Forest of disordered of gold covered silicon nanowires: a versatile platform for interfacing astrocytes

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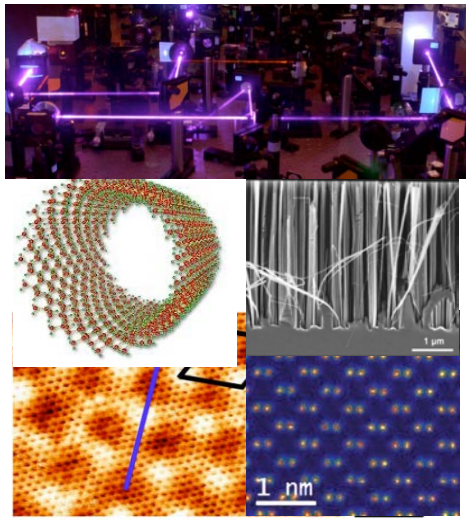
Institute for Microelectronics and Microsystems
Italian National Research Council (permanent staff of 195 people and a temporary staff including 47 post-docs and 61 PhD students).

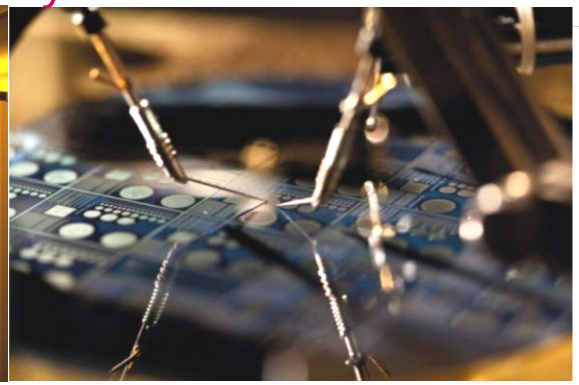
IMM sites in Italy

IMM: research activity



Innovative materials

Micro– and nano fabrication processes



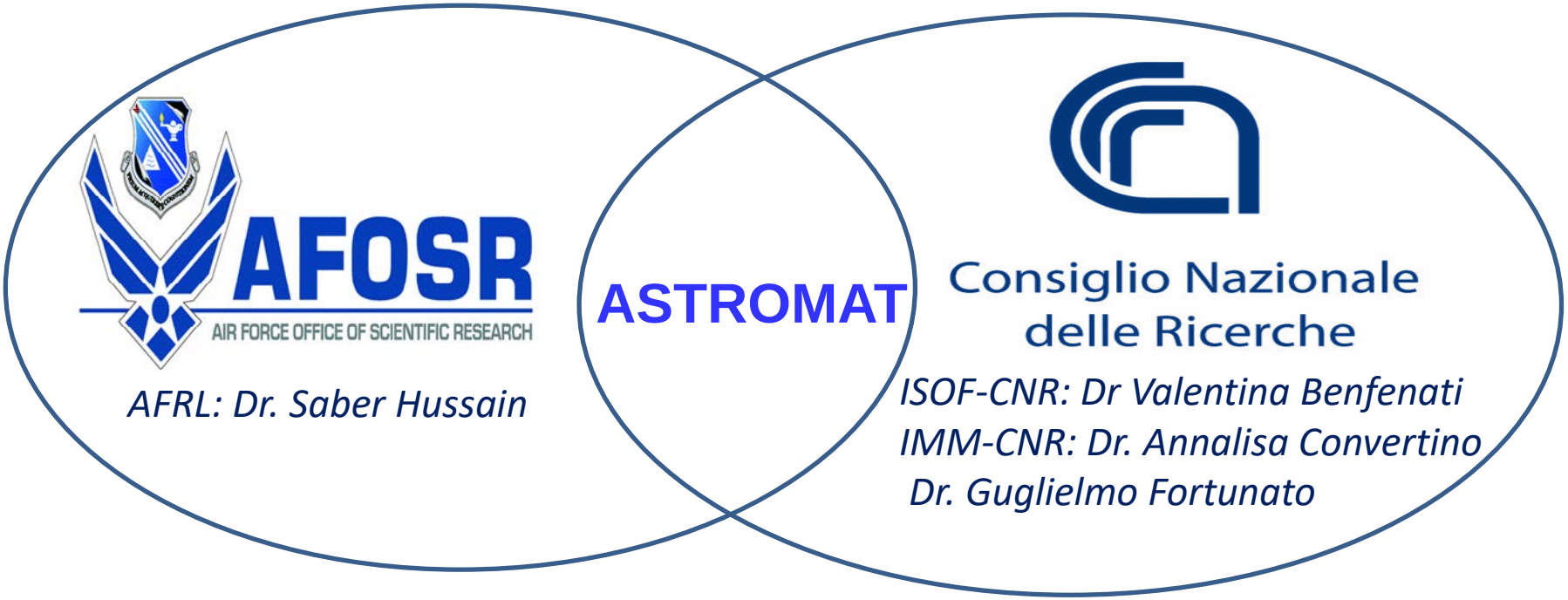
Materials and process integration in complex microsystems

- micro and nanoelectronics;
- optoelectronics and photonics;
- sensors and multifunctional micro/nanosystems.

