POLITECNICO di TORINO

IIT - Italian Institute of Technology @ POLITO

Center for Human Space Robotics

MEMS for biological applications and energy

Fabrizio Pirri

Politecnico di Torino

Center for Space Human Robotics -Italian Institute of Technology

International Symposium on Integrated Microsystems (ISIM)

10 February 2011, Tsukuba JAPAN

… Piedmont in the heart of European development

www.centroestero.org

www.investintorinopiemonte.org

Torino and Piemonte: a diversified dynamic economy

- 4.3 million inhabitants = 7.4 % of the national total
- *€ 109 billion GDP (8.4% of the national* total)
- *€ 34.7 billion exports of goods and services*
- Torino first Italian city in terms of FDI inflows
- 1st Italian region in terms of capacity for collaboration between universities and industries
- Torino second centre in Italy for venture capital operations

over 700 foreign companies have already chosen to locate in Piemonte

www.centroestero.org

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Nanotechnology

- Excellence in micro and nanotechnology
  - Materials and chemicals
  - MEMS/NEMS
  - agriculture and food engineering
  - Bio-medical applications
  - energy and environment

- Links with major education and research centres in Italy, France and Switzerland

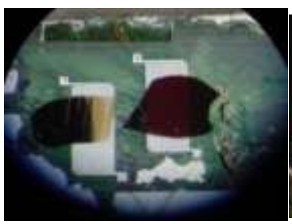
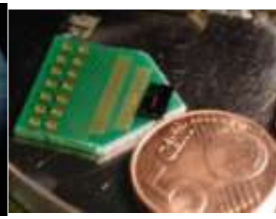
The Politecnico of Torino's Master in Nanotechnology for ICT sector, in collaboration with the Ecole Politechnique of Grenoble and Lausanne

Xlab Materials & Microsystems Laboratory

iNRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Turin and Piedmont for Nanotechnology

- Piedmont has a very diversified economy that fosters new ideas, inter-sectorial alliances, technological change. Economic sectors range from textile, automotive and food and wine to information and communication technology and life science.


- Turin and Piedmont are located in the hub of an internationally recognised network of academic, public and private subjects in Italy, France and Switzerland, active in the field of micro and nanotechnology.

- Qualified scientific professionals
- Highest concentration of students enrolled in scientific courses in Italy, with its three public universities
- Piedmont offers an integrated system of science and technology parks, aimed at supporting R&D activities and accomplishing technological transfer. The parks offer an extensive network of potential partners and human skills, as well as business related services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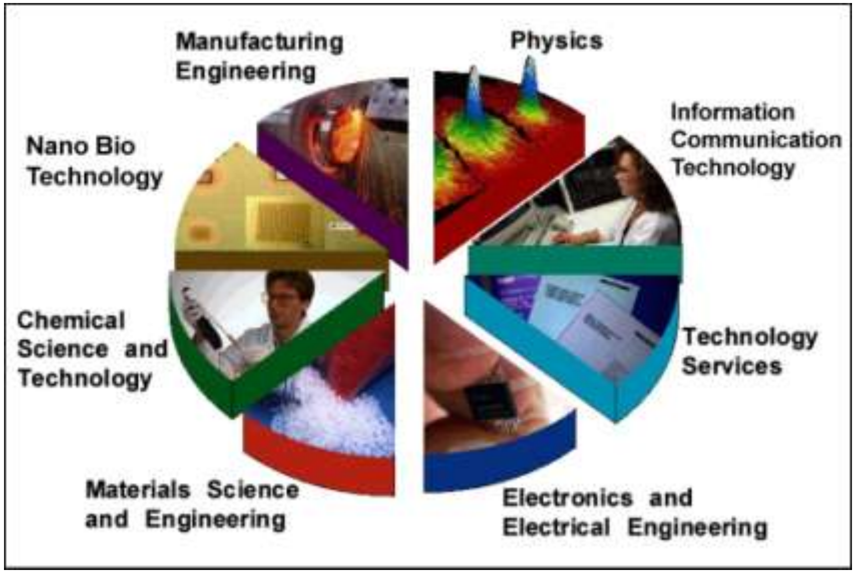
Areas of specialisation

- **Biomedical**: areas of interest are lab-on-chip, sensors for diagnostic, drug delivery systems, biocompatible materials;
- **Nanomaterials**: the local excellence is related to production and applications of nanostructured materials;
- **Agriculture and Food engineering**: new nanomaterials, sensors and surface treatments for Quality, Safety and Traceability;
- **Energy and Environment**: innovative and alternative sources (hydrogen, solar cells, biomasses, …), environment monitoring and renewing of industrial processes;
- **Textile**: innovative technologies in materials, surface and chemicals are the base of textile industry renaissance;

www.centroestero.org

- **Micro Electro Mechanical Systems (MEMS):** both public and private actors carry out research to improve the availability of micro-components and micro-devices;
- **Nano Systems**
- **IT & Electronics**: the areas of nanotechnology incorporate IT & Electronics.



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Industrial Expertise

Sorin Biomedica, is focussed on research in high-technology bioengineering;

Olivetti I-jet, dedicated to research, development and production of ink-jet technology;

Degussa Novara Technology, specialized in the production of solgel coated silica glasses;

Elettrorava with a long experience in the electromechanical field, producing vacuum pumps;

Nanovector, a start up active in the field of drug delivery systems;

Vishay Semiconductors Italia, leader in the semiconductor industry;

Stabilimenti tessili Ozella, working in the textile field, producing special application tissues;

Avago Tech, spin off of Agilent Technologies. This laboratory’s activities range from applied research in communication and life science;

MEMC, silicon wafer supplier and manufacturer

- **Alcatel Alenia Space** operating in the field of aerospace;

Fiat Group Research Centre, applying nanotechnologies to the automotive sector, spacing from mems to special materials research;

Industrial Expertise

Nanosynthex, is focussed on industrial realization of micro/nanosystems for bio;

TrusTech, dedicated to technological transfer and consulting in the micro and nanotech sector;

Ribes Tecnologie, specialized in the MEMS sensors;

MICROLA a spin off of Politecnico with experience in the solid state lasers for surface treatments;

Politronica, a start up active in the polymeric innovative solutions;

GRINP, working in the plasma solutions;

BIODIVERSITY, specialized in bio-medical diagnostic;

DIASORIN, focused on kit and devices for medical analysis;

INPECO, automation and systems for medical applications;

APAVADIS, a young nano-bio company;

IONVAC, a thin film technology company;

VARIAN, a company leader in vacuum technology;

techfab

microla OPTOELECTRONICS

RIBES tecnologie

VARIAN

TRUSTECH

Politecnico Campus

27 000 Undergraduate and Master students

1000 PhD students

3 300 Foreign students

A budget of more than 320 MEuro in 2009 only 40% from Ministry

Strong vocation to industrial projects and partnerships, technological transfer and spin off creation

Research activities

Areas
Industrial engineering
Information technologies
Civil/architectural engineering
Environmental engineering
Management engineering
Architecture
Industrial design

Research focus
ICT
Sustainable energy
Automotive
Nanotechnology
Aerospace and aeronautics
Environment
Management

NANOTECH RESEARCH LABS

The MATERIALS and MICROSYSTEMS LAB - CHILAB

Established in 1999 by Regione Piemonte and POLITO

Dedicated to Micro and Nano Technologies

AIMS

Basic research on materials and processes for MEMS and NEMS development

MEMS and NEMS design and realization

Micro and nano technologies for bio-applications

Technological transfer and education






MATERIALS & MICROSYSTEMS LABS

(CHILAB / LATEMAR)

LATEMAR

http://www.polito.it/micronanotech

http://www.latemar.polito.it/

Mission

- fundamental research on materials and processes for micro- and nano-technologies
- design and fabrication of MEMS and nanostructures
- technological transfer
- education

Staff

- 4 Professors
- 10 Permanent Researchers
- 22 Fellowships / Post Doc
- 10 PhD students
- 5 Technicians
- 3 Administrative

