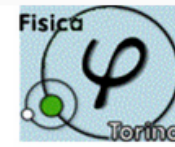




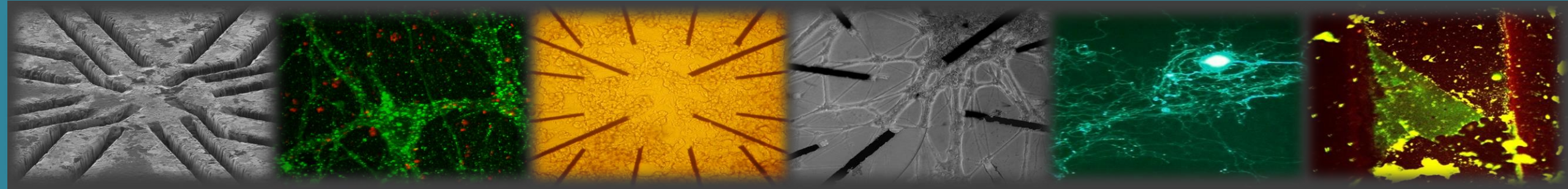
UNIVERSITA' DEGLI  
STUDI DI TORINO

# Solid State Physics group



PHYSICS  
DEPARTMENT

## Diamante artificiale: applicazioni nella bio-sensoristica



<http://www.ph.unito.it/dfs/solid/index.html>

Mail: [federico.picollo@unito.it](mailto:federico.picollo@unito.it)

**FEDERICO  
PICOLLO**

**PHYSICS DEPARTMENT**  
UNIVERSITY OF TORINO



Istituto Nazionale di Fisica Nucleare  
SEZIONE DI TORINO

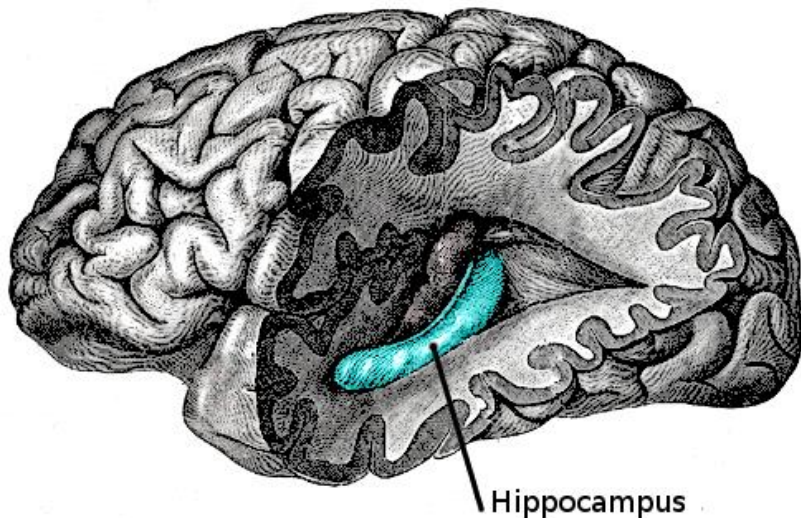
# SINGLE CRYSTAL DIAMOND BIOSENSORS

# Neurodegenerative diseases

3

## Alzheimer's disease

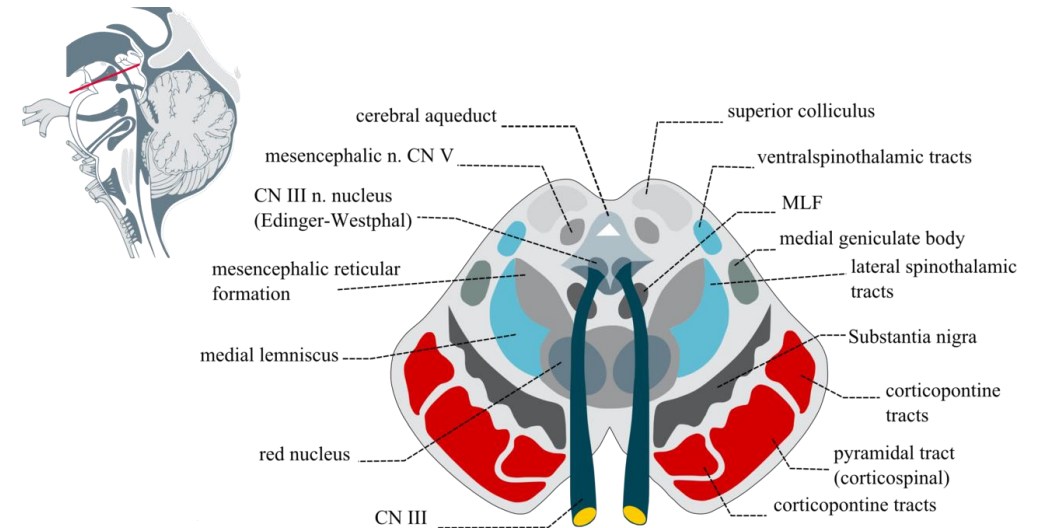
consequence of several cellular degenerative processes, primarily affecting memory encoding brain regions, such as hippocampus



By Henry Vandyke Carter - Henry Gray (1918) Anatomy of the Human Body (See "Book" section below) Bartleby.com: Gray's Anatomy, Plate 739, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=3907047>

## Parkinson disease

progressive degeneration of the *substantia nigra* pars compacta (SNc) dopaminergic neurons



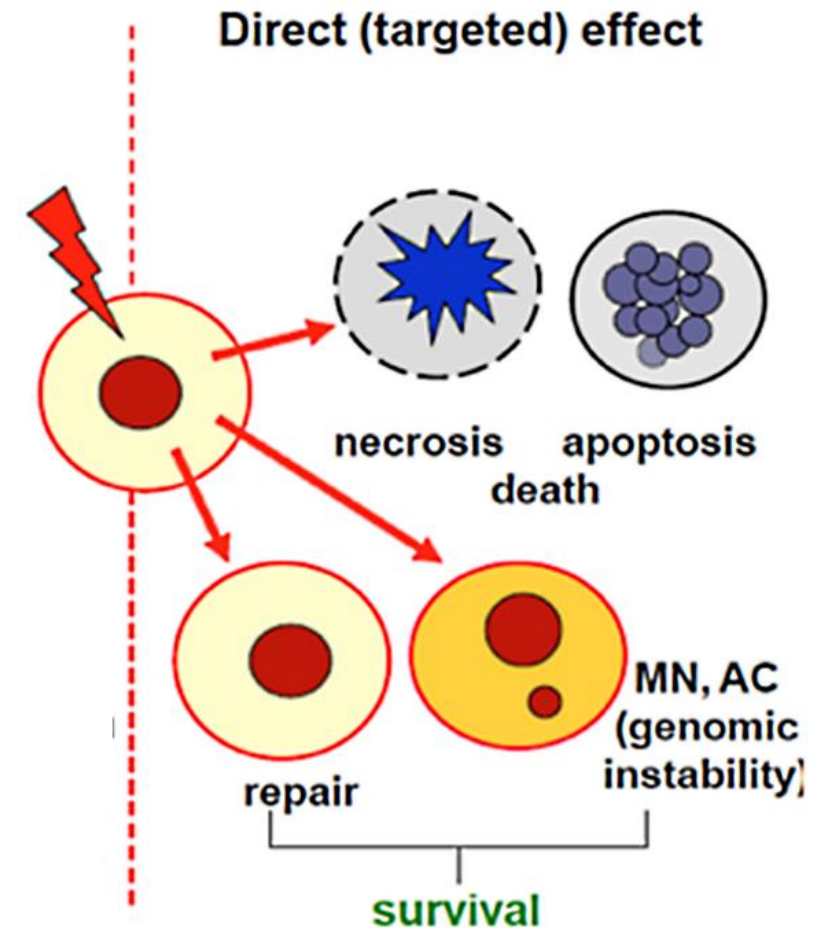
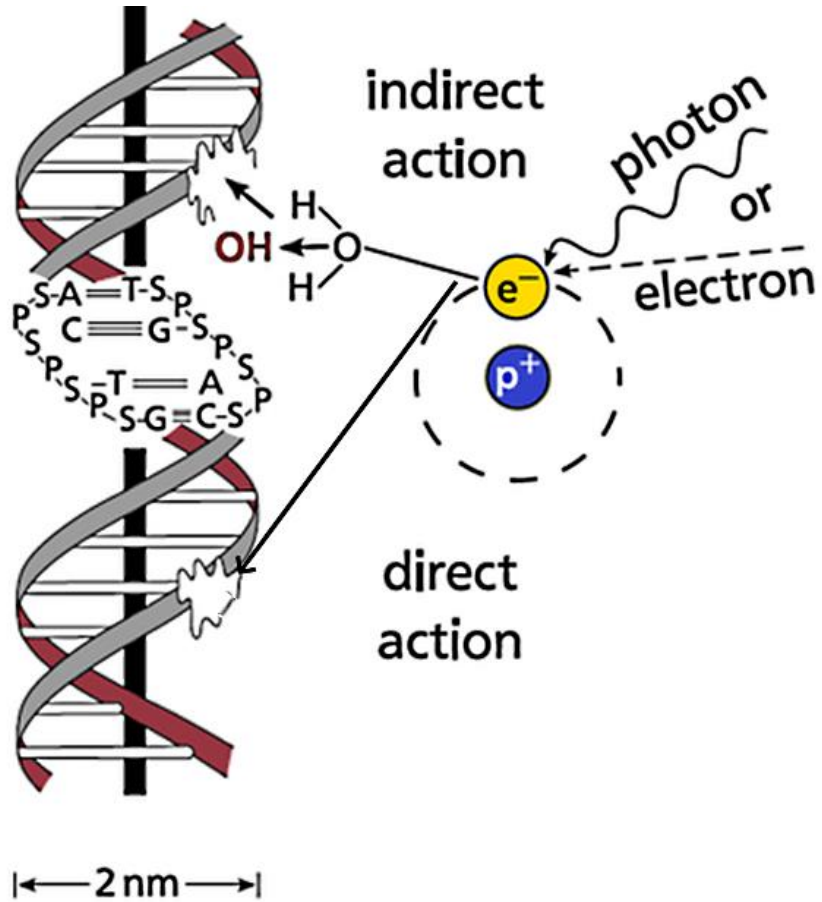
By Madhero88 - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=7157181>

