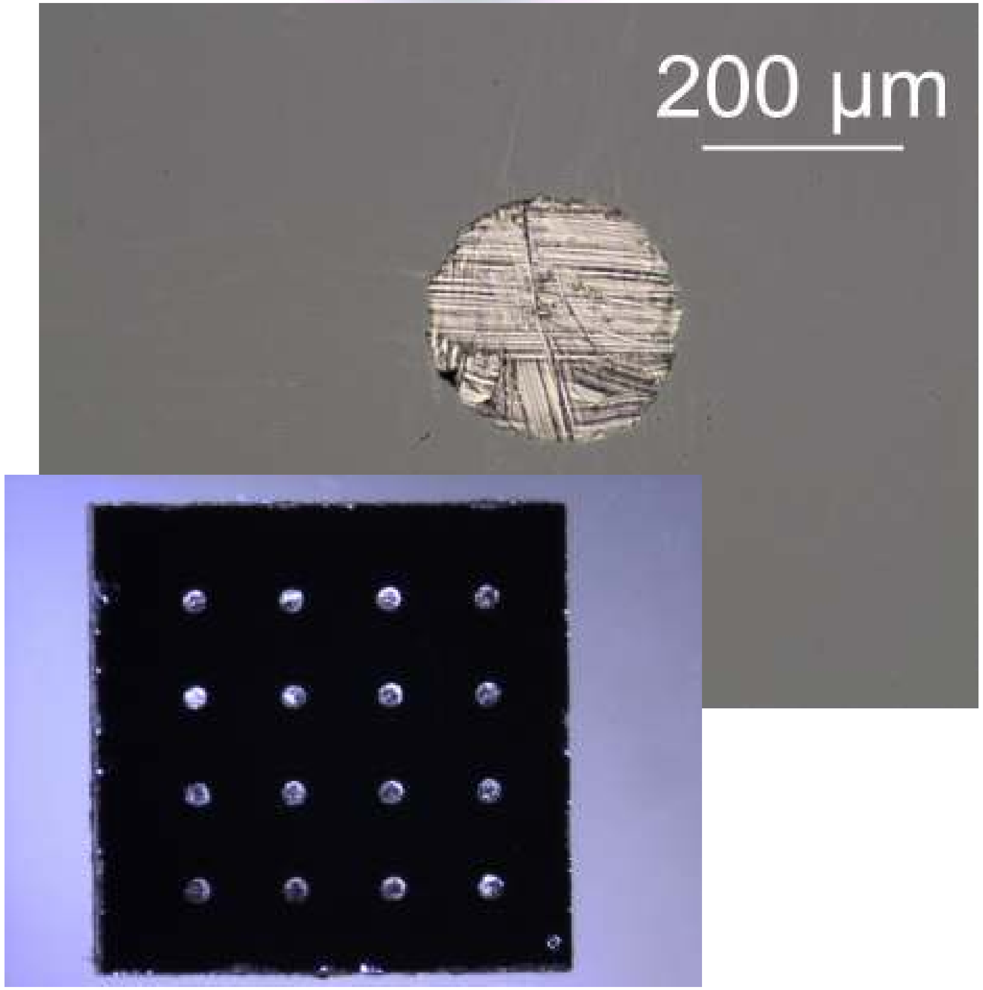


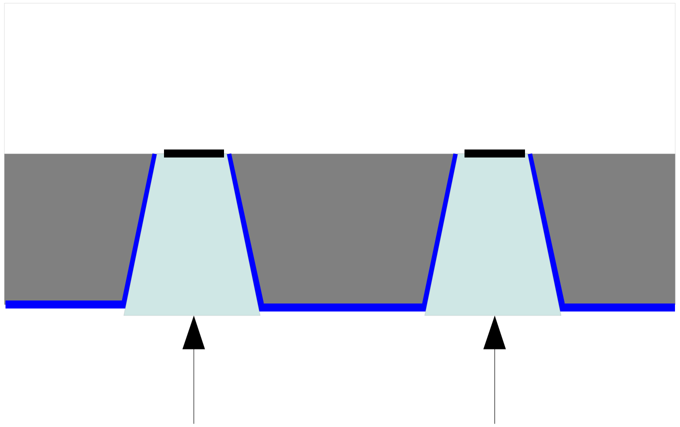
Laser graphitization



Laser ablation of the bottom oxide

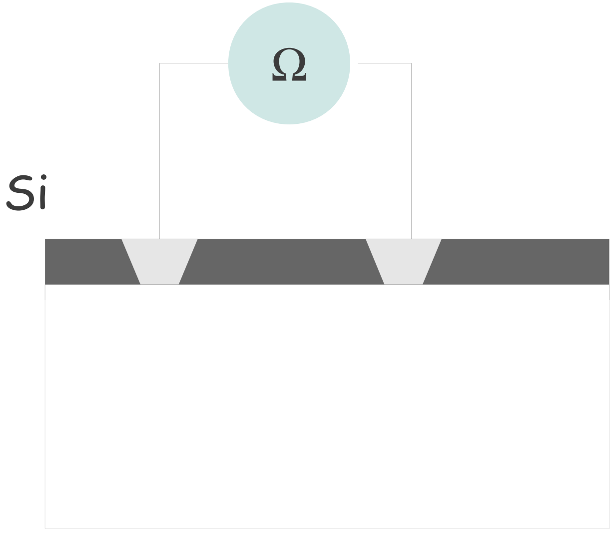




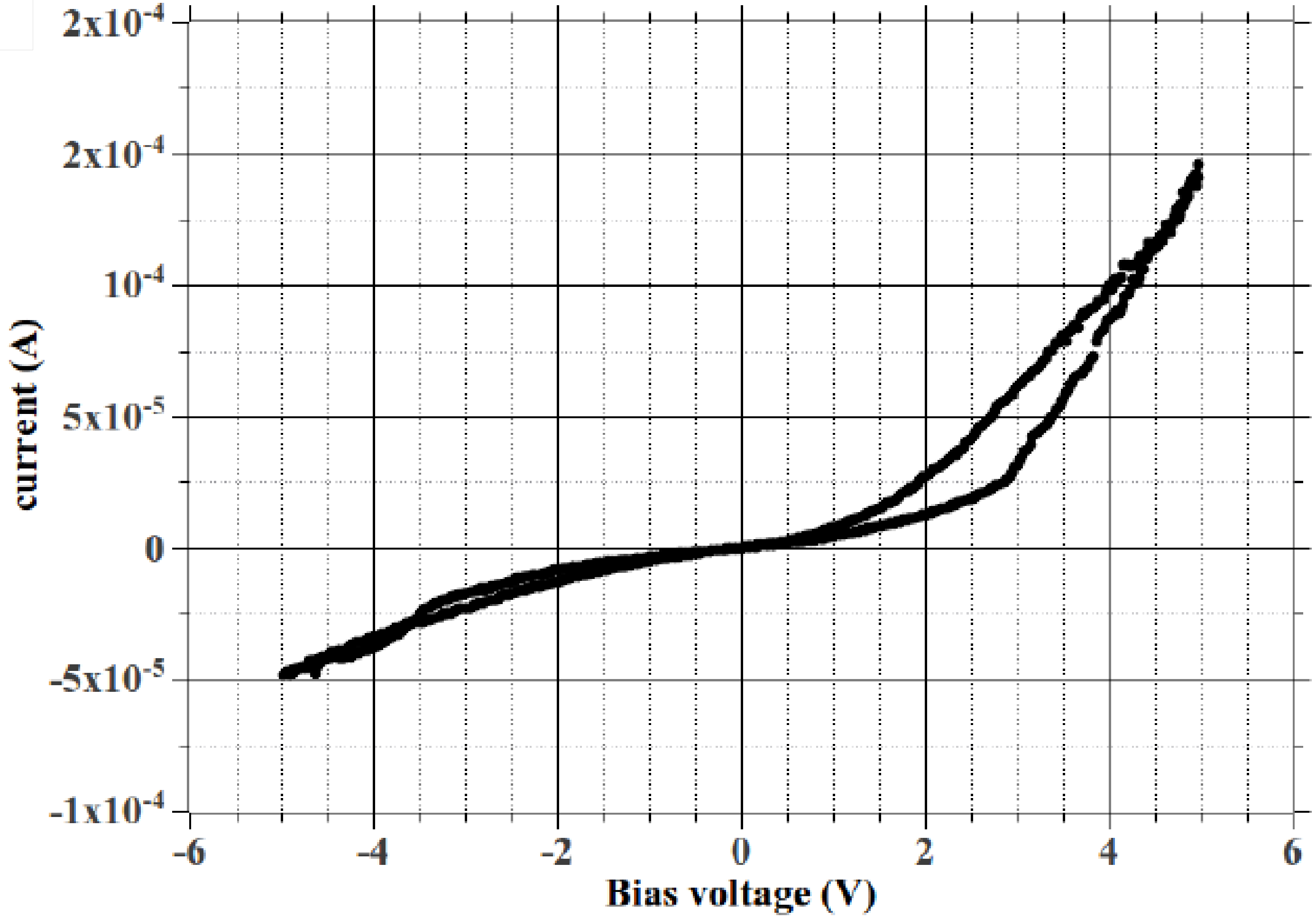



Filling with Ag nanoparticles sintered at 220 °C

*IV* between TSV 100 μm diameter
400 μm apart

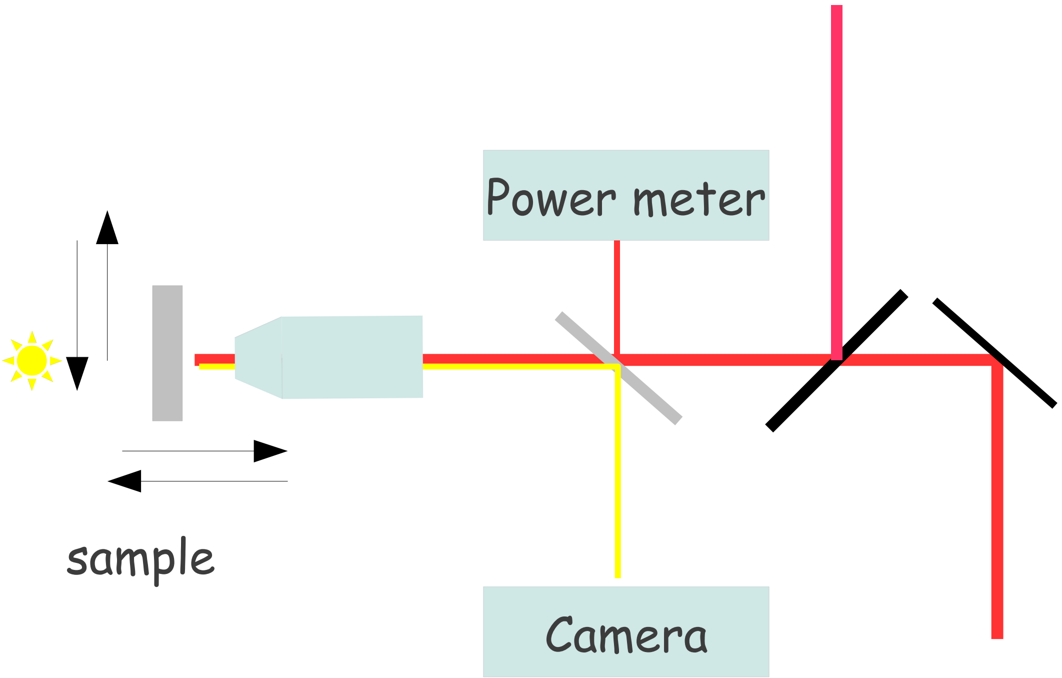