CHILAB

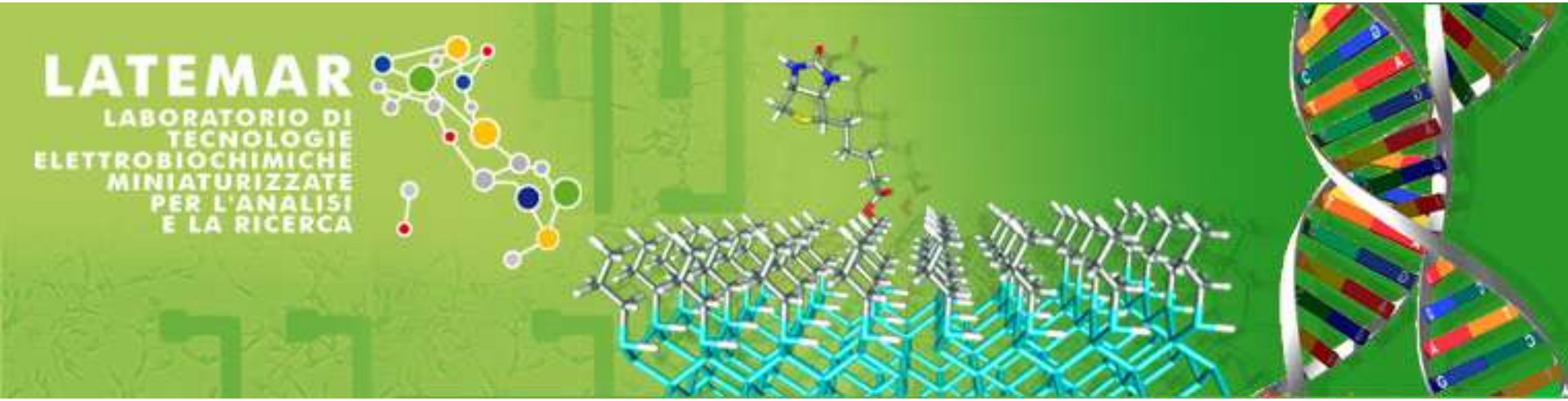
The research activities are focused on:

- materials and technologies for energy
- sensors
- materials for microelectronics
- carbon nanotubes and nanostructures materials
- plasma treatments of surfaces and thin films
- Laser technologies
- MEMS and NEMS
- materials for optical application and nanophotonics
- surface functionalizations
- …

The experimental facilities are mainly devoted to:

- new micro and nanostructured materials
- design and realization of micro andd nanodevices
- Surface treatments
- characterizations

NANO-BIO RESEARCH LABS: LATEMAR



Centre of Excellence funded by Italian Ministry for Research

Biotech + **Micro- & Nano-Technologies** =

INTEGRATED SYSTEMS

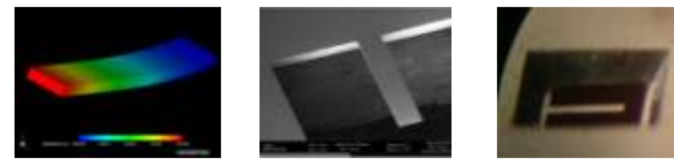
for

Biomedicine, Pharmacology, Agriculture and Food Science

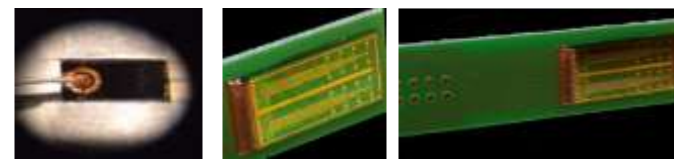
BIO-RELATED RESEARCHES

Silicon based Lab-on-chip - **Development of 3 different modules respectively for extraction and purification of DNA from whole blood, DNA amplification through PCR and hybridization/detection through a traditional fluorescence approach implementing the APEX protocol for SNPs detection**

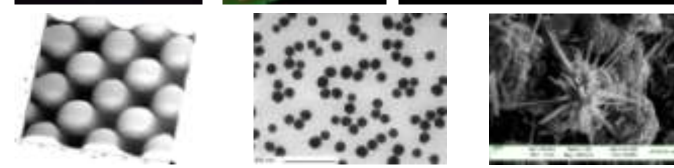
Polymeric Lab-on-chip - **Realization of polymeric (thermoplastics and elastomers) microfluidic modules devoted to genomic and proteomic applications, integration of microfluidic interconnections and fluidic actuation.**



ECL detection - **ElectroChemical Luminescence (ECL) is a disruptive alternative to the standard fluorescence detection. We are currently developing a complete detection scheme, starting from the synthesis of new ECL markers, through the fabrication of customized microelectrodes, up to the development of a readout dedicated optoelectronic system.**



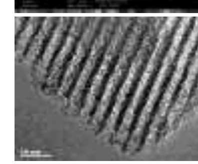
Micro & nano cantilevers - **The use of a cantilever system for genomics and proteomics may result in larger sensitivity, quantitative analyses and label-free detection, opening a wide range of applications in genomic and molecular diagnostics.**



Nanostructures/Nanoparticles for biosensing – **Exploration of novel detection schemes for oligonucleotides and small biomolecules by exploiting some of the key functional optical, electrical and mechanical properties achievable through the synthesis and the integration of nanostructured systems.**

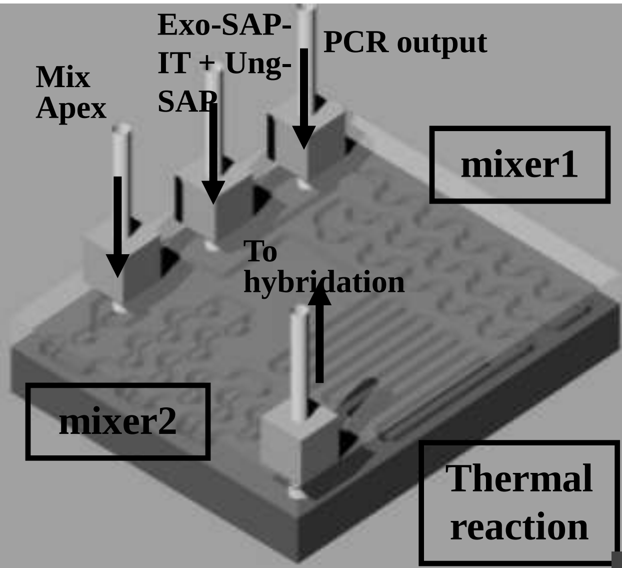
Nanostructured carbon bioactivity - **Production, characterization, modification and biological properties investigation of carbon based nanostructured materials (nanotubes and nanographite) for biosensing applications and in particular for the development of a DNA detection device.**

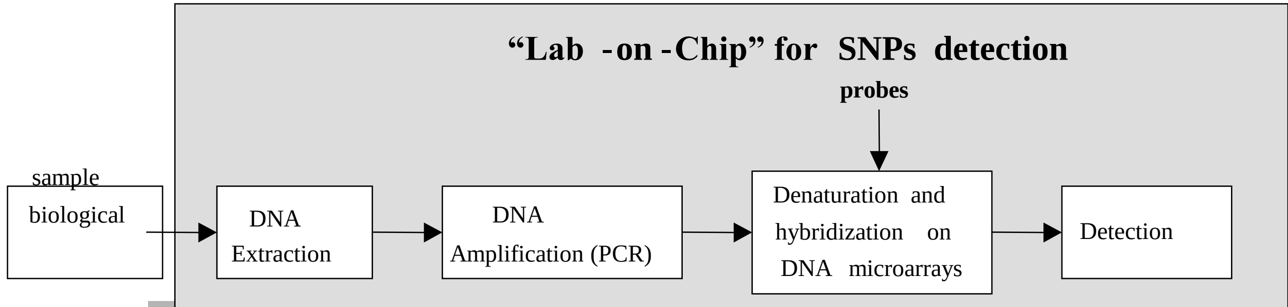
Nanostructures for DNA separation – **Nano-structured porous materials, prepared by a bottom-up approch are promising systems for high-resolution DNA separation to drastically reduce the length of separation and to achieve dimensions comparable with a microchip format.**