Advanced Nano-Structured Material Interface and Devices for In Vivo-like-In Vitro Monitoring of Astrocytes Physiology and Brain Toxicology

ASTROMAT-FA9550 16 1 0502

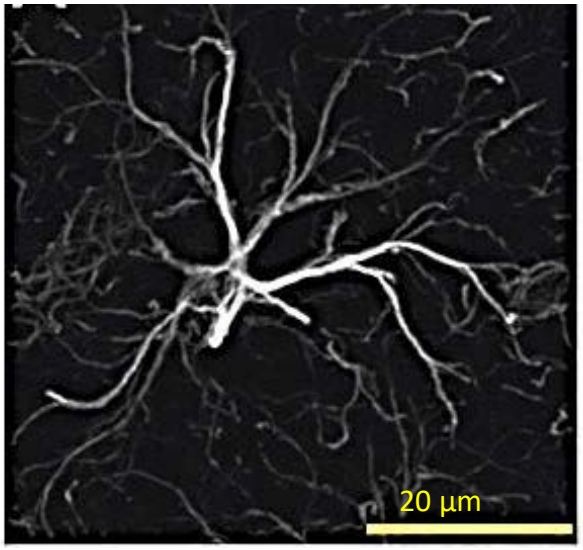
Project Duration: *SEP 2017- May 2018*



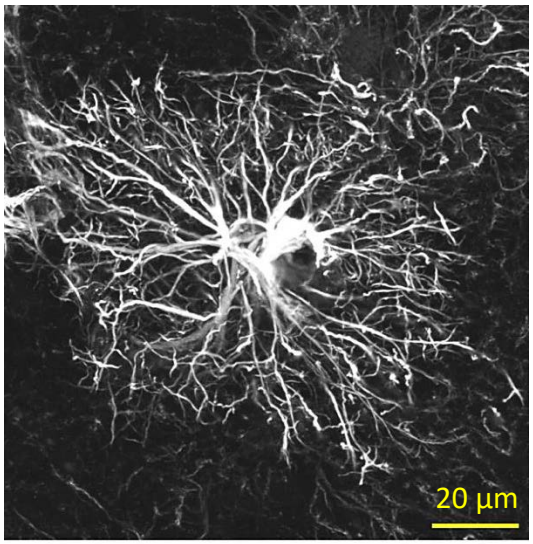
- To develop and validate a vivo-like-in vitro model of astrocytes, resembling their morphological, molecular and functional properties, for answering to fundamental questions on brain physiology and for testing brain toxicology of material

Nanostructured platform for ASTROMAT

Typical mouse protoplasmic astrocyte



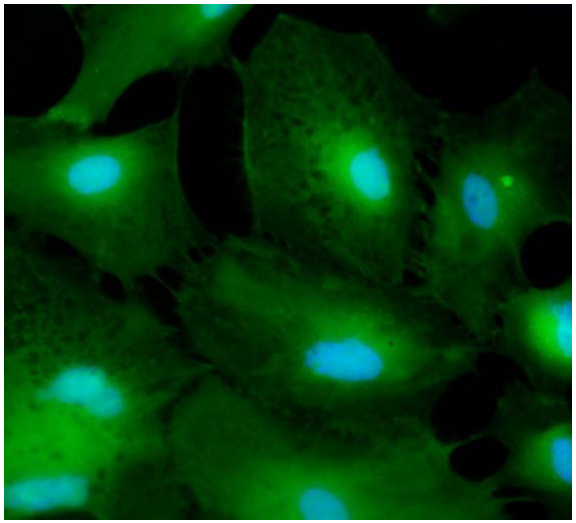
Typical human protoplasmic astrocyte



In vivo, **star-shaped morphology** with multiple radial processes contacting synapses and completely surrounding brain capillaries

Scal bar 20 µm
N.A. Oberheim,et al. *J. Neurosci.* 29, 3276(2009)

In vitro (PDL)



