“Inkjet-printing of nanobiosensors with consumer printers”

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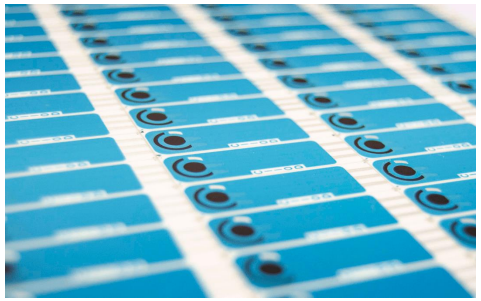
Electrochemical nanobiosensors

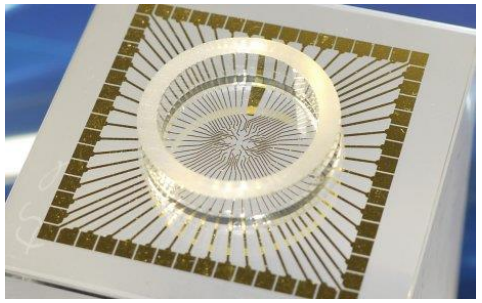
Physical device size

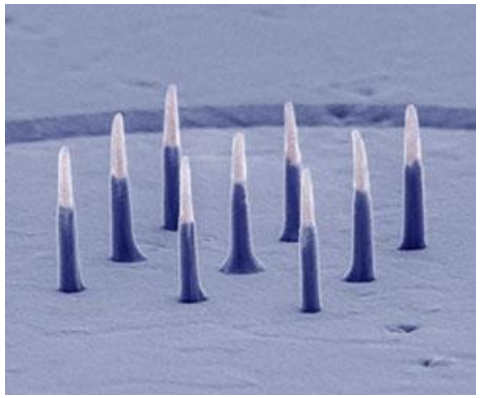
