ELECTRICAL NANOBIOSENSORS FOR ENVIRONMENT DIAGNOSTICS

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Summer School
Sustainable nanosensors for water pollution detection
Tirana, Albania 22-25 March 2023

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The Catalan Institute of Nanoscience and Nanotechnology (ICN2)

ICN2 Institut Català de Nanociència i Nanotecnologia

Barcelona Institute of Science and Technology

Institució CERCA Centres de Recerca de Catalunya

Generalitat de Catalunya

CSIC Consejo Superior de Investigaciones Científicas

UAB Universitat Autònoma de Barcelona

A cluster with nearly 750 scientists and technicians in the areas of Materials, Micro and Nanotechnologies.

ICN2 is part of BIST

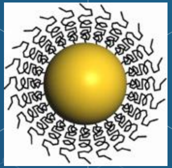
THE BARCELONA INSTITUTE OF SCIENCE AND TECHNOLOGY

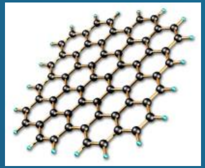
- The BIST – a private foundation created in 2015 - is a leading institution of multidisciplinary research encompassing seven top Catalan public research centres of excellence.

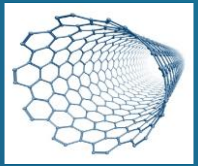
NANOBIOELECTRONICS AND BIOSENSORS

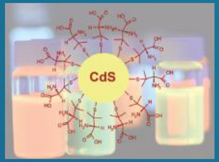
The Group

Focuses on the **discovery** and **technological development** of cutting edge nanotechnology and nanomaterials to create **simple and cost effective nanobiosensing platforms.** We do this by controlling their architectures on both the **nano** and **macro** scales with the objective to link these two worlds.









Application areas:

- ✓ Diagnostics
- ✓ Environmental Monitoring
- ✓ Food quality
- ✓ Safety / security
- ✓ Other industrial applications

Technology transfer:

paperdropdx

GraphenicaLab

OUR RESEARCH

Nanomaterials

Graphene and 2D materials,
Metal nanoparticles, quantum dots

Paper-based

Lateral flow assay, hybrid electrochemical/LFA, optical redout

Printing technologies

Inkjet printing, screen printing, graphene transfer electrodes,
FET-based biosensors,
electrochemical readout

Fully integrated PoC devices

Smartphone based,
wearables,
wireless readout

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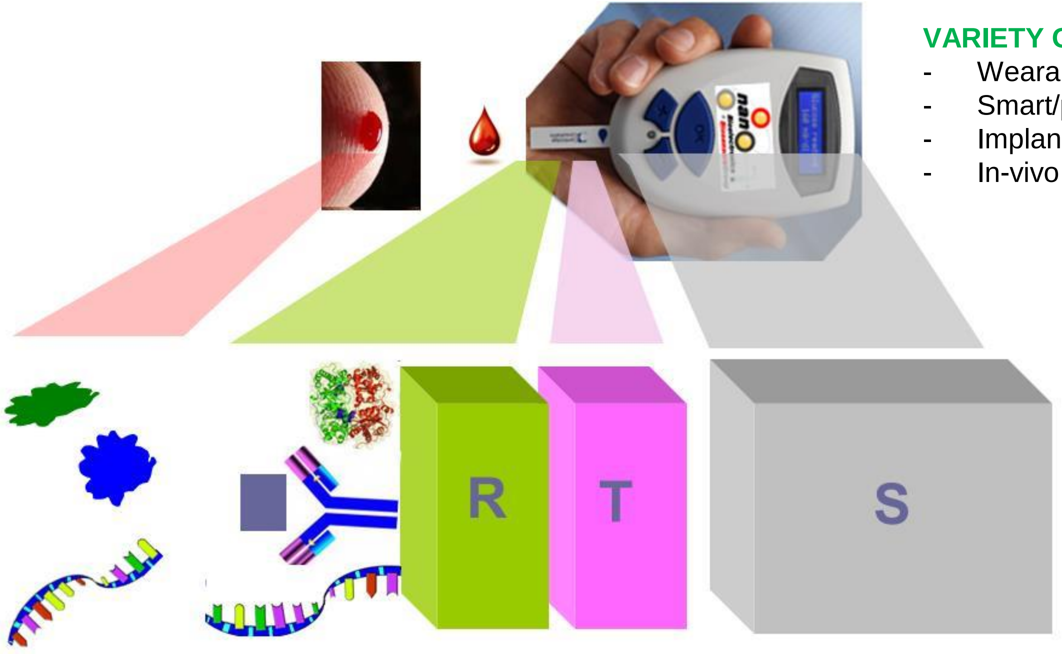
PLENTY OF POSSIBILITIES FOR NANOBIOSENSORS

VARIETY OF CONFIGURATIONS

- Wearable sensors
- Smart/packaging /food control
- Implanted devices
- In-vivo formats



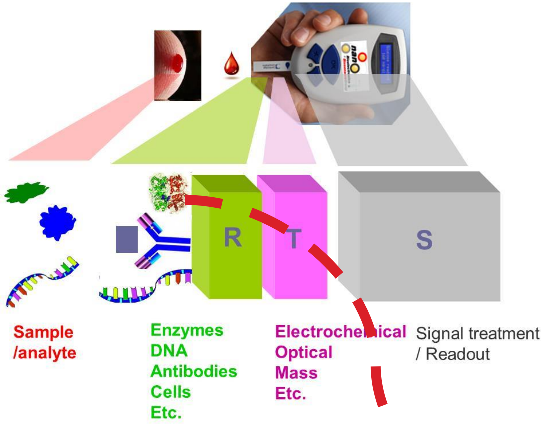
Sample /analyte

Enzymes
DNA
Antibodies
Cells
Etc.

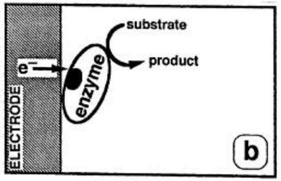
Electrochemical
Optical
Mass
Etc.

Signal treatment / Readout

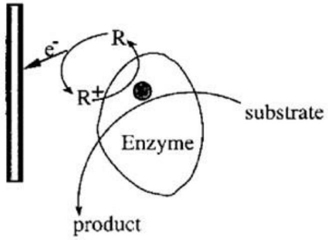
PLENTY OF POSSIBILITIES FOR NANOBIOSENSORS



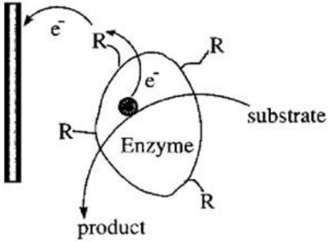
1. Direct electron transfer (DET) by suitable orientation



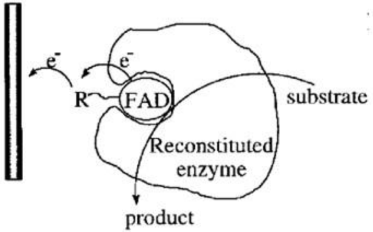
2. By diffusional mediator



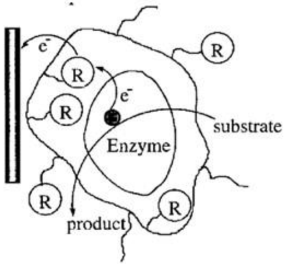
3. Tethering mediator on protein



4. Reconstitution of an apo-flavoenzyme

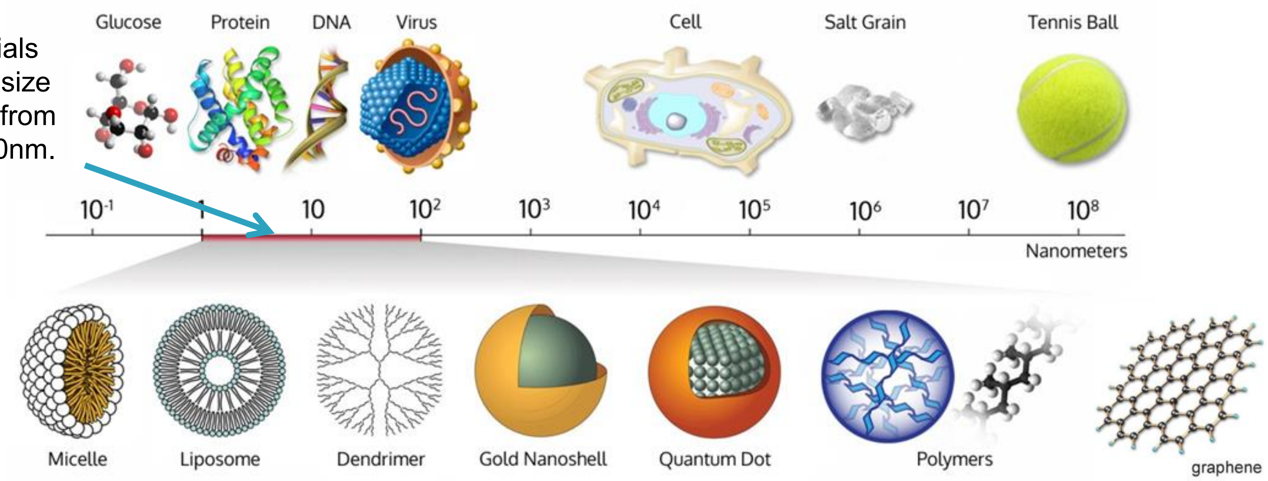


5. Immobilization into a redox polymer



Nanotechnology: New source of possibilities to improve biosensors. Most of expectations comes from the fact that matter behaves differently at the nanoscale -> Plenty of new possibilities emerge from nanomaterials.

Materials whose size ranges from 1 to 100nm.



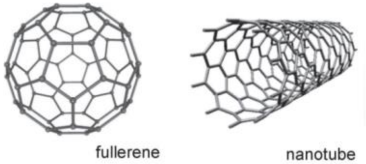
http://wichlab.com/research/

Nanomaterials advantages:

- Large surface-to-volume ratio
- Shape
- Physicochemical properties regarding composition
- Binding characteristics

Examples of nanomaterials:

- **Nanoparticles**
- Nanowires, nanotubes
- Graphene
- **Nanochannels**
- Nanostructured surfaces.



Fullerenes, Graphene and Carbon nanotubes
http://www.naturphilosophie.co.uk/graphite-graphene-kitchen-blender/

BIOSENSORS CAN BE EVERYWHERE

Medical devices

Wearables

Smart Phone

Smart TV

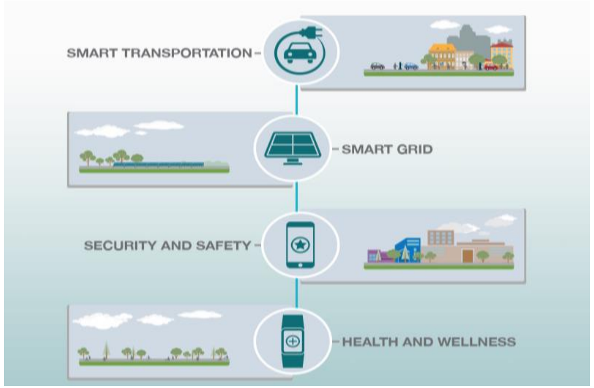
Smart Fridge

Smart washing machine

Smart houses

Food/plant control

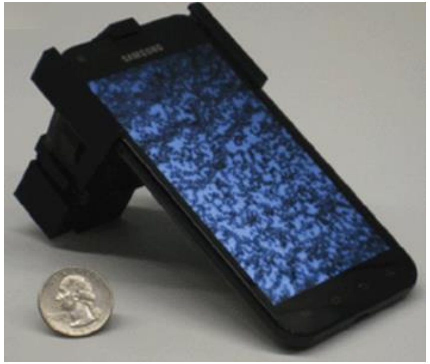
Environment control



Smart cities

Integration of biosensors with real world applications

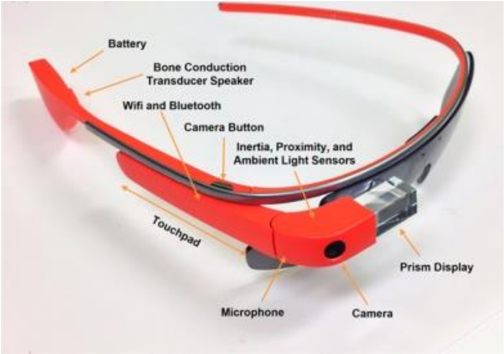
http://store.idetekt.com

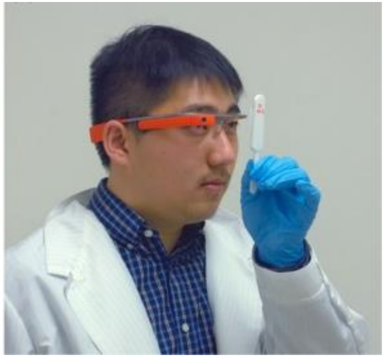


Navruz I, et al. ***Lab Chip****, 2013, 13, pp. 4015-4023*

Nimerosky A, et al. ***PNAS****,*
111, 33, pp. 11984–11989

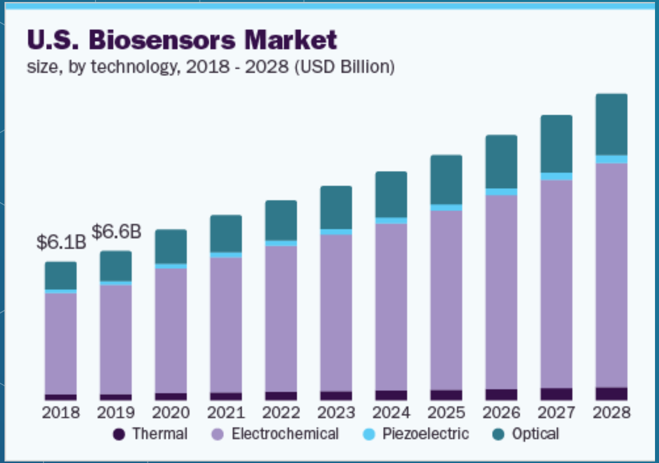
Gallegos D, et al. ***Lab Chip,***
2013, 13, pp. 2124-2132





Feng S, et al. ***ACS Nano.*** *2014, 8(3),pp. 3069–3079.*

Quesada, Merkoçi, Biosensors and Bioelectronics 73 (2015) 47–63



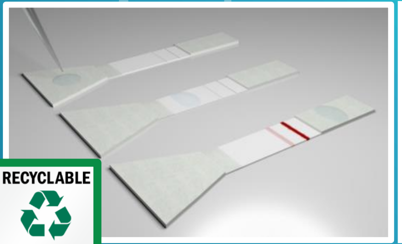
Diagnostic devices to be used at the Point of Care need to be REASSURED:

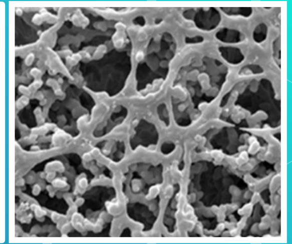
The need

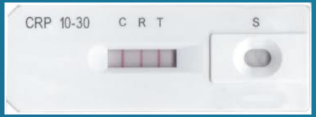
- **R**eal-time connectivity
- **E**ase of Specimen collection
- **A**ffordable
- **S**ensitive
- **S**pecific
- **U**ser-friendly
- **R**apid and **R**obust
- **E**quipment-free
- **D**elivered

Substrates

- Paper
- Flexible/sustainable plastics



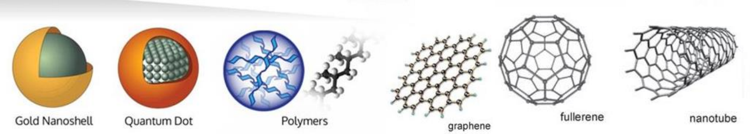




- Low-cost and abundant material
- Easy to manufacture
- Recyclable & sustainable
- Microfluidic properties

Transducers

- Metallic NPs
- Graphene
- Aptamers



- Plasmonic properties
- Electrocatalytic materials
- Conductive nanoinks
- DNA-based bioreceptors

Readers

- Naked eye
- Smartphones
- Portable readers

OUR CHALLENGES

❶ Can we make diagnostic devices completely non-invasive?