Resistance still low the oxide layer thickness (now 500 nm) must be increased

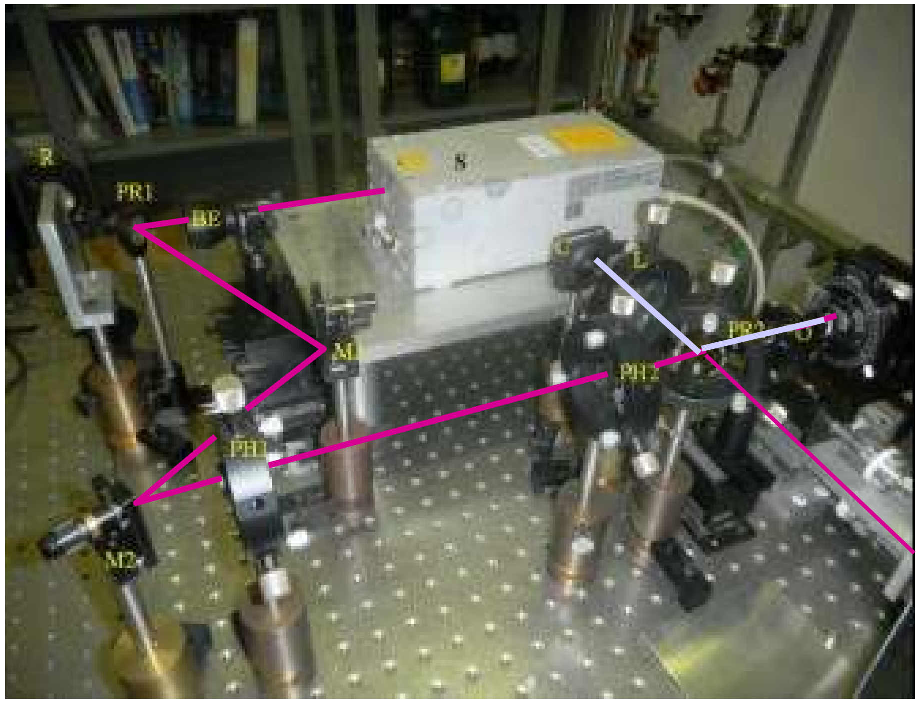


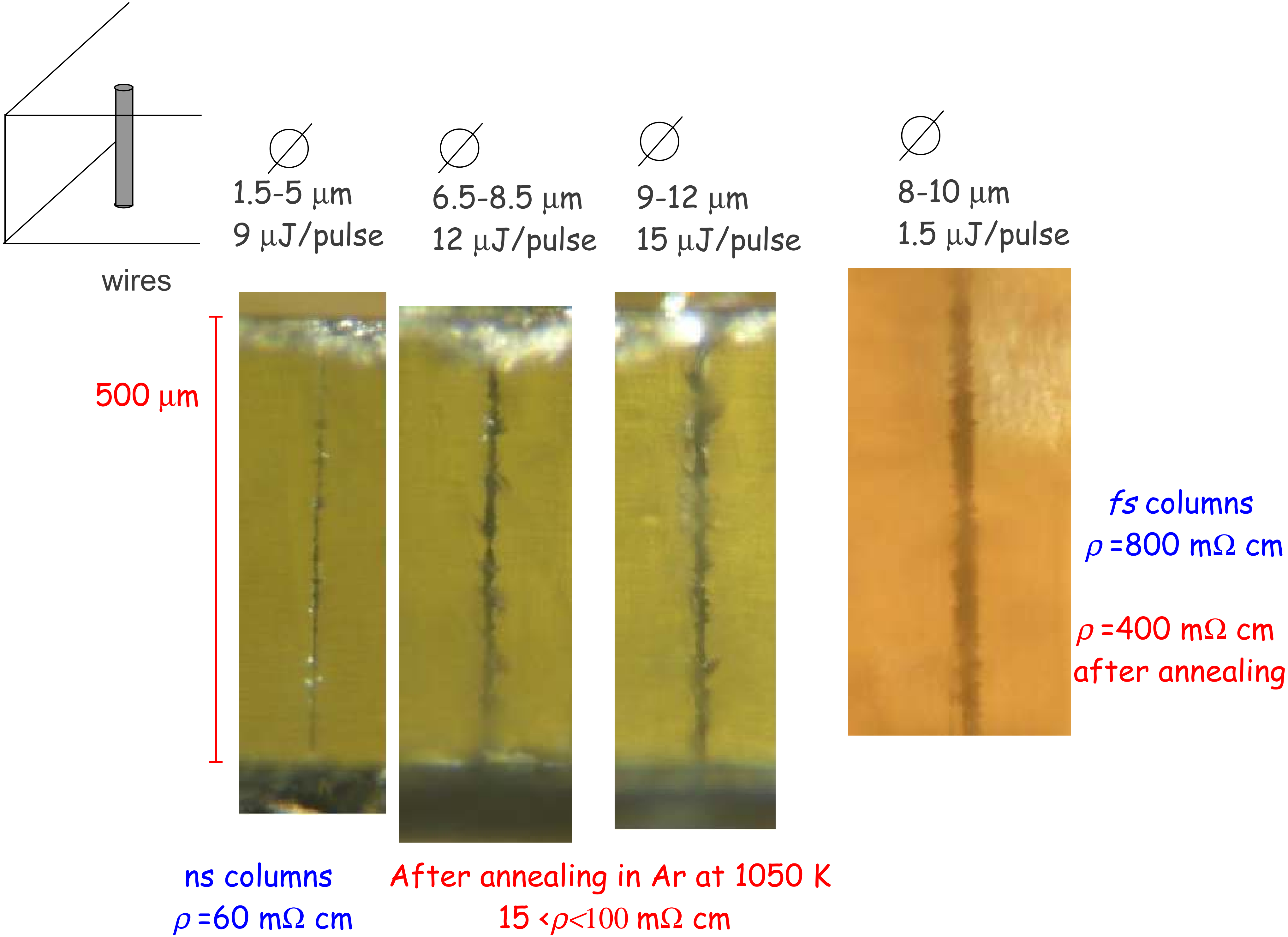
# Graphite channels

Ti:Sa laser source
800 nm wavelength
30 fs pulse width

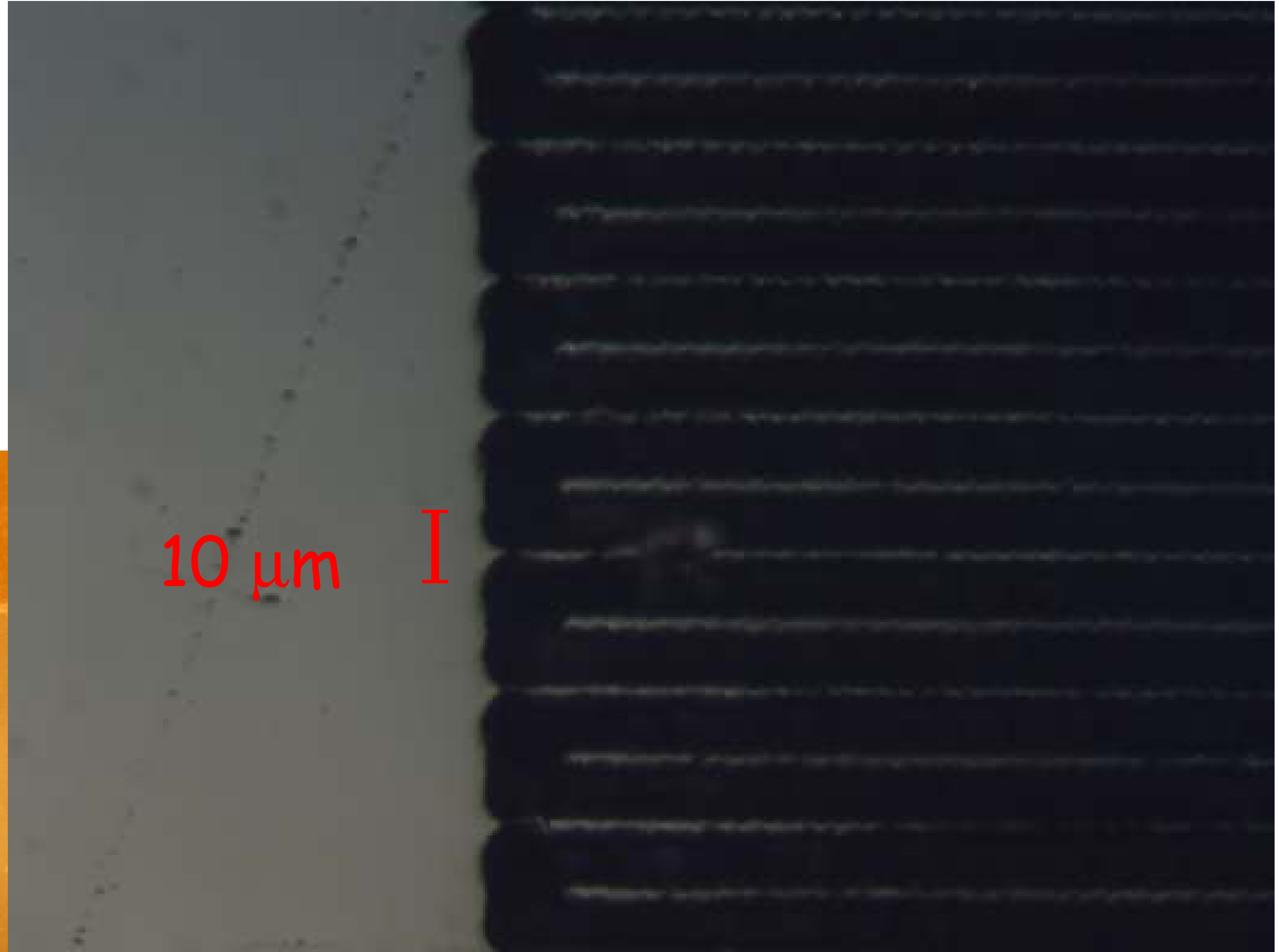


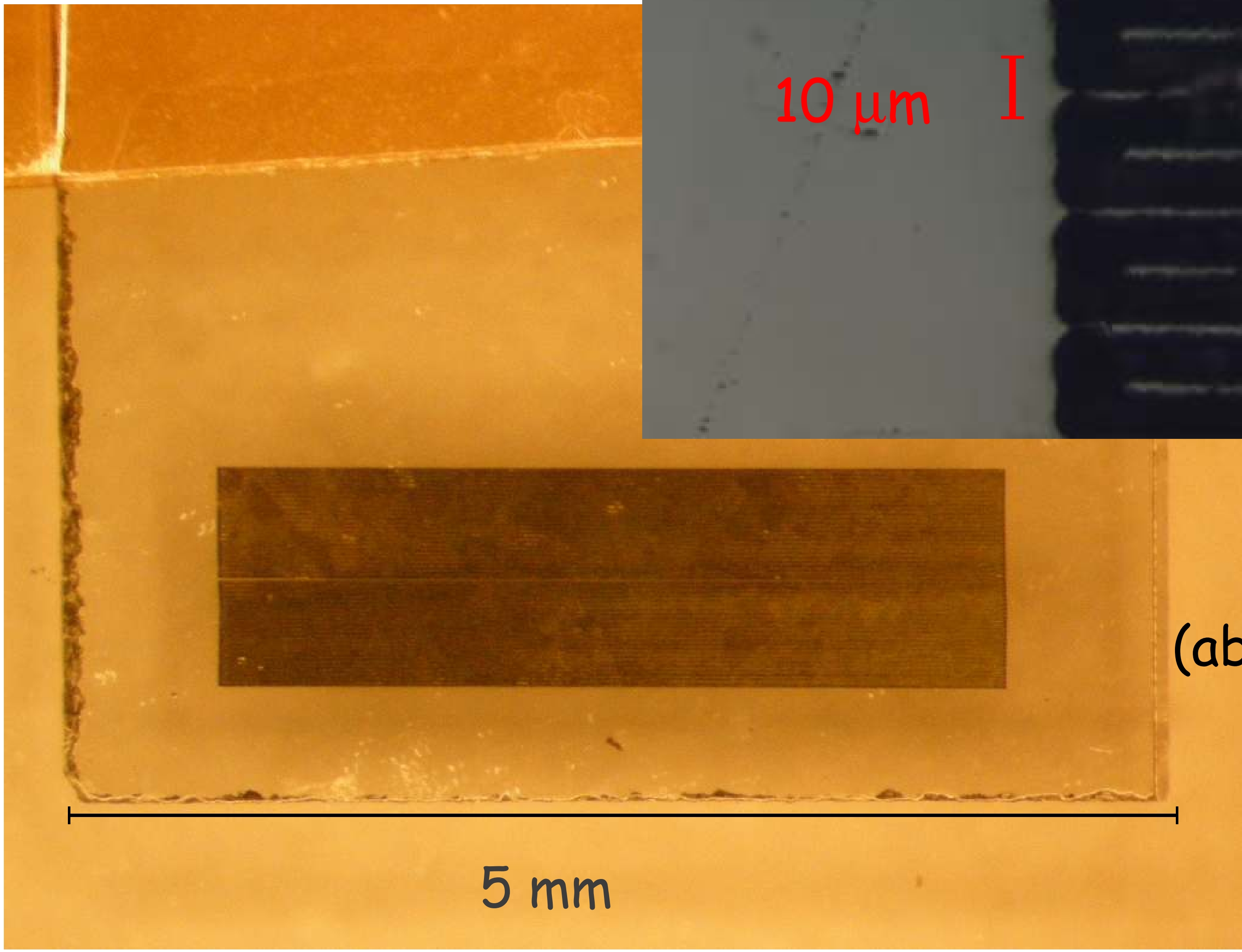

Nd:YAG
Q-switched laser source
1064 nm wavelength
8 ns pulse width



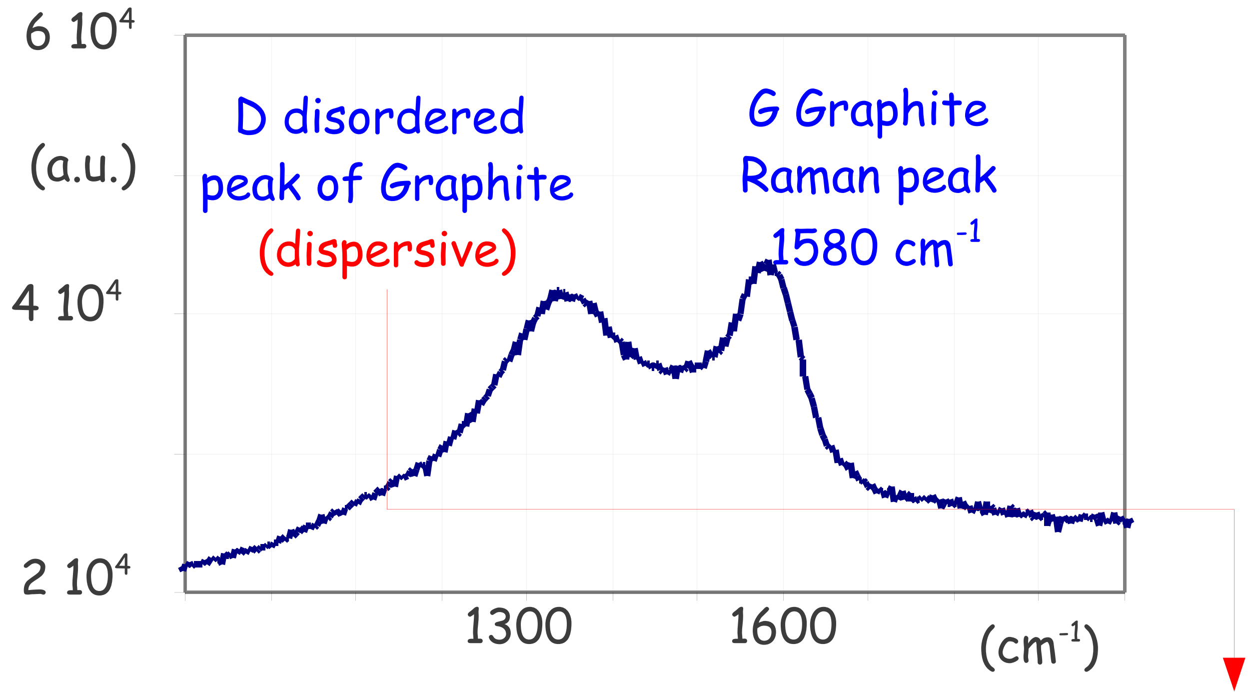

