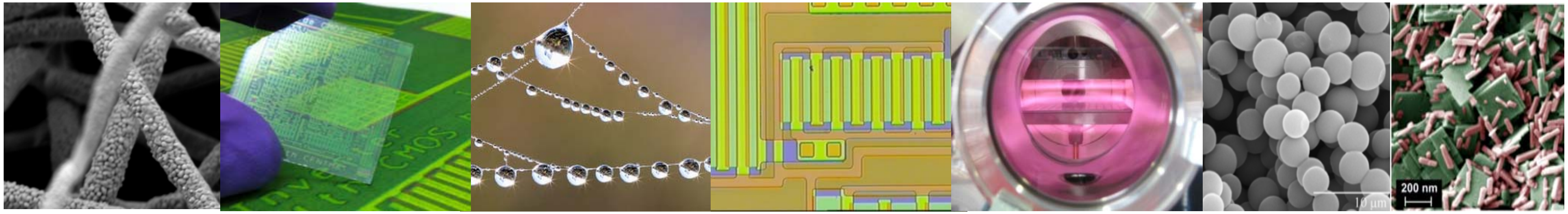
i3N

Institute of Nanostructures, Nanomodelling and Nanofabrication

Materials for Electronics, Optoelectronics and Nanotecnhologies (MEON) – ***Prof. Rodrigo Martins***



Aveiro, 10 April, 2015

Universidade do Minho
Escola de Engenharia
universidade de aveiro
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
i3N

General Outline

- Transparent Electronics
- Paper Electronics
- Electrochemical Devices
- Biosensors / Microfluidics
- Nanoplasmonics

Transparent Electronics

Transparent Electronics

What?

New materials and processes for conventional thin film technology

- Replace conventional oxide thin films by random networks of NWs
- Future TCOs

Ordered arrays of oxide semiconductor NWs for ultimate oxide nanoscale performance

Speed, scientific/technological challenge

How?

- Indium-free semic.
- Hybrid dielectrics…
- Solution processing

- Spin-coating or printing of NW solution in µm-scale devices.
- Grids/meshs of metallic NWs

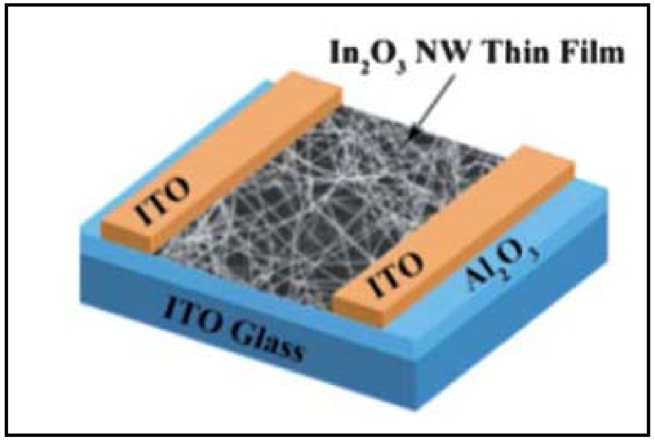
- Transfer and direct grow methods
- Aligned and ordered arrays using NIL seed layers

Process and device simulation + novel circuit design for high performance/low power consumption

Transparent Electronics

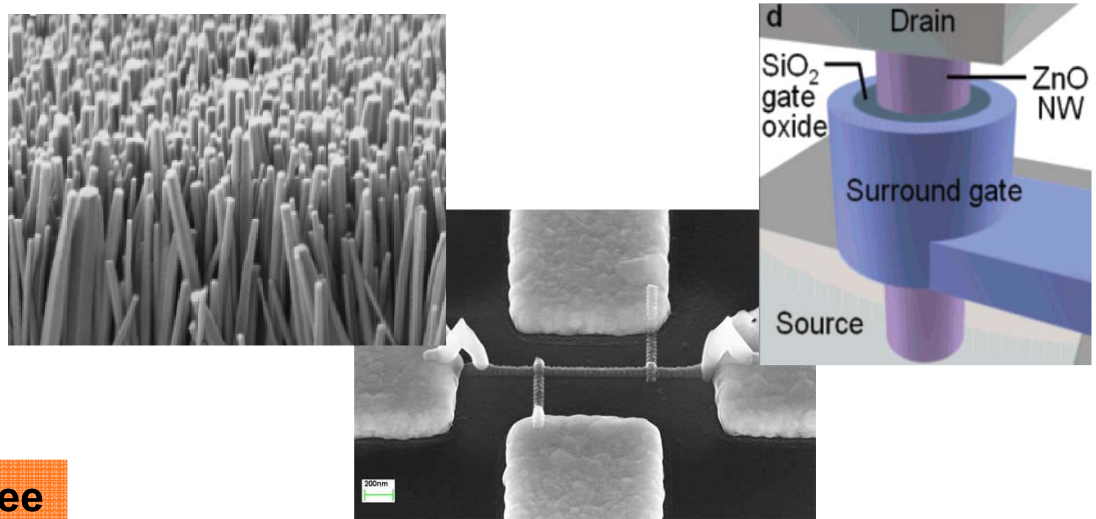
Materials and device structures

Random networks of oxide NWs



- Hydrothermal synthesis of **indium-free** oxide semiconductor NWs (e.g. ZTO)
- Synthesis decoupled from deposition – easy migration to **flexible substrates**
- **μ>100 cm²/Vs, L≈1 μm, kHz-low MHz operation**

Ordered arrays of oxide NWs



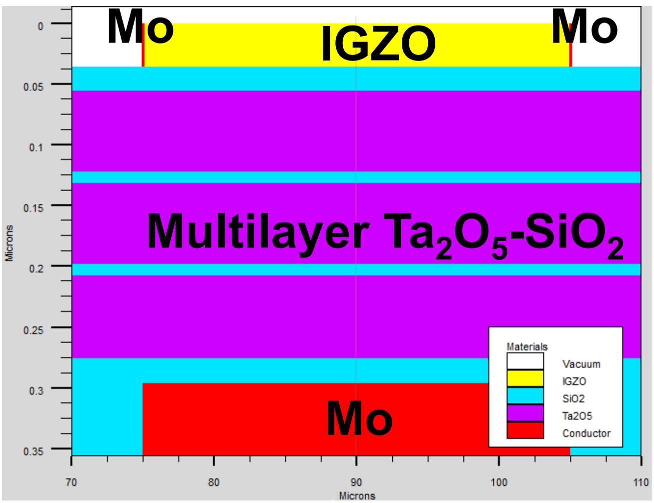
- Full device @ nanoscale: **speed+multifunctionality**
- Precise positioning with NIL and EBL
- High density of surrounding gate structures
-**μ>1000 cm²/Vs, L<50 nm, GHz operation**

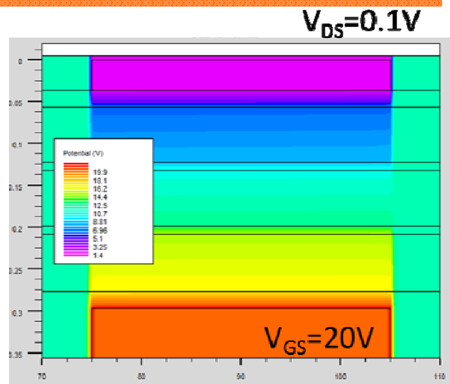
+ Integration with transparent metal nanostructures (nanoscale TCOs, ↓R_s, ↑T)

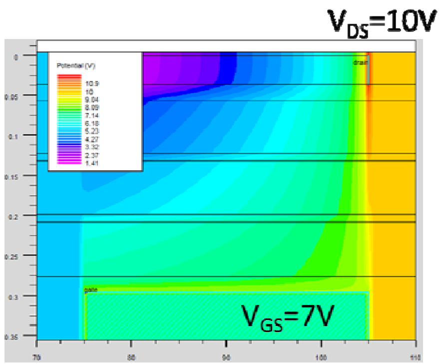
Transparent Electronics

Process and device simulation

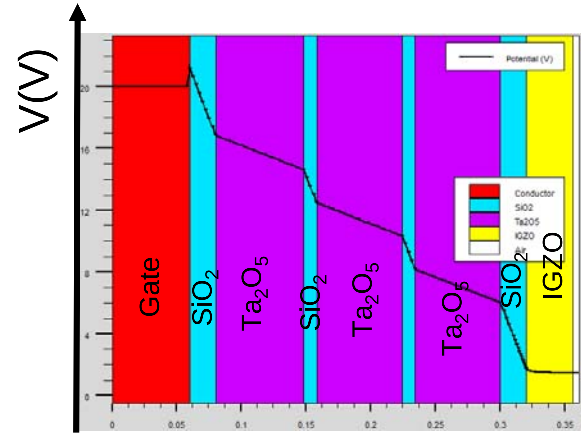
- Optimize vacuum/non-vacuum deposition routes
- Insights on device physics, stability improvement
- Prediction of device/circuit performance depending on processing conditions and device structure
- Work already started with **SILVACO TCAD** on sputtered IGZO TFTs, will expand to other materials/structures