❷ Can we ensure continuous / real time (bio)monitoring?

❸ Which partners & expertise's we need to develop devices for real applications that generate (bio)data?

❹ How to make cheap/low cost devices that can be disposable?

❺ How to correlate (sensor)data to get insights about the body?

Nanobiosensors

Nanomaterials

- Gold Nanoparticles
- Quantum dots
- Iridium Oxide Nanoparticles
- Gold Nanoclusters
- Graphene

Readout

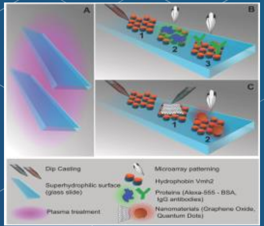
Electrochemical and optical sensors, including smartphone sensing and portable readers

Substrate

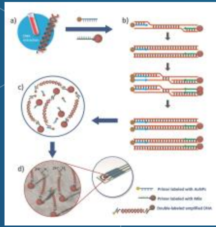
- Paper
  - Nitrocellulose
  - Cellulose
- Plastic
  - PET
  - PDMS

Applications

- Alzheimer disease
- Cancer
- Leishmania
- Pesticides
- Bacteria
- Pollutants

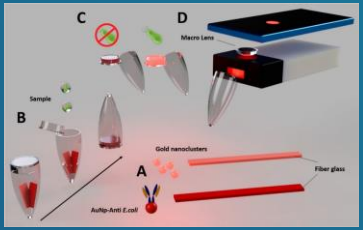


Adv F Mat 25, 6084, 2015



Small 12, 205, 2016

Sci Rep 7, 976, 2017

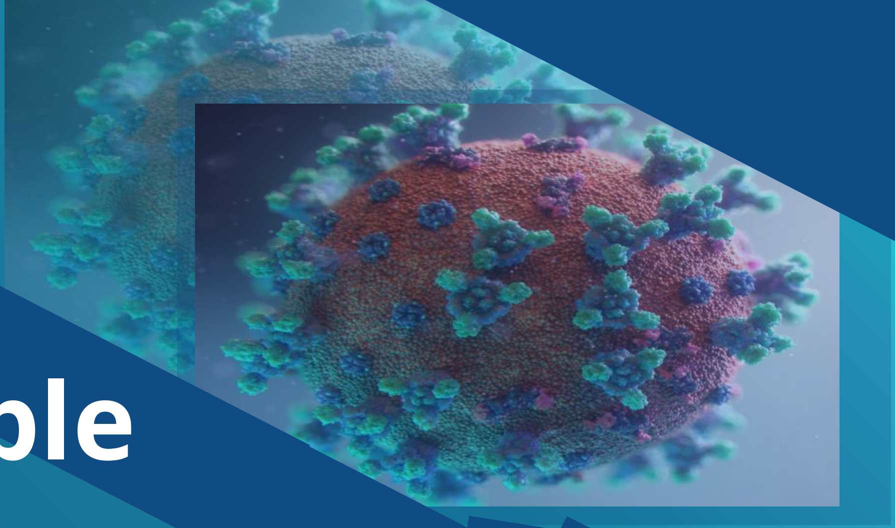


Anal. Chem. 92, 4209, 2020

ACS Nano 14, 2585, 2020

WHY DO WE NEED FAST AND EFFICIENT DIAGNOSTICS?

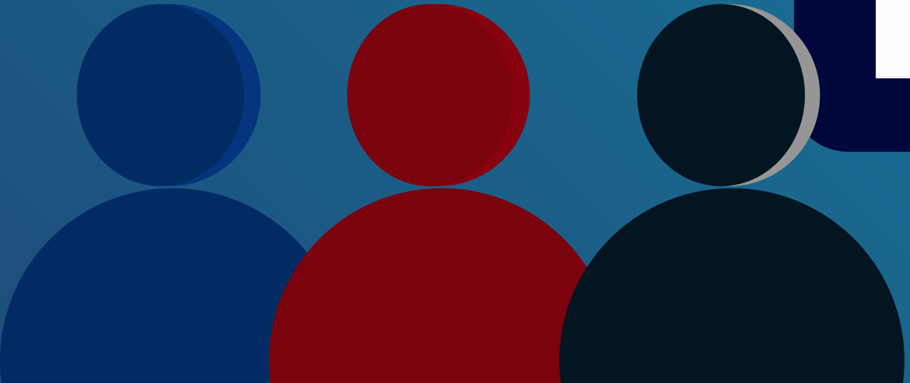
COVID-19: A tremendous real world example



Showing the necessity of efficient diagnostics for the protection of us all

We are living through a global crisis:

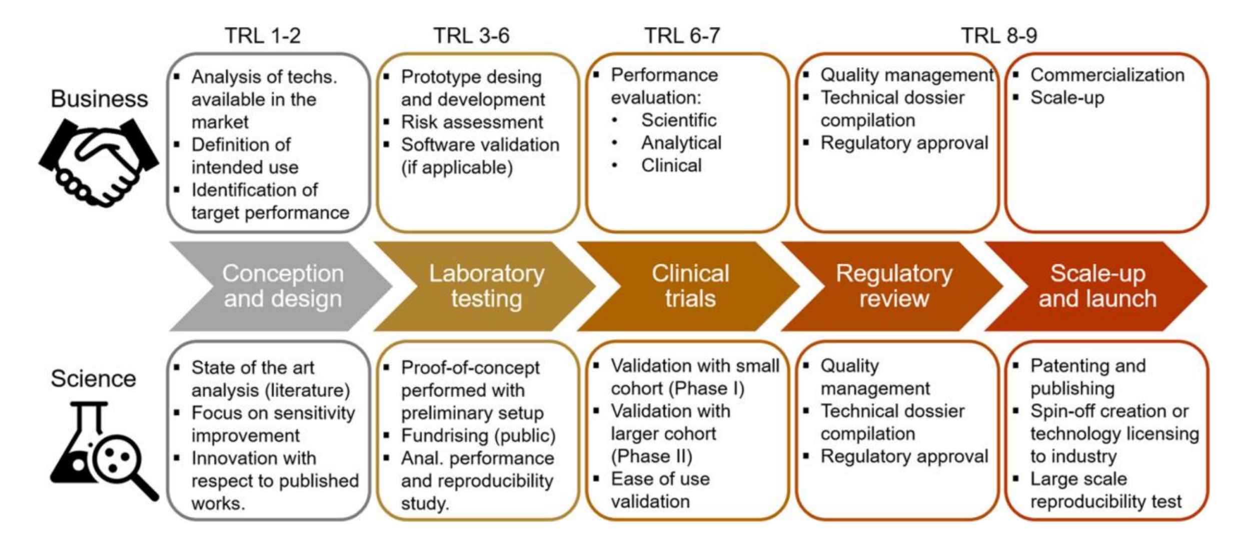
- 252 million infected
- 5 million death



How COVID19 changed the scenario

The development of new diagnostic devices is a process characterized by several bottlenecks. Most of them related to sub-optimal interactions between the actors involved, i.e.:

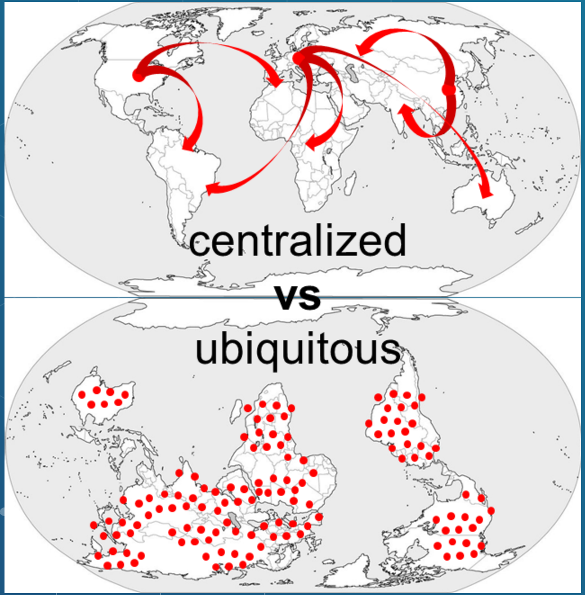
- **The scientists**
- **The clinics**
- **The regulatory bodies**
- **The companies**



What can we do to change the status quo?

Merkoçi et al. 2021 Nanodiagnostics to Face SARS-CoV-2 and Future Pandemics: From an Idea to the Market and Beyond **ACS Nano**. https://doi.org/10.1021/acsnano.1c06839

Ubiquitous fabrication of nanobiosensors



Centralized production of nanobiosensors

↓

Ubiquitous fabrication of nanobiosensors

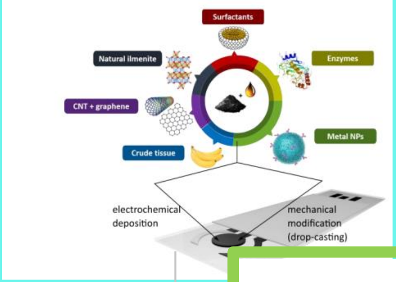
With appropriate materials, inks, and easy protocols, a consumer printer can be used to fabricate advanced nanobiosensors, successfully facing supply chain interruptions and democratizing these technologies

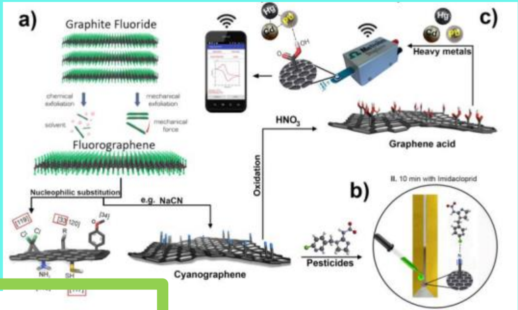
DEMOCRATIZE THE DIAGNOSTICS

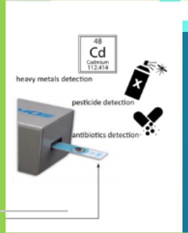
- Innovative nanomaterials and nanotechnologies
- In-situ and easy production
- Low-cost scalability
- Portability
- Sensitive, reproducible
- Equipment-free

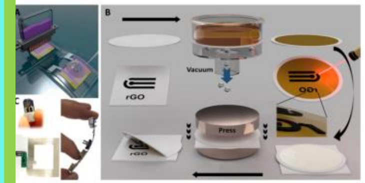
DEVELOPMENT OF SUISTANAIBLE NANOBIOSENSORS

BOOSTING RESEARCH CAPABILITIES IN OTHER COUNTRIES









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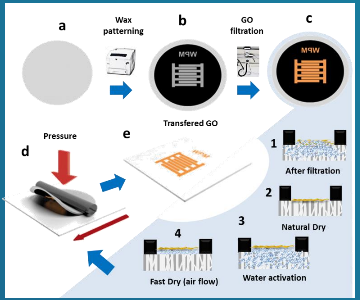
Electrochemical Biosensors

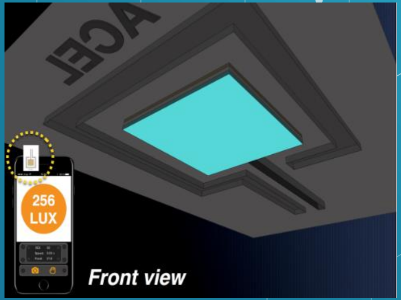
Fabrication technologies

Detection methods

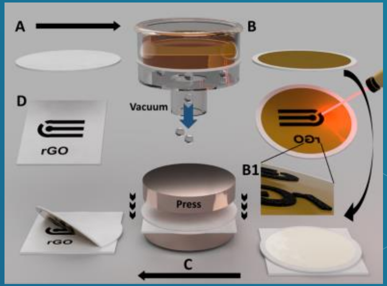
- Amperometric
- Potentiometric
- Conductometric
- Impedimetric
- Field effect



ACS Nano 10, 853, 2016



Appl Mater Interfaces 10, 20775, 2018

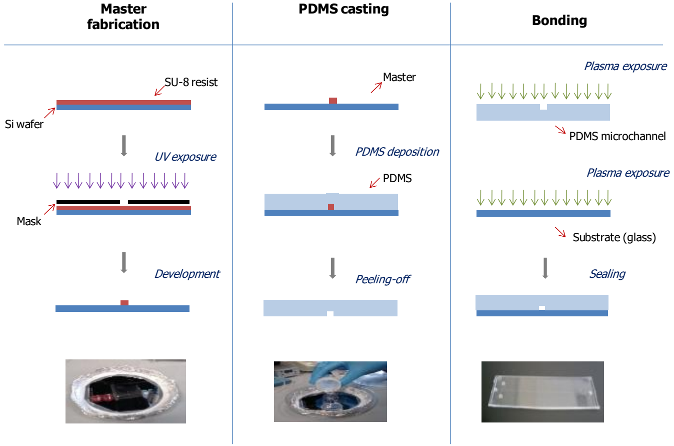


2D Mater. 7, 024006, 2020

Chip fabrication and electrode integration

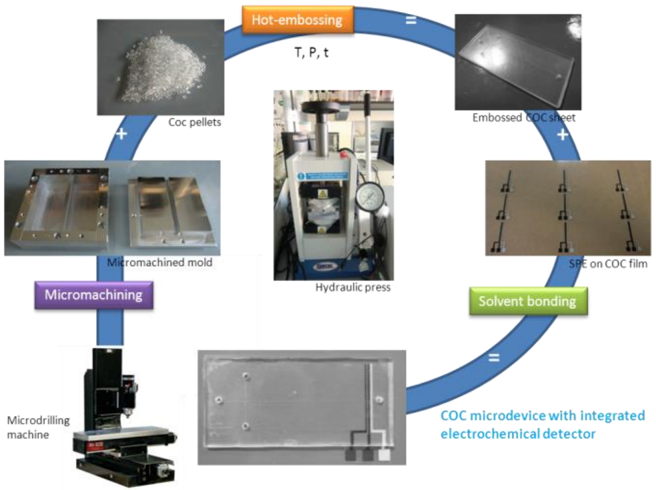
PDMS Chips

softlithography process

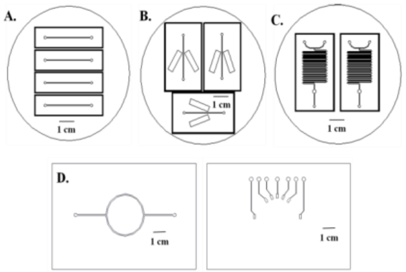


COC Chips (Collaboration. J.L.Viovy)

Simple and low cost fabrication techniques

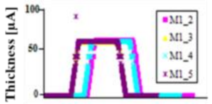


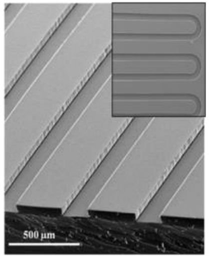
Chip fabrication and electrode integration



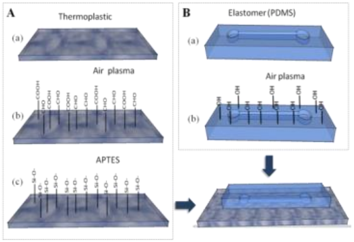
Designs of different microfluidic platforms

M1	63.12 µm		
M2	71.37 µm		
M3	64.87 µm	Average	54.89 µm
M4	61.47 µm	Standard Deviation	3.82 µm
M5	61.99 µm		
M6	57.49 µm		