- To develop nanostructured platform that promotes in astrocytes in vitro the morphological, molecular and functional properties like *in vivo*;
- To integrate the nanostructured platform in a multi-electrode-array (MEA) device able to monitor and to manipulate astrocyte ion channel conductance in vitro

Nanostructured platform for ASTROMAT

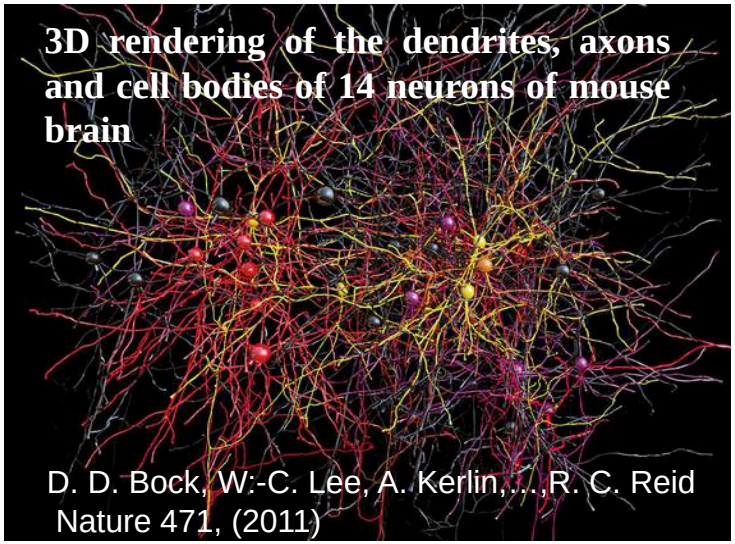
Glassy and/or flexible substrates

Fabrication process compability

Low-cost, easy fabrication

Biocompability

Material & Nanotopography Selection

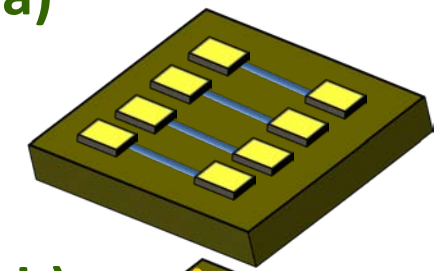


No influence on the astrocyte organization

- ✓ No specific geometrical order
- ✓ No strict size control

a)

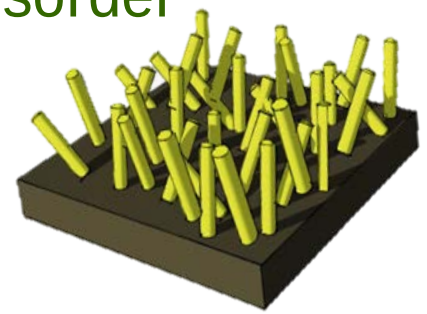
b)



Order => Cell organization

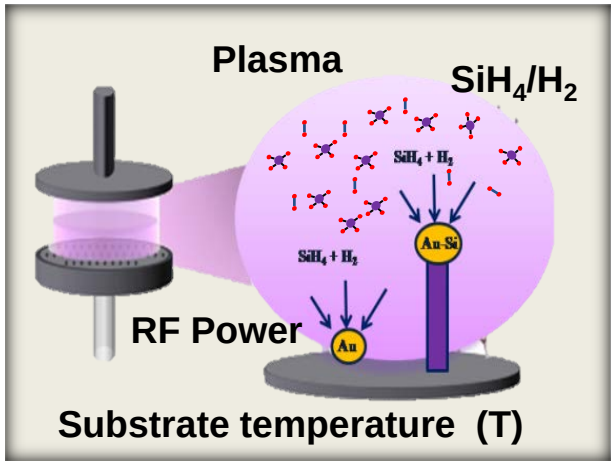
Semiconducting Nanowires

Disorder



Silicon nanowires (SiNWs) by Plasma Enhanced Vapor Chemical Deposition (PECVD)

