Development of Nanostructurated Platforms for Sensing and Destroying of Pollutants

www.nanobiosensors.org

Arben Merkoçi

ICREA & Institut Català de Nanotecnologia

Bellaterra, Catalonia, Spain

arben.merkoci@icn.cat

2nd JAPANESE- SPANISH BILATERAL SYMPOSIUM
"NANOTECHNOLOGIES AND NEW MATERIALS FOR ENVIRONMENTAL CHALLENGES" (SJ-NANO 2013)
TSUKUBA (JAPAN), 2013, MARCH 5th

INDEX

- **Introduction – Our motivation and detection systems**
- **Lab-on-a-chip systems: Detection of pesticides and phenols**
- **Lateral flow / nanomotors based biosensing platforms**
- **Future perspectives & conclusions**

INDEX

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- **Lab-on-a-chip systems: Detection of pesticides and phenols**
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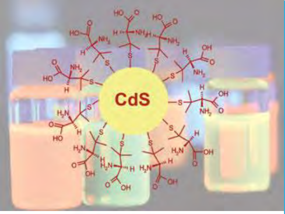
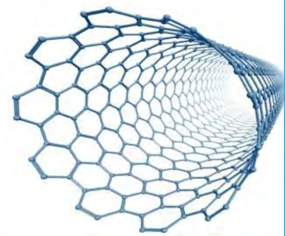
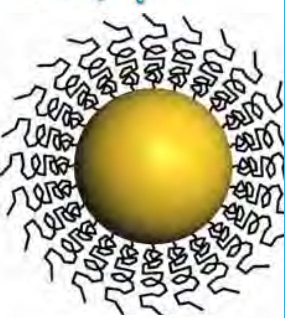
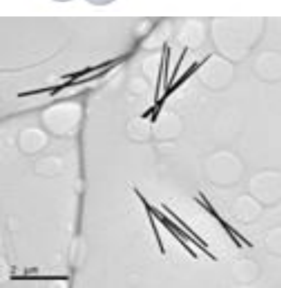
RESEARCH AREAS

Bioelectronics & Biosensors Group





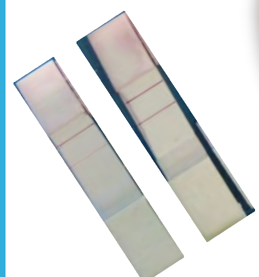


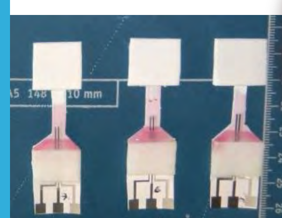


NANOMATERIALS

DEVICES








Environmental monitoring

Diagnostics

NANOBIOELECTRONICS & BIOSENSORS's research aims to integrate nanotechnology methods, tools and materials into low cost, user friendly and efficient (bio)sensors with interest for diagnostics , safety /security and other fields

Other industrial applications

Food quality

Safety / security

State of the art nanobiosensing technologies

NANO Bioelectronics & Biosensors Group

www.nanobiosensors.org

CHEMICAL REVIEWS
REVIEW
pubs.acs.org/CR

Recent Trends in Macro-, Micro-, and Nanomaterial-Based Tools and Strategies for Heavy-Metal Detection

Gemma Aragay,[†,‡] Josefina Pons,[‡] and Arben Merkoçi[*,†,§]

[†]Nanobioelectronics & Biosensors Group, Institut Català de Nanotecnologia (CIN2, ICN-CSIC), 08193, Bellaterra, Barcelona, Spain
[‡]Departament of Chemistry, Universitat Autònoma de Barcelona, 08193, Bellaterra, Barcelona, Spain
[§]ICREA, Barcelona, Spain

Chemical Reviews, 111 (5), 3433-3458, 2011.

ACS Nano, 2012, DOI: 10.1021/nn301368z

Nanochannels Preparation and Application in Biosensing

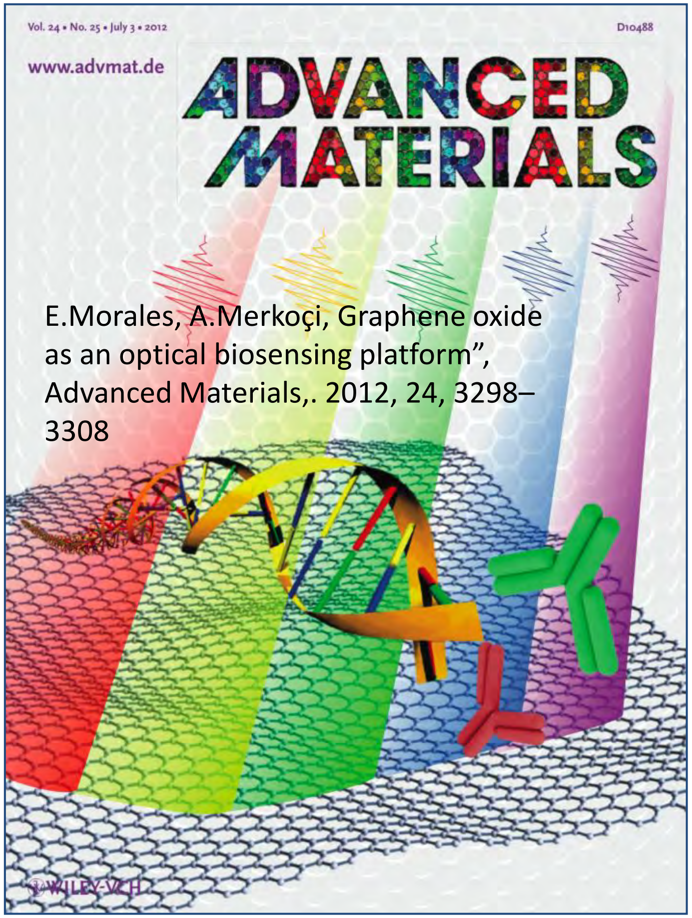
Alfredo de la Escosura-Muñiz[†] and Arben Merkoçi[†,‡,*]

REVIEW

CHEMICAL REVIEWS
Review
pubs.acs.org/CR
Chemical Reviews, 2012, 112, 5317–5338

Nanomaterials for Sensing and Destroying Pesticides

Gemma Aragay,[†] Flavio Pino,[†] and Arben Merkoçi[*,†,‡]



E.Morales, A.Merkoçi, Graphene oxide as an optical biosensing platform", Advanced Materials,. 2012, 24, 3298–3308

Chem Soc Rev
Dynamic Article Links
Cite this: *Chem. Soc. Rev.*, 2012, **41**, 2606–2622
www.rsc.org/csr
TUTORIAL REVIEW

Cancer detection using nanoparticle-based sensors†

Maëlle Perfézou,[ab] Anthony Turner[bc] and Arben Merkoçi[*ad]

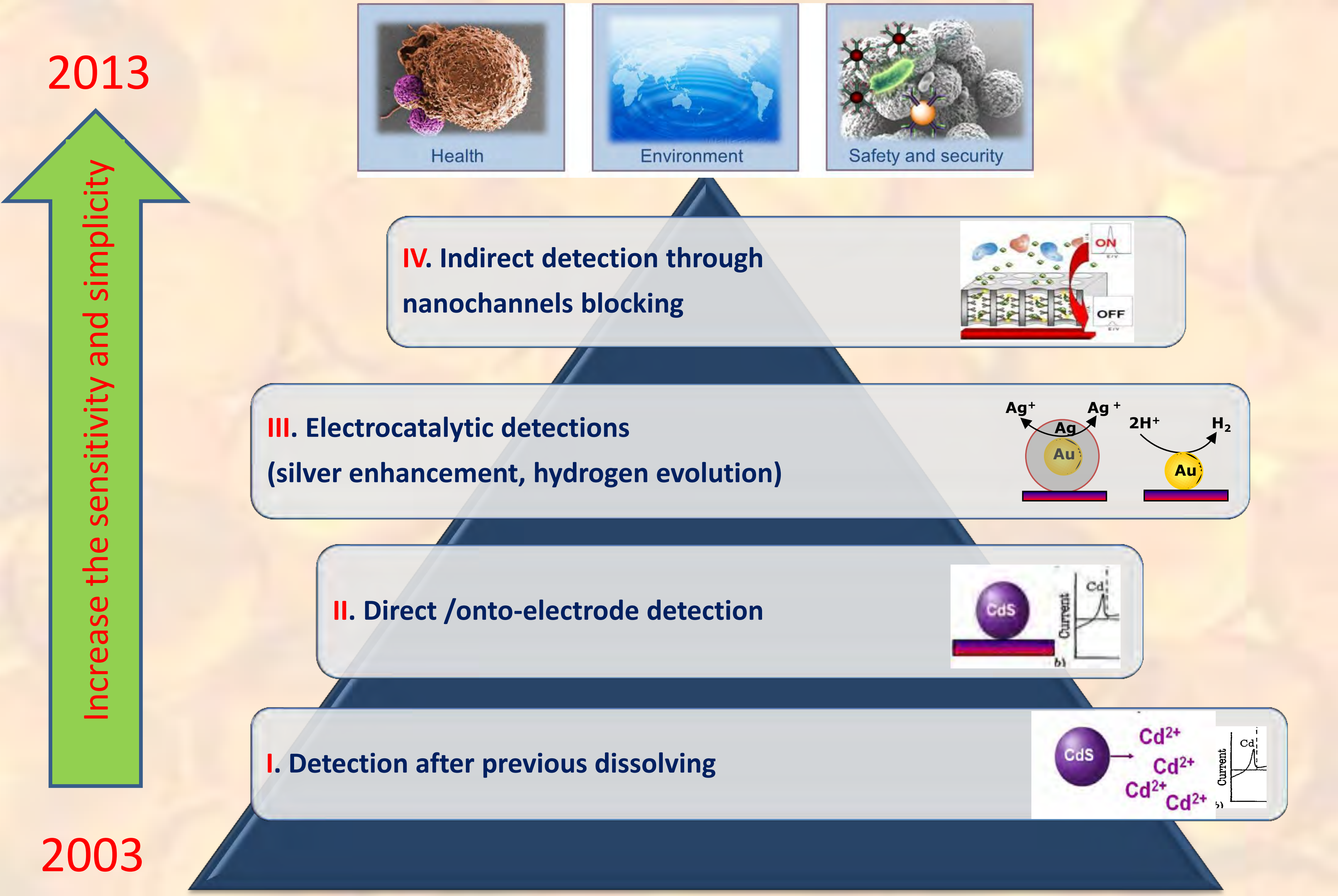
Chem Soc Rev
Dynamic Article Links
Cite this: DOI: 10.1039/c2cs35255a
www.rsc.org/csr
TUTORIAL REVIEW

Paper-based nanobiosensors for diagnostics

Claudio Parolo[a] and Arben Merkoçi[*ab]