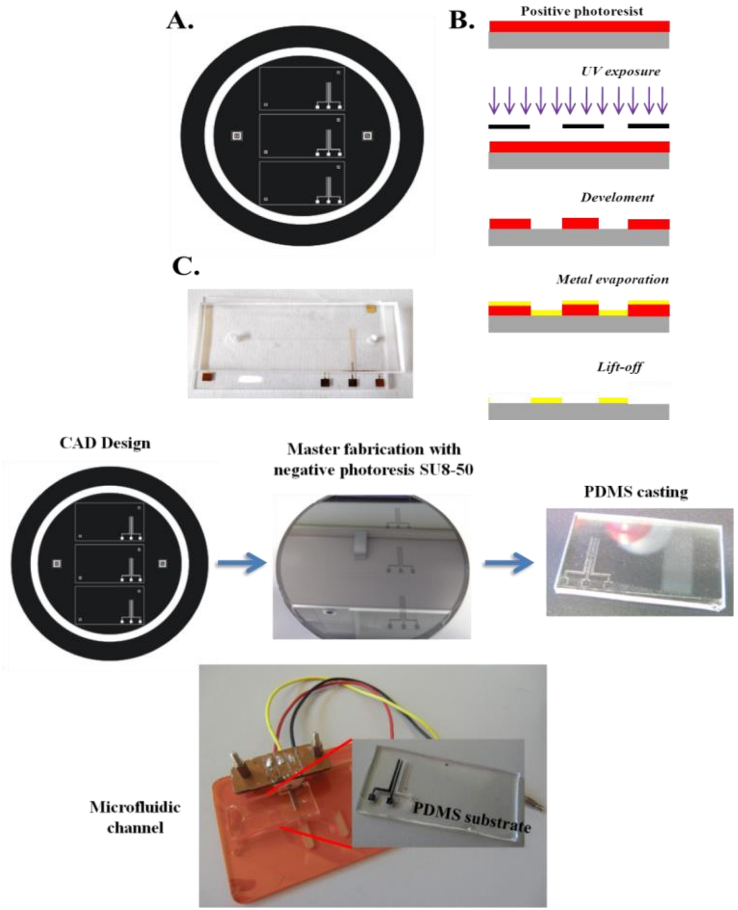




SEM images of the PDMS channel



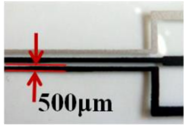
Bonding thermoplastics and PDMS

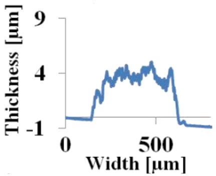


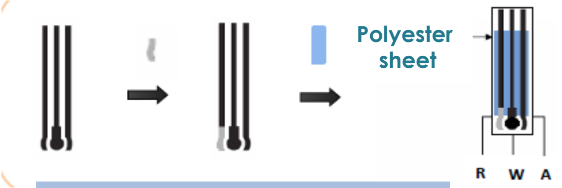
Electrode integration

Electrode fabrication

Screen printing

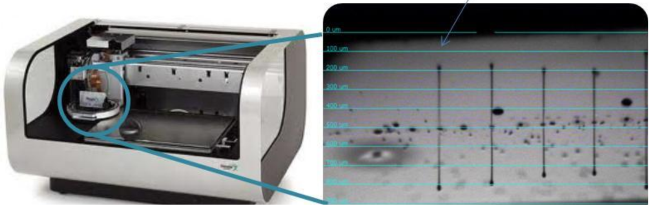


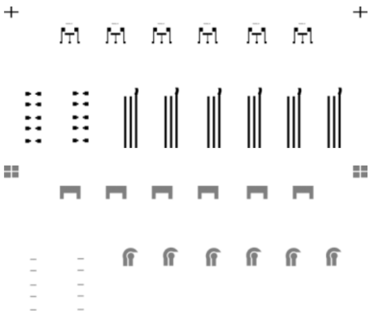


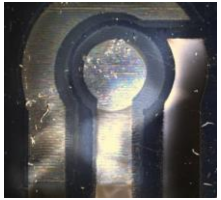


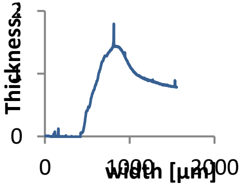
-High viscosity inks
-Electrodes width up to 20 µm (if the surface is pretreated)
-Thickness up to ~ 4 µm

Inkjet printing









-Low viscosity inks
-Electrode width up to 20 µm without surface treatment
-Thicknesses up to 1µm

Paper-based biosensors

Why to move biosensors to paper format?

Paper…

…is formed by cellulose.

- Low-cost and aboundant material.
- Easy to manufacture
- Recyclable & biosustainable.

…has a porous matrix.

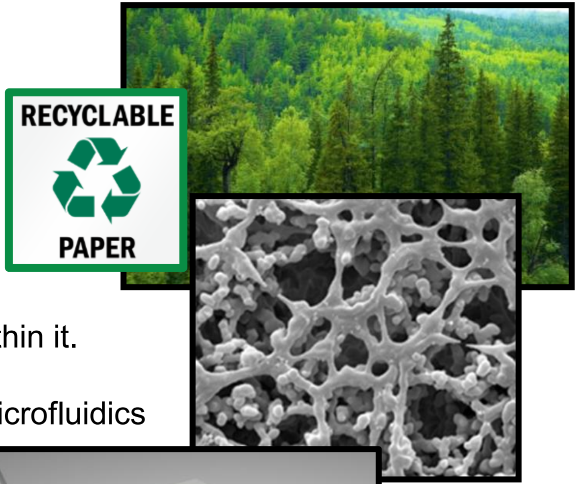
- Several reactions can be carried out within it.
- The porosity can be modified.
- Capillary forces creates autonomous microfluidics making "zero energy" device!

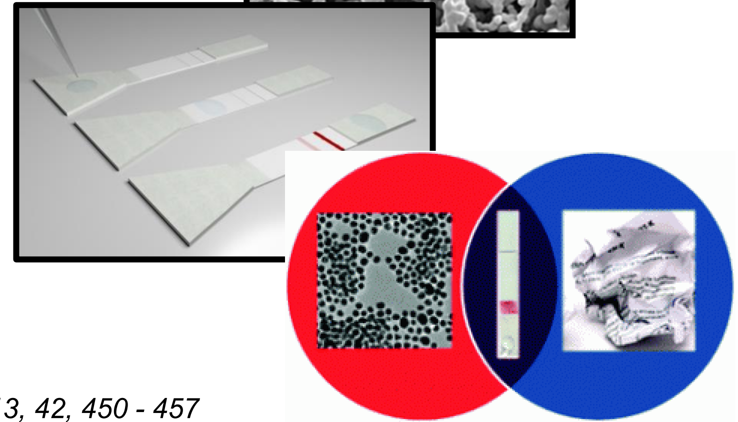
…is easily tunable.

- Its microfluidics by porosity.
- Its architecture.

…is compatible with nanomaterials

- Printing of nanomaterials
- Easy nanoplasmonics





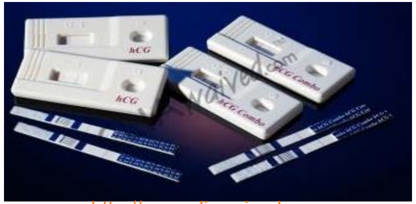
Claudio Parolo, Arben Merkoçi. *Chem. Soc. Rev., 2013, 42, 450 - 457*

Paper based biosensors

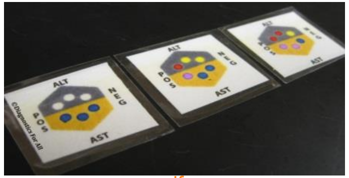
Simple is the best

- **Dipsticks**
- **Lateral Flow strips**
- **Microfluidic devices**

https://www.microessentiallab.com/



http://www.cliawaived.com

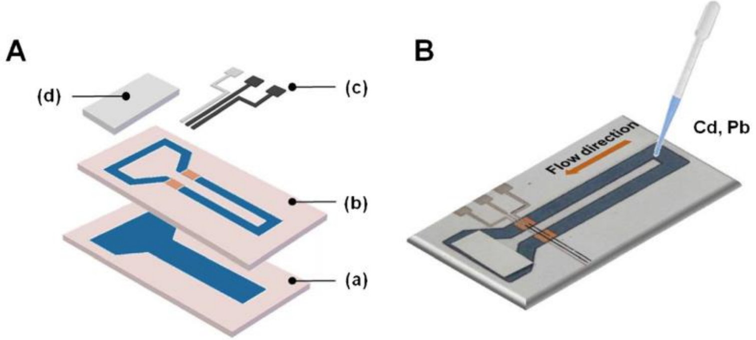


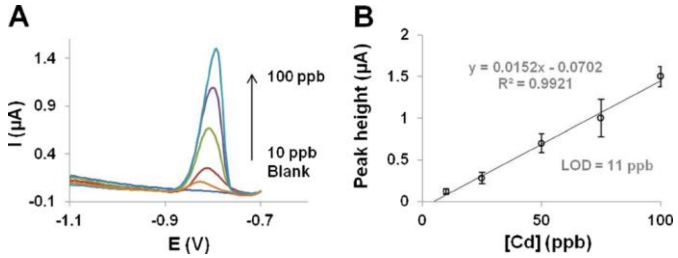
www.dfa.org

Type of paper-based biosensor	Possible detection methods	Advantages	Disadvantages
Dipstick	• Optical	• Easy design • Fast optimization	• Just one step • Only optical detection • Mostly no quantification
LFA	• Optical • Electrochemical	• Versatile • Flow • Electrochemical detection • Possible quantification	• Long optimization times • Long fabrication • Sample volume (around 100 µL)
µPAD	• Optical • Electrochemical • Chemiluminescence • MEMS	• Versatile • Flow • Different detection methods • Quantification • Small sample volume (less than 10 µL) • Massive production	• Long optimization times

Parolo, Merkoçi Chem. Soc. Rev., 2013, 42, 450

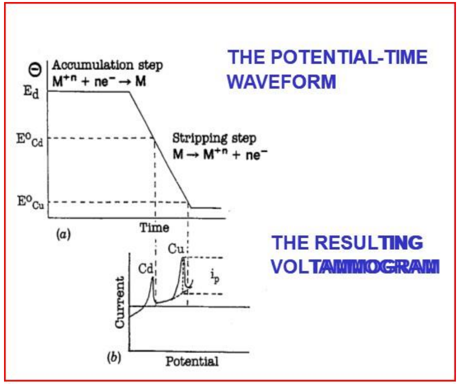
Electrochemical lab-on-paper for heavy metal detection

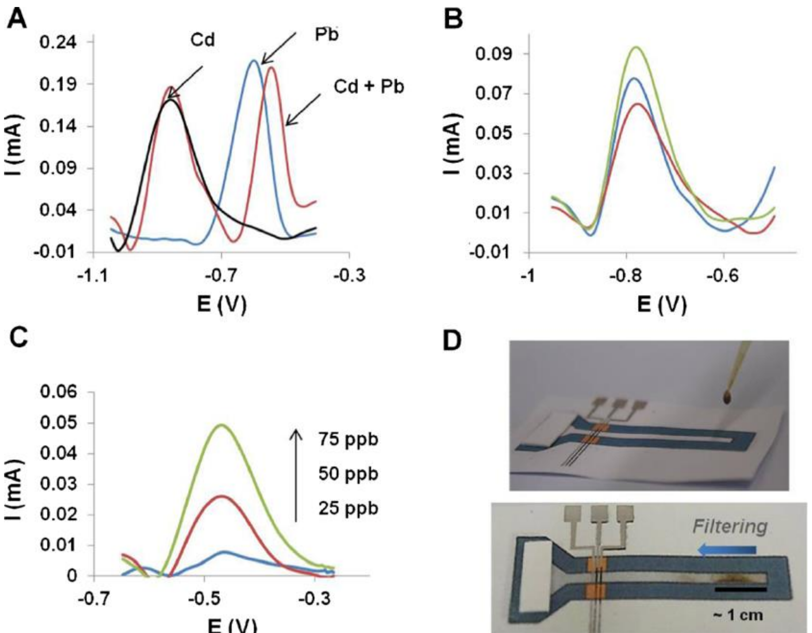




The quantification of lead and cadmium in aqueous samples

from 10 to 100 ppb with a limit of detection of 7 and 11 ppb respectively.



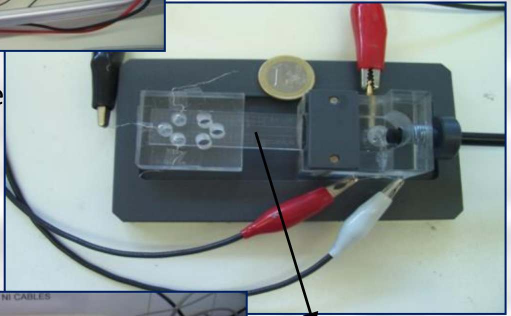


Merkoçi et al., Anal Bioanal Chem (2015) 407:8445–8449

CNT / LOC and capillary electrophoresis-based analysis

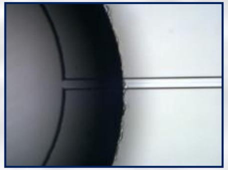
Carbon based detectors for out-channel LOC detections
Rigid Graphite-Epoxy Composite Detector / CNT modified electrodes
Detection of nitrocompounds, phenols etc.

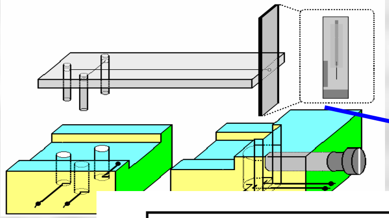
High voltage

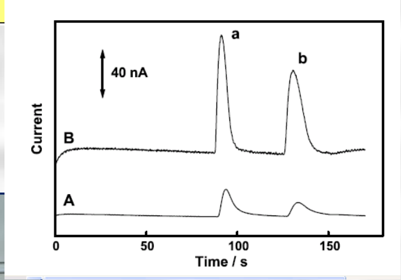


Chip (Micralyne; MC-BF4-001)

Measuring instrument





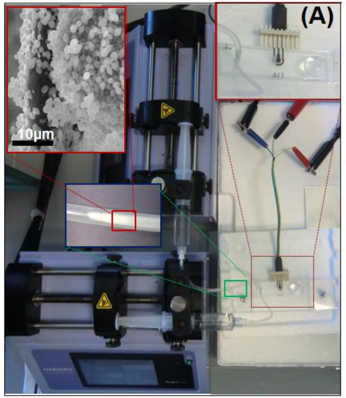


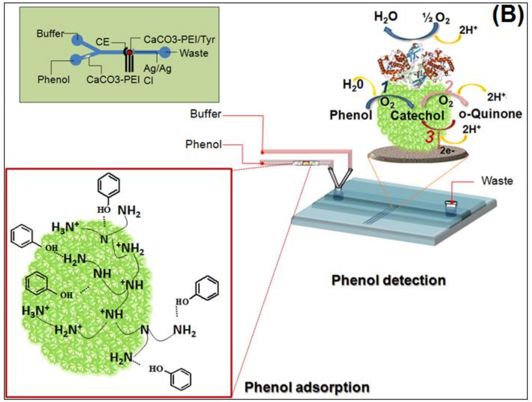
p-aminophenol (a)
o-aminophenol (b)

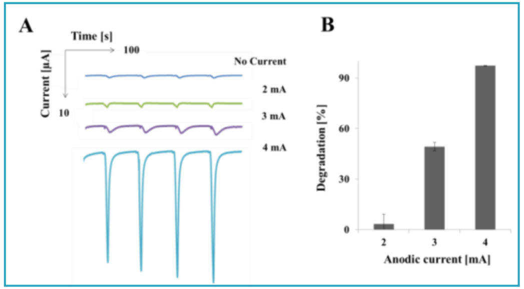
Microchimica Acta, 152, 261–265, 2006
Electrophoresis 27, 5068–5072 , 2006
Electroanalysis 18, 207 – 210, 2006
Electrophoresis 28, 1274–1280 , 2007