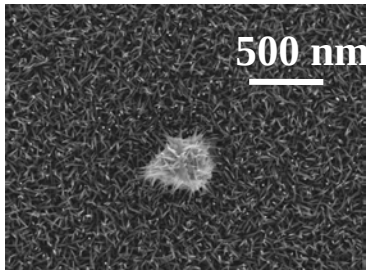
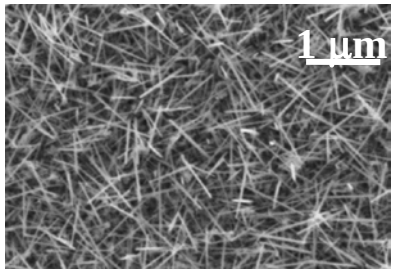
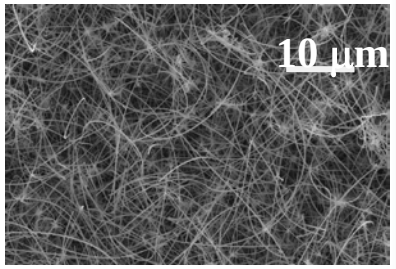
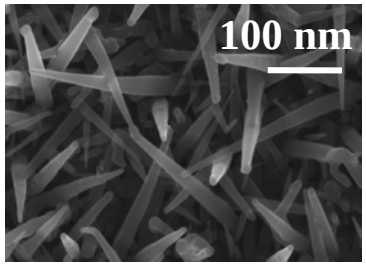
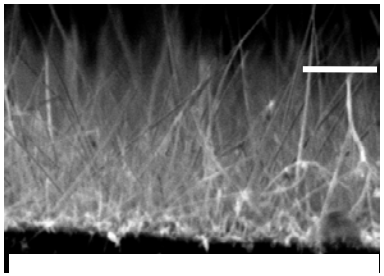
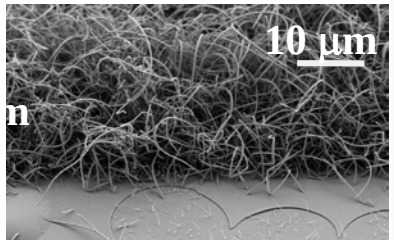
Bottom-up approach



Growth temperature as low as

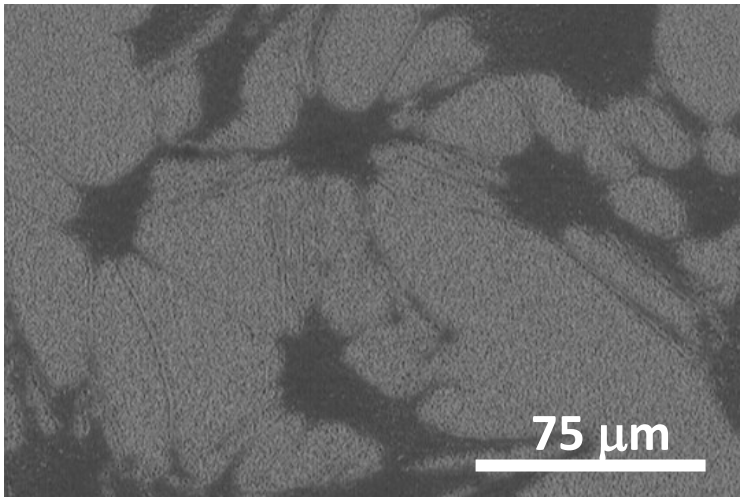
350 °C

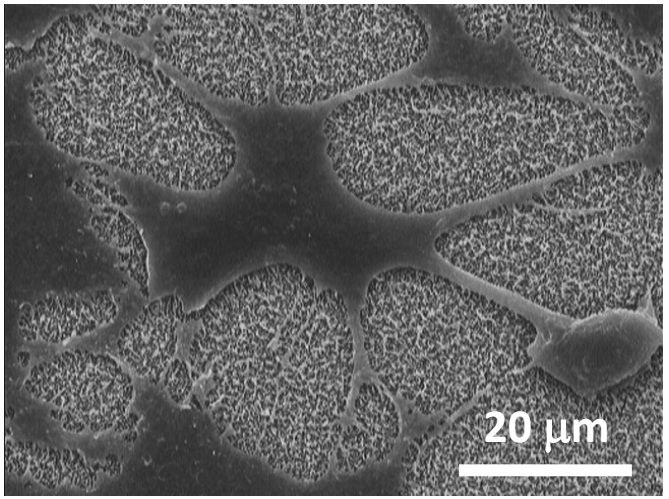
- ***Polyimide***
- ***Glasses***

$H_2:SiH_4=12:1$	$H_2:SiH_4=4:1$	pure SiH_4
		
		
L= 500-700 nm D_{basis}= 60-80 nm	L ≈ 3-5 µm D_{basis}= 100-150 nm	L ≈ 20 µm D_{basis}= 200-250 nm