Neurodegenerative diseases such as **Parkinson** and **Alzheimer's disease** (PD, AD) are characterized by a long lasting **asymptomatic phase** during which neurons alter their synaptic and excitable properties without clearly affecting brain function

# Radiobiology

4

Branch of biophysics concerned with the effects of ionizing radiation on organisms





# 16 ch MEA: Amperometry or Potentiometry

5

diamonds:

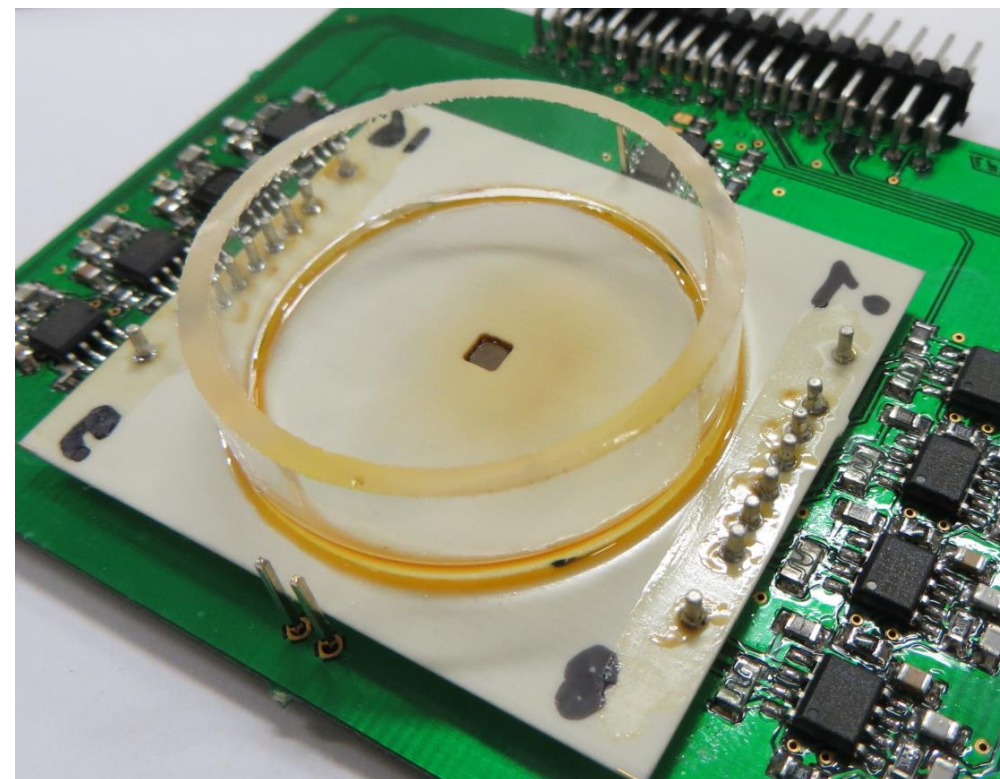
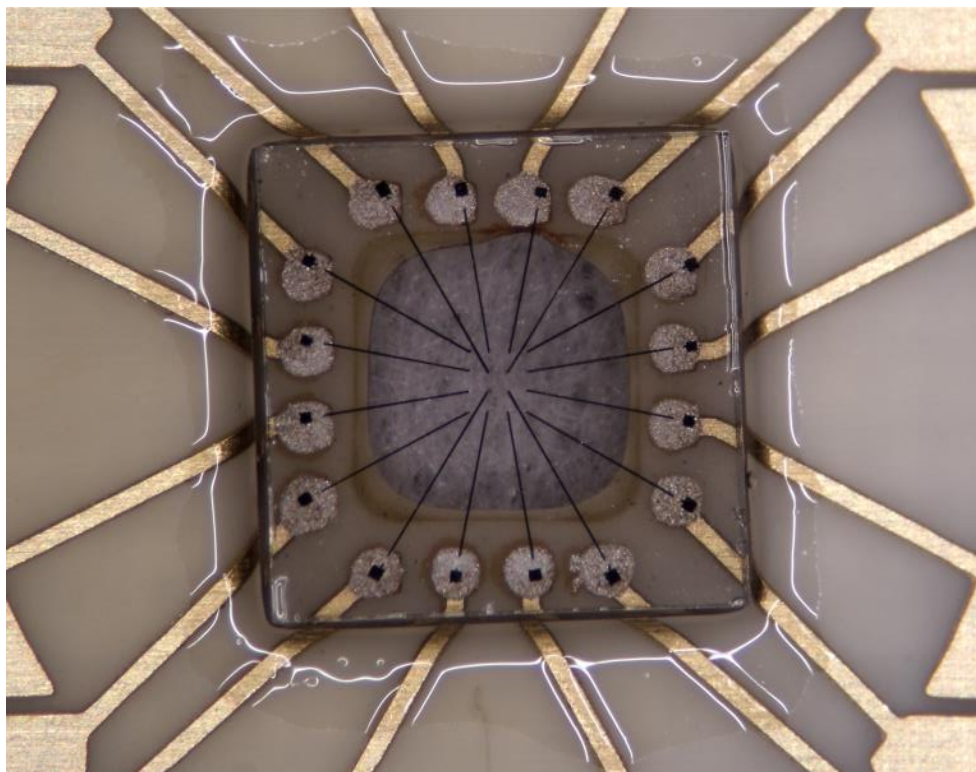
- Chemical Vapour Deposition
- single crystal
- type IIa
- $4.5 \times 4.5 \times 0.5 \text{ mm}^3$

implantation:

- $\text{He}^+$  @ 1.2 MeV
- fluence  $1.2 \cdot 10^{17} \text{ cm}^{-2}$
- penetration depth  $\sim 2 \text{ }\mu\text{m}$

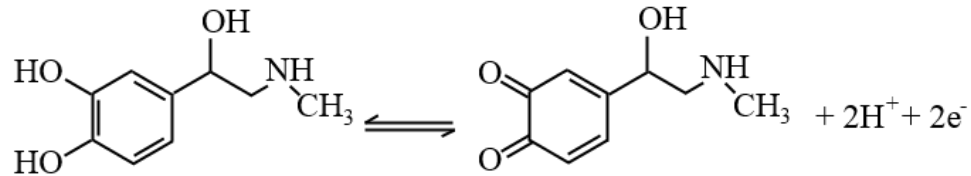
thermal treatment:

