Torino, 23 Marzo 2022

Nano-beams di radiazione di sincrotrone e loro interazione con ossidi semiconduttori e superconduttori

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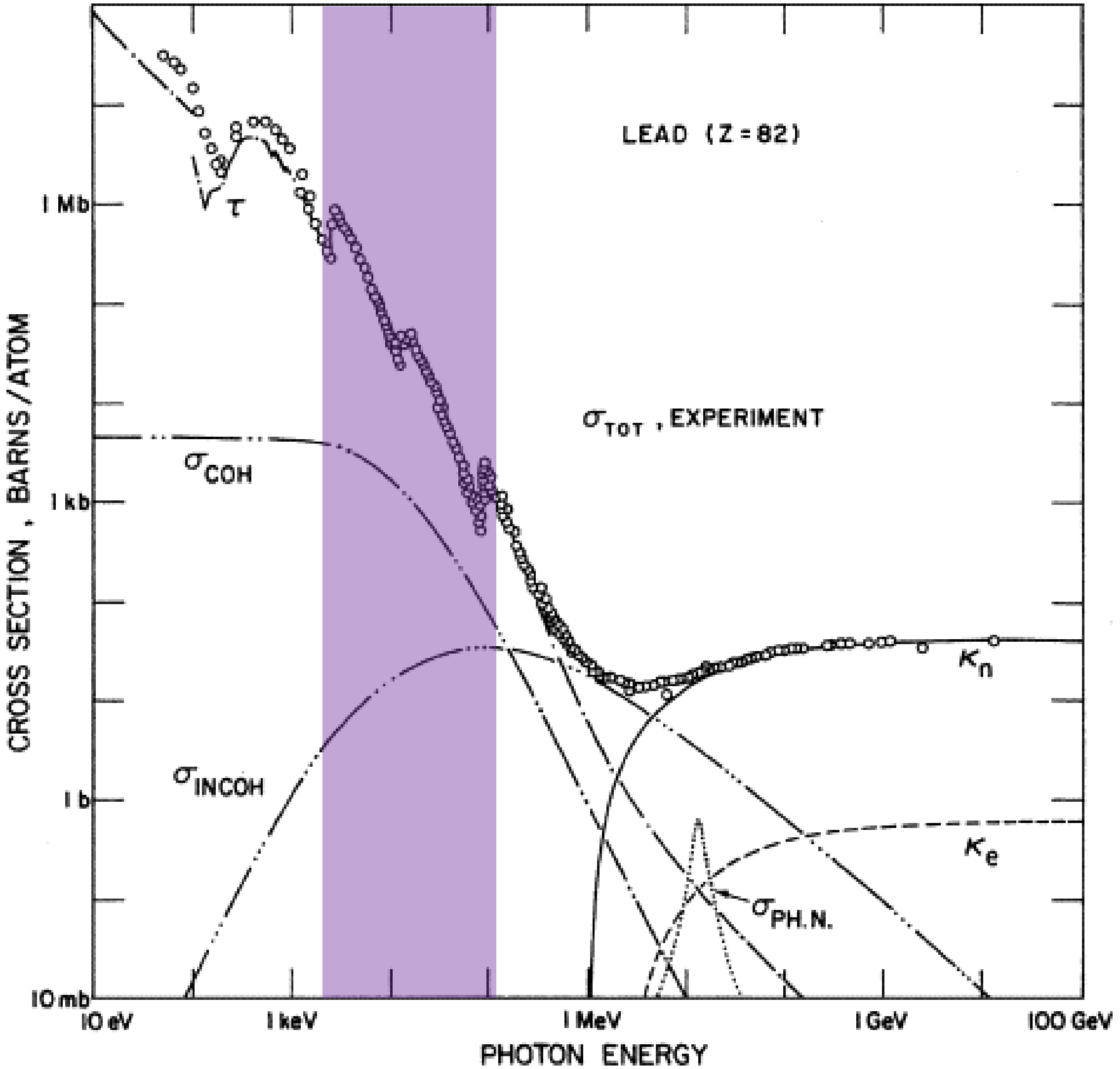
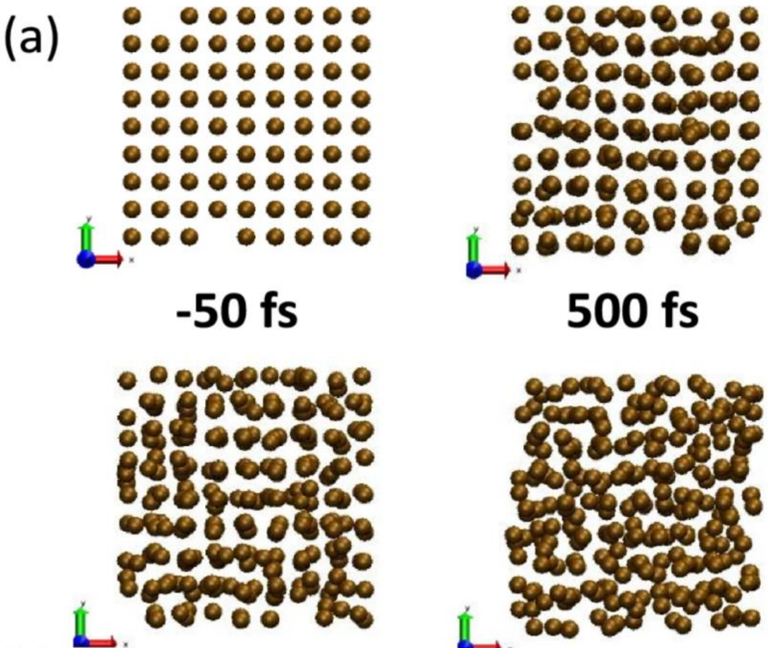
Typical X-ray matter processes