Au(150nm) coated SiNWs (Au/SiNWs) to interface astrocytes

Cortical rat astroglial cells on Au/SiNWs



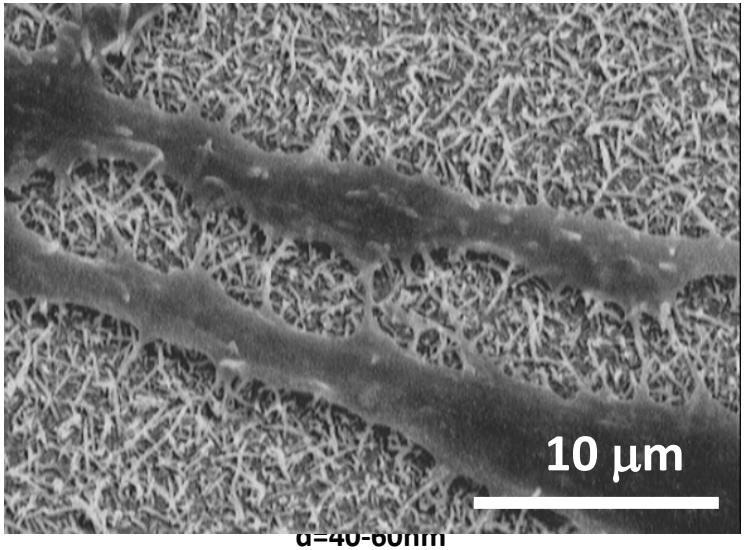


No surface functionalization

Star-like shape

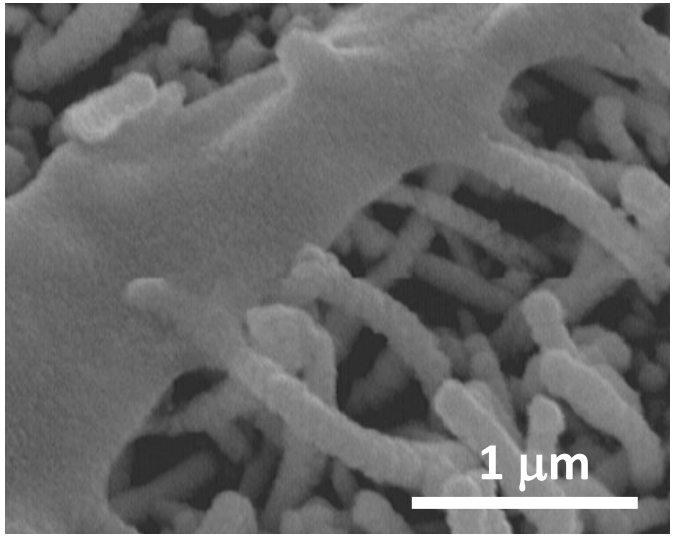
Long and straight projections

Small endfeet projections



d=40-60nm

Conical shape



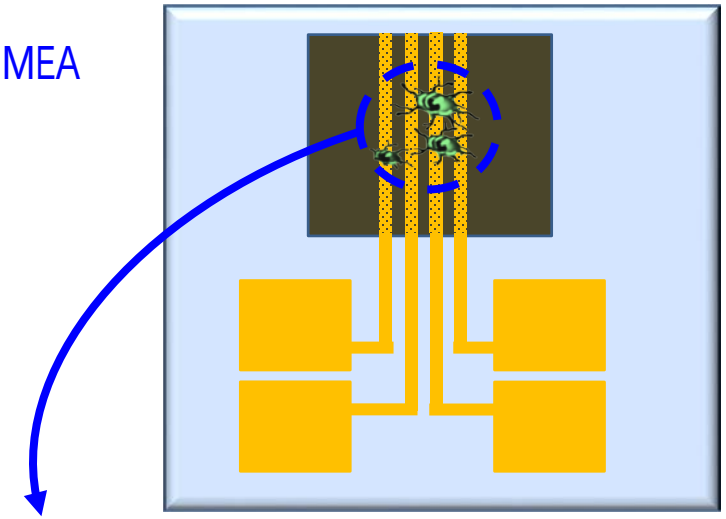
Cylindrical shape

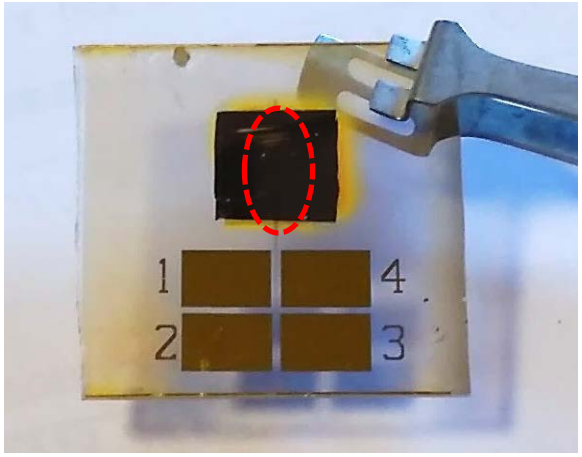
Intimate contact