- $950 \text{ }^\circ\text{C}$  for 2 hours
- $\sim 10^{-6} \text{ mbar}$



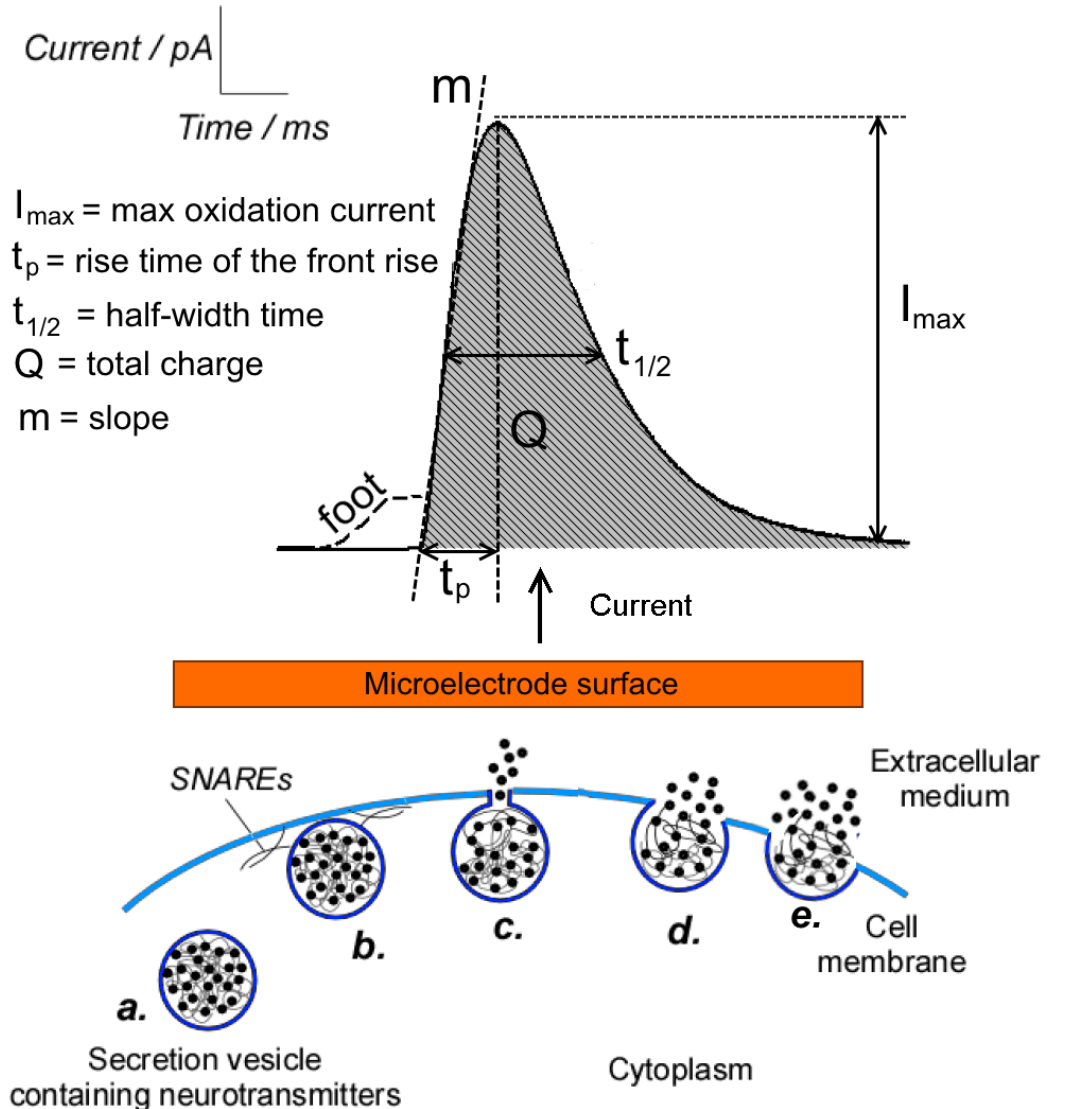
# Amperometric detection of exocytosis

6



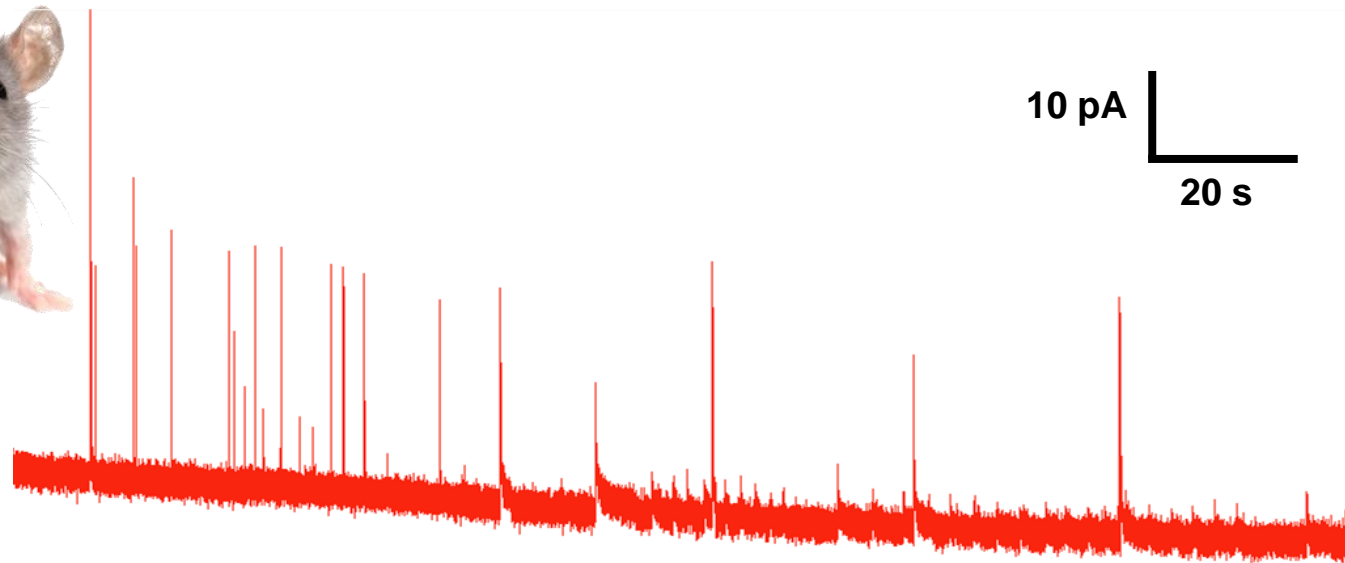
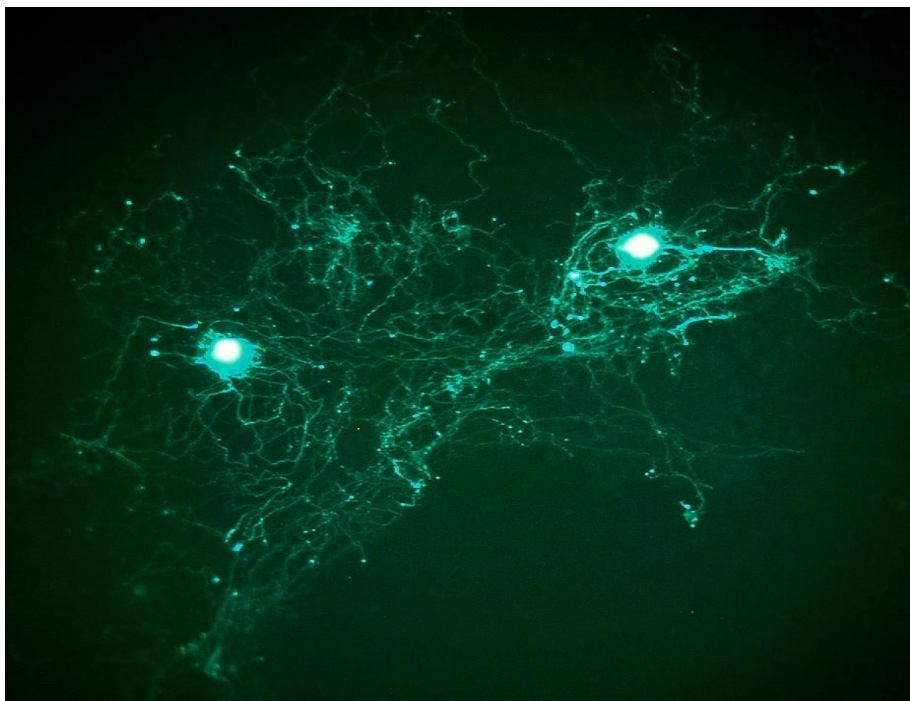
Adrenaline oxidation

- **secretion of catecholamines** (adrenaline, noradrenaline, etc.)
- catecholamines are **secreted from vesicles** in which they are highly concentrated → **strong signal**
- secretion from 1 vesicle: 50-100 ms
- **detection of the oxidized species** in correspondence of a biased electrode
- **electrically or chemically stimulated**



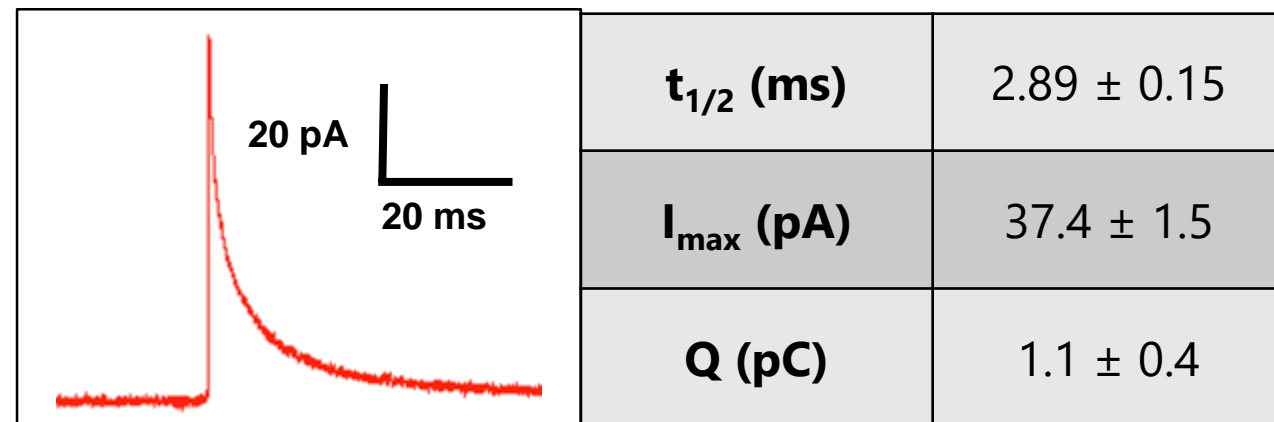
# Exocytosis detection from *substantia nigra* neurons

