Tecnologia Umano-Centrica Bioispirata
Roberto Cingolani - IIT

ISTITUTO ITALIANO DI TECNOLOGIA

Genova Central Research Lab
- Advanced Robotics
- Drug Discovery and Development
- iCub Facility
- Nanochemistry
- Nanophysics
- Nanostructures
- Neuroscience and Brain Technologies
- Pattern Analysis & Computer Vision
- Robotics, Brain and Cognitive Sciences

Research Centers
- Center for Space Human Robotics Torino
- Center for Nano Science and Technology Milano
- Center for Genomic Science Milano
- Center for Neuroscience and Cognitive Systems Trento
- Brain Center for Motor and Social Cognition Parma
- Center for Nanotechnology Innovation Pisa
- Center for Micro-Bionics Pisa
- Center for Life Nano Science Roma
- Center for Advanced Biomaterials for Health Care Napoli
- Center for Biomolecular Nanotechnologies Lecce

MIT-outstation
Machine Learning

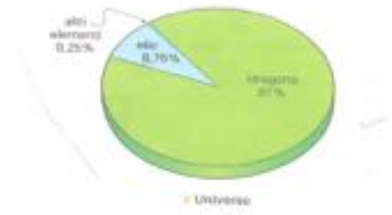
Harvard-outstation
Nanotech for brain

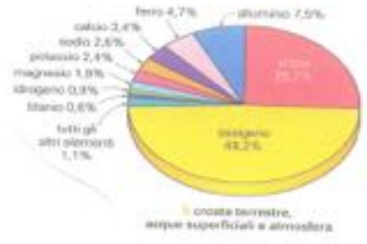
1440 staff
41% donne
Eta' 33 anni
47% da 56 stati
450 PhD
380 Post doc

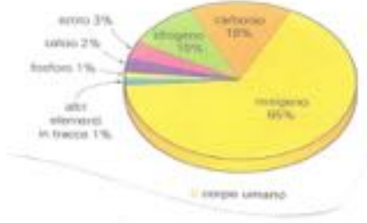
50000 mq labs

109 EC projects
8 ERC
310 brevetti
10 start up

HOW MANY ATOMS ARE NEEDED FOR LIFE ?

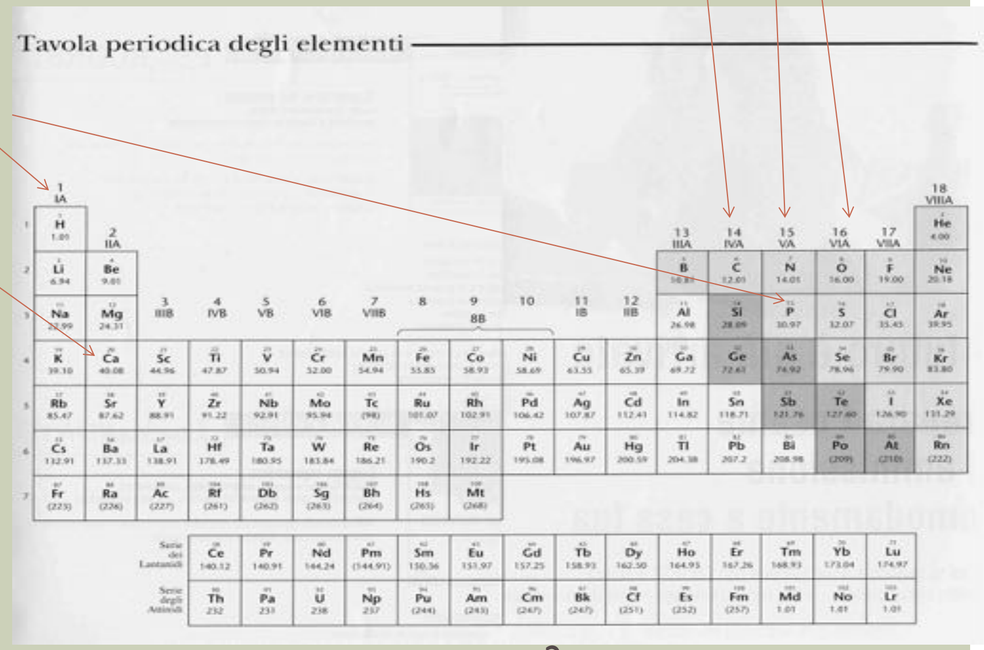






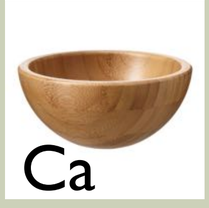
- Nel mondo organico/biologico la natura fa quasi tutto con 6 atomi

- Ossigeno 65%
- Carbonio 18%
- Idrogeno 10%
- Azoto 3%
- Calcio 2%
- Fosforo 1%

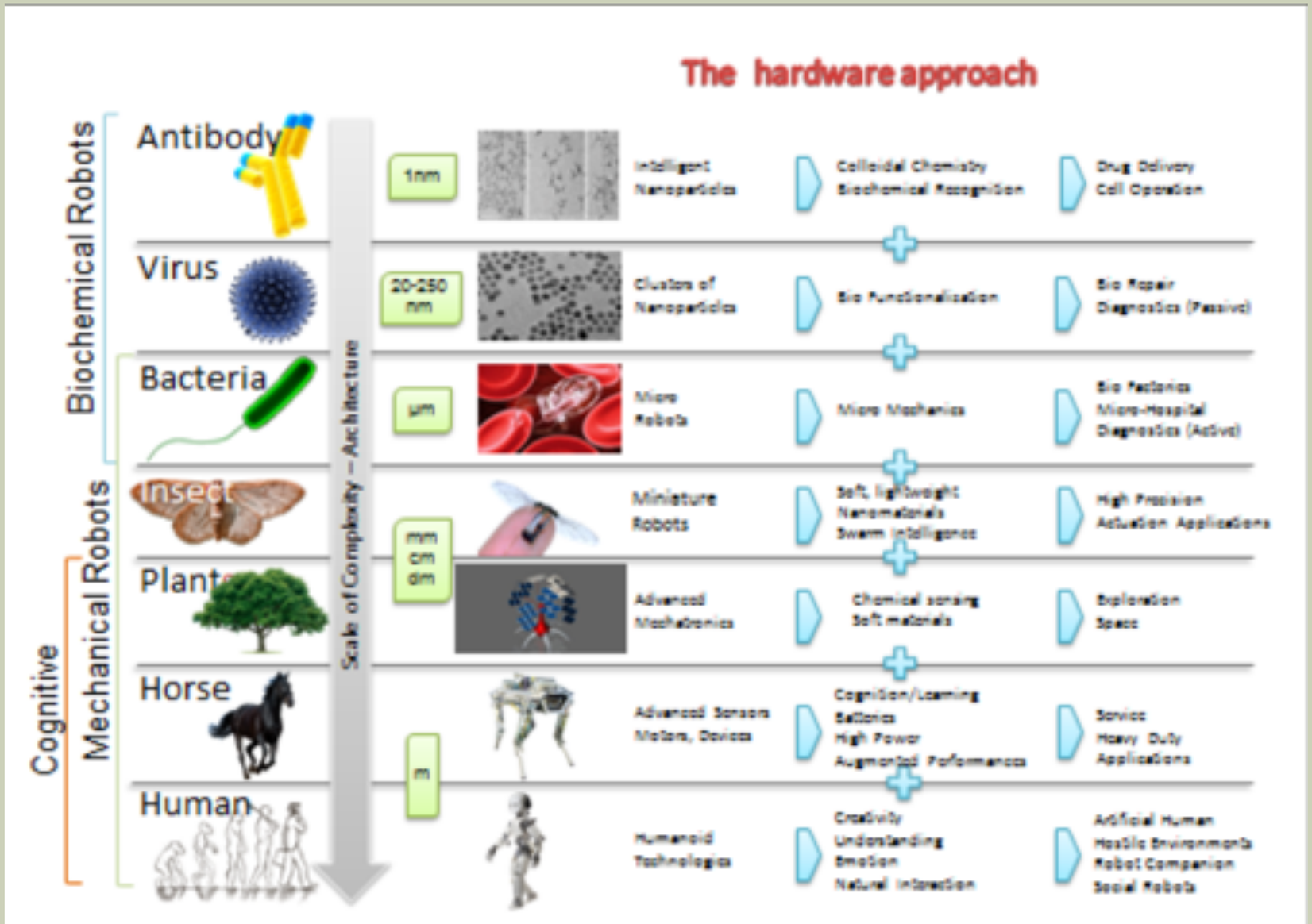


THE CONCEPT OF ARCHITECTURE

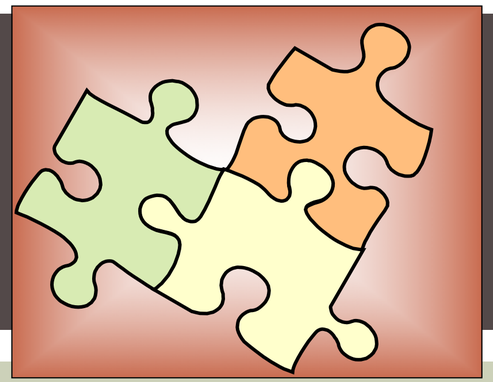
- Le infinite combinazioni possibili di atomi in un volume molto piccolo danno origine a cose macroscopiche molto diverse. La biodiversita' dipende dall'architettura con cui gli atomi sono assemblati alla nanoscala e poi messi insieme su distanze grandi.