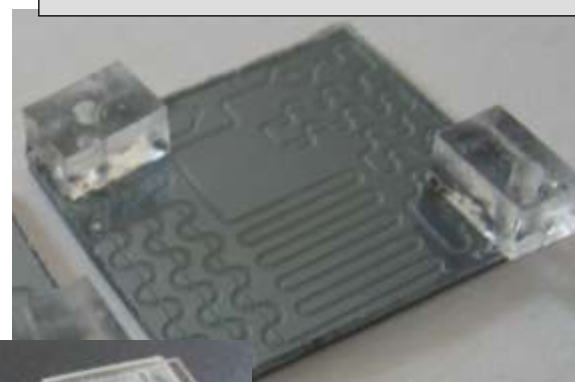


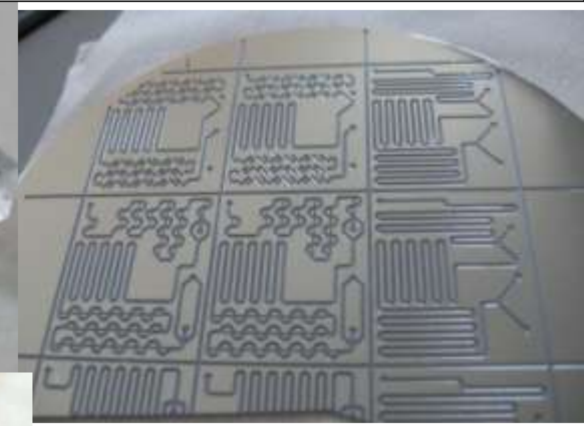
LAB-ON-A-CHIP FOR MOLECULAR ANALYSIS

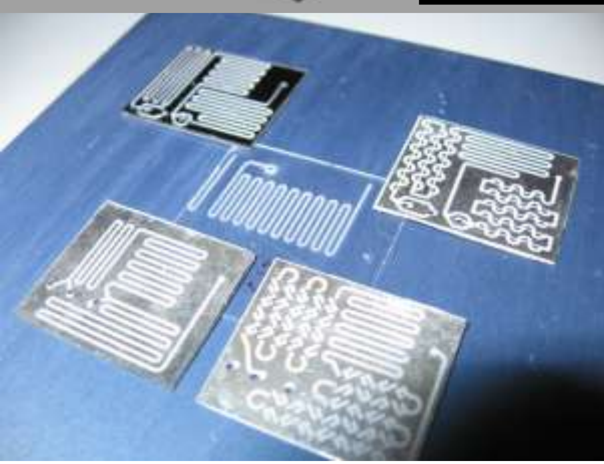
Si-based Lab-on-chip



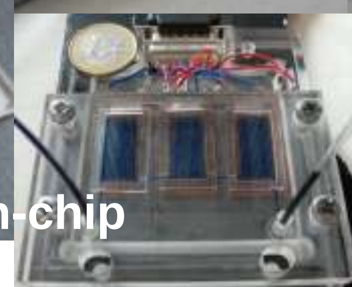


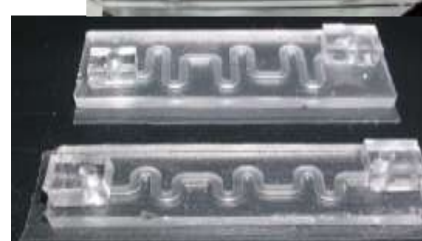






polymeric Lab-on-chip



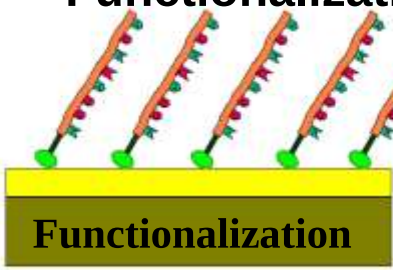


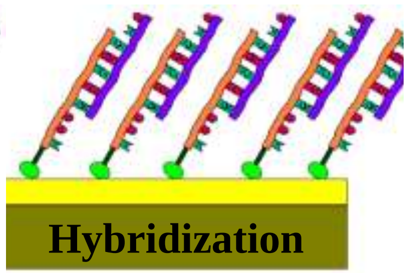
micropumps

SENSORS ARRAYS FOR MOLECULAR DETECTION

Design, Simulation and Realization of sensors; Set-up of different technological processes and realization of sensor arrays through Bulk and Surface Micromachining, Functionalization

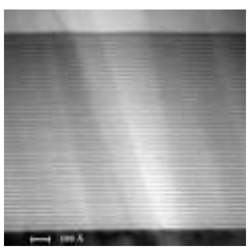
Functionalization

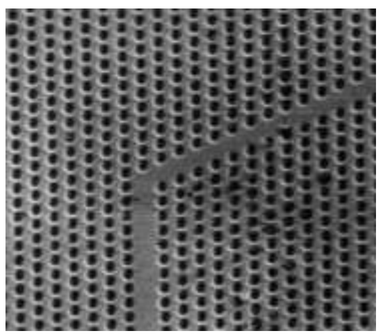




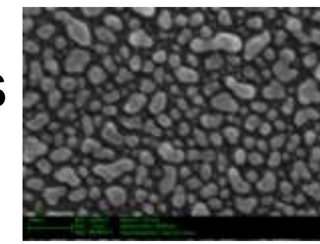
Arrays of cantilevers

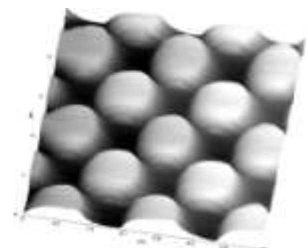
Photonic crystals



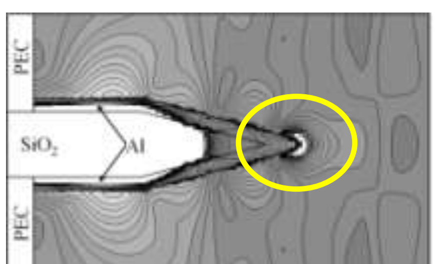


Nanostructures for SERS

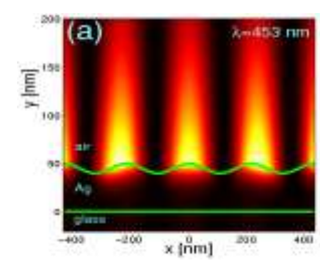




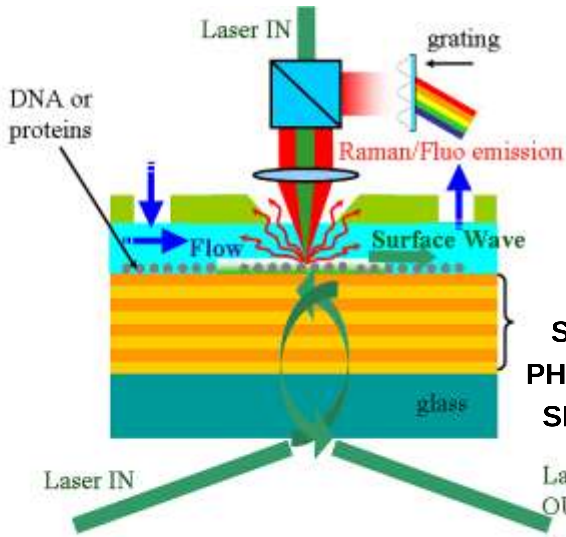
Near-field optical techniques for Raman spectroscopy