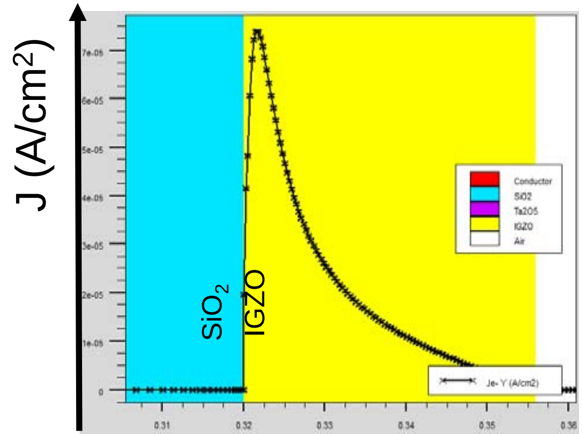






Potential and current density distribution

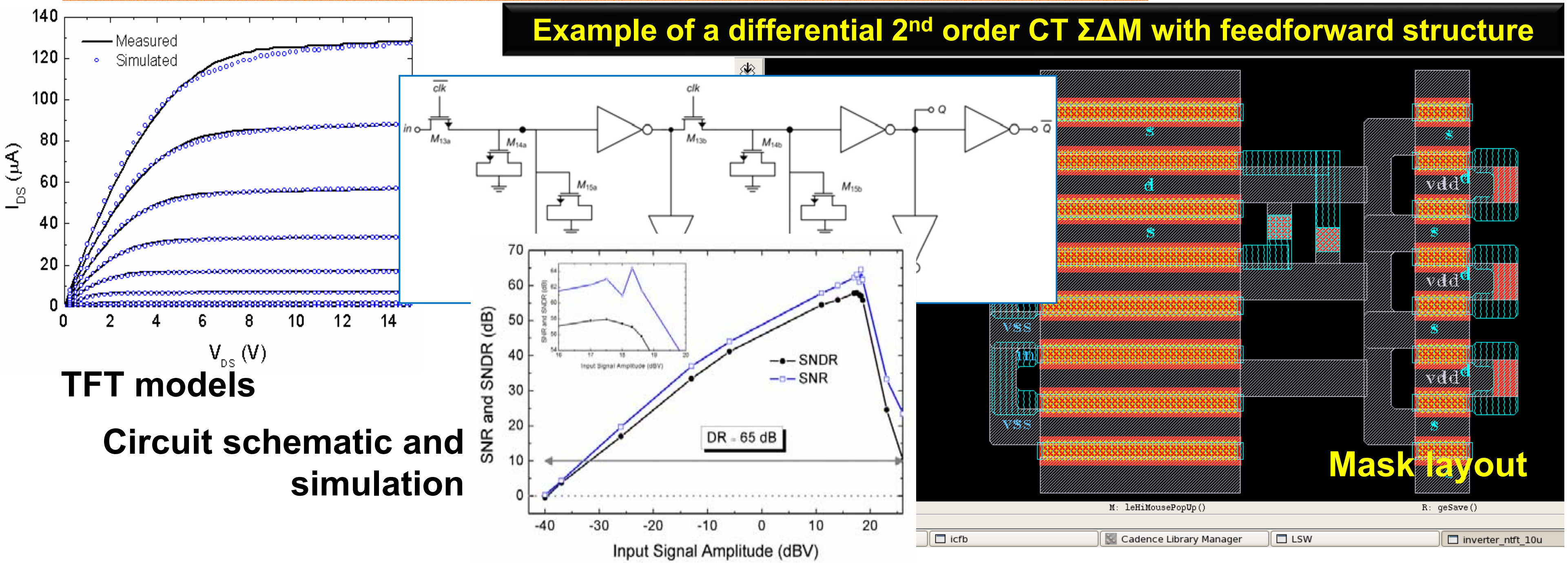




Building of PDK to create more complex circuits, µm and nm scale devices

- Standard cell library
- Design rule check, layout-versus-schematic, parasitics (DRC, LVS, RCX)
- Simulation models
- nMOS and CMOS architectures

Example of a differential 2nd order CT ΣΔM with feedforward structure



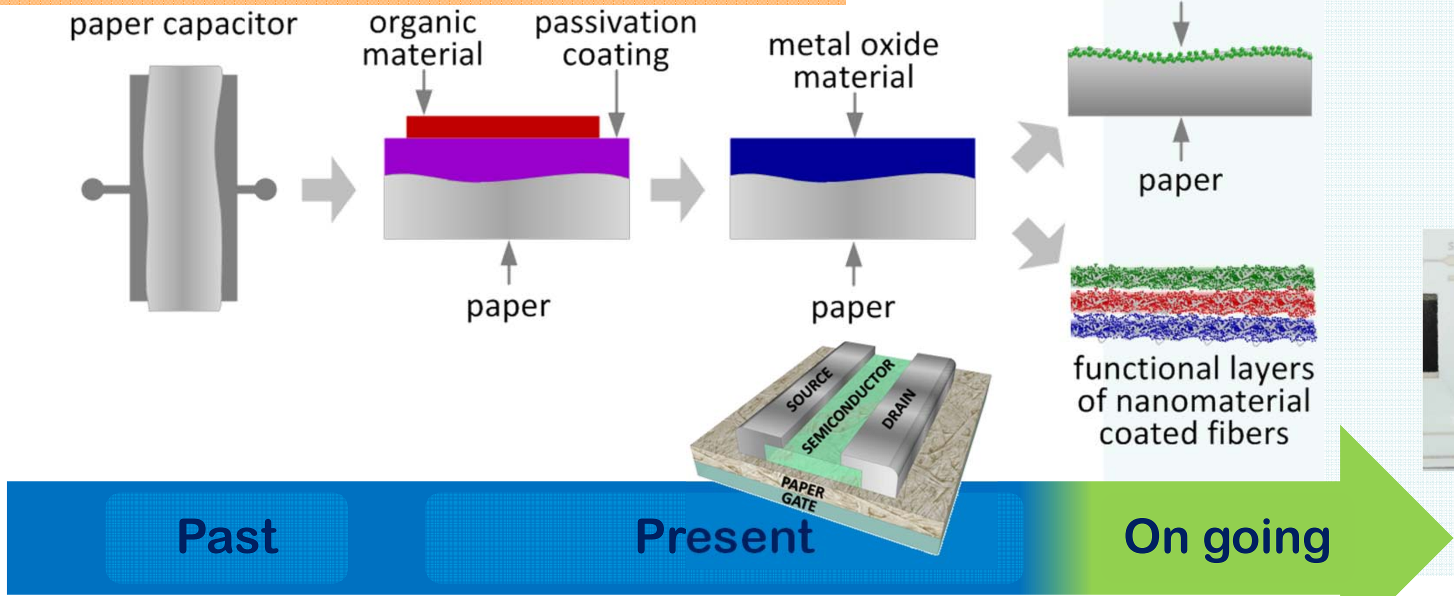
P.G. Bahubalindruni, V.G. Tavares, P. Barquinha, C. Duarte, N. Cardoso, P.G. de Oliveira, R. Martins, E. Fortunato, "a-GIZO TFT neural modeling, circuit simulation and validation", **Solid State Electronics**, 105 (2015), pp. 30-36.

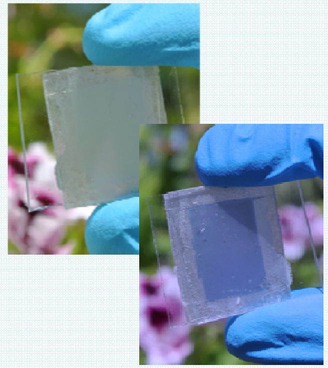
Paper Electronics

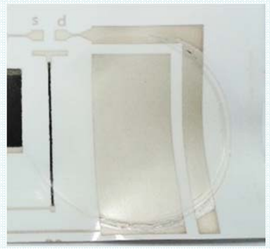
Paper Electronics

Bottlenecks/opportunities

- Paper substrates
- Deposition of functional materials
- Proper functionality







"There is increasing work on printed inorganics as people struggle with the performance of organics… for transistor semiconductors with ten times the mobility, look to the new inorganics."
ID TechX , 2014-2024: Needs, Opportunities, Forecasts.

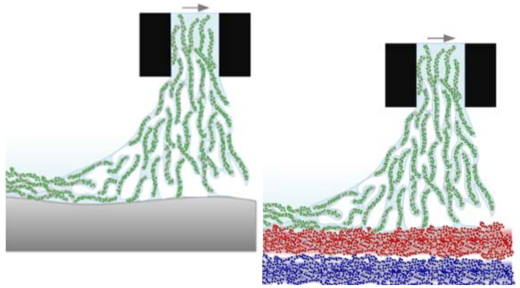
- Cellulose nanocomposites
- Low cost devices/systems
- Sustainability/Recyclability
- New Markets/Benefits PT/EU INDs.