mm

µm

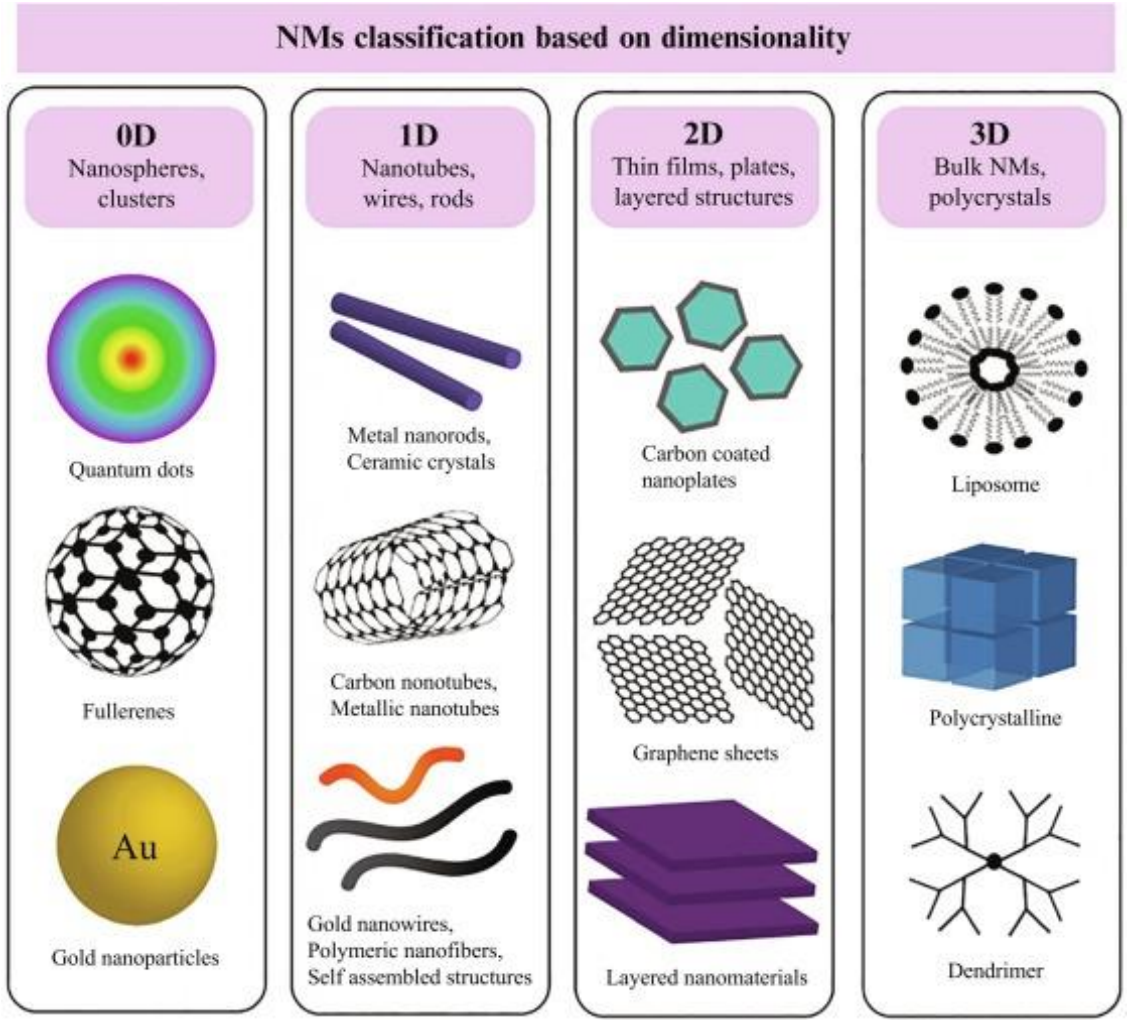
nm



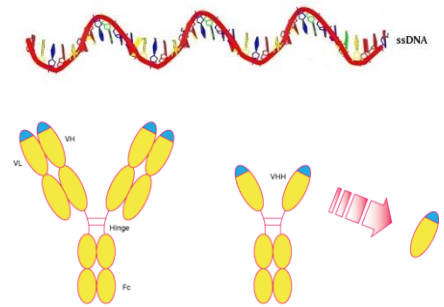




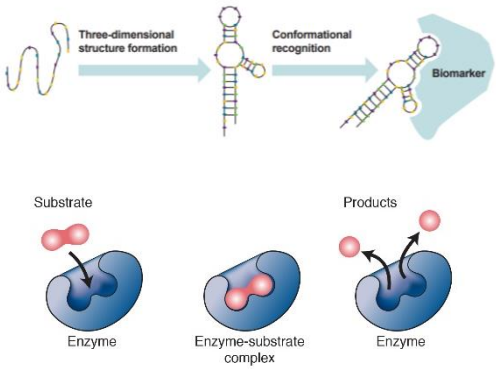
Nanomaterials



Nanobiotechnology

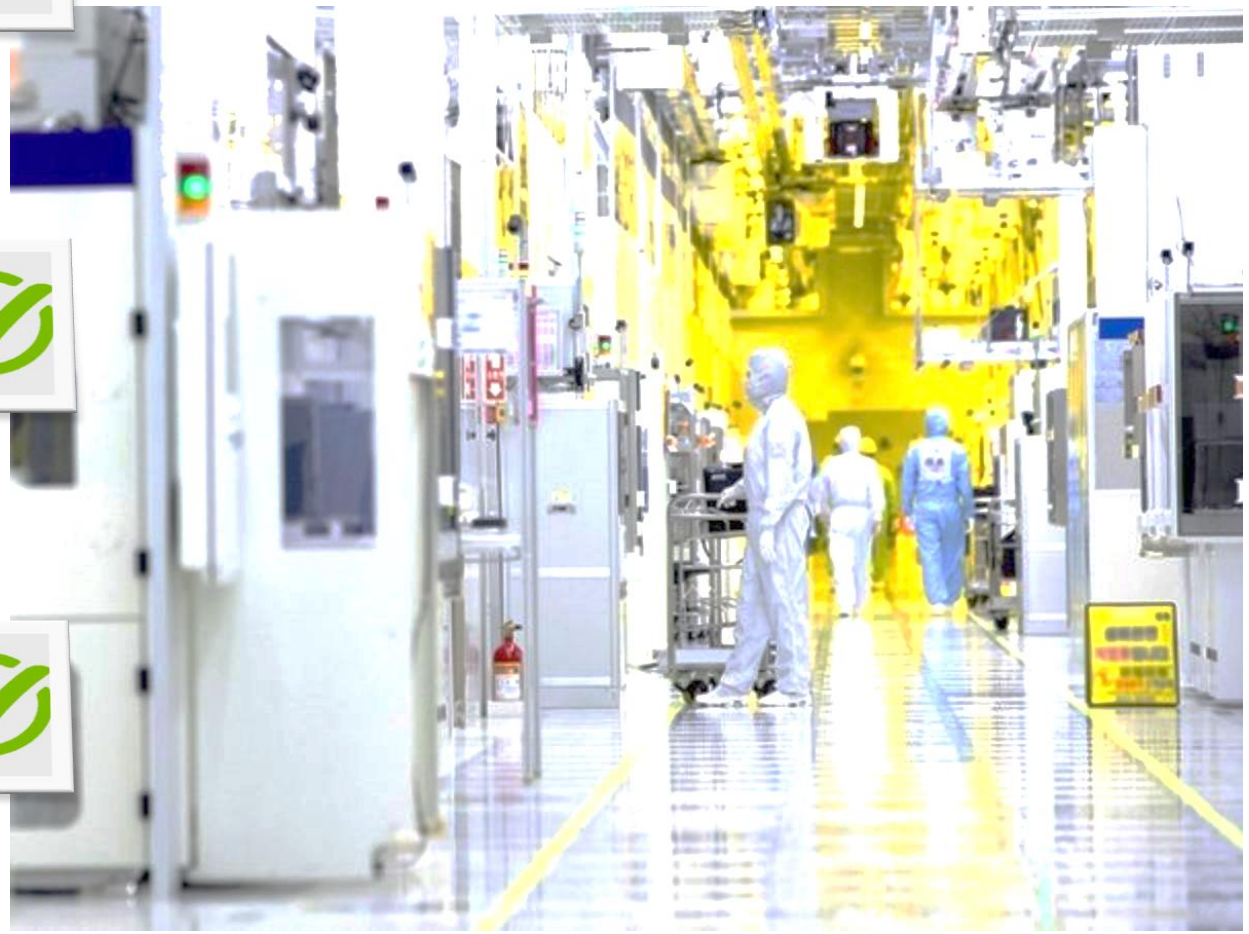


Bioreceptors



Fabrication