wires
Ø
1.5-5 μm
9 μJ/pulse
Ø
6.5-8.5 μm
12 μJ/pulse
Ø
9-12 μm
15 μJ/pulse
Ø
8-10 μm
1.5 μJ/pulse
500 μm
fs columns
ρ =800 mΩ cm
ρ =400 mΩ cm
after annealing
ns columns
ρ =60 mΩ cm
After annealing in Ar at 1050 K
15 <ρ<100 mΩ cm

Surface contacts
$\rho \approx 4$ mΩ cm, about
the value of graphite



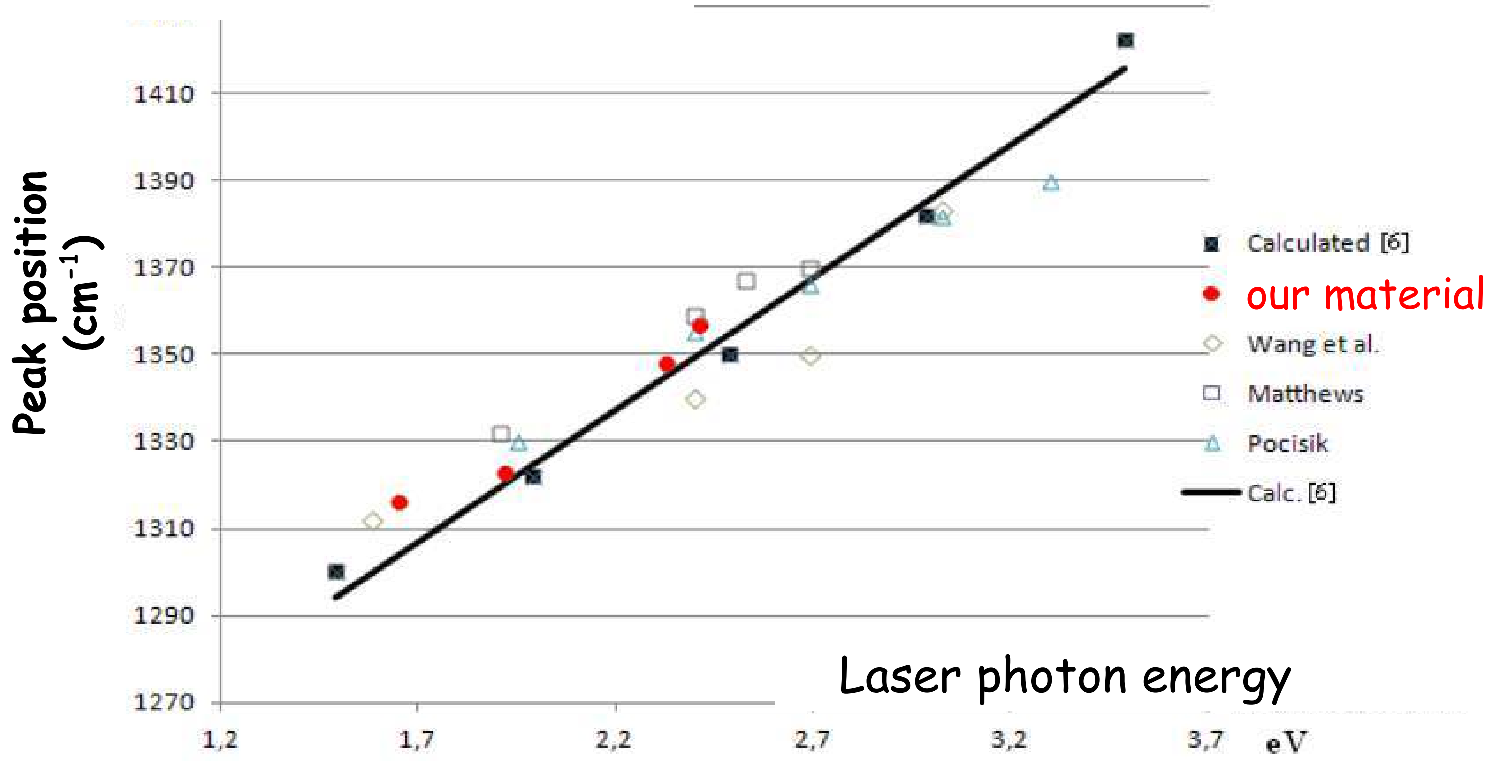




ns laser
(ablation with fs laser)