R. Martins, et al., Recyclable, Flexible, Low-Power Oxide Electronics, **Advanced Functional Materials** 23 (17) (2013), pp. 2153-2161

Paper Electronics

Multifunctional materials

- Inorganic/hybrid particles
- Functional cellulose

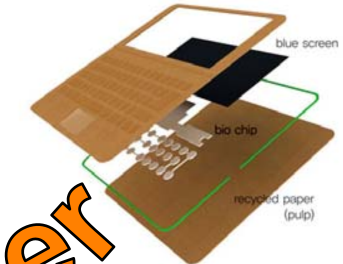


Deposition and formation

- Inks/dispersions
- Paper/films formation

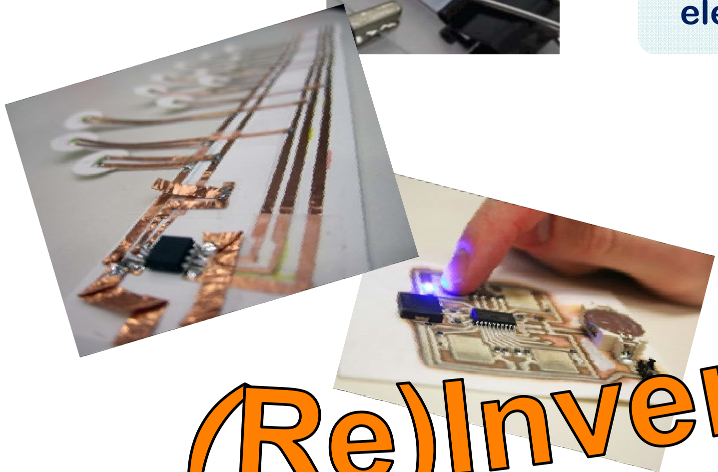
Devices

- Cellulose based electrical and electrochemical components



Systems

- Integration
- Proof of concept



(Re)Inventing the paper

L Pereira, D Gaspar, D Guerin, A Delattre, E Fortunato and R Martins, The influence of fibril composition and dimension on the performance of paper gated oxide transistors, **Nanotechnology** 25 (2014) art nº 094007 (11pp).

Paper Electronics

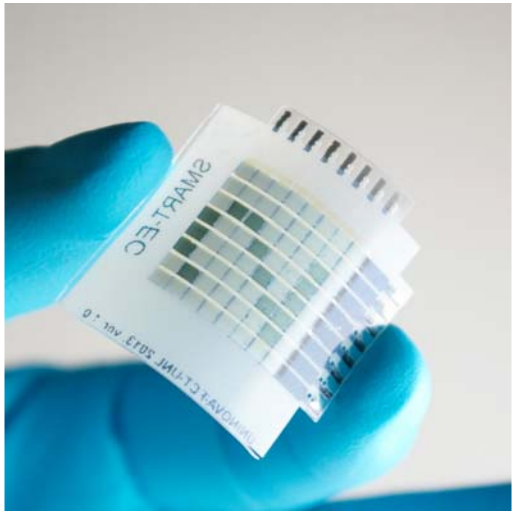
A. Vicente, H. Águas, T. Mateus, A. Araújo, A. Lyubchyk, S. Siitonen, E. Fortunato, R. Martins, Solar Cells for Self-Sustainable intelligent Packaging, **J. Materials Chemistry A**, 2015, DOI 10. 1039/C5TA01752A.

Electrochemical Devices

Electrochemical Devices

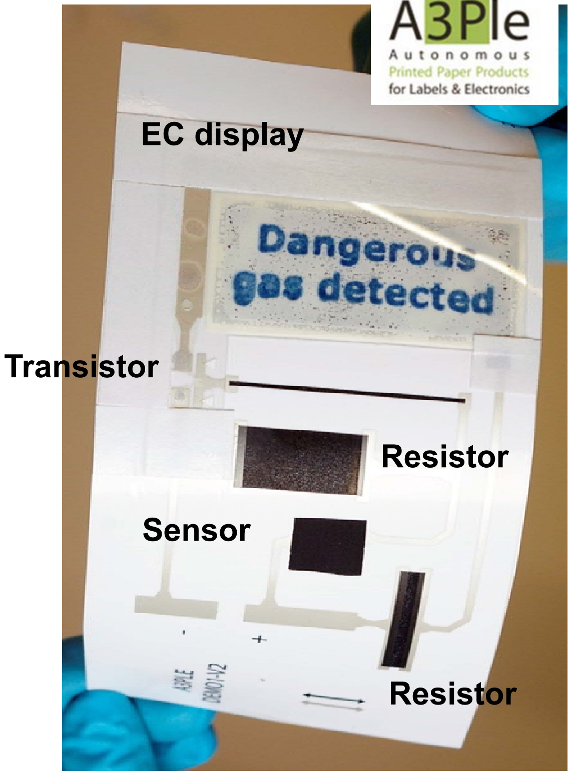
SMART-EC

www.smart-ec.eu

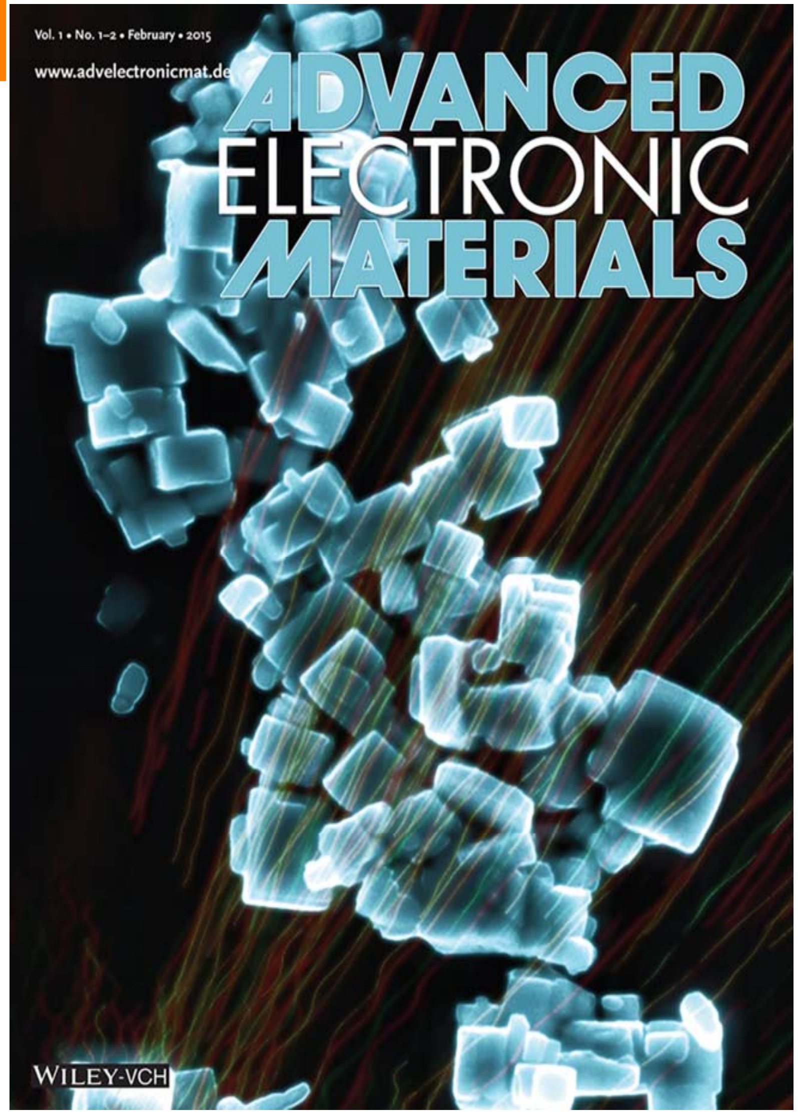


Printed, flexible, all-solid-state, 8x8 passive electrochromic matrix (display), 1.65x1.65 mm pixel.

A3Ple
Autonomous Printed Paper Products for Labels & Electronics



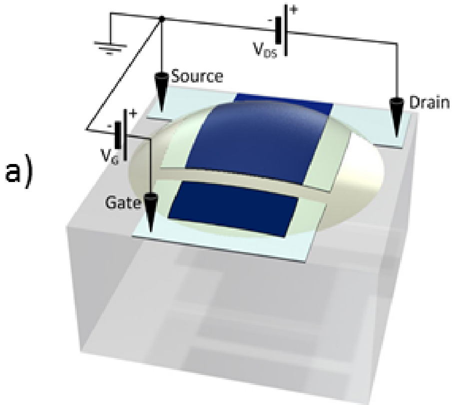
Inkjet/screen printed, all-solid-state, bendable, paper display
Printed circuits and transistors.

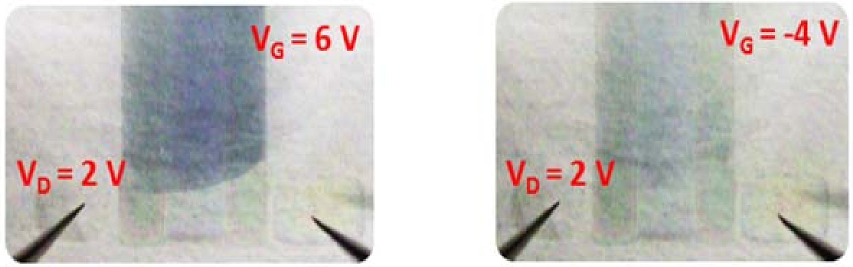


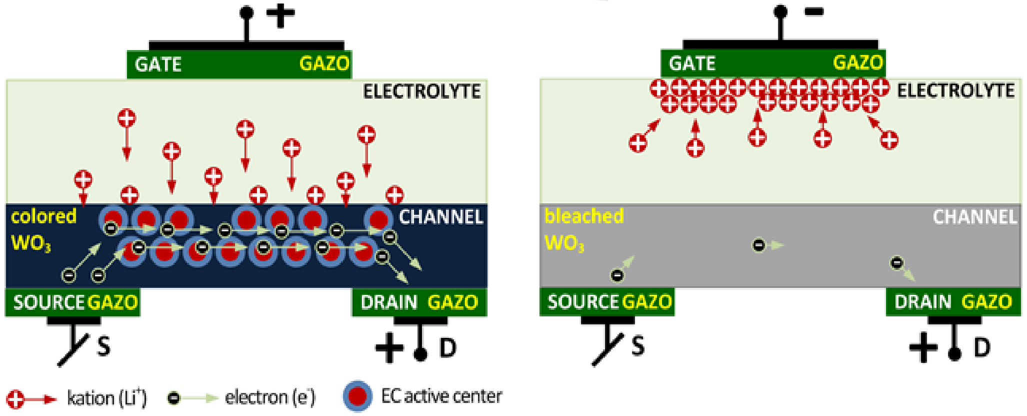
L. Santos, P. Wojcik, J.V. Pinto, E. Elangovan, J. Viegas, L. Pereira, R. Martins, E. Fortunato "Structure and Morphologic Influence of WO 3 Nanoparticles on the Electrochromic Performance of Dual-Phase a -WO3 /WO3 Inkjet Printed Films", **Advanced Electronic Materials**, 2015, DOI. 10.1002/aelm.201400002.