Au/SiNW based multi electrode array for astrocyte signal recording

Mantaining the disordered nanotopography

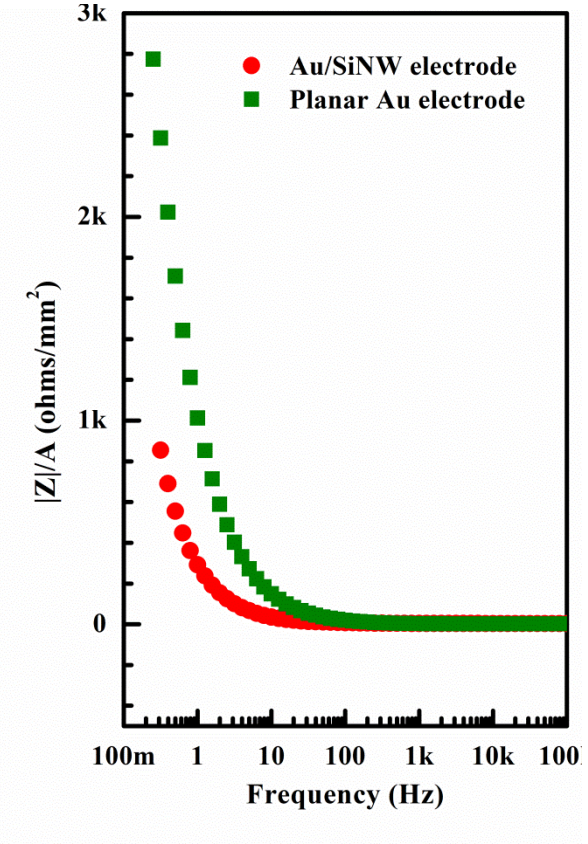
Zebrine MEA





Nanostructured *vs* planar Au electrode

(100mM KCl, ***A=geometrical area of the electrode***)



- ✓ Astrocyte pattern of the expressions like in-vivo
- ✓ Low impedance interface

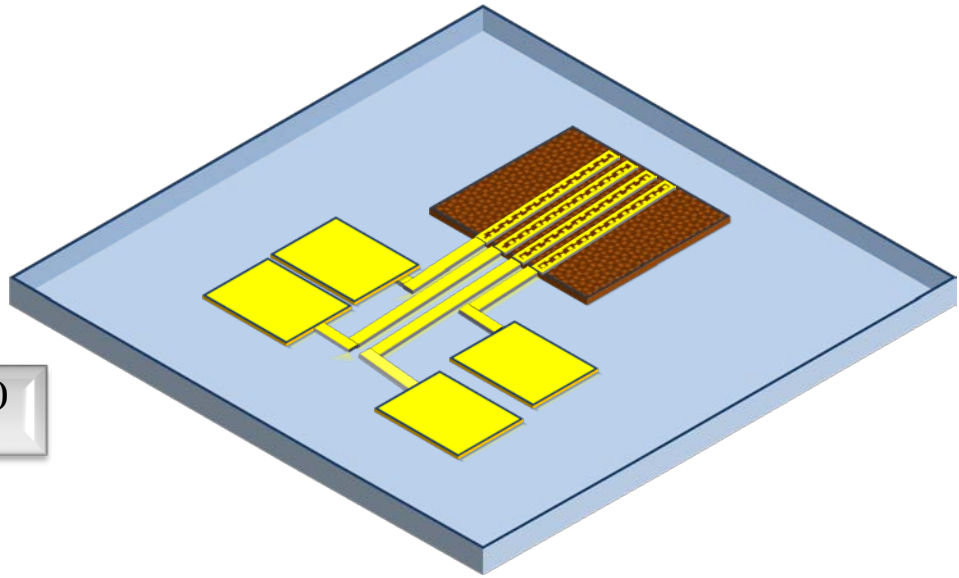
Au/SiNW based electrodes for astrocyte signal recording