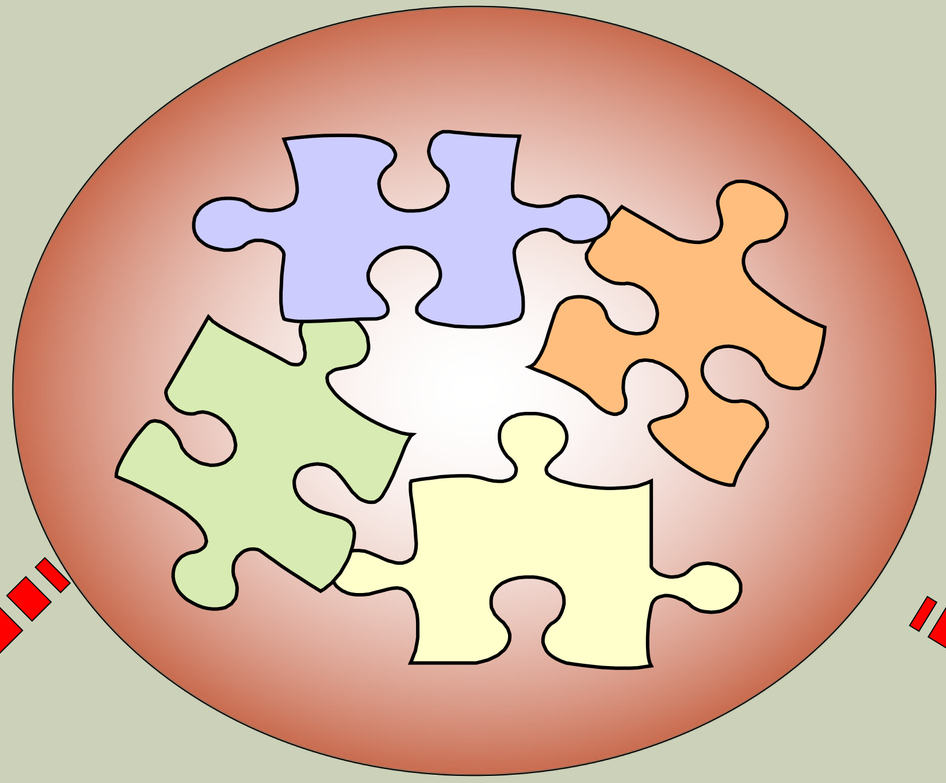
EVOLUTION AND ARCHITECTURE

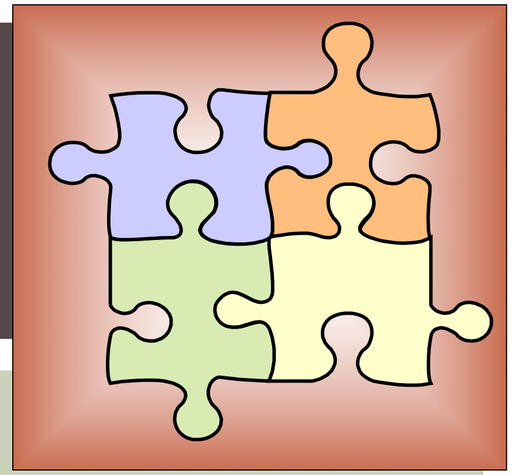


BIOCHEMICAL ROBOTS



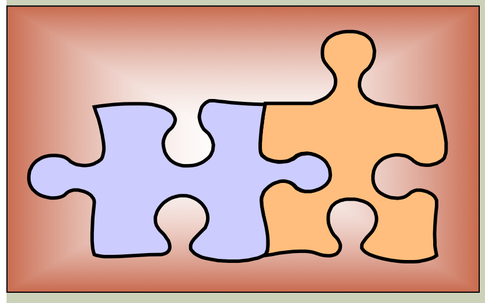
Imaging



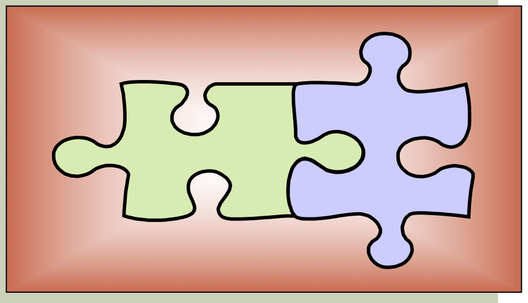


Rilascio Medicinale

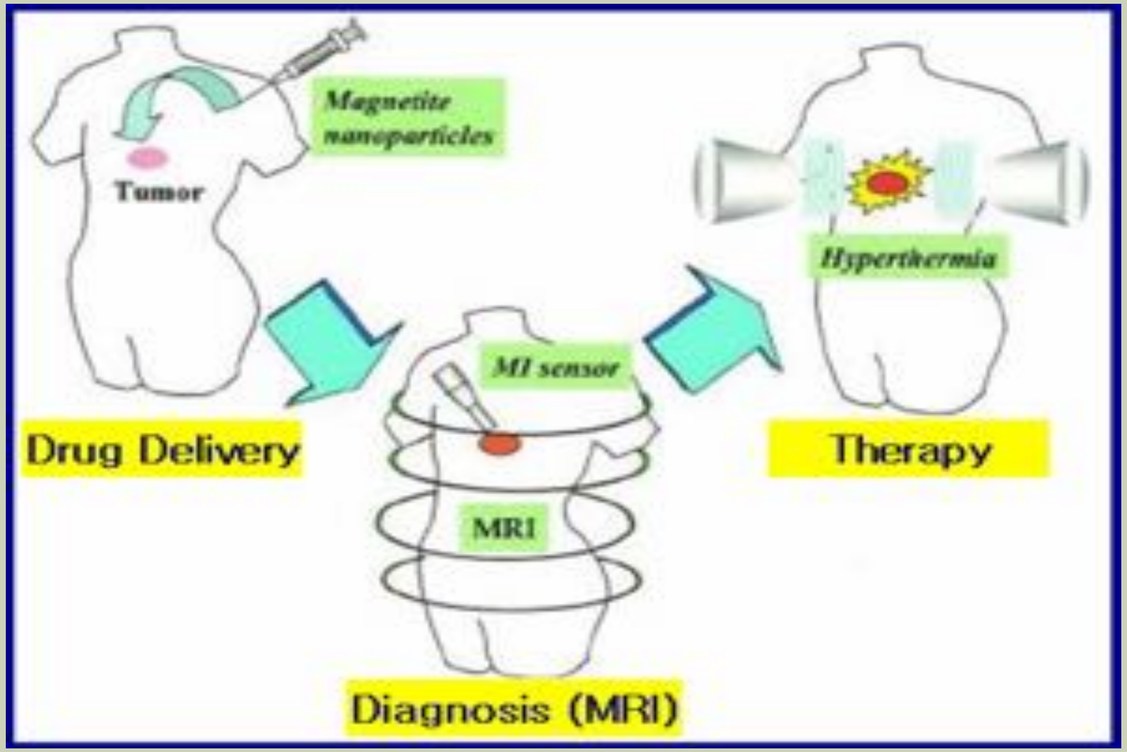
Sensing

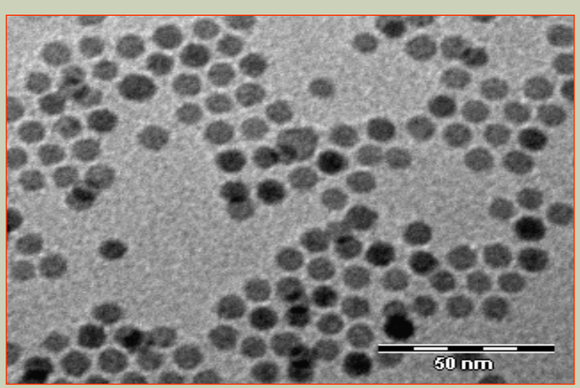


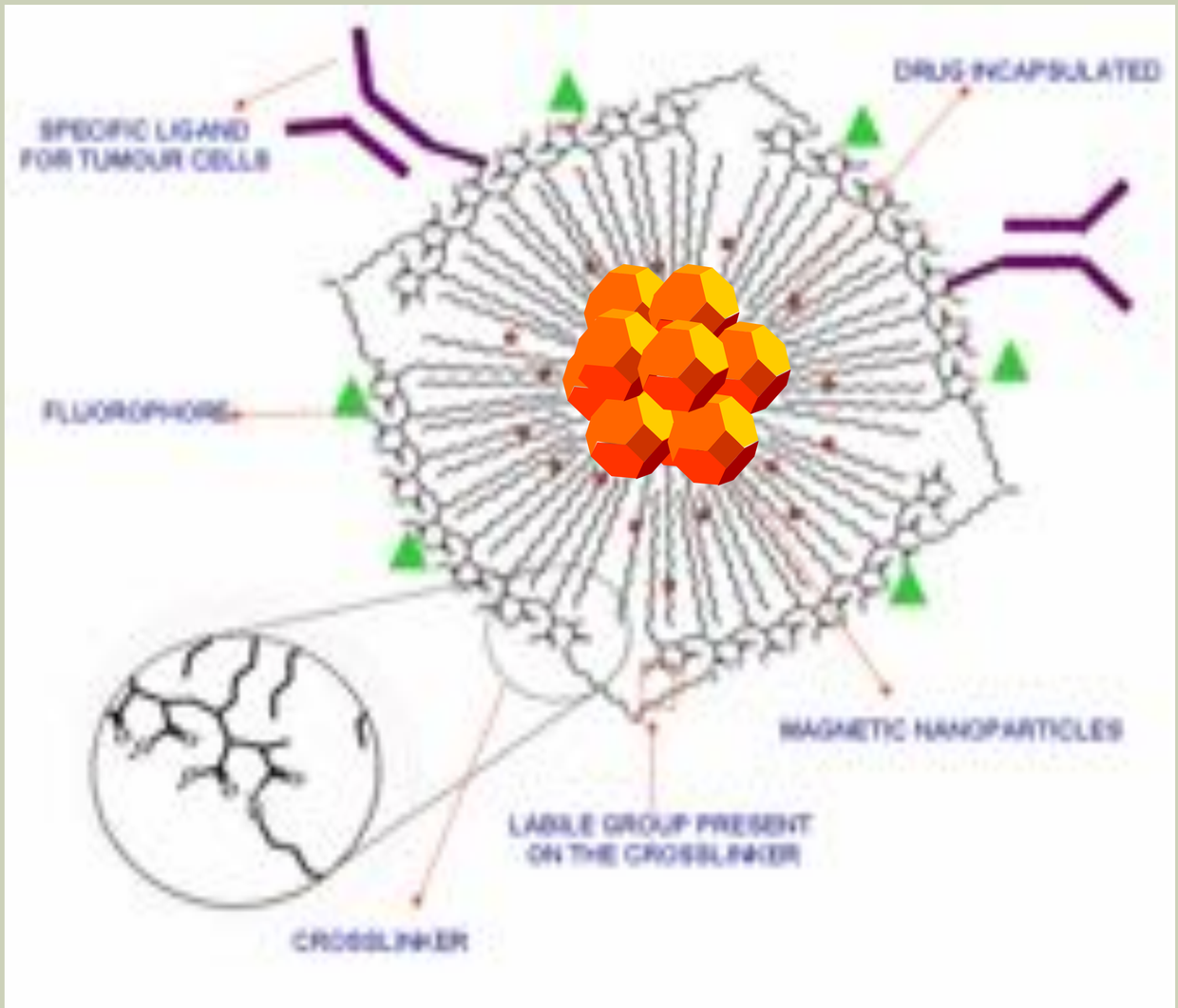
Responsivi



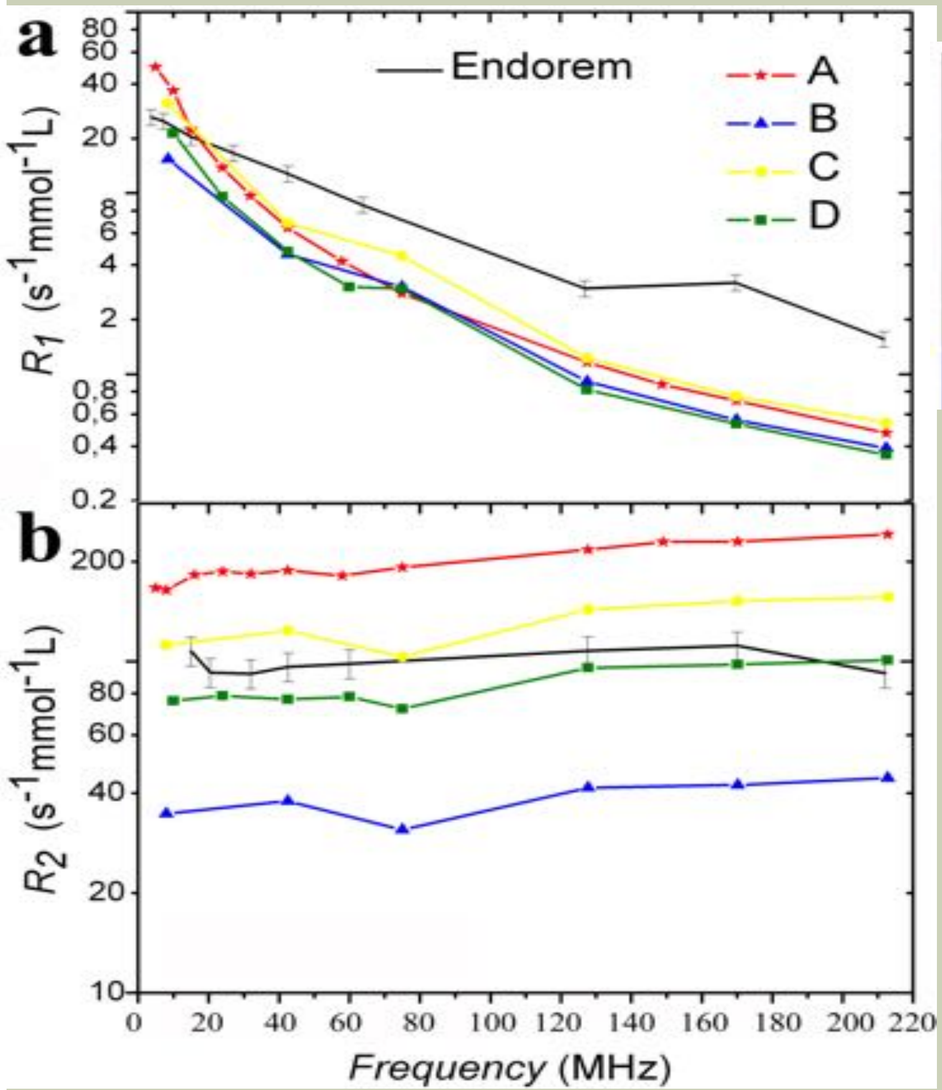
ARTIFICIAL ANTIBODIES

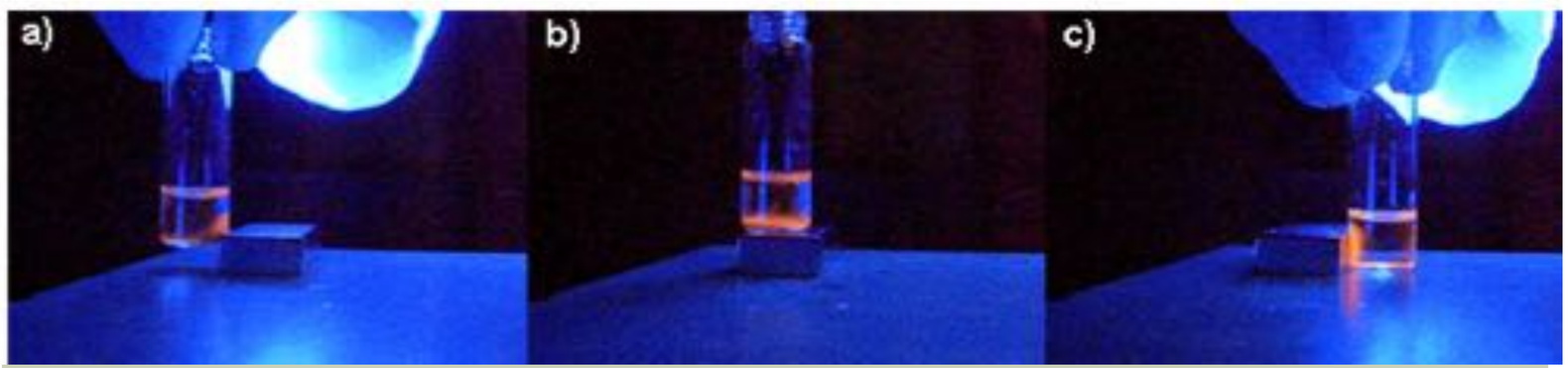






Amphiphilic polymer coated dimers





The $FePt/Fe_3O_4$ sizes:

A) 10.0nm / 16.0 nm

B) 4.0 nm / 11.1 nm

C) 6.2 nm / 15.4 nm

D) 8.9 nm / 12.0 nm.

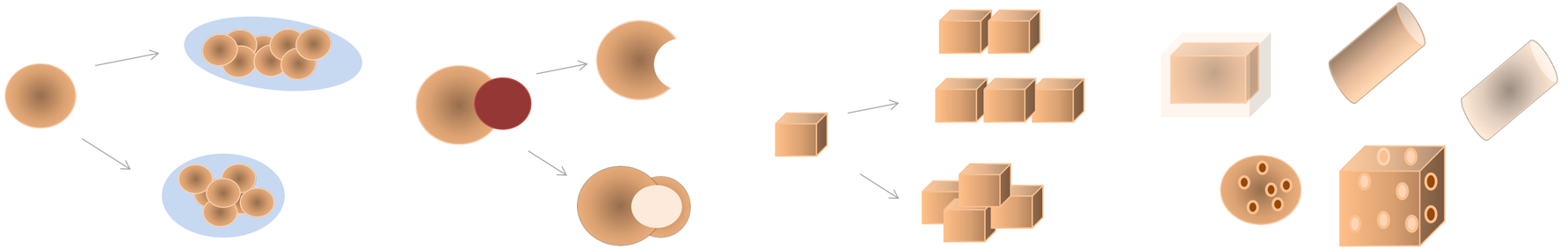
1) Pellegrino T. Nano Lett 2004, 4, 703.

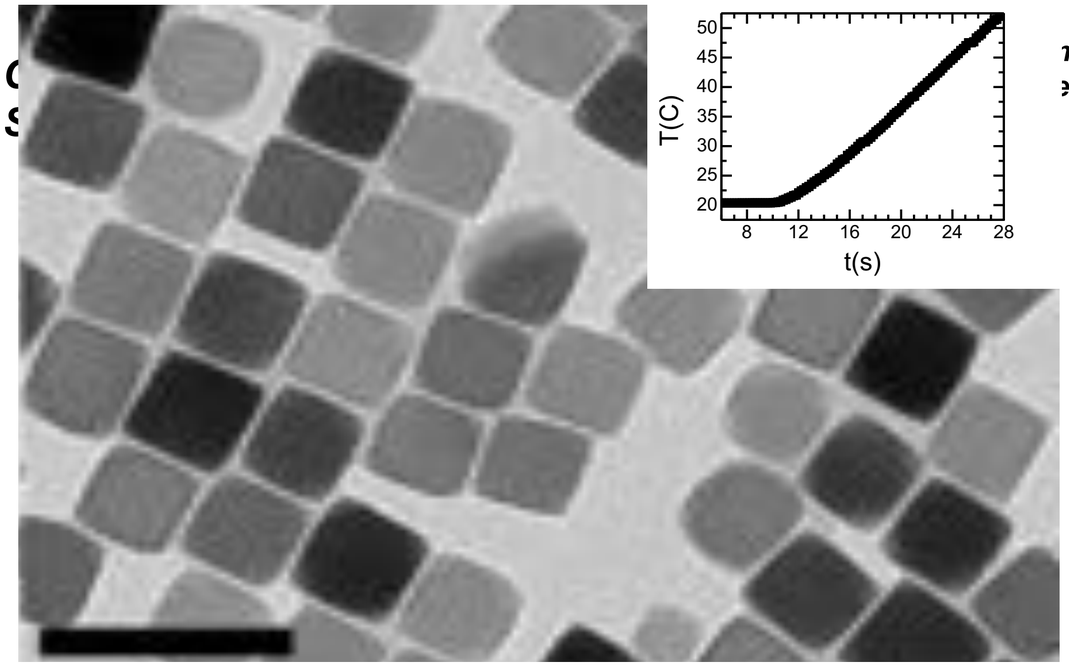
2) Figuerola A., JACS 2008, 130, 1477

DRUG DELIVERY EXPLOITING NANOSYSTEMS

Cargo Nanoparticles

Complex Nanostructures





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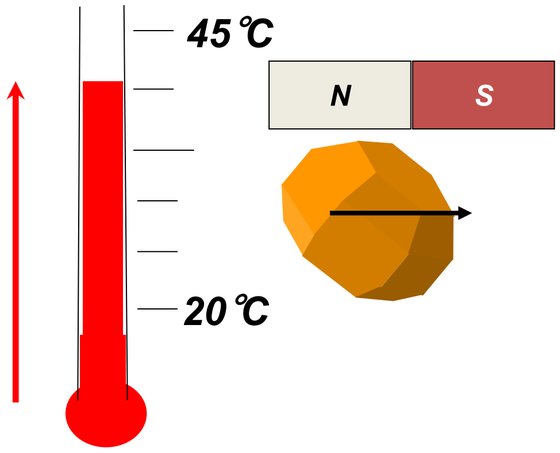


- ***Synthesis of novel inorganic magnetic nanocrystals***
- ***Develop of water solubilization procedure***
- ***Their assembly in controlled colloidal nanostructures***
- ***Their physical and magnetic characterization***

In vivo Hyperthermia experiments

Tumor diameter ≈ 7 mm (tumor initiated by A431 cell injection)

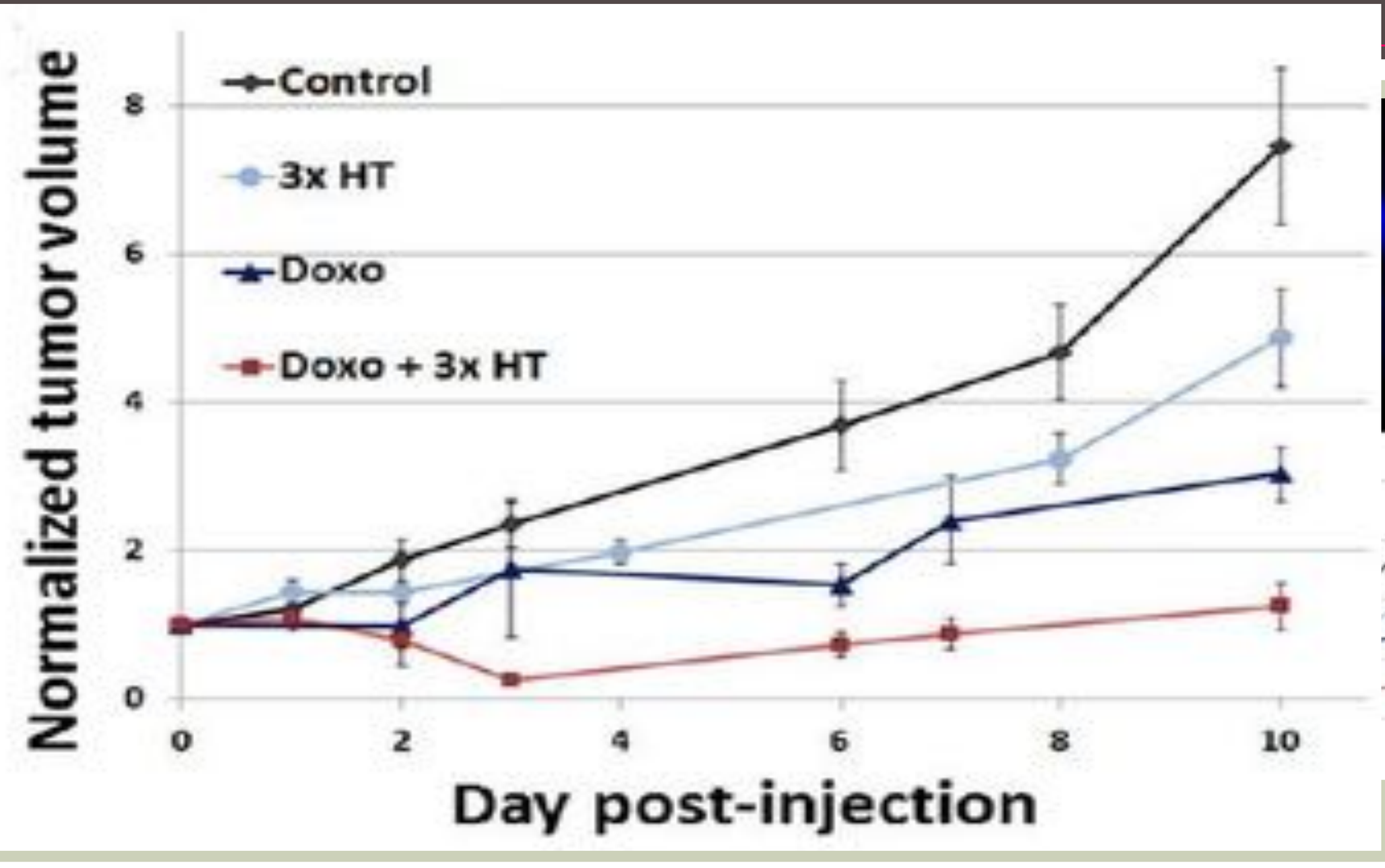
Hyperthermia: H = 30 mT, f = 111 kHz, T = 30°C

50 µL nanocube suspension in NaCl (0,9%) at iron concentration of 250 mM

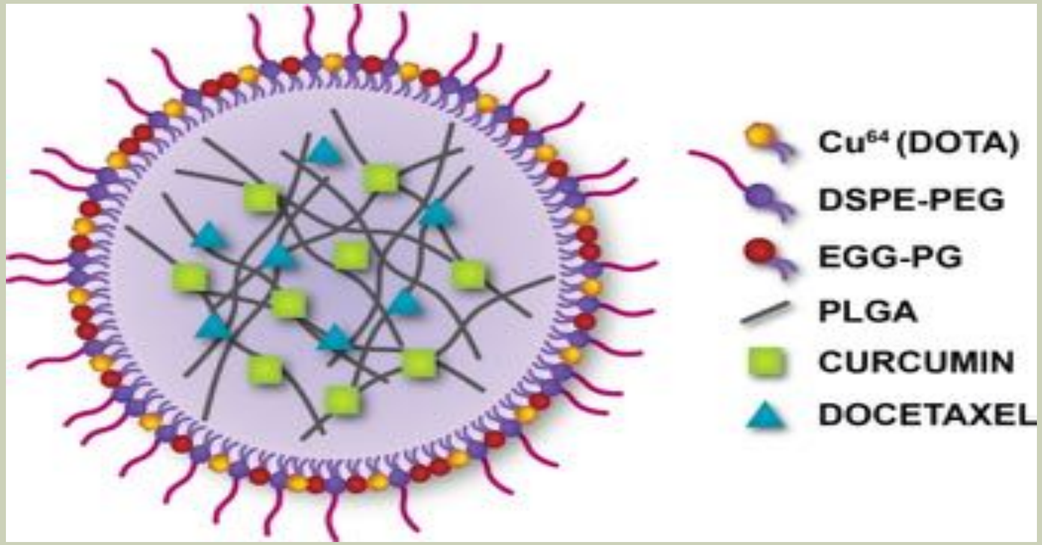
(0.7 mg of iron in average 28 mg iron/kg body weight)

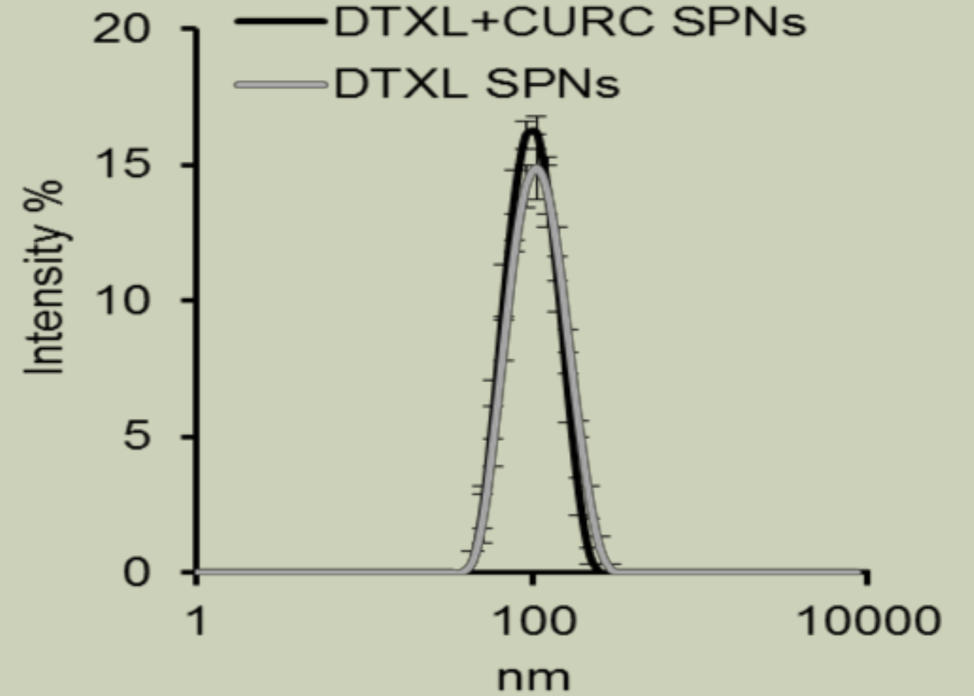
In Collaboration with CNRS (J. Kolosnjaj-Tabi, F. Gazeau, R. Di Corato and C. Wilhelm)