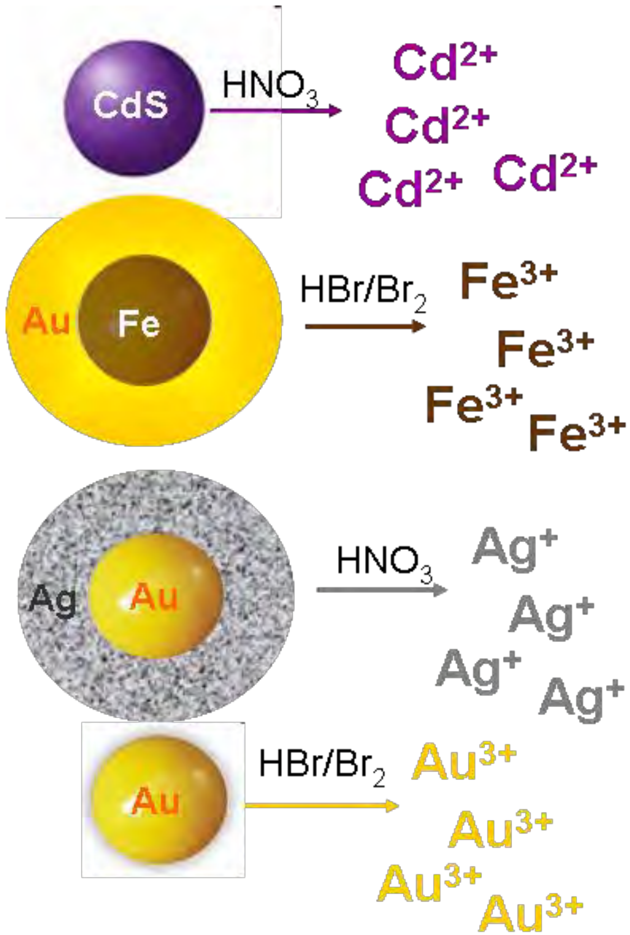
Received 11th July 2012

Nanomaterials based electrochemical detection tools



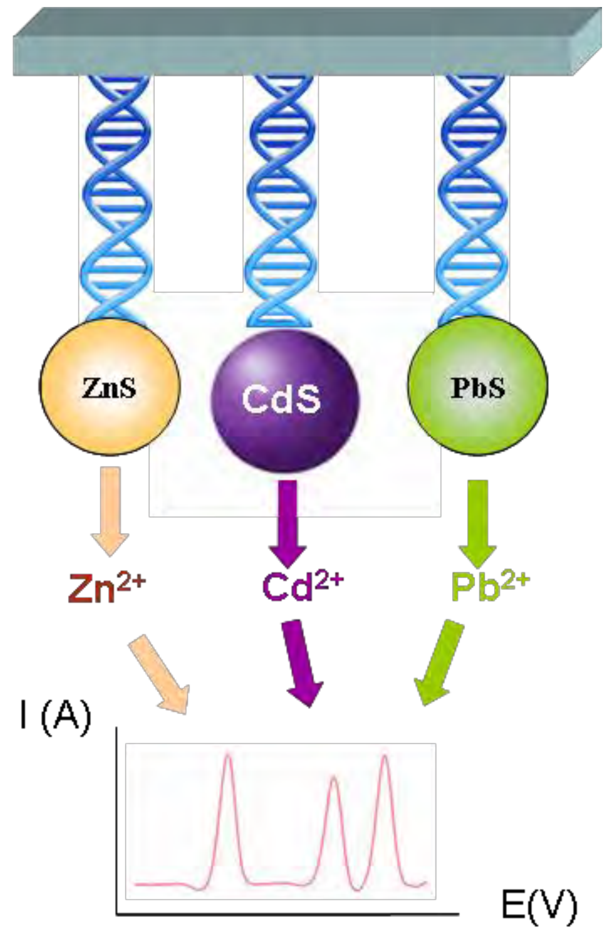
NANOPARTICLES & ELECTROCHEMICAL STRIPPING

Chemical dissolving followed by stripping analysis



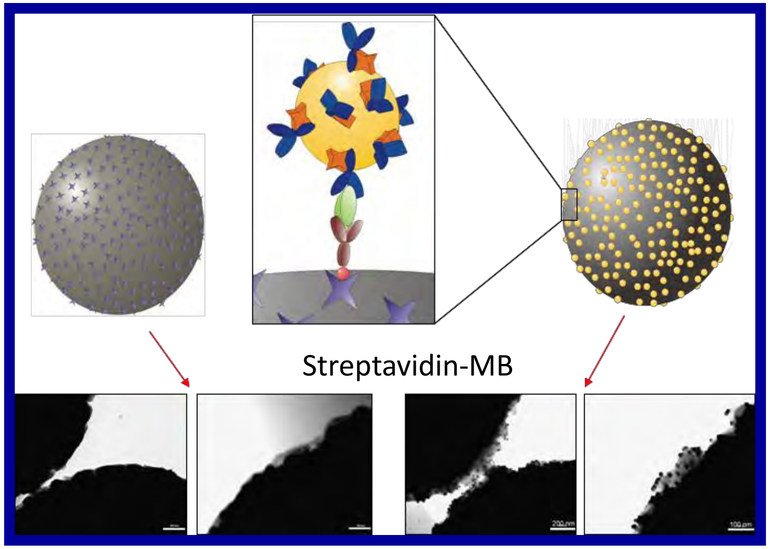
TRAC 24 341-349 (2005)
ACA 482 149–155 (2003)

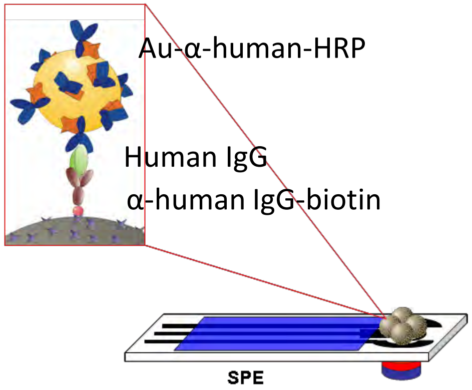
Multicoding technology
Breast cancer DNA related

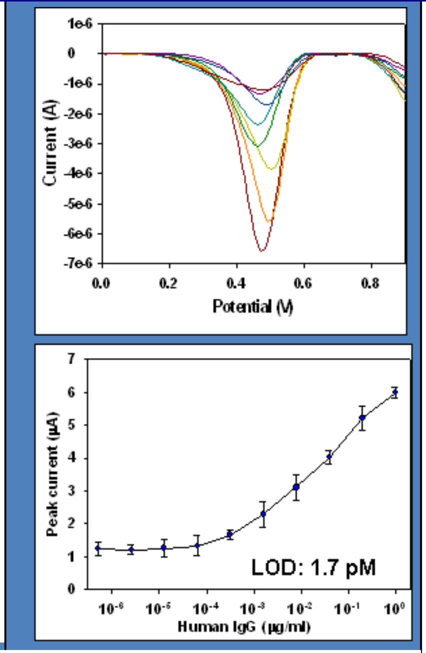


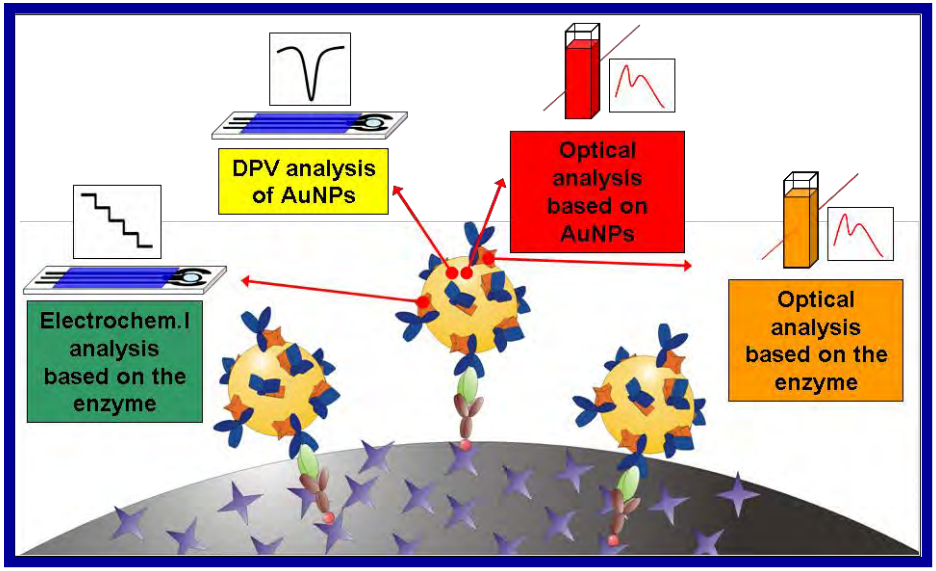
JACS, 125 3214-3215 (2003)

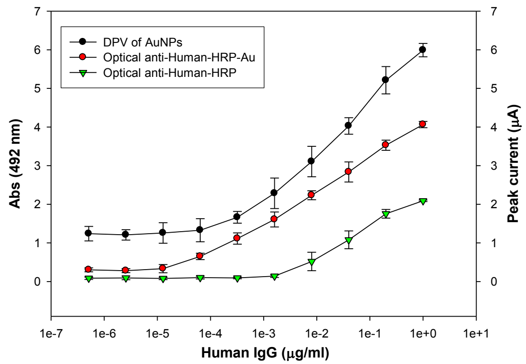
Protein detection- direct detection of AuNP











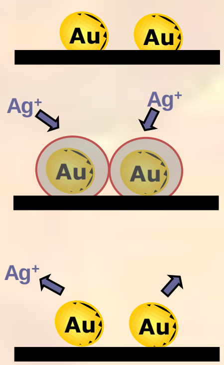
L.O.D: 52 and 260 pg of human IgG/mL for HRP and electrochemical AuNP-based detections

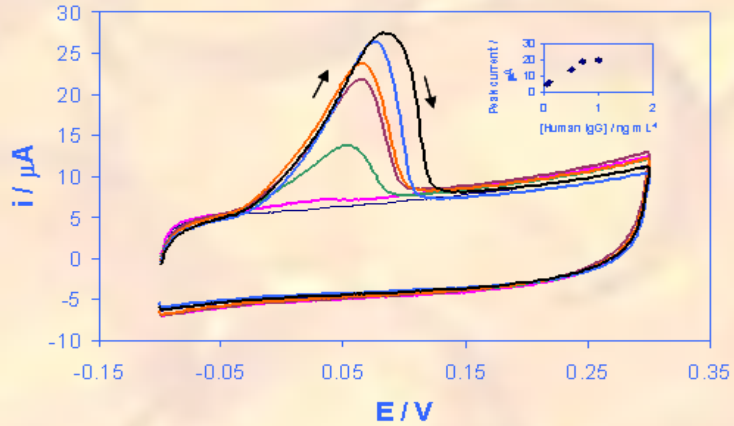
Analytical Chemistry, 2007, 79, 5232-5240

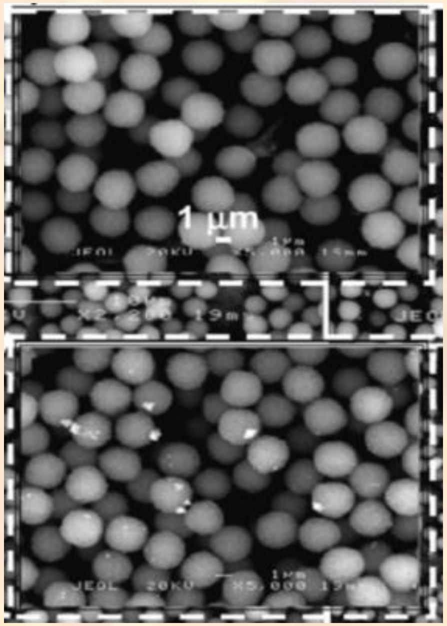
Analytical Chemistry, 2010, 82, 1151–1156

Indirect gold nanoparticles detection

Catalytic effect of AuNPs towards Ag deposition







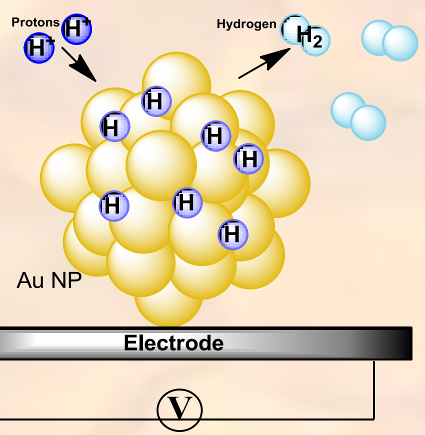
Detection of human IgG

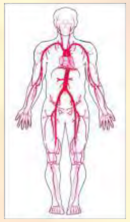
L.O.D. : 23 fg mL $^{-1}$

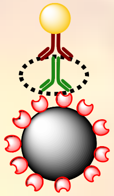
Biosens. Bioelectron, 2009, 24, 2475 (8pp)

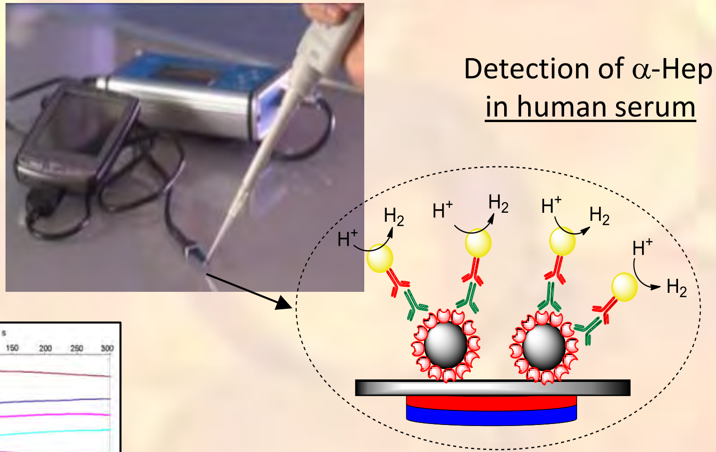
Catalytic effect of AuNPs towards H_2 evolution

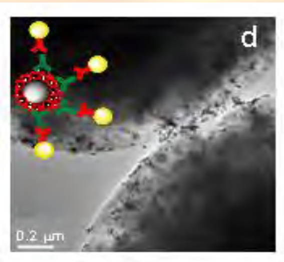
Hydrogen evolution squeme

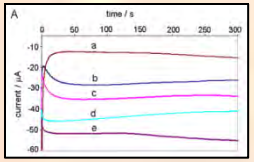












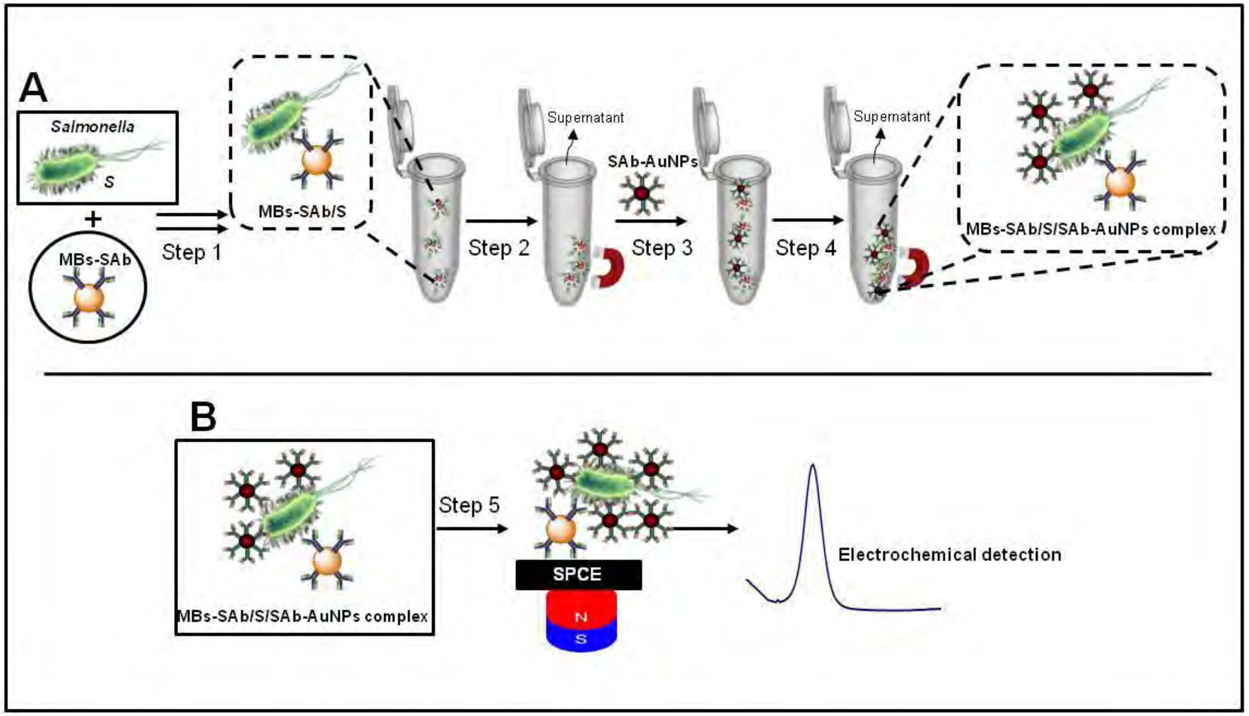
Detection of α-HepB
in human serum

L.O.D. : 3 mUI mL $^{-1}$

Biosens. Bioelectron., 2010, 26, 1710(4pp)