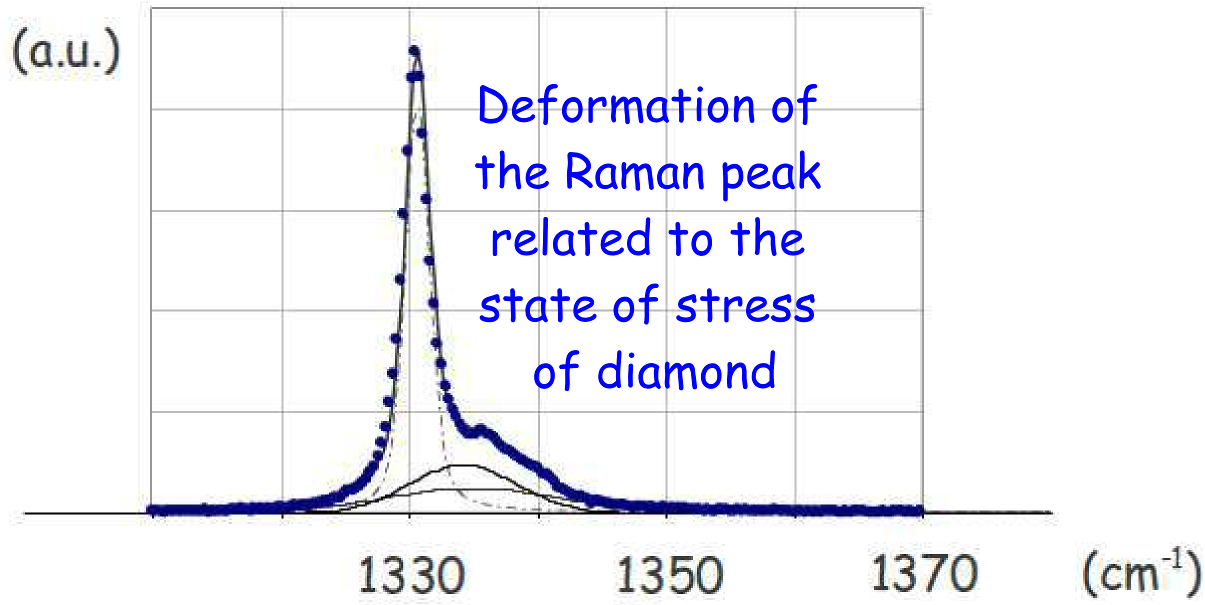


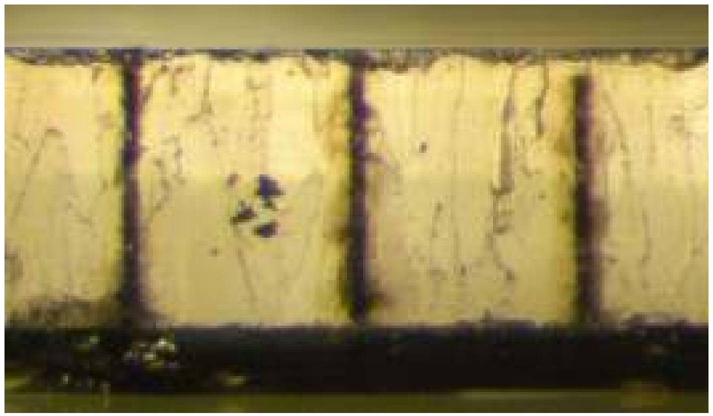

# Raman Spectroscopy on surface channels

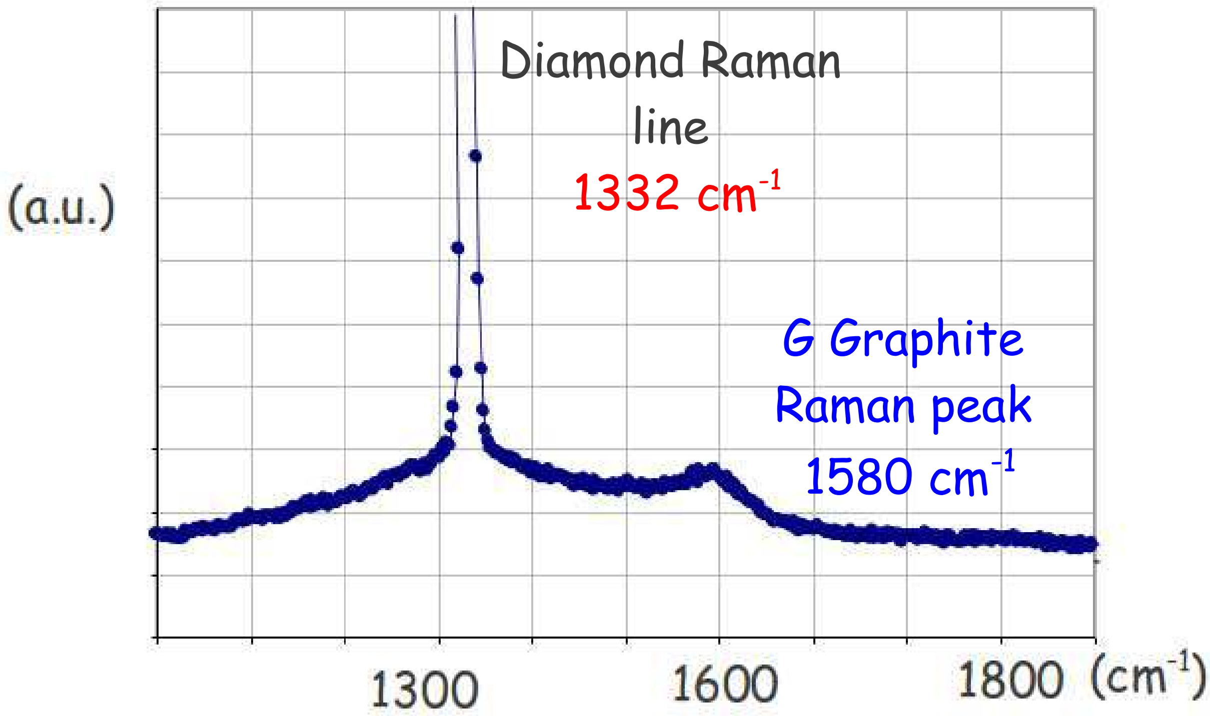
# Surface channels are graphitic

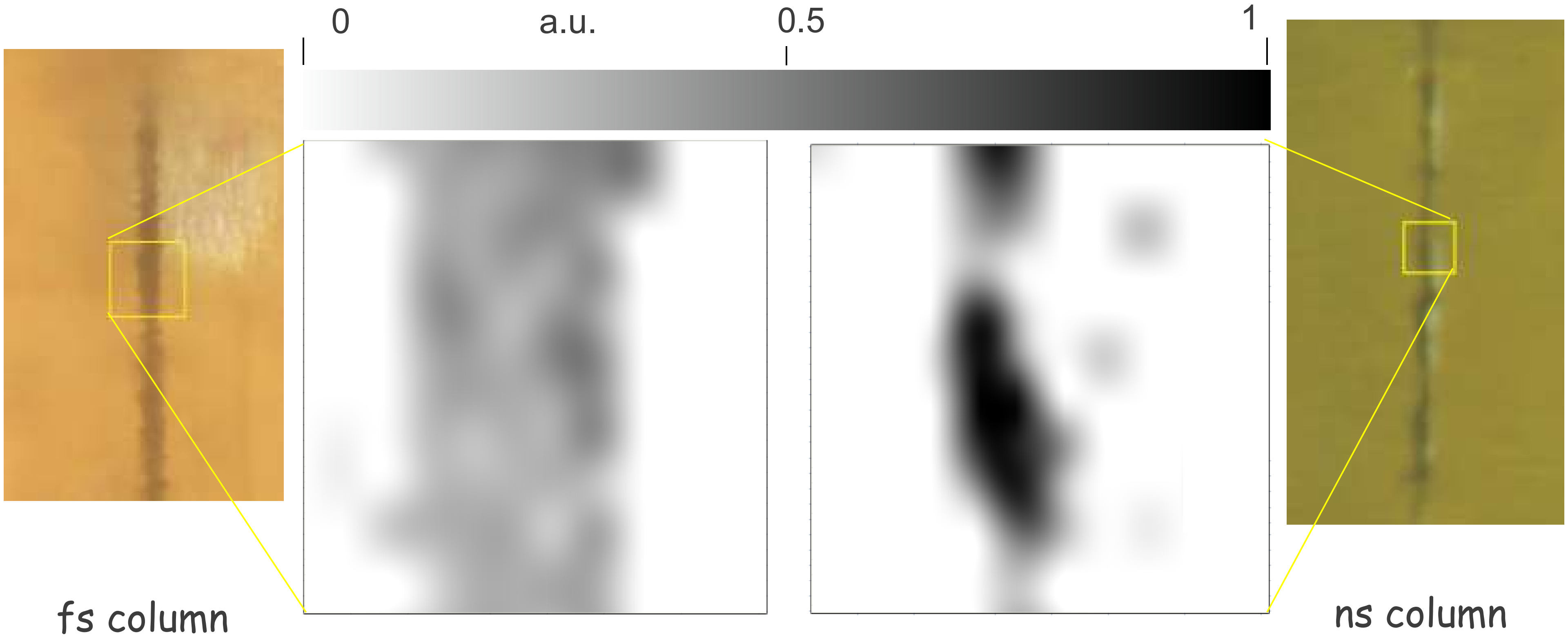


# Raman Spectroscopy of buried structures



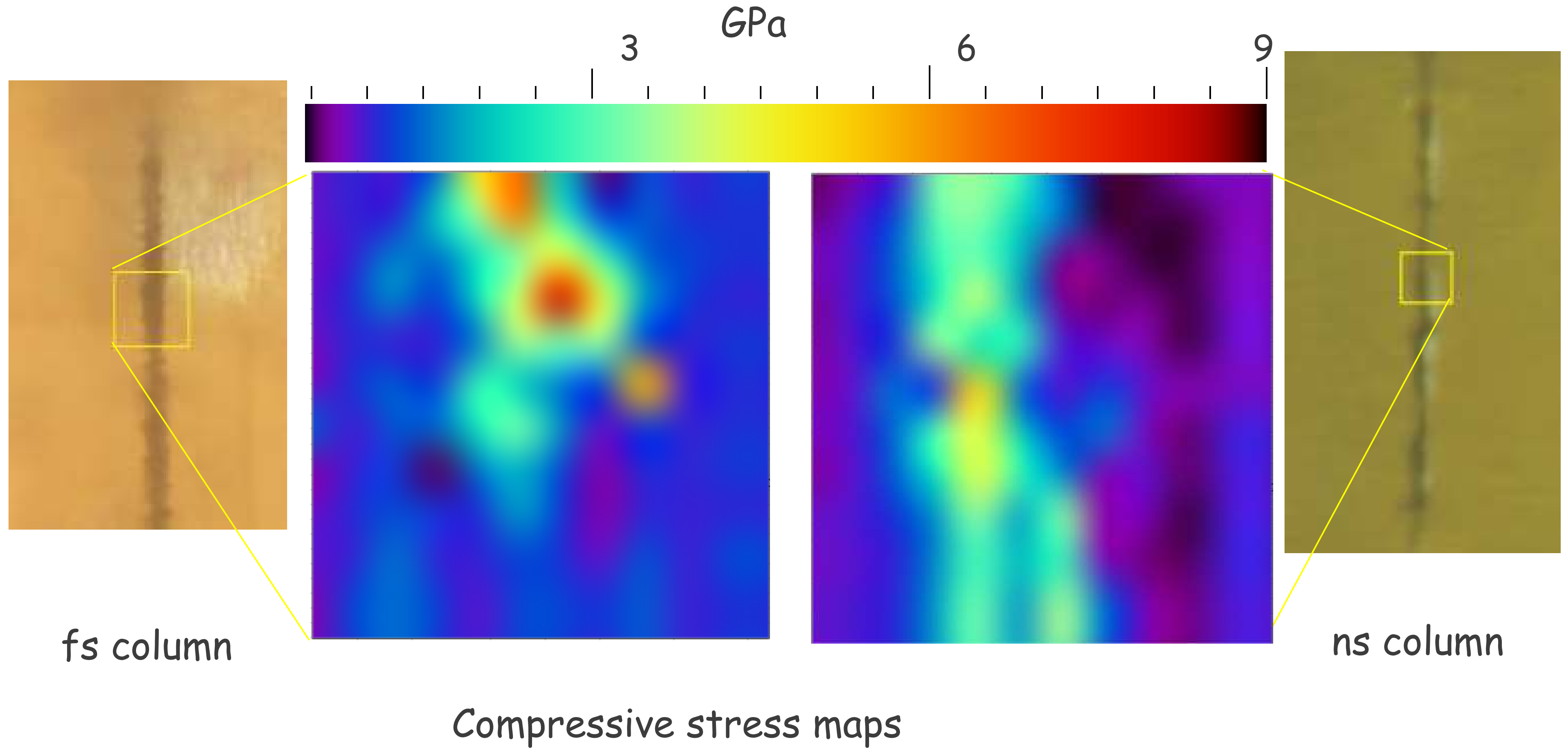



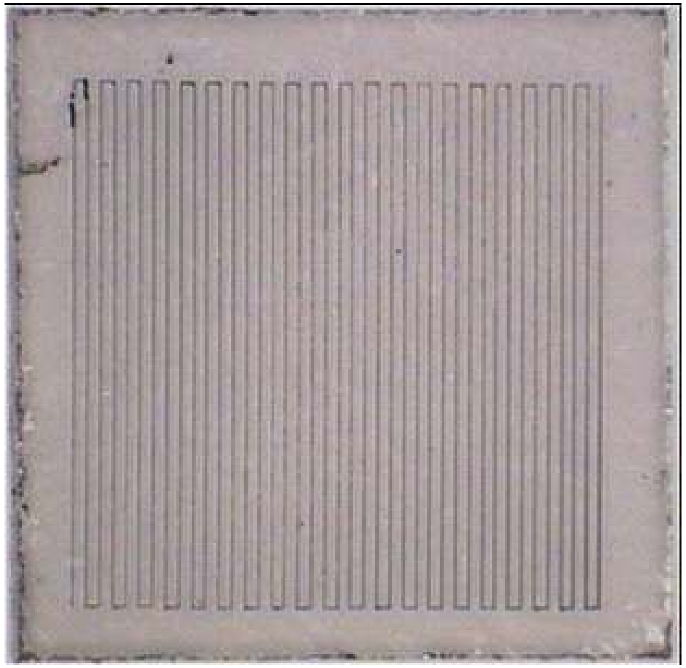


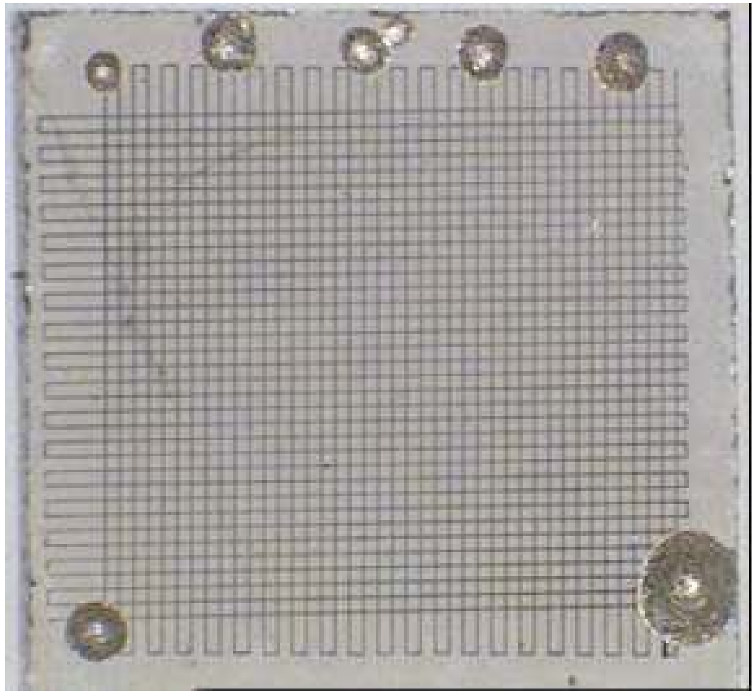



Graphitic "G" peak maps

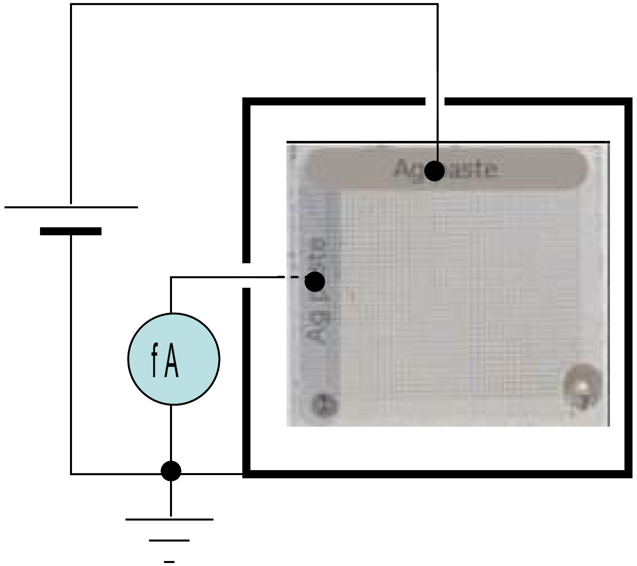
Mixed diamond-graphite phase, percolative conduction?