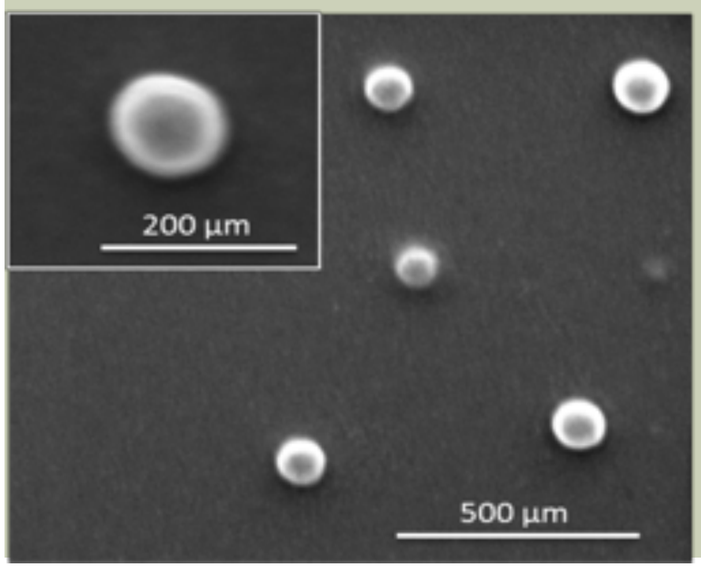
INTRATUMORAL HEATING

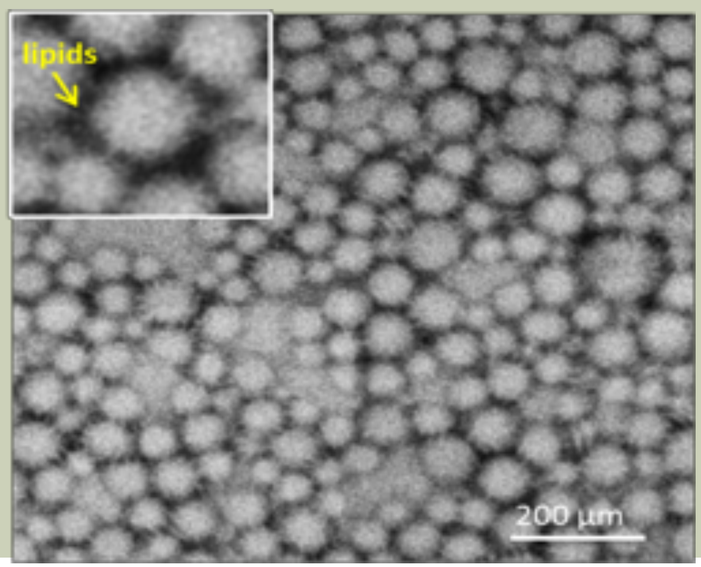


Polymeric constructs: Theranosis and SPNs





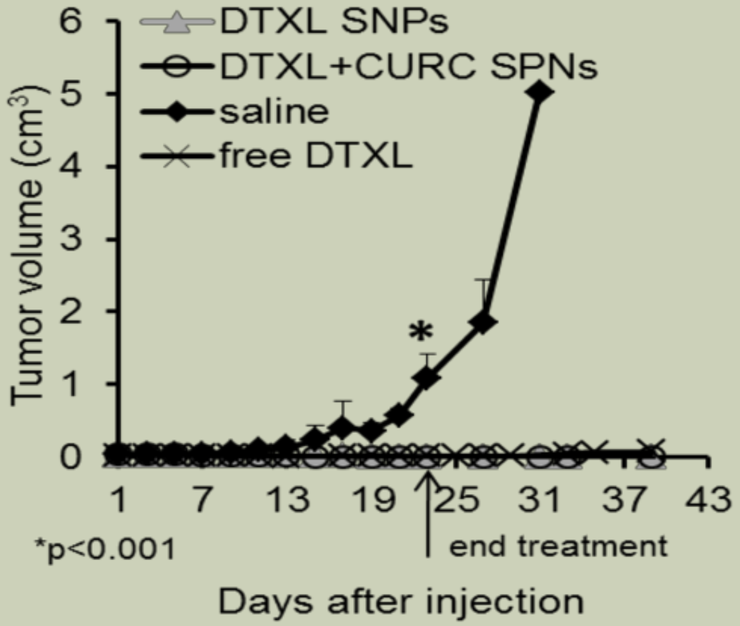


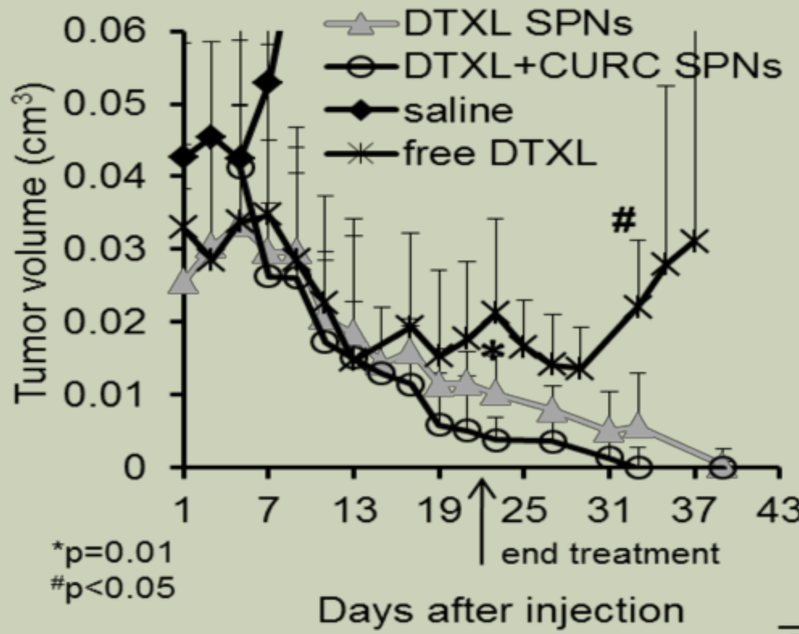


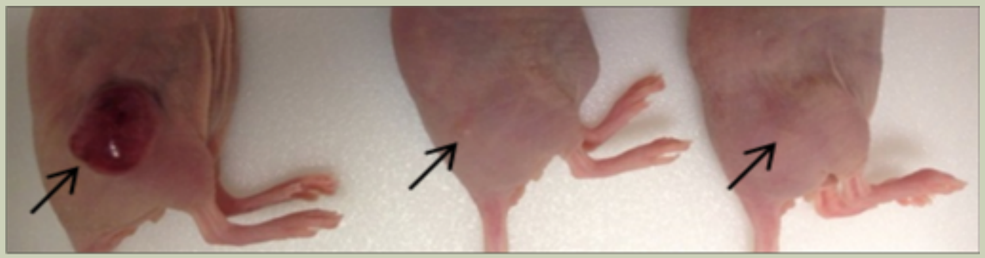
	DTXL+CURC SPNs	DTXL SPNs
Diameter (nm ±s.d.)	89.58 ±2.32	98.16 ±1.87
PdI	0.141	0.145
Z-potential (mV)	-65.0 ±3.5	-63.7 ±2.4

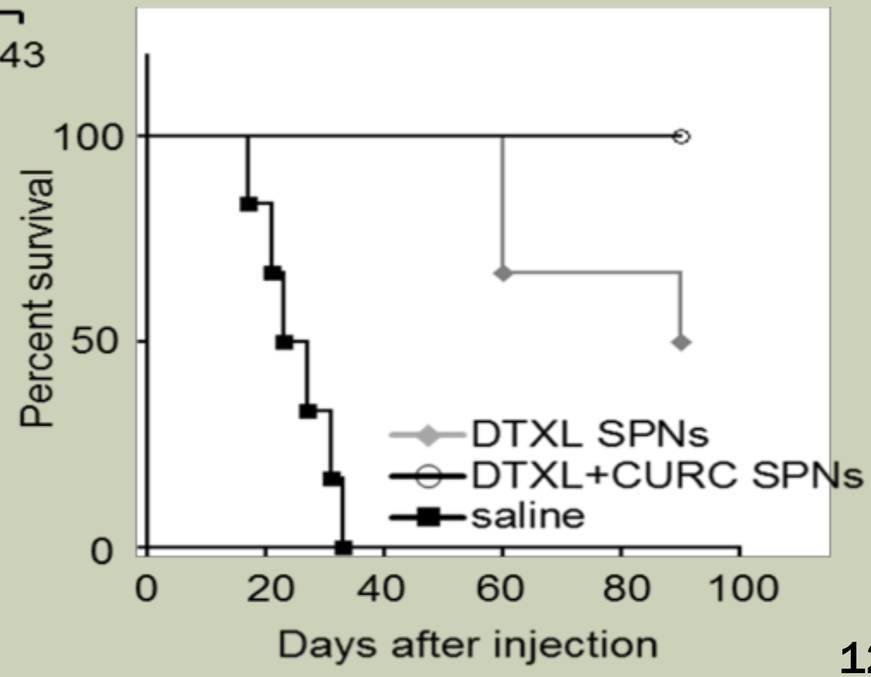
Stigliano, … Decuzzi, 2015, Adv. Func. Mat.

Combinatorial Drug Release and IC50
In vivo tumor treatment



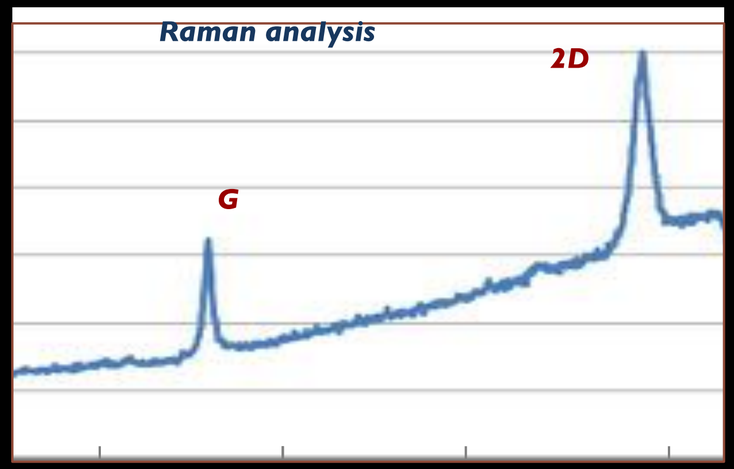


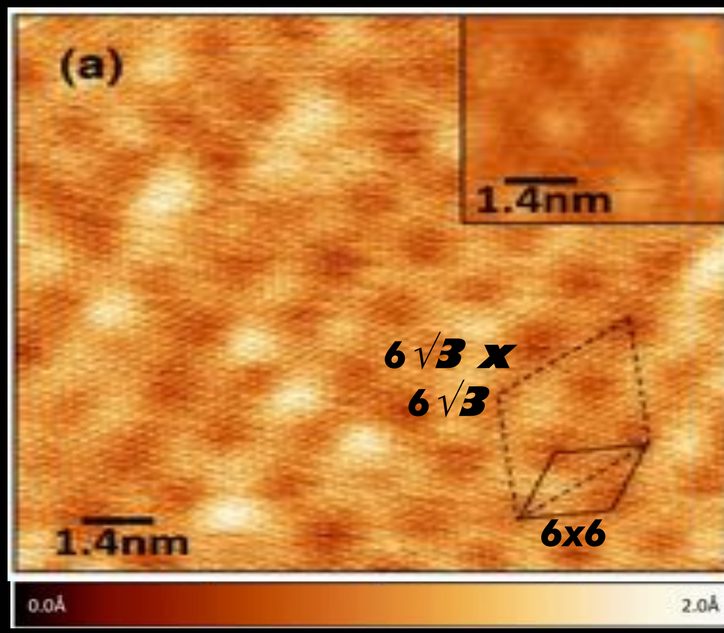


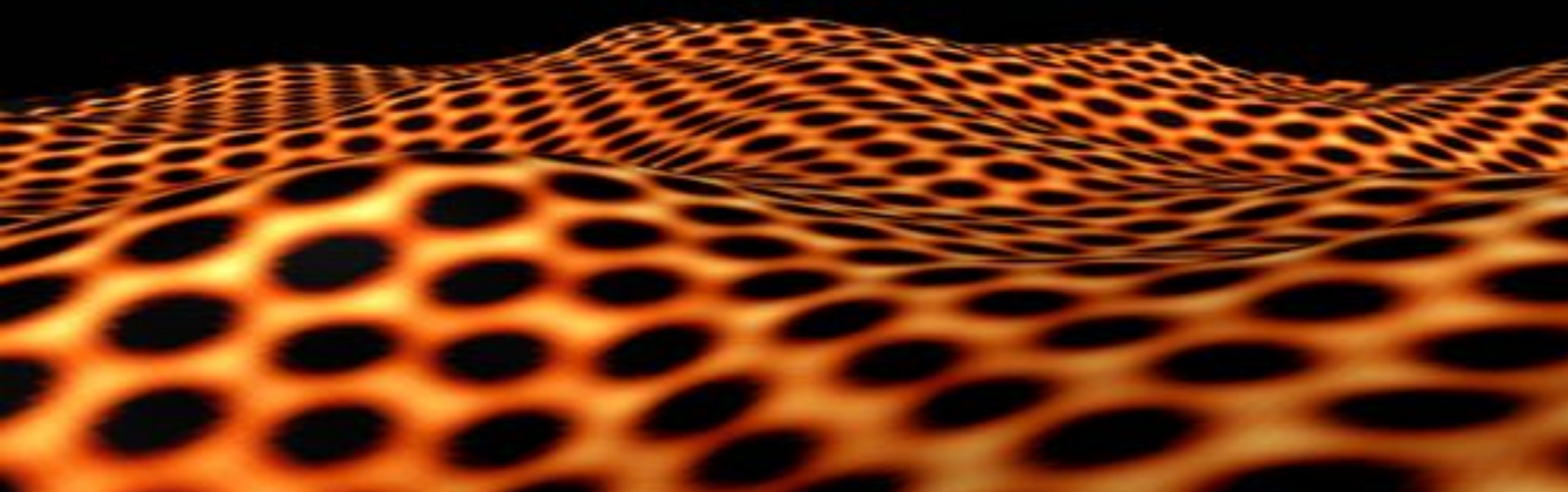


Stigliano, … Decuzzi, 2015, Adv. Func. Mat.

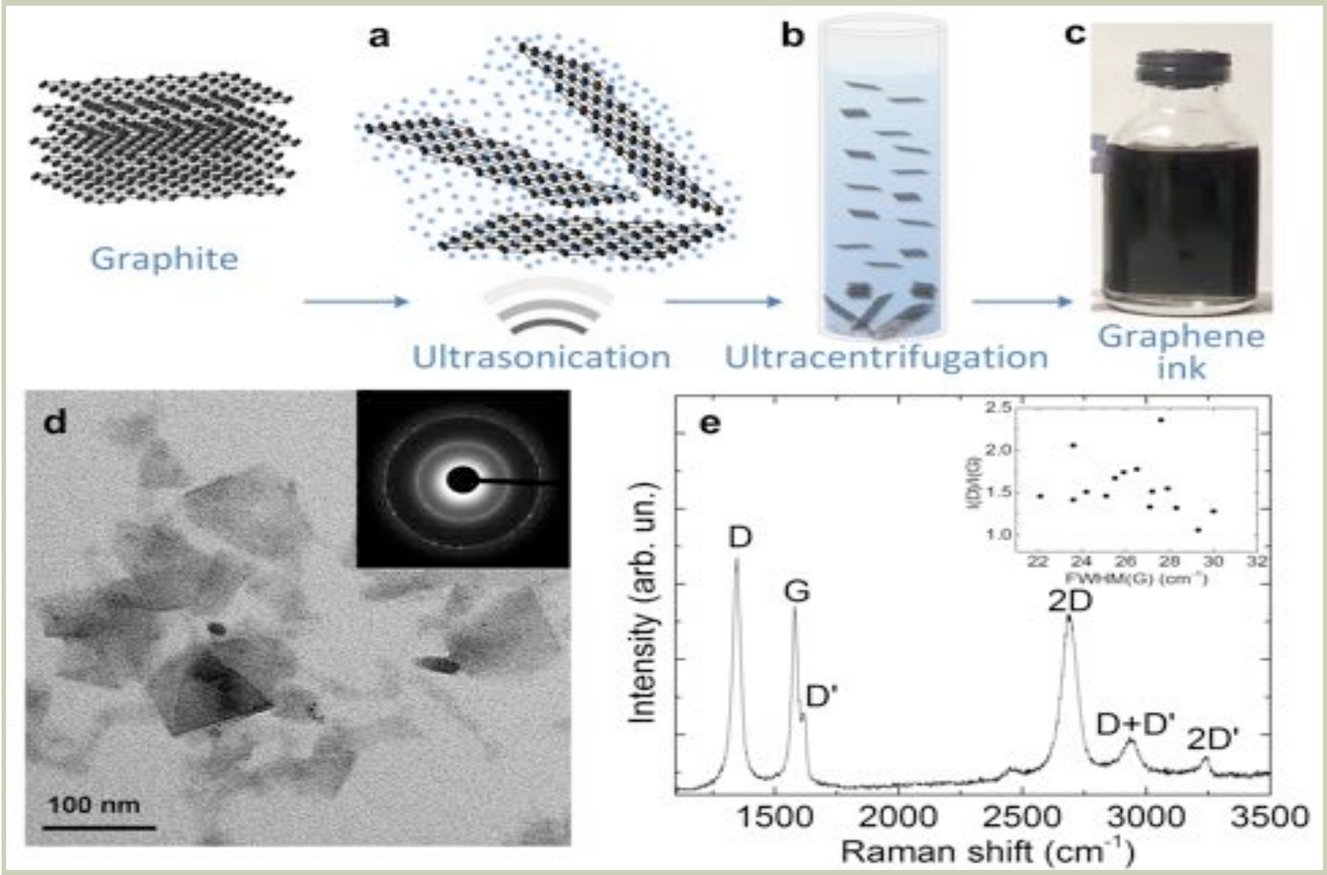
GRAPHENE







Smart Materials: printable graphene

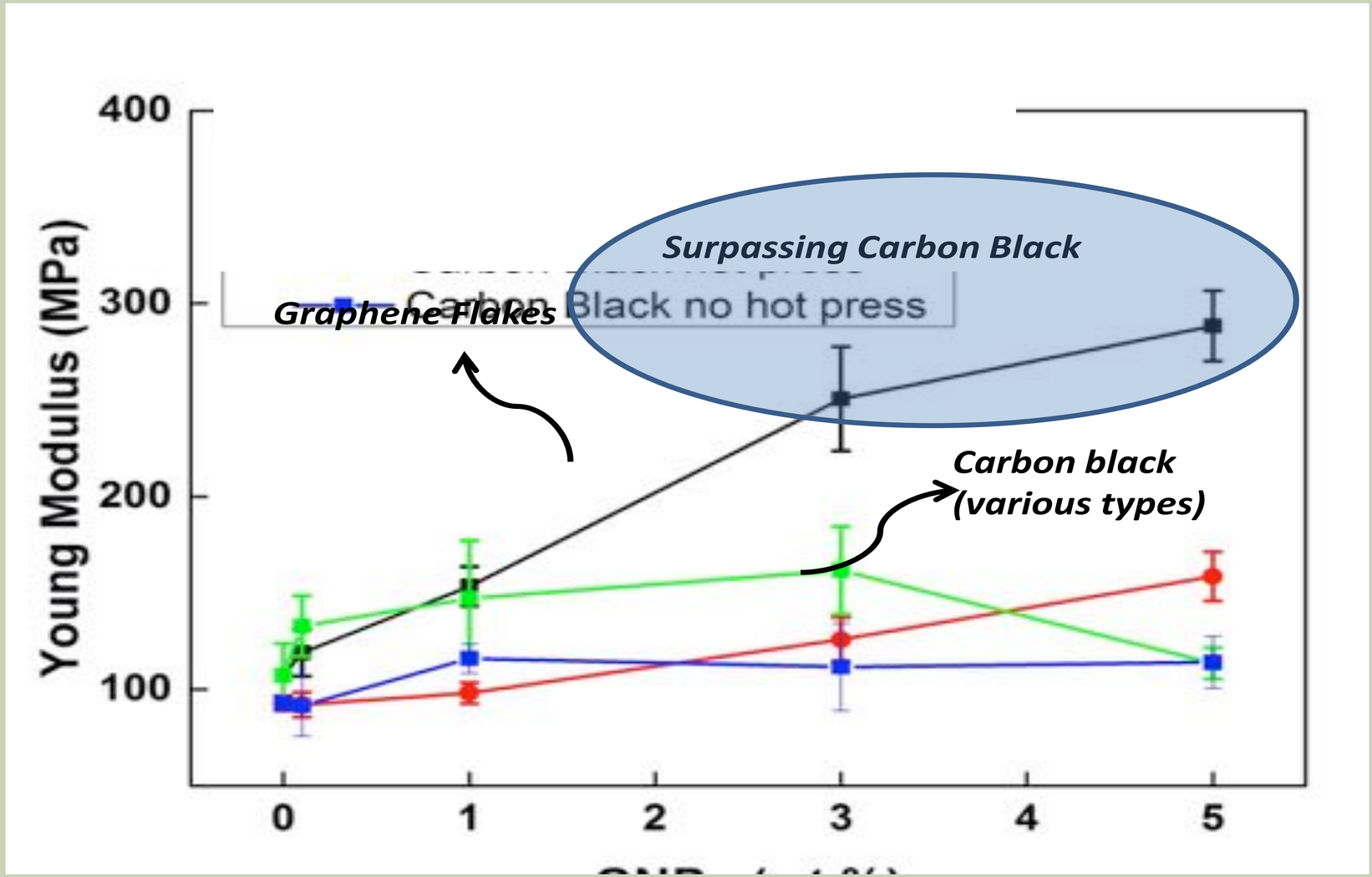


Printable 2d material solutions

Graphene and TDM inks by liquid phase exfoliation

A.C.Ferrari et al. Nanoscale, 7, 4598-4810, 2015

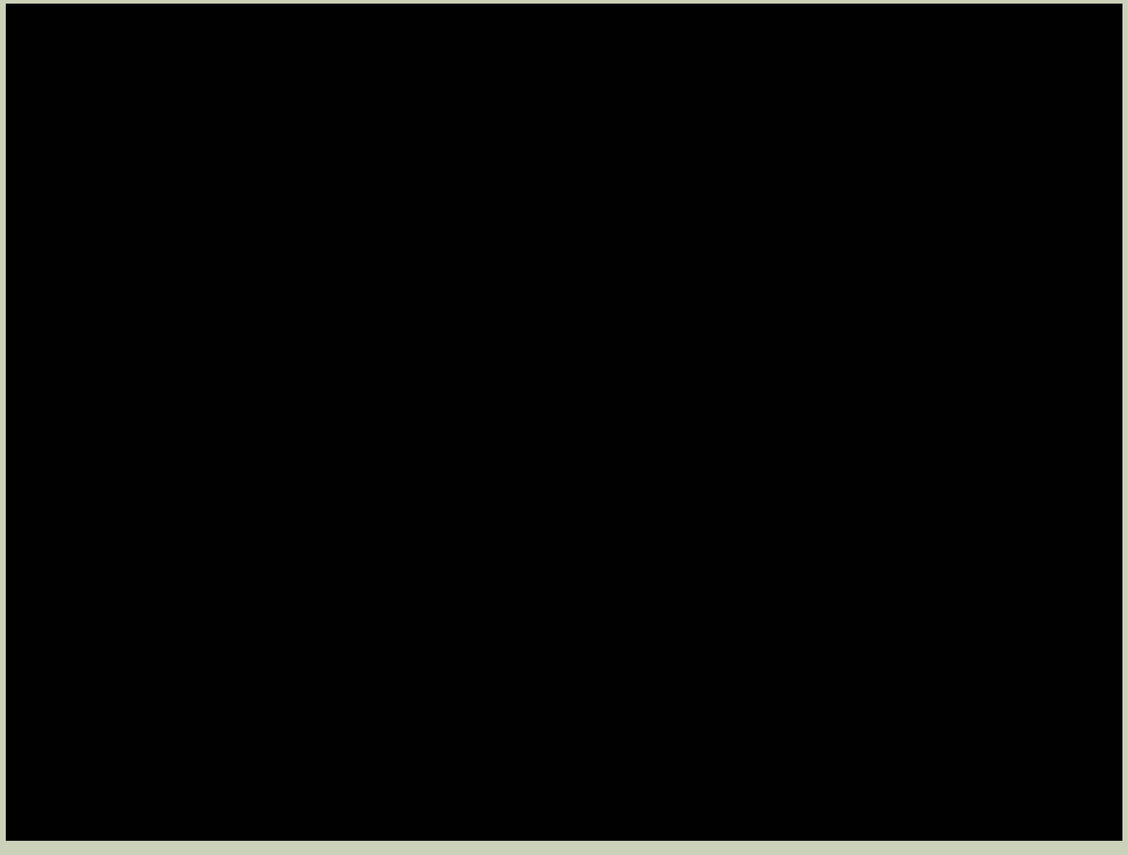
Enhancement of Young's Modulus of Thermoplastic Starch Composite (Mater-Bi®) with Graphene NanoplateS