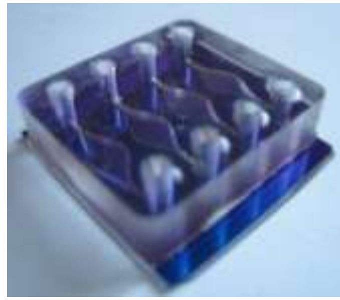


Surface Plasmon and Polaritons



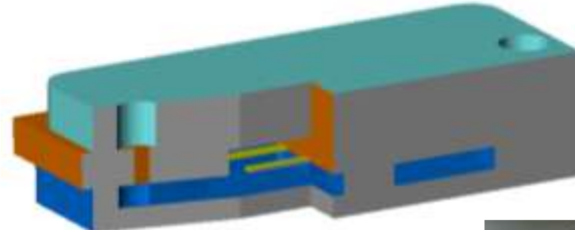
Customised Solutions



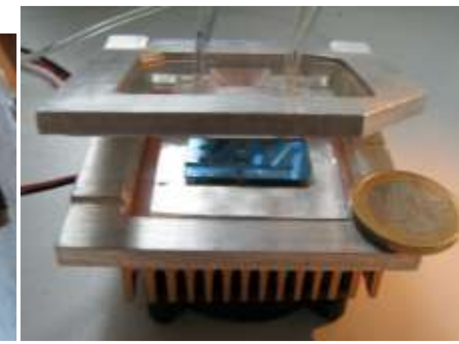


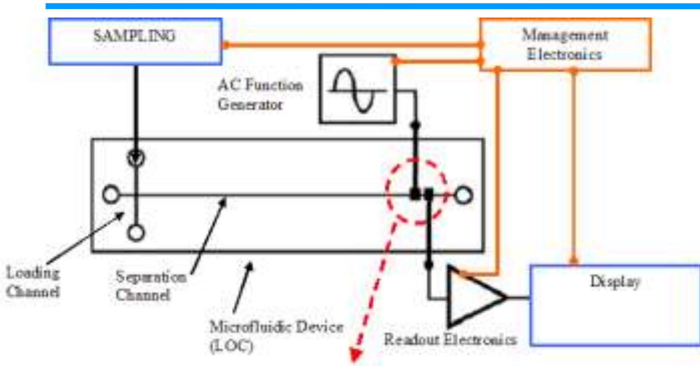
SURFACE WAVES IN 1D PHOTONIC CRYSTALS FOR SENSING APPLICATIONS

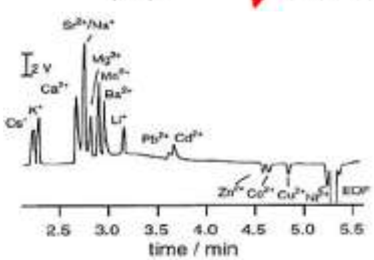
inpeco



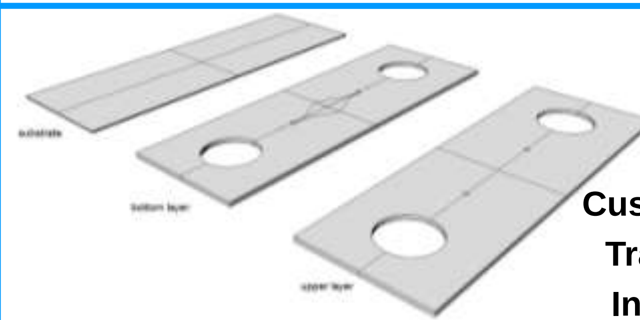
CANTILEVER ARRAY based LAB-ON-CHIPs



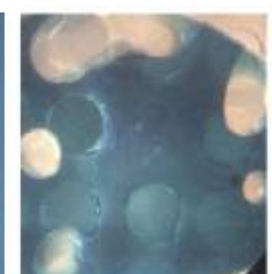




C⁴D LOC for WATER ANALYSIS



Customised Bubble-Traps, Valves and Interconnections



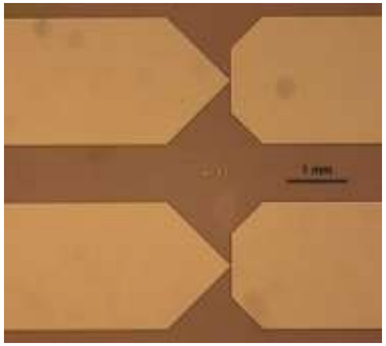
Protocol applications

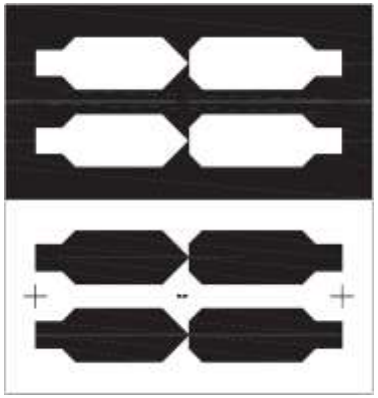
MICROFLUIDICS for FISH protocol

(Fluorescence In Situ Hybridization)

MICROFLUIDICS FOR

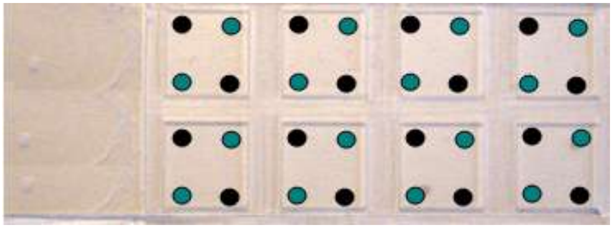
BLOOD CELLS COUNTING





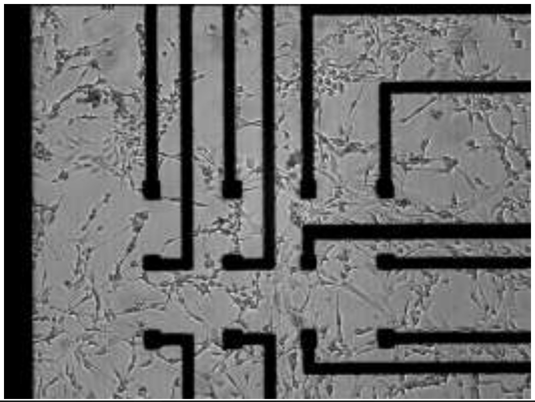
DNA MUTATION

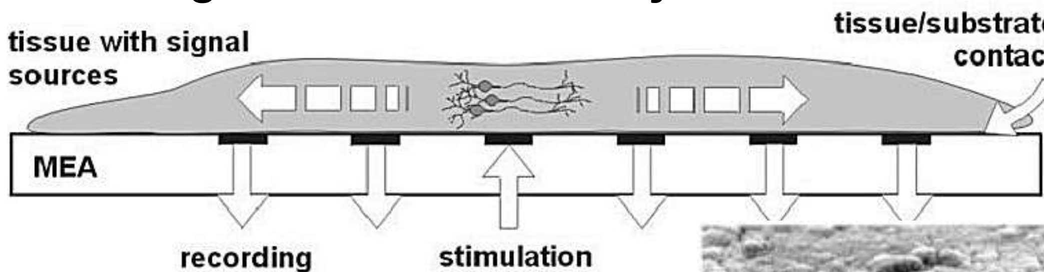
COLORIMETRIC DETECTION

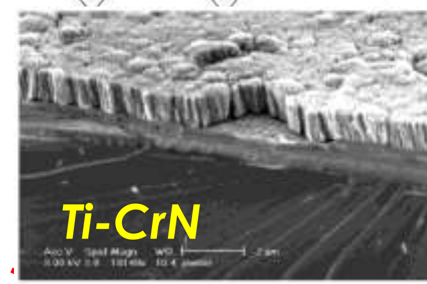


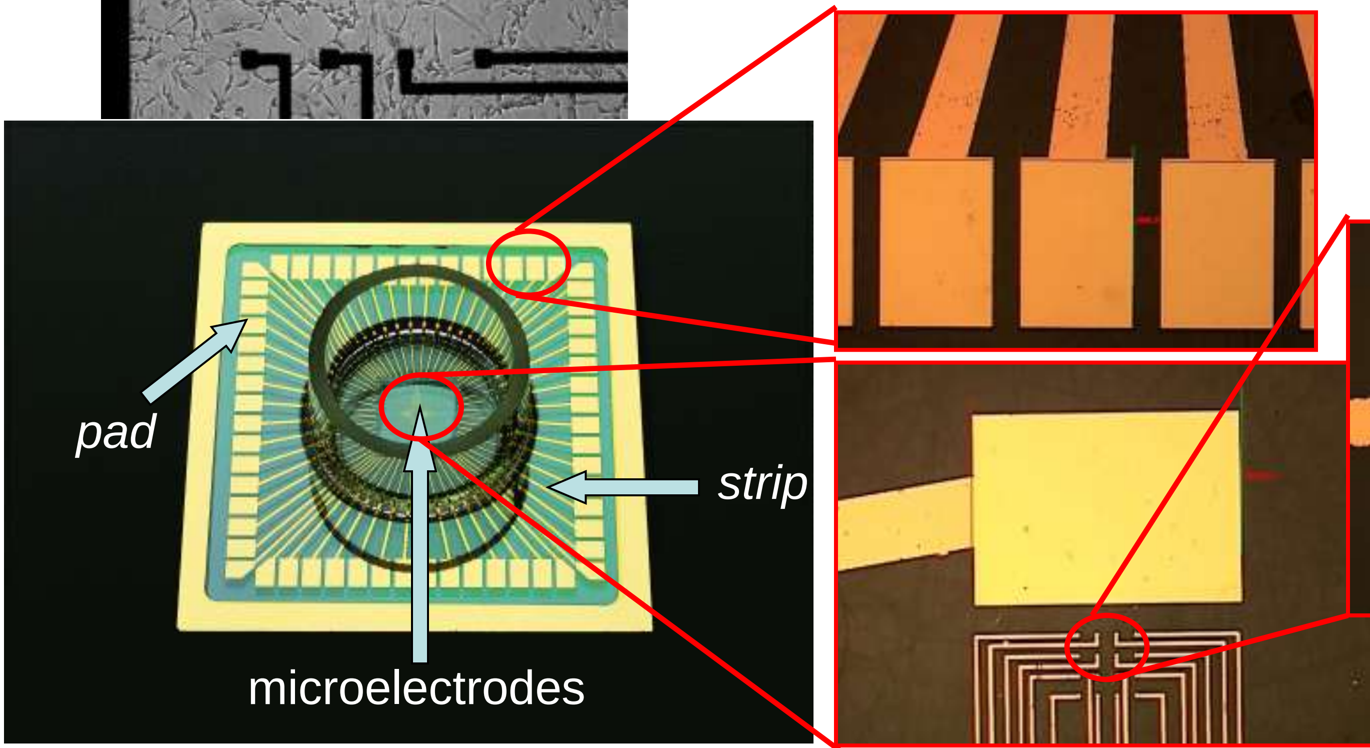
MULTIELECTRODE ARRAYS → MEA

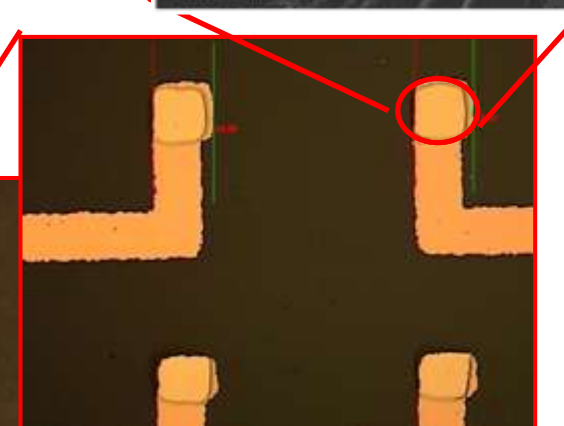
Matrix of microelectrodes → **Excitation and simultaneous multi-point monitoring of electrical activity of neuronal cells**