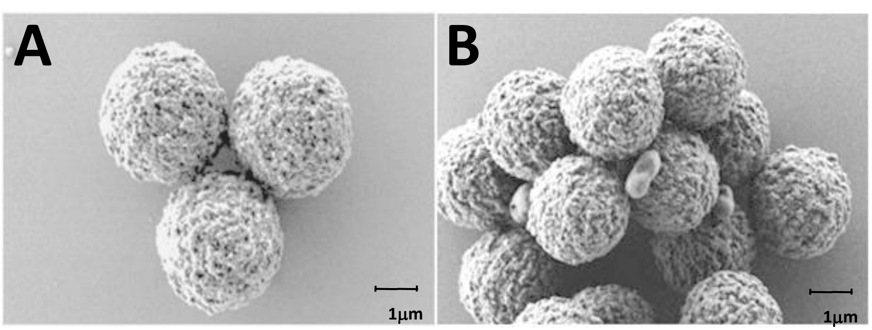
Electrochem. Commun. , 2010, 12, 1501(3pp)

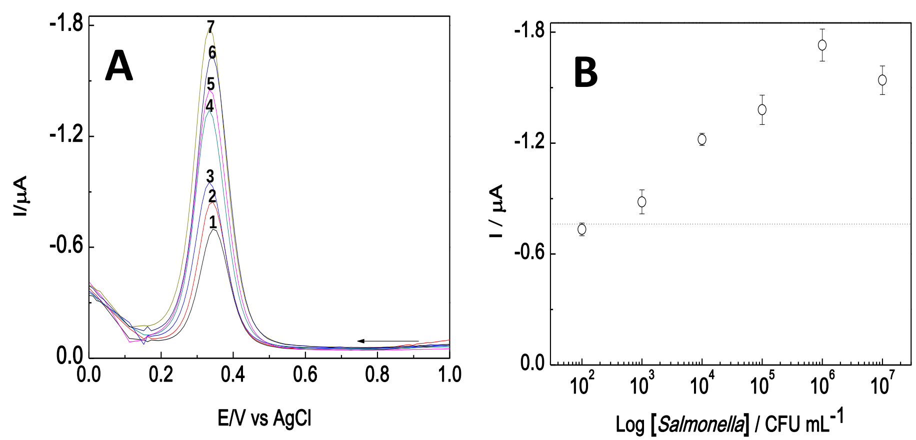
Salmonella detection based on diferential voltammetry of AuNP



Schematic (not in scale) of *Salmonella* detection

DPV using AuNPs electrochemical detection

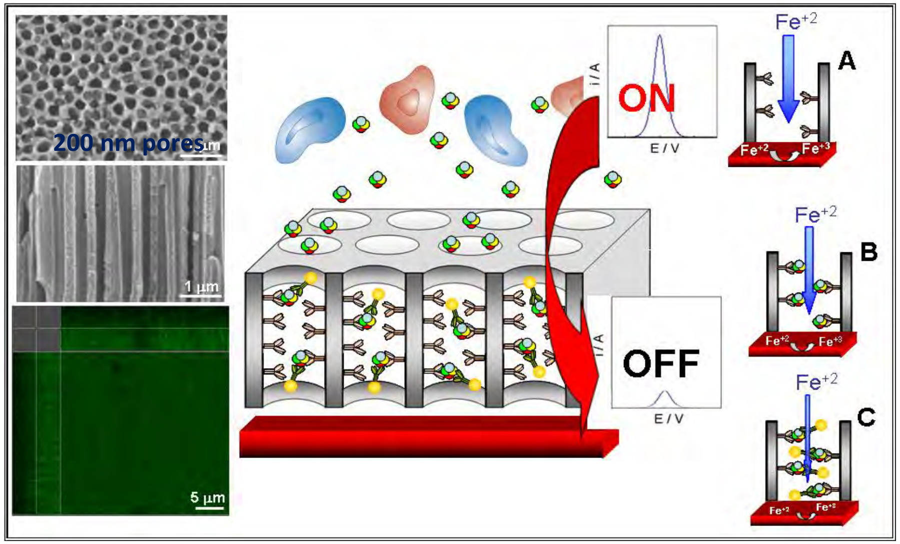


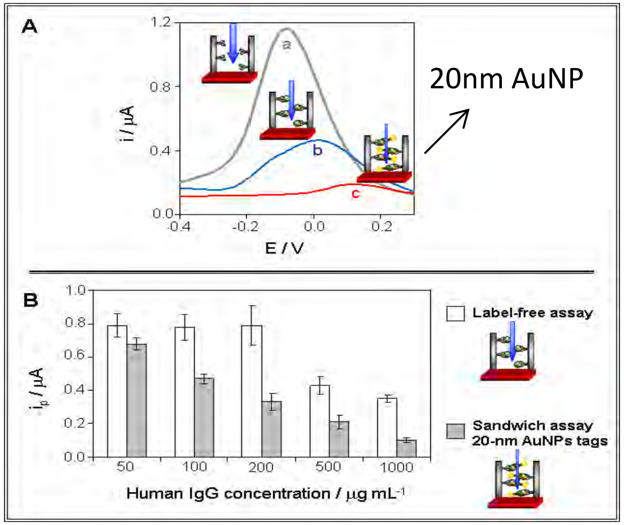


Biosensors and Bioelectronics 40 (2013) 121–126.

Protein detection - AuNP & nanochannels

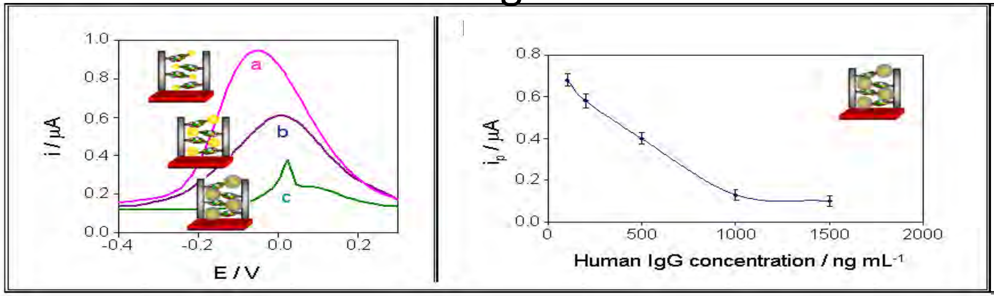
Nanochannels immunoblocking using nanoparticles

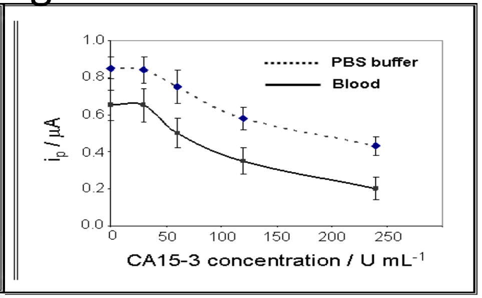




Responses to blood samples spiked with CA15-3

Effect of AuNP size and Ag enhancement on blocking



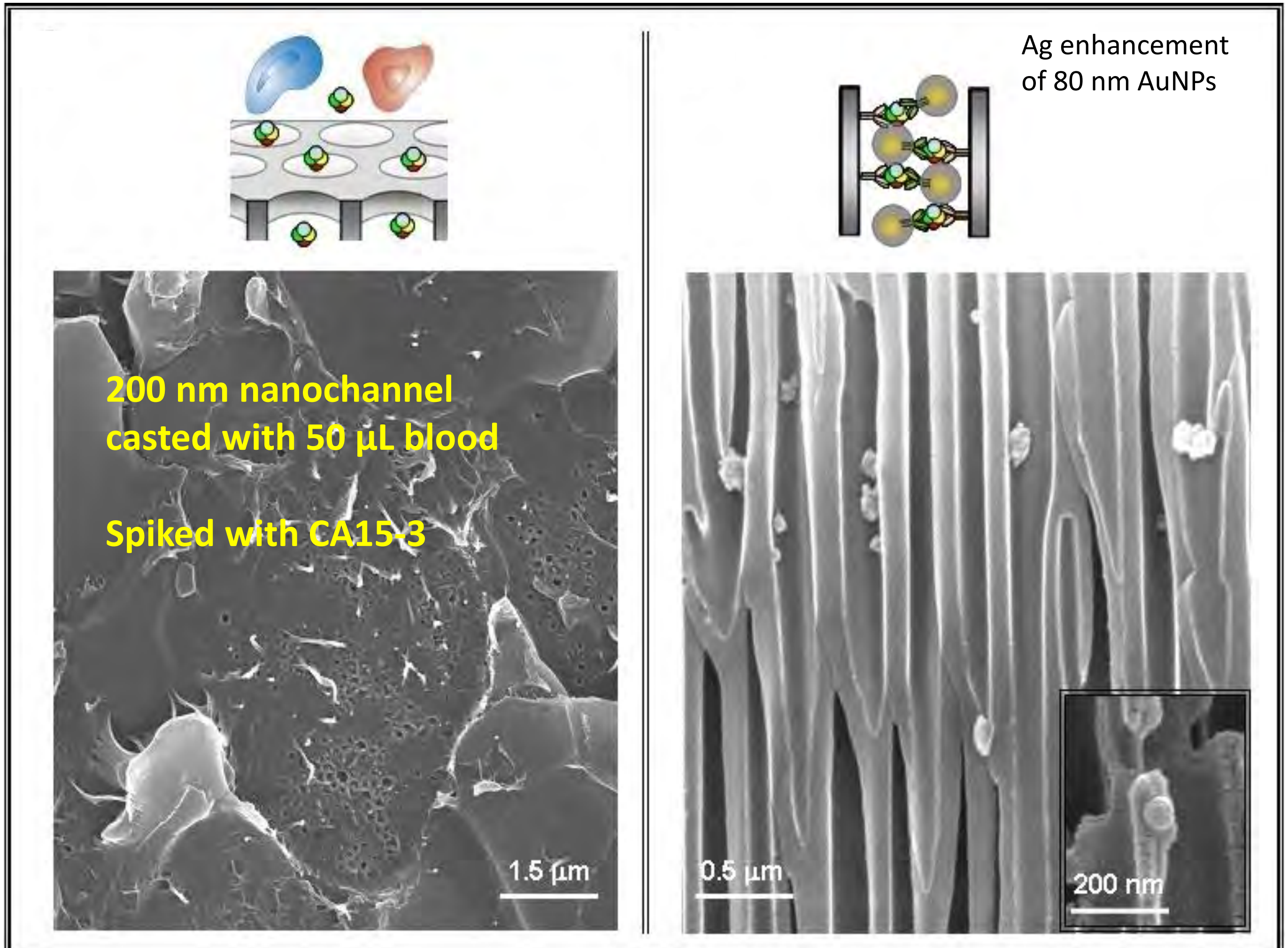


Responses to human IgG using 20-nm AuNPs; 80-nm AuNPs; 80-nm AuNP tags anmd Ag enhancement

RSD of 8% ([CA15-3]: 120 U/mL; n=3)
LOD: 52 IU/mL of CA15-3

Small, 2011

Protein detection - AuNP & nanochannels



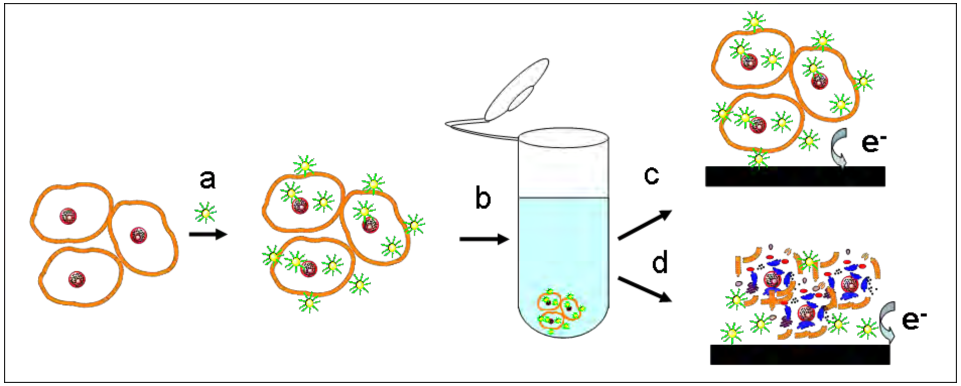
RSD of 8% ([CA15-3]: 120 U/mL; n=3)
LOD: 52 IU/mL of CA15-3