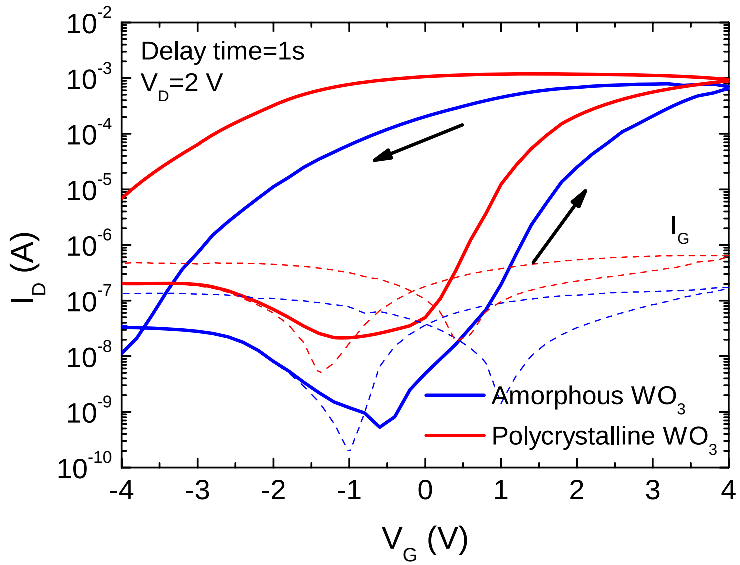
Electrochemical Devices

EGT WO_3 transistors with electrical and optical modulation







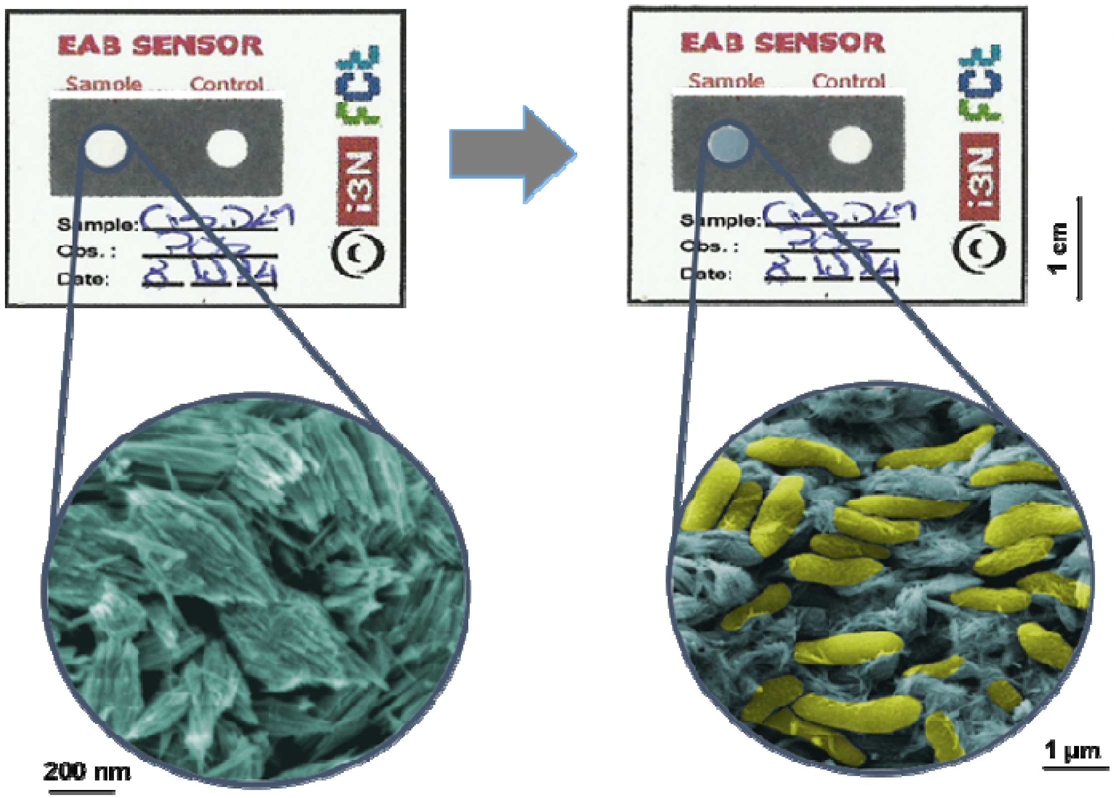


P. Barquinha, et al., accepted **Advanced Electronic Materials**, 2015.

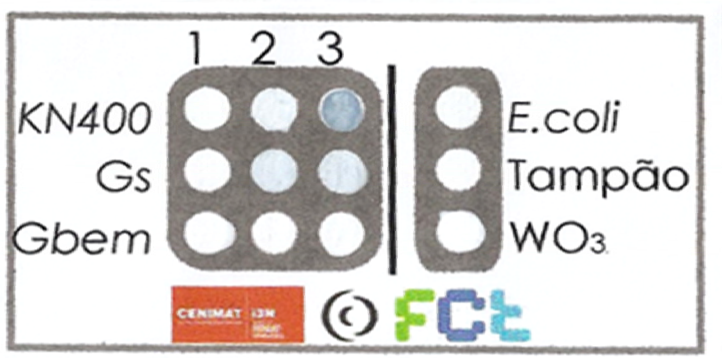
Biosensors / Microfluidics

Biosensors / Microfluidics

WO_3 NPs used as Bioelectrochromic Detection of Electrochemically Active Bacteria



Sensor with different bacteria



KN400 – *Geobacter sulfurreducens*, strain KN400
Gs – *Geobacter sulfurreducens*, strain DL1
Gbem – *Geobacter bemidjiensis*

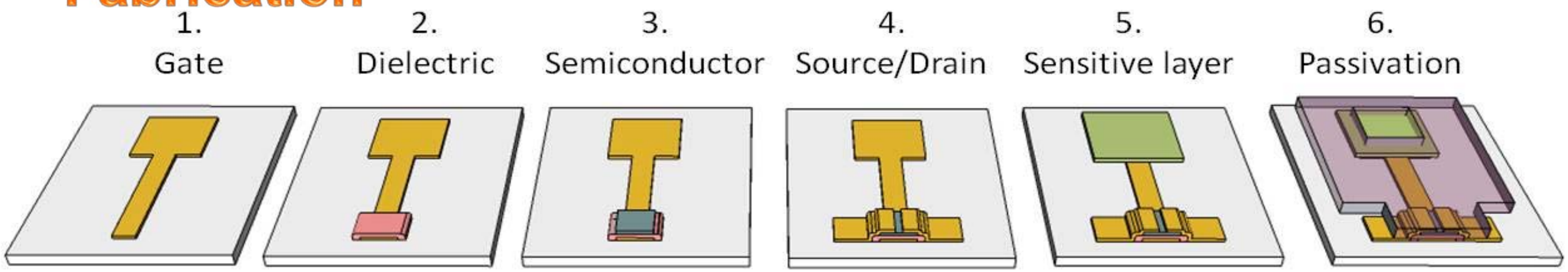
Color distintion between the electron transfer ability of the bacteria to the WO_3 probe, and consequently, to generate current!

A.C. Marques, et al., accepted **Scientific Reports**, 2015.