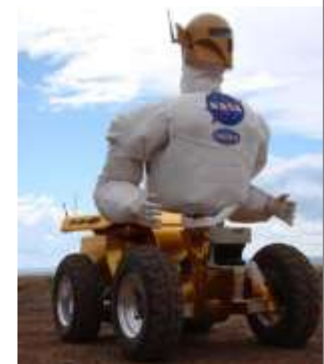


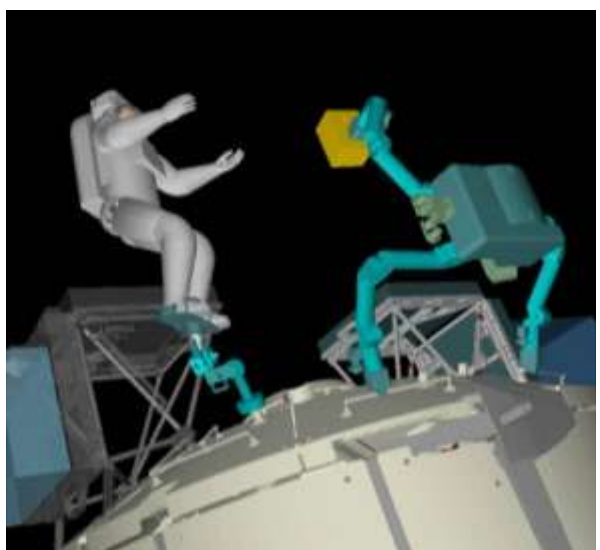




Italian Institute of Technology at POLITO (IIT@polito)

The mission of the site "Centre for Space Human Robotics of **IIT@polito**"
is focused on Robotics for space exploration.
Space applications require research in different technological areas





Research structure of IIT@polito

- The research activities will be focused on:
  - Robotic Platform "**Human Space Robotics**" for development of space systems and prototype of robots
  - Technological Platforms:

    "**Smart Materials**"

    "**Portable Energy**"

    for development of components and methods for human robotics

Nanotechnologies for Enegy: IIT@polito

New materials and processes for portable energy:

- **Innovative Systems for Electric Energy production**

1. Nanostructured thin films for new photovoltaic solar cells
2. DSC based on nanostructured TiO_2/CNT, ZnO/TiO_2 NWs and TiO_2/Ag-Au Nps
3. Miniaturized and Microbial Fuel Cells

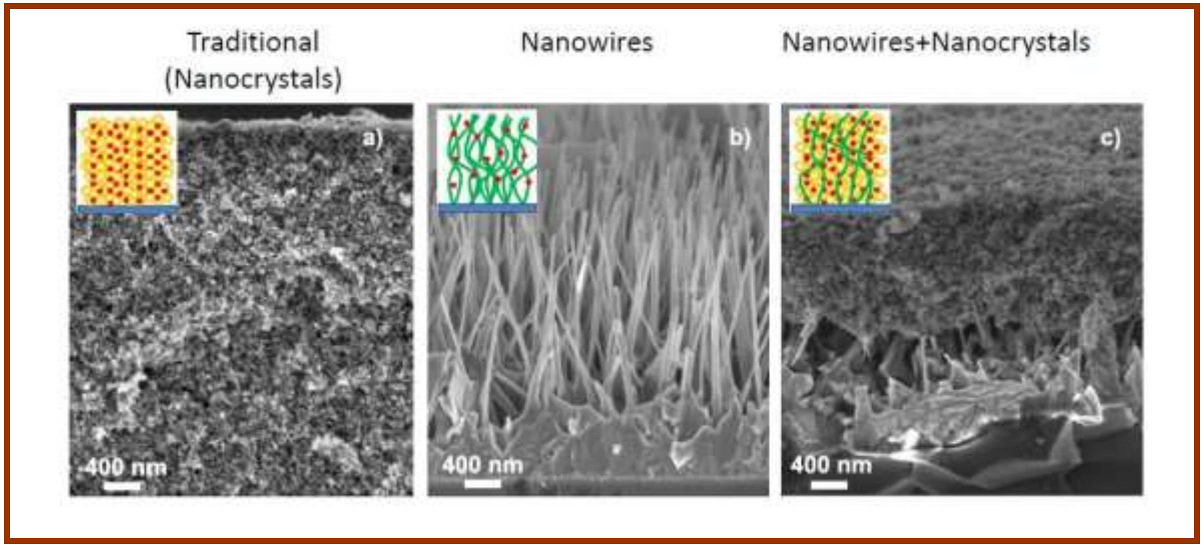
- **Innovative Systems for Energy storage**

1. Flexible Nanostructured Lithium-polymer thin cells and flexible nanostructured supercapacitors
2. Nanodesigned electrochemical reactors for H_2 production

"core-shell" systems

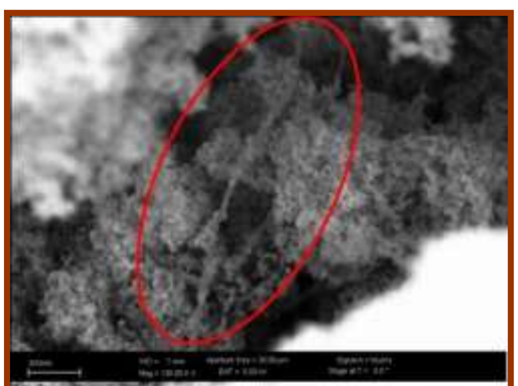
in ZnO NWs / TiO_2 (NPs and film) or CNTs / TiO_2 (NPs and film)