Small, 2011

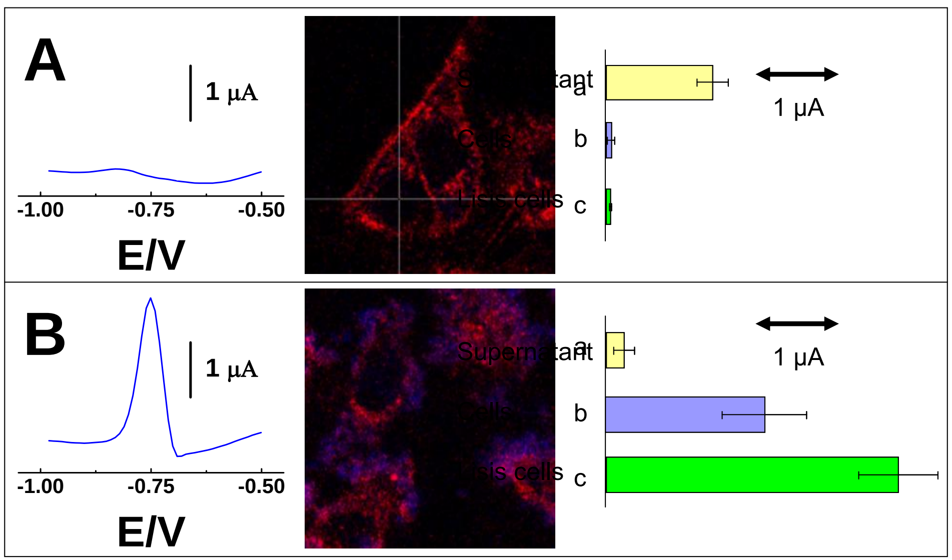
Cell studies based on CdS QDs

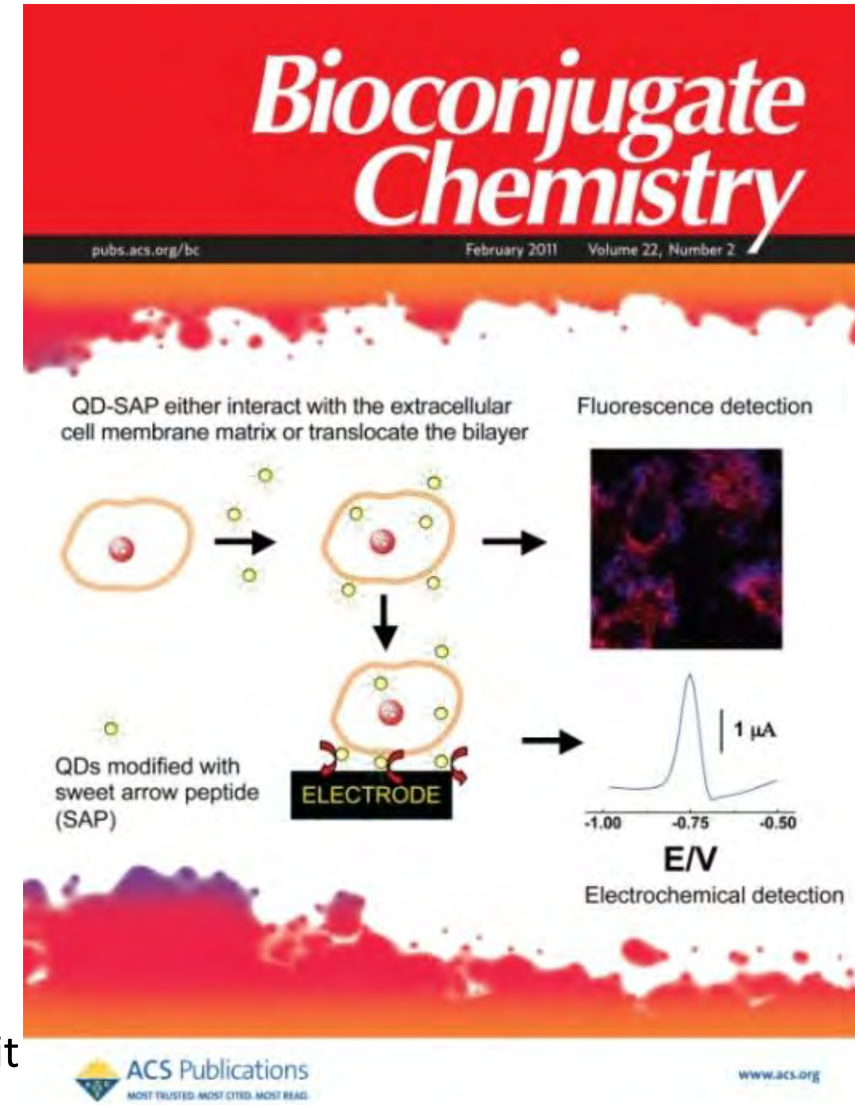
Collaboration with E.Giralt. (UB)

Electrochemical interrogation of cellular uptake of quantum dots decorated with peptide



CdS QD-SAP interaction with HeLa cells:



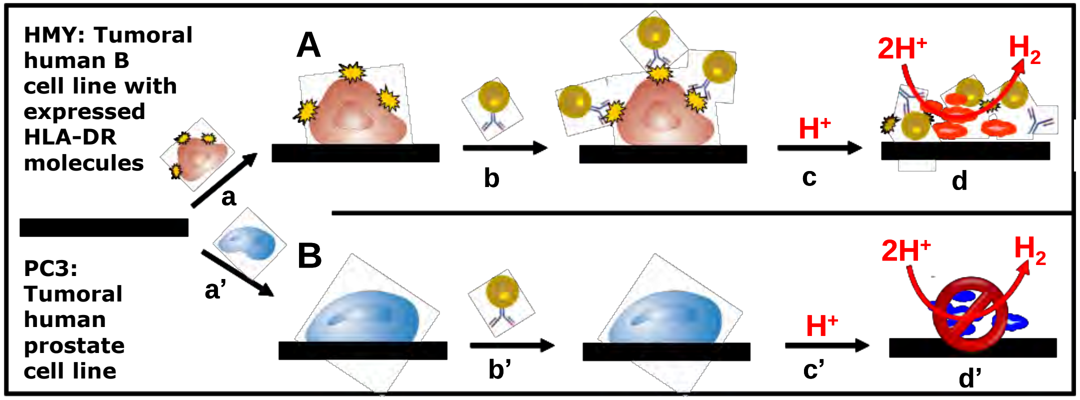


SWV and CLSM images of cells incubated wit QDs incliuding blanks

Cells detection based on AuNP & H_2 catalysis

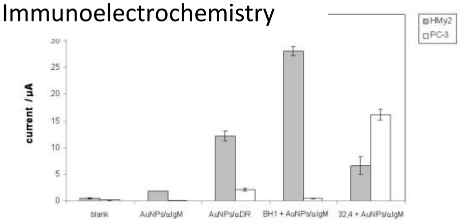
Collaboration with Dr. A. González (UV)

Cancer cell detection (ICN&UV patent)

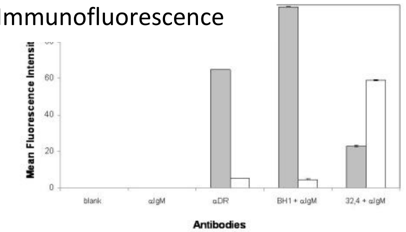


4000 cells per 700 µL suspension

Immunoelectrochemistry

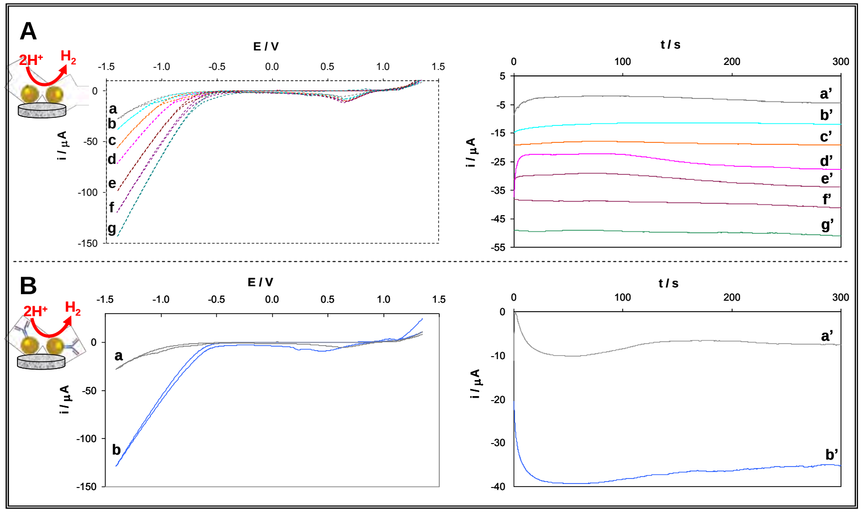


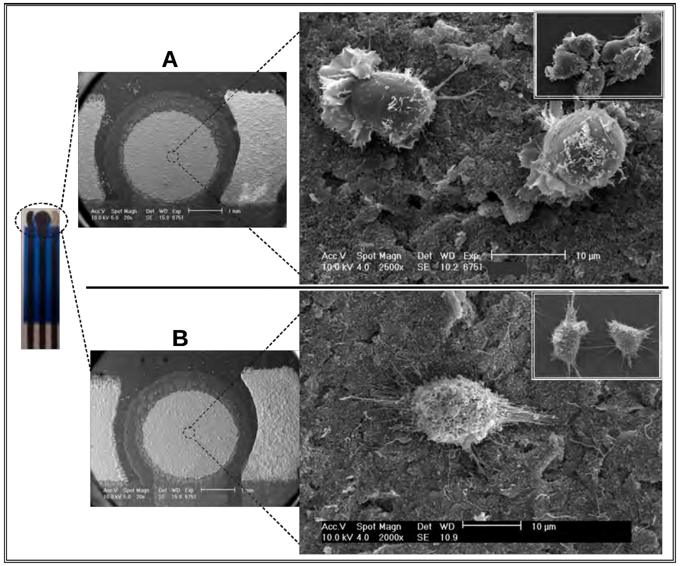
Immunofluorescence



Immunofluorescence analysis by flow cytometry and electrochemical analysis of both HMy2 and PC-3 cell lines agreed.

AuNP & AuNP-Ab detection



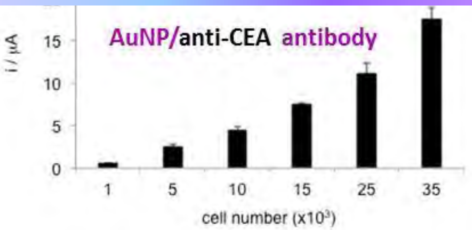


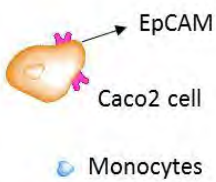
Analytical Chemistry, 2009, 81, 10268–10274

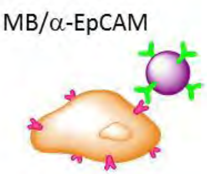
Catalytic Nanoparticles for Detection of circulating Cancer Cells (CTC) (Collaboration with Prof. C.Nogues, UAB)

HER based biosensing device developed by Nanobioelectronics & Biosensors Group LEITAT