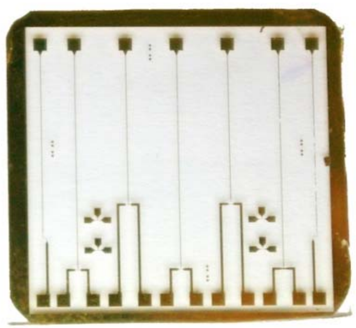
Biosensors / Microfluidics

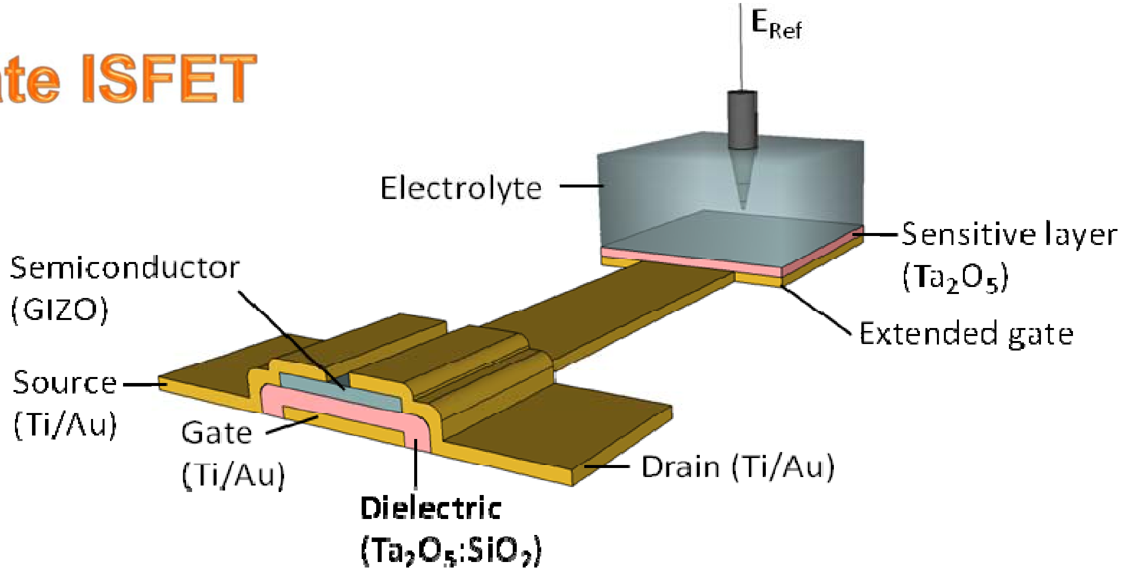
Oxides Based ISFET Devices

Fabrication



Structure: Extended Gate ISFET



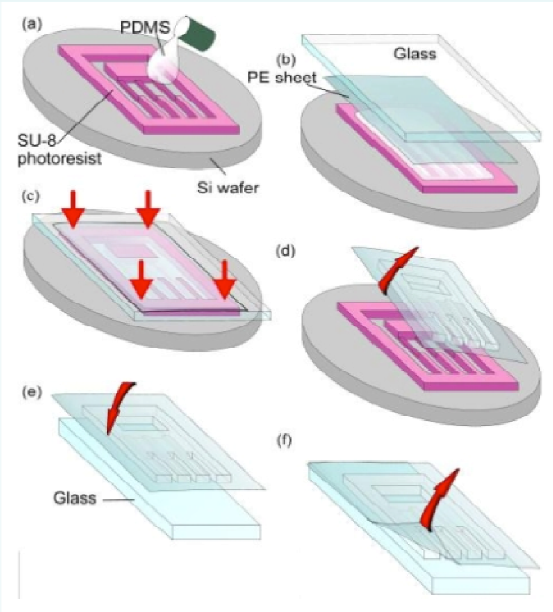


Bruno Veigas, Rita Branquinho, Joana Pinto, Pawel Wojcik, Rodrigo Martins, Elvira Fortunato, Pedro V Baptista, Ion sensing (EIS) real-time quantitative monitorization of isothermal DNA amplification, **Biosensors & Bioelectronics** Vol 52 (2014), pp. 50-5.

Biosensors / Microfluidics

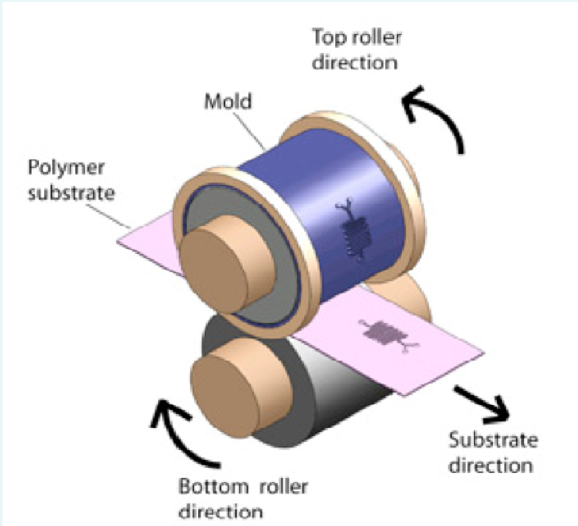
Microfluidic technologies

SU8/PDMS Lithography



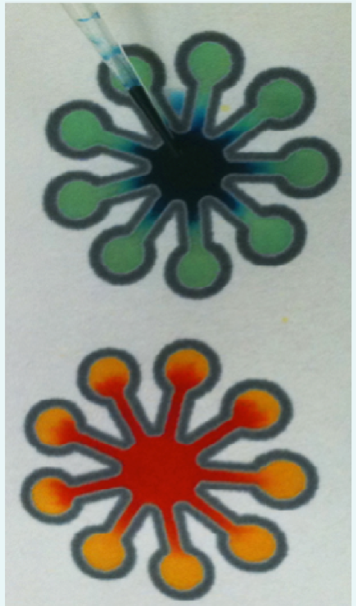
Schematic illustration of the simplified fabrication process for PDMS microfluidic alginate microbead generator chip.

Embossing



Embossing depicting the principle of fabrication of polymer-based microfluidic devices using the hot roller embossing technique.

Lab-on-Paper



Example of paper microfluidic devices developed at FCT-UNL, Portugal.