ZnO

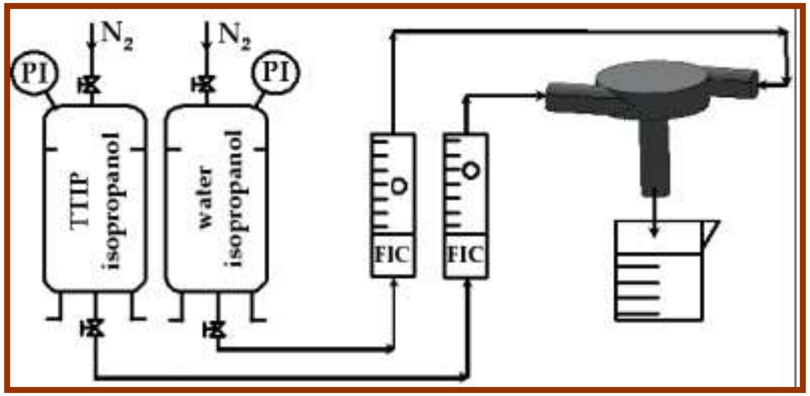


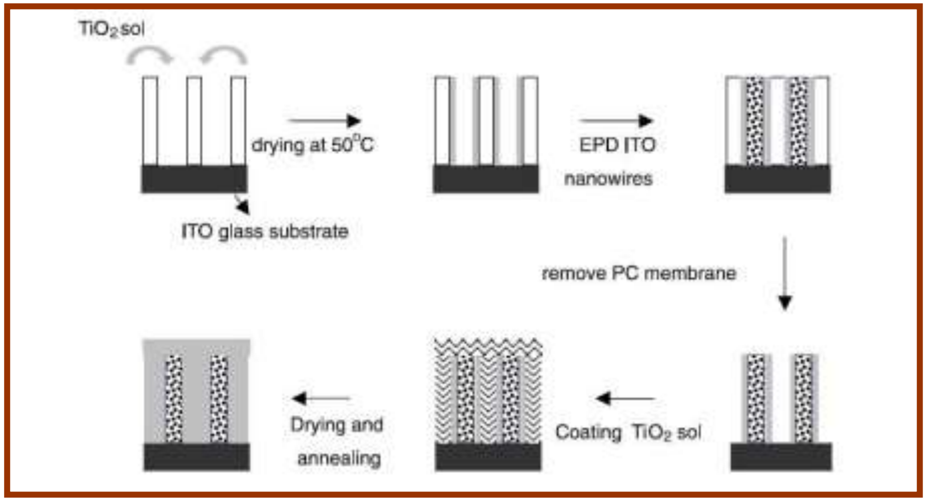
MWCNTs

by CVD



SOL – GEL nanostructured TiO_2



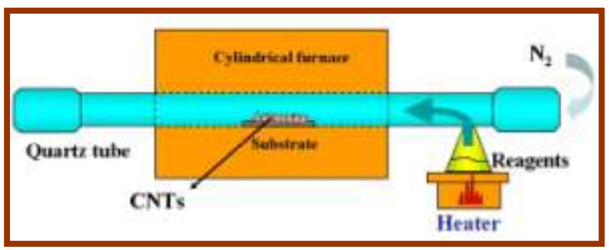


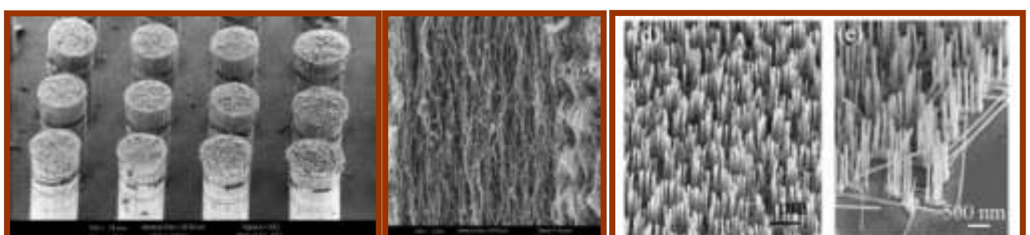
Compatible with Ink Jet Printing

Nanostructured Oxide

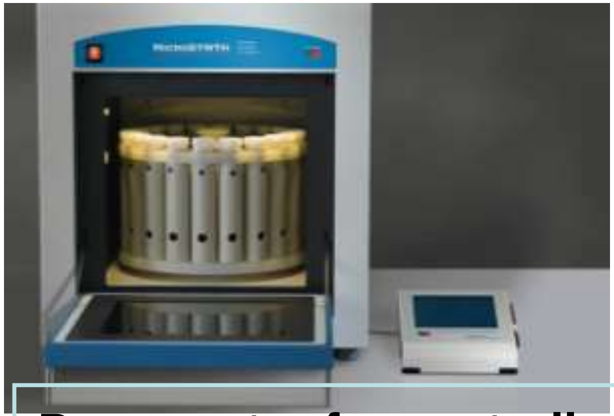
LPCVD

Thermal CVD





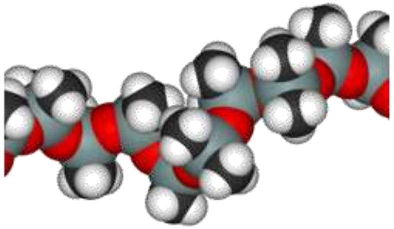
Microwave assisted synthesis

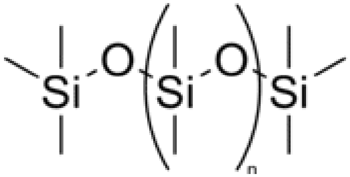


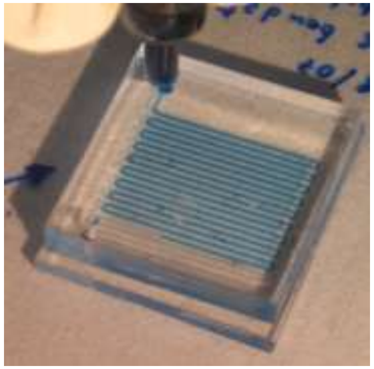
Parr reactor for controlled hydrothermal synthesis

PDMS

SYLGARD® 184 SILICONE ELASTOMER KIT







Product	Dielectric Strength		Dielectric Constant at 100 Hz	Dielectric Constant at 100 kHz	Volume Resistivity, ohm-cm	Mix Ratio	Color	Viscosity, centipoise or mPa-s	Durometer, Shore A	Specific Gravity	Thermal Conductivity		Linear Coefficient of Thermal Expansion, µm/m-°C or ppm	Shelf Life from Date of Manufacture at Room Temp, months
	volts/mil	kV/mm									Watt/meter-°K	cal/cm-sec °C		
Sylgard® 184 Silicone Elastomer	350	14	2.72	2.68	2.9×10^{14}	10:1	Clear	4575	48	1.03	0.16	3.8×10^{-4}	325	24

http://www.dowcorning.com

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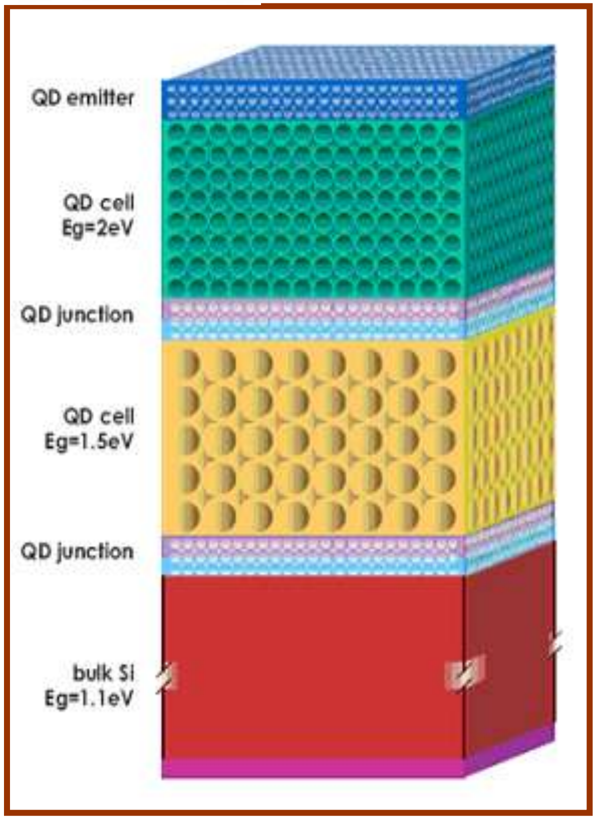
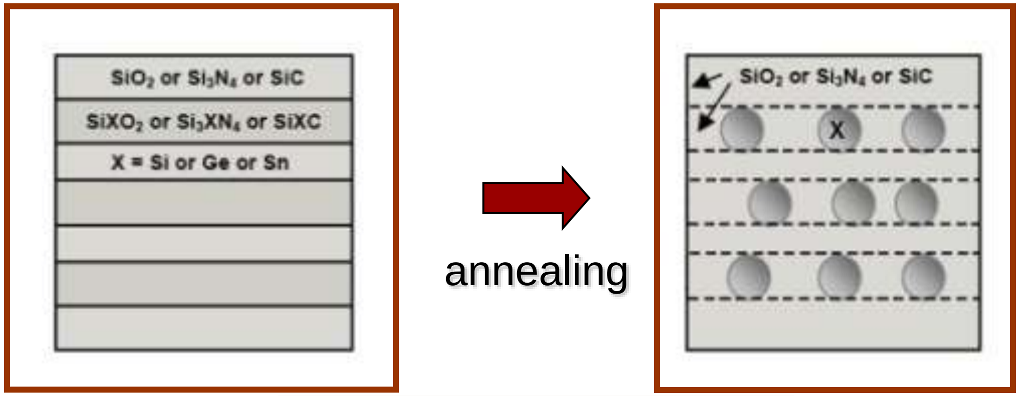
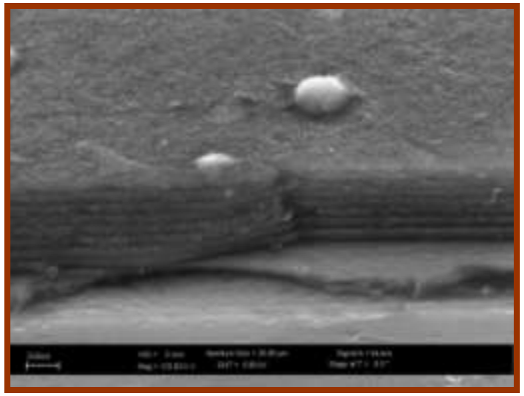
"all Si" tandem cells







- Deposition of Si_3N_4 /Si_xN_{1-x} [or SiC/Si_xC_{1-x}, or SiO_2/Si_xO_{1-x}] multilayers (PECVD, co-sputtering)
- Thermal Annealing / laser annealing
- Q-dots dimension control by layer thickness