BIOSENSOREMOVAL NanoTechnologies

Phenol detection and removal



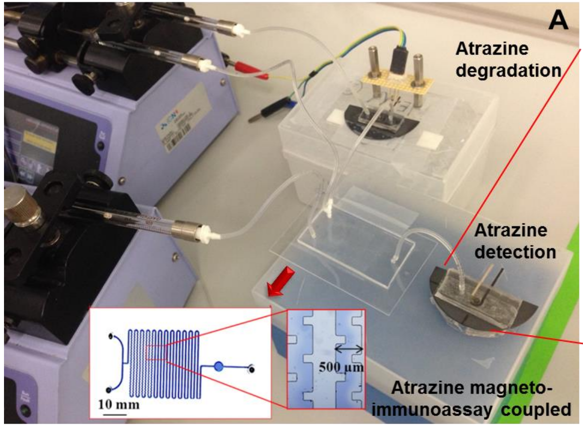


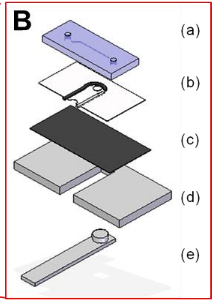


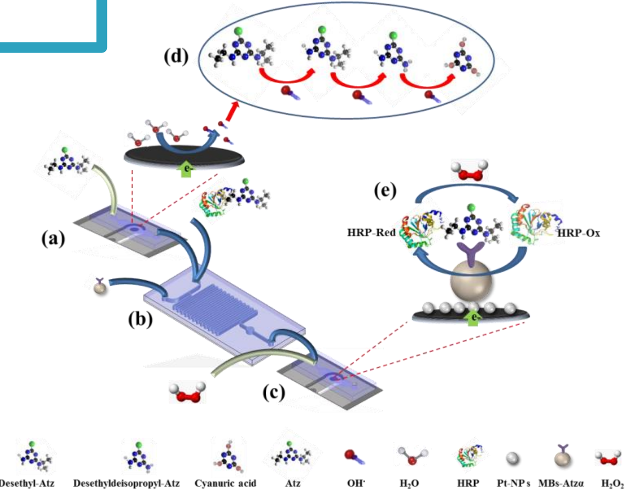
Nanostructured vaterite ($CaCO_3$) / Poly(ethyleneimine) (PEI)

Biosensors and Bioelectronics, 2015, 67, 670–676.

Pesticide detection and removal

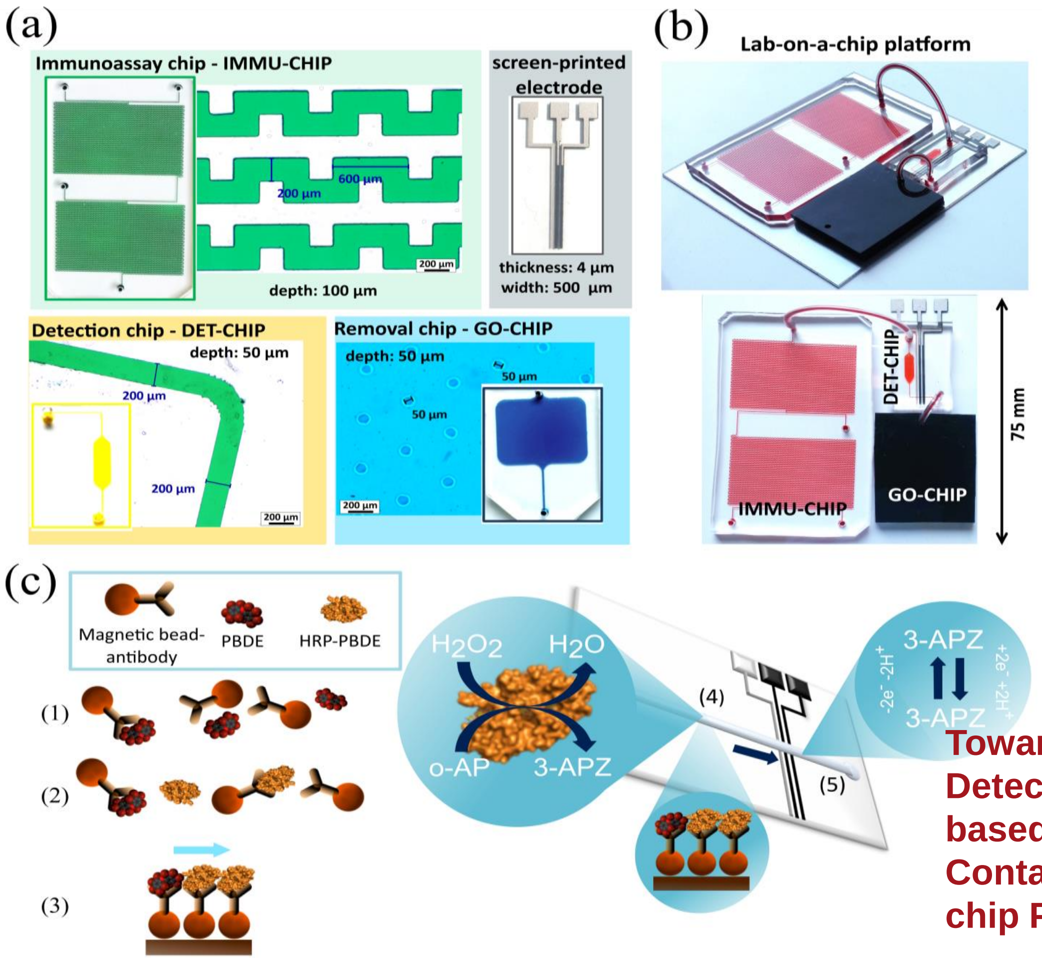






Biosensors and Bioelectronics, 75, 2016, 365-374

BIOSENSOREMOVAL NanoTechnologies

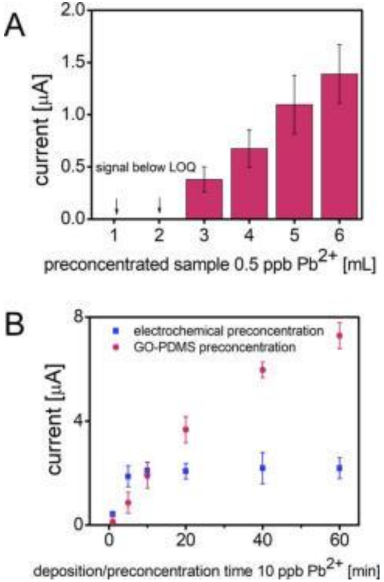


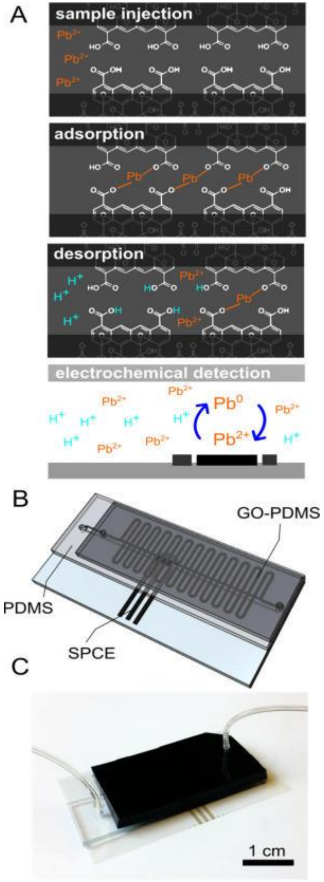
Polybrominated diphenyl ethers (PBDEs), a class of halogenated compounds, similar to polychlorinated diphenyls (PCBs) and commonly used as flame retardants.

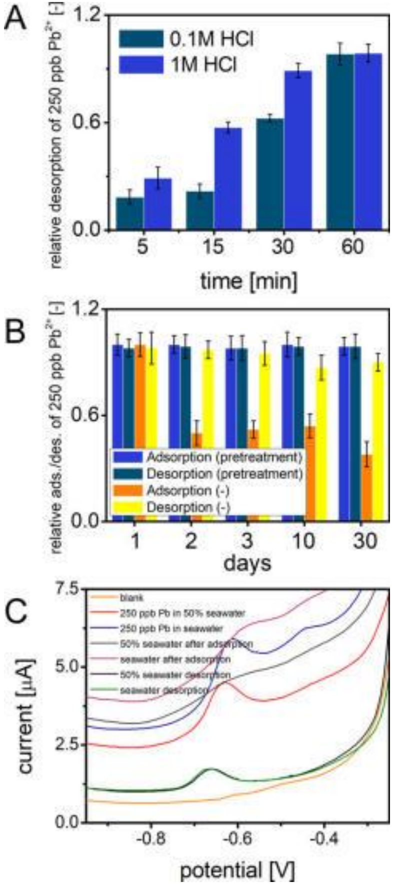
Towards Integrated Detection and Graphene-based Removal of Contaminants in Lab-on-a-chip Platform

Merkoçi et al., Nano Research, 2017, Vol 10 (7), pp 2296-

Graphene Oxide−Poly(dimethylsiloxane)-Based Lab-on-a-Chip Platform for Heavy-Metals Preconcentration and Electrochemical Detection

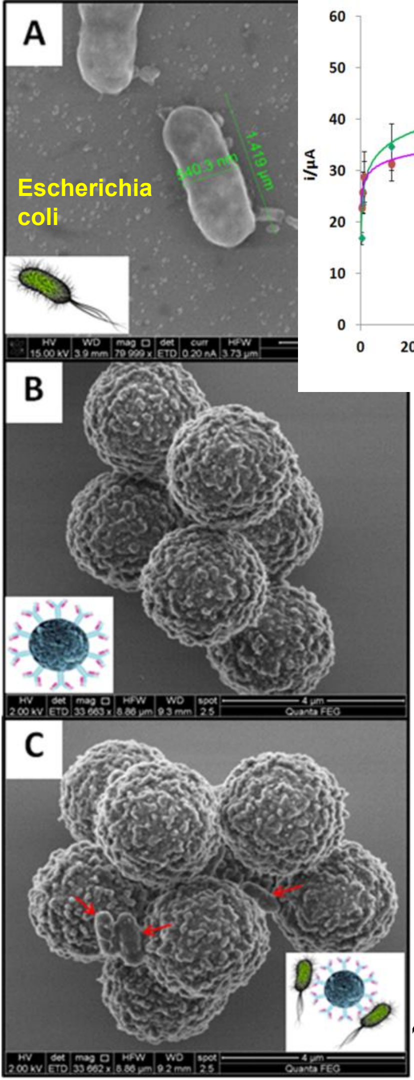


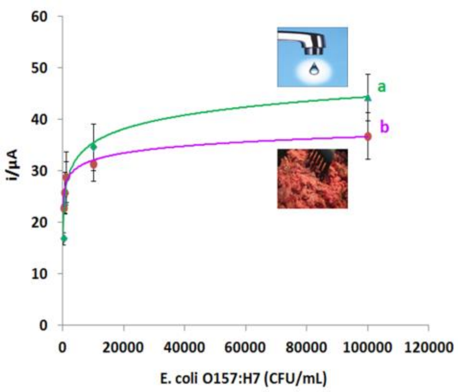


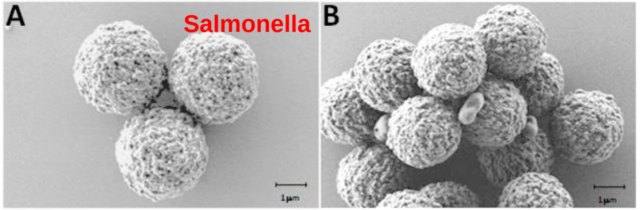


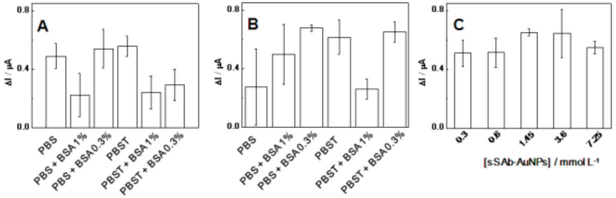
Merkoçi et al., ACS Appl. Mater. Interfaces 2017, 9, 44766−44775

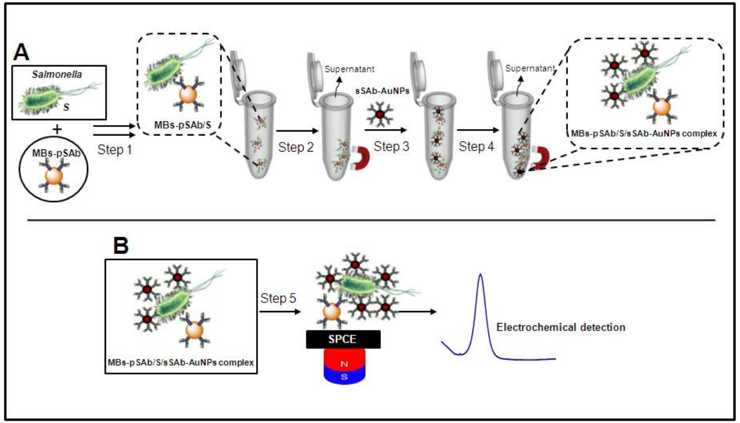
Au-NP-based detection of bacteria





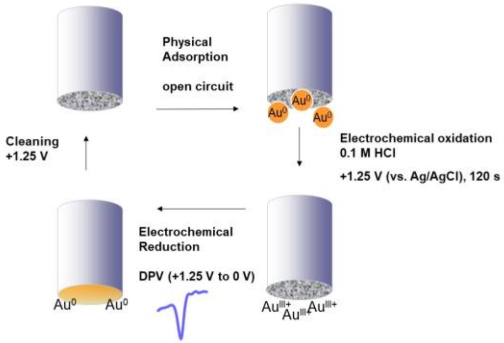




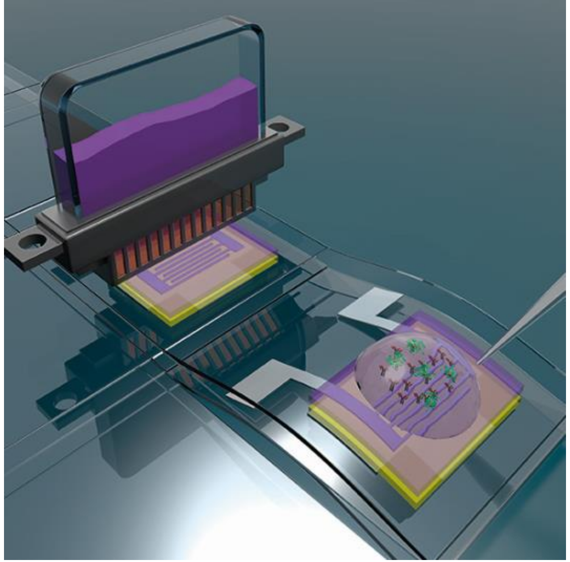


A. Merkoçi et al., Biosensors and Bioelectronics, 2013, 40, 121–126

DIRECT VOLTAMMETRIC DETECTION OF Au-NPs



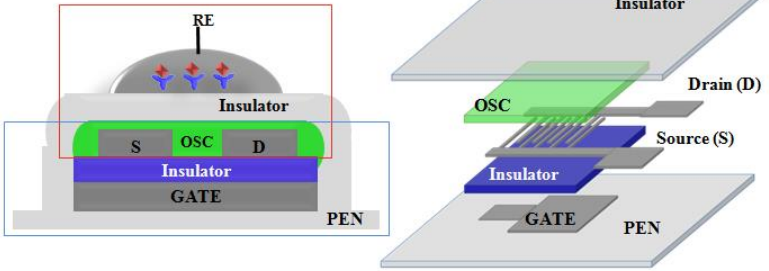
A.Merkoci et al., , Electrochimica Acta 50 (2005) 3702–3707

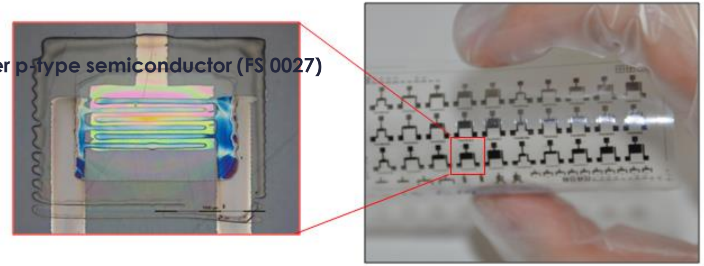


Inkjet-printed sensing platforms using nanomaterial-based inks and other materials

No need for clean room at all!