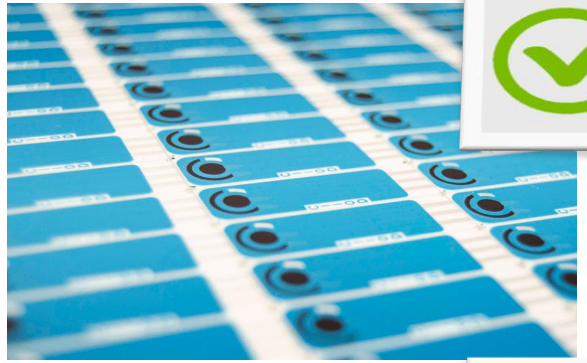
Cleanroom fab

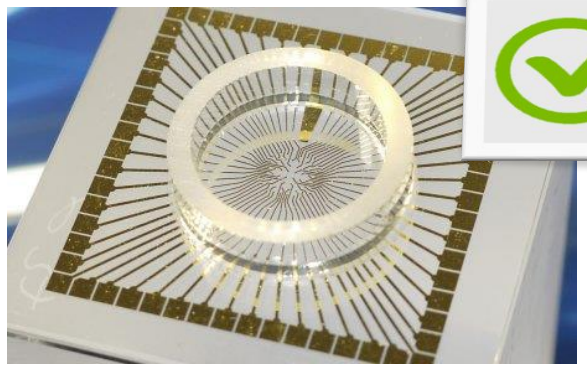


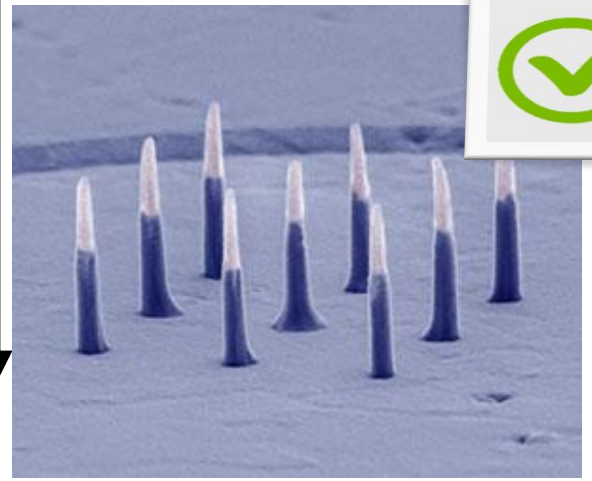
mm

µm

nm







PROs

- Highest precision
- Scalable
- <u>Prone to supply chain interruptions</u>
- Expensive

CONs

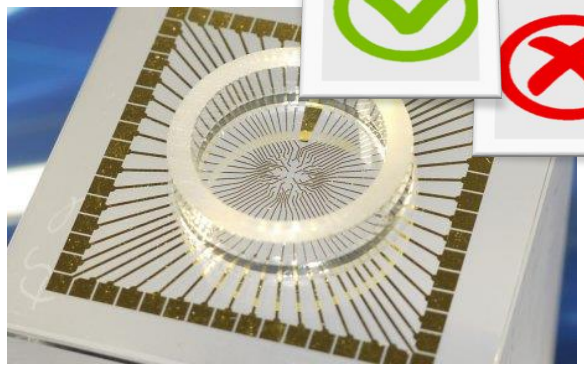
Fabrication

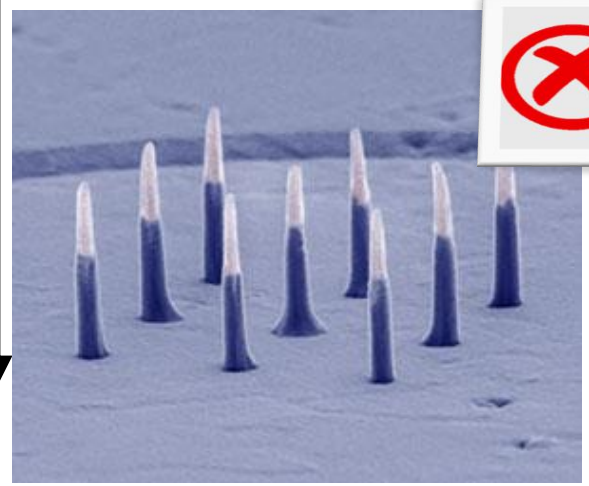
Centralized printing

mm

µm

nm





PROs

- Fast/lower costs
- Scalable
- <u>Prone to supply chain interruptions</u>
- Less precise

CONs

Is there any other option available?

What if we could fabricate them anywhere?