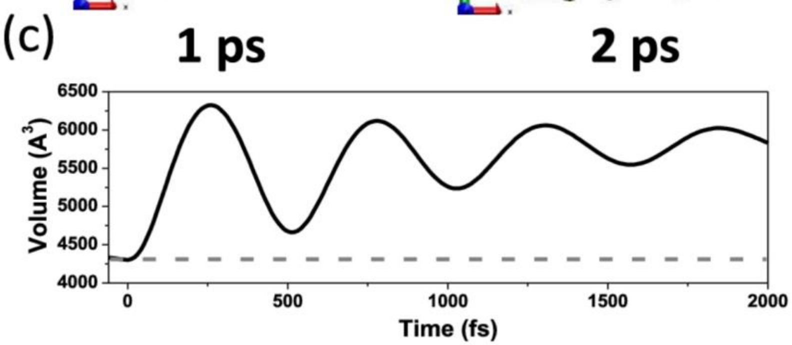
Hard X-ray region

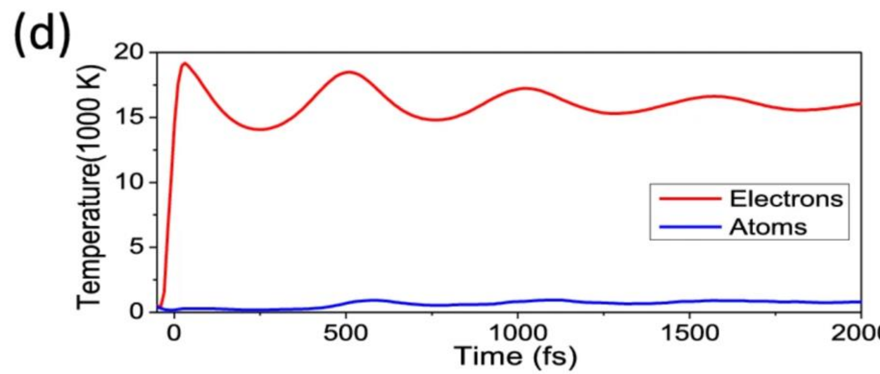
Novel mechanism: Non-thermal melting

Gold, NPH, 3.5 eV/atom, BO



N. Medvedev, Scientifc Reports, 10, Article number: 12775 (2020)



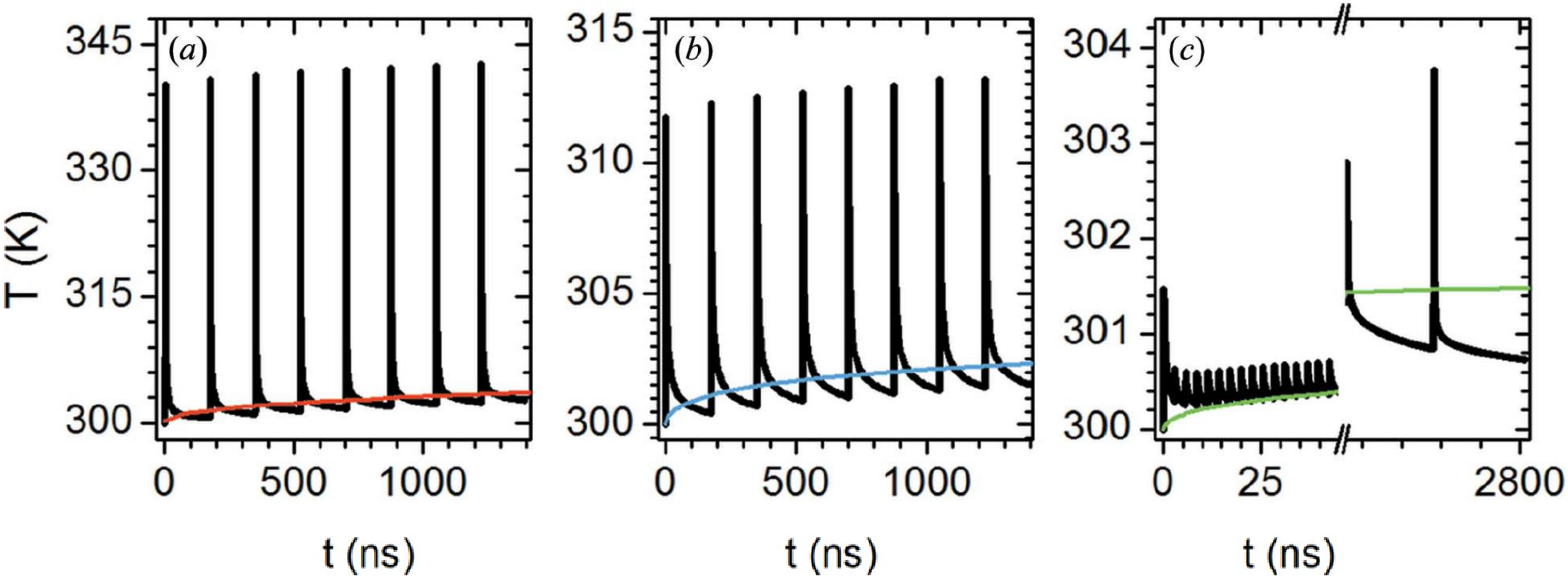


(**a**) Atomic snapshots of an NPH supercell of gold, irradiated with 3.5 eV/atom dose, modeled with XTANT-3 within the BO approximation. (**b**) Electronic DOS at corresponding instants in time; red lines depict the electron distribution function. (**c**) Evolution of the volume of the supercell (solid line); the dashed line marks the volume of the supercell at ambient conditions. (**d**) Electronic and atomic temperature evolution.

3rd generation synchrotrons: Thermal fatigue ?

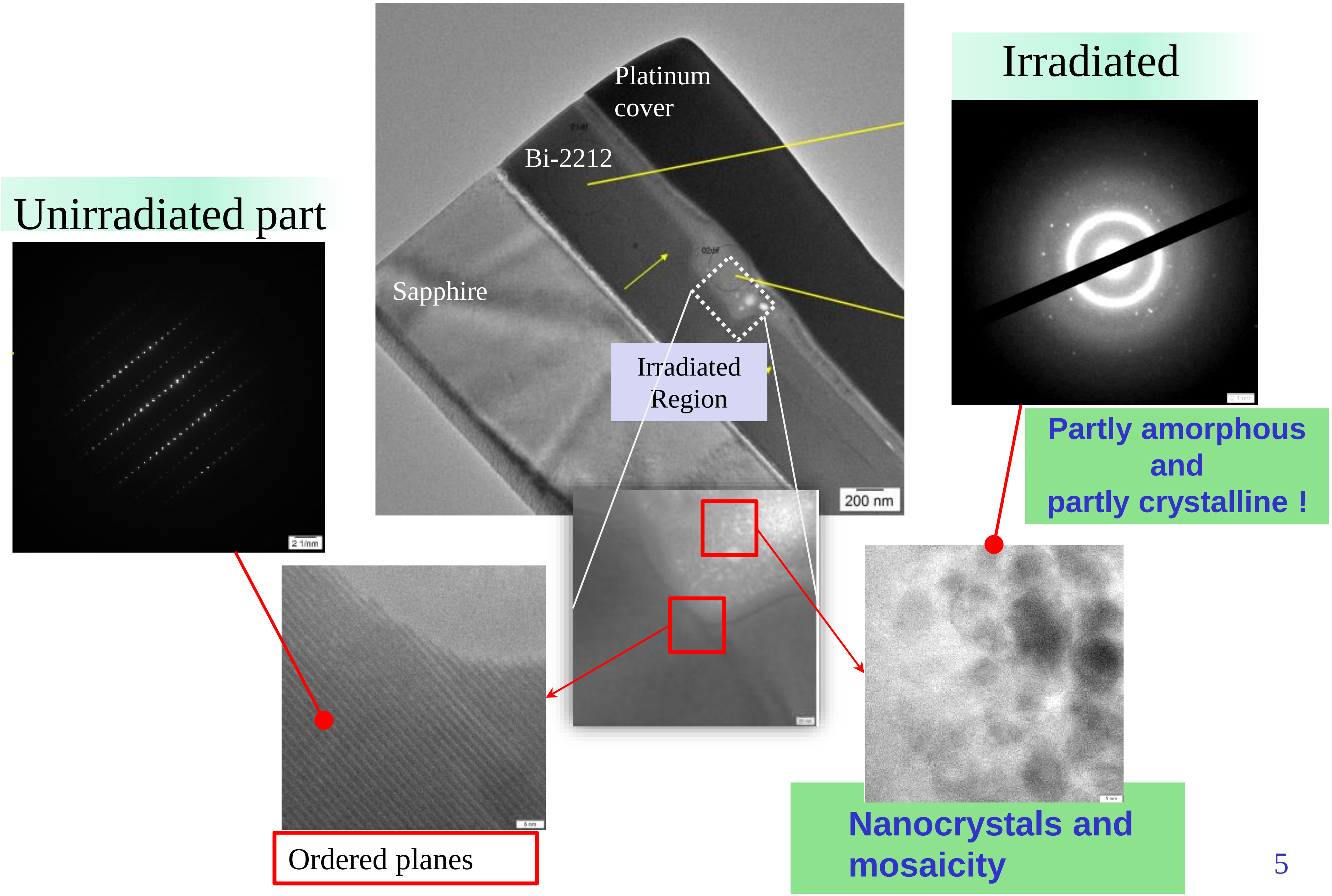
ESRF
The European Synchrotron

The case of a superconducting oxide: $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212)



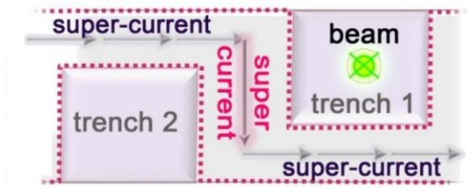
V. Bonino,….M. Truccato, Journal of Synchrotron Radiation, (2020). 27, 1662–1673