7



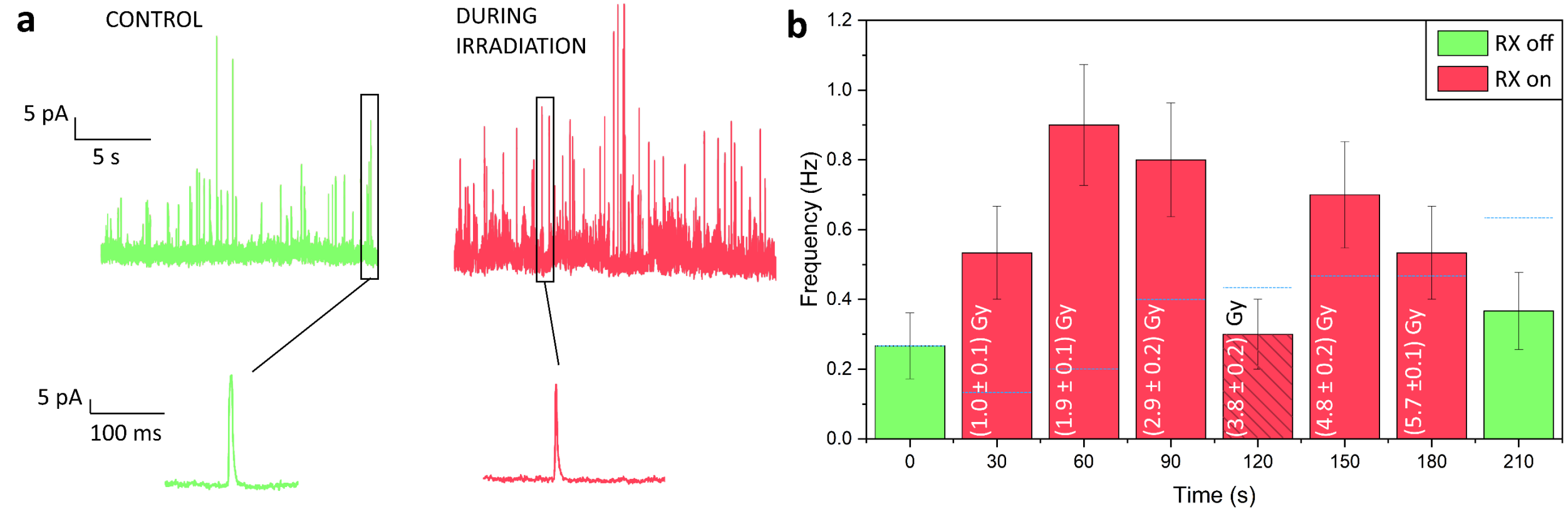
## Network of *substantia nigra* neurons

- Experiment performed after 21 DIV
- Cell network treated with L-Dopa for 1 h  
→ increasing of vesicles dimension
- Stimulation with KCl solution