“Ubiquitous”

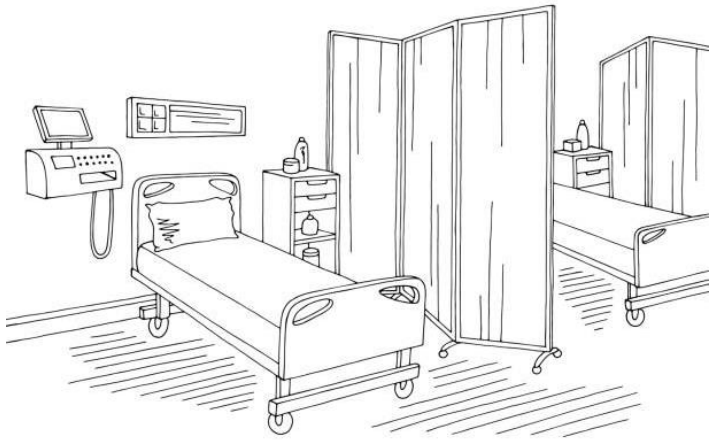
Democratic

Need-precise

printing

at home

in the lab



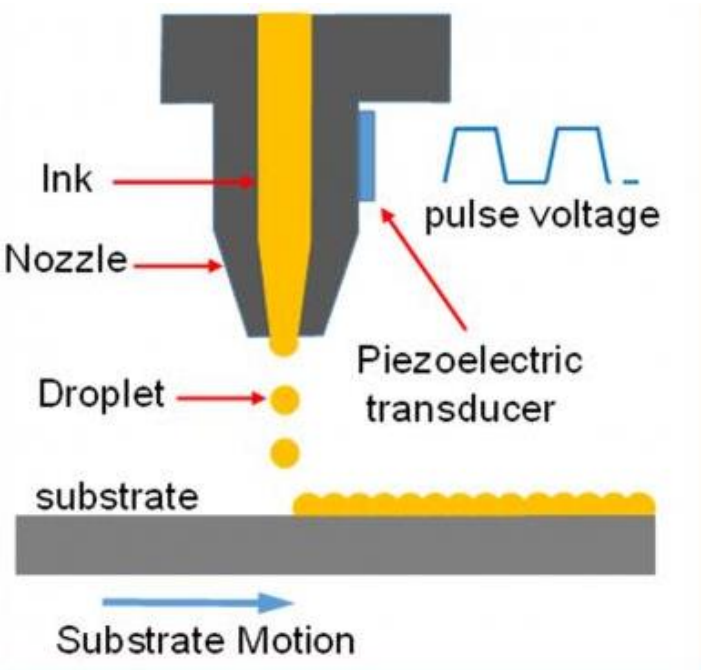
at the point of care

Inkjet with consumer printers

Drop-on-demand system:

- no ink waste
- maskless
- multinozzle – rapid
- low-volume (thin-film)

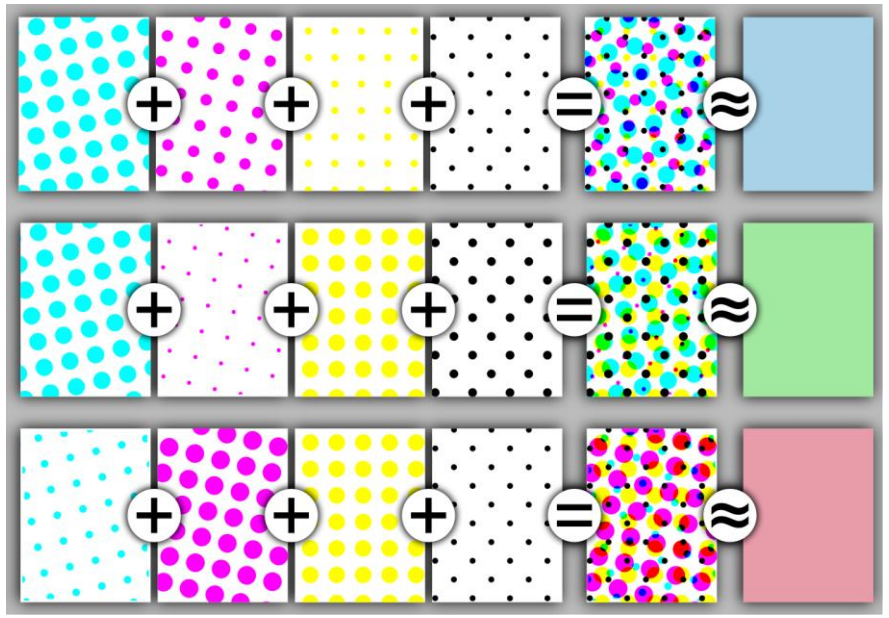
Multi-color option!