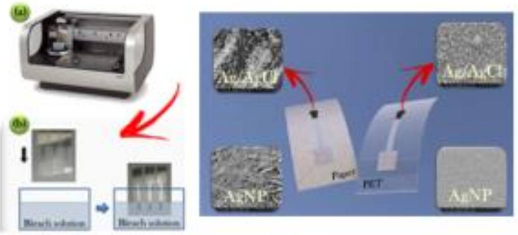
BioFET





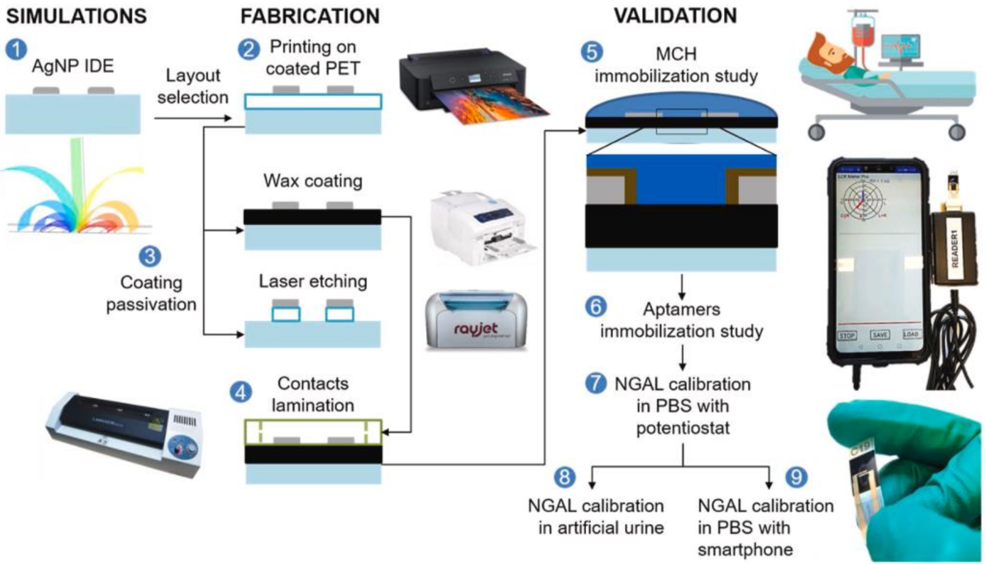
Merkoçi et al.
Advanced Functional Materials, 20, 6291–6302. 2014

AgNP-ink jet printed reference electrode in paper or plastic



Merkoçi et al. Anal. Chem. 86, 10531–10534. 2014

A plug, print & play inkjet printing and impedance-based biosensing technology operating through a smartphone for clinical diagnostics



The concept in a nutshell:

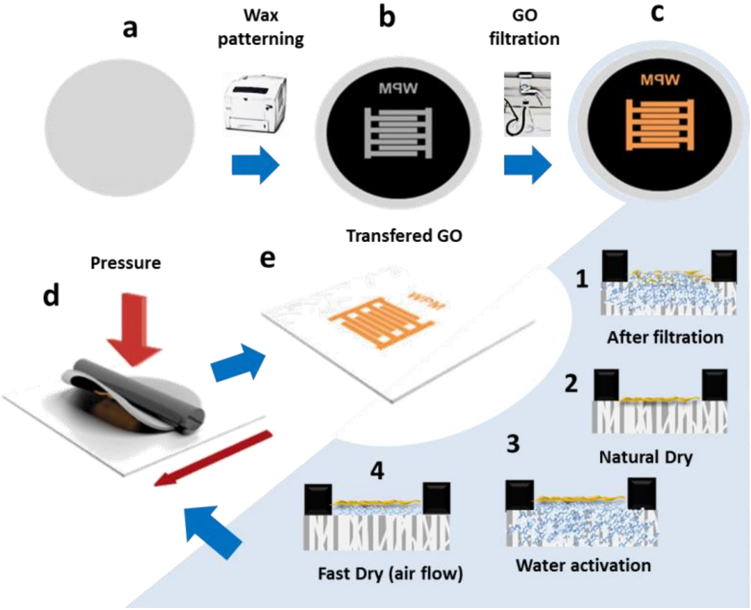
1. Draw your biosensor on your PC
2. Load nanomaterials in your consumer inkjet printer
3. Print your nanobiosensor
4. Functionalize it with aptamers
5. Connect it to your smartphone
6. Get your result!

We fabricated a nanobiosensor based on aptamers NGAL.

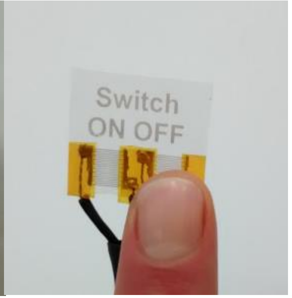
NGAL (Neutrophil Gelatinase-Associated Lipocalin)
NGAL in urine is a biomarker of acute kidney infection (AKI) and of liver cirrhosis

Biosensors and Bioelectronics 196, 113737, 2022

Water Activated Graphene Oxide Transfer Using Wax Printed Membranes for Fast Patterning of Electrical Devices

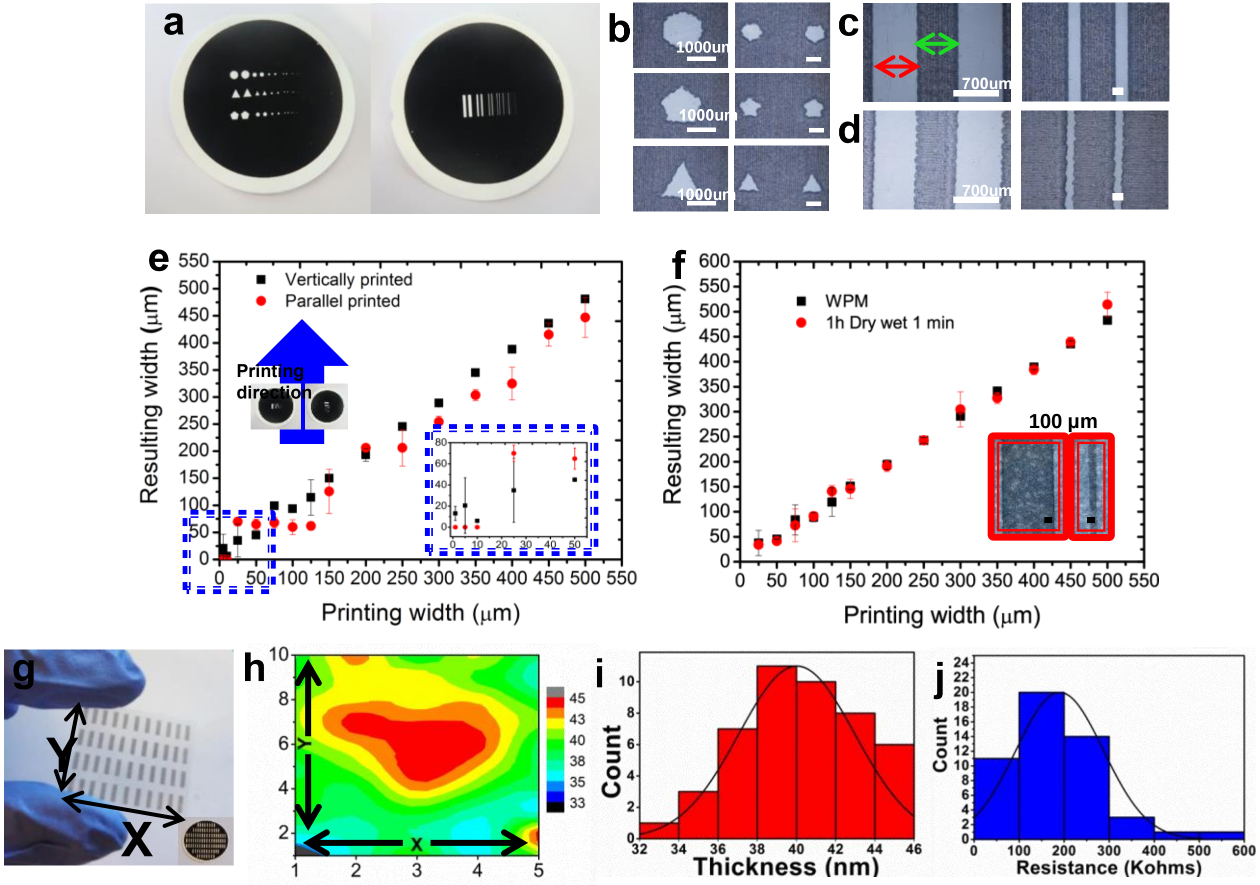


Video of printing



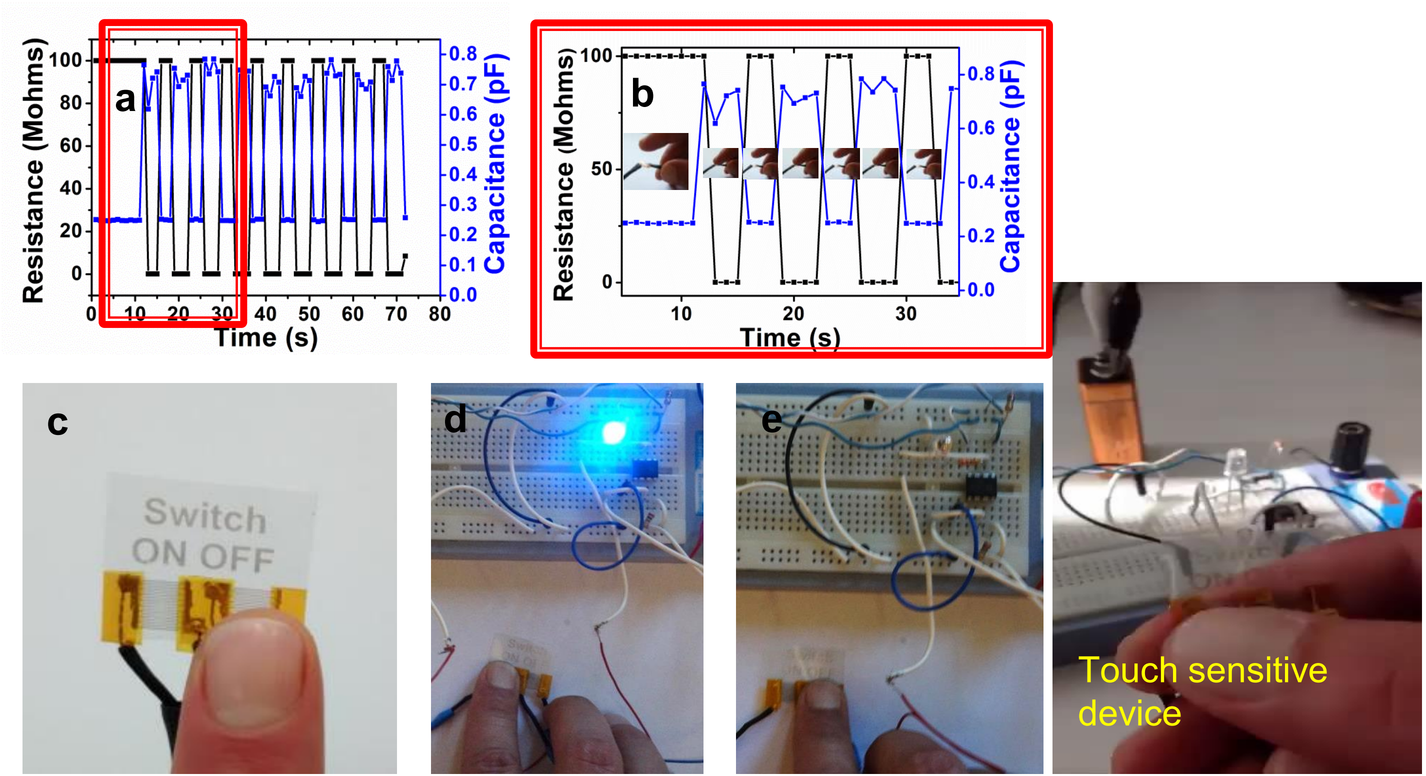
Baptista-Pires,Mayorga-Martínez, Medina-Sánchez, Montón, Merkoçi, **ACS Nano** 2016, 10, 853−860

Water Activated Graphene Oxide Transfer Using Wax Printed Membranes for Fast Patterning of Electrical Devices



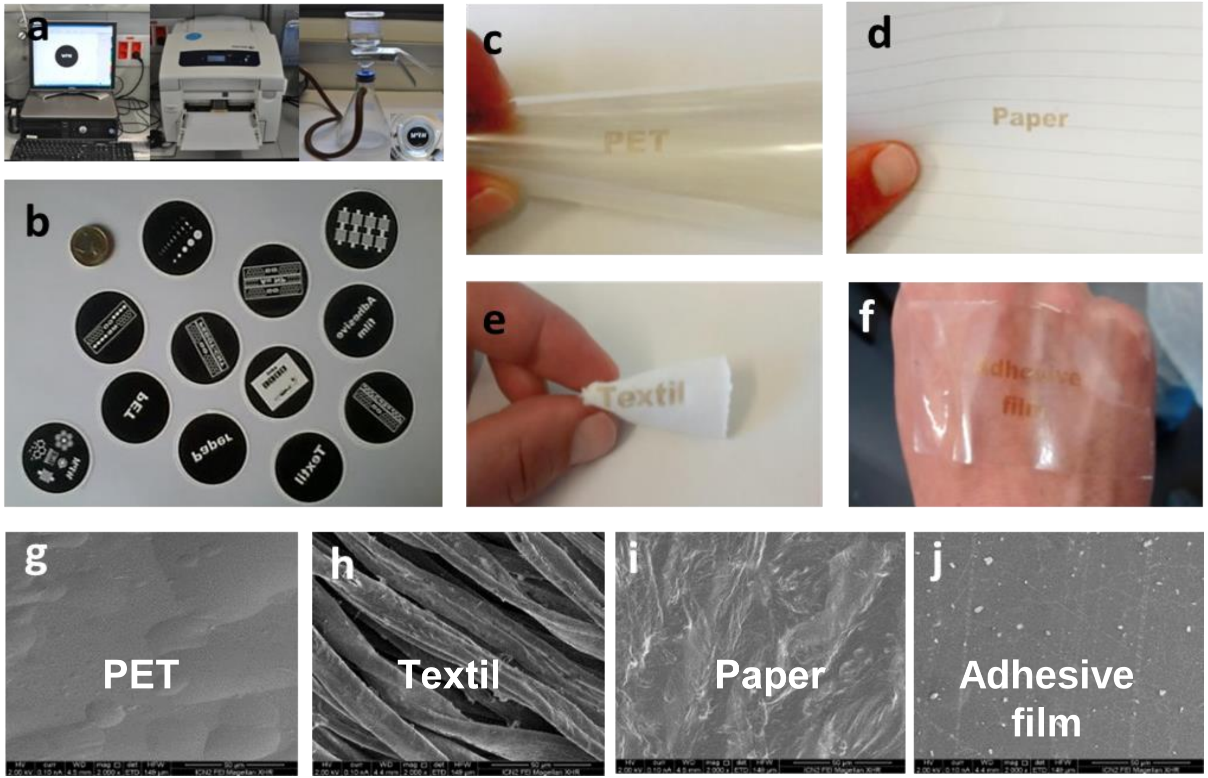
Baptista-Pires,Mayorga-Martínez, Medina-Sánchez, Montón, Merkoçl, **ACS Nano** 2016, 10, 853−860