Complexity
Cost

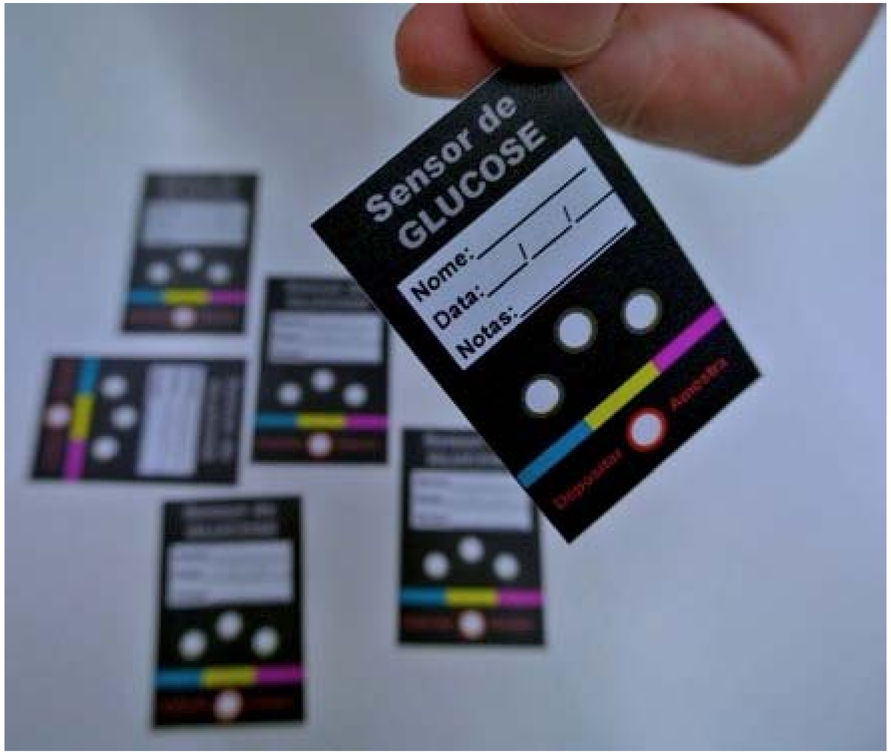
Safety
Time

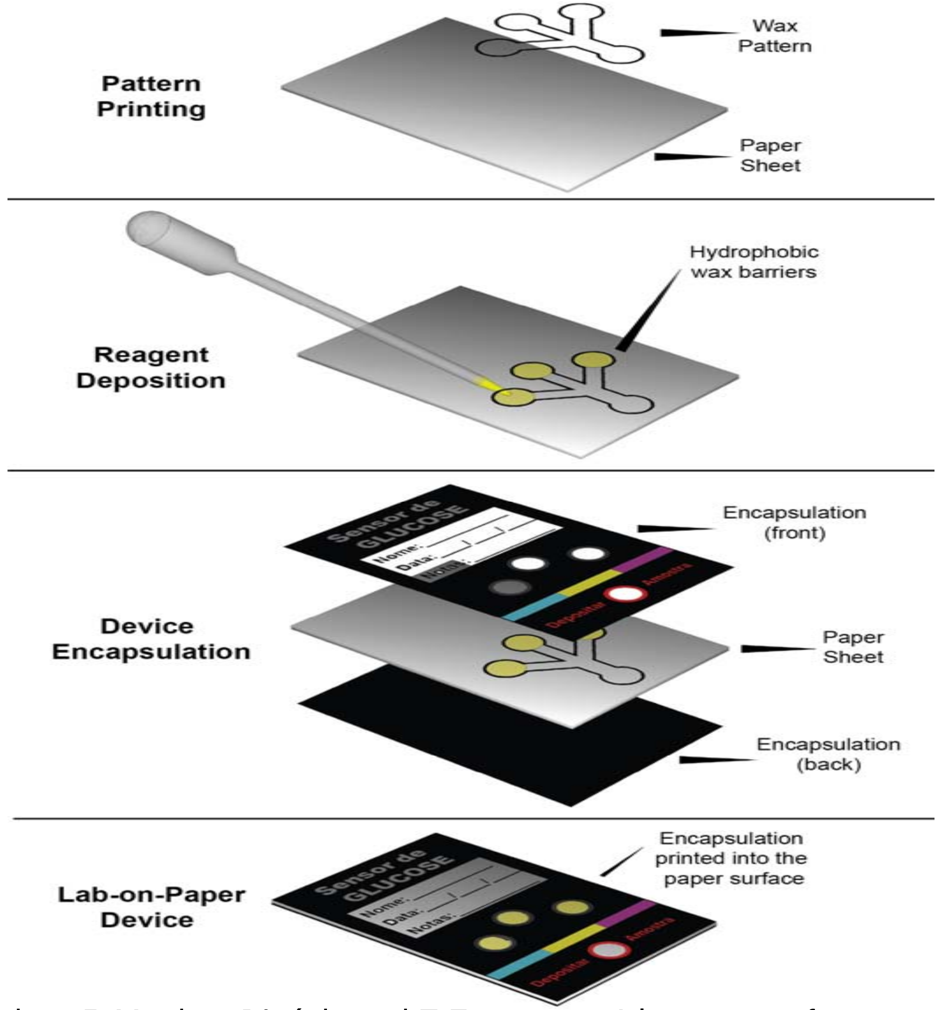
⊘ energy
Resolution

Lab-on-Paper

Glucose biosensor

Paper Analytical Device



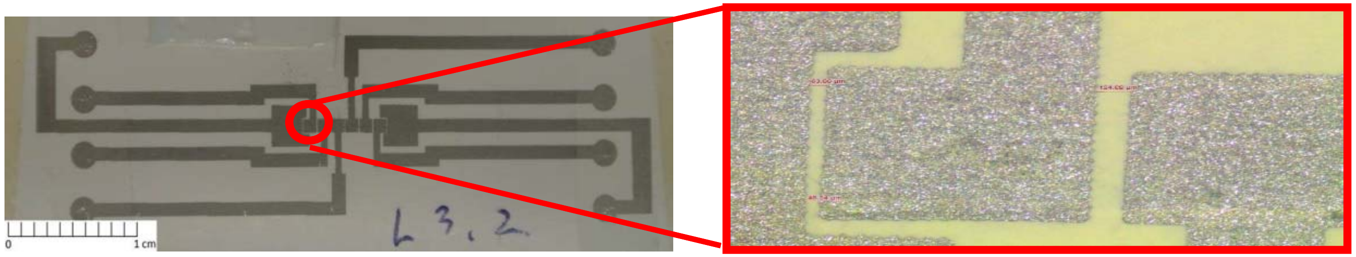


M N Costa, B Veigas, J M Jacob, D S Santos, J Gomes, P V Baptista, R Martins, J Inácio and E Fortunato, A low cost, safe, disposable, rapid and self-sustainable paper-based platform for diagnostic testing: lab-on-paper, **Nanotechnology** 25 (2014) art nº 094006.

Biosensors / Microfluidics

Digital Microfluidics

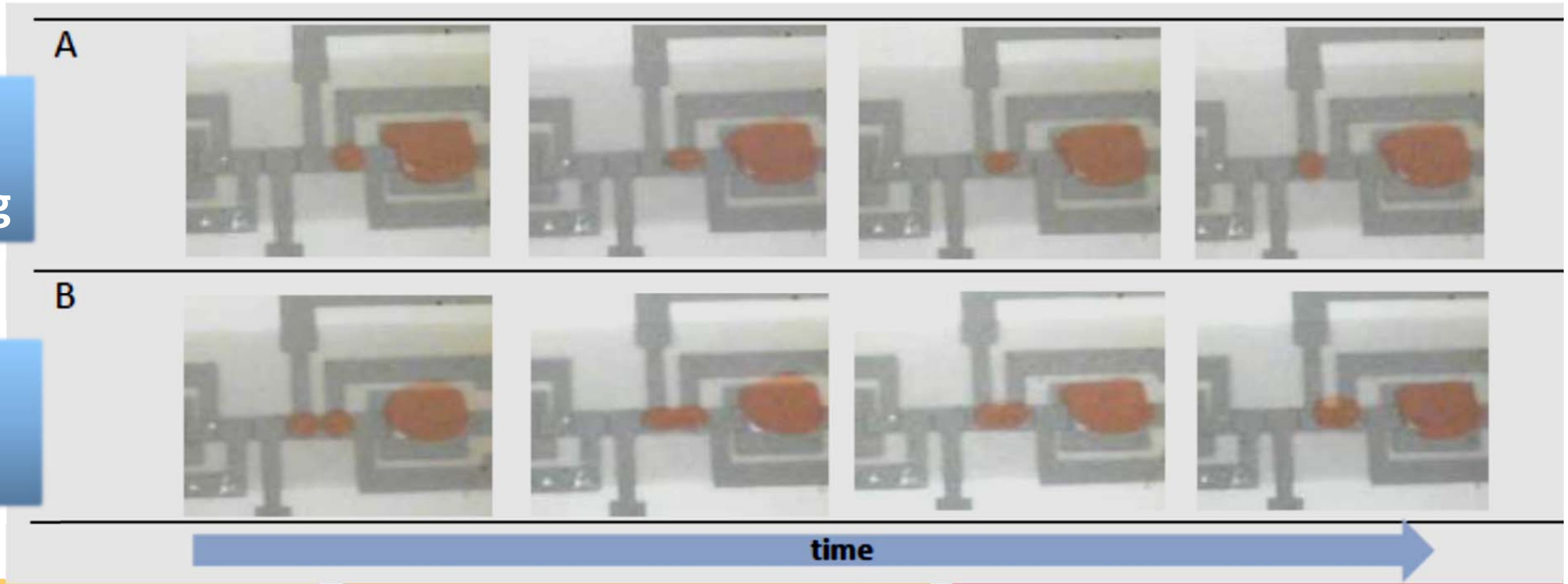
Paper-based devices



Screen printed electrodes

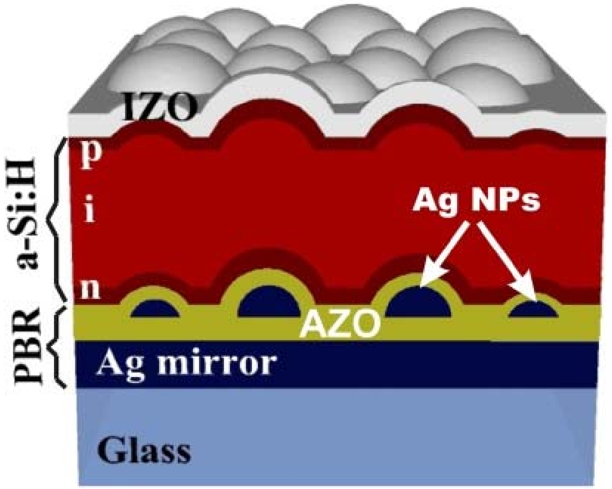
Droplet dispensing

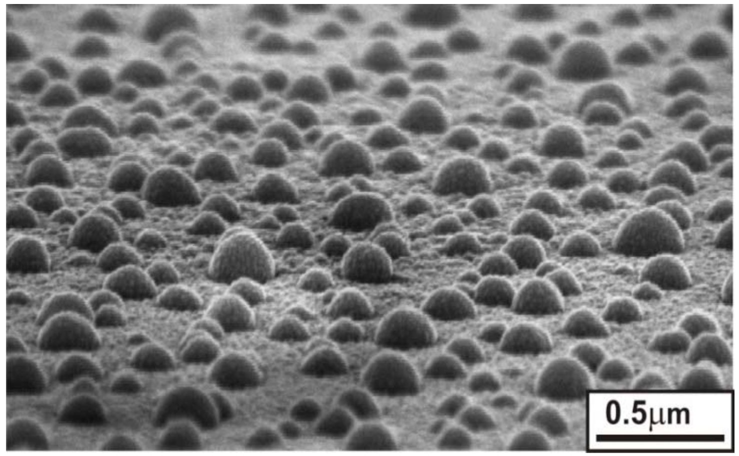
Droplet merging

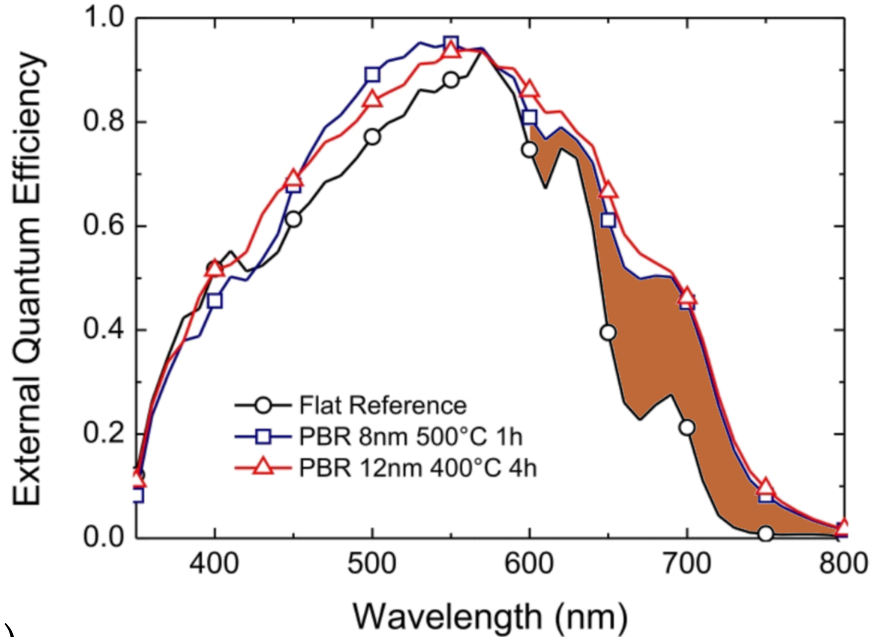


Nanoplasmonics

Plasmonic Back Reflectors with Ag NPs formed by Thin Film Annealing (solid-state dewetting)