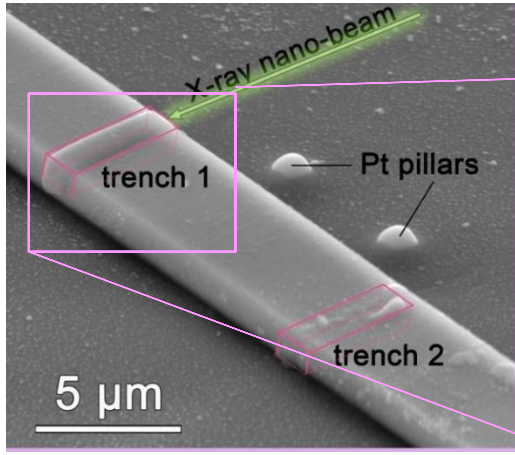
TEM cross section

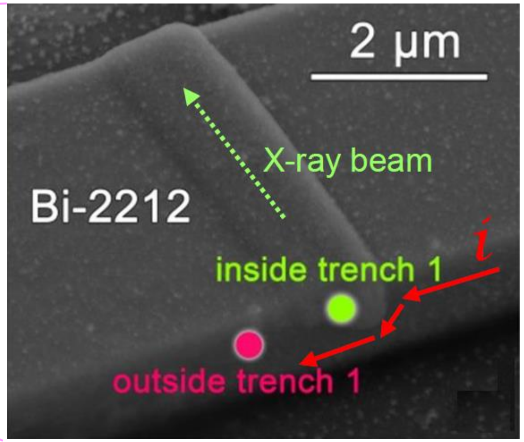


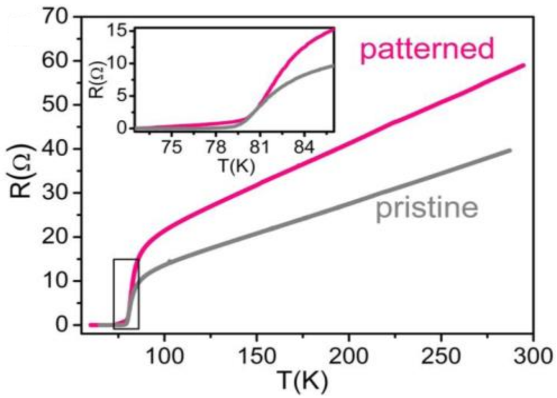
X-ray Nano Patterning

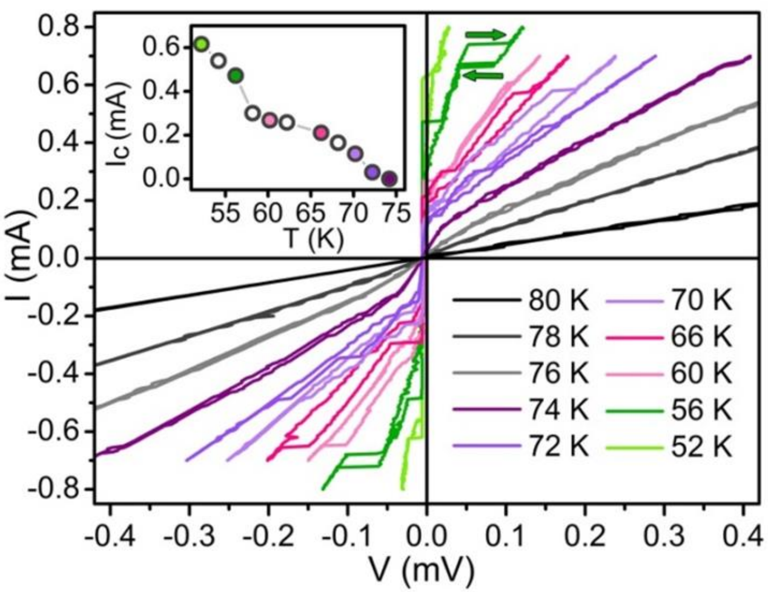
- ID16-B, ESRF, Grenoble.
- Nanoprobe: 45 (H) × 53 (V) nm^2
- Φ_0 = (1-5) × 10^{11} s^{-1} , E=17.6 keV
- Pink-beam mode: $\Delta E/E \approx 10^{-2}$









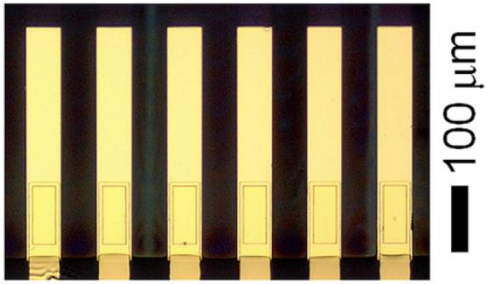


Intrinsic Josephson junctions with no material/vacuum interfaces

M. Truccato et al., Nano Lett. 16, 1669 (2016)

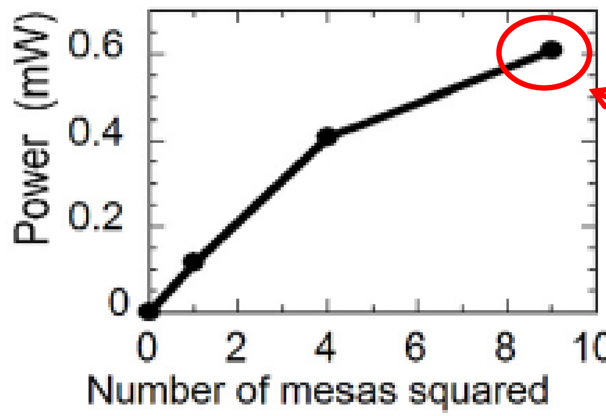
Objective: maximizing THz emission in Bi-2212

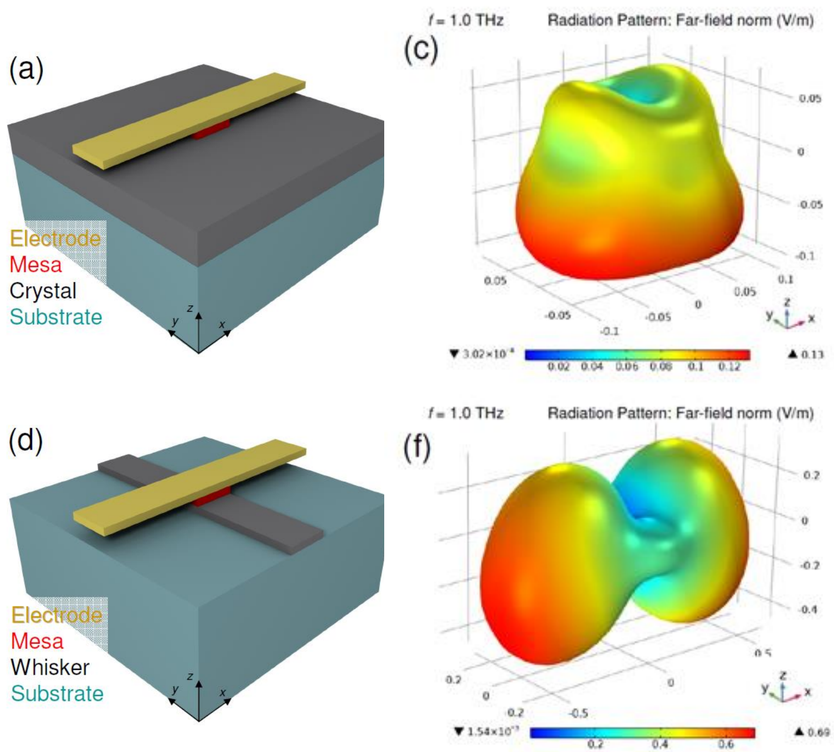
- THz emitter: 6 Bi-2212 mesa (view from top)



T.M. Benseman et al., Appl. Phys. Lett. **103**, 022602583 (2014)

Mesa synchronization implies emitted power $\propto N^2$



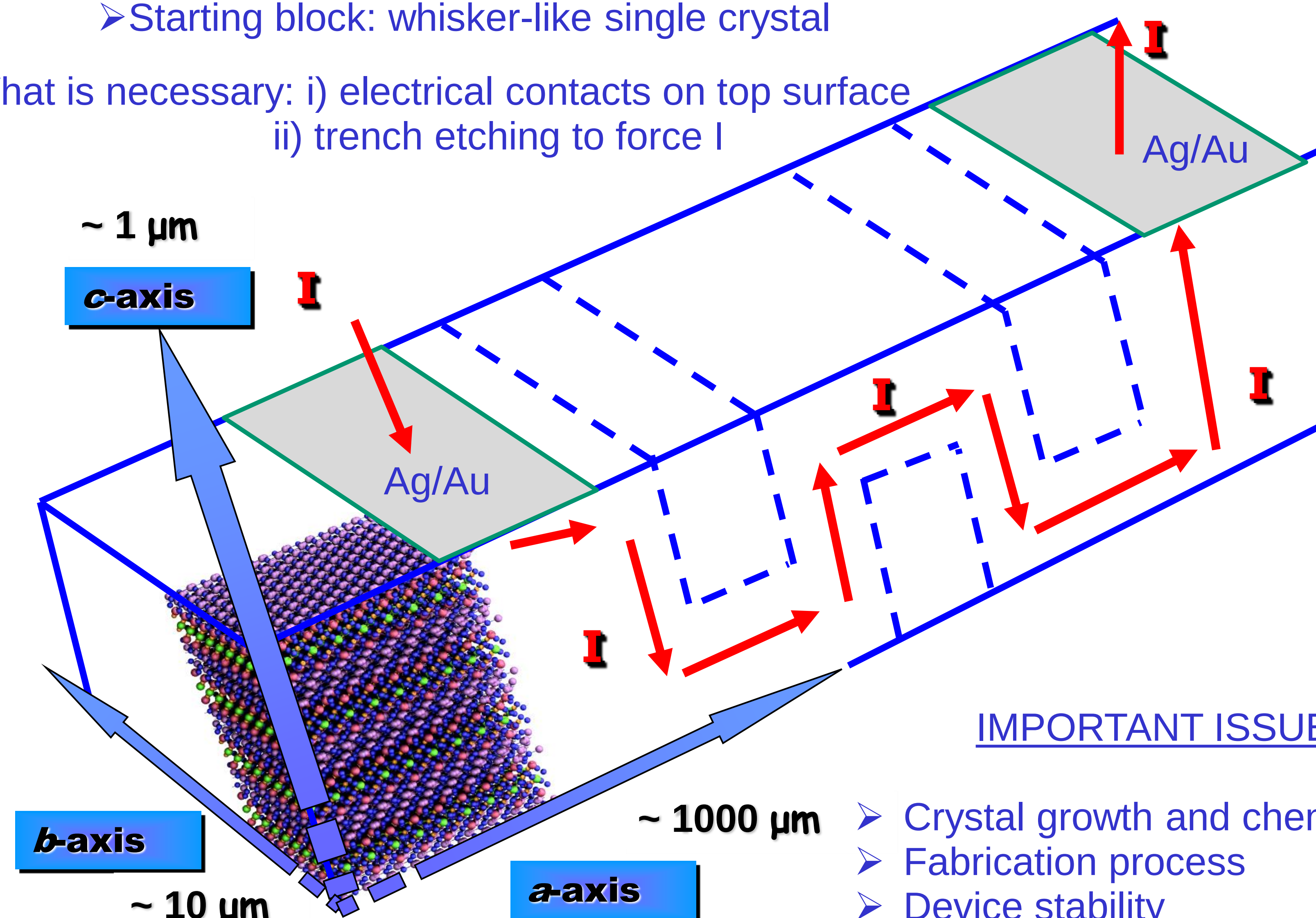


Advantage of whisker design: better antenna and impedance matching (more than one order of magnitude in emitted power)