Water Activated Graphene Oxide Transfer Using Wax Printed Membranes for Fast Patterning of Electrical Devices



Baptista-Pires,Mayorga-Martínez, Medina-Sánchez, Montón, Merkoçl, **ACS Nano** 2016, 10, 853−860

Transfer onto flexible substrates



ACS SENSORS

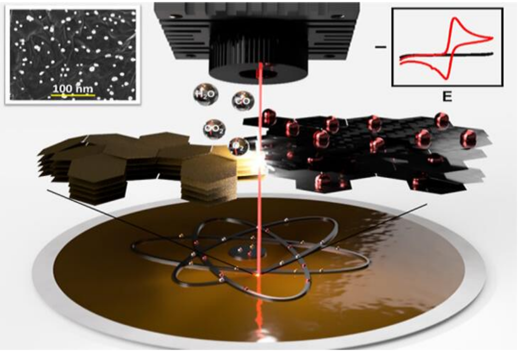
pubs.acs.org/acssensors Article

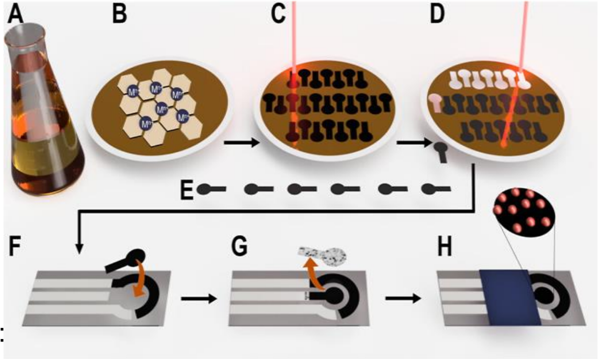
One-Step Laser Nanostructuration of Reduced Graphene Oxide Films Embedding Metal Nanoparticles for Sensing Applications

Annalisa Scroccarello,[#] Ruslan Álvarez-Diduk,*[,#] Flavio Della Pelle, Cecilia de Carvalho Castro e Silva, Andrea Idili, Claudio Parolo, Dario Compagnone, and Arben Merkoçi*

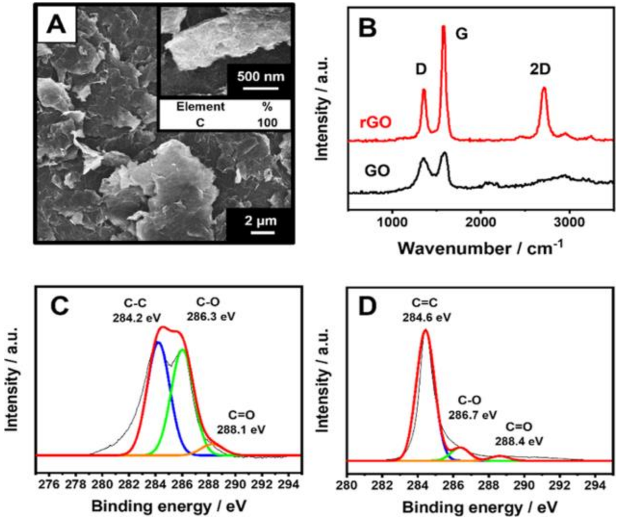
Cite This: https://doi.org/10.1021/acssensors.2c01782 Read Online

ACS Sens. 2023, Publication Date: February 3, 2023

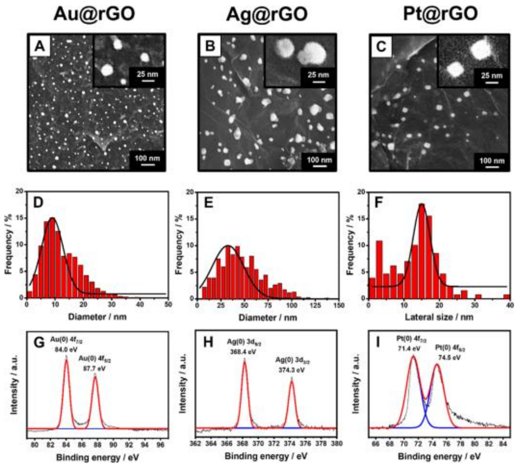




DOI:



(A) SEM micrograph of the GO film after laser treatment. (B) Raman spectra of the GO (black line) and rGO (red line) film. (C) C 1s XPS spectrum of the GO film. (D) C 1s XPS spectrum of the rGO film obtained via laser treatment. All the analyses were performed after the film integration into the sensor.



SEM micrographs and XPS spectra of the MNPs@rGO films formed with the laser treatment. (G) XPS spectrum of the Au 4f of the Au@rGO film. (H) XPS spectrum of the Ag 3d of the Ag@rGO film. (I) XPS spectrum of Pt 4f XPS spectra of the Pt@rGO films. All the analyses were performed after the film integration into the sensor.

ACS APPLIED MATERIALS & INTERFACES
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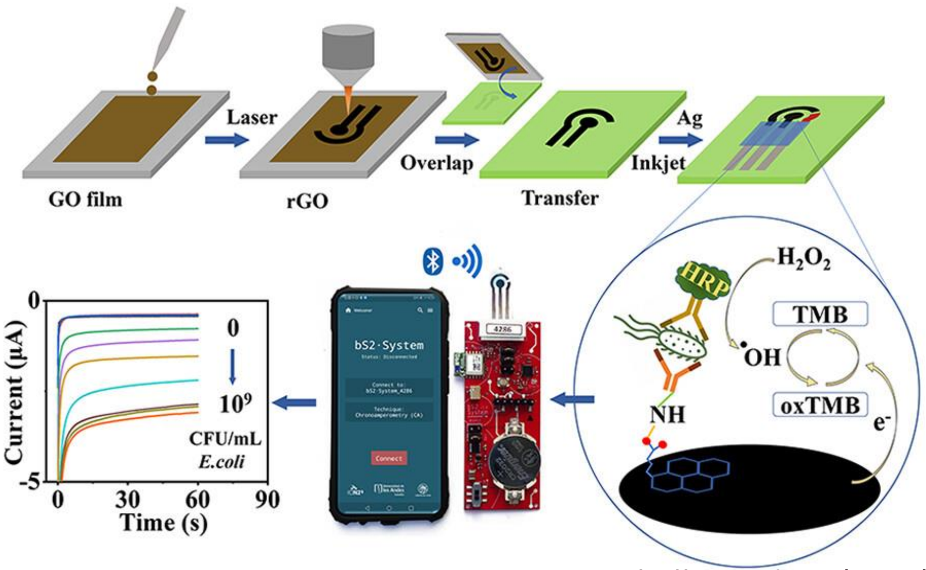
Research Article

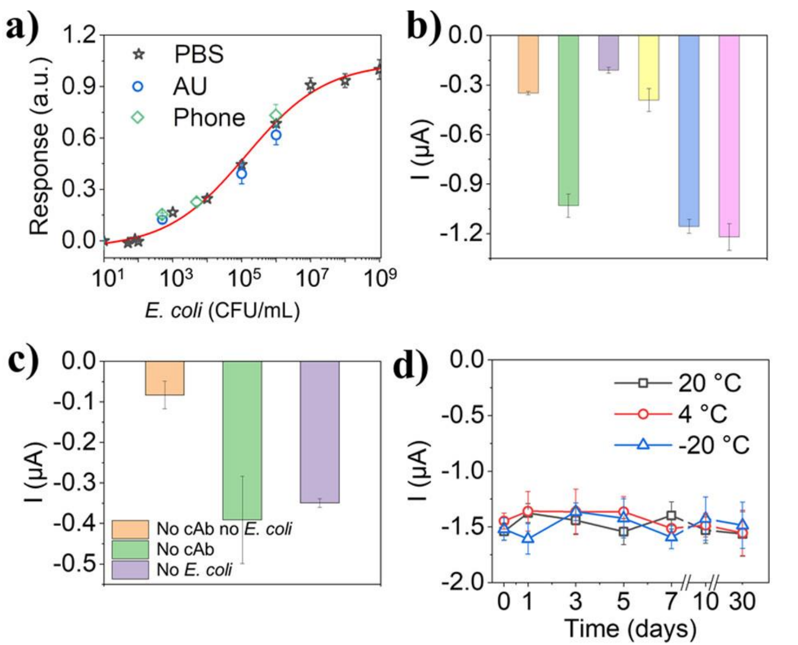
Laser Reduced Graphene Oxide Electrode for Pathogenic *Escherichia coli* Detection

Lei Zhao, Giulio Rosati,* Andrew Piper,* Cecilia de Carvalho Castro e Silva, Liming Hu, Qiuyue Yang, Flavio Della Pelle, Ruslán R. Alvarez-Diduk, and Arben Merkoçi*

Cite This: ACS Appl. Mater. Interfaces 2023, 15, 9024–9033
Read Online



tetramethylbenzidine (TMB)

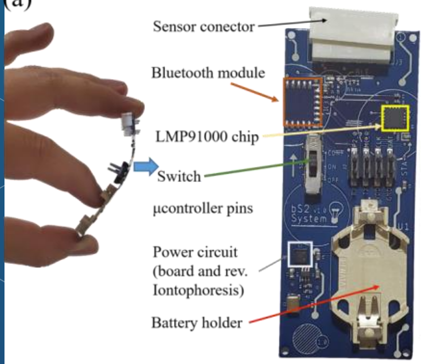


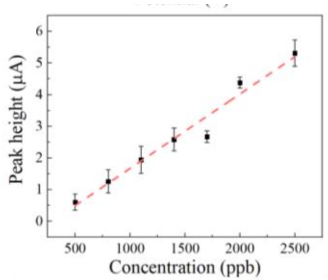
This proof-of-concept sensing platform could detect *E. coli* between 917 and 2.1 × 10^7 CFU/mL, with a LOD of 283 CFU/mL, within the clinically relevant range for *E. coli* in human urine.

Wearable and fully printed microfluidic nanosensor for sweat rate, conductivity, and copper detection with healthcare applications

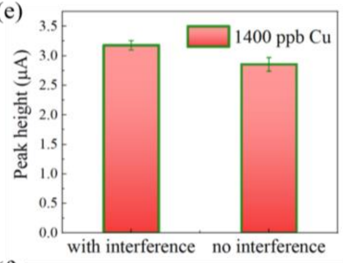
We fabricated a printed nanosensor to be applied on the skin for copper detection in sweat:

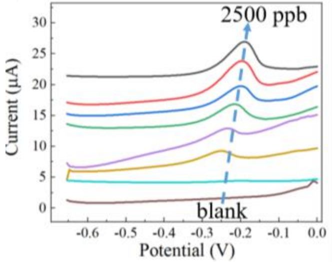
- Active sweat stimulation (reverse iontophoresis)
- Sweat rate compensation
- Continuous monitoring
- Microfluidic (low vol.)



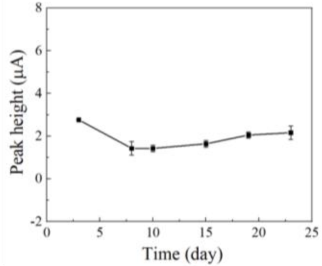


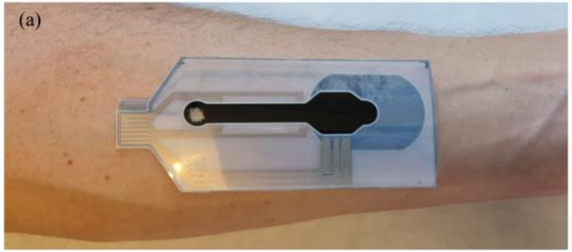
(e)

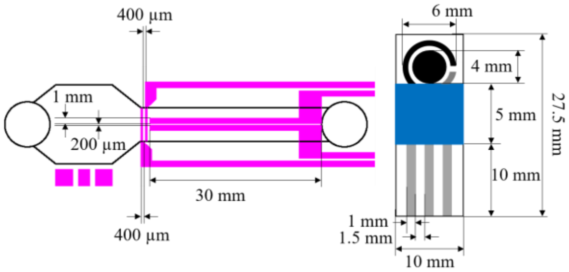


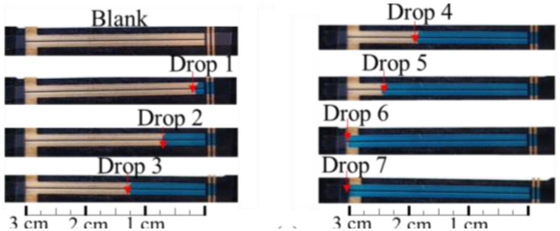


(f)





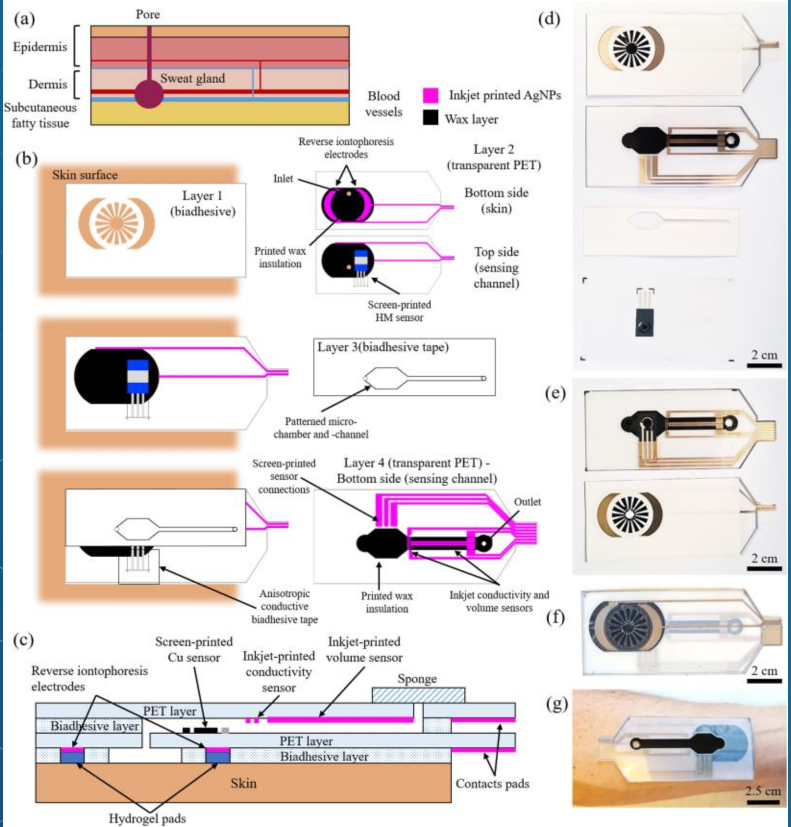




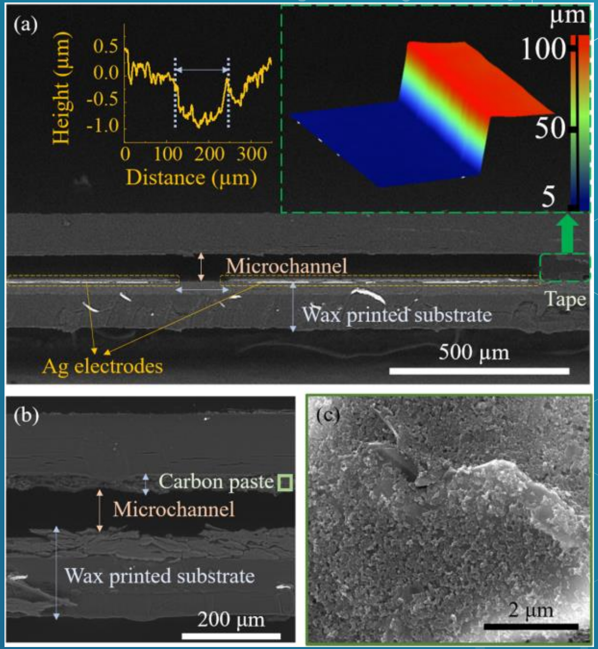
Biosensors and Bioelectronics 202, 114005, 2022