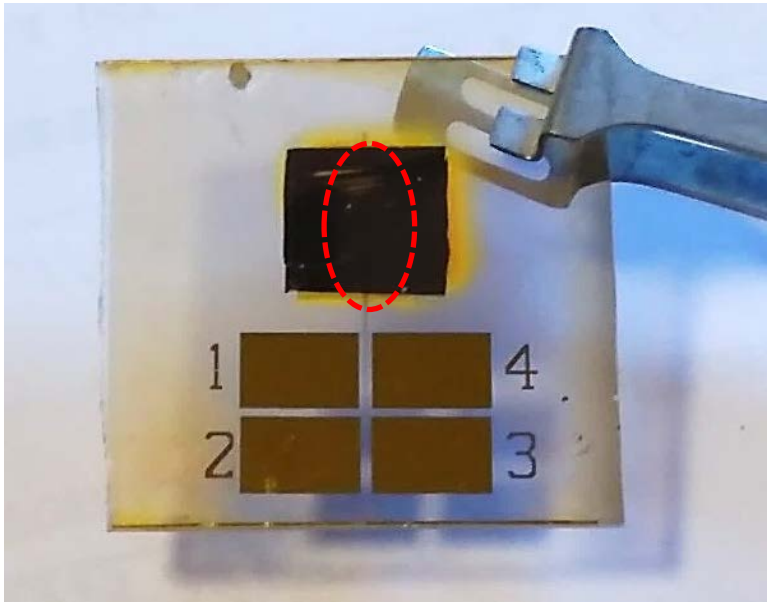
Zebrine MEA

Growth of SiNWs on a selected area of a glass substrate

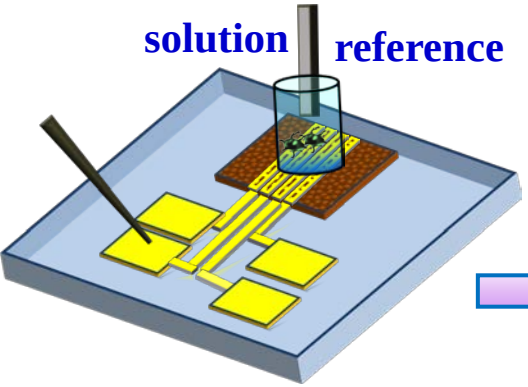
Coverage with SiO_2 thin layer

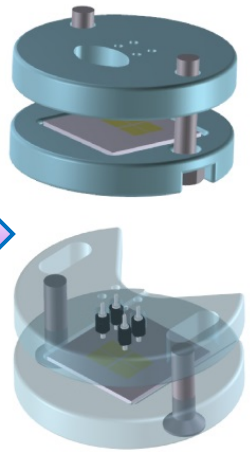
Deposition, photolitography and etching of Ti (20nm)/Au (150nm)) covering the NWs and forming conductive paths



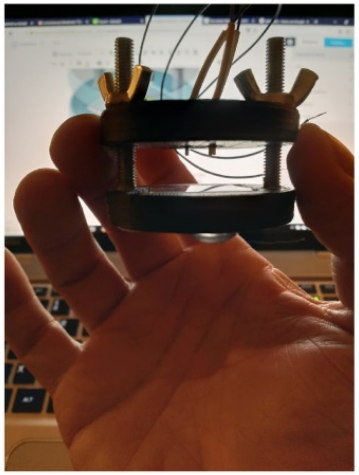


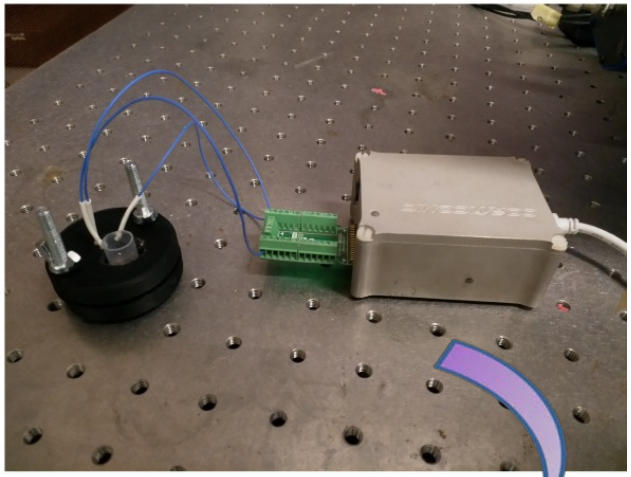
Astrocytes recording





Recording setup: holder + data acquisition board





Conditions

- Voltage measurament
- Acquisition time =4 min
- Sampling at 25 KHz
- 4 channels

Neuro Data Acquisition Board: NeuroDaq

- ADC (RHD2000 Intan), 32 channels with 16 Bit resolution
- Filtering and amplification (200x)
- BaudRate > 1 Msamples/s
- Microcontroller 80 Mips @ 200 MHz
- High Speed USB
- USB/Battery Powered Option
- Memory 4 MByte
- Dimensions: 45 x 68 mm