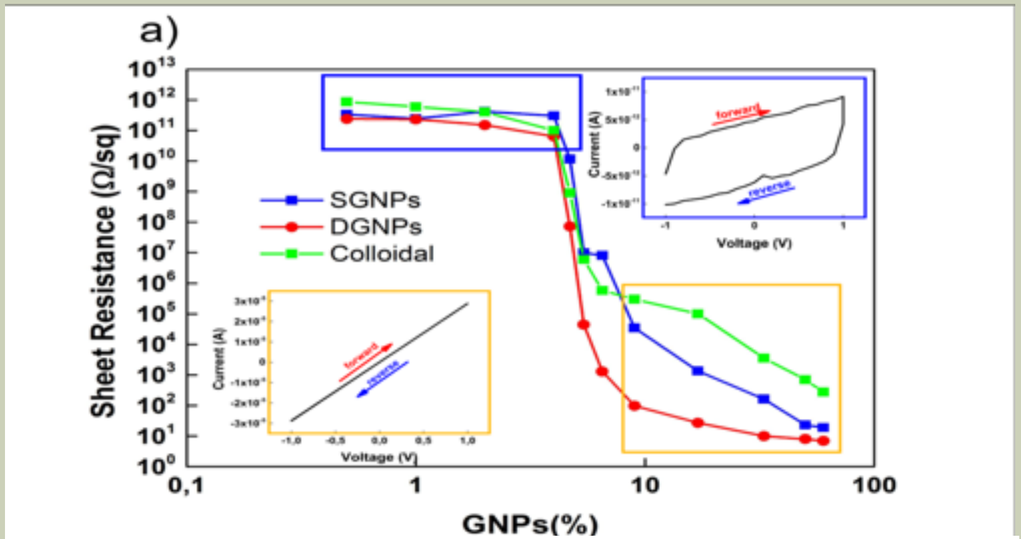


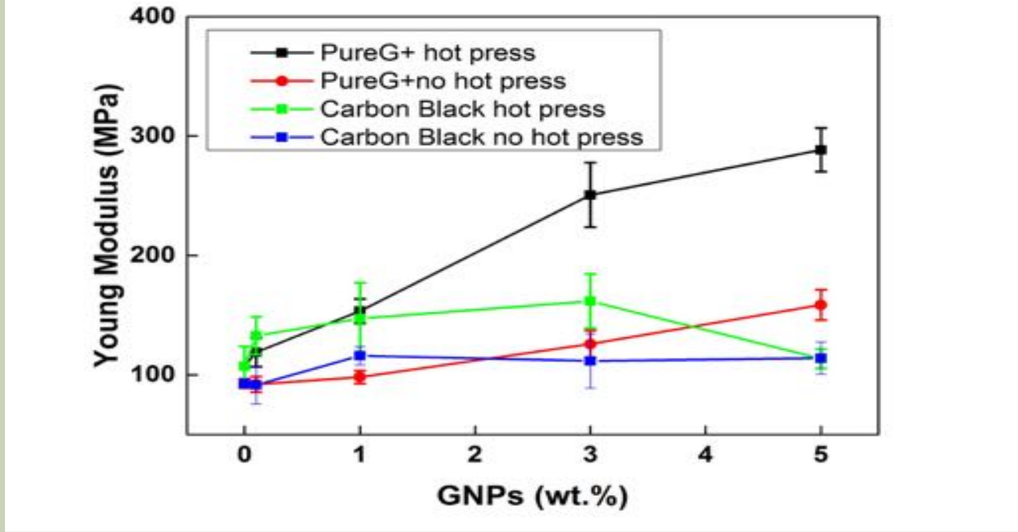
Cataldi *et al*. *Advanced Electronic Materials*, 2015 (in press).