# Exocytosis detection from *neuroendocrine cell* durin X-ray irradiation

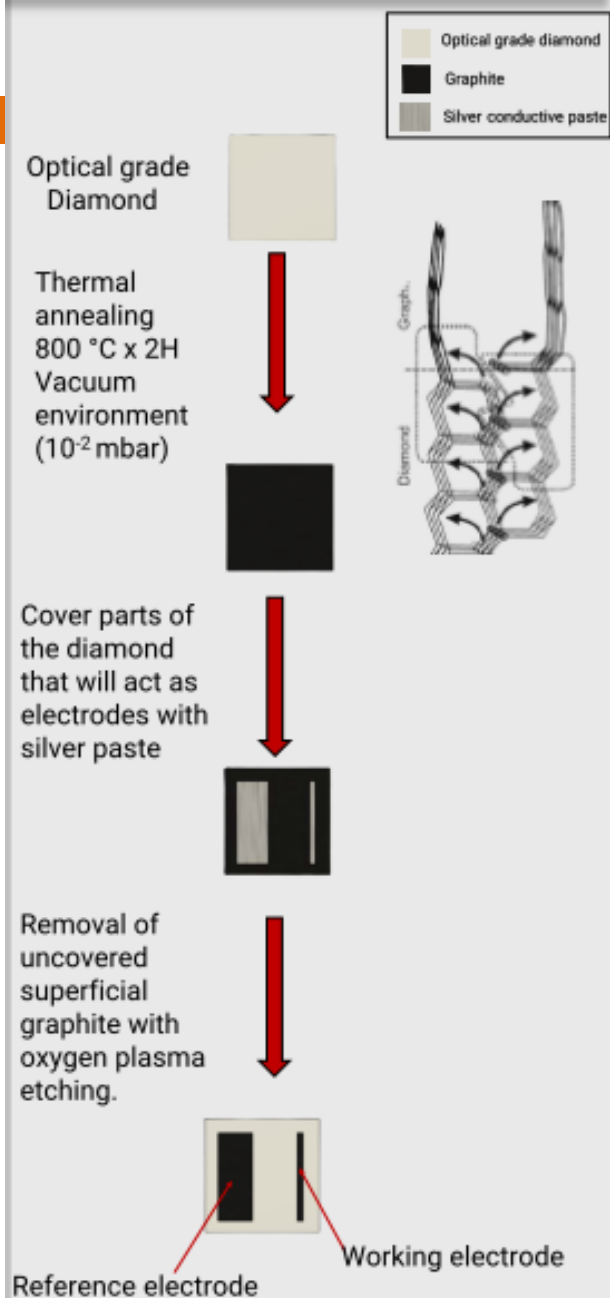
8



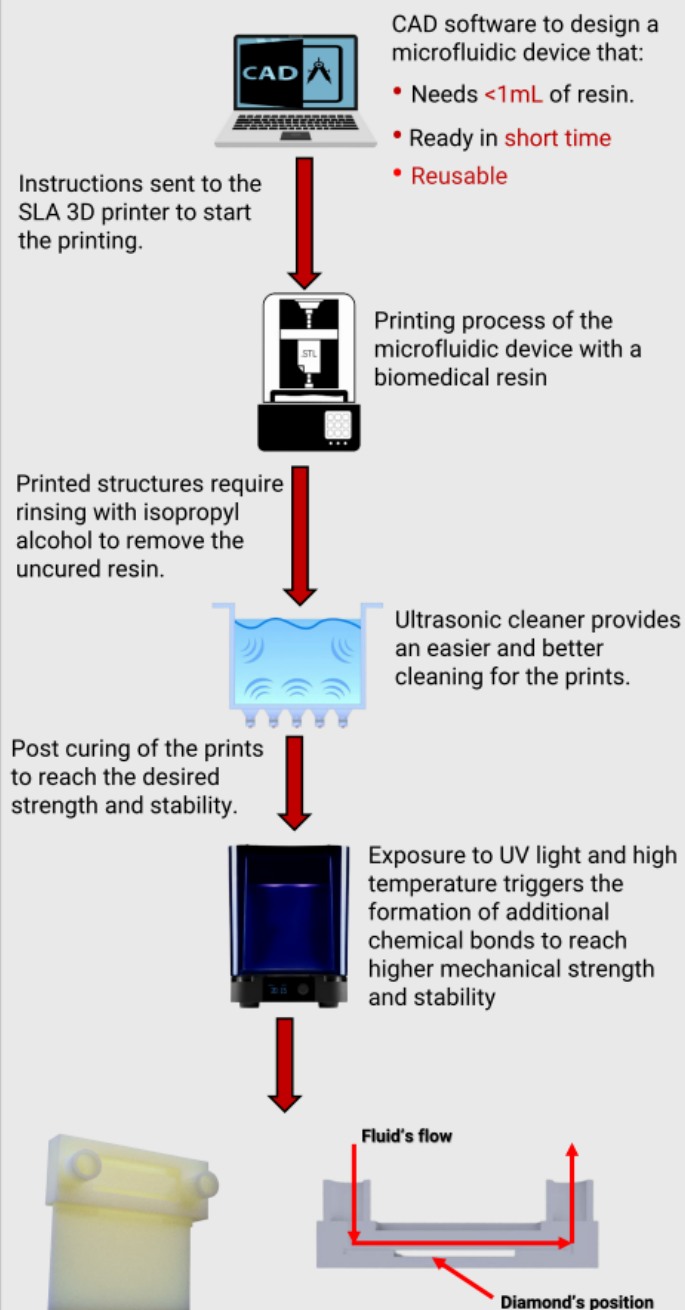


# MICROFLIDIC Lab-on-a-Chip

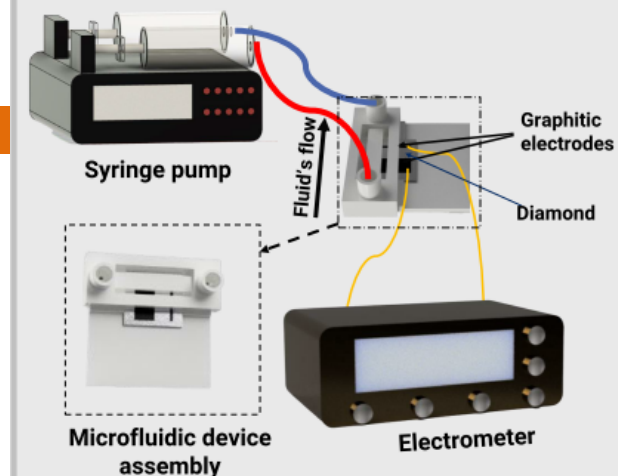
## Thermal inducing of graphite on the diamond's surface



## Fabrication of the microfluidic device

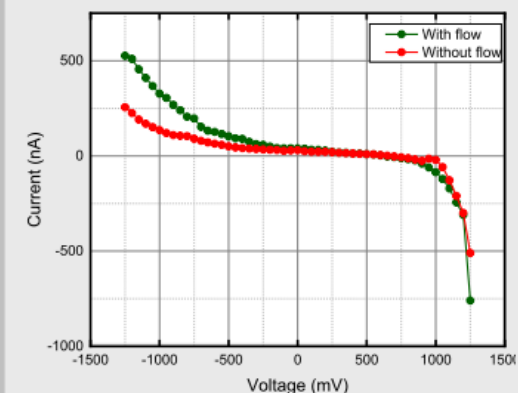


## Device assembly



## Preliminary results

- Tests were performed with a Tyrode solution to test the device electrochemical detection in **cellular conditions**.
- Measurements can be performed **in static and Flow conditions**



Reduction current :

Without flow :  
Between 600 and 650 mV

With flow :  
Between 700 and 700 mV

# HIGH DOSE-RATE & SPATIALLY RESOLVED X-RAY LAB

# Liquid metal X-rays source

*Traditional* microfocus sources → anode heating issue → **LOW brilliance**  
(electron beam power: values as small as 4 W)

*Liquid metal* sources:

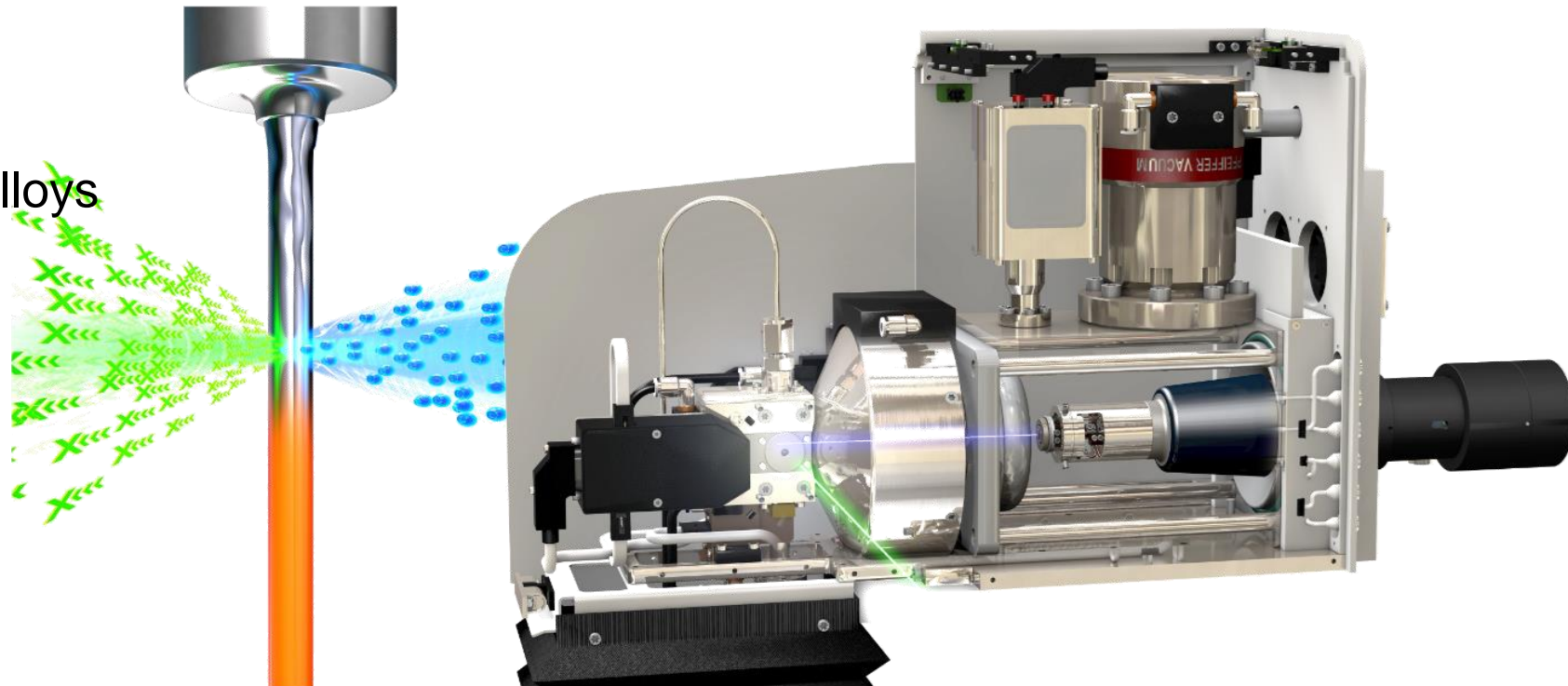
New technology (**Liquid-metal-jet anode electron-impact x-ray source** Appl. Phys. Lett. **83**, 1483 (2003))