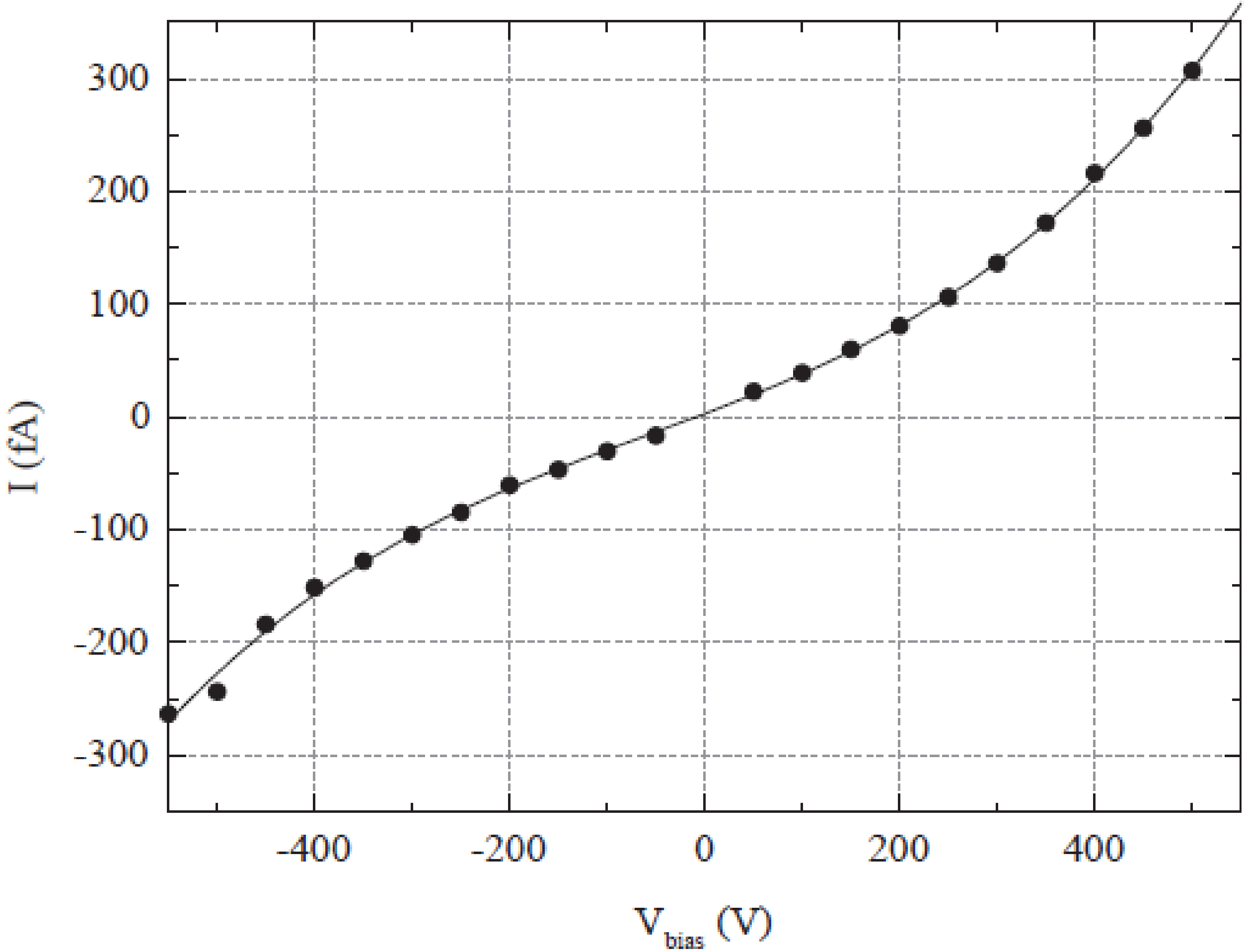

GPa
3
6
9
fs column
ns column
Compressive stress maps

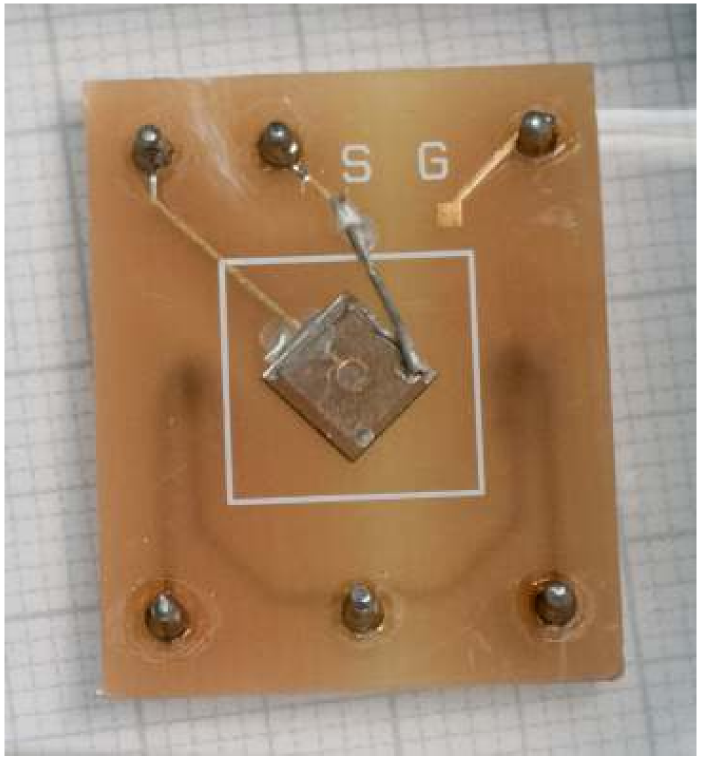




Diamond detector with graphite contacts



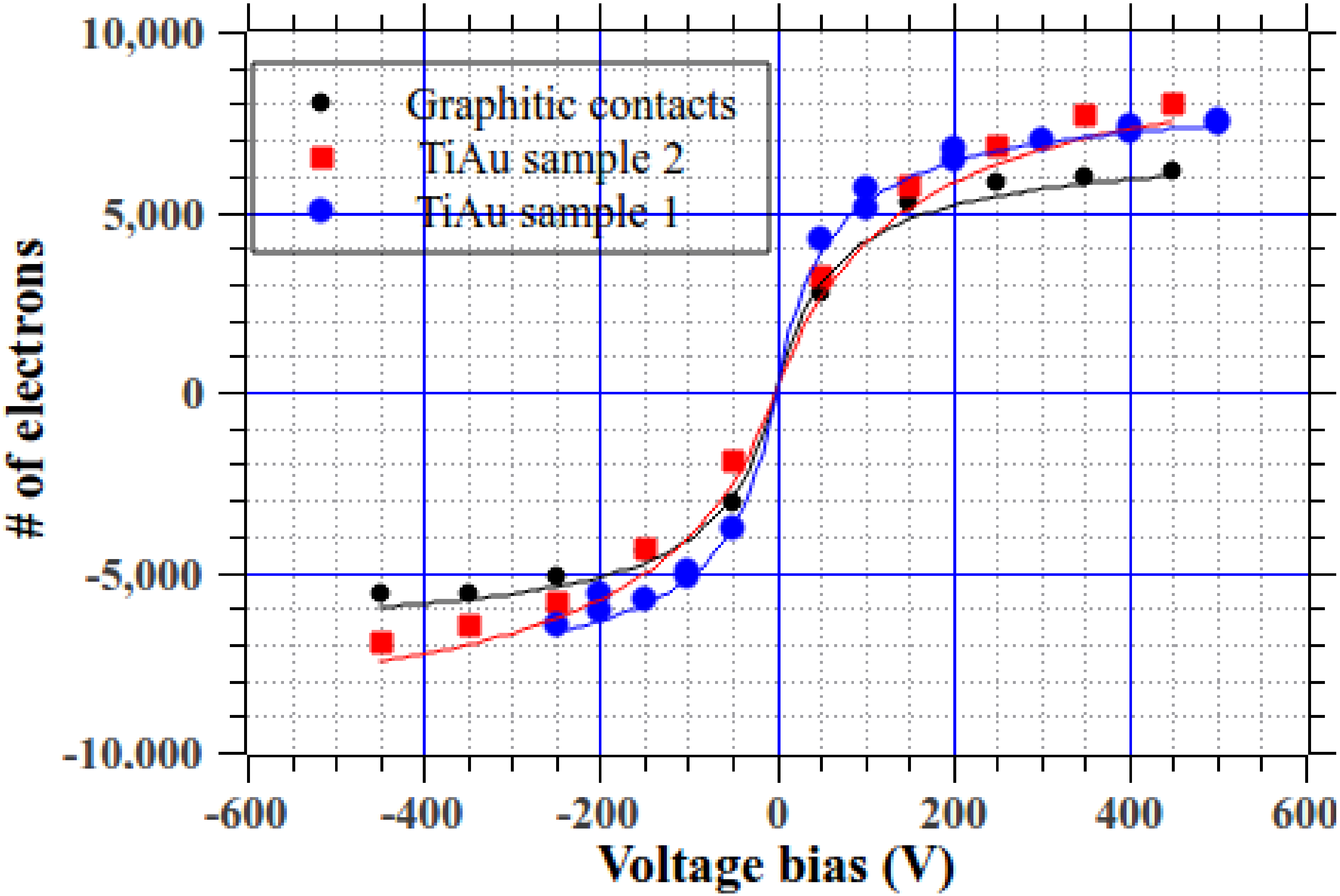




$$C = 2.4 \ \text{pF}$$

$$R \sim 10^{15} \ \Omega$$

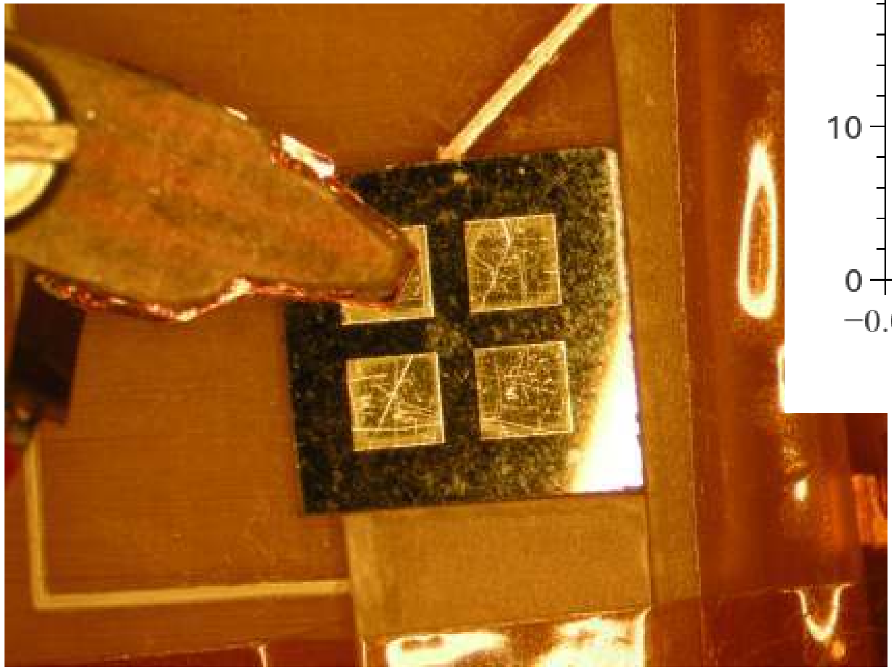