Stack fabrication principle in Bi-2212

- Starting block: whisker-like single crystal

What is necessary: i) electrical contacts on top surface
ii) trench etching to force I

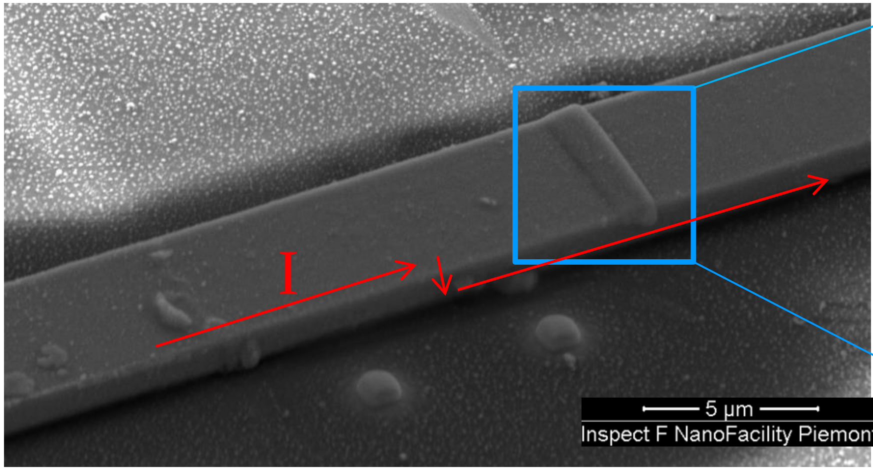


IMPORTANT ISSUES:

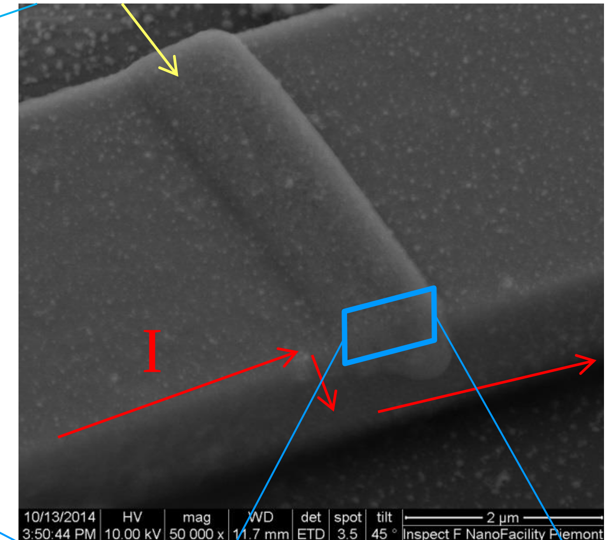
- Crystal growth and chemistry
- Fabrication process
- Device stability

Novel way: X-ray nanopatterning

- Nano-beam: 57 × 45 nm^2
  E= 17.65 keV

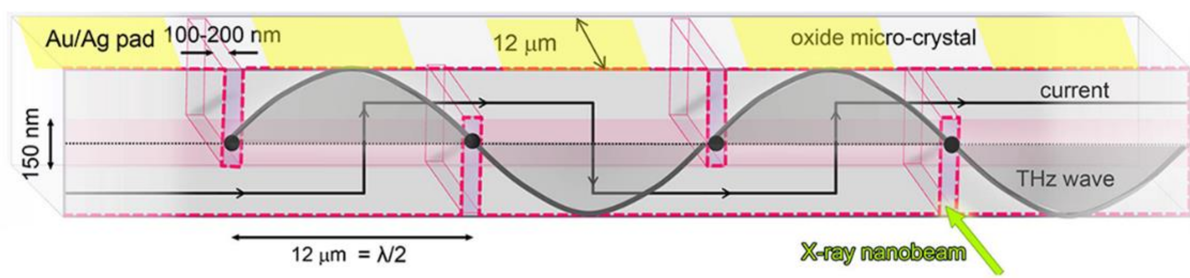


Nanobeam



- Dose effective in changing the current direction without destroying the lattice !!!

New design

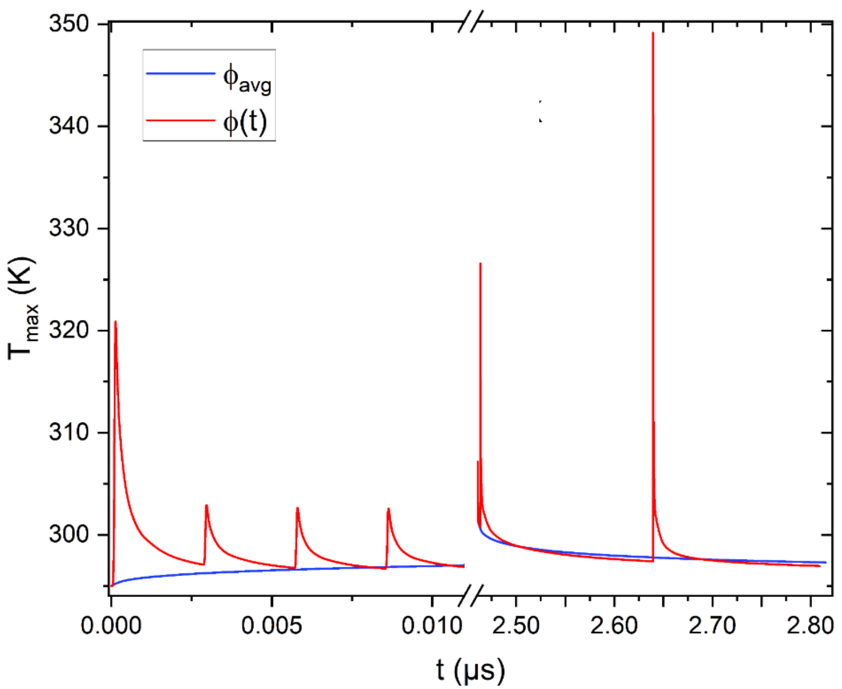


M. Truccato et al., Nano Lett. **16**, 1669 (2016)

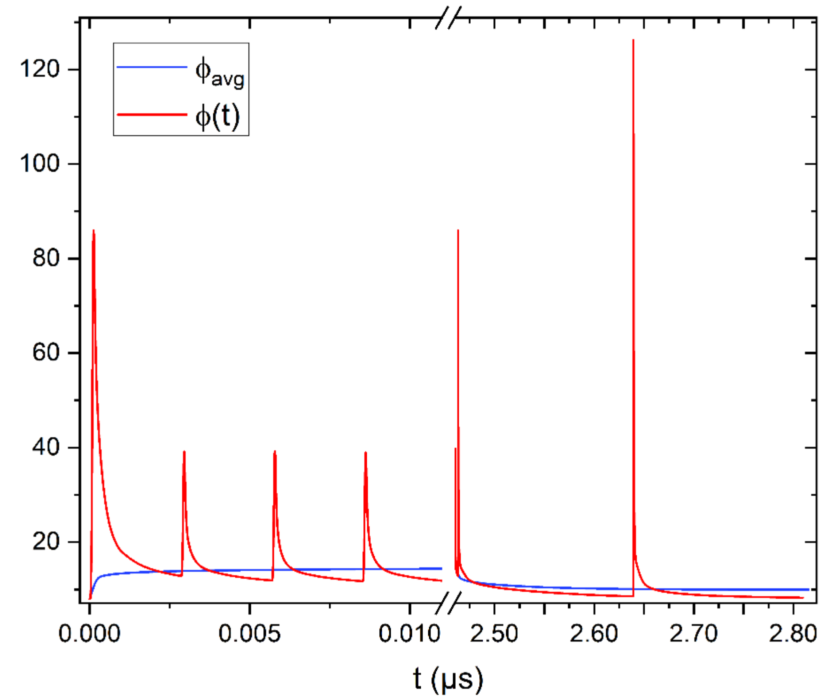
4th generation synchrotrons: Semiconducting oxides