Wearable and fully printed microfluidic nanosensor for sweat rate, conductivity, and copper detection with healthcare applications

Scheme of the skin tissue vertical structure

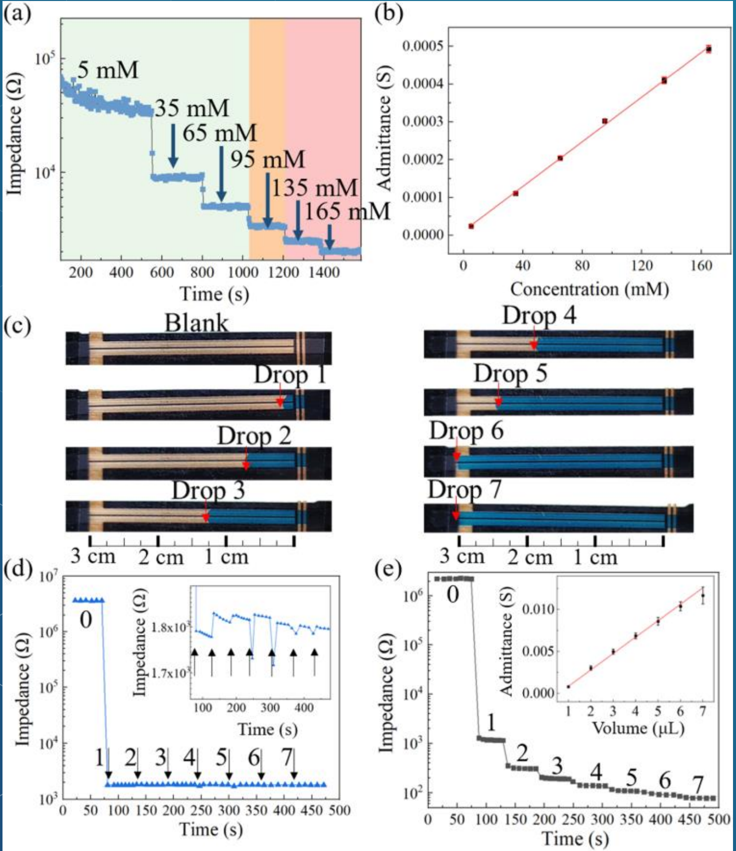


Cross-section of the microchannel, profilometry of the gap between two printed Ag electrodes (Inset left) and 3D profilometry of the open microchannelborder (Inset right) (a), cross-section of the copper detection chamber (b), and SEM picture of the SPCE working electrode (c)



Biosensors and Bioelectronics 202, 114005, 2022

Wearable and fully printed microfluidic nanosensor for sweat rate, conductivity, and copper detection with healthcare applications



a) Staircase calibration of he conductivity nanosensor impedance with NaCl at a frequency of 10 kHz. CF diagnosis relevant ranges marked with colors (green=healthy, orange=suspicious, red=pathological)

b) admittance calibration curve

c) pictures of the microfluidic channel in correspondence to 1 μl colored dye drops at the device inlet

d) impedance of the conductivity sensor at 10 kHz in correspondence to artificial sweat introduced drop-by-drop

e) impedance of the volume sensor at 10 kHz with artificial sweat introduced drop-by-drop and calibration of the volume nanosensor by means of its admittance (inset).

Biosensors and Bioelectronics 202, 114005, 2022

Green Chemistry

ROYAL SOCIETY OF CHEMISTRY

PAPER

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Cite this: DOI: 10.1039/d2gc02978b

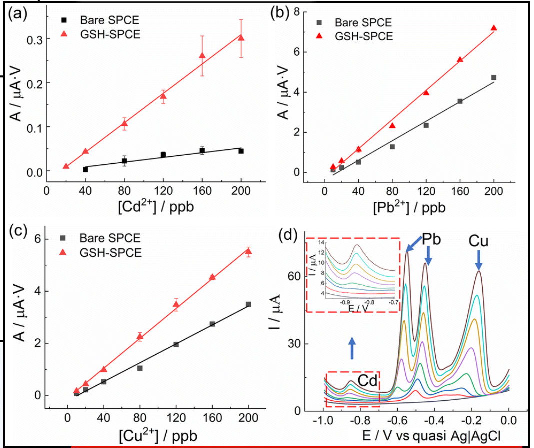
Metal-free cysteamine-functionalized graphene alleviates mutual interferences in heavy metal electrochemical detection†

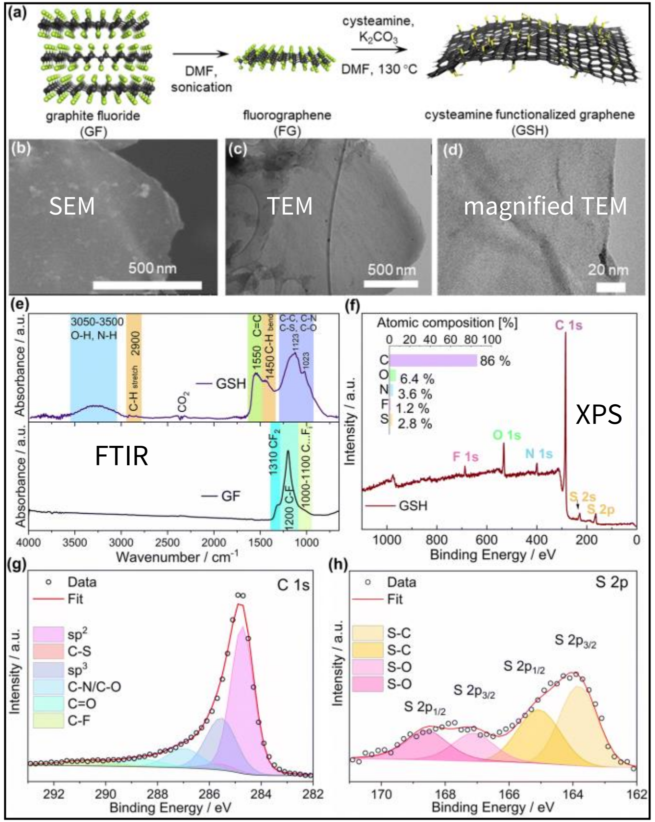
Qiuyue Yang,[a,b] Emily P. Nguyen,[a] David Panáček,[a,c] Veronika Šedajová,[c] Vítězslav Hrubý,[c,d] Giulio Rosati,[a] Cecilia de Carvalho Castro Silva,[a,e] Aristides Bakandritsos,[c,f] Michal Otyepka[c,g] and Arben Merkoçi*[a,h]

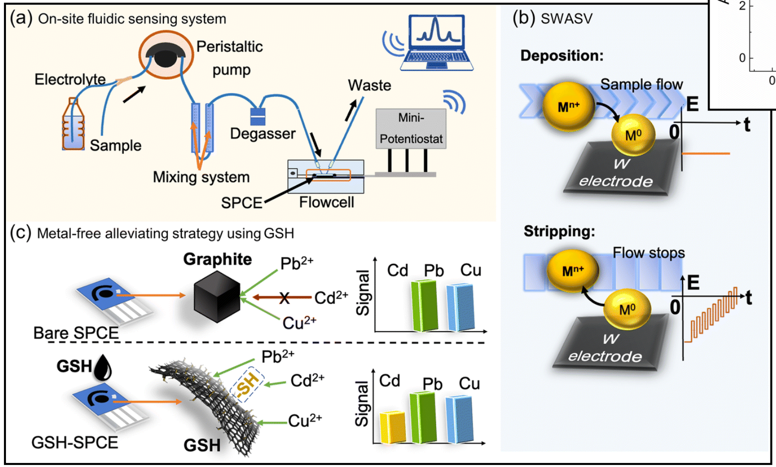
Accepted 13th January 2023

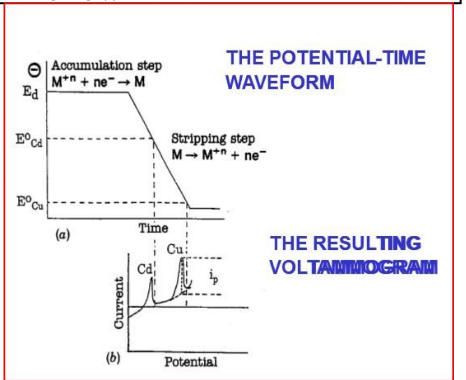
DOI: 10.1039/d2gc02978b

Cysteamine covalently functionalized graphene (GSH), was found to lead to a 6-fold boost in the Cd^{2+} sensitivity of the screen-printed carbon electrode (SPCE), while the sensitivities to Pb^{2+} and Cu^{2+} were not influenced in simultaneous detection.









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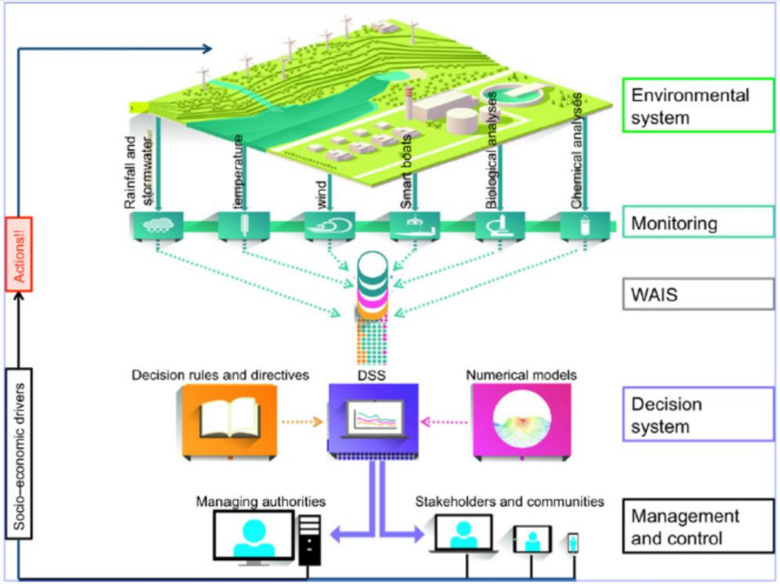


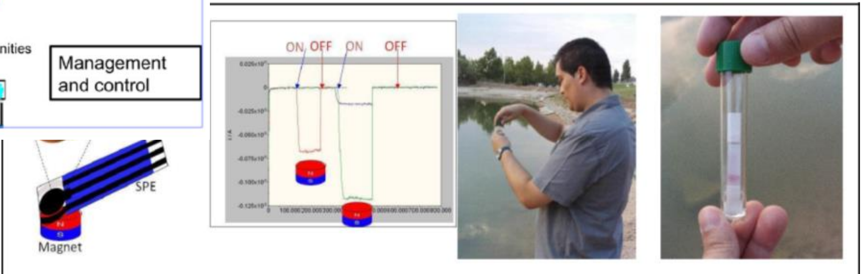
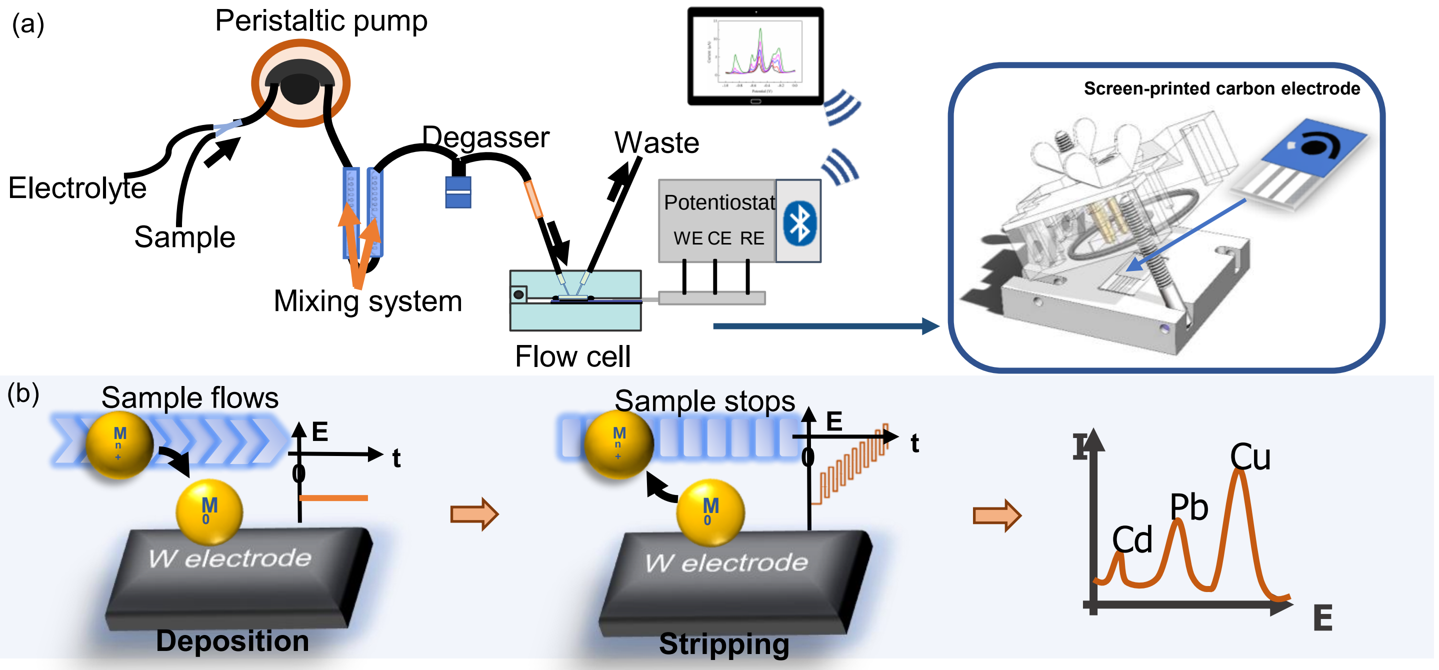


Figure 1.4 The two approaches to using innovative sensors the nanoparticle based metal system for the boats (left), and the land-based strips (right)

Laboratory set-up for *in-situ* and automatic heavy metal sensing measurements



Yang, Qiuyue, Merkoçi et al. "Development of a heavy metal sensing boat for automatic analysis in natural waters utilizing anodic stripping voltammetry."
ACS ES&T Water 1.12 (2021): 2470-2476