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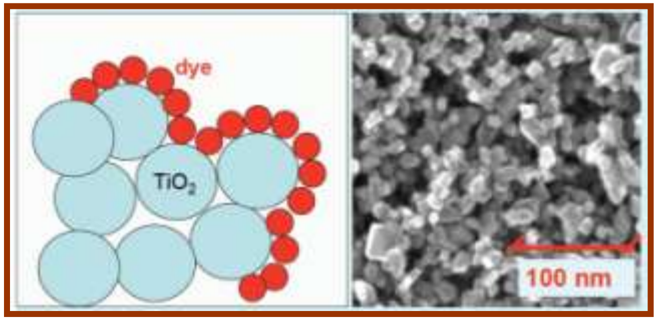
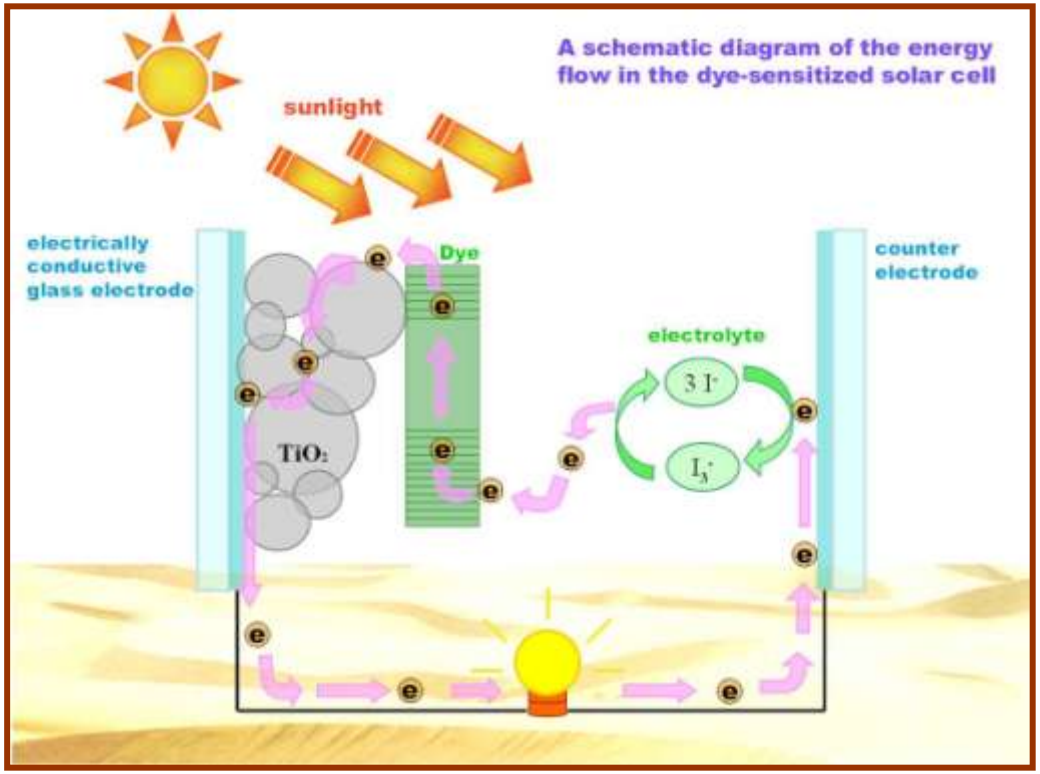
Nanostructured oxides for anode

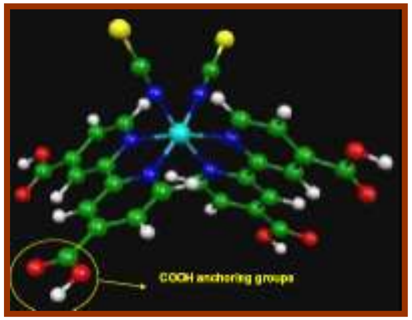


DSC cells



Nanostructured electrolyte

New dyes for light absorption



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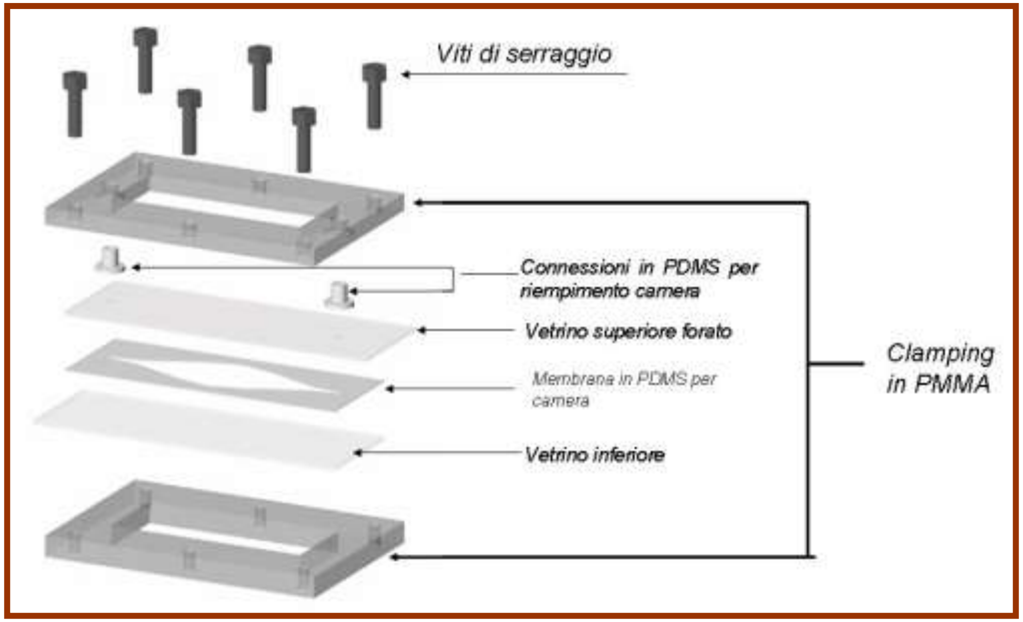
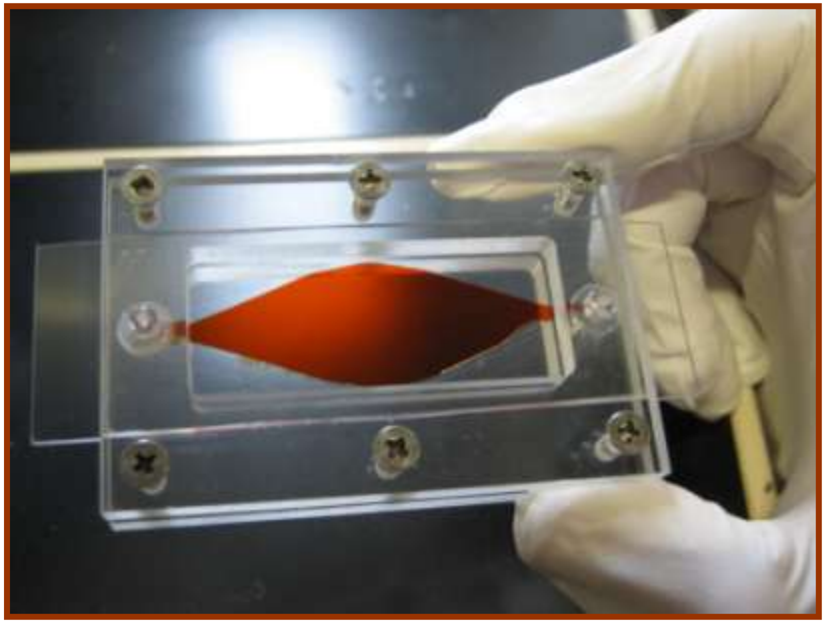
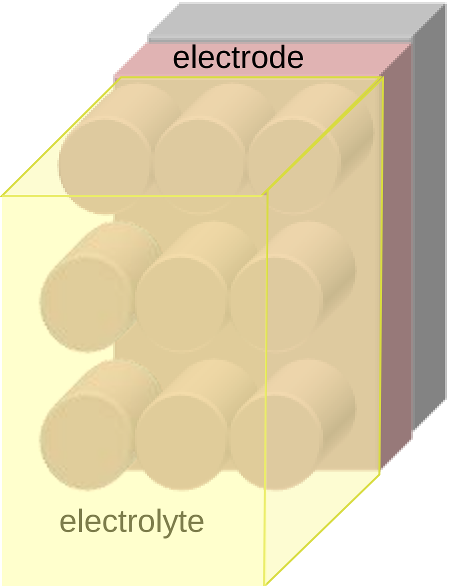
New polymeric packaging techniques for DSC cells

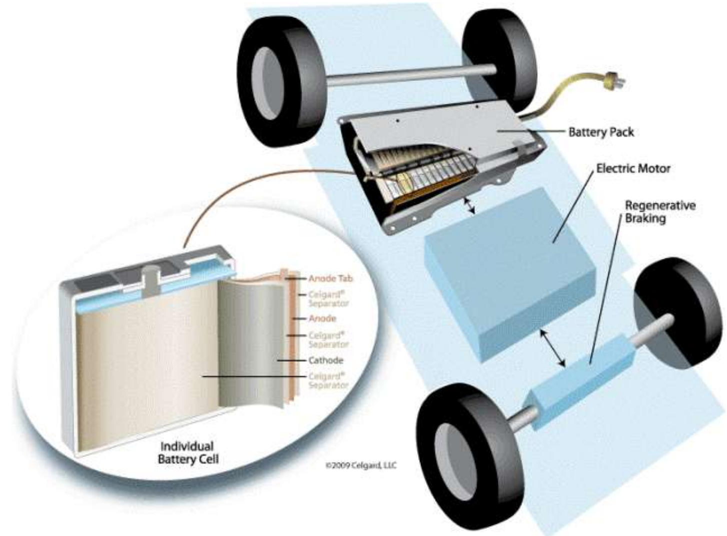




Flexible Nanostructured Lithium-polymer batteries



Electrode-Electrolyte Assemblies
=
nanowires & polymer electrolyte



Main objective: study of **nanostructured electrodes** and **polymeric electrolyte materials**, their synthesis and the electrode-electrolyte assembling techniques

- Composite cathode nanoparticles and nanostructured anodes

- Free-radical photo-polymerisation (UV-curing) for the preparation of polymer electrolytes.