The influence of temperature

$SrTiO_3$ at T=295 K



$SrTiO_3$ at T= 8 K

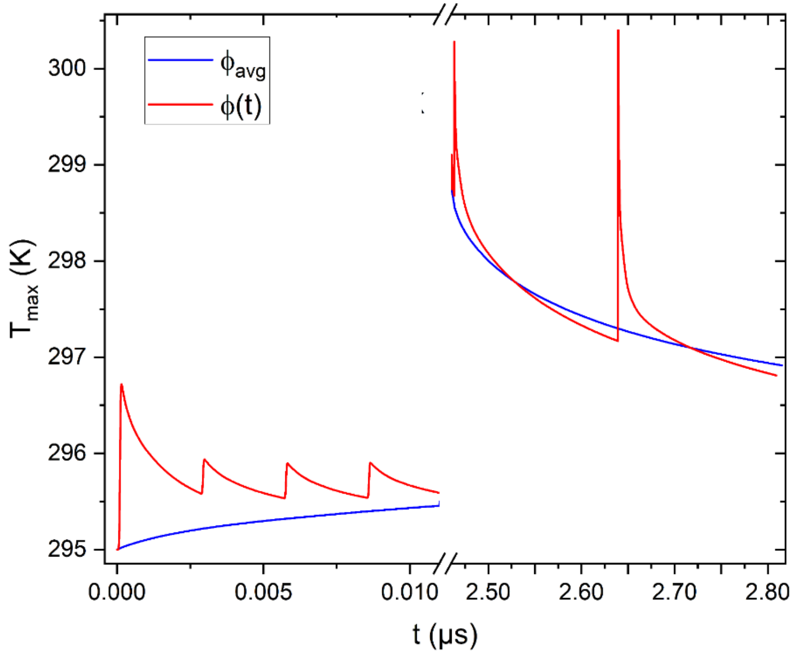


ΔT≈ 50K

ΔT≈ 120 K

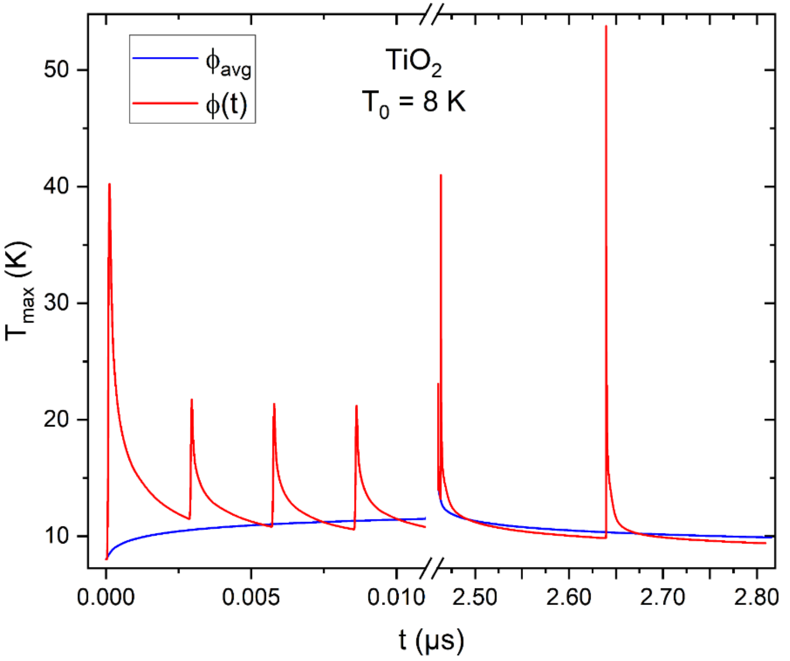
4th generation synchrotrons: Semiconducting oxides