Au/SiNWs interfacing astrocytes

Au/SiNWs interfacing astrocytes

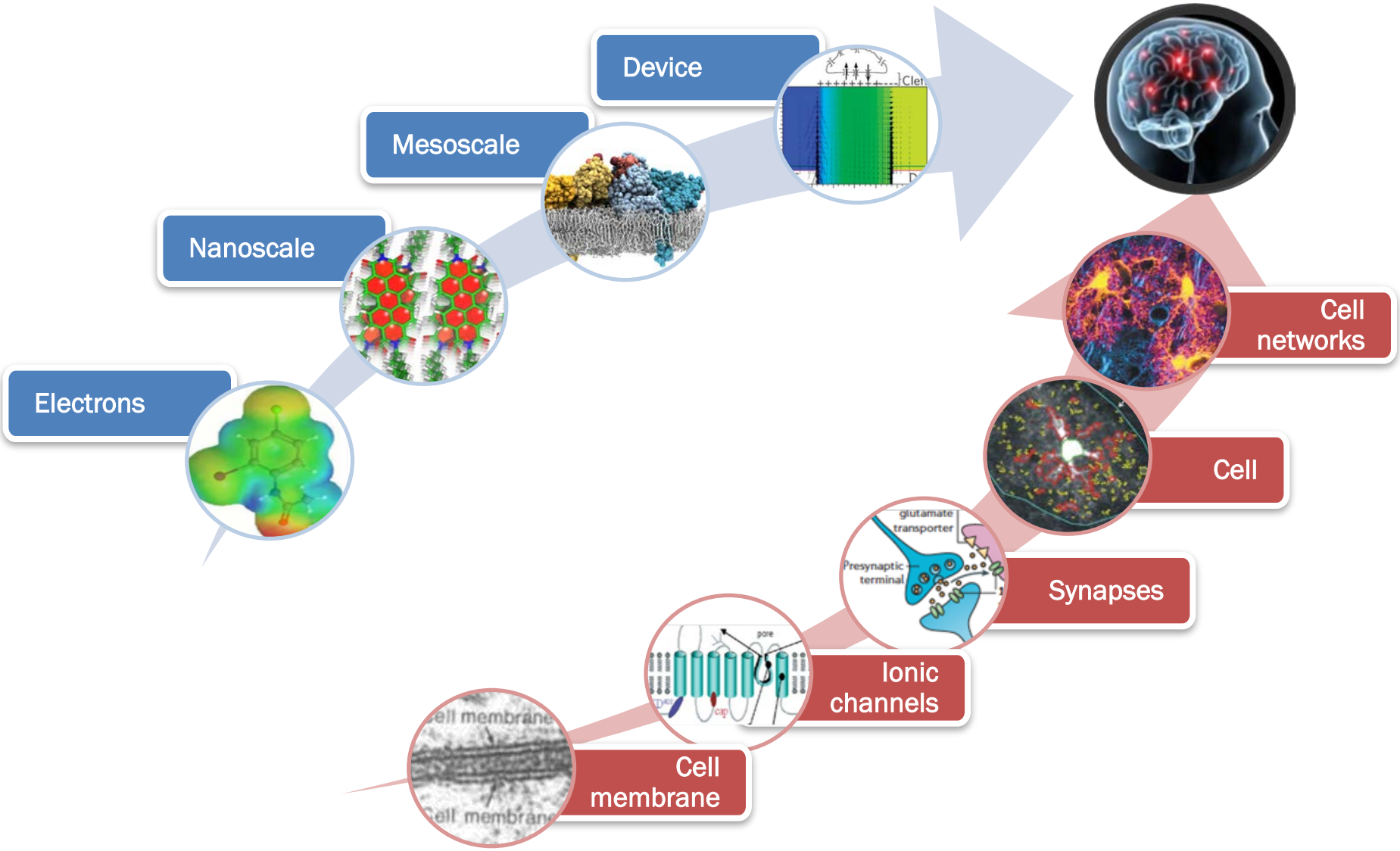
Pattern of expression like in-vivo **and** ***no surface functionalization***

Recording electrical signals and Raman detection

Prospects

- ✓ **Investigation on the ionic activity of astrocytes**
- ✓ **Raman investigation of living astrocytes**
- ✓ ***Simoultaneous detection of the Raman and electrical signals in vitro*** **from living astrocytes with a like-in-vivo pattern of expression**

Multiscale interfacing



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