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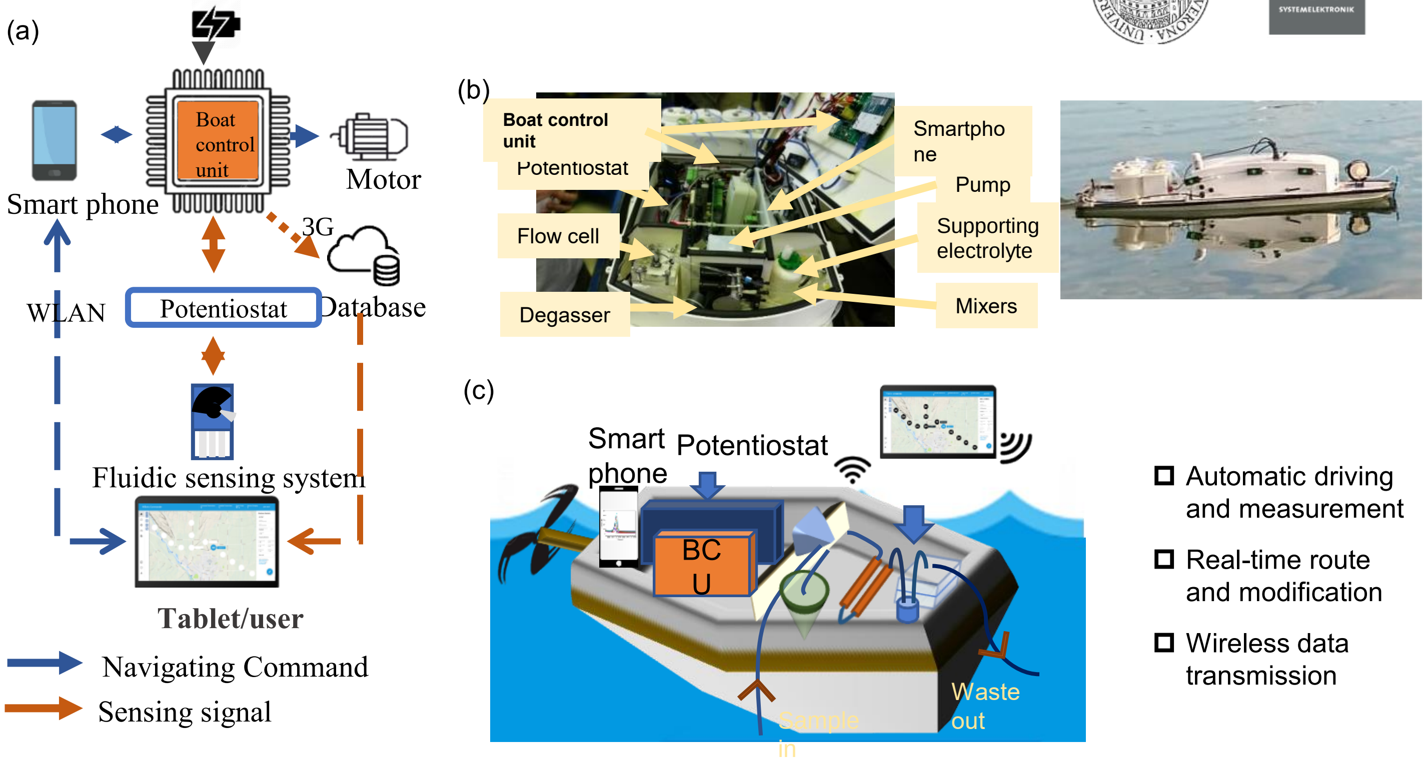
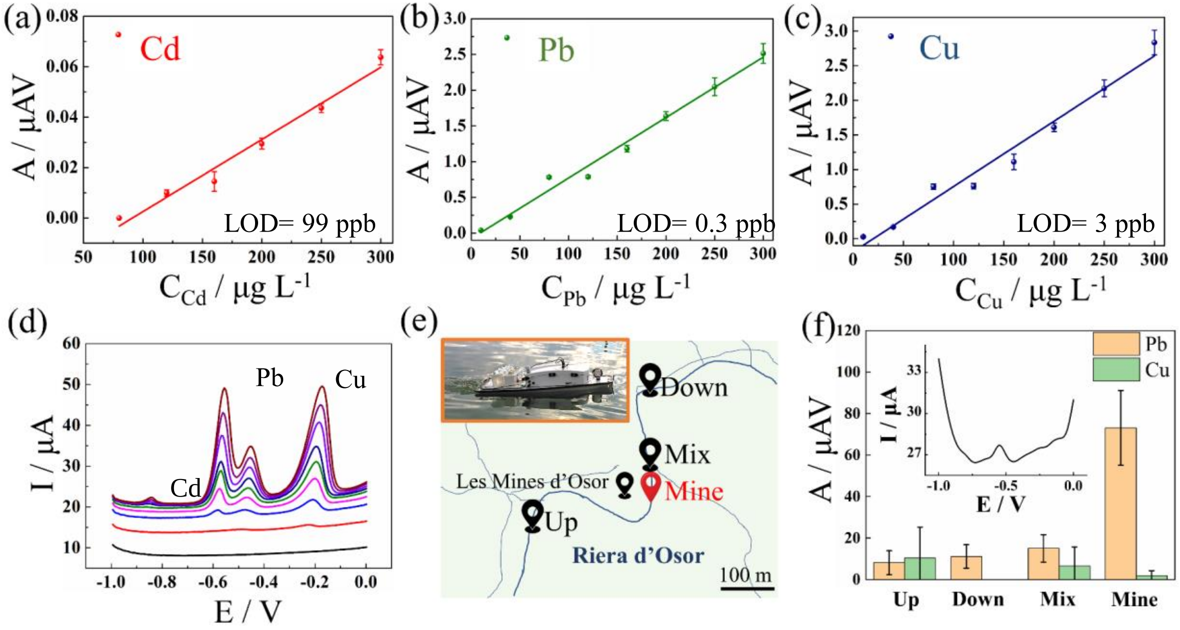
Autonomous boat for heavy metal sensing measurements



- Automatic driving and measurement
- Real-time route and modification
- Wireless data transmission

Yang, Qiuyue, Merkoçi et al. "Development of a heavy metal sensing boat for automatic analysis in natural waters utilizing anodic stripping voltammetry." ACS ES&T Water 1.12 (2021): 2470-2476

Heavy metal sensing performance



originated from F–Ba–Pb–Zn mine vein

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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

REVIEW

Nanochannels Preparation and Application in Biosensing

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

nature protocols REVIEW ARTICLE

https://doi.org/10.1038/s41596-020-0357-x

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Tutorial: design and fabrication of nanoparticle-based lateral-flow immunoassays

Claudio Parolo[1,5], Amadeo Sena-Torralba[1,5], José Francisco Bergua[1], Enric Calucho[1], Celia Fuentes-Chust[1], Liming Hu[1], Lourdes Rivas[1], Ruslan Álvarez-Diduk[1], Emily P. Nguyen[1], Stefano Cinti[2], Daniel Quesada-González[3] and Arben Merkoçi[1,4]

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Nano/Micromotors in (Bio)chemical Science Applications

Maria Guix,[†] Carmen C. Mayorga-Martinez,[†] and Arben Merkoçi[*,†,‡]
[†]Nanobioelectronics & Biosensors Group, Institut Català de Nanosciencia i Nanotecnologia (ICN2), UAB Campus, 08193 Bellaterra, Barcelona, Spain
[‡]ICREA, Passeig de Lluís Companys, 23, 08010 Barcelona, Spain

Chemical Reviews, 114 (12), 6285–6322 (2014)

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

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Toward Nanotechnology-Enabled Approaches against the COVID-19 Pandemic

Carsten Weiss,[*,#] Marie Carriere,[*,#] Laura Fusco,[#] Ilaria Capua, Jose Angel Regla-Nava, Matteo Pasquali, James A. Scott, Flavia Vitale, Mehmet Altay Unal, Cecilia Mattevi, Davide Bedognetti, Arben Merkoçi, Ennio Tasciotti, Açelya Yilmazer, Yury Gogotsi, Francesco Stellacci, and Lucia Gemma Delogu[*]

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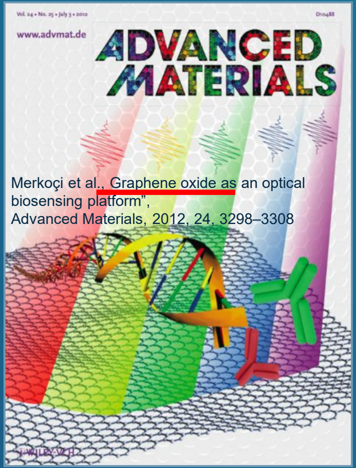
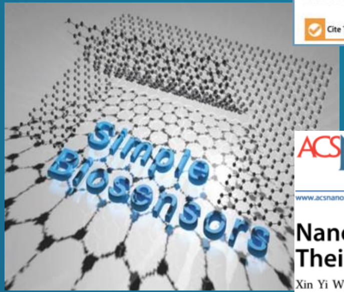
Cancer detection using nanoparticle-based sensors†

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



Merkoçi et al., Graphene oxide as an optical biosensing platform",
Advanced Materials, 2012, 24, 3298–3308



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Eden Morales-Narváez, Luis Baptista-Pires, Alejandro Zamora-Gálvez and Arben Merkoçi

Advanced Materials, 2016

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TUTORIAL REVIEW

Paper-based nanobiosensors for diagnostics

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

Received 11th July 2012
DOI: 10.1039/c2cs35255a

ACS NANO REVIEW

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Nanomaterials for Nanotheranostics: Tuning Their Properties According to Disease Needs

Xin Yi Wong, Amadeo Sena-Torralba, Ruslan Álvarez-Diduk, Kasturi Muthoosamy,[*] and Arben Merkoçi[*]

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REVIEW

Nanodiagnostics to Face SARS-CoV-2 and Future Pandemics: From an Idea to the Market and Beyond

Giulio Rosati, Andrea Idili, Claudio Parolo, Celia Fuentes-Chust, Enric Calucho, Liming Hu, Cecilia de Carvalho Castro e Silva, Lourdes Rivas, Emily P. Nguyen, José F. Bergua, Ruslan Alvarez-Diduk, José Muñoz, Christophe Junot, Oriol Penon, Dominique Monferrer, Emmanuel Delamarche, and Arben Merkoçi*

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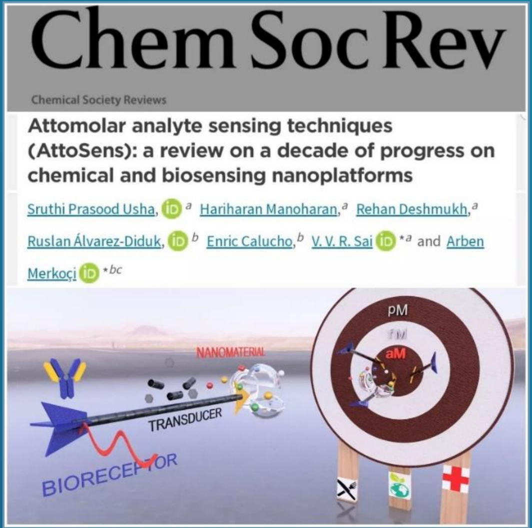

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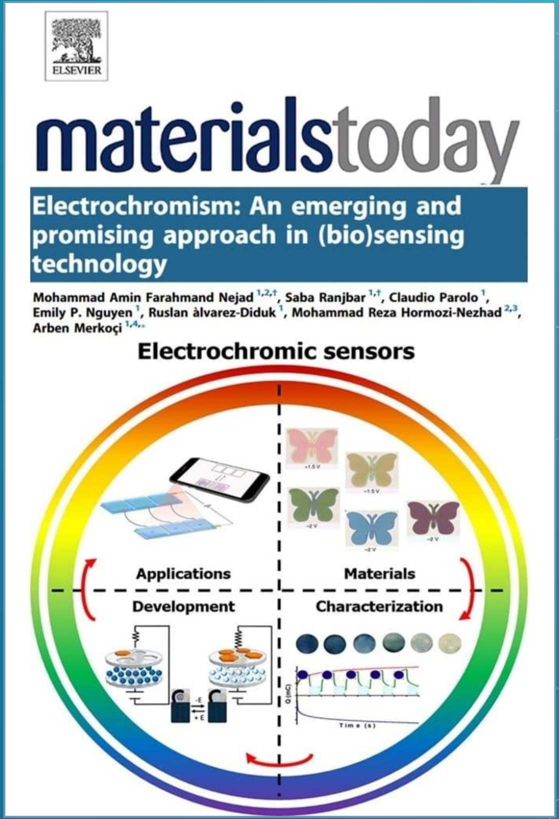
Chemical Society Reviews

Attomolar analyte sensing techniques (AttoSens): a review on a decade of progress on chemical and biosensing nanoplatforms

Sruthi Prasood Usha,[a] Hariharan Manoharan,[a] Rehan Deshmukh,[a] Ruslan Álvarez-Diduk,[b] Enric Calucho,[b] V. V. R. Sai *[a] and Arben Merkoçi *[bc]



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Electrochromism: An emerging and promising approach in (bio)sensing technology

Mohammad Amin Farahmand Nejad[1,2,†], Saba Ranjbar[1,†], Claudio Parolo[1], Emily P. Nguyen[1], Ruslan àlvarez-Diduk[1], Mohammad Reza Hormozi-Nezhad[2,3], Arben Merkoçi[1,4,*]

Trends in Chemistry

CellPress

Available online 25 April 2022

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Review

Paper-based biosensors for cancer diagnostics

Claudia Pereira[1, 2, 3, 9], Claudio Parolo[1, 4, 9], Andrea Idili[1, 5], Roger R. Gomis[6, 7], Lígia Rodrigues[3, 8], Goreti Sales[2], Arben Merkoçi[1, 7]

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Toward Integrated Molecular Lateral Flow Diagnostic Tests Using Advanced Micro- and Nanotechnology
Ana Rubio-Monterde, Daniel Quesada-González*, and Arben Merkoçi*
Cite this: Anal. Chem. 2023, 95, 1, 468–489

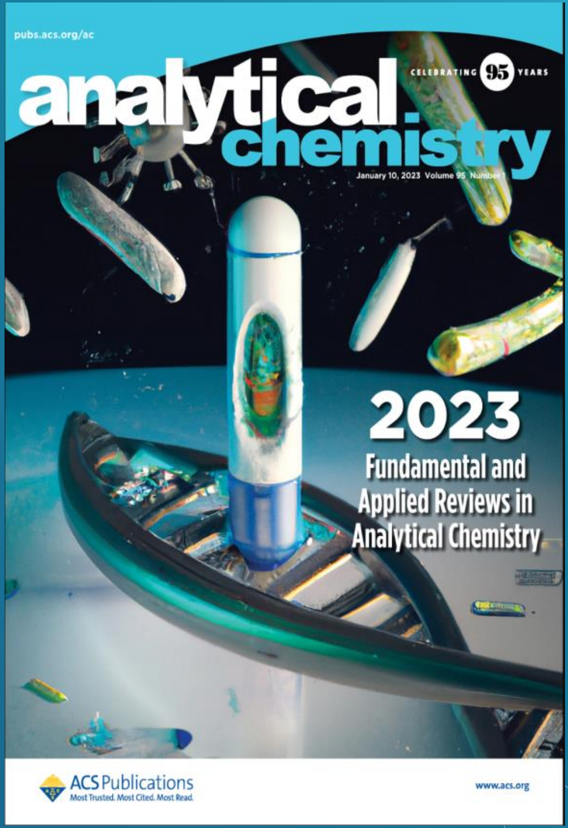

Table of contents

Conclusions

Electrical nanobiosensors represent a great alternative for environment monitoring

These devices and related fabrication technologies offer unpresented alternative for the democratization of monitoring systems

Nanomatarials can be easily coupled to paper-based platforms to build cost/efficient nanobiosensors

Nanomaterials exhibit unprecedented properties as either electrical or optical transducer for biosensing applications

Their properties and related platforms can enable:
- Connection to a variety of (bio)receptors and nanomaterials
- Simple assay procedures and avoid time consuming labours
- Compatibility with mobile phone technology and other smart environment monitoring systems.

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