TiO_2 at T=295 K



ΔT≈ 5K

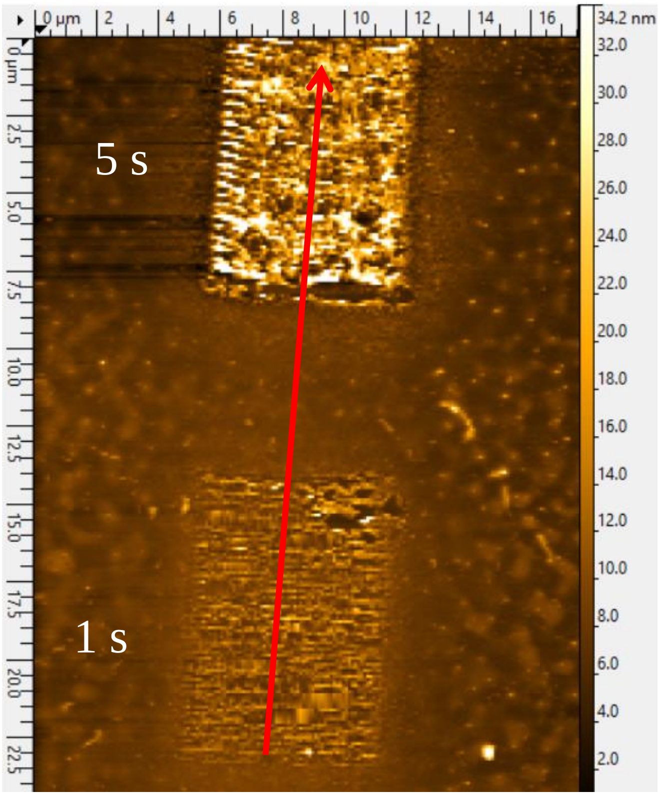
TiO_2 at T= 8 K

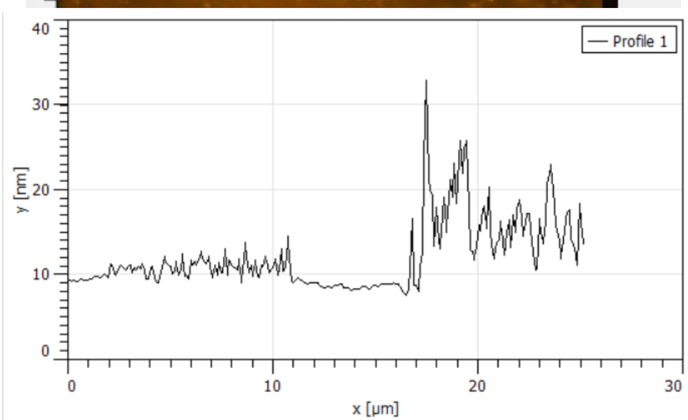


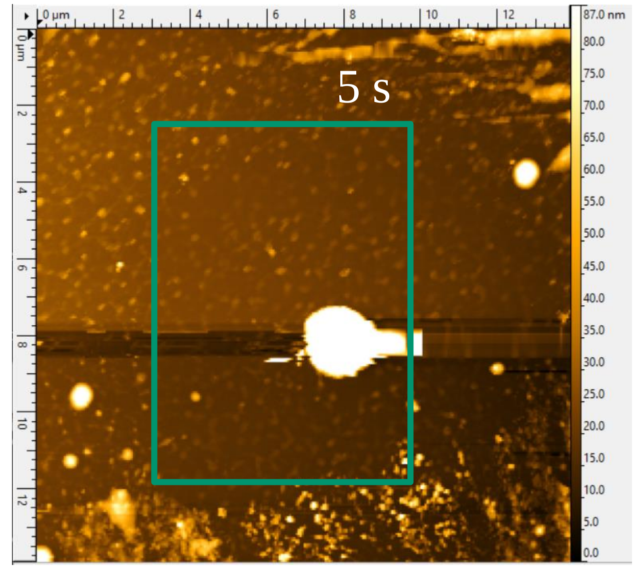
ΔT≈ 45K

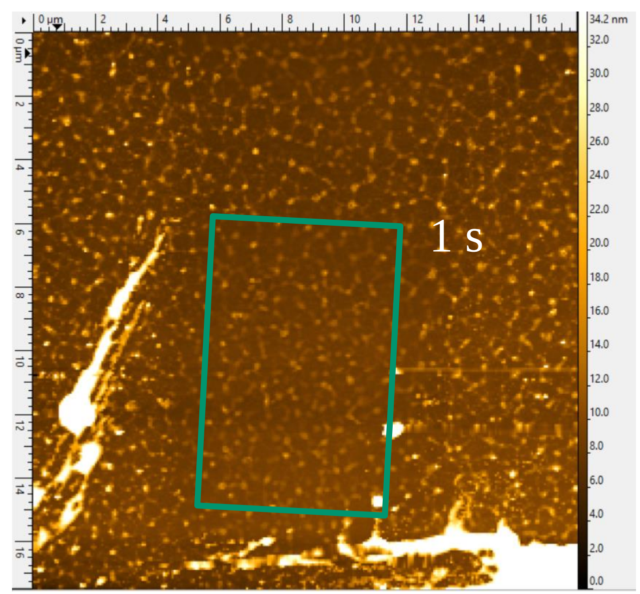
Fe:STO vs TiO_2 when irradiated at T=8K

Fe:STO

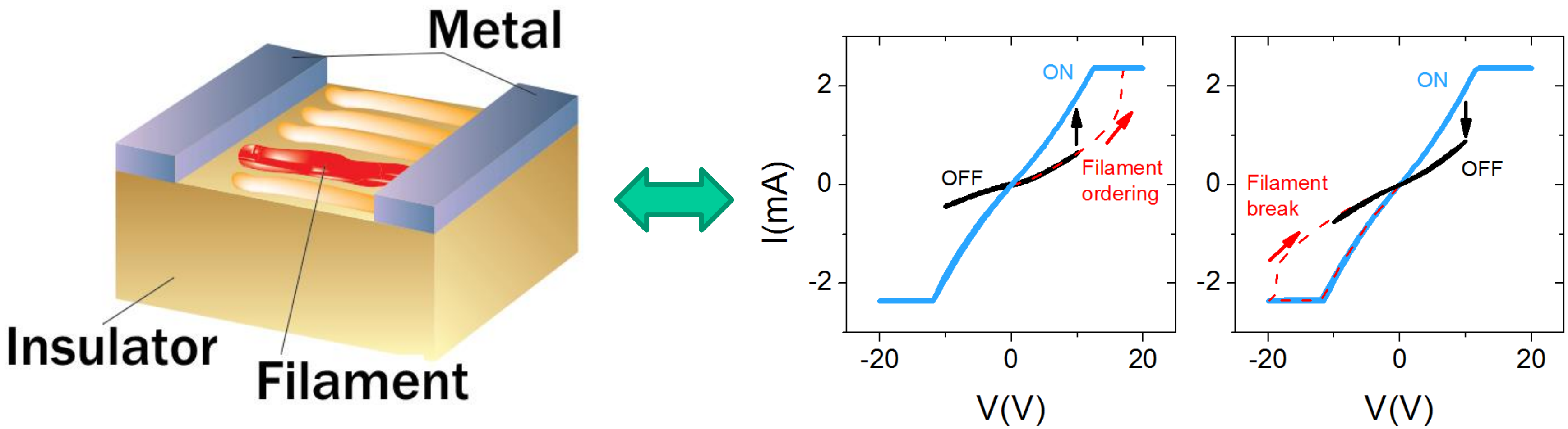






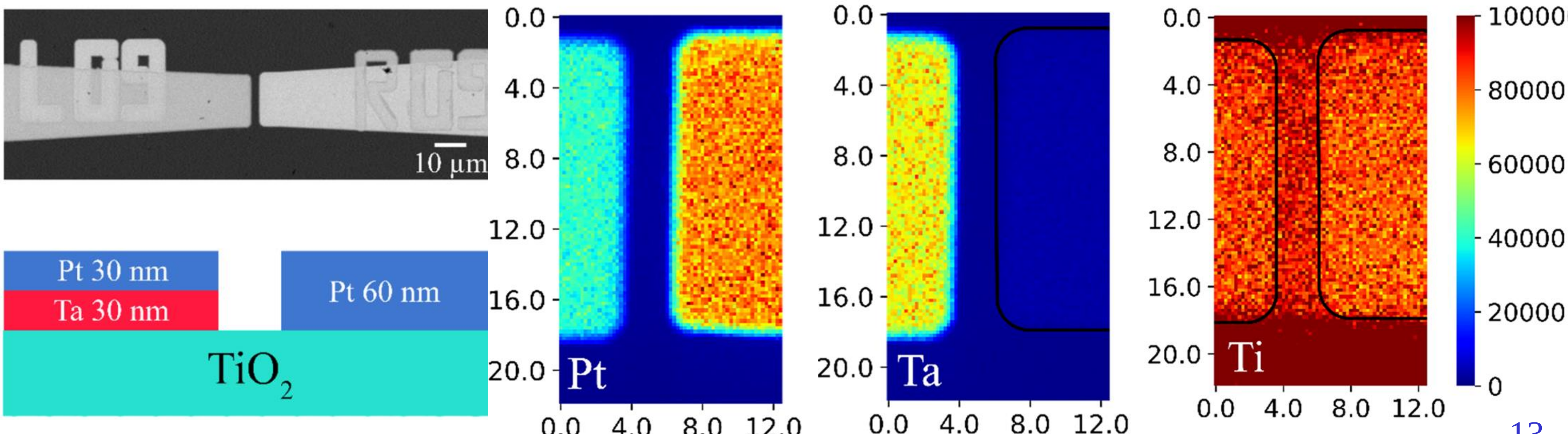


Objective: Tuning the functional properties of oxides and produce memristors



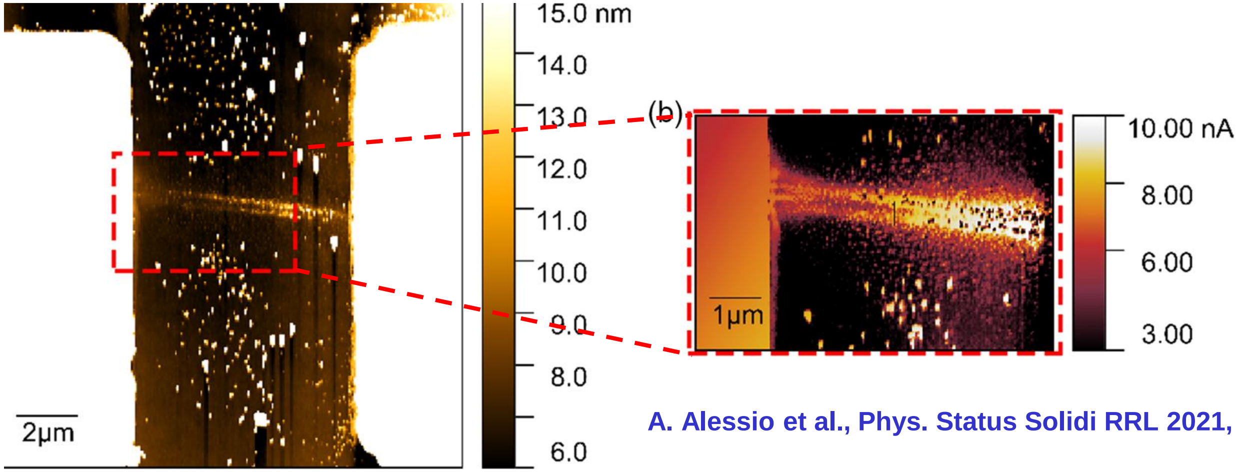
Pristine samples

Asymmetric contacts



A. Alessio,…, M. Truccato., Phys. Status Solidi RRL 2021, 15, 2100409

Changes in topography and conductivity after irradiation

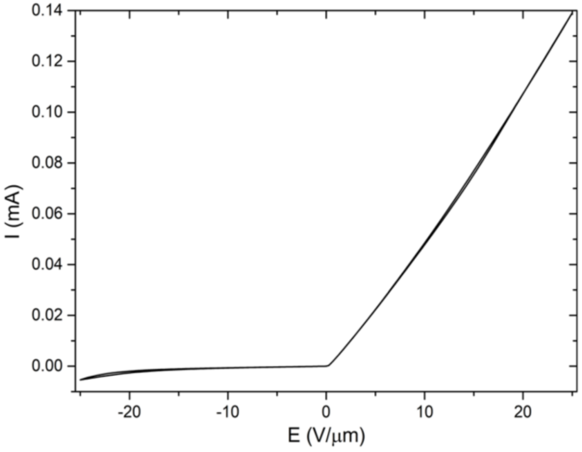


C-AFM

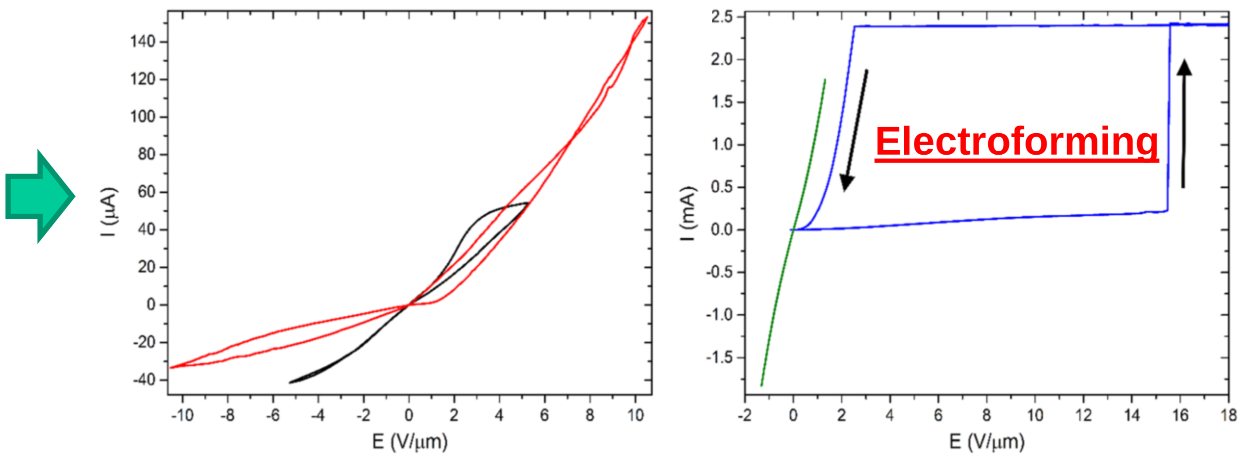
A. Alessio et al., Phys. Status Solidi RRL 2021, 15, 2100409