## Key element:

Anode made of liquefied Ga / In alloys

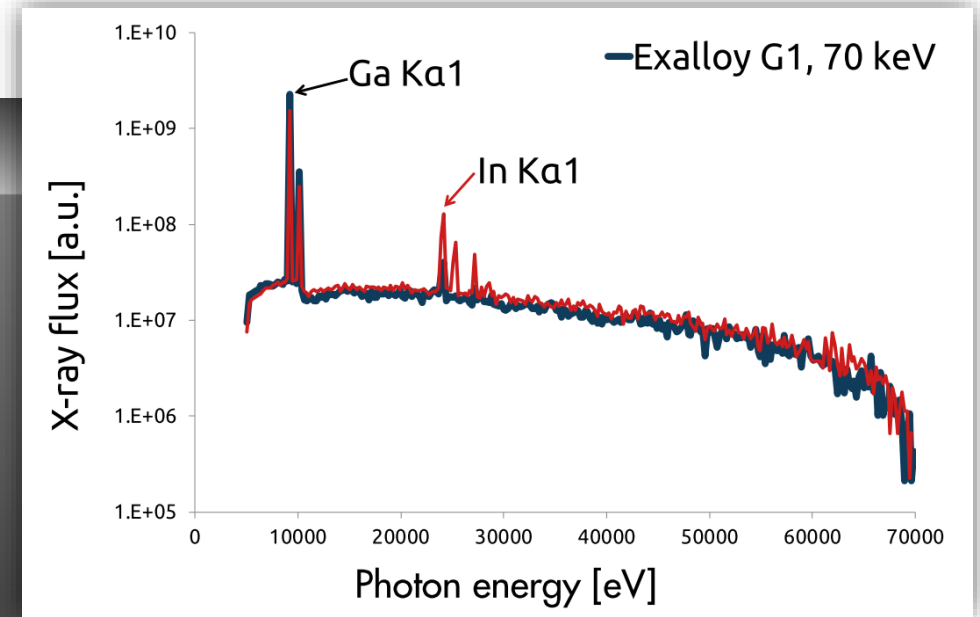
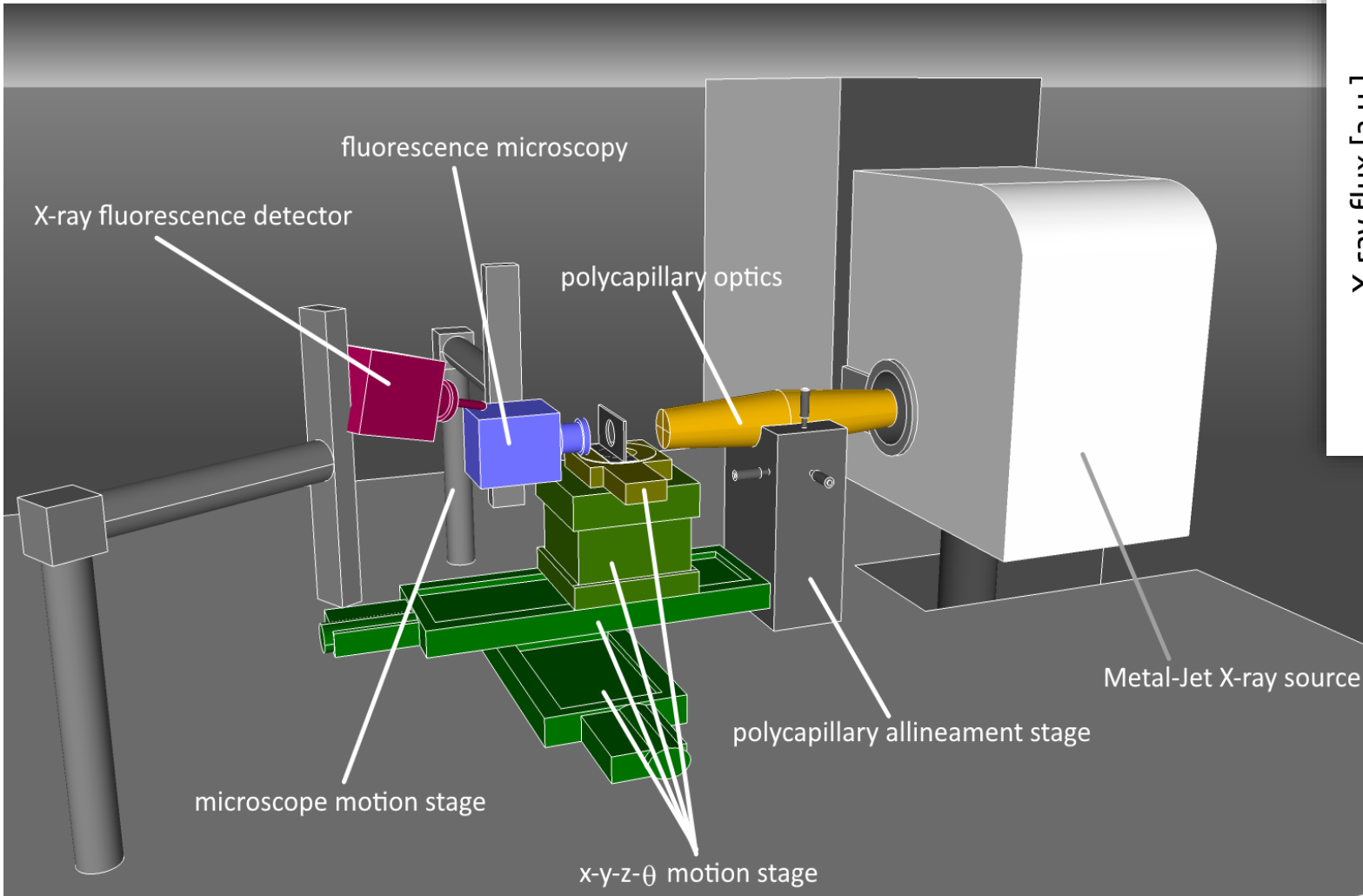
jet diameter ~ 70  $\mu\text{m}$  flowing  
speed ~60  $\text{m s}^{-1}$

power of 250 W





# RESOLVE irradiation set-up MetalJet D2+



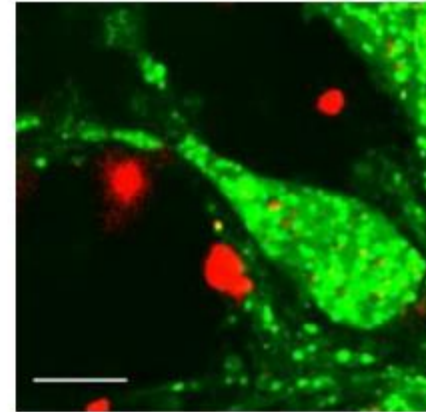
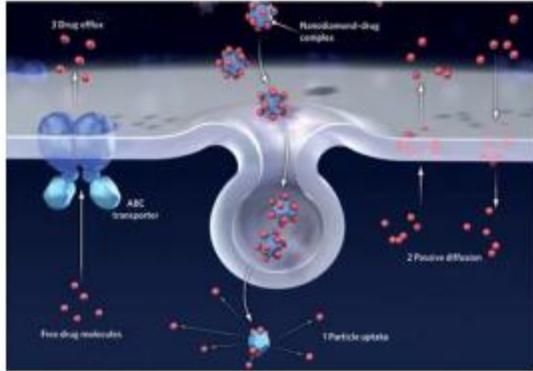
- voltage up to 160 keV
- fast shutter (length pulses < 200 ms)

After focalization with standard optics

- flux density  $\geq 2 \times 10^{13} \text{ ph s}^{-1} \text{ mm}^{-2}$
- focal spot size < 20  $\mu\text{m}$