- Optimisation of the polymer electrolytes properties

- Study of cells assembling: Cathode- (C.E.A.) and anode (A.E.A.) electrolyte assemblies.

- Li-ion polymer cell assembly by the one-shot process: the most interesting CEA's and AEA's will be assembled together to form a complete Li-ion polymer cell, where the contact point will be the electrolyte phase (no problem arising by the insufficient contact usually observed in conventional systems).

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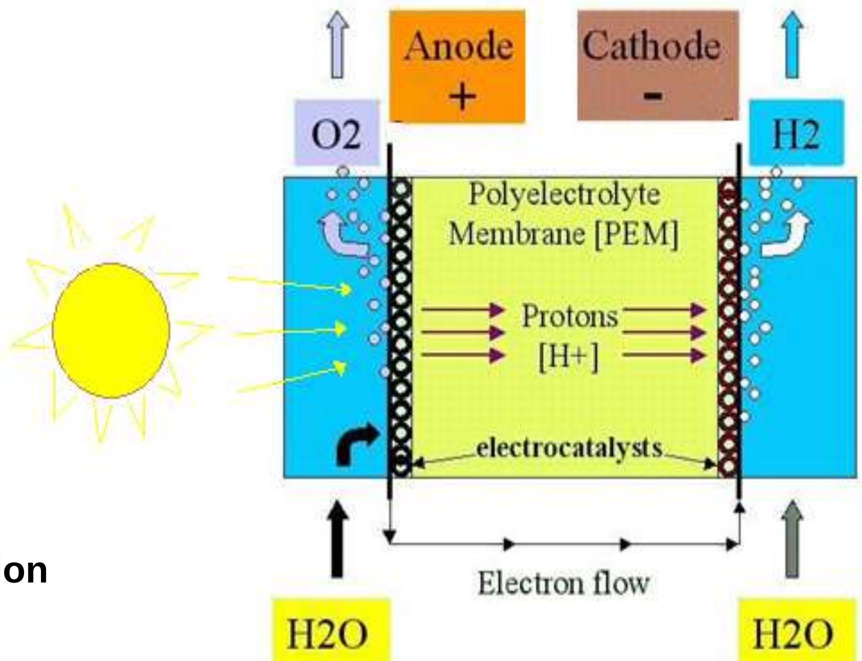
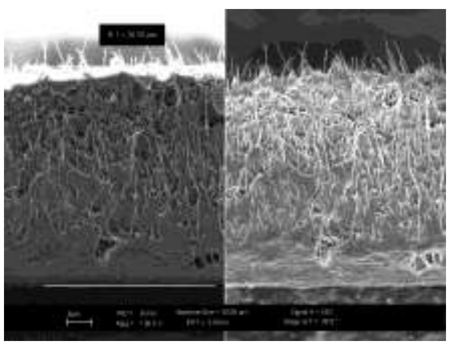
Nanodesigned electrochemical reactors for H_2 production

The main research activities:

1) Development of **nanostructured electrodes**

2) *Development of* ***a membrane enabling transport of both electrons and protons*** ***(***carbon nanotubes or TiO_2 and ion-exchange resins like Nafion)

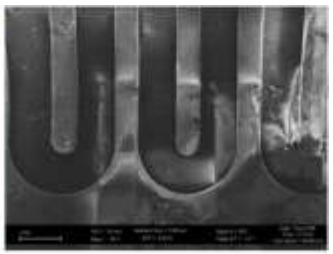




–membranes for protons / electrons conduction (Nafion and carbon NT)

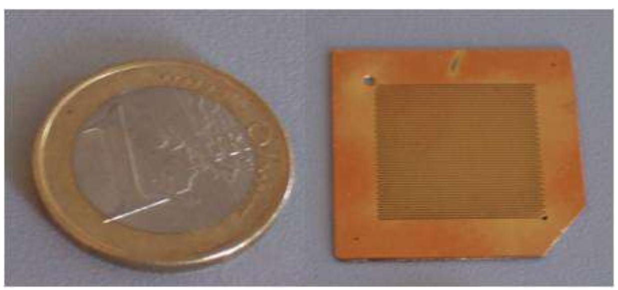
– PDMS membranes with carbon NT “pillar”

Micro-Fuel Cells



- **Plastic fuel cells by hot-embossing obtained with silicon master**

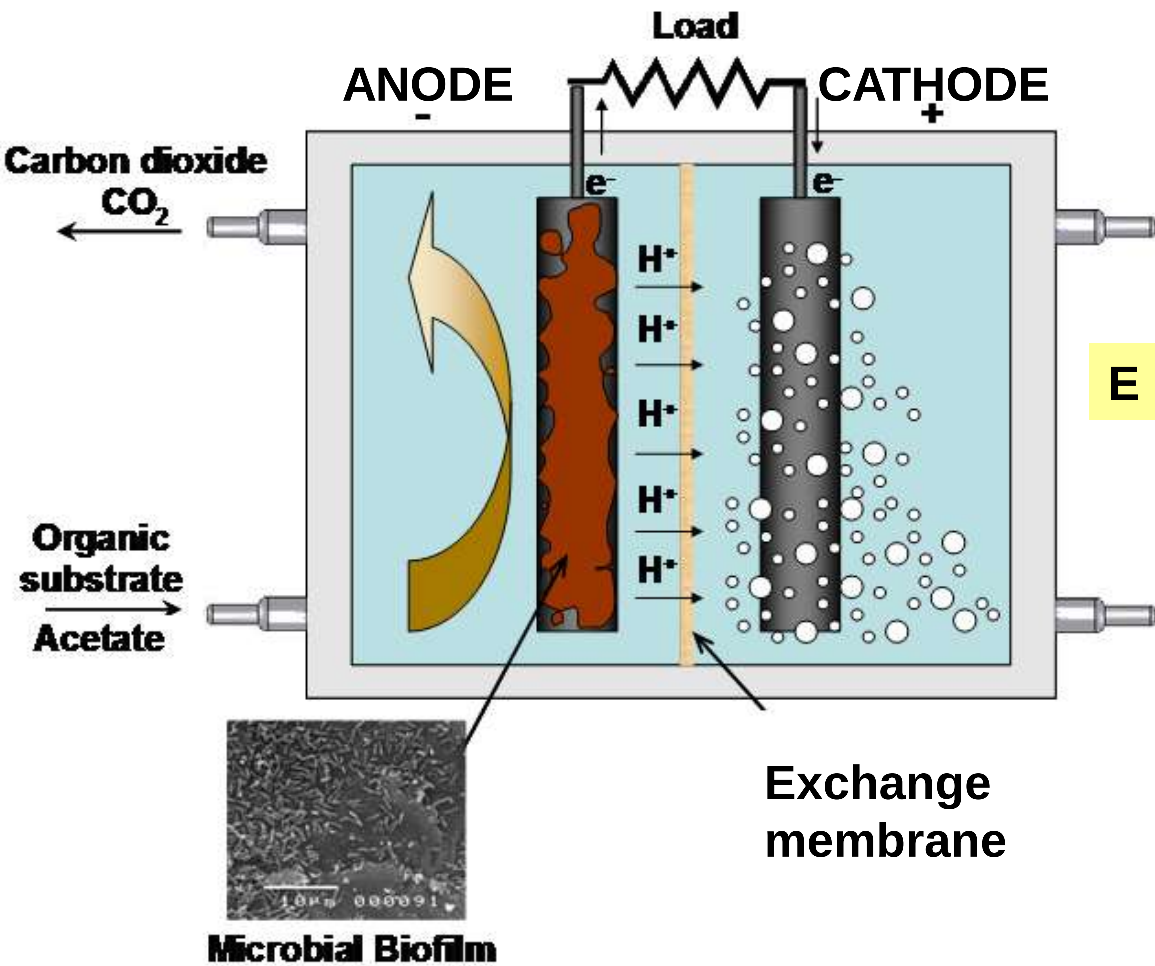
dimensions 2x2 cm2,
Materials PC and COC (cyclic olefin)



- **Silicon based fuel cells by powder blasting e RIE**

-**Prototype of Si micro-fuel cell (housing in teflon and PMMA)**

Microbial Fuel Cells



Power = $E_{MFC} \cdot I$

$E_{MFC} = E_{cathode} - E_{anode} - \Sigma I \cdot R_e$

Potential losses
during electron tranfer

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Thank you for your attention

For further infos:

http://shr.iit.it/
http://www.polito.it/micronanotech
http://www.latemar.polito.it/

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