Changing the IV curves

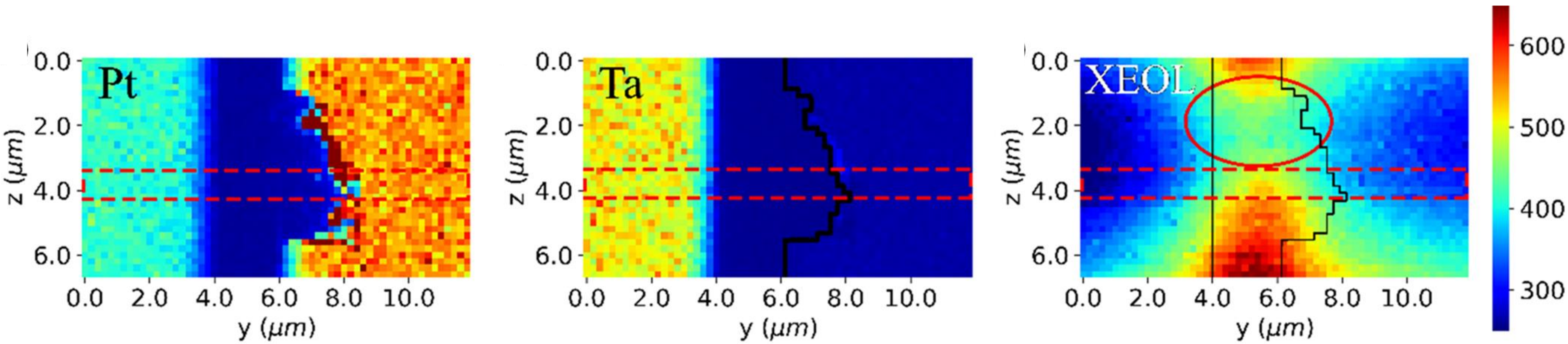
CD = 0

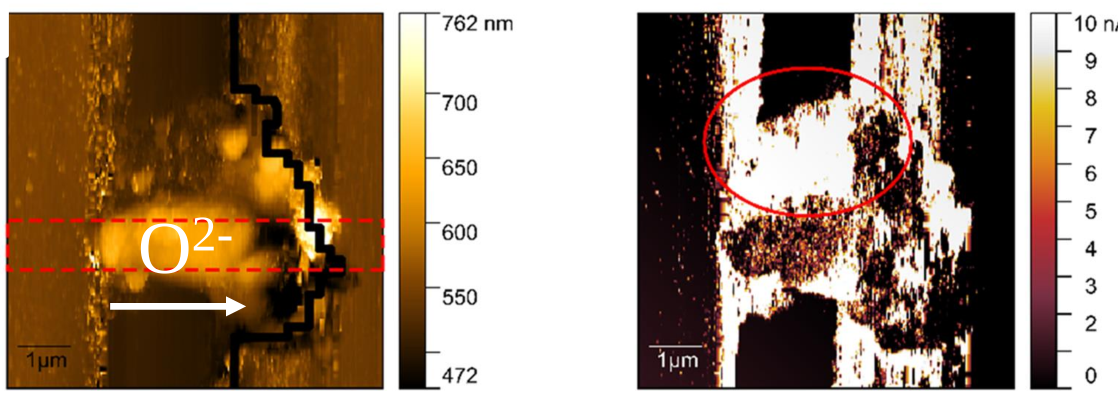


CD = 2.4×10^{13} Gy or CF = 5.3×10^{13} J m^{-2}



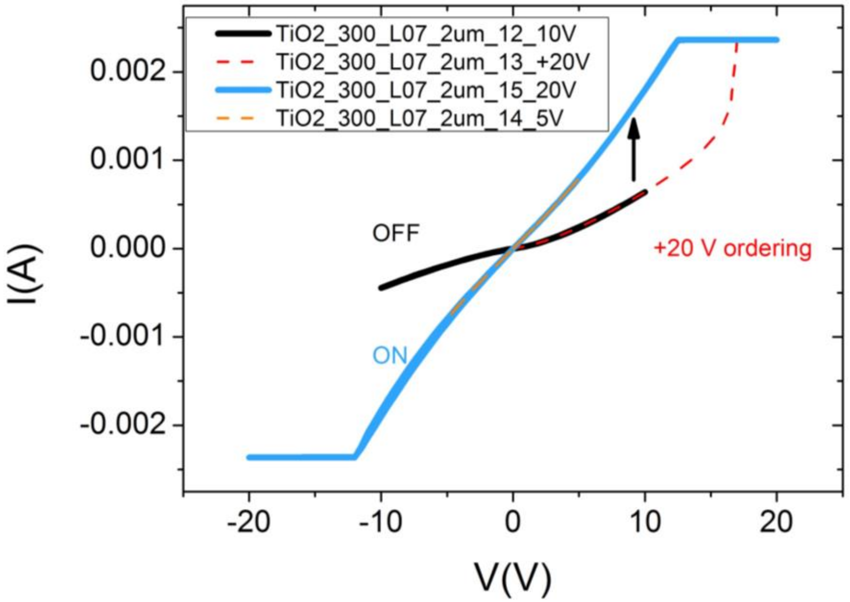
Microscopic features of electroforming





A. Alessio et al., Phys. Status Solidi RRL 2021, 15, 2100409

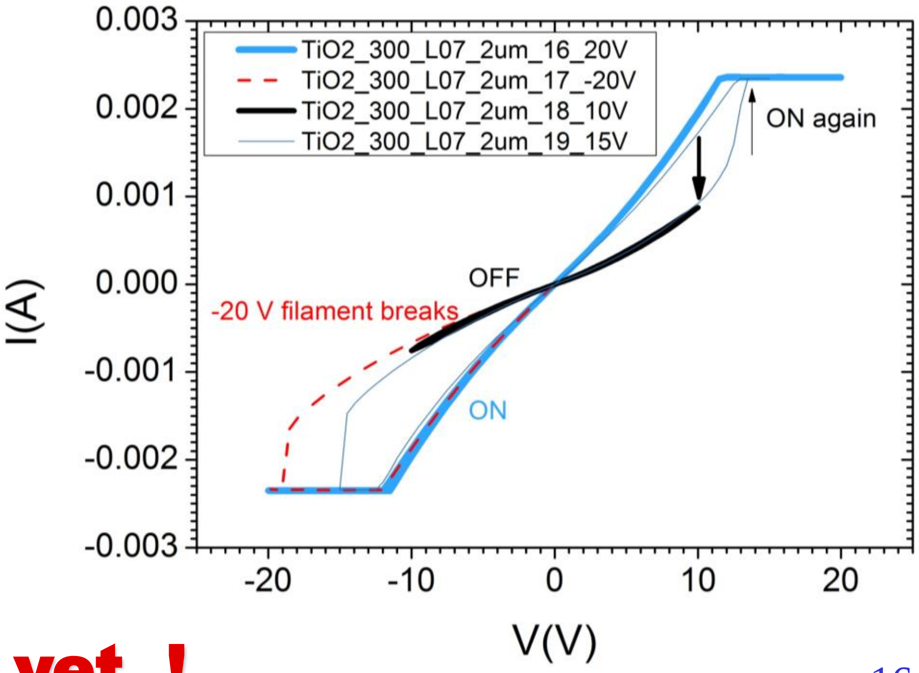
Effect of nanobeam irradiation:



Switching ON

MEMRISTOR behaviour

Switching OFF
and
ON again



But NOT fully reversible yet !

Open questions:

a) **Which is the microscopic mechanism responsible for conducting channel formation?**

b) **Which is the role played by asymmetric electrodes?**

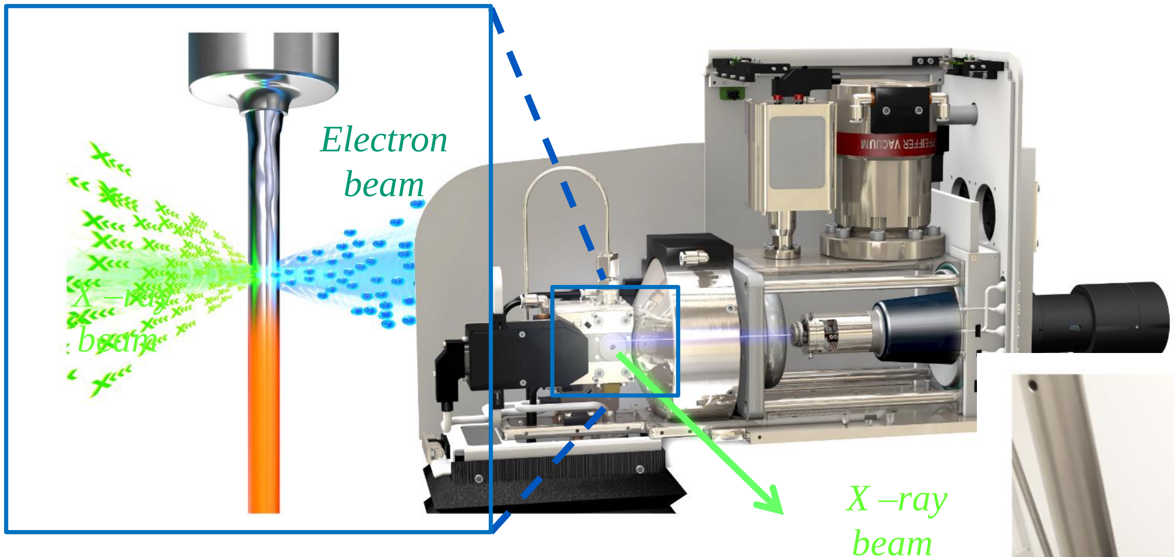
c) **What's the role of starting oxygenation conditions and of electrode distance?**