Comparison between graphite and standard (Ti-Au) contacts
Three samples of the same quality and geometrical thickness

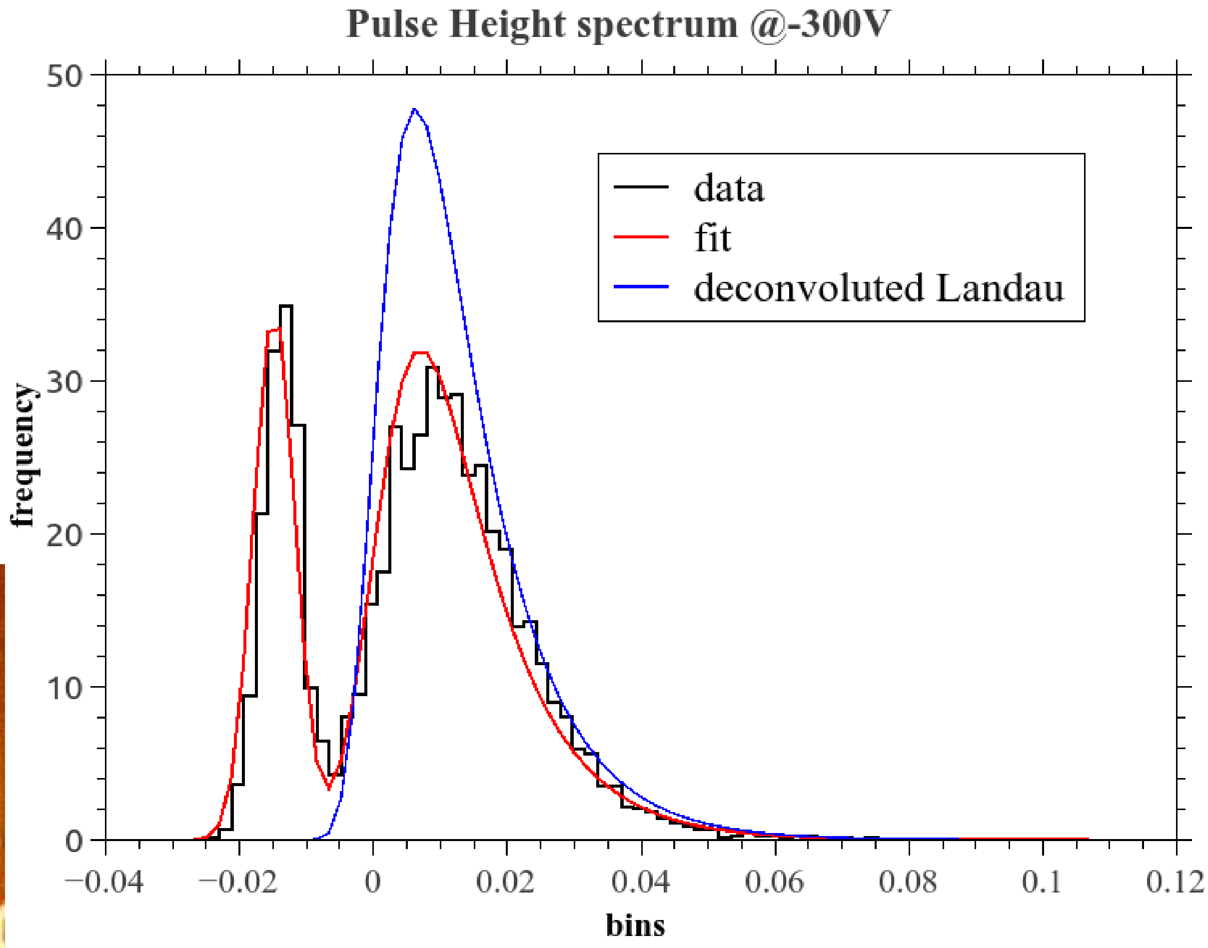


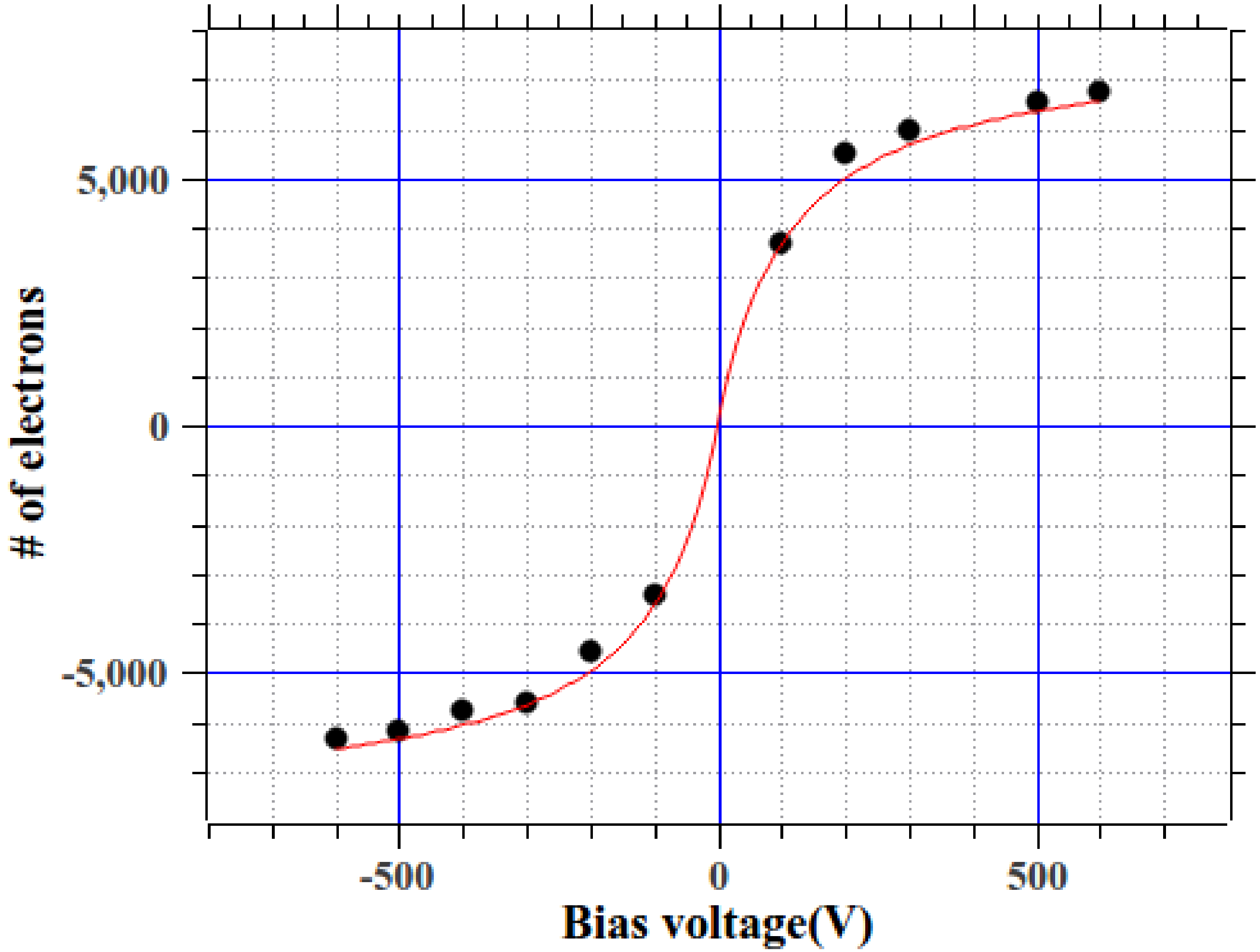

Agreement in the mesaurements according to the lower sensitive volume thickness of the graphite detector