Many brands available:

hp Lexmark EPSON Canon

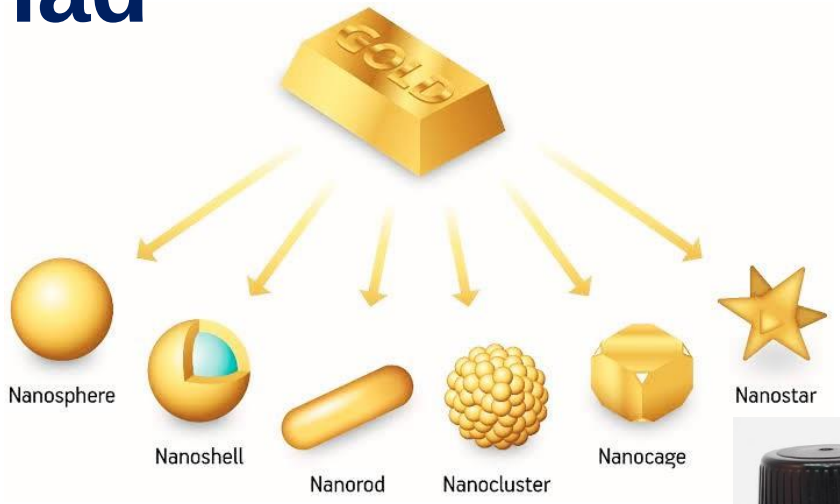
. . .

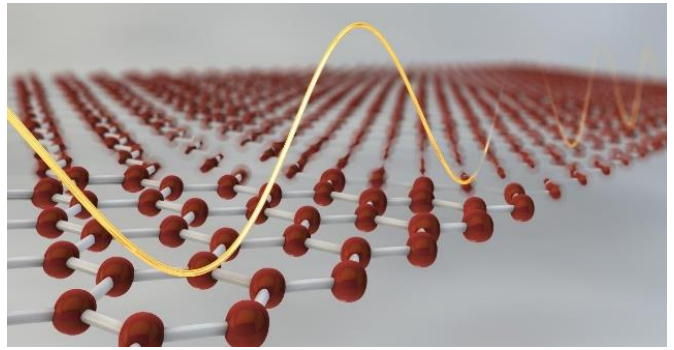


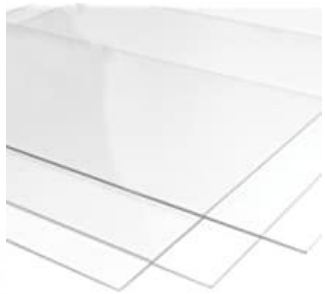
The printing triad

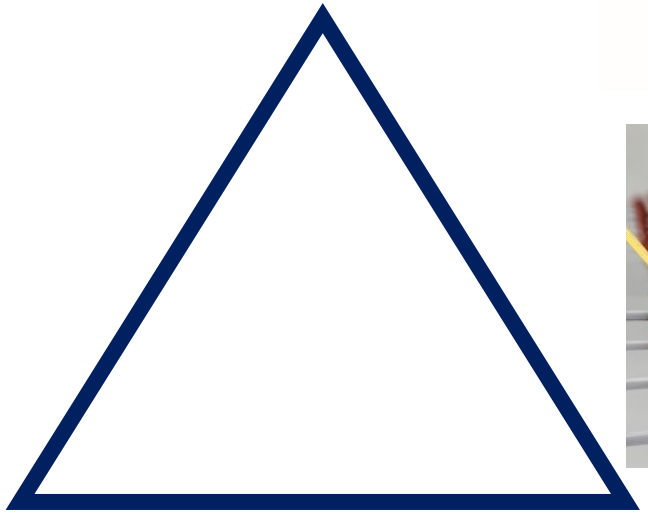
Resolution
Speed
XY control/step
Plate temperature
Number of inks