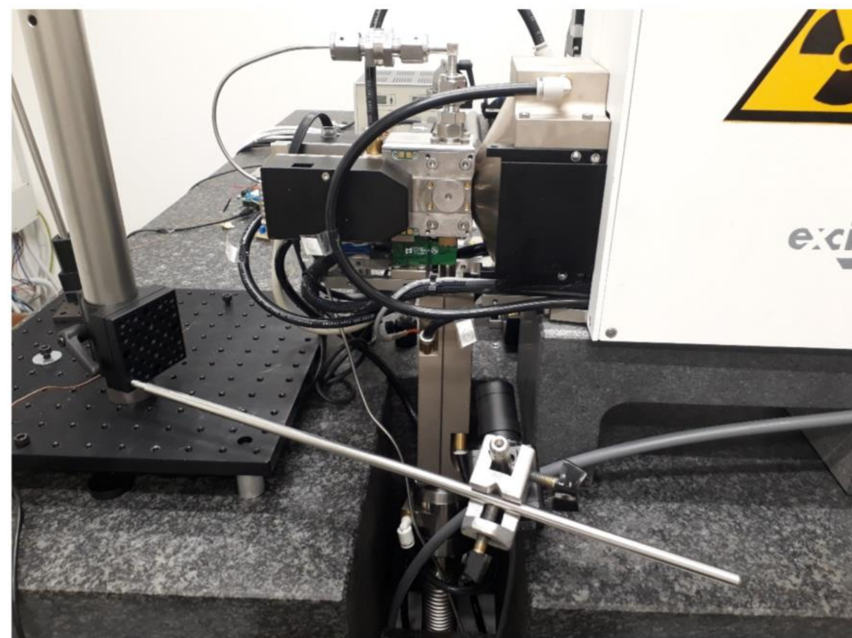
d) **What's the difference with respect to irradiation with protons?**

e) **Does it work also with other semiconducting oxides like $SrTiO_3$?**

Recent developments:
a) Intense Lab X-ray source

World's brightest X-ray source at the lab scale: Now in Torino (the only one in Italy)





Objective: X-ray focussing and testing XNP at the lab scale

Recent developments:
b) Room temperature superconductors

Experimental claim of T_c =287.7 ± 1.2 K (= 15°C) in a H-C-S compound in 2020
UNFORTUNATELY, pressure is NOT the ambient pressure: T_c achieved at 267 ± 10 GPa equivalent to 2.6 × 10^6 atmospheres

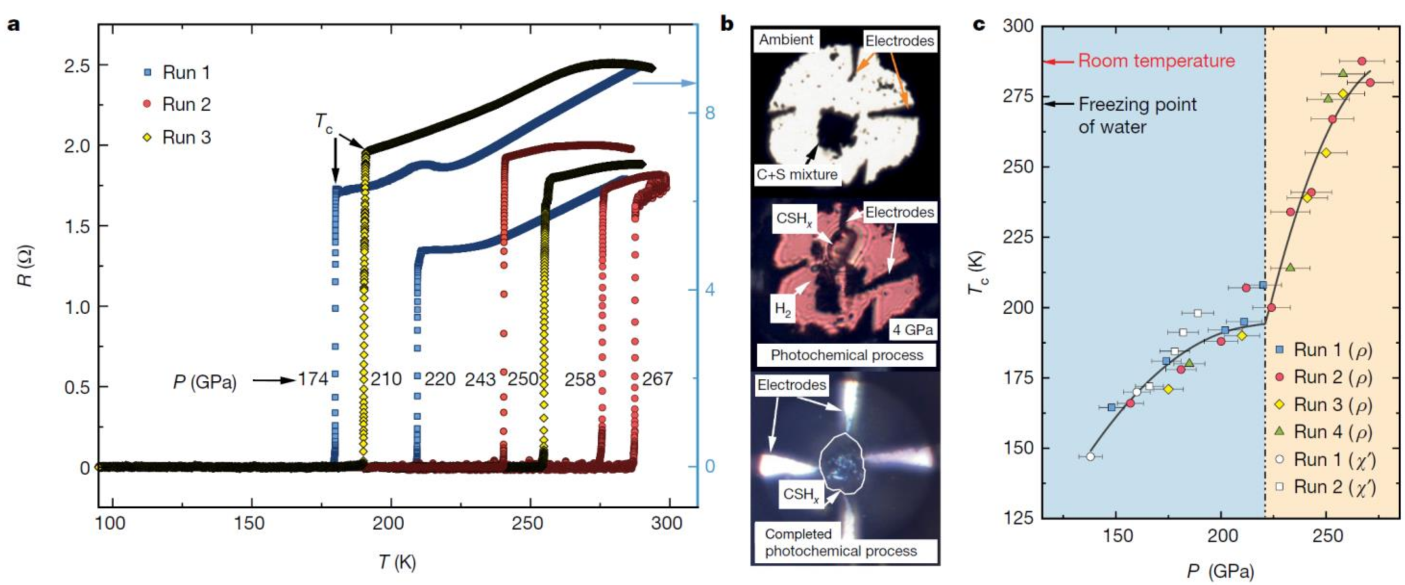
Article

Room-temperature superconductivity in a carbonaceous sulfur hydride

https://doi.org/10.1038/s41586-020-2801-z
Received: 31 August 2020
Accepted: 8 September 2020
Published online: 14 October 2020

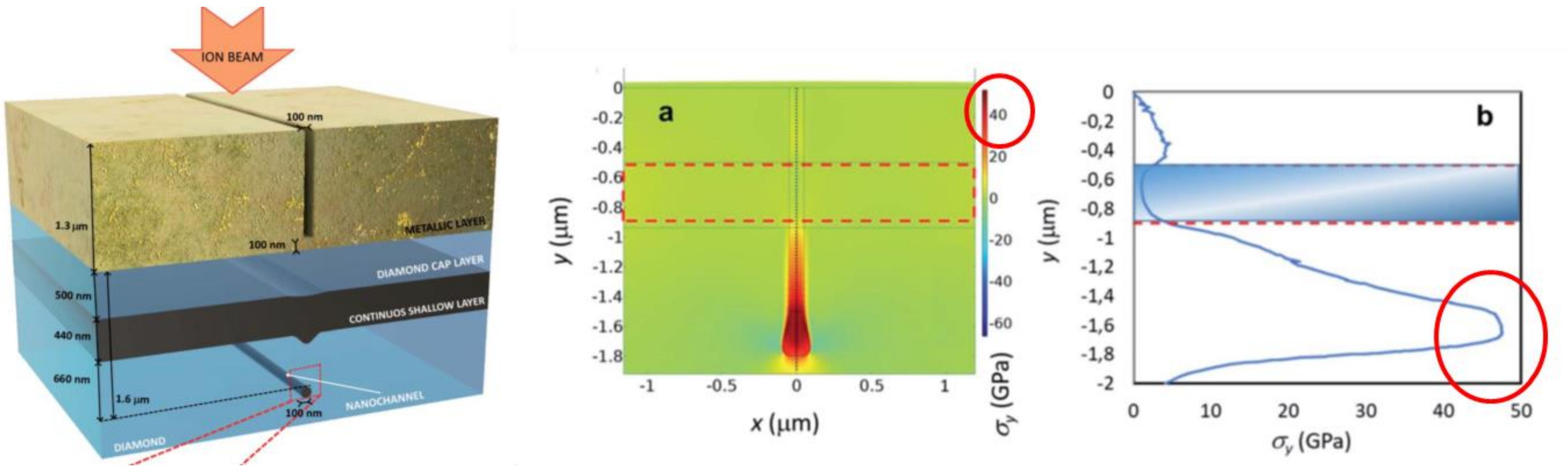
Elliot Snider[1,6], Nathan Dasenbrock-Gammon[2,6], Raymond McBride[1,6], Mathew Debessai[3], Hiranya Vindana[2], Kevin Vencatasamy[2], Keith V. Lawler[4], Ashkan Salamat[5] & Ranga P. Dias[1,2]✉

One of the long-standing challenges in experimental physics is the observation of room-temperature superconductivity[1,2]. Recently, high-temperature conventional



Experimental trick:

exploiting diamond internal pressure over embedded nanofilaments



Picollo et al Nanoscale Adv., 3 , 4156, (2021)

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