Simple nanoparticle based technology

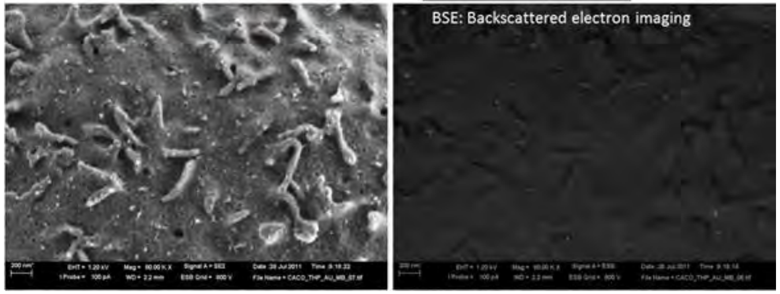






L.O.D. 1.6 x10 ^{2} cells

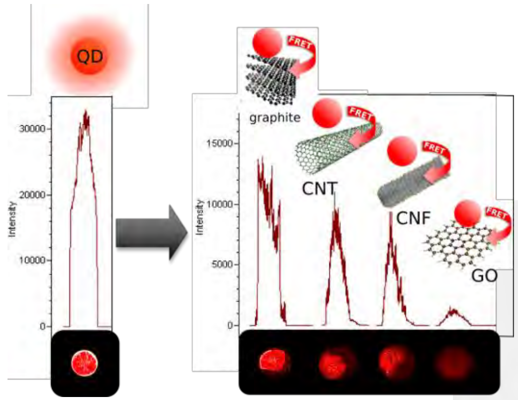
SEM characterization



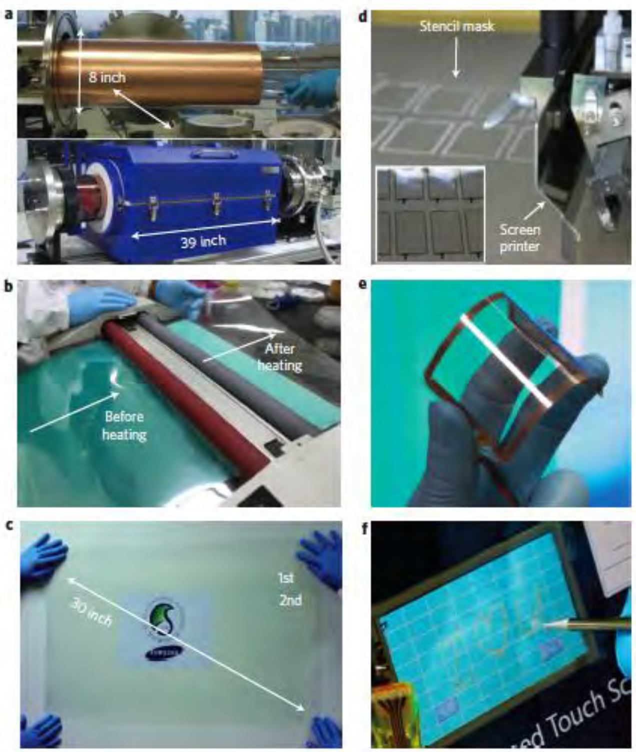
Small 2012, 8, No. 23, 3605–3612

Nano Lett., 2012, 12 (8), pp 4164–4171

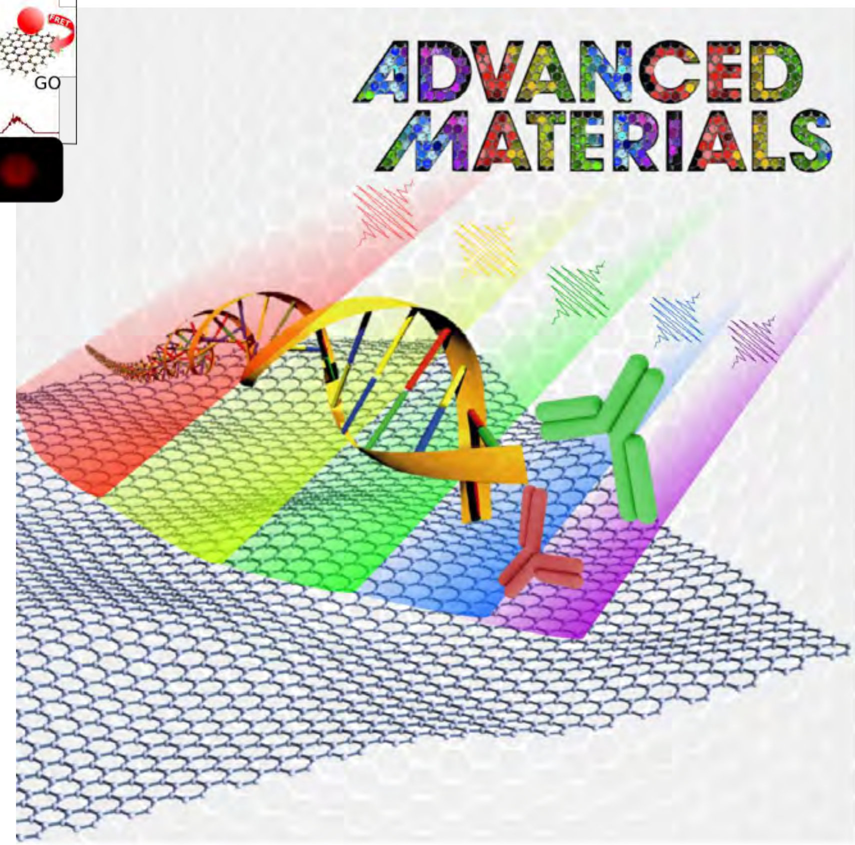
Tailoring graphene production toward biosensors applications



Merkoçi et al. Carbon **2012**, *50:2987*



- roll to roll
- ink-jet printing
- screen-printing
- graphene composites / inks



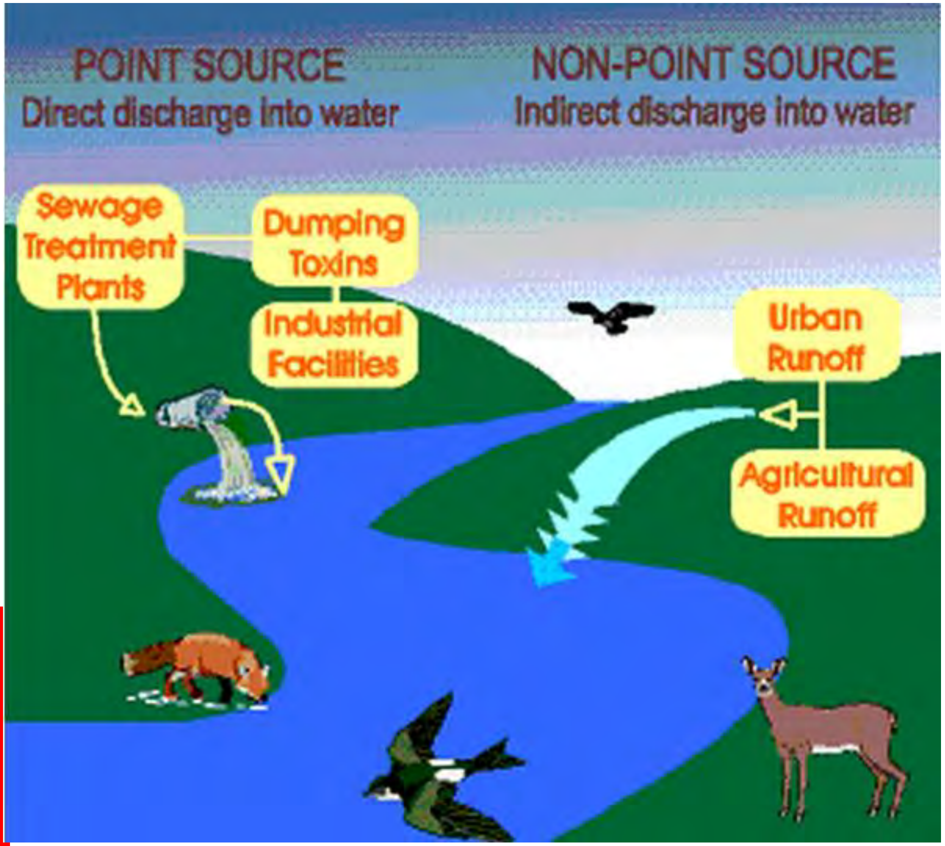
Graphene Oxide as an Optical Biosensing Platform
Merkoçi et al. Adv Mater **2012**
DOI: 10.1002/adma.201200373

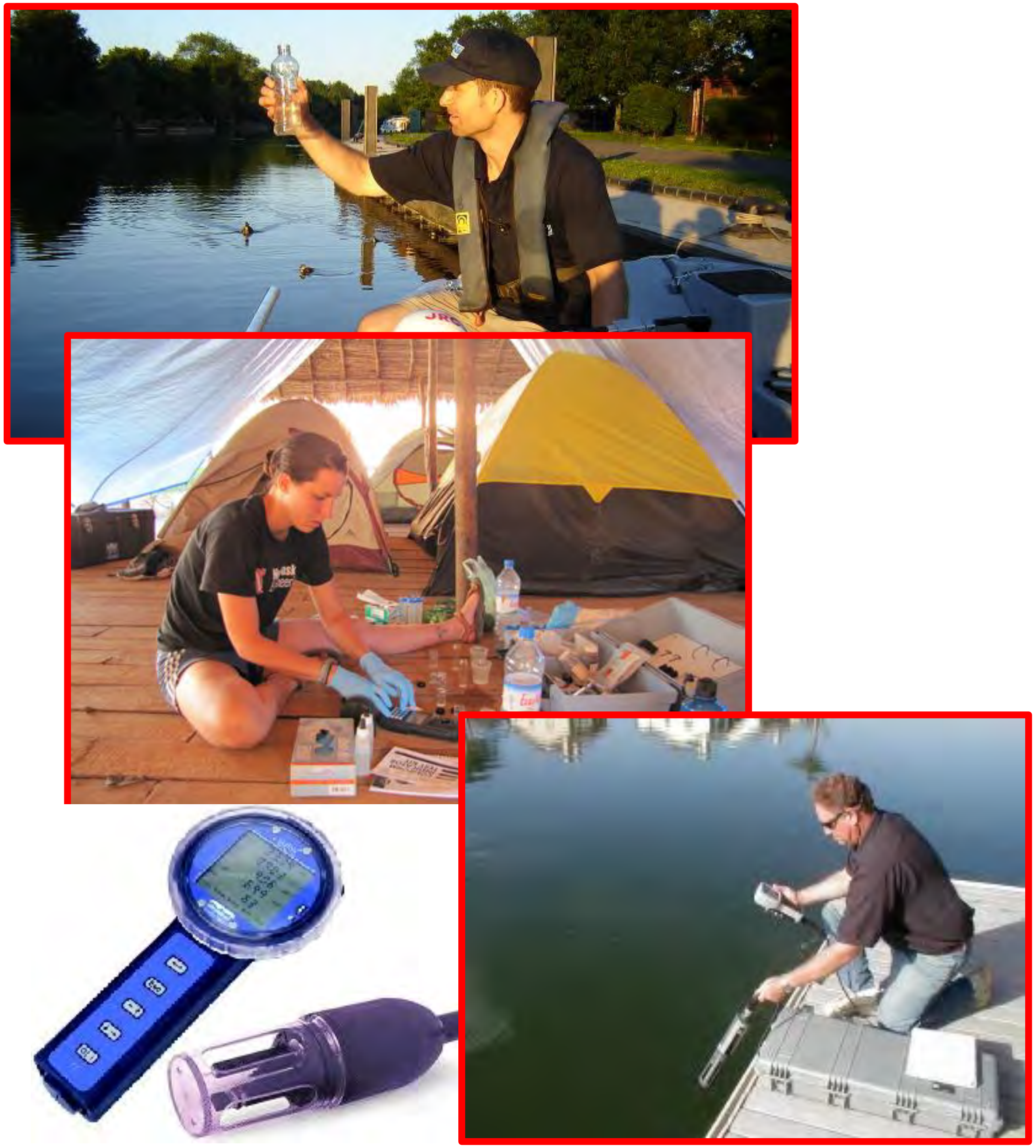
WATER POLLUTION

Water, air and soil pollution causes 40 % of deaths worldwide
http://www.news.cornell.edu

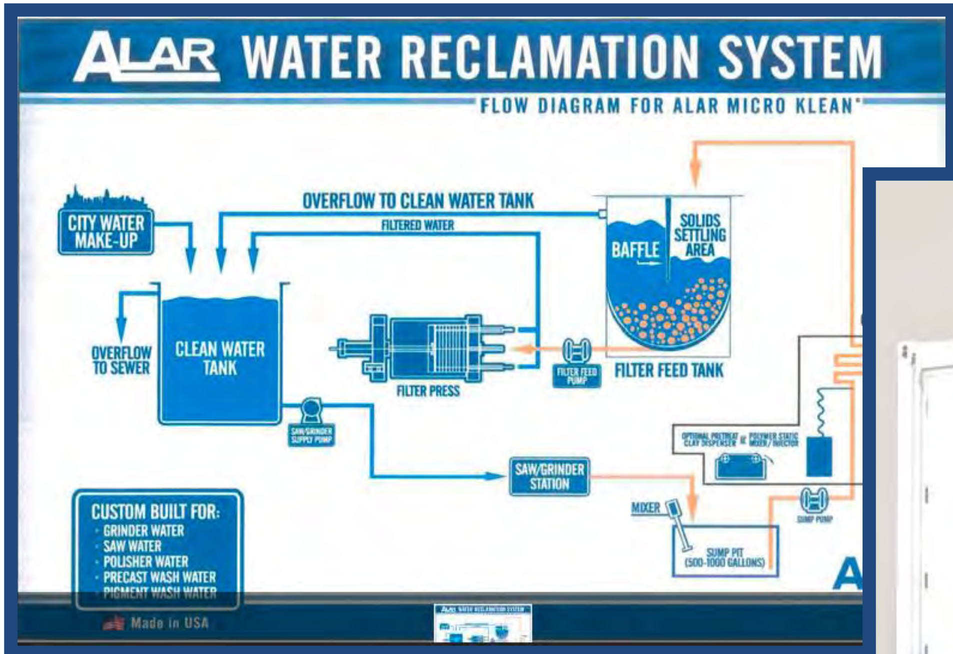
Water-related diseases are one of the leading causes of death worldwide. Over 3 million people die each year.
http://worldsavvy.org/monitor

Pesticides
Phenols
Heavy metals
Bacteria
Toxins etc.





Monitoring water quality should be done periodically to check for aquatic problems   *in-field sensing systems are necessary*



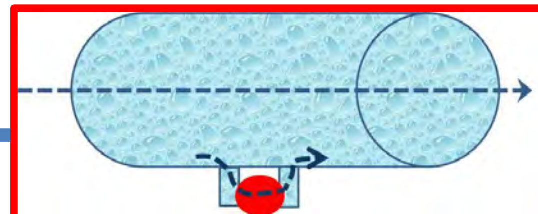
Micro-Klean™ Industrial Wastewater Treatment Systems

QuickShip Water Treatment Equipment
www.ge-energy.com

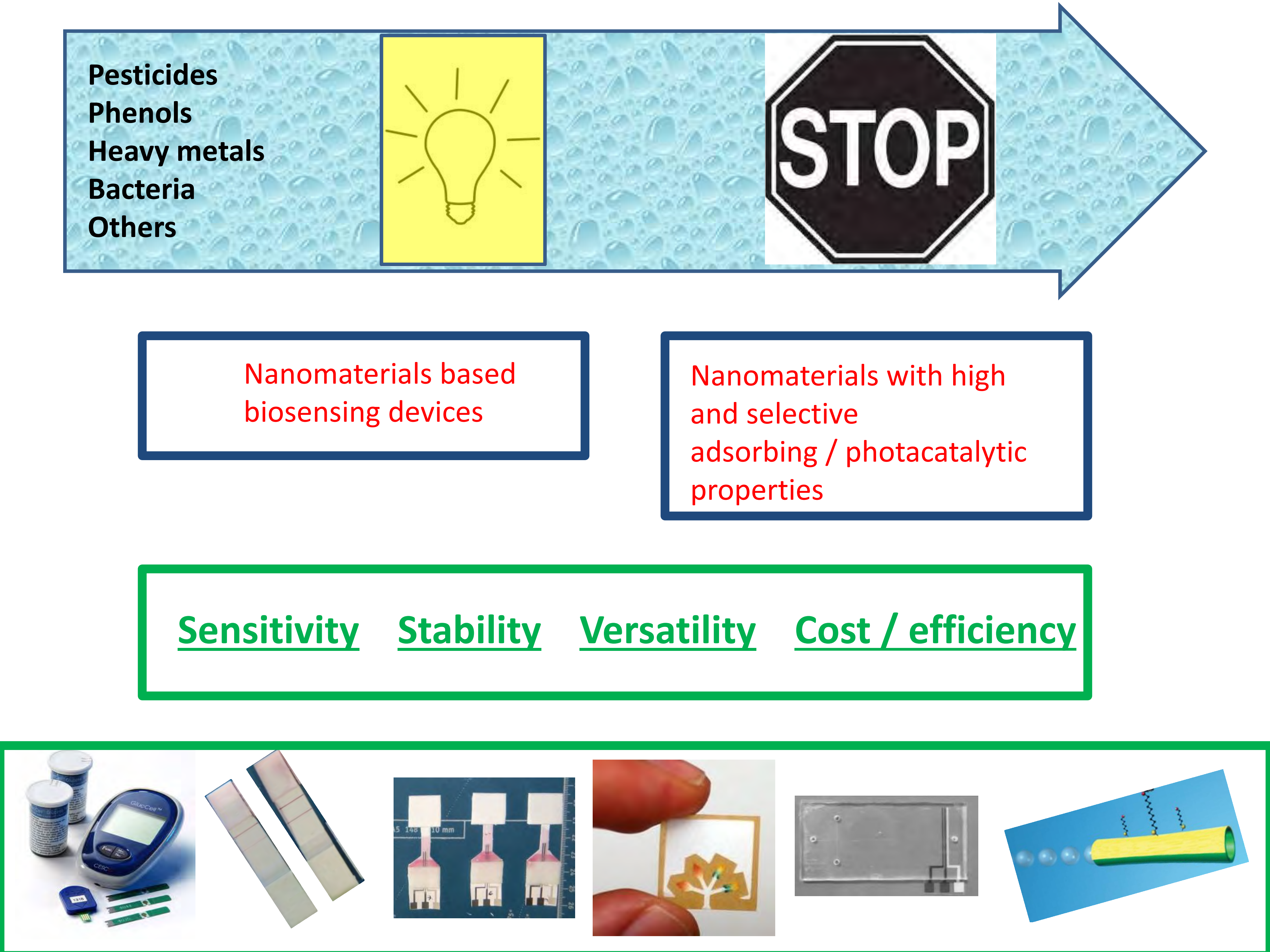
Solutions are needed for smart systems that can detect pollutants and evaluate the efficiency of their removal