# SOD detector

SOD28 Cr-Au contacts on diamond, 500 μm thick,
Al contact on Si , 50 μm thick
Antonio de Sio & Emanuele Pace
Department of Physics & Astronomy, Florence



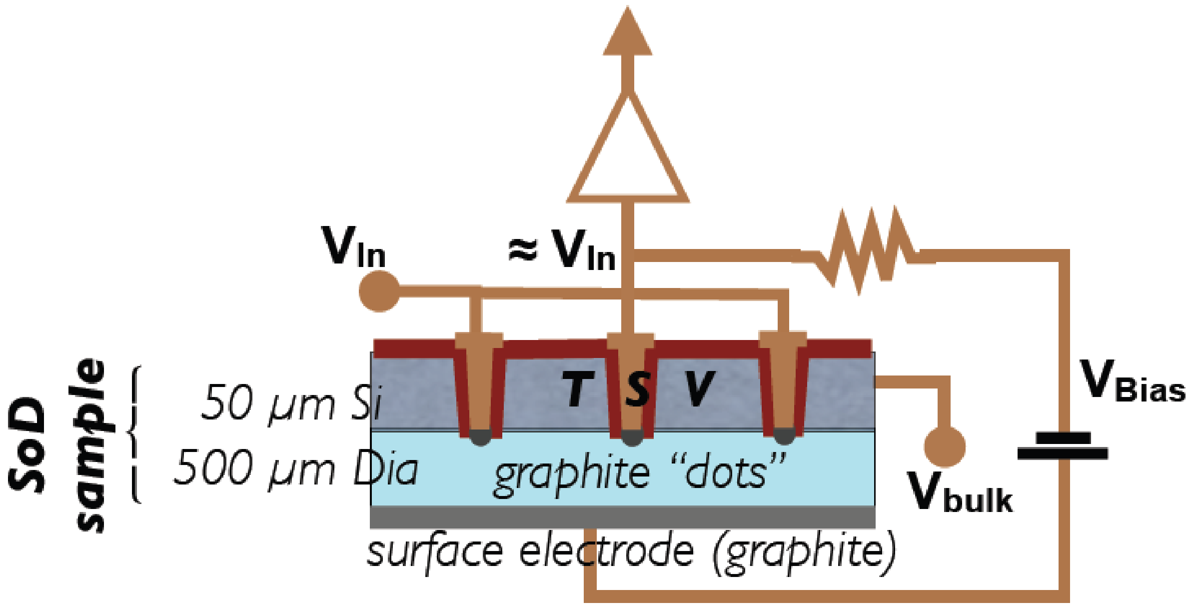




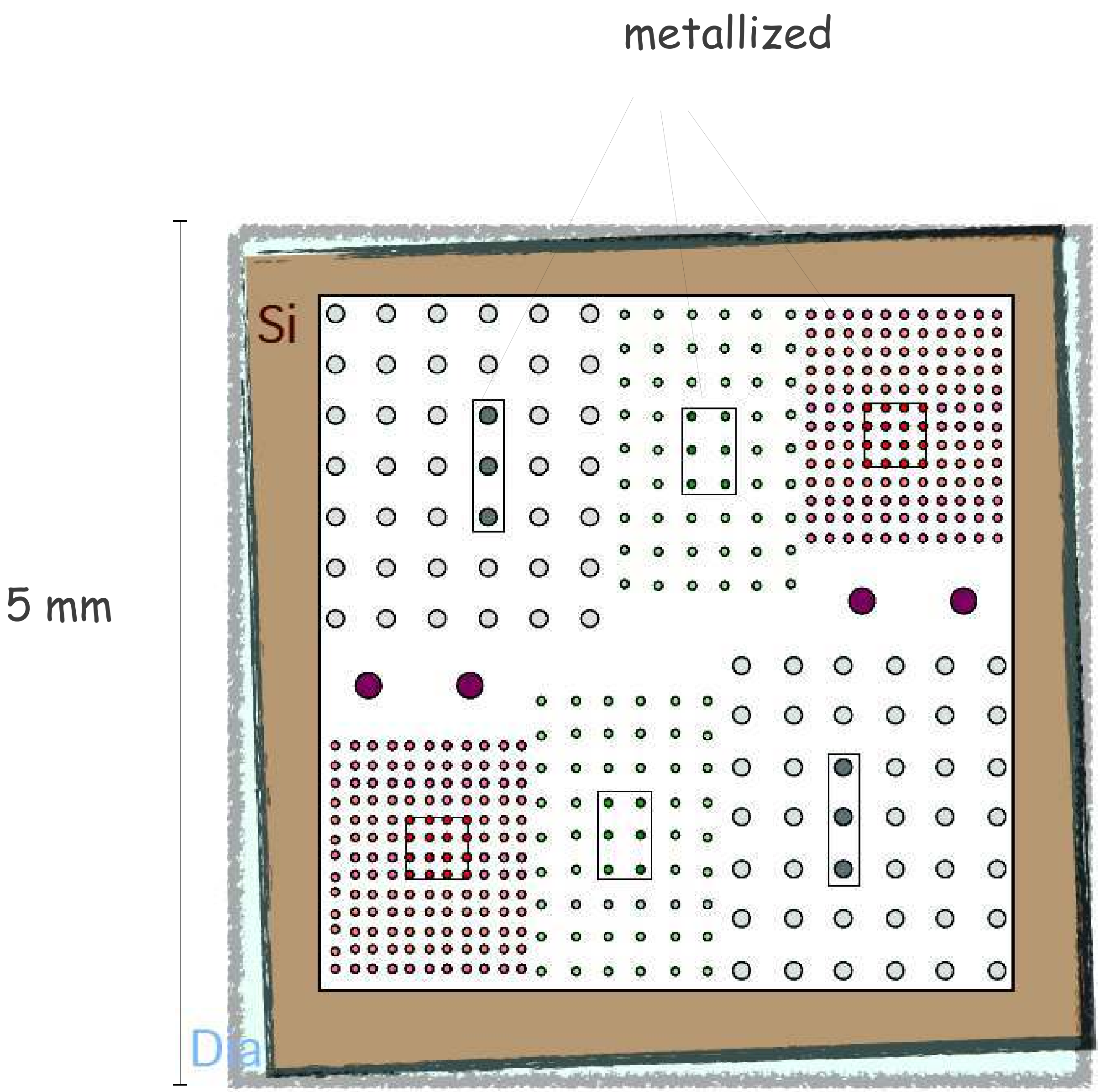

Charge is collected through the bonding Si-diamond interface

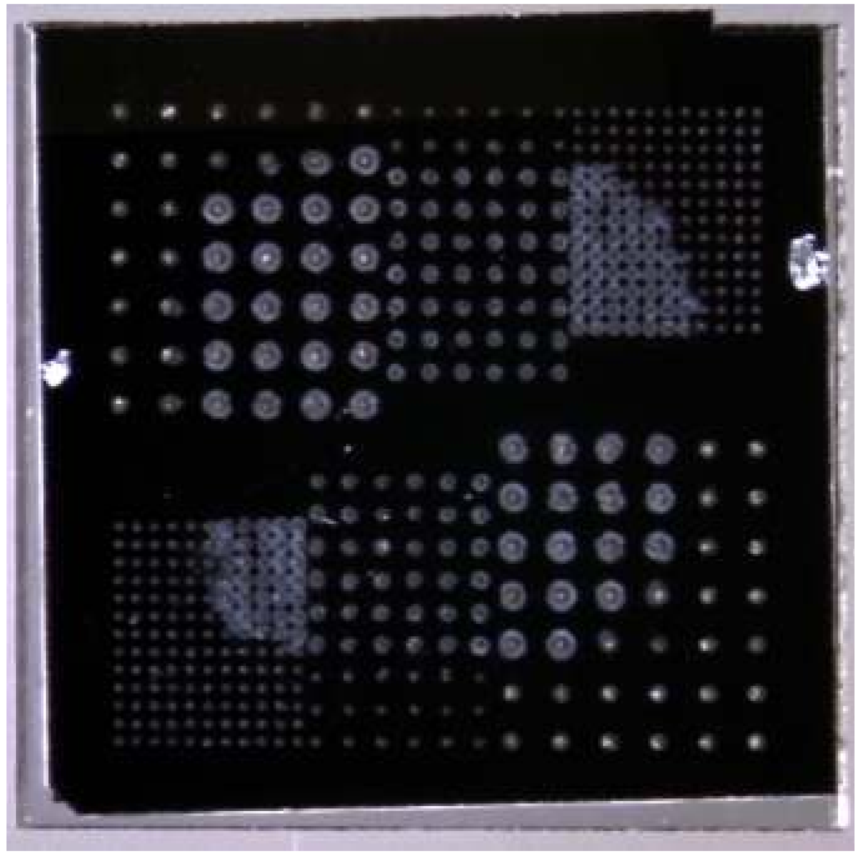
# Next implementations

a)Prototype 0 underway : TSV connecting the diamond to the three surface of silicon, pads wire-bonded to external electronics




b)Prototype 1 within 2013: dedicated pixel chip-on-diamond with electronics on board