Stampa dei circuiti

Printed conductive circuits based on graphene ink



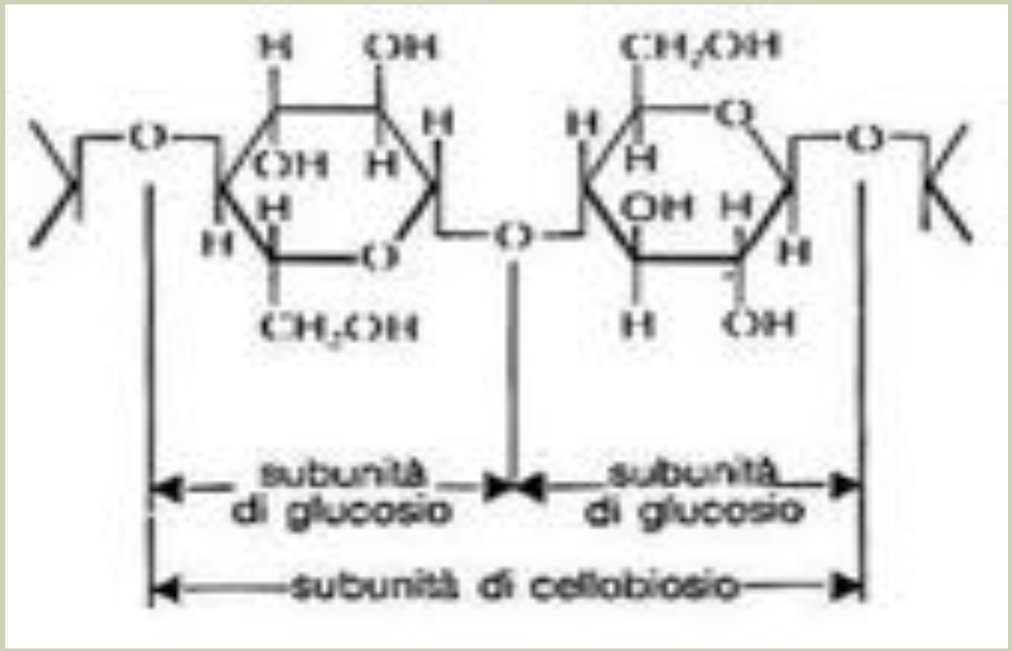


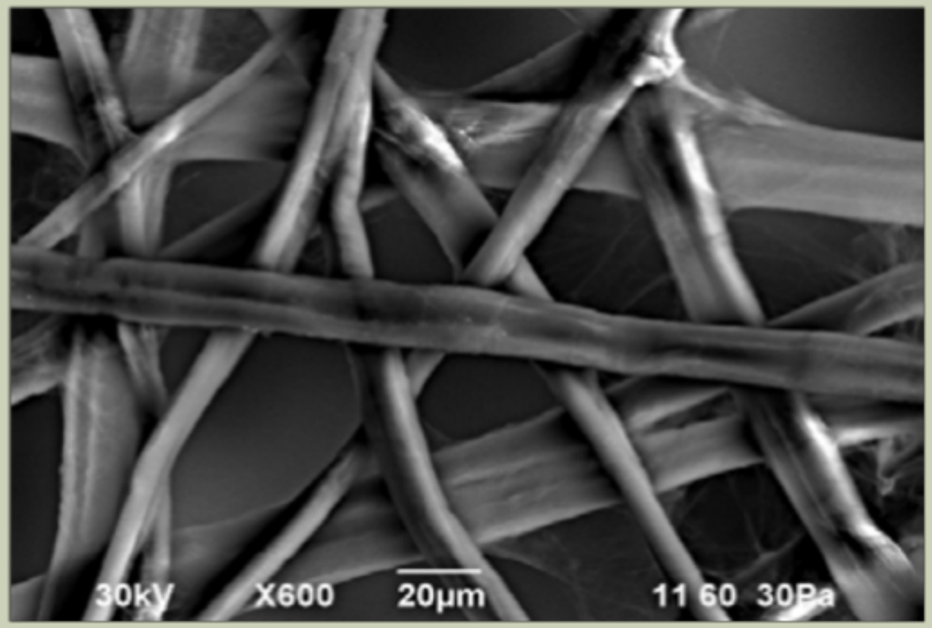


I.Bayer et al,. Macromolecules 47, no. 15 (2014): 5135

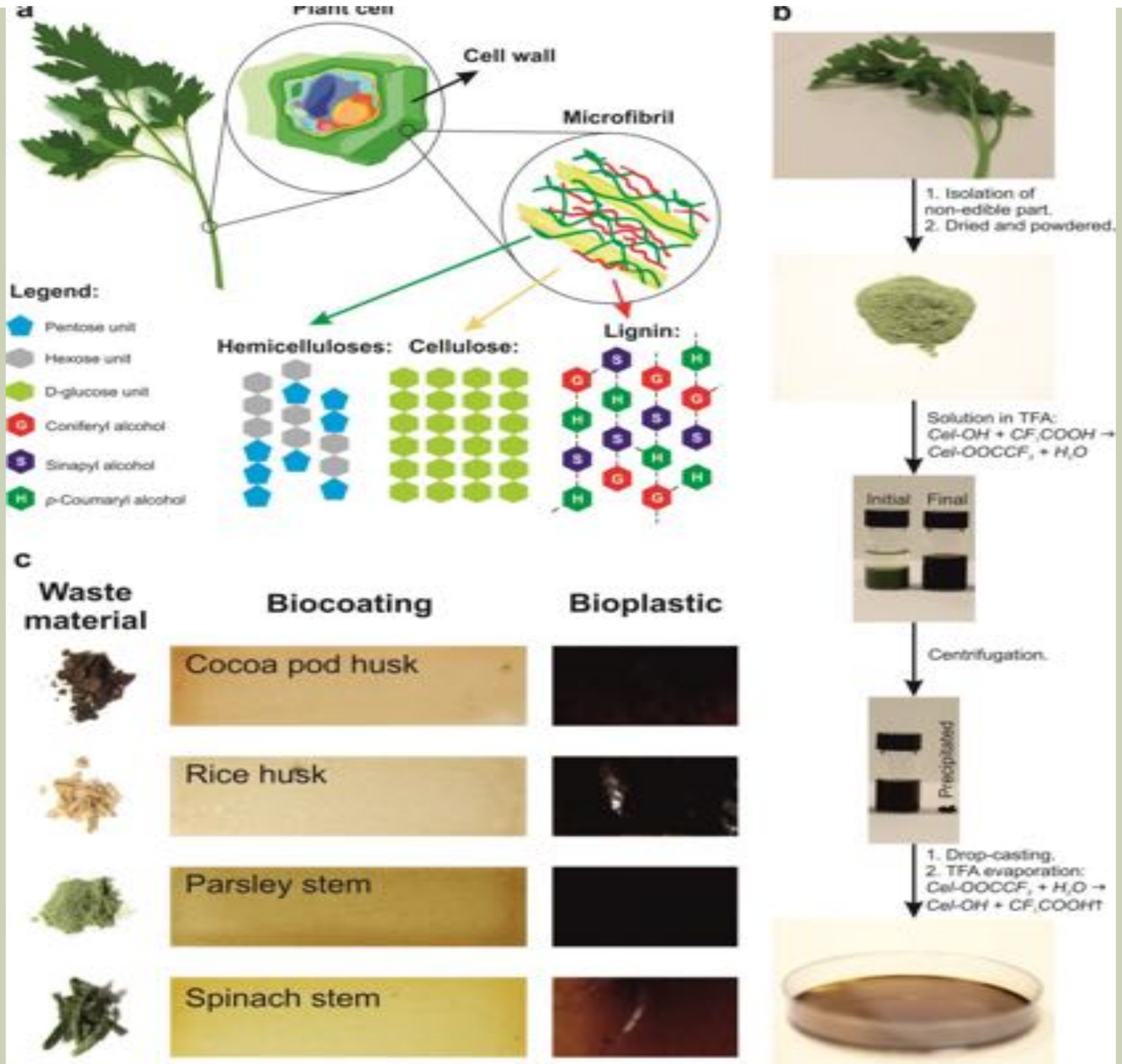
I.Bayer et al. Adv. Elec. Mat. 2015

CELLULOSE: THE UNIVERSAL FIBER



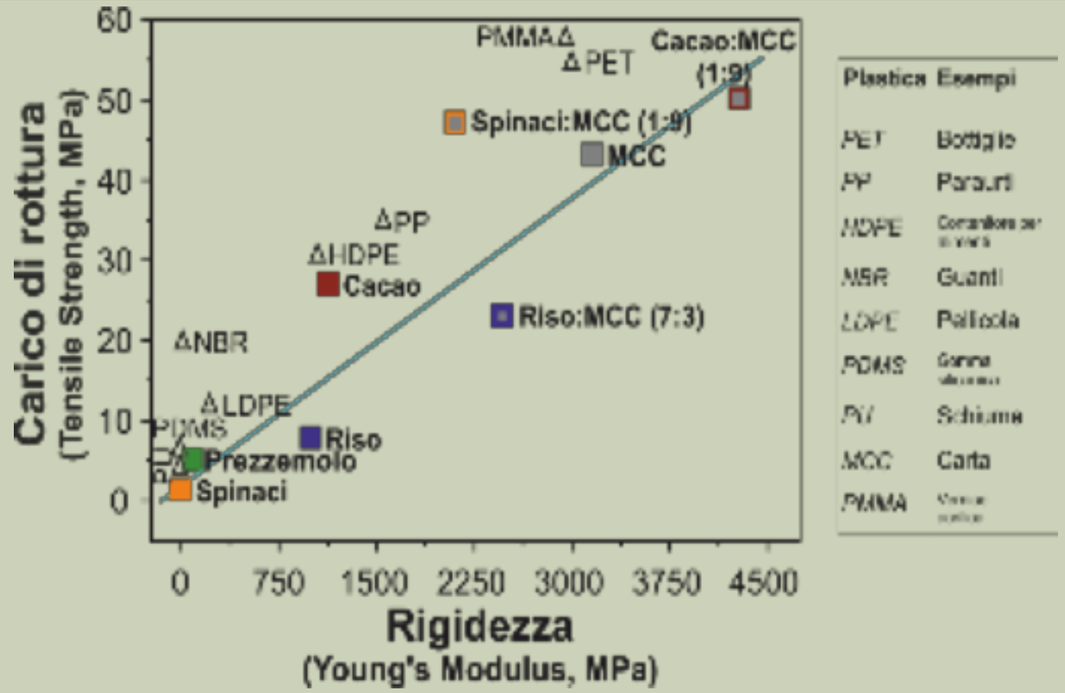


NATURAL FIBERS VS OIL FIBERS

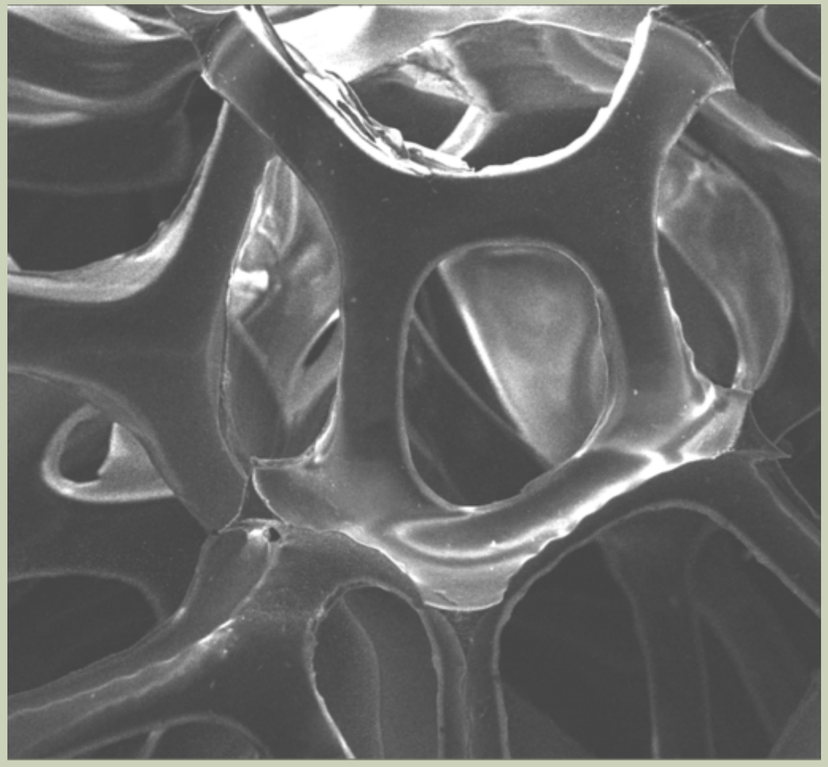


VEGETABLE PLASTIC -1

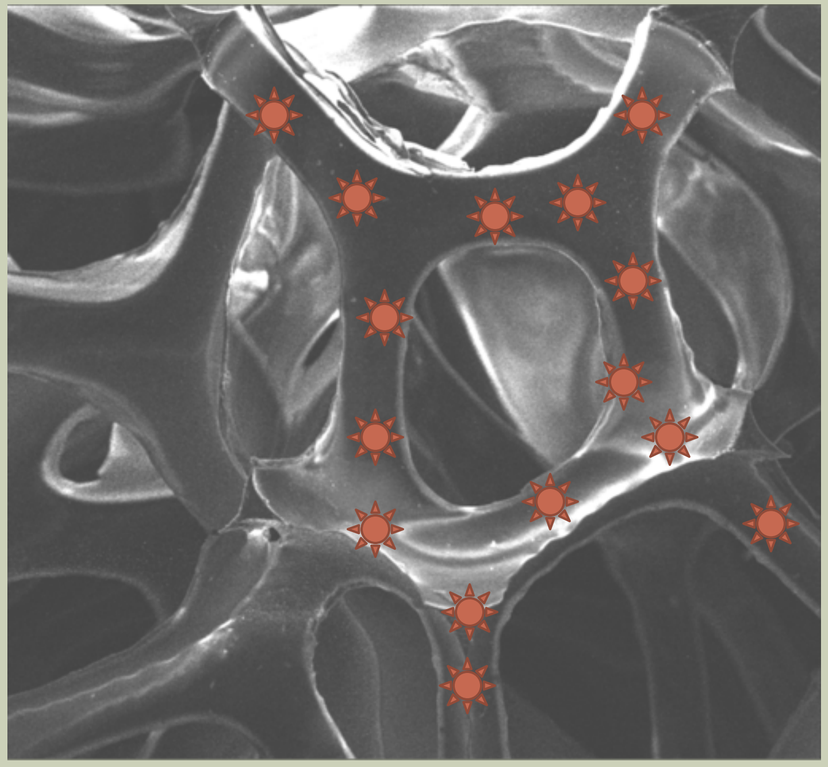
VEGETABLE PLASTIC - 2



NATURAL SPONGES -1



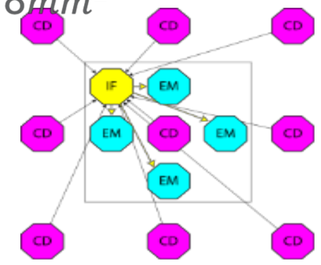
MAGIC SPONGES

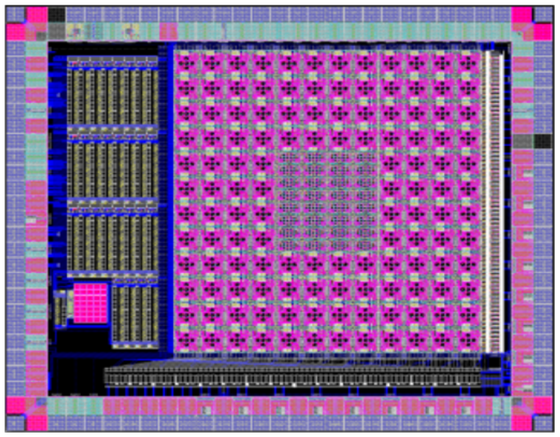


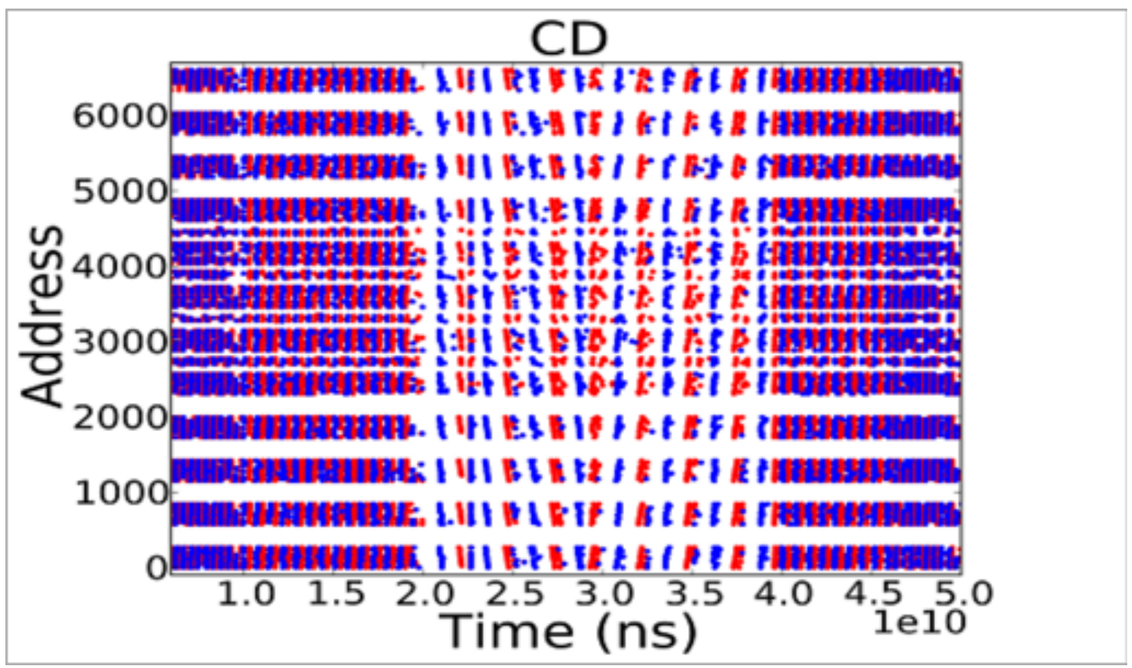
Neuromorphic cameras

low-res space-variant prototype

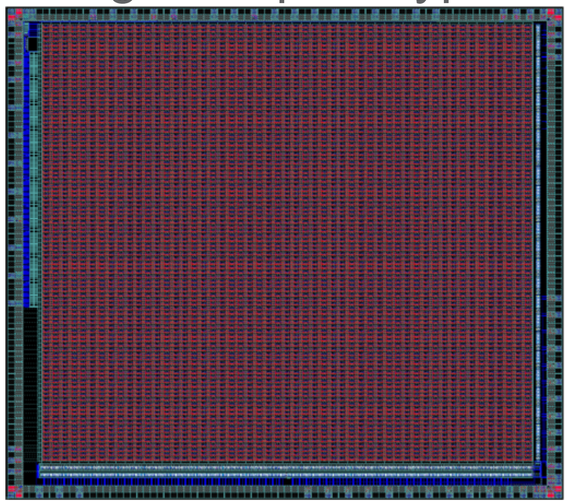
Fovea: 8x8
Periphery: 12x12
AMS 350nm
$8mm^2$

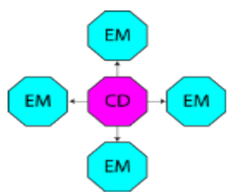






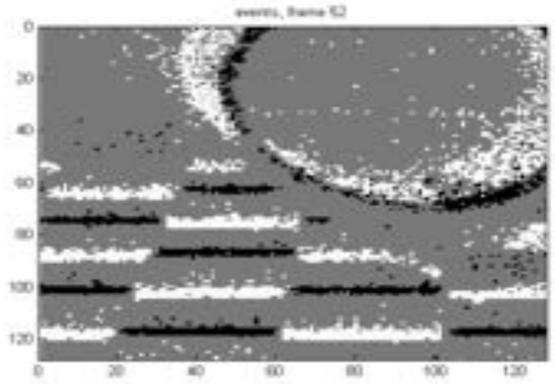
high-res prototype

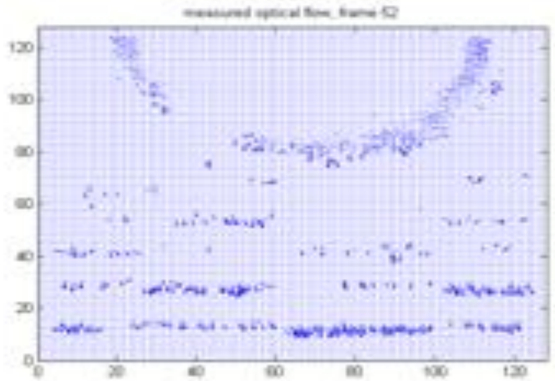


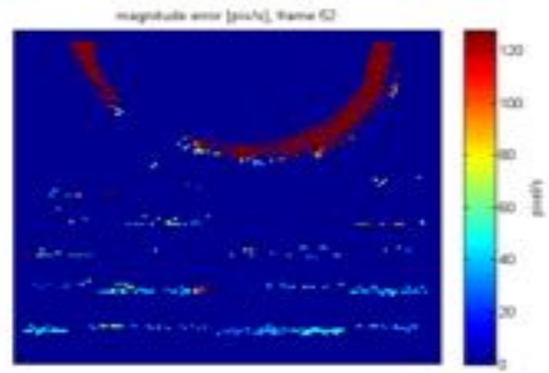


Array: 106x96
AMS 350nm
$72mm^2$

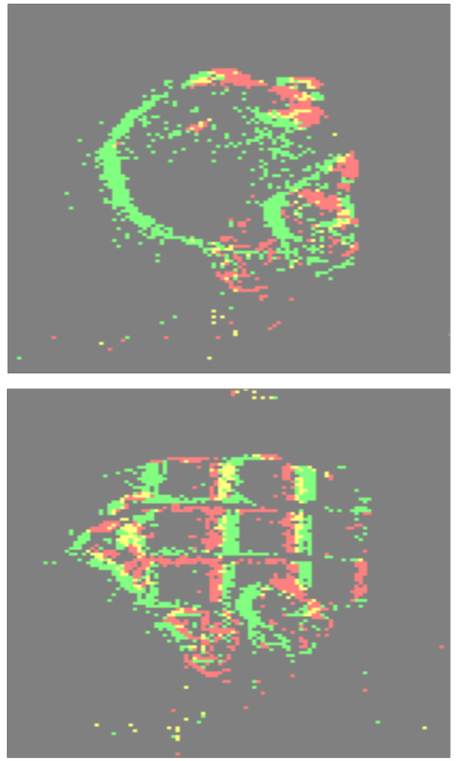
event-based encoding



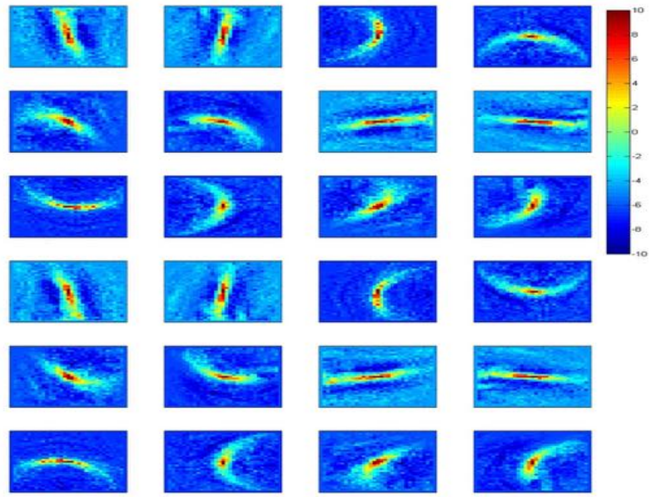




Neuromorphic vision



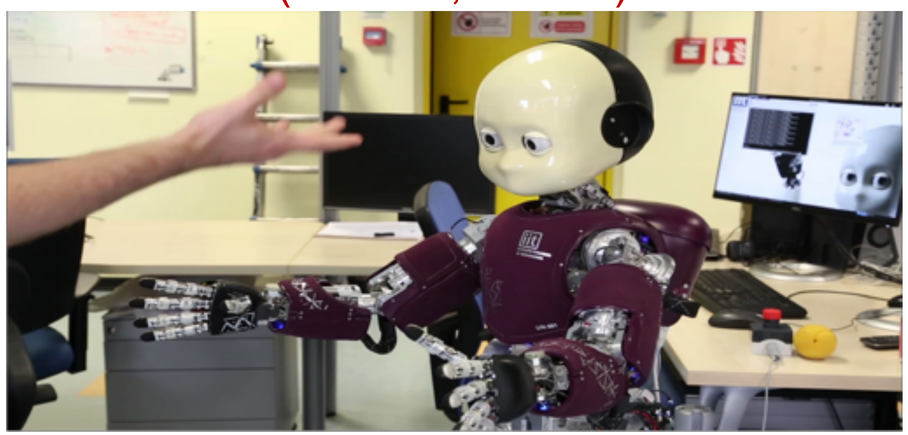
input data (events)



directional filters (learned)

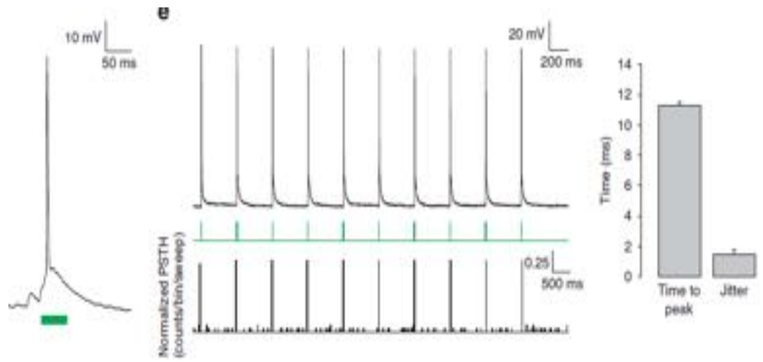
object recognition
(what)

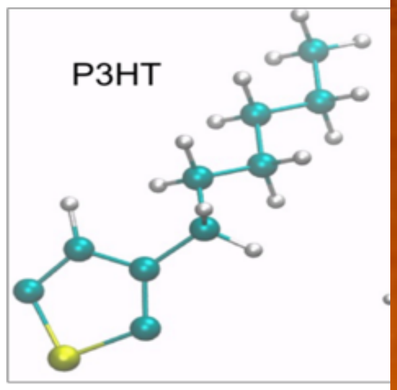
tracking
(location, motion)