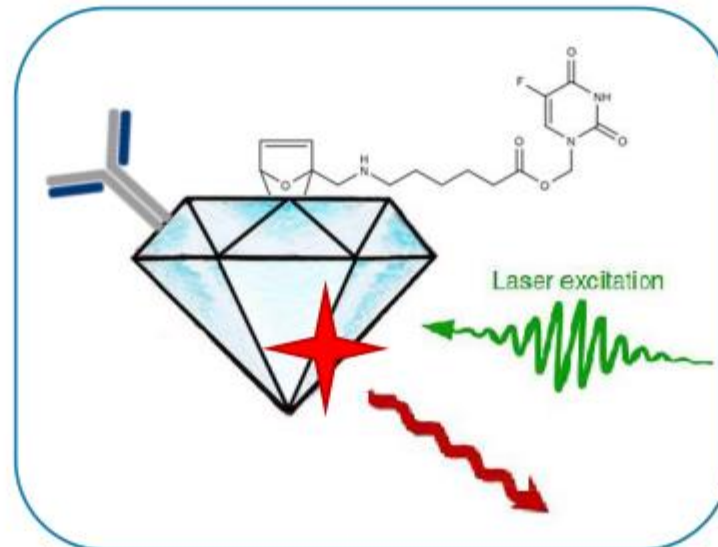
# NANO-DIAMOND for NANOMEDICINE

# Multifunctional nano-particles



## Drug Delivery:

veicolazione farmaci in target cellulari specifici

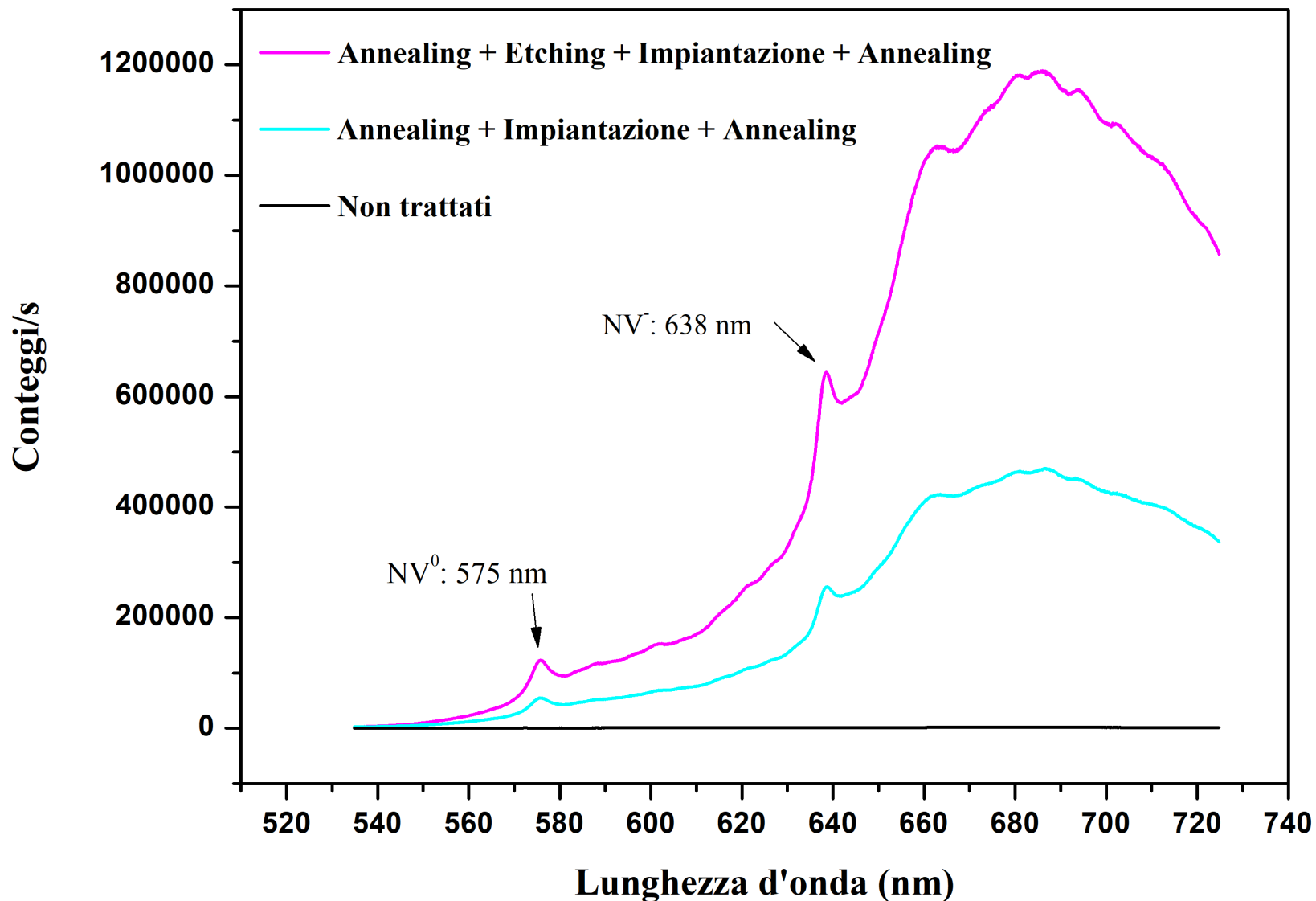


## Luminescenza:

possibilità di tracciare le nanoparticelle nel processo biologico

# Photoluminescence spectra

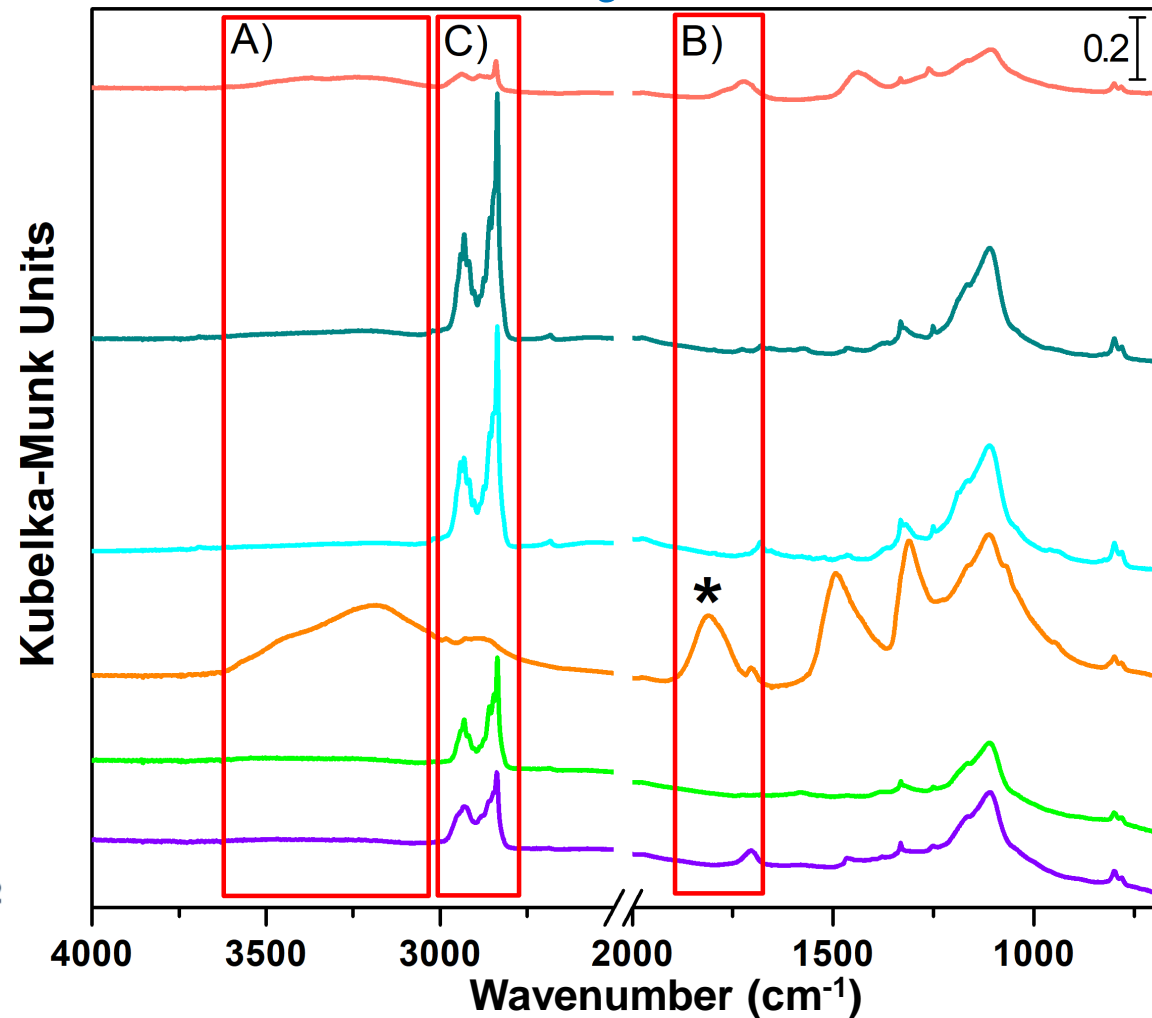
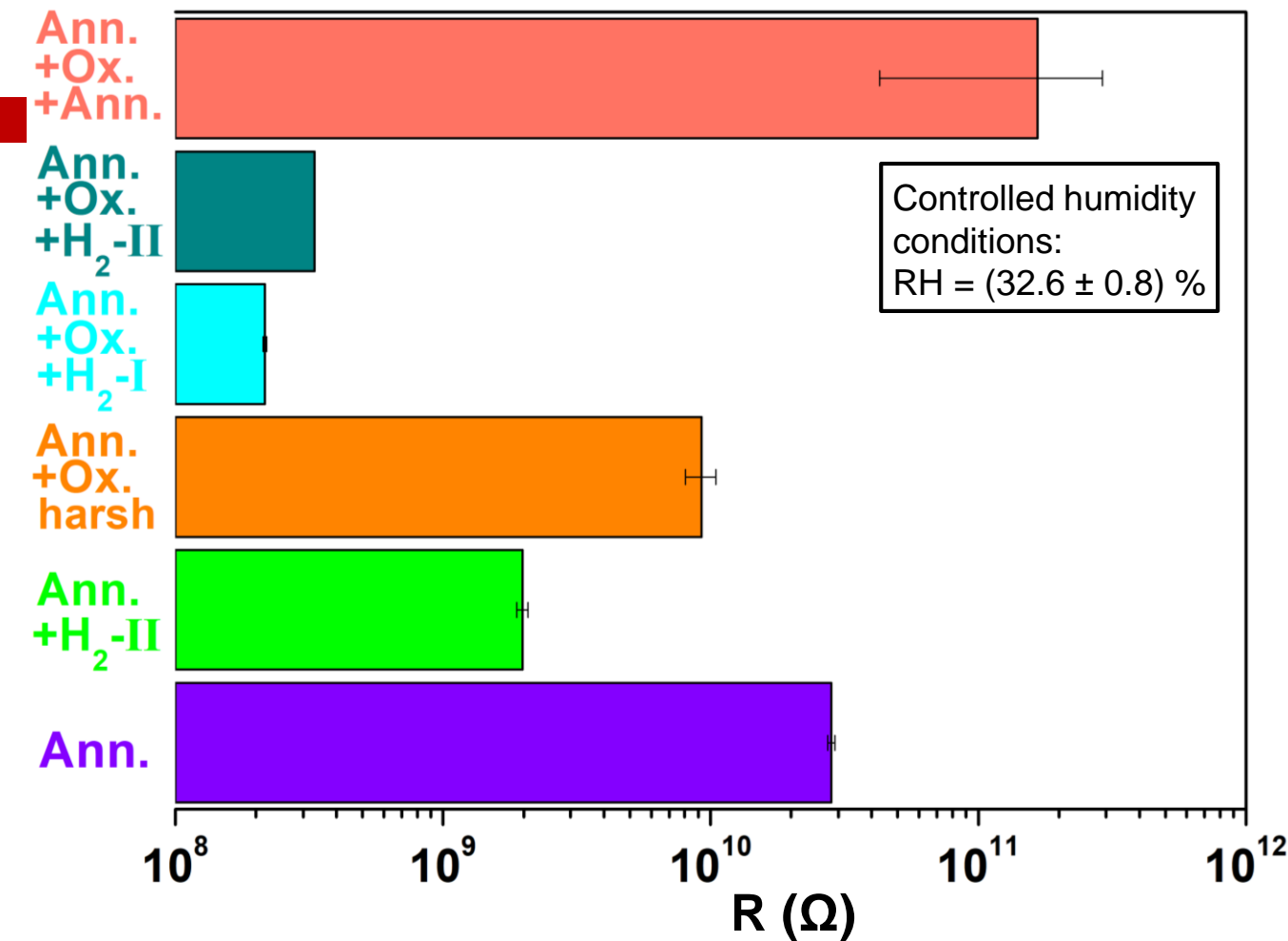
16