In-situ smart sensors and evaluators of the pollutants removal efficiency

- High sensitivity for various potential pollutants
- Versatility in evaluating pollutants removal efficiency
- Easy to be integrated
- Cost / efficiency



Detect pollutants and gives qualitative & quantitative information for their destruction/removing strategies.

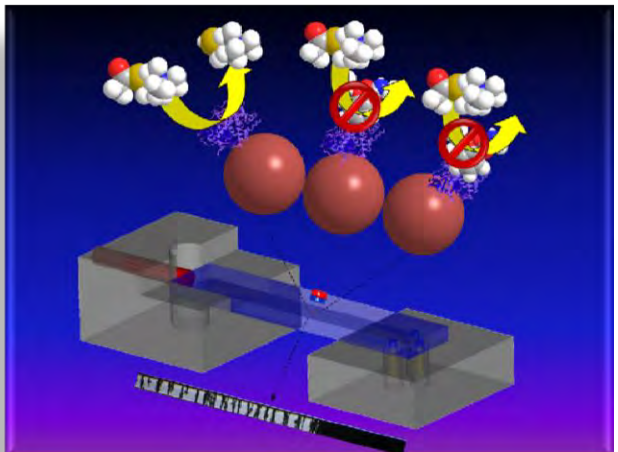

Pesticides
Phenols
Heavy metals
Bacteria
Others
STOP
Nanomaterials based biosensing devices
Nanomaterials with high and selective adsorbing / photacatalytic properties
Sensitivity
Stability
Versatility
Cost / efficiency

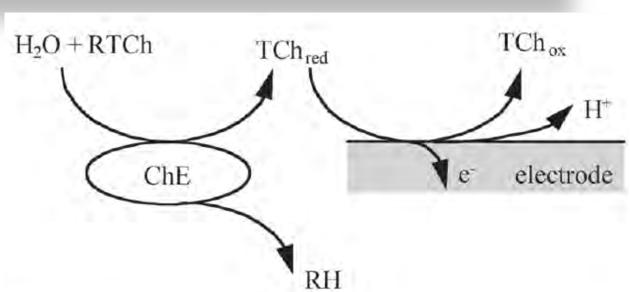
INDEX

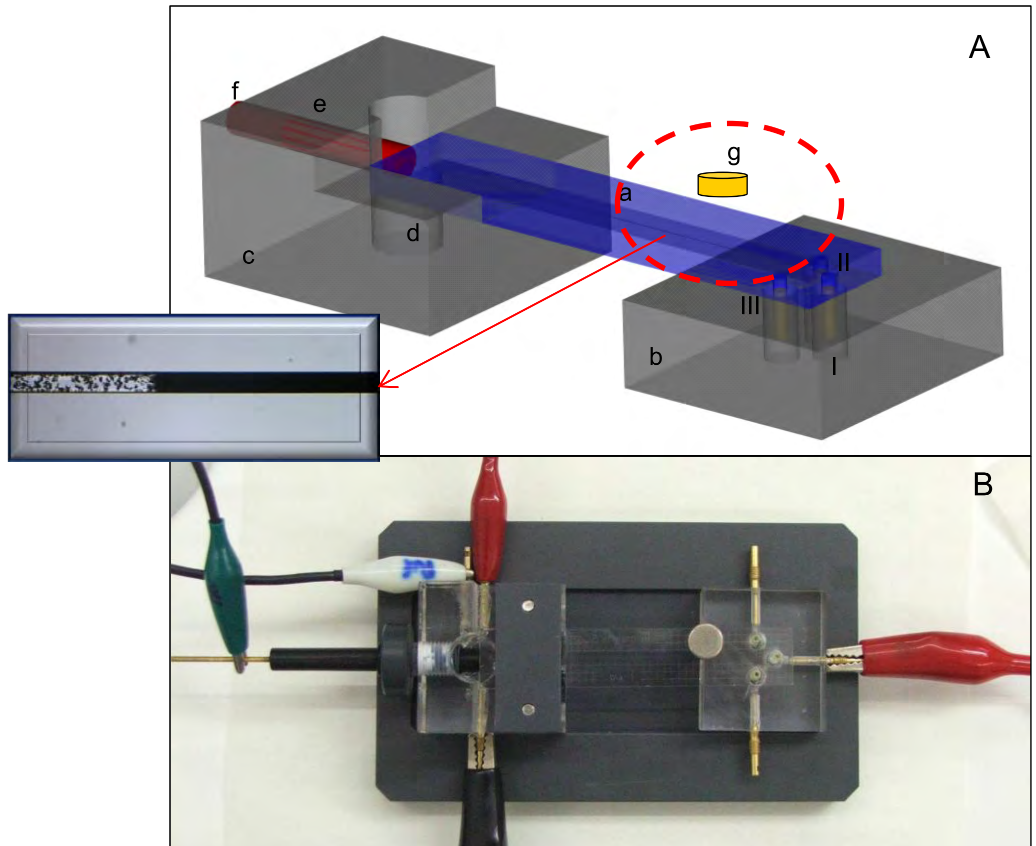
- Introduction – Our motivation and detection systems
- Lab-on-a-chip systems: Detection of pesticides and phenols
- Lateral flow / nanomotors based biosensing platforms
- Future perspectives & conclusions

Pesticides detection

Lab-on-a-chip for ultrasensitive detection of carbofuran by enzymatic inhibition with replacement of enzyme using magnetic beads.

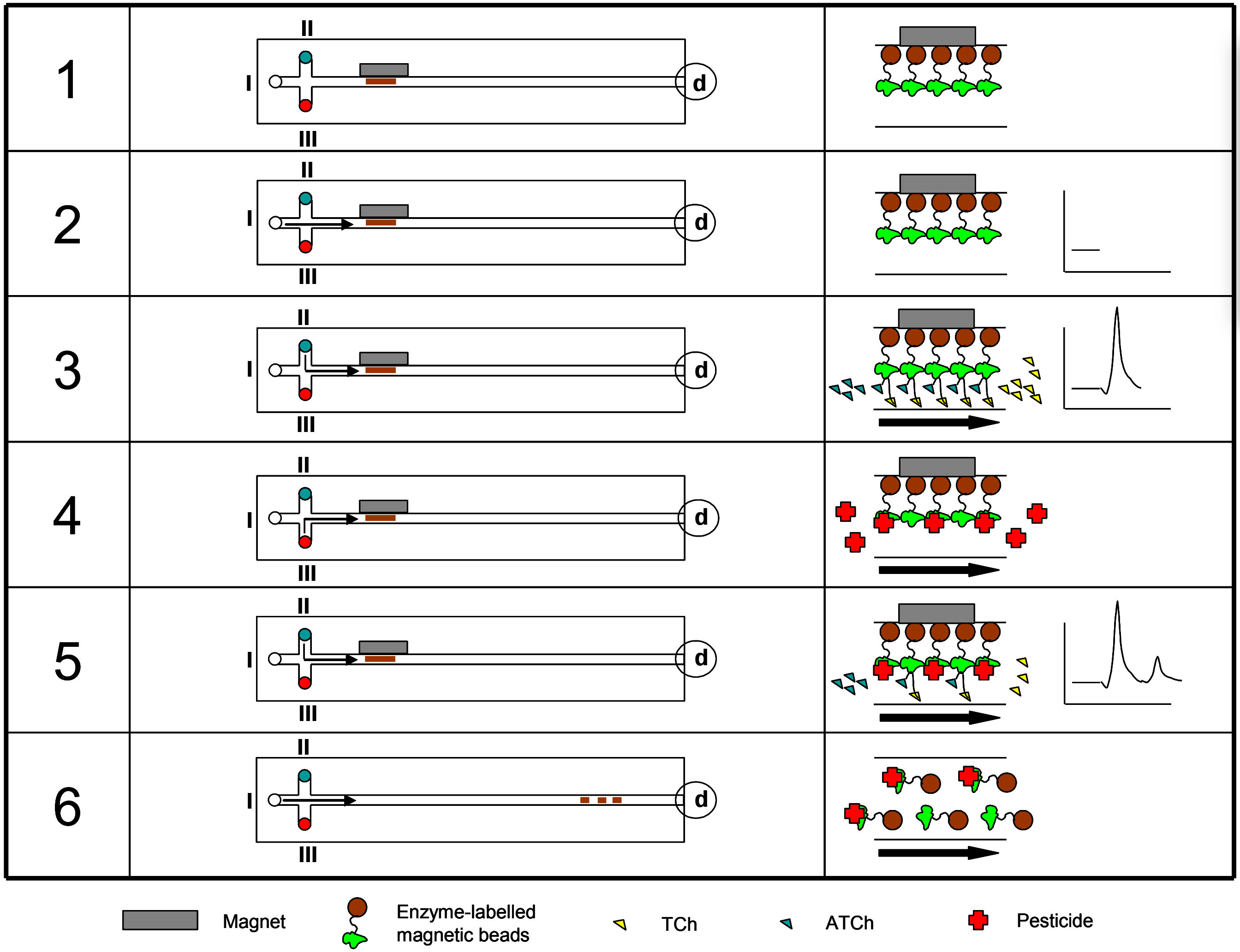


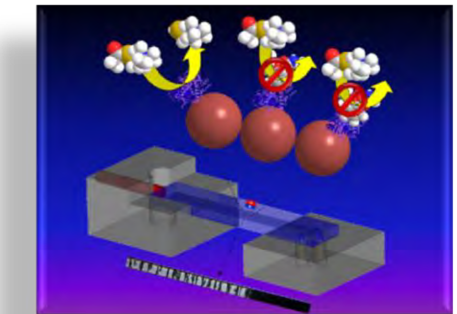




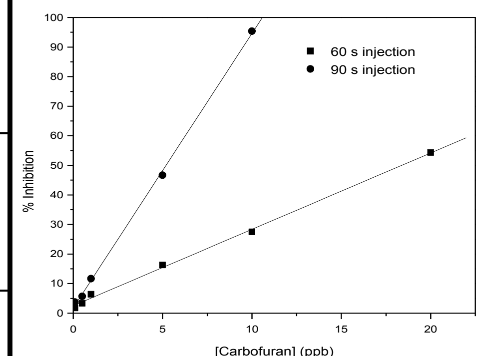
Lab Chip, 9, 213–218, 2009

Pesticides detection





$$\%I = \frac{S_{blank} - S_{inhibition}}{S_{blank}} \times 100$$

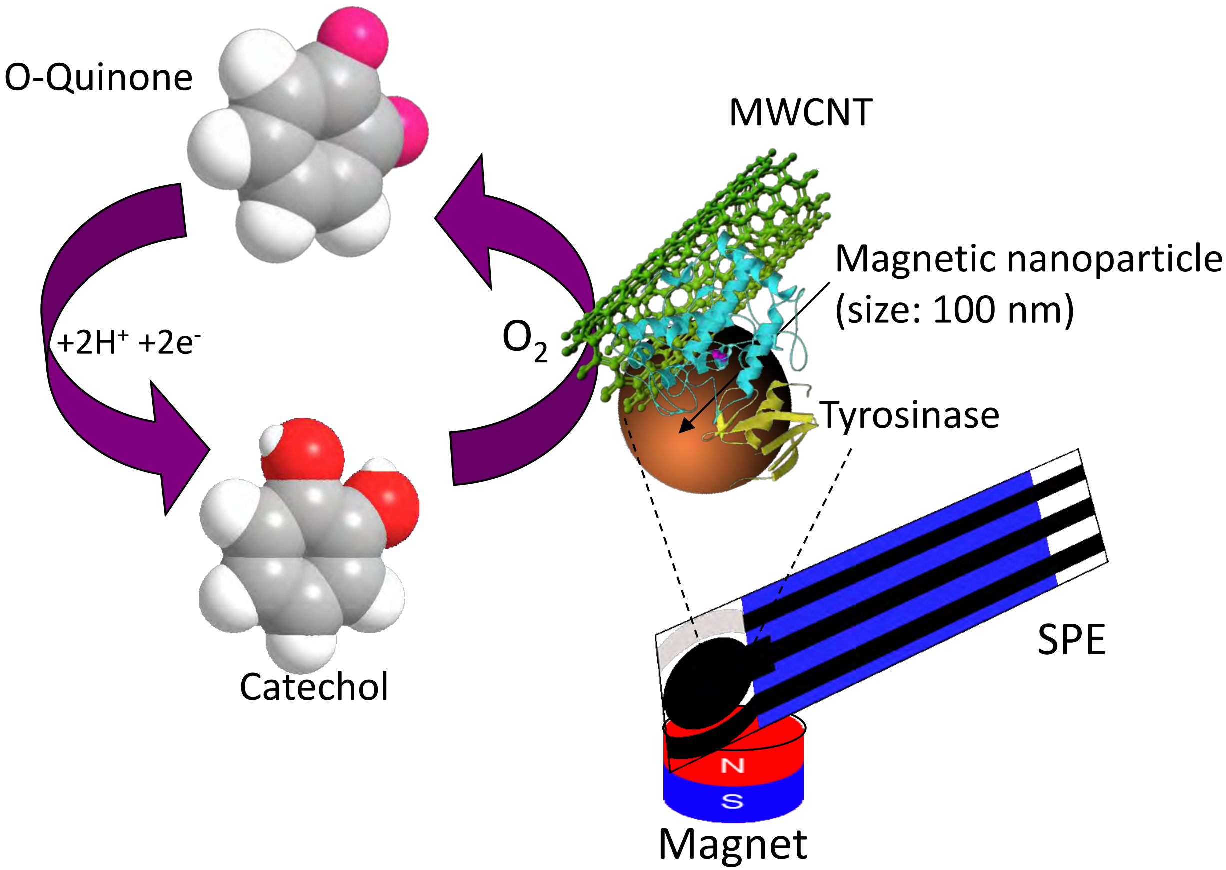


L.O.D: 0,34 ppb
(90” inhibit. time; 5% inhibit)

Lab Chip, 9, 213–218, 2009.