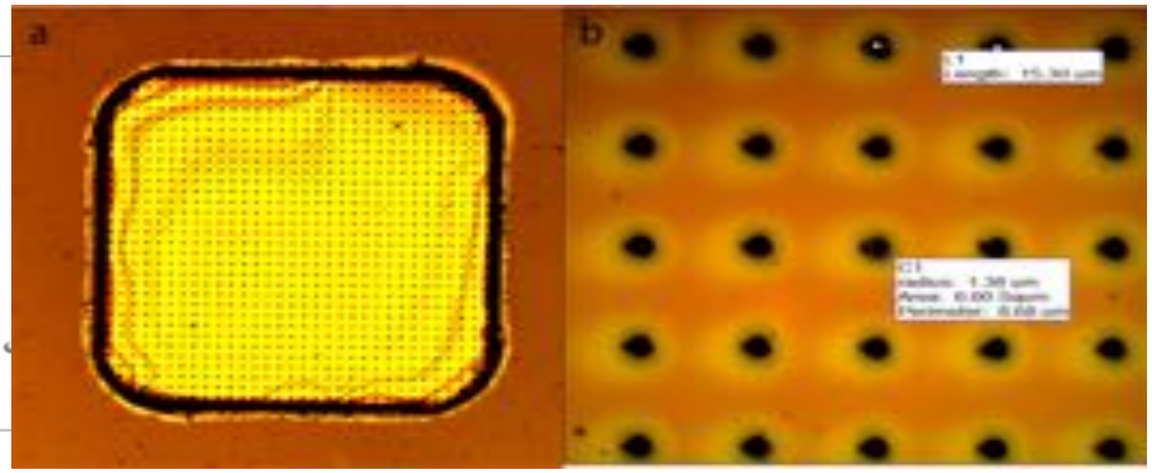
Future: Artificial Retina

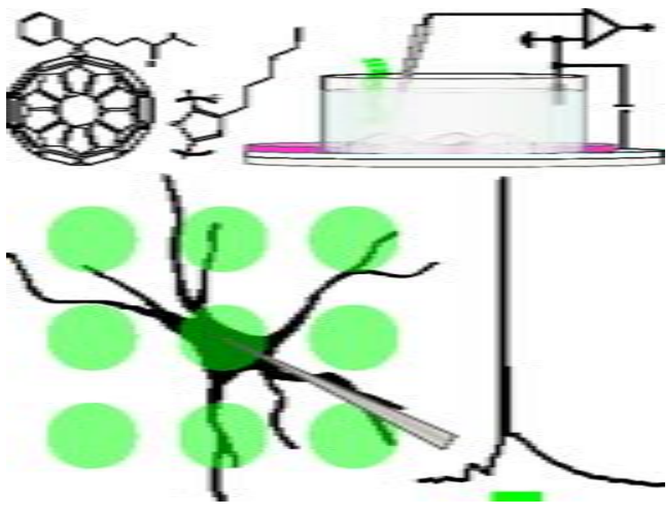
ISTITUTO ITALIANO
DI TECNOLOGIA

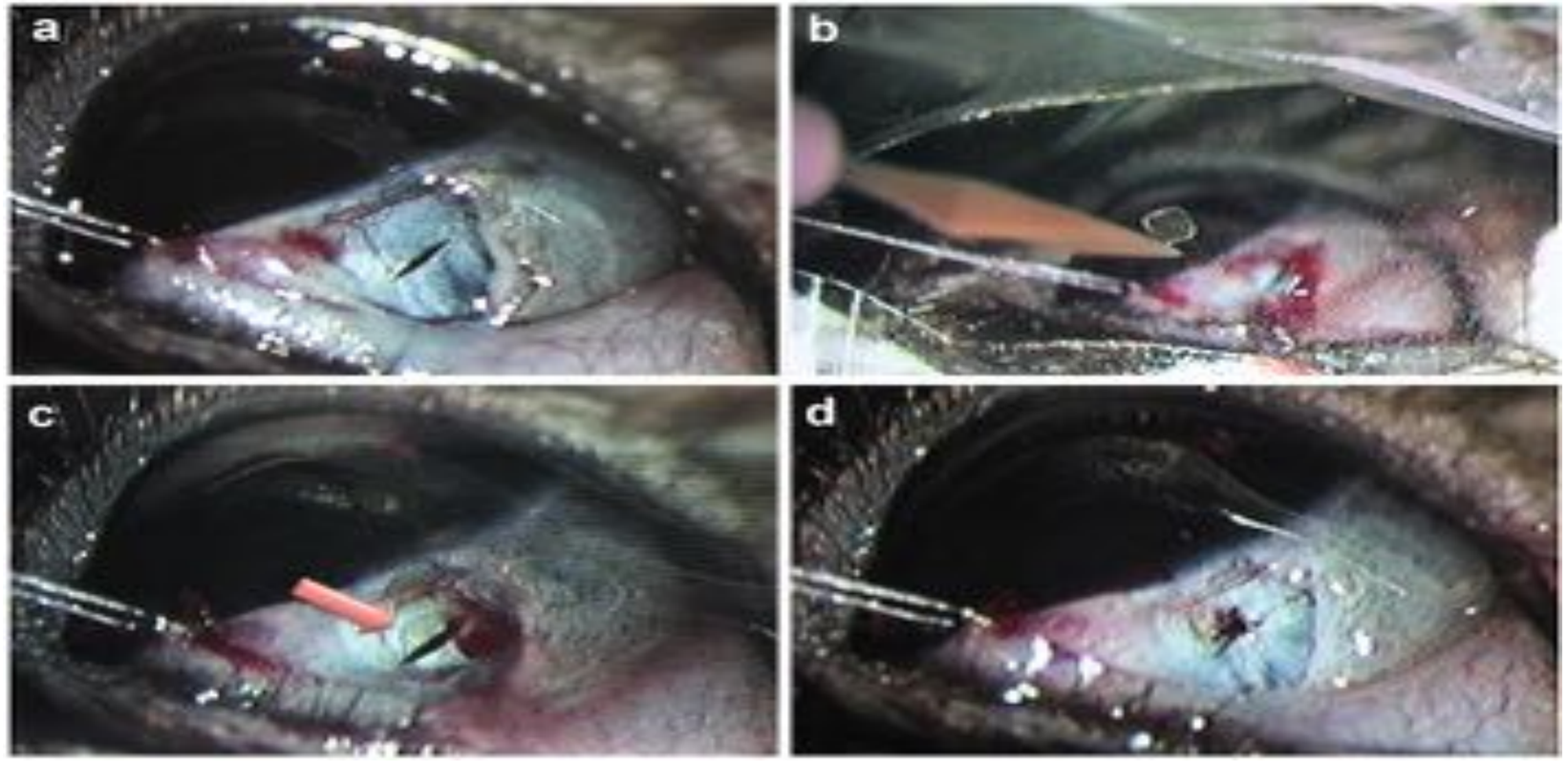




Silk / Pedot / P3HT-Fullerenes

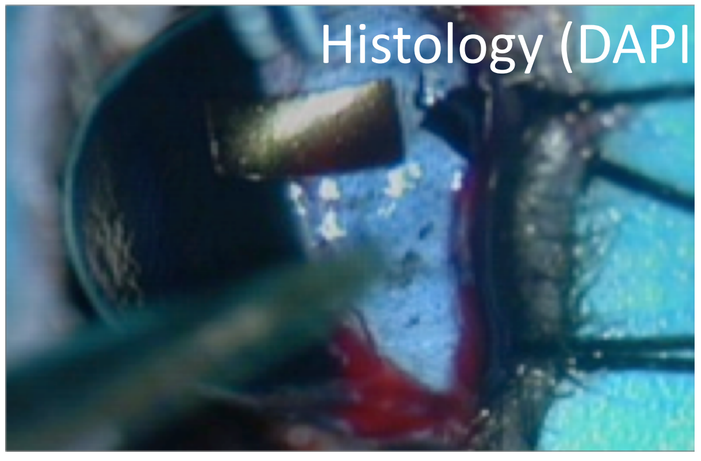


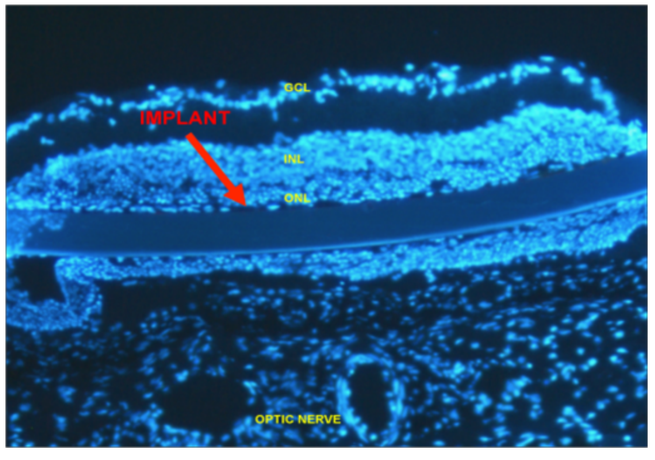


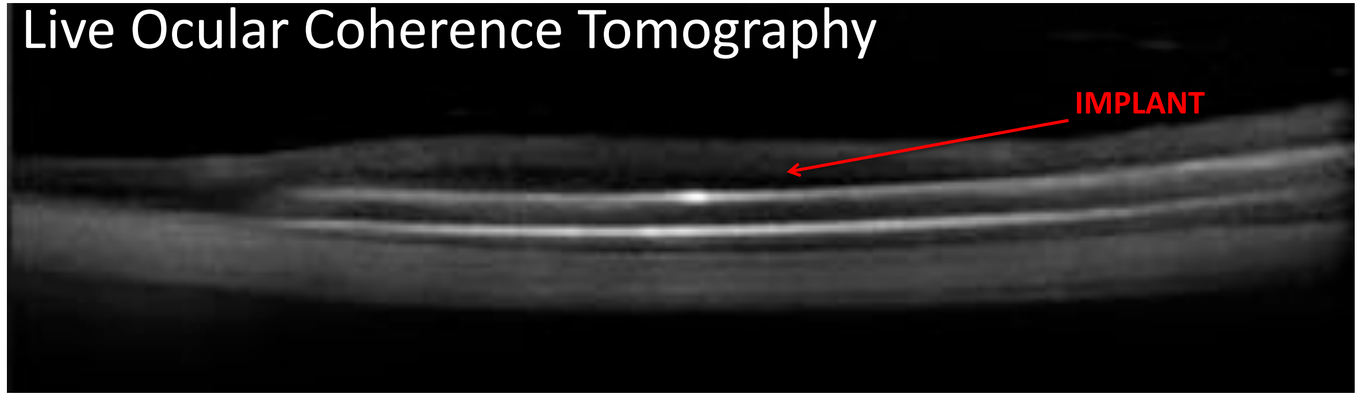


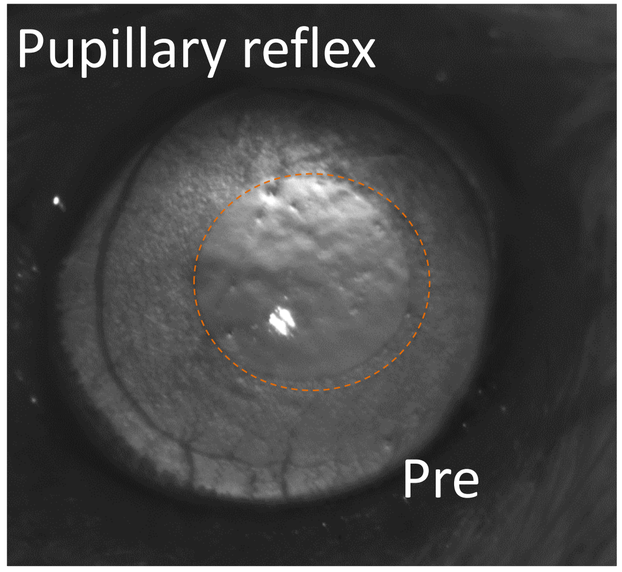
Nature Photonics, 7, 400 (2013)
J.Mater.Chem B1, 3768 (2013)
Nature Com. 2011,doi10.1038/ncomms1164

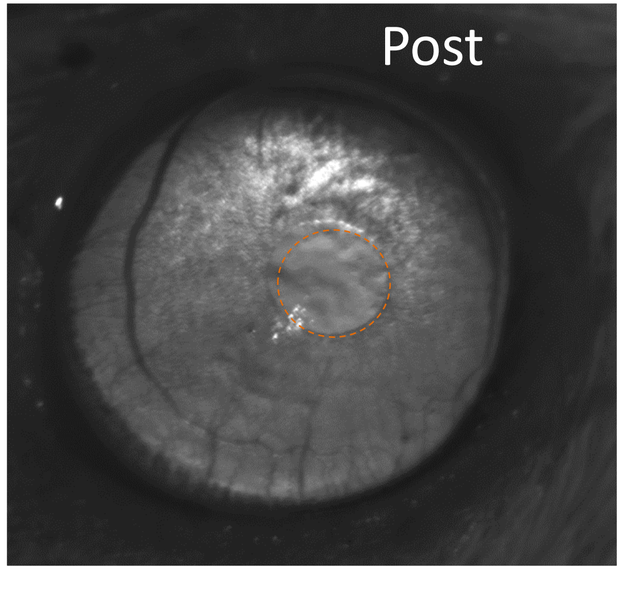
- Toward the development of a fully organic artificial retina
- Implantation of a fully organic device in the eye of RCS rats a model of human *Retinitis pigmentosa*



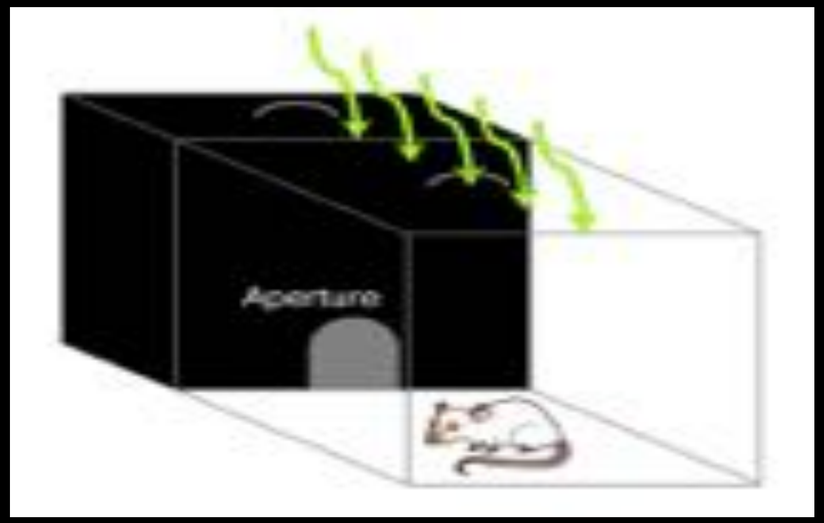




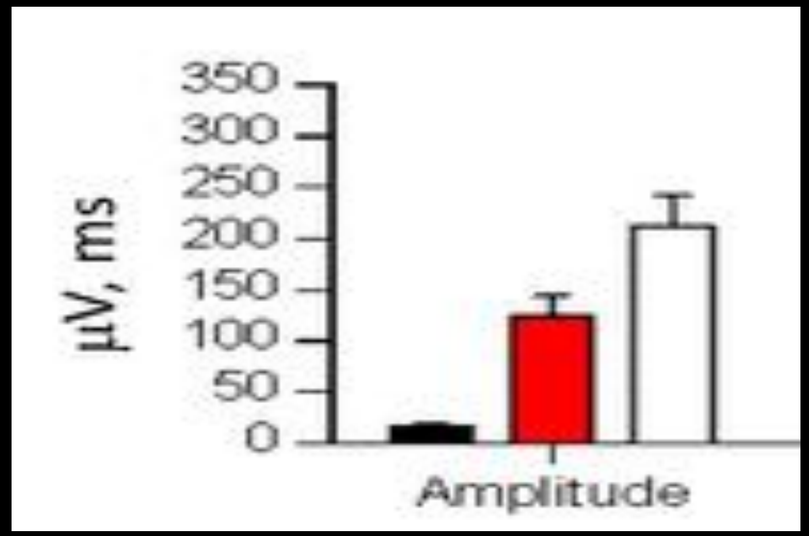




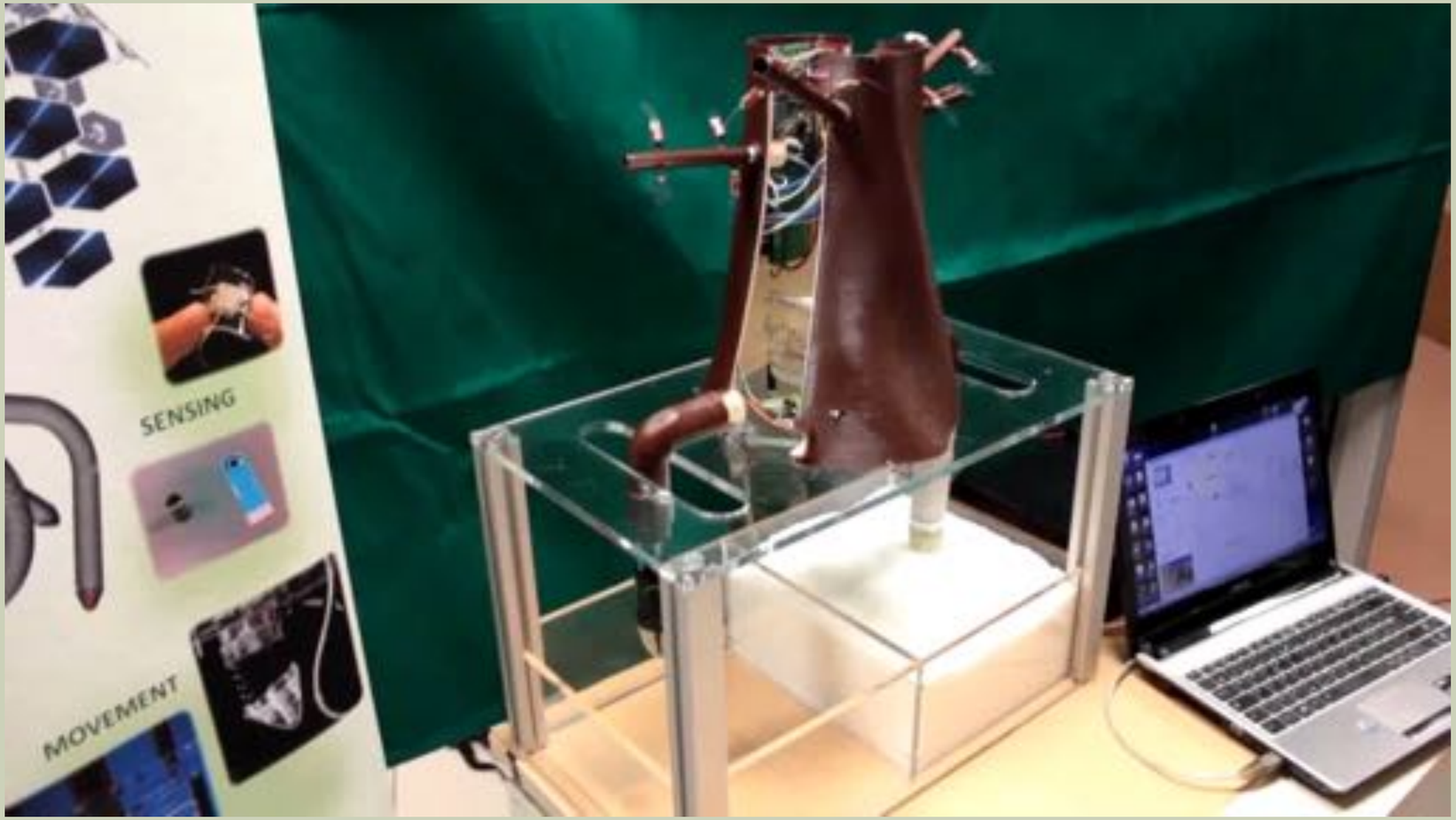
In VIVO experiments

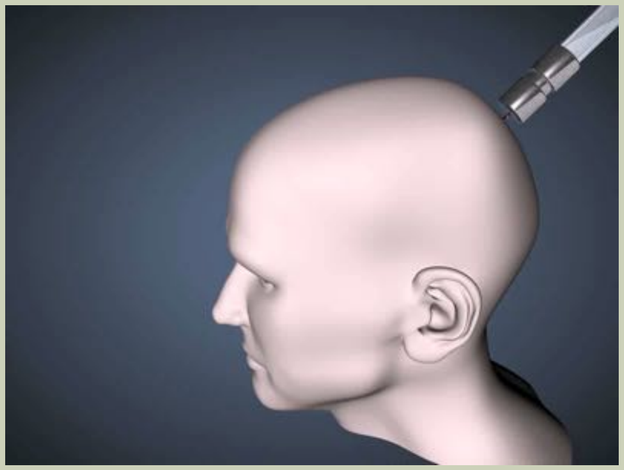


Visually evoked potentials



PLANTOIDS





ANIMALOIDI

HOW FAR CAN WE GO ?

1 robot companion in every family

4 sensed humanoid

Fully plastic

Below 1 KW, self powered

Cloud intelligence

Wireless fast com protocol (>6G)