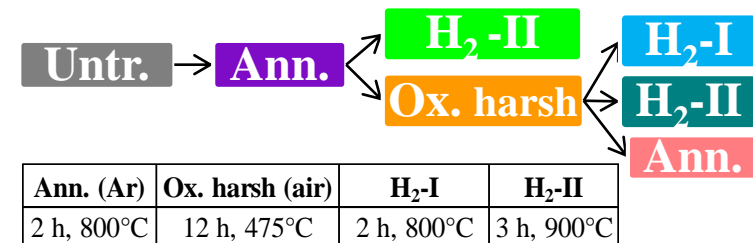
	Confronto	Valore
1	$\frac{I_{685nm}(ann + etch + imp + ann)}{I_{685nm}(non\ trattati)}$	<b>770 ± 20</b>
2	$\frac{I_{685nm}(ann + imp + ann)}{I_{685nm}(non\ trattati)}$	<b>310 ± 20</b>
3	$\frac{I_{685nm}(ann + etch + imp + ann)}{I_{685nm}(ann + imp + ann)}$	<b>2.506 ± 0.004</b>



# Electrical properties and surface chemistry



- Decreased water adsorption due to **lower hydrophilicity** →  $R_{\text{Ann.}}$  and  $R_{\text{Ann.+Ox.+Ann.}} > R_{\text{Ann.+Ox.}}$
- H-ND: **lowest R for H terminations**

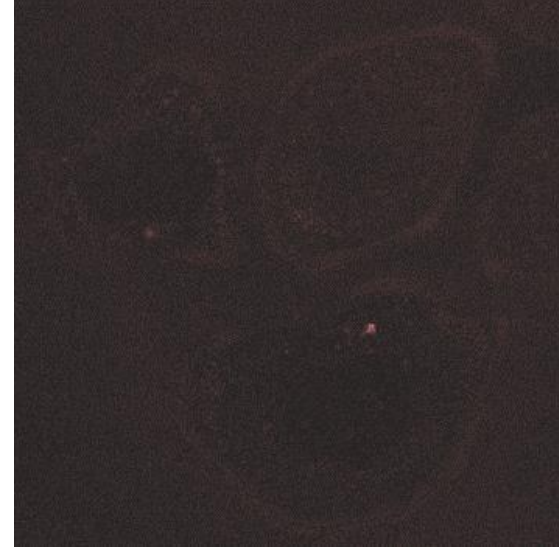
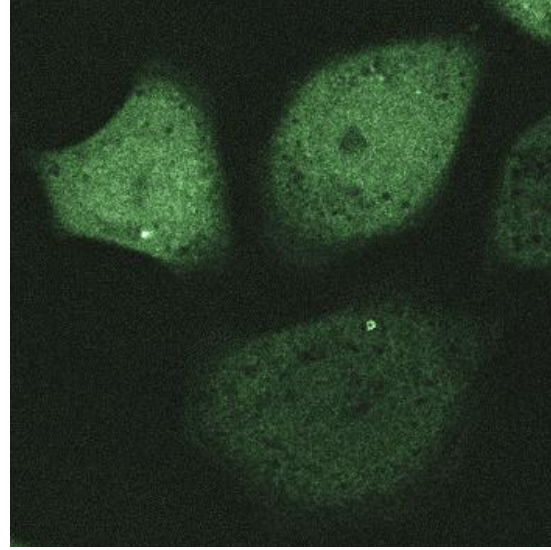
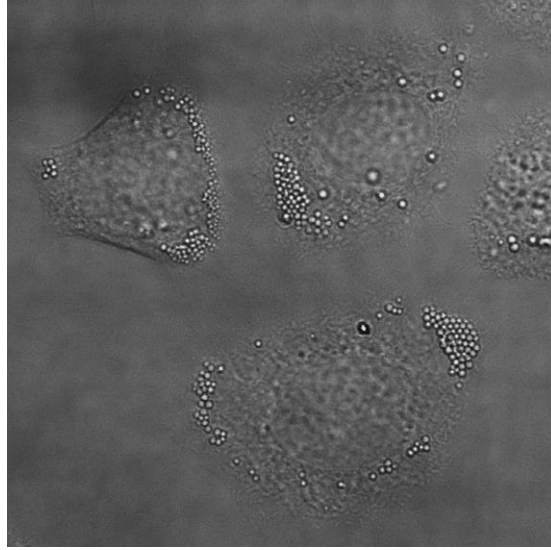


# Confocal microscopy

18

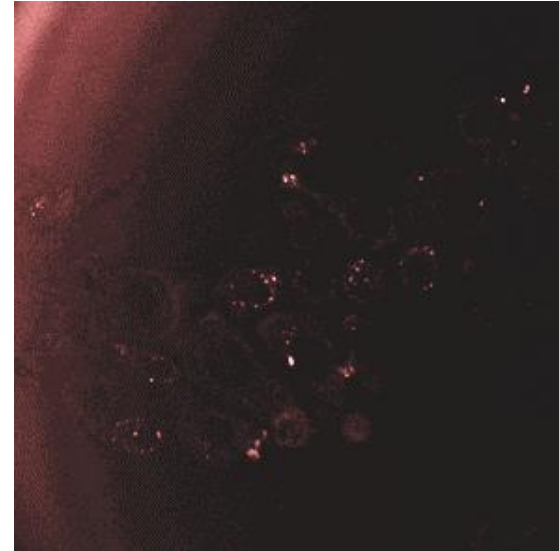
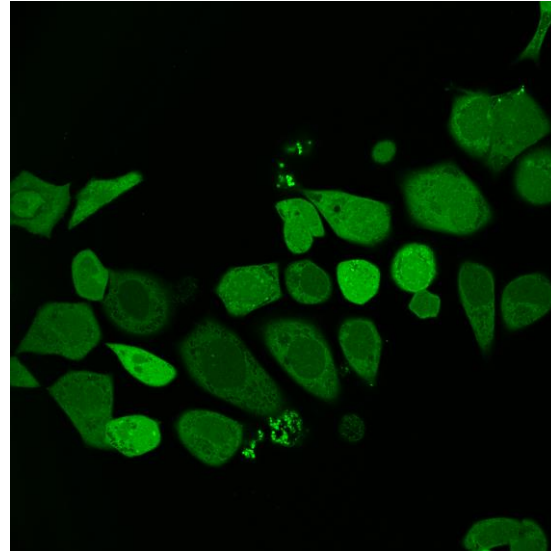
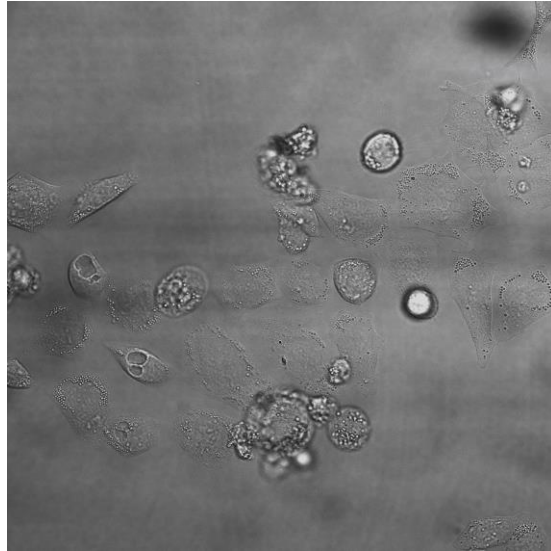
CONTROL

Only Nanodiamond



Modified Nanodiamond

ND + CETUXIMAB



## TESI MAGISTRALI

- ✓ **Biosensoristica** studio degli effetti delle radiazioni ionizzanti a livello cellulare
- ✓ Sviluppo di **dispositivi microfluidici** in diamante artificiale
- ✓ Modificazione e caratterizzazione di **nanodiamanti** per applicazioni nella biofisica
- ✓ Doping e danneggiamento del **diamante** tramite **impiantazione ionica**
- ✓ Allestimento e impiego di una **facility per irraggiamento con RX** ad alta intensità e focalizzati

## TESI TRIENNALI

- ✓ **Modificazione** tramite trattamenti termici del **diamante** e **caratterizzazione** Raman ed elettrica
- ✓ Sviluppo di **codici Matlab per analisi segnali** biofisici
- ✓ **Realizzazione** e caratterizzazione di un **sensore per fotoni** mediante litografia laser
- ✓ **Tutte le tematiche delle tesi magistrali**, ma affrontando gli argomenti meno approfonditamente



**Federico Picollo**

federico.picollo@unito.it

011 670 7879

Dip. Fisica, ufficio primo piano edificio vecchio (A26)