Phenolic compounds detection

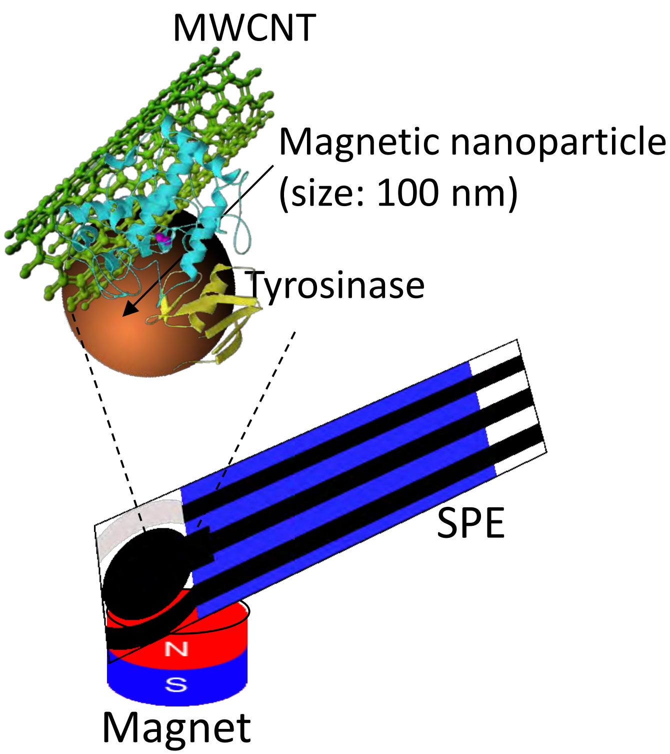
REACTION OF CATECHOL &TYROSINASE
USING A BIO-CONJUGATE ON SCREEN PRINTING ELECTRODE (SPE)

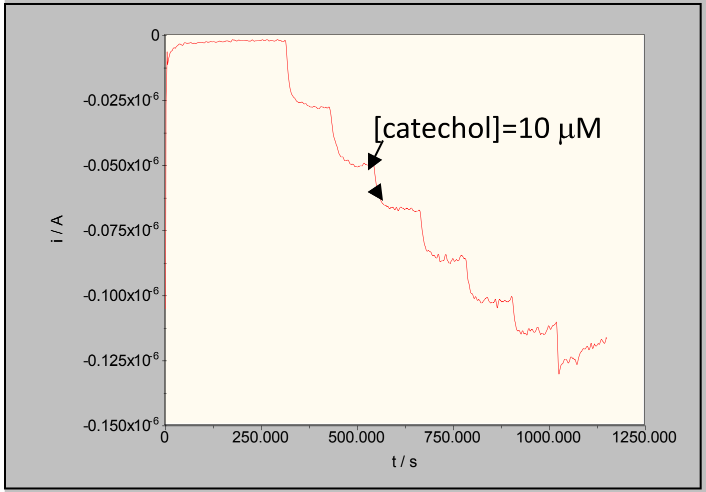


Advanced Functional Materials , 2010

Phenolic compounds detection

REACTION OF CATECHOL &TYROSINASE
USING A BIO-CONJUGATE ON SCREEN PRINTING ELECTRODE (SPE)





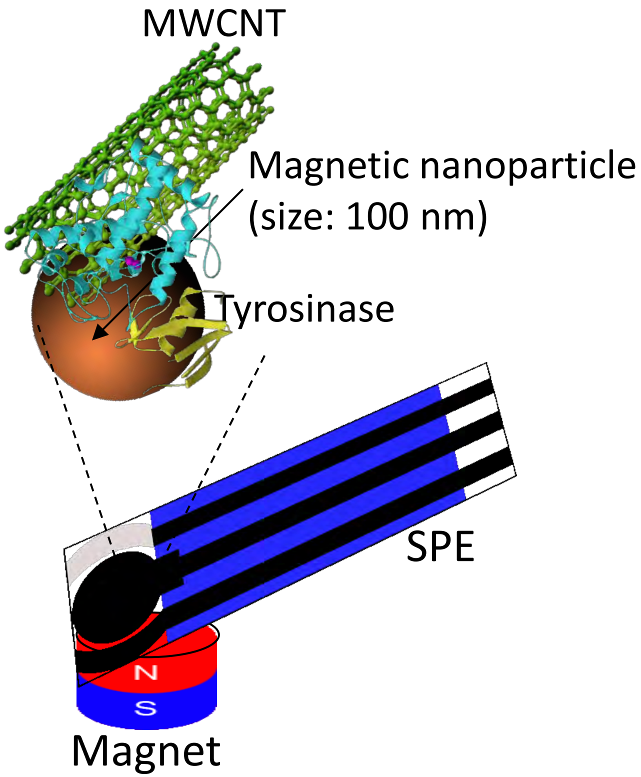
LOD= 5.4 nM
LOQ= 17.9 nM

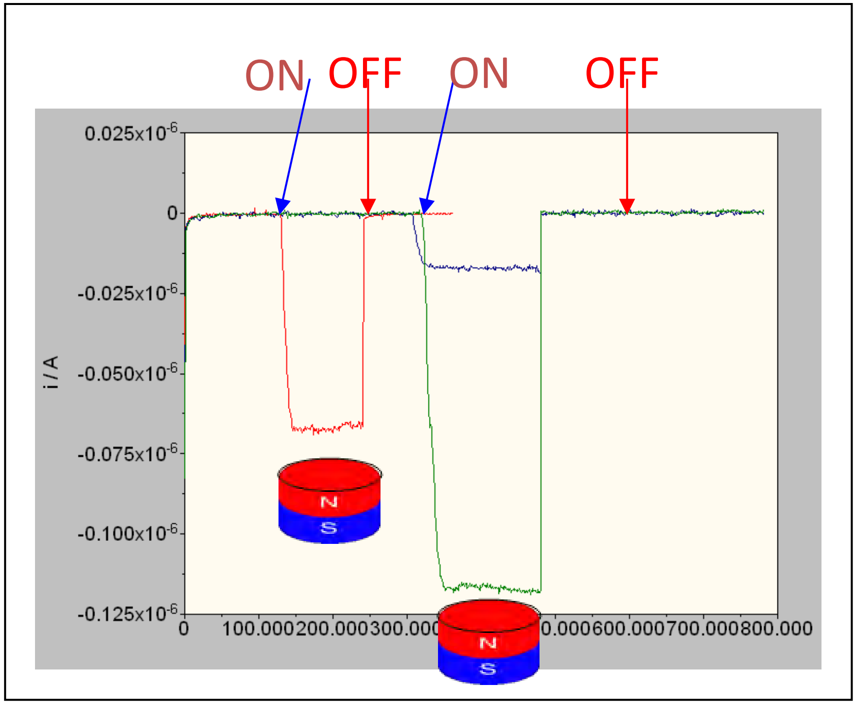
Advanced Functional Materials , 2010

Phenolic compounds detection

REACTION OF CATECHOL &TYROSINASE
USING A BIO-CONJUGATE ON SCREEN PRINTING ELECTRODE (SPE)

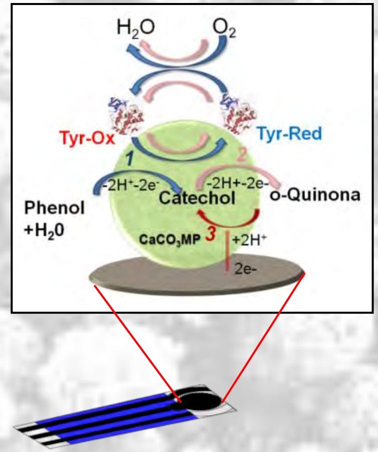
ON-OFF EFFECT INDUCED BY THE MAGNET

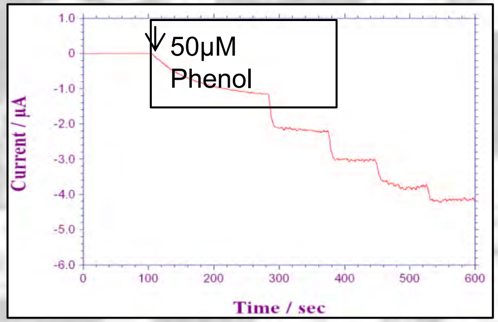




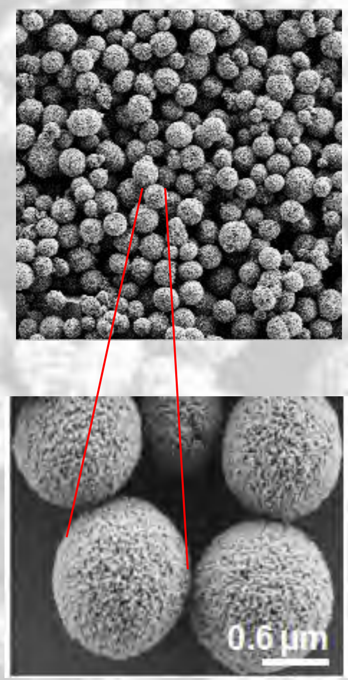
Advanced Functional Materials , 2010

$CaCO_3$/Tyr Biosensor for phenol detection

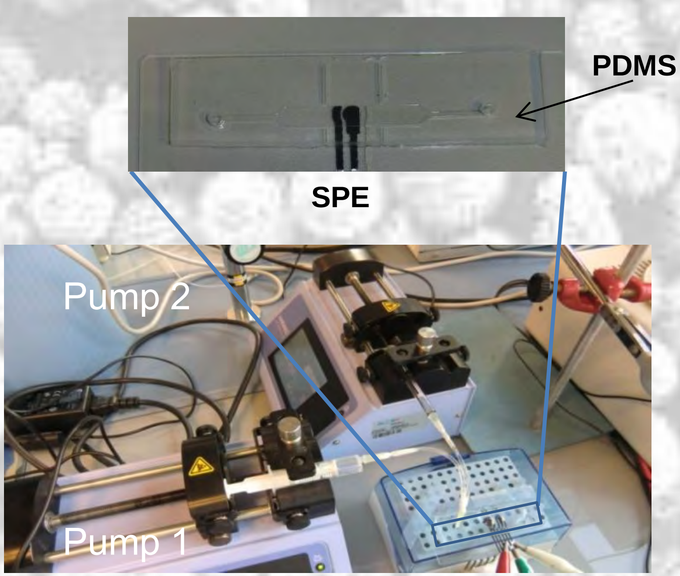




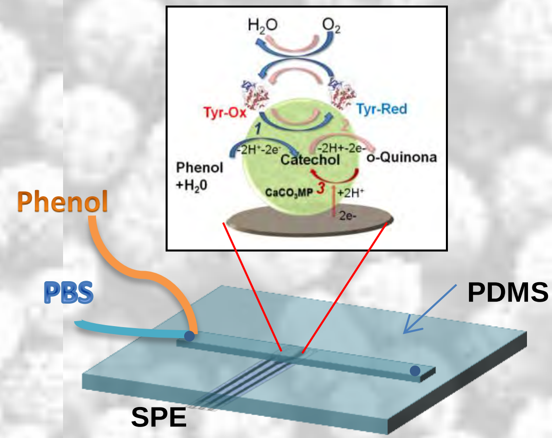
Optical and SEM Characterization of $CaCO_3$ microparticles

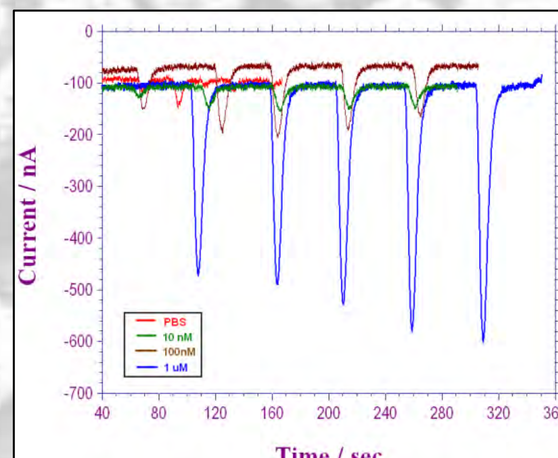


Fluidic System for Phenol Detection



Electrochemical enzyme-based biosensors constitute promising technology for the *in situ* monitoring of phenolic compounds