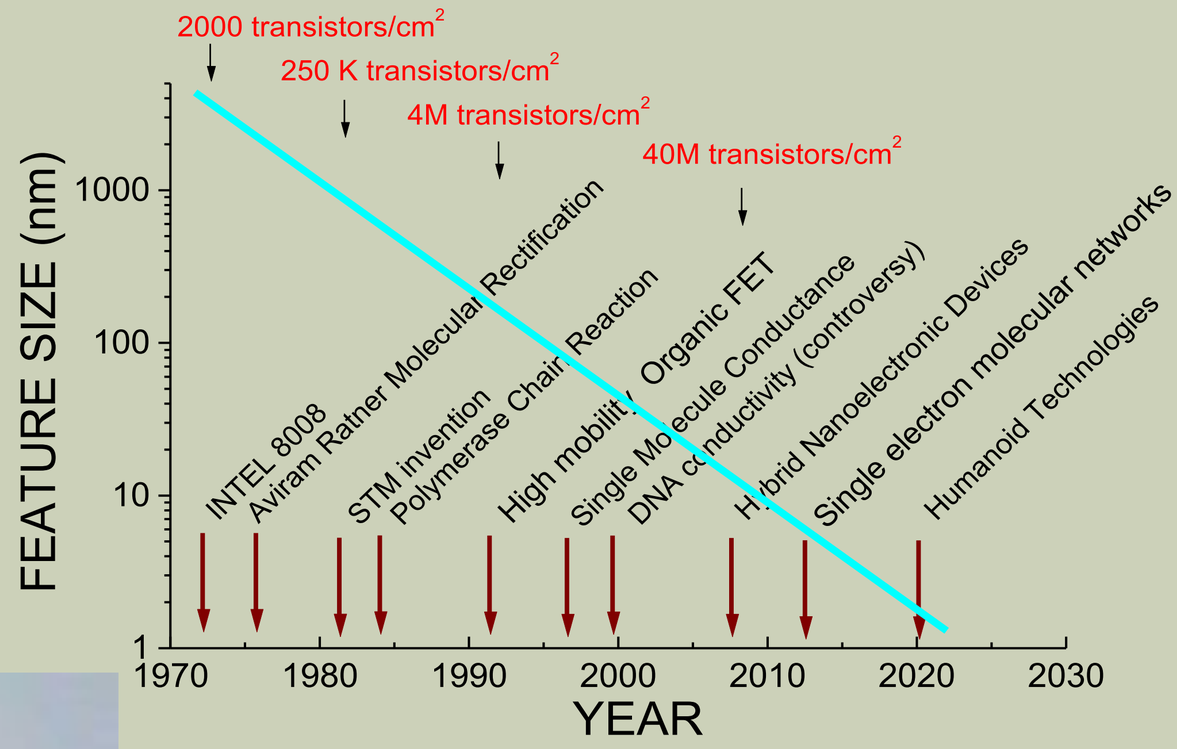
Cost < 10000 euro

City car business model

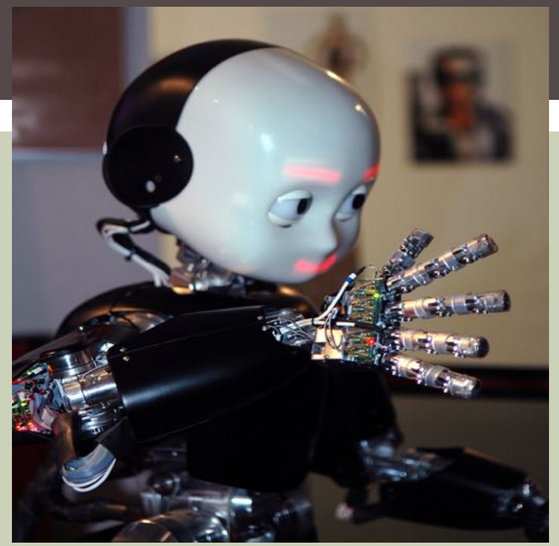
NANOWORLD: HOW IT STARTED

1950

2000

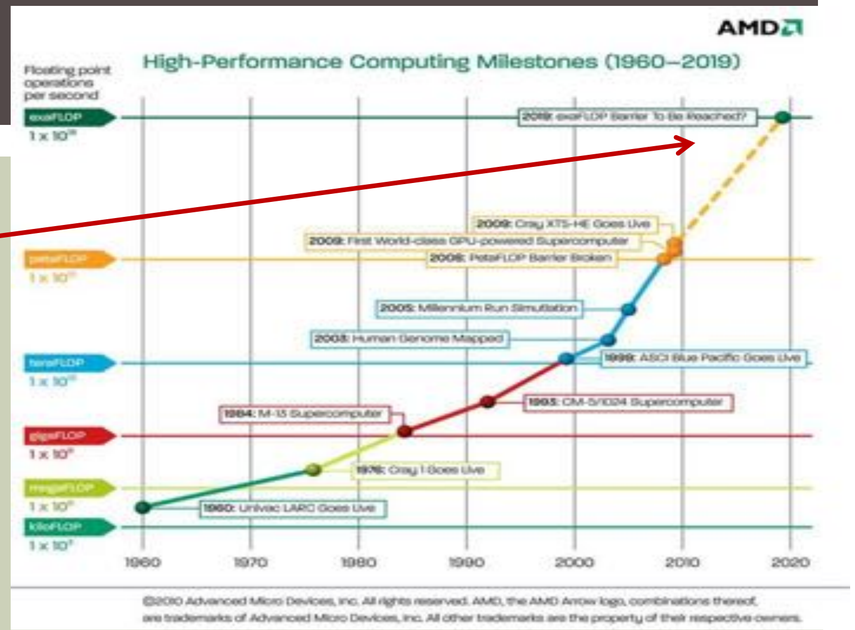


COMPUTATIONAL POWER

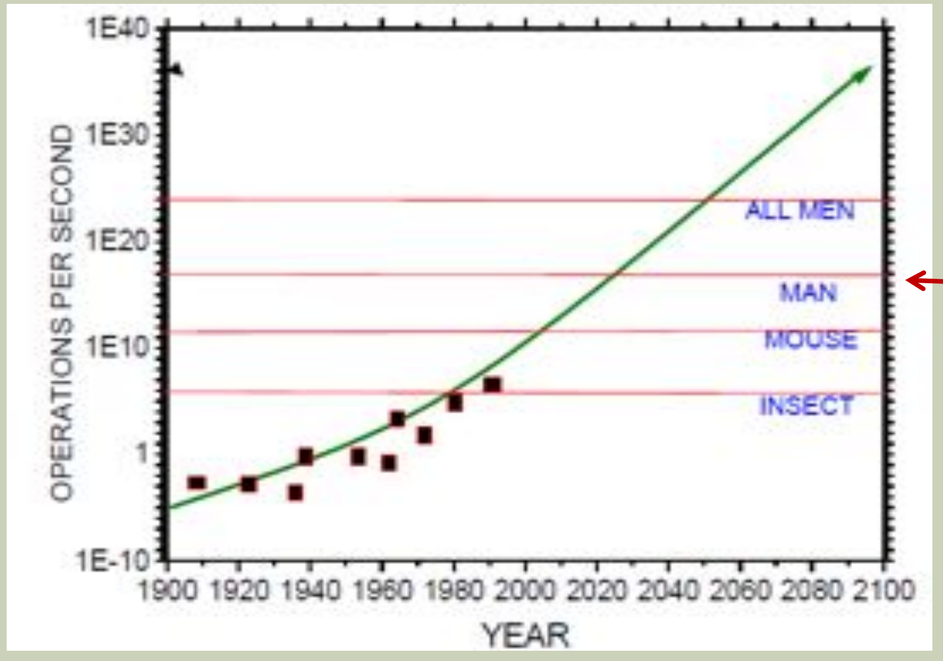


1300 W
10^8 op/sec

35 MW
10^{16} flop/sec



200 W
10^{16} op/sec



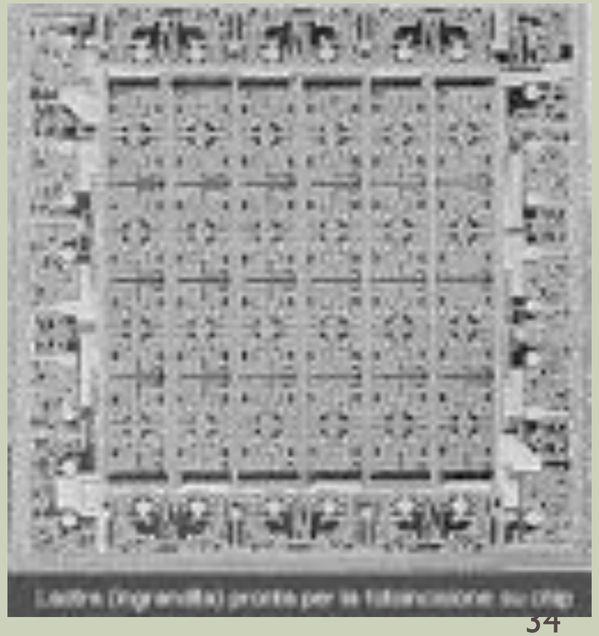
2000 KCal
10^{16} op/sec

R.Kurzweil 2011

NATURAL BRAIN VS ARTIFICIAL BRAIN

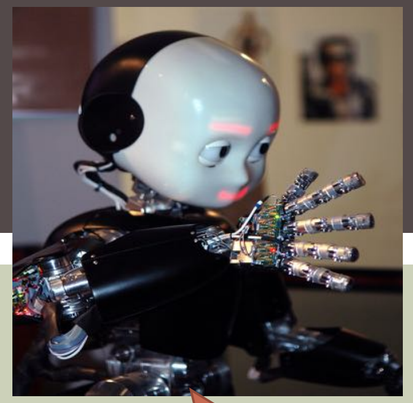
- 10^9 TRANSISTORS
- Bidimensionale
- Silicio
- 10 interconnessi primi vicini nel piano
- 200 W
- 10^8 operazioni/secondo

- 10^14 NEURONI
- Tridimensionale
- 75% H2O
- 10000 interconnessi
- 40 W
- 10^18 operazioni/secondo



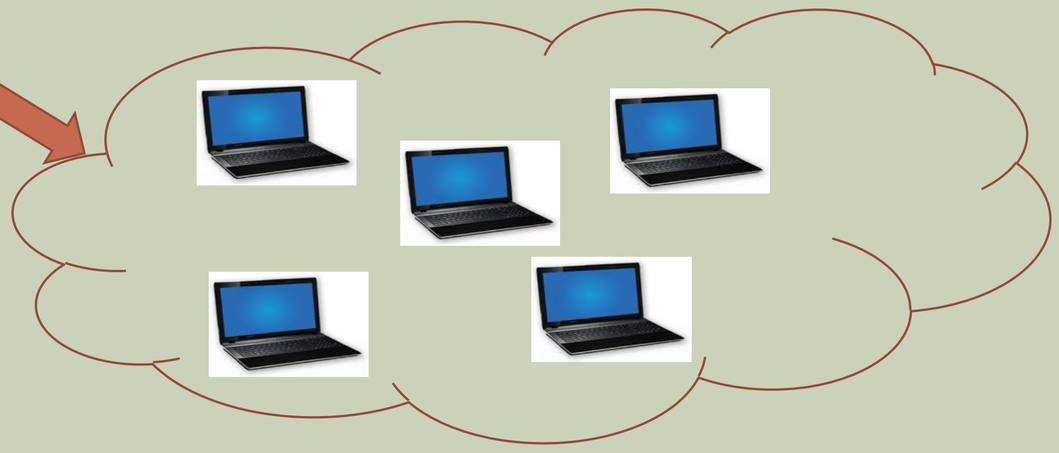
GLOBAL REPOSITORY OF THE INTELLIGENCE WITH FAST WIRELESS CONNECTIONS

Robot 1kW



Wireless >300 Mbps

5G



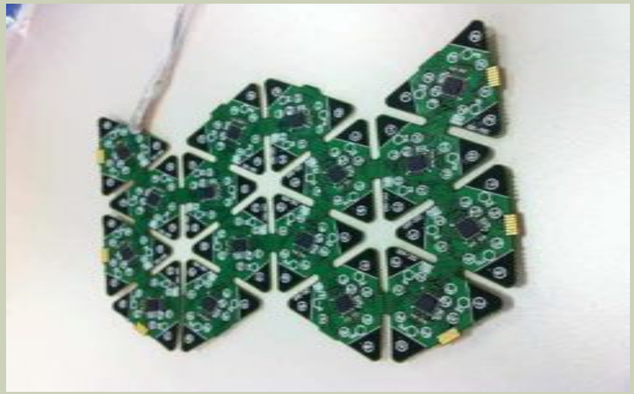
Cloud 1 Gbps,
300 ms burst

5G players are planning robots as part of the Internet of things infrastructure
Targeted for year 2020, 1.4b€ EU investment (5G-PPP)

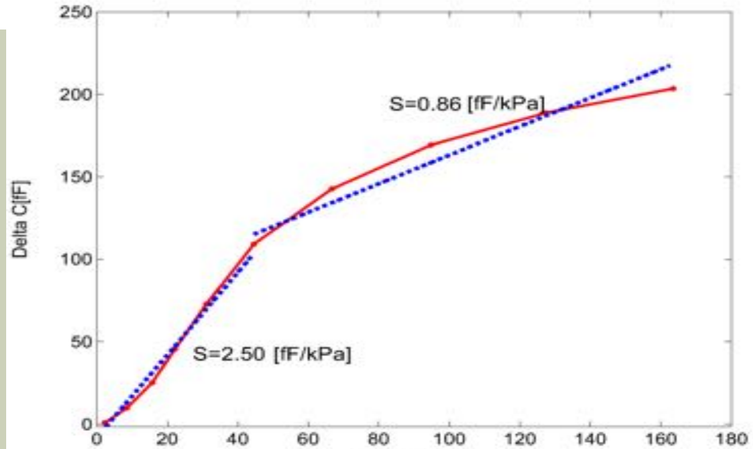
UMANI e UMANOIDI

Assistenza agli anziani Monitoraggio Disaster recovery Divertimento Educazione

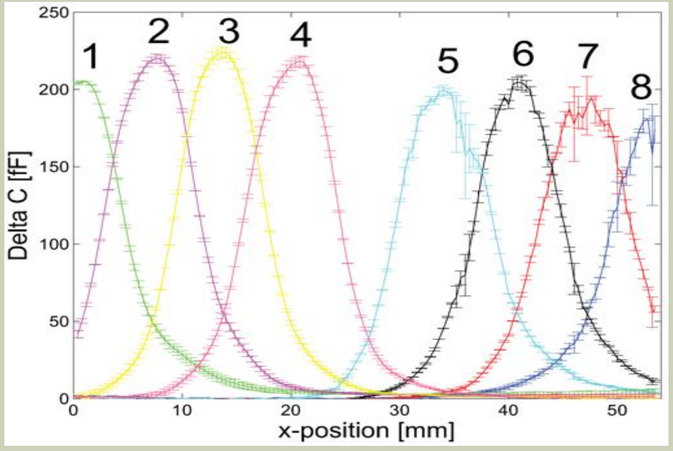
ROBOTIC SKIN (TOUCH)



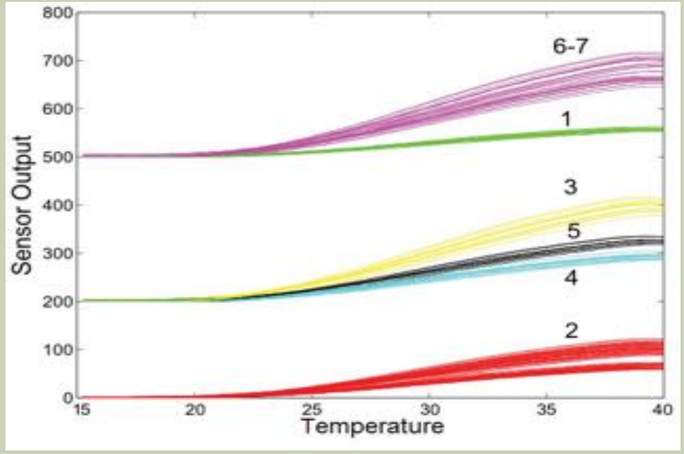
Multilayered skin: PCB/Mylar/Lycra

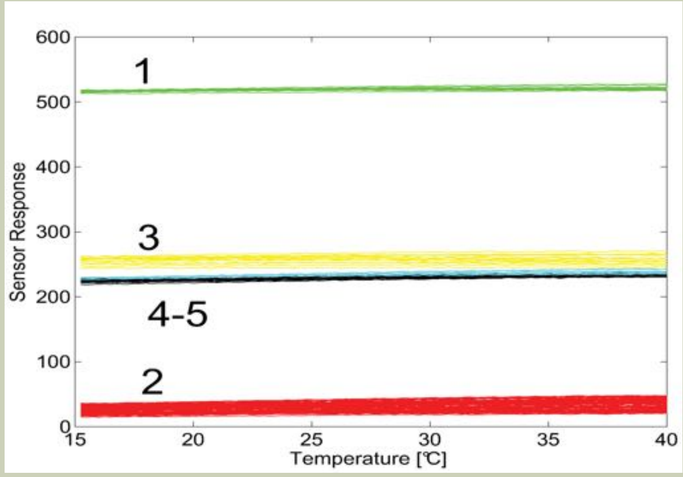


sensor sensitivity



spatial resolution analysis



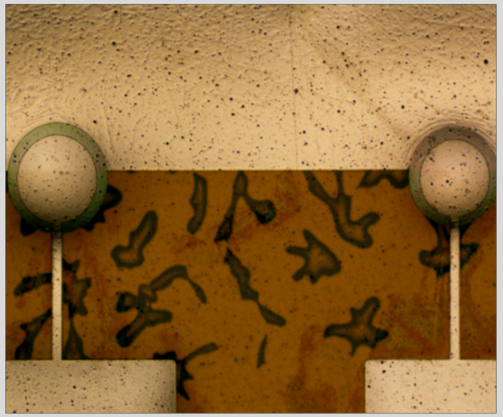


temperature drift compensation

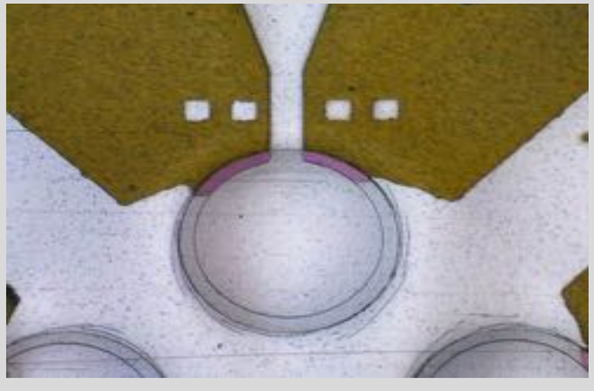
http://pasa.cognitivehumanoids.eu/pasapdf/1269_Maiolino_etal2013.pdf

FUTURE: TACTILE TECHNOLOGIES

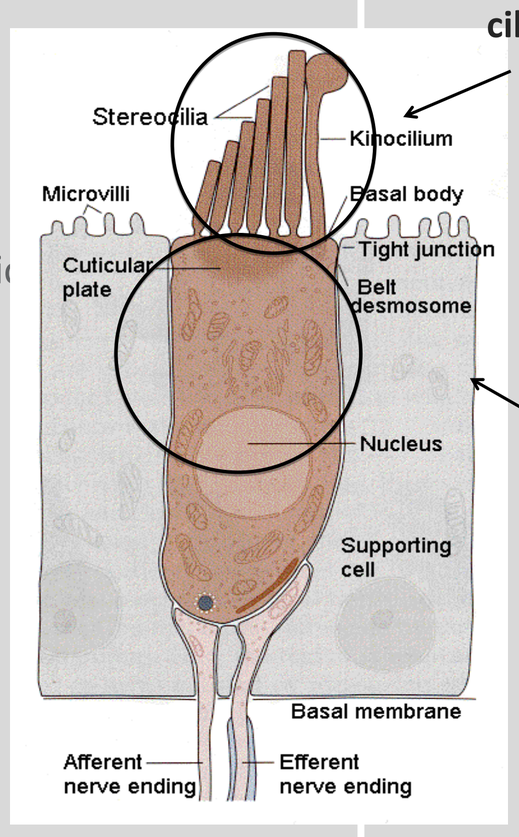
Soft MEMS for Tactile Sensors



Biomimetic multifunctional touch sensor for stati
and normal/shear forces



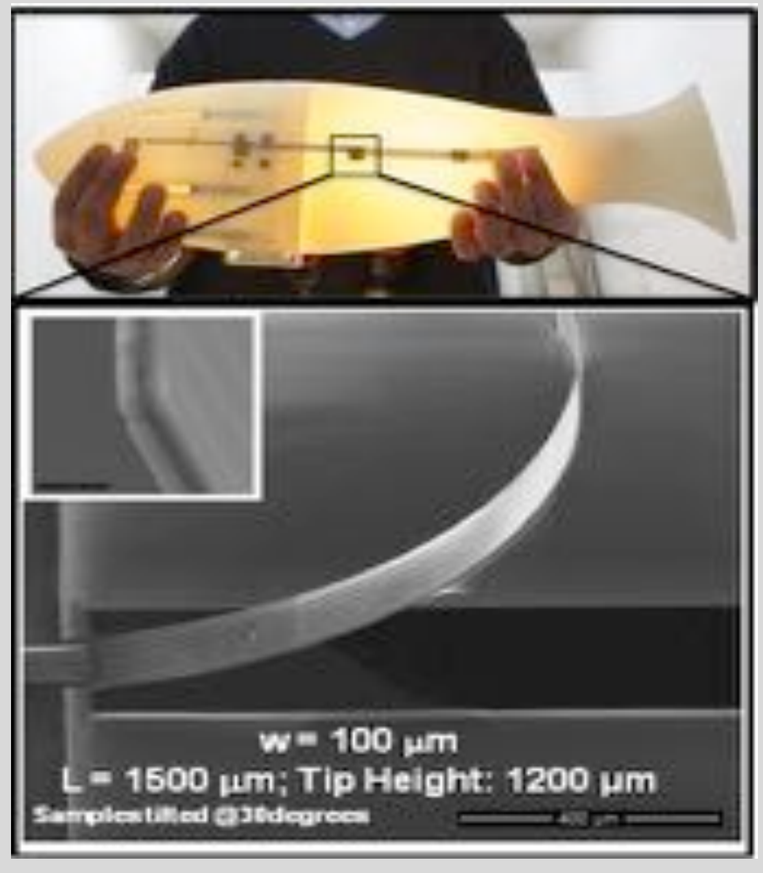
RSC Adv., vol. 5, no. 18, pp. 14047, 2015.
APL, 106, Issue 16, 2015



Hair Cell

HAIR CELLS

IEEE Robot. Autom. Mag., 21, no. 3, pp. 51–62, 2014.

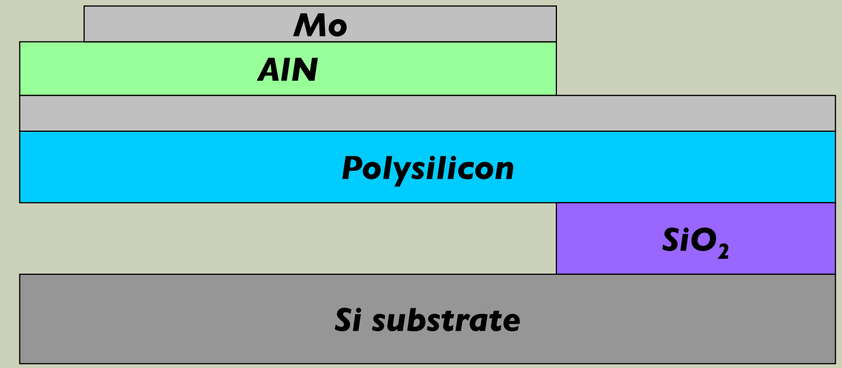


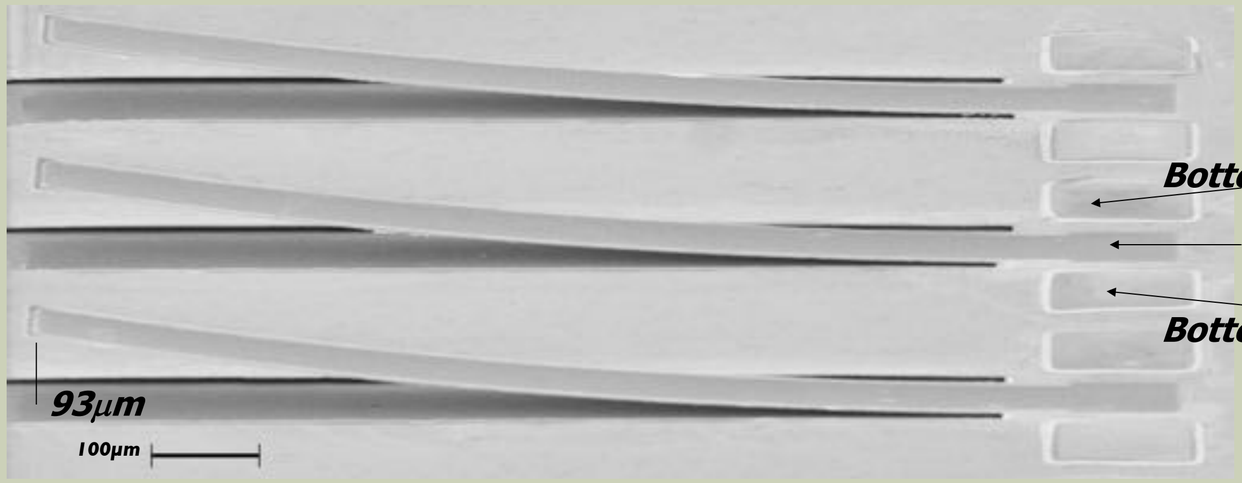
Team M.DeVittorio – IIT-Le

ALN-BASED CANTILEVERS: FABRICATION

Layered AlN structure:

- Molybdenum (bottom electrode) 120 nm
- AlN (piezoelectric layer) 1 μm
- Molybdenum (top electrode) 120 nm
- PolySilicon (elastic layer) 1.4 μm





- Layered AlN structure deposited by DC sputtering on Si substrate
- Cantilever micro-fabrication by lithography and wet/dry etching
- Beams width of 20 μm
- Beams length from 100 μm to 1 mm