Printers







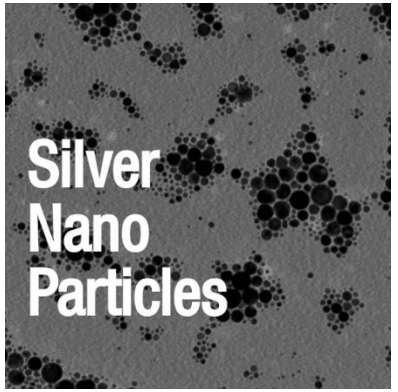


Substrates

Rigidity
Flexibility
Deformability
Sintering
Texture

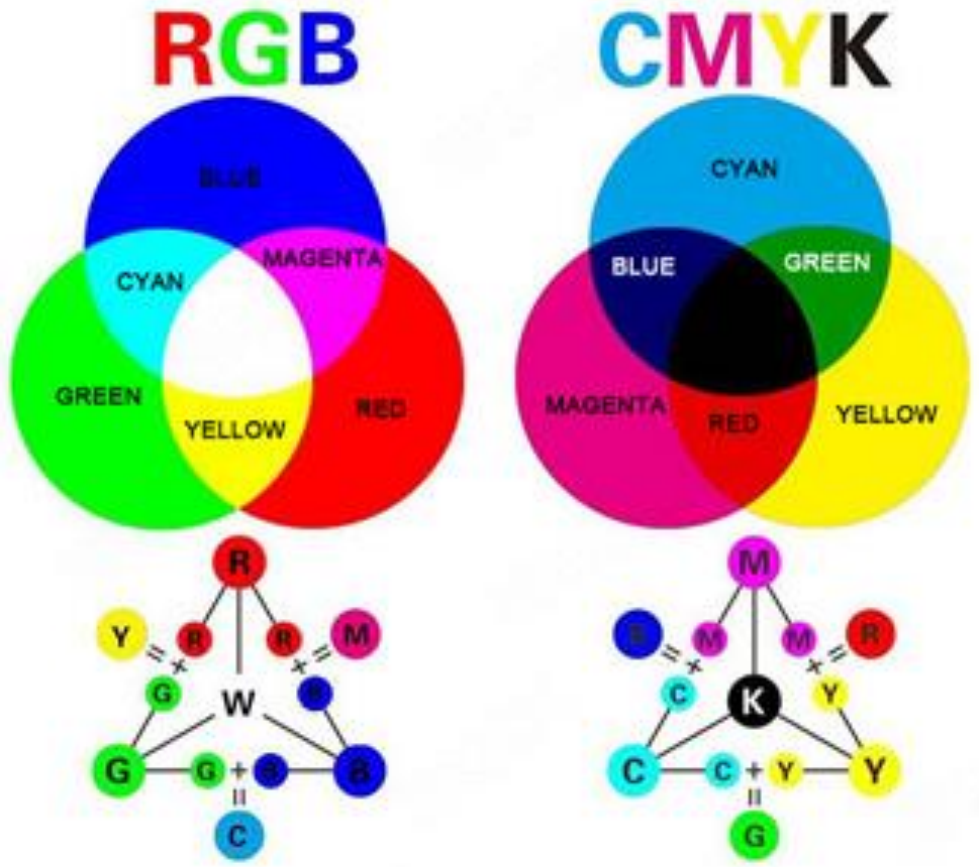
Inks

Quantity/price
Printability
Clogging
Stability



Printing parameters