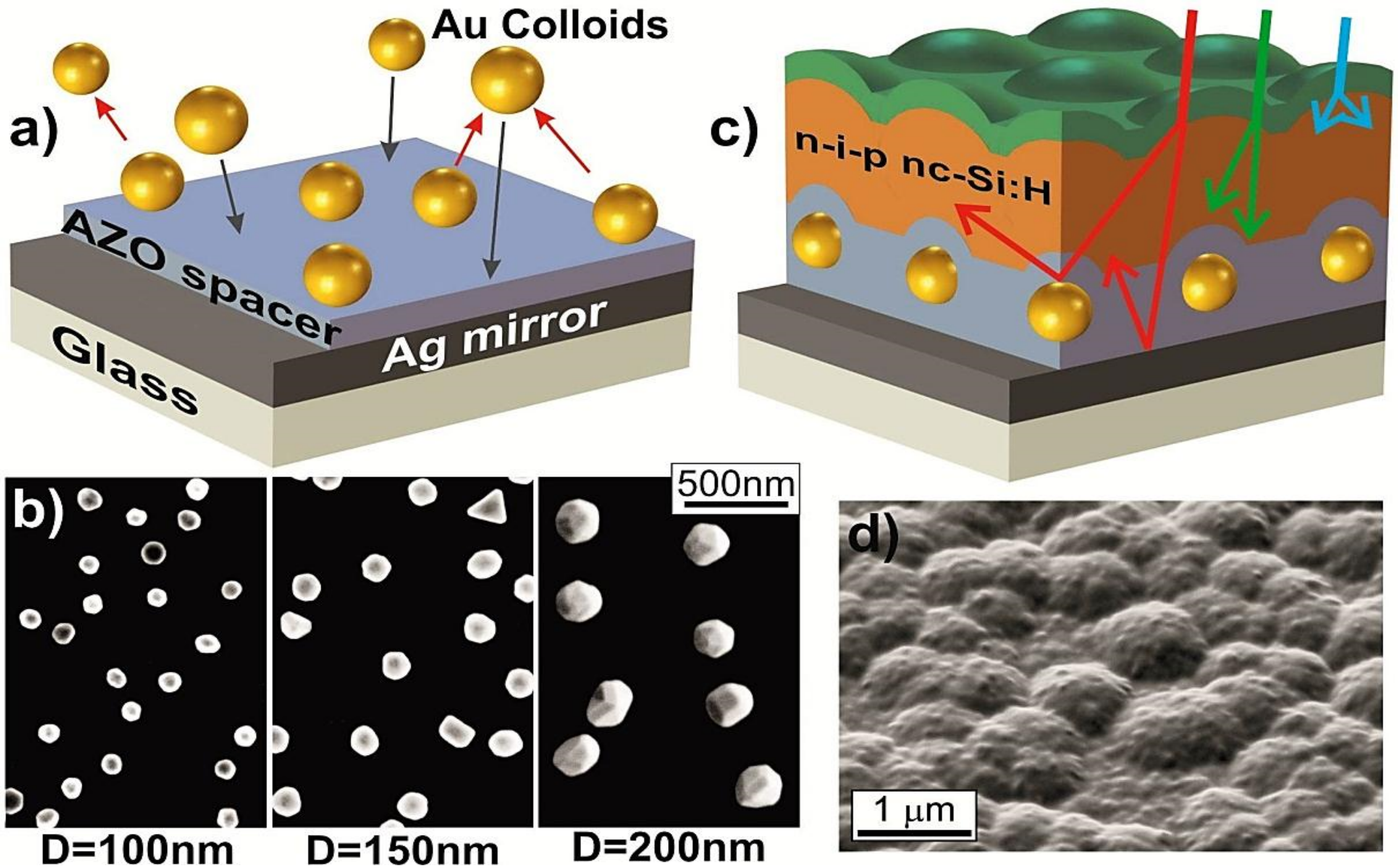
- 22.3% current (J_{SC}) enhancement
- **25.2% efficiency enhancement**

S. Morawiec, M. J. Mendes *et al.* Optics Express (2014)

Nanoplasmonics

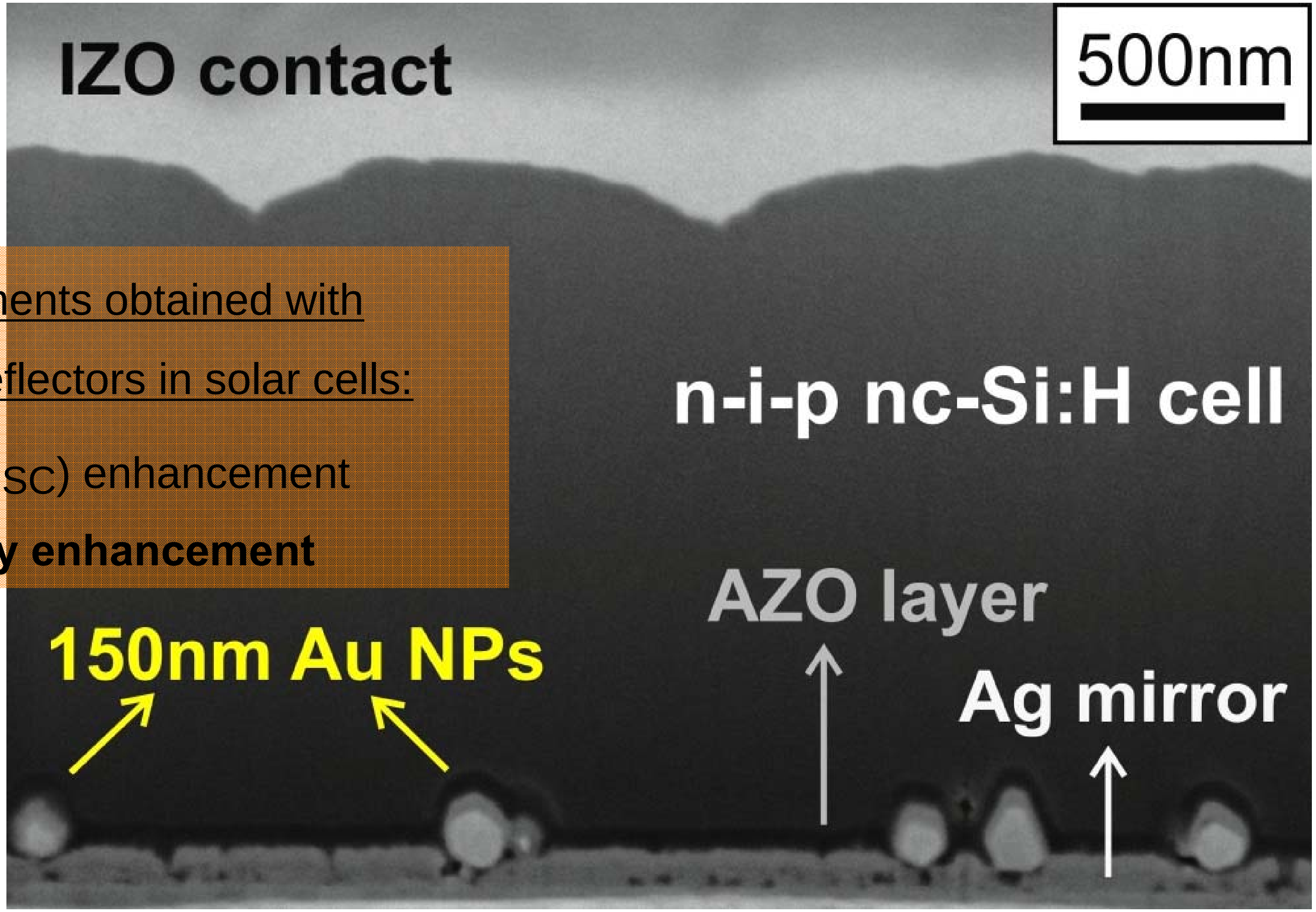
M. J. Mendes, S. Morawiec *et al.*
Nanoscale 6 (2014)

Novel Plasmonic Back Reflectors with Spherical Au NPs formed by Colloidal Self-Assembly (wet coating)