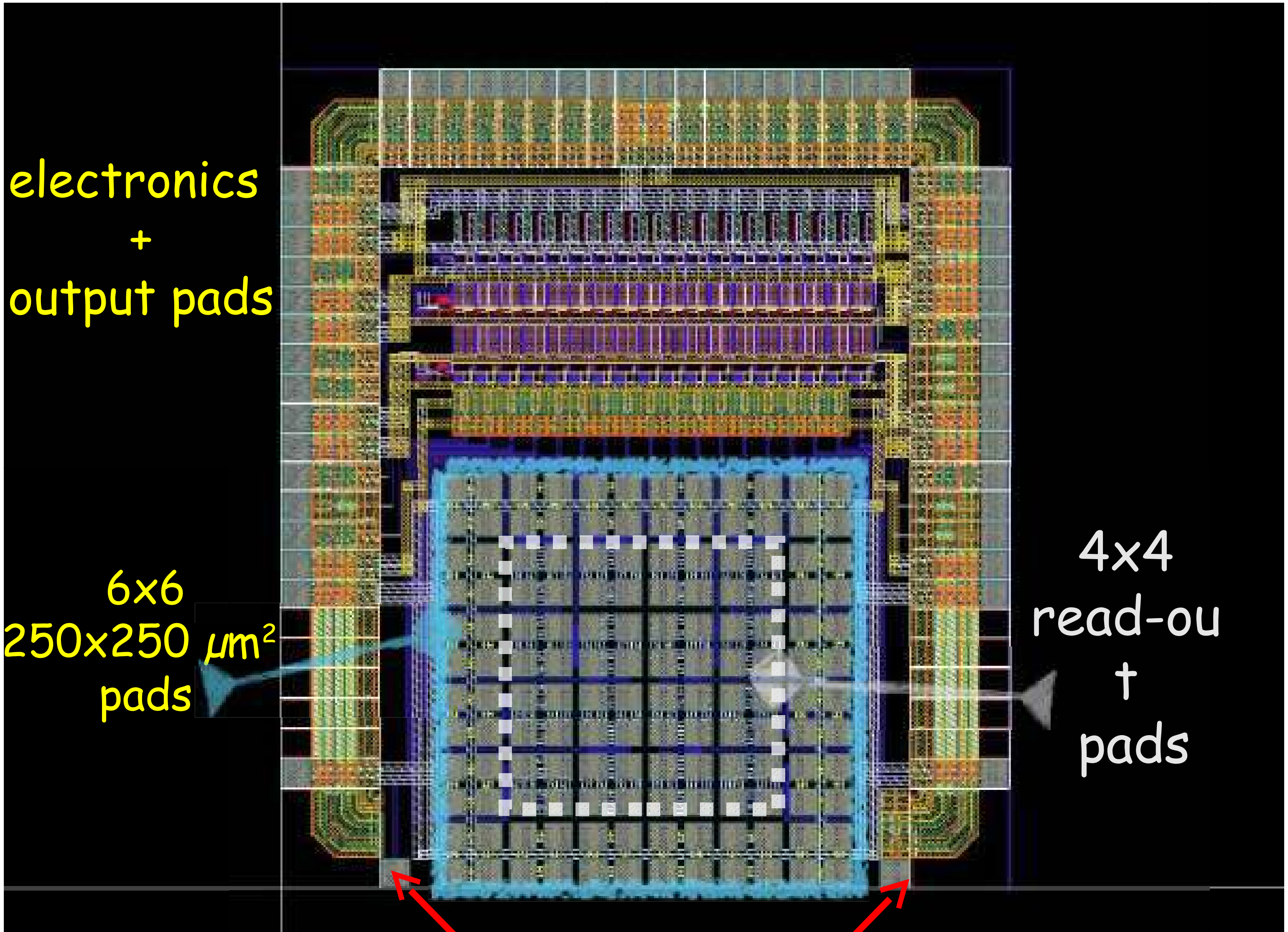
13 x 11
110 μm pitch
50 μm diam

9 x 6
200 μm pitch
50 μm diam

7 x 6
300 μm pitch
100 μm diam

# b) CHIPSODIA chip

(G. De Robertis, F. Loddo e A. Ranieri - BA)




$\approx$ 3x3 mm²

CMOS 0.35 μm

τp = 500 ns

ENC 135+30 e/pF

2 extra channels

25 chips by the end of January 2013

# Conclusions

- A uniform silicon-diamond bonding by pulsed laser technique can be achieved
- Chips can be bonded to diamond without damage
- Conductive  channels through diamond and graphitic ohmic contact can be laser-written (fs for bulk channels, ns for ohmic contacts). Resistivity is still an issue
- Charge can be collected by the metallized SOD structure
- SOD with TSVs connecting the silicon free surface to the diamond (prototype zero) is underway
- A dedicated pixel chip is in preparation (prototype one)

# Thank you for listening!

INO-CNR

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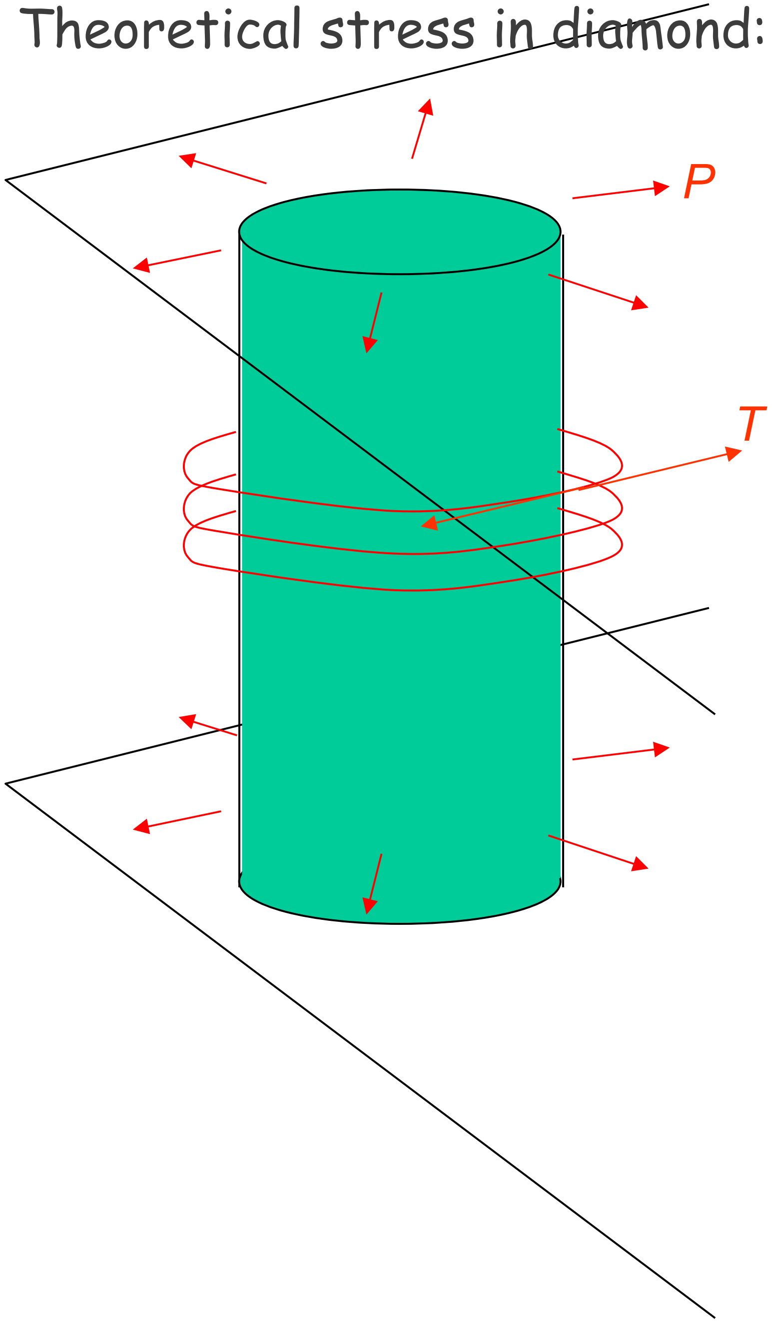
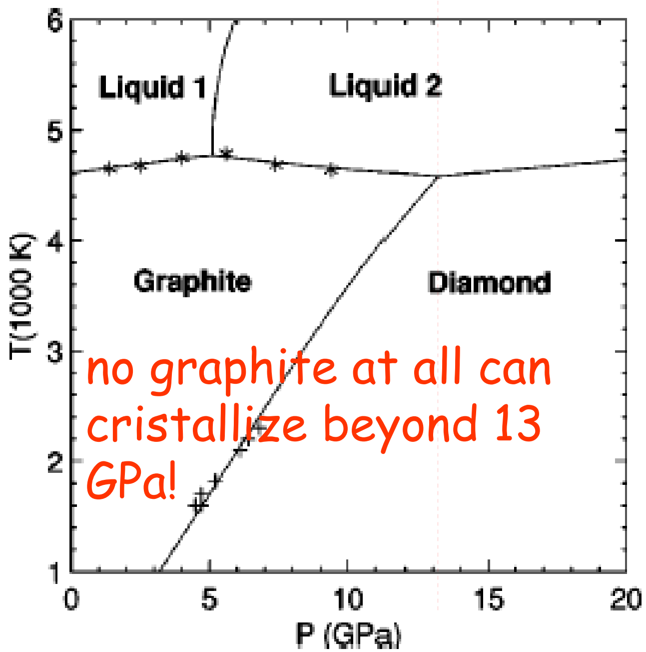
of Florence

Graphite density is much lower than that of diamond

Theoretical stress in diamond:

$$P \approx T \approx \frac{\left(C_{11}^{G}+C_{44}^{G}\right)\left(C_{11}^{D}-C_{44}^{D}\right)}{C_{11}^{G}+C_{44}^{G}+C_{44}^{D}-C_{44}^{D}}\left(\sqrt{\frac{\delta_{D}}{\delta_{G}}}-1\right) \approx 60\, GPa$$




Ultimate tensile strength of diamond ~ 2.8 GPa

Graphite density is much lower than that of diamond

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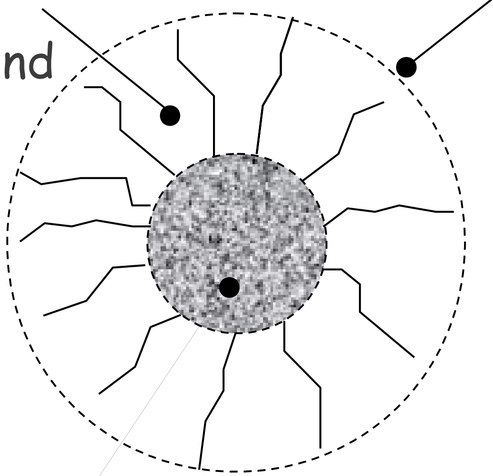
Stressed Diamond

$P_{max}= T_{max}$=2.8 GPa

$T \sim 0$

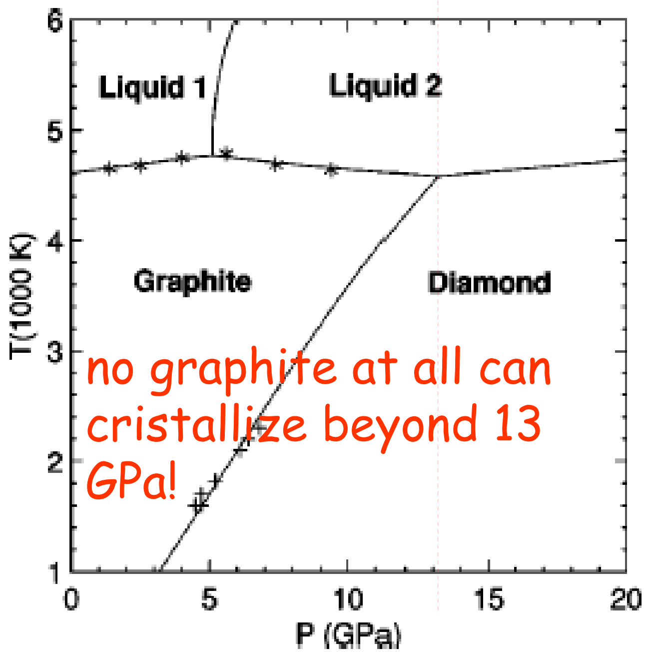
Cracked

Diamond



Mixed phase
graphite+diamond

Higher density and higher resistivity than graphite

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