REHABILITATION AND PROSTHESES

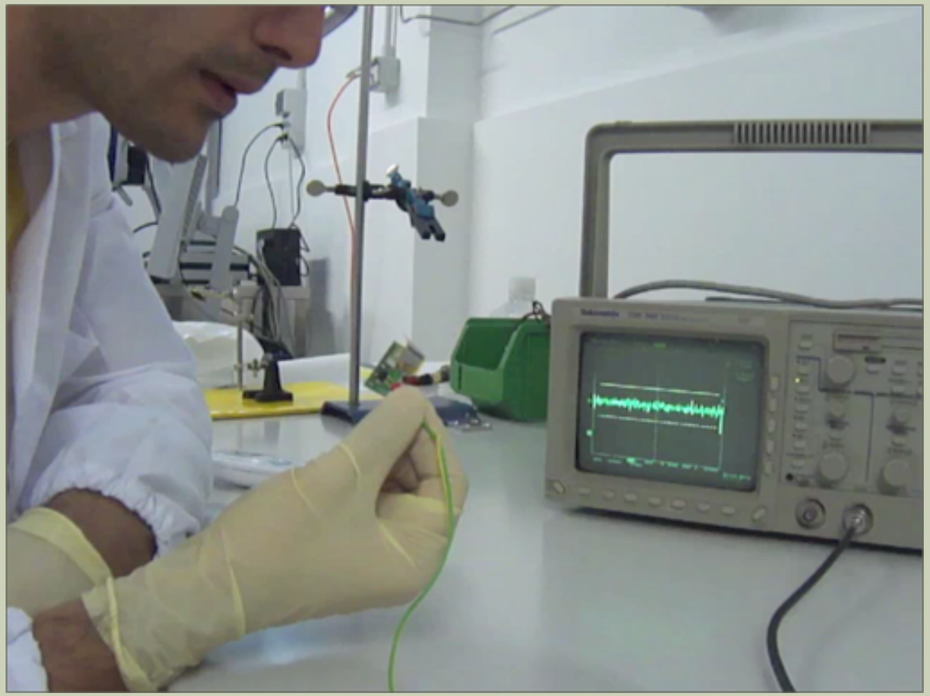
Compliant Attitude Control and Stepping Strategy for Balance Recovery with COMAN

N. Perrin, N. Tsagarakis, D. G. Caldwell

Department of Advanced Robotics,
Istituto Italiano di Tecnologia

SOFT GIANT PIEZOELECTRICS AND TRIBOELECTRIC NANOGENERATORS FOR ENERGY HARVESTING AND SENSING

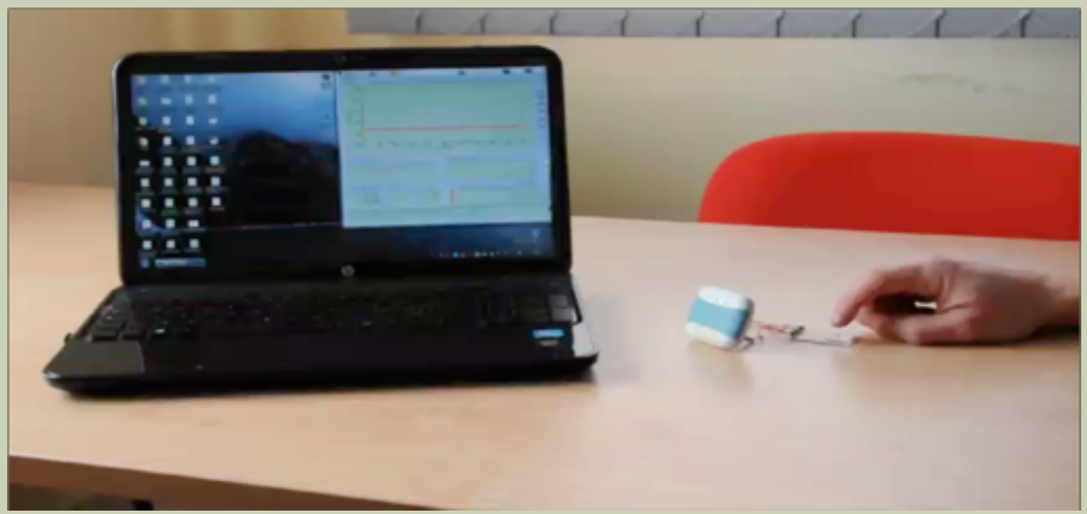
Energy harvesting from fluids



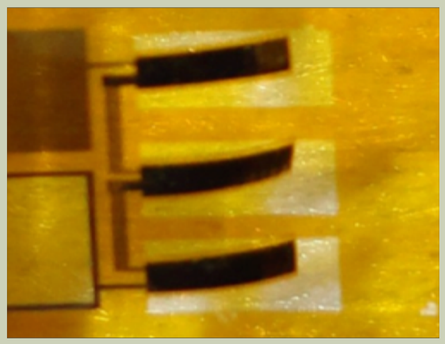
- ultra low cut-in wind speed: 0.1 m/s (breath)
- ultra low frequency and out-of-resonance operation (<10 Hz)
- High power (>1mW/cm^2)

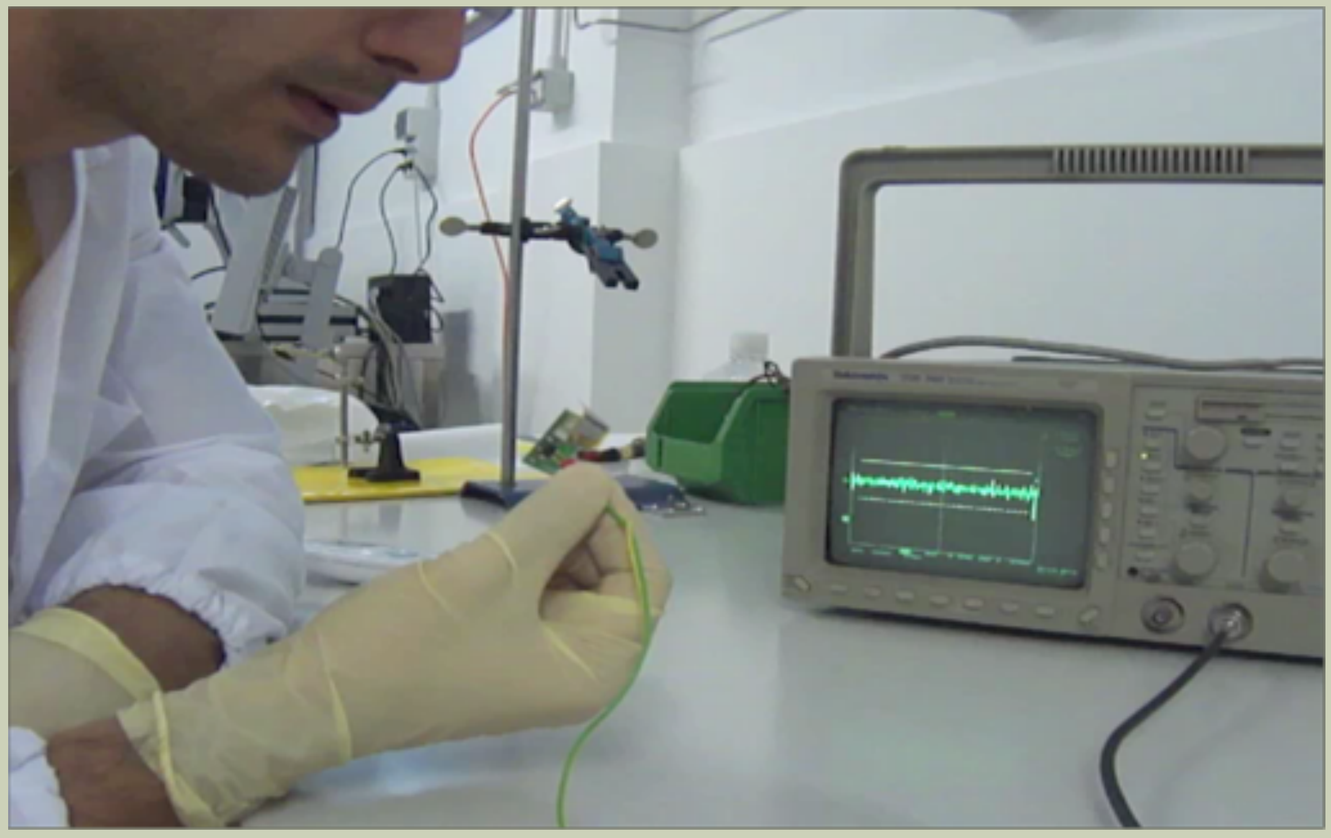
Wearable/implantable autonomous sensors

- sensing and energy from motion blood pressure and heartbeat for monitoring vital parameters
- powering implanted systems (eg pacemakers) and wireless comm.

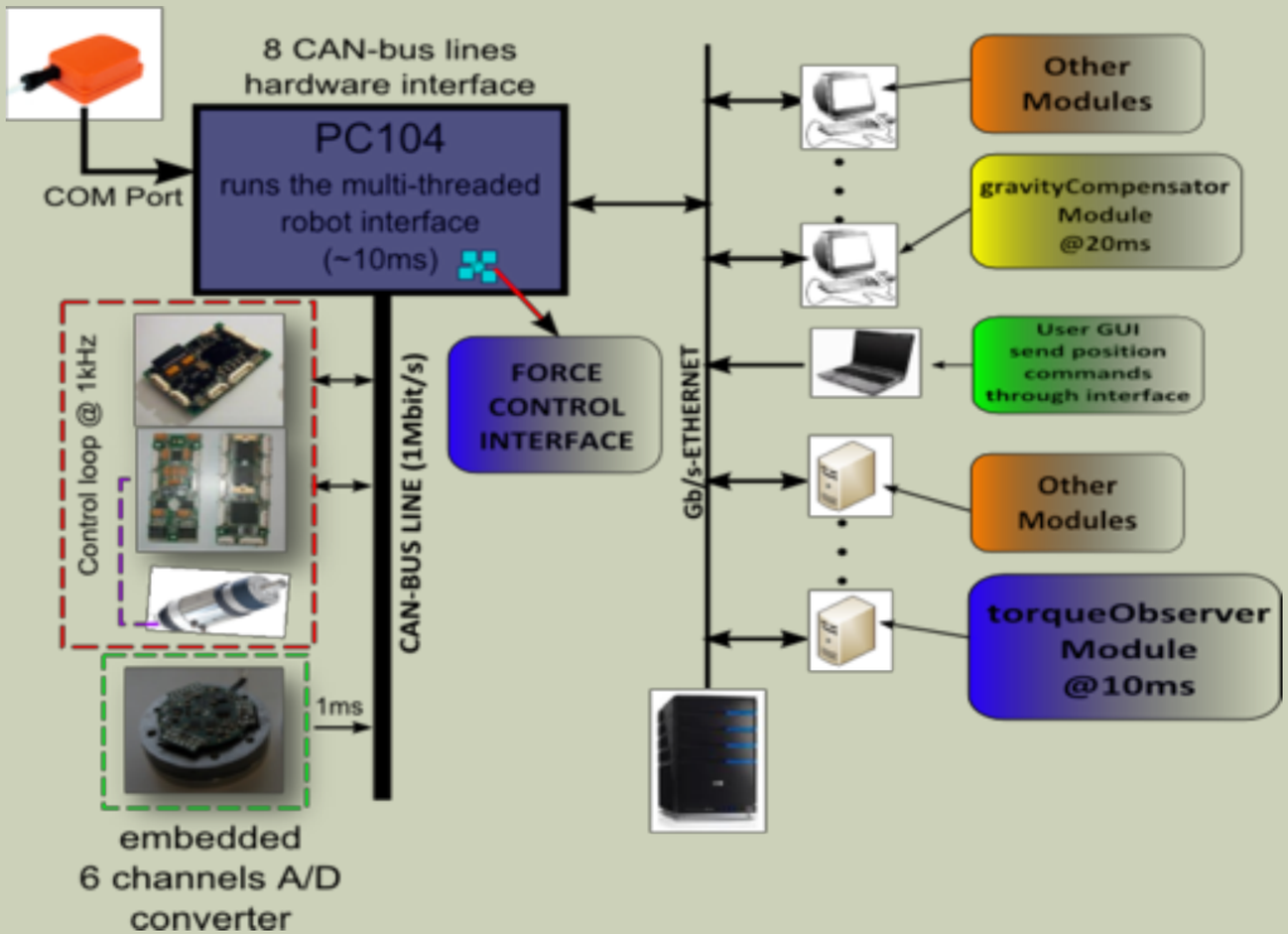


Molibdenum/AlN heterostructures coverded with Parilene

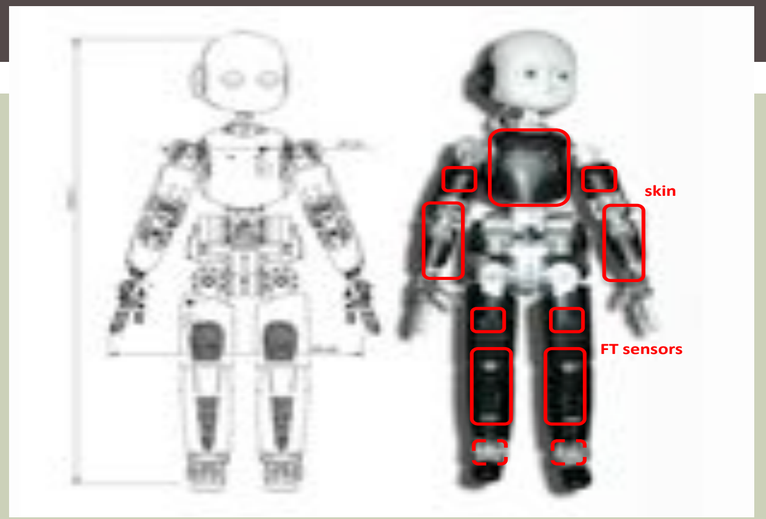




SENSORY FUSION & CONTROL



Touch+motion > 2100 sensors

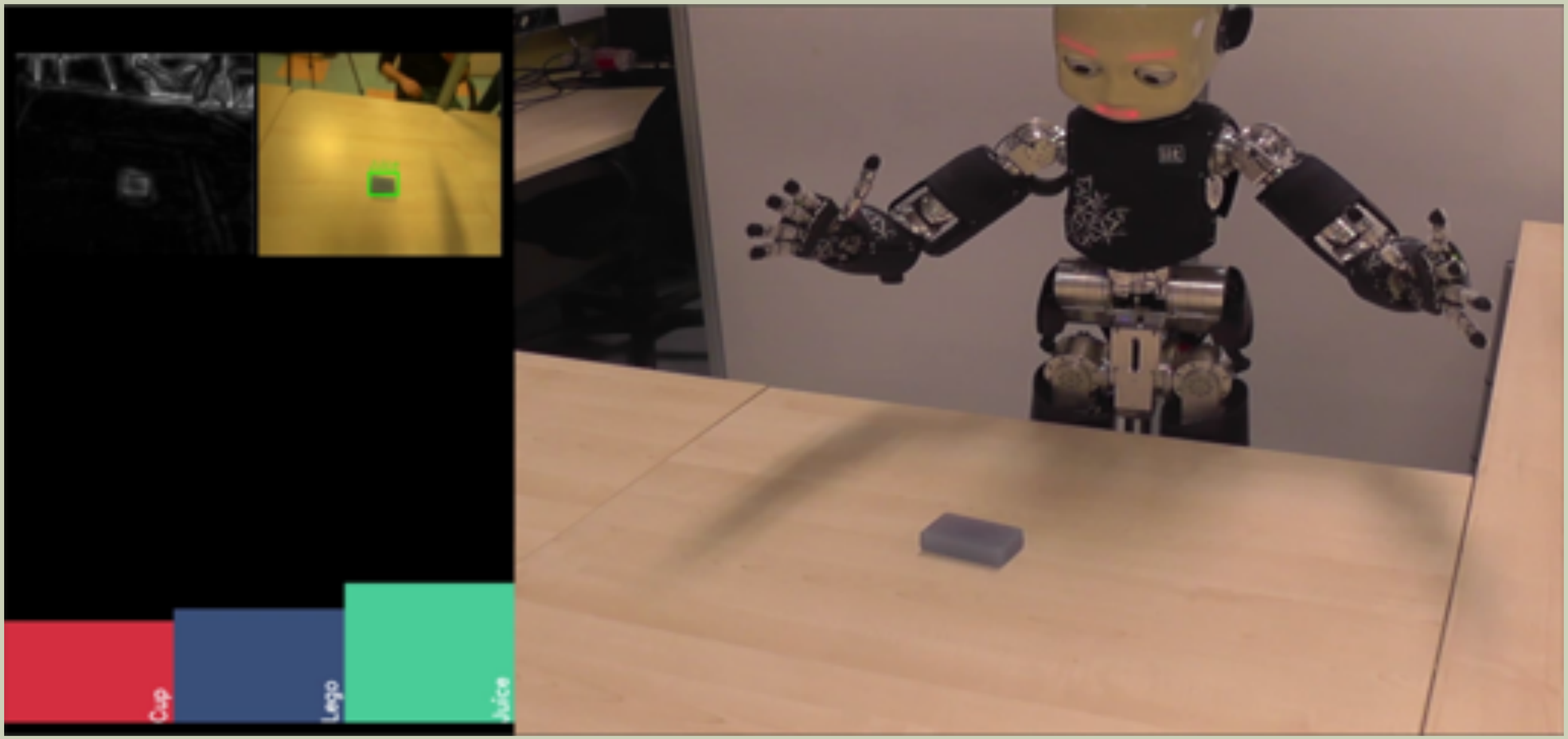


take measurements from inertial (e.g. gravity)
position, velocity, acceleration,
forces and torques

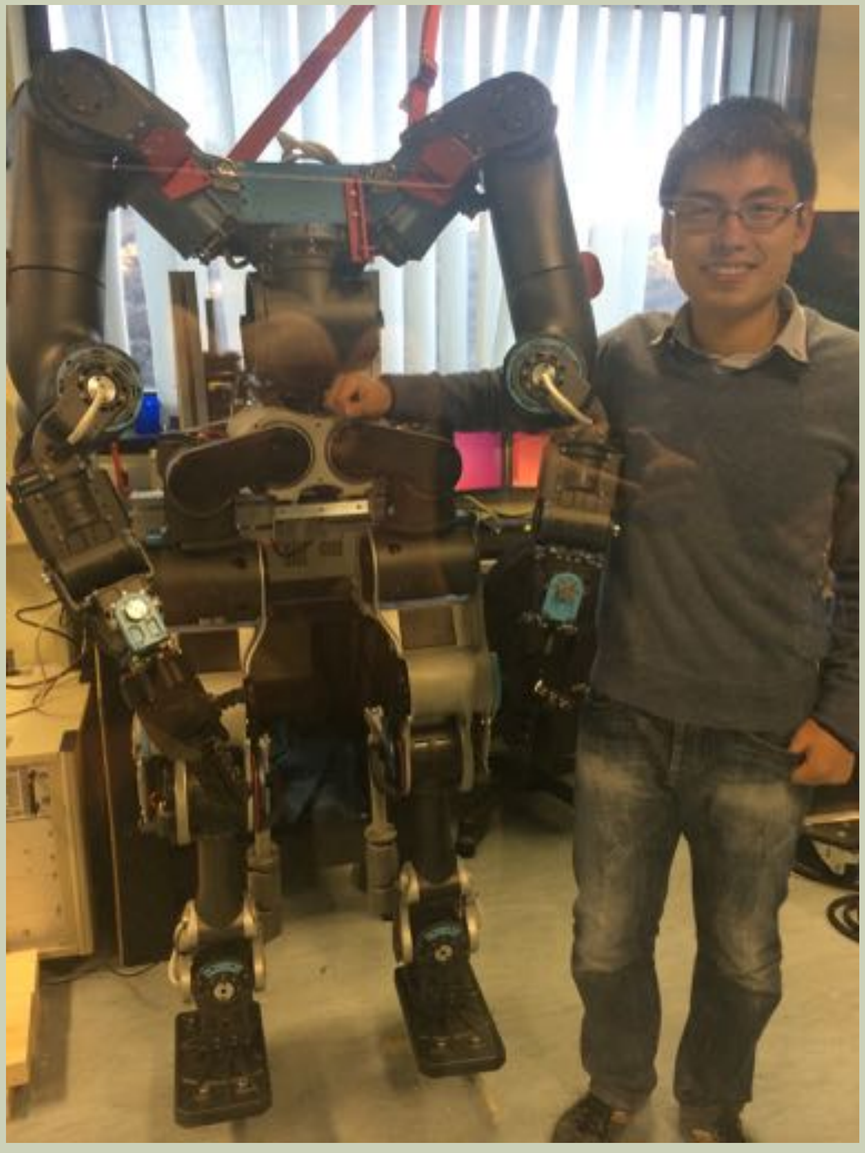
compute the external forces by combining their location (from skin) with intensity (from force-torque sensors)
AND
removing the internal dynamics
(inertial, Coriolis and gravitational effects)

compute movements depending on the external forces (e.g. keep them to zero or any other preset value)

LEARNING



WALKMAN:
190 CM,120 KG…VERY POWERFUL



WHAT IS REALLY DIFFICULT TODAY?

…for sure not the camel passing through the needle head !