Electrophoresis 2013

INDEX

- **Introduction – Our motivation and detection systems**
- **Lab-on-a-chip systems: Detection of pesticides and phenols**
- **Lateral flow / nanomotors based biosensing platforms**
- **Future perspectives & conclusions**

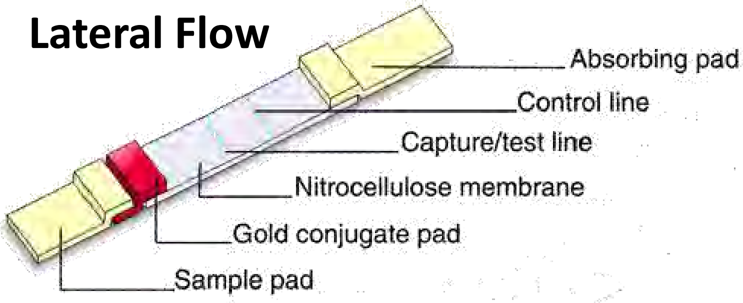
PAPER BASED NANOBIOSENSORS

Lateral flow / nanoparticles biosensing platforms

µPAD
microfluidic paper-based analytical device

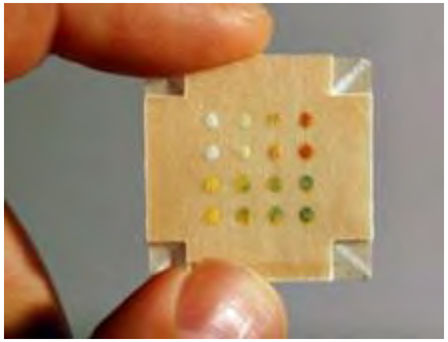
Dipstick

Lateral Flow



http://www.chimicabioanalitica.unito.it/immunoassay.htm

Anal. Chem. 2010, 82, 3(8pp)



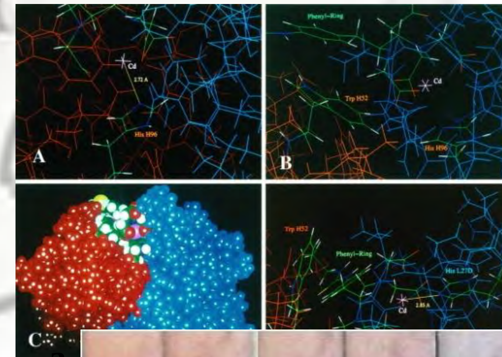
A 3-Cent HIV Test by Harvard

What can nanoparticles bring?

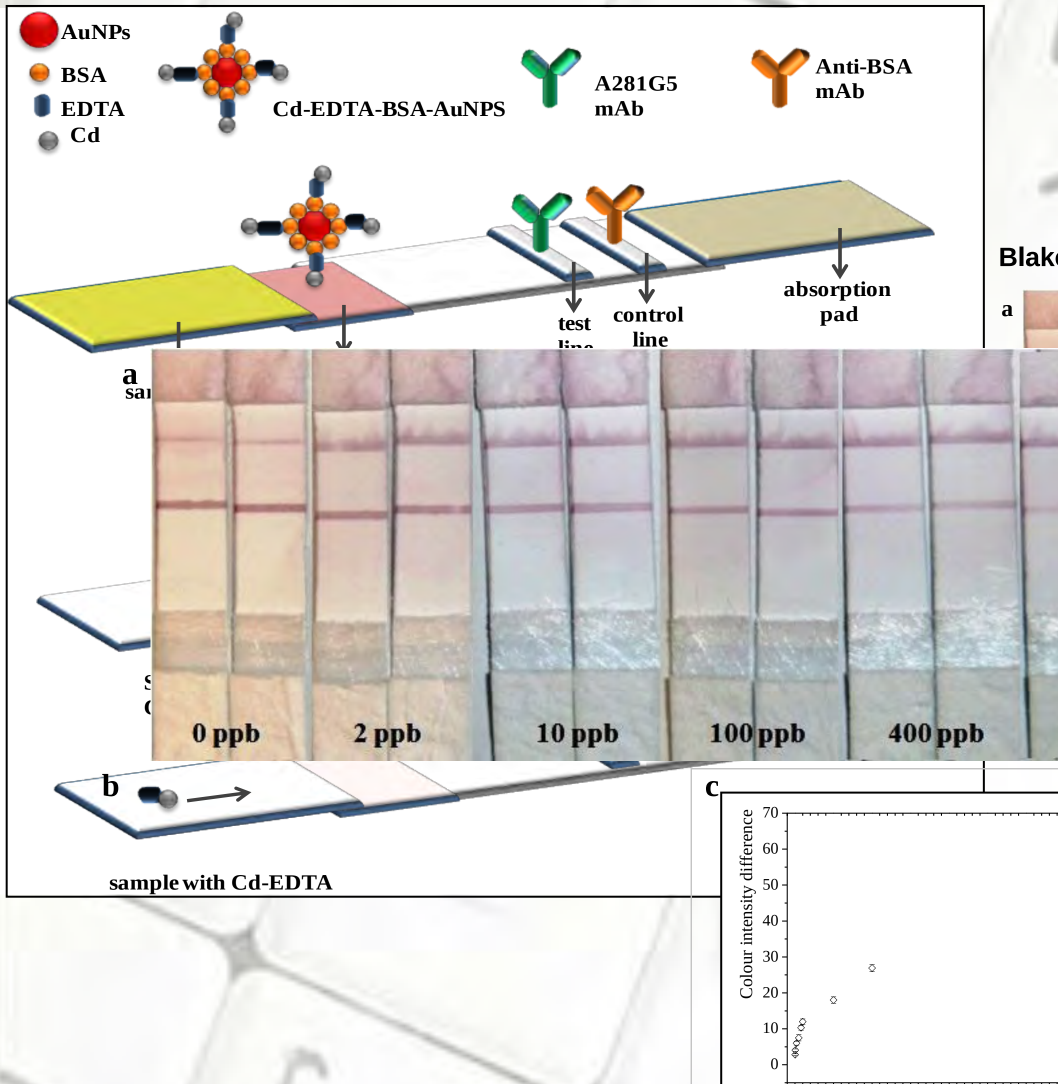
- **More stability**
- **Multidetection capability**
- **Higher sensitivity**
- **Novel / versatile detection platforms**

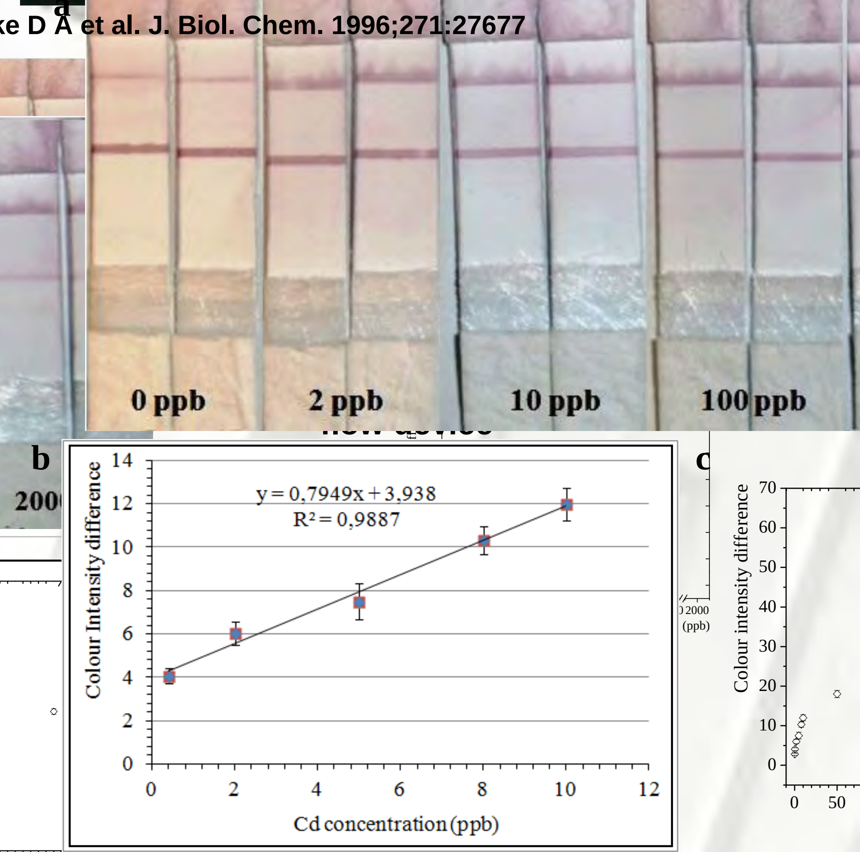
LFIA (Cadmium determination in drinking water)

Collaboration with Prof. D.Blake, Univ. Of Tulane, USA



Blake D A et al. J. Biol. Chem. 1996;271:27677



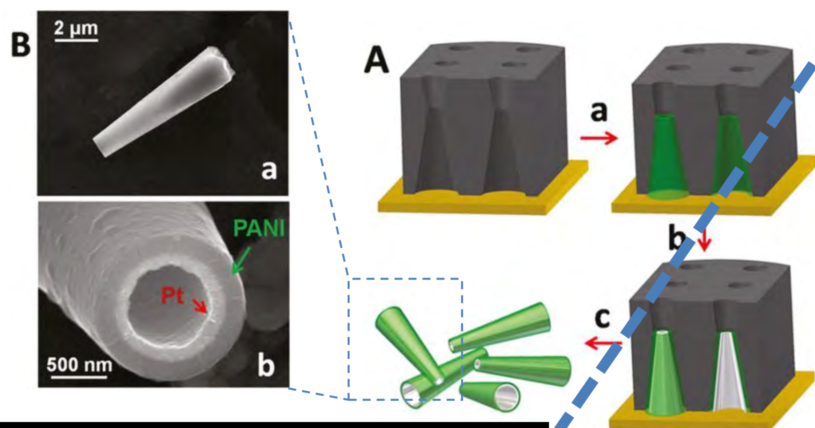


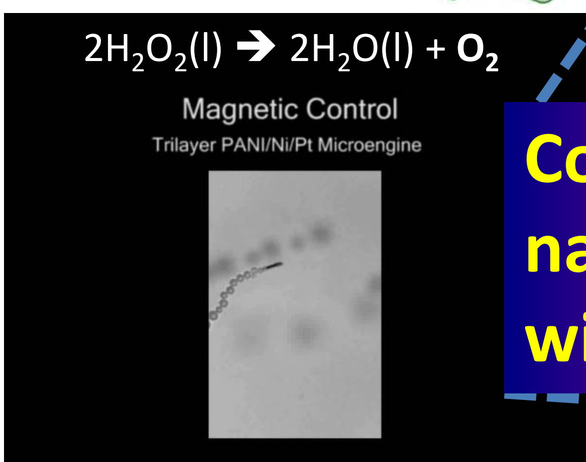
Cd-EDTA conventional biosensor device

Nano/micromotors (Collaboration with J.Wang, USA)

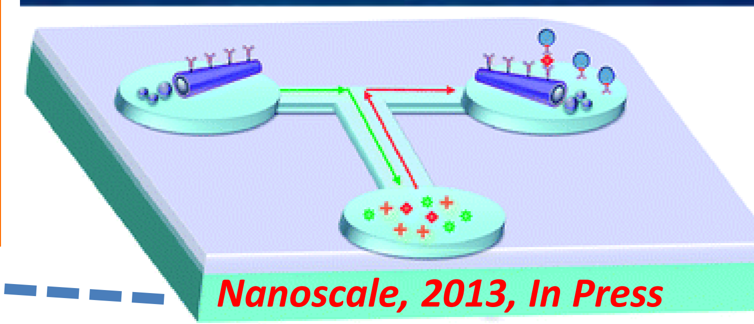
Enhancing of biosensing

Template-based catalytic microengines (no need for clean room)





Coupling nanomotors effect with biosensing



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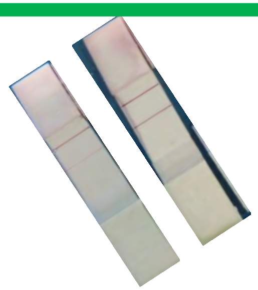
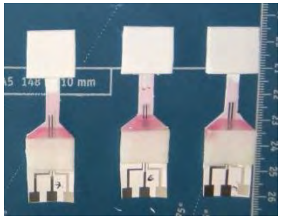
CONCLUSION / Research outcomes

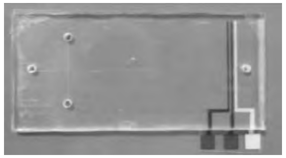
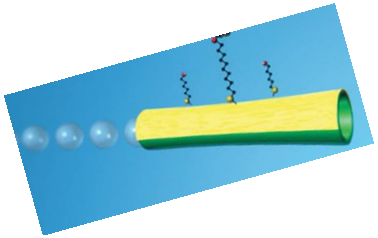
- Nanotechnology allows us to develop smaller , easy to use and cost-effective devices such as biosensors or lab-on-a-chip

- Nanoparticle based biosensing systems are shown to be high sensitive and cost effective devices with interest for environmental applications between other industries

- Simple cost/efficient paper based devices as well as nano/micromotors as novel material for enhancing of biosensing technology are promising alternatives in environmental monitoring.

- Further improvement and more efficient designs of pollutants detection systems using nanostructurated detectors including integration of pollutants sensing and removal/destruction at the same platform are still necessary.

14 nationalities

Thank you! Any question?

Nanobioelectronics and Biosensors Group
Catalan Institute of Nanotechnology (ICN)

Read more at: www.nanobiosensors.org

NANO Bioelectronics & Biosensors Group

ICN Institut Català de Nanotecnologia

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