Nanoplasmonics

Novel PBRs formed by Colloidal Self-Assembly



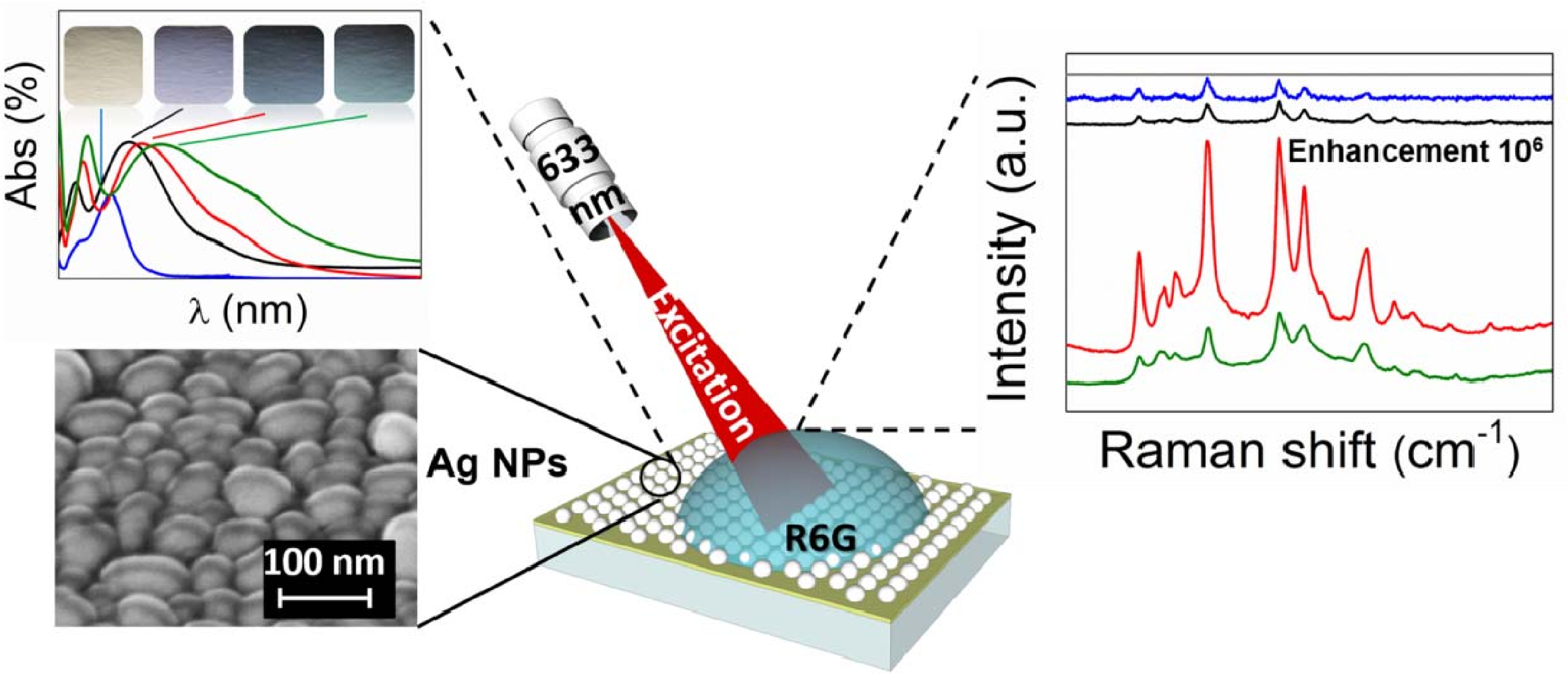
Record enhancements obtained with plasmonic back reflectors in solar cells:

- 43% current (J_{SC}) enhancement
- **41% efficiency enhancement**

M. J. Mendes, S. Morawiec *et al.* **Nanotechnology** 26 (2015)

Biosensors / Microfluidics

Disposable SERS Microfluidic platforms

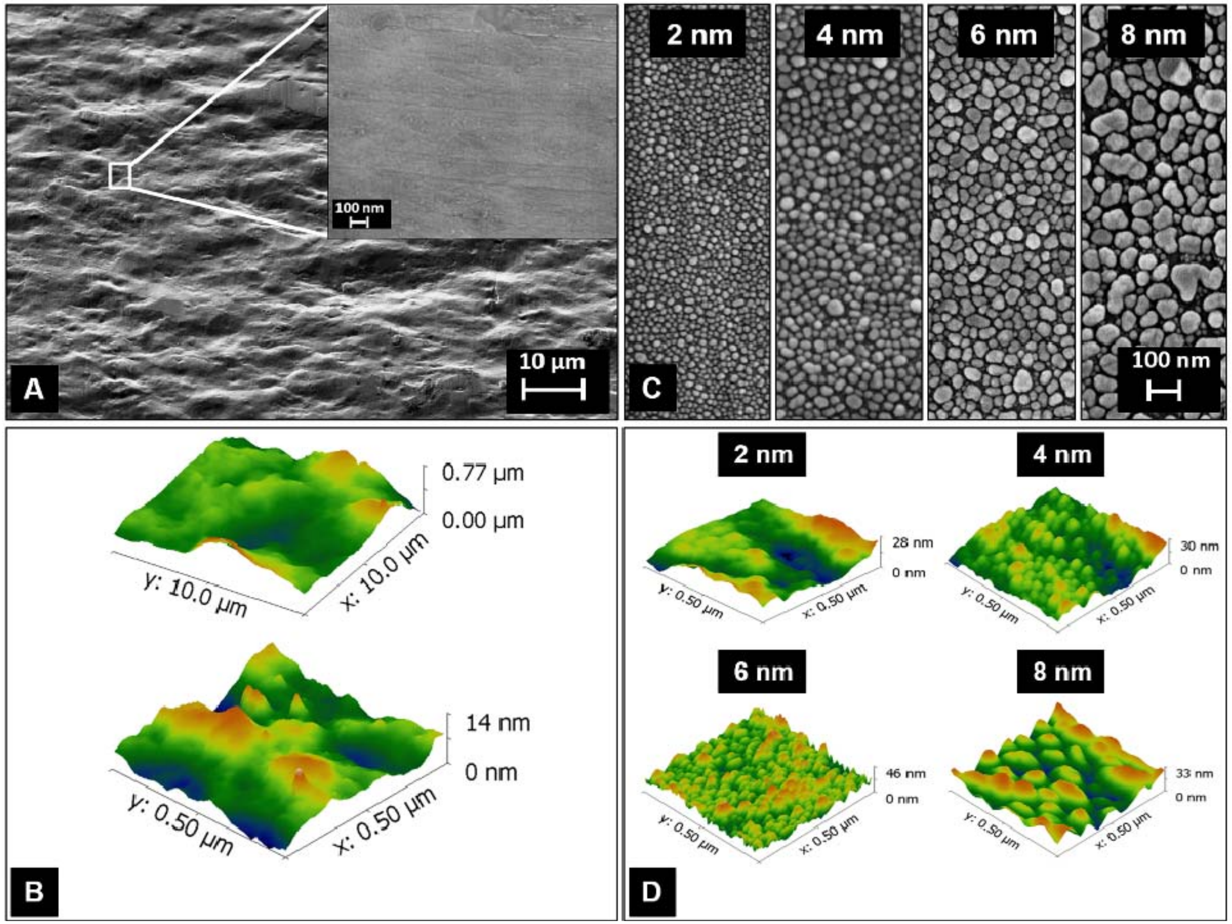


Araujo, A., C. Caro, M.J. Mendes, D. Nunes, E. Fortunato, R. Franco, H. Aguas, and R. Martins, *Highly efficient nanoplasmonic SERS on cardboard packaging substrates.* **Nanotechnology**, 2014. **25**(41): p. 415202

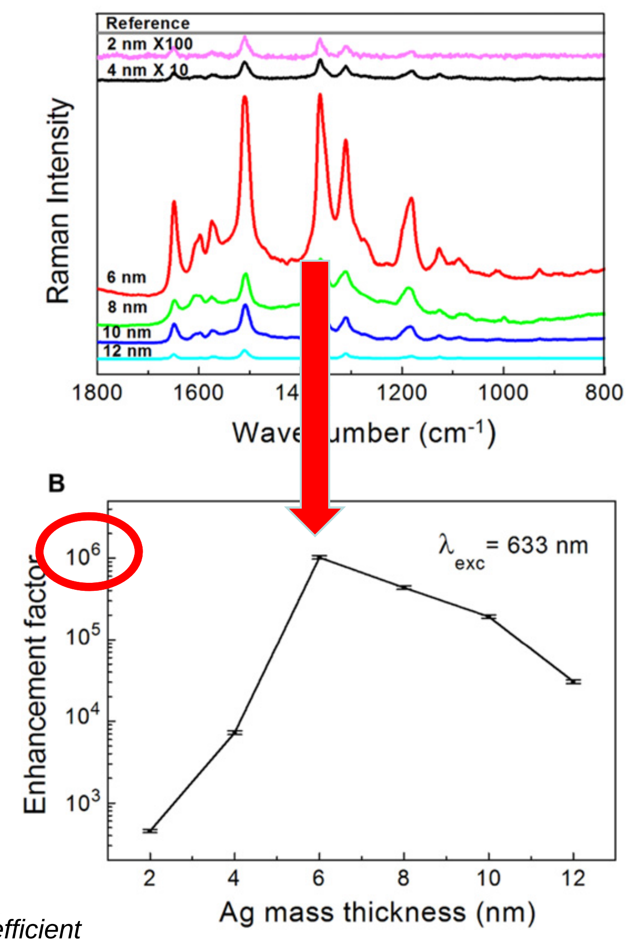
Biosensors / Microfluidics

Disposable SERS Microfluidic platforms

Cardboard Surface | Ag Nanoparticles



SERS with R6G



Araujo, A., C. Caro, M.J. Mendes, D. Nunes, E. Fortunato, R. Franco, H. Aguas, and R. Martins, *Highly efficient nanoplasmonic SERS on cardboard packaging substrates.* **Nanotechnology**, 2014. **25**(41): p. 415202

Running FP7/H2020 projects

CoG ERC, CapTherPV, Grant nº 647596
StG ERC, NewFun, Grant nº 640598

iFLEXIS, Grant nº 611070 (ICT)
AllOxidePV, Grant nº 309018 (FET)
APPLE, Grant n° 262782 (NMP)
CEOPS, Grant nº 309984 (NMP)
MATCH, Grant nº 319142 (CSA)
InnoNet, Grant nº 319024 (CSA)
Roll-Out, Grant nº 644631 (ICT)
TRANSFLEXTEG, Grant nº 645241 (ICT)
Symbiotic, Grant nº 665046 (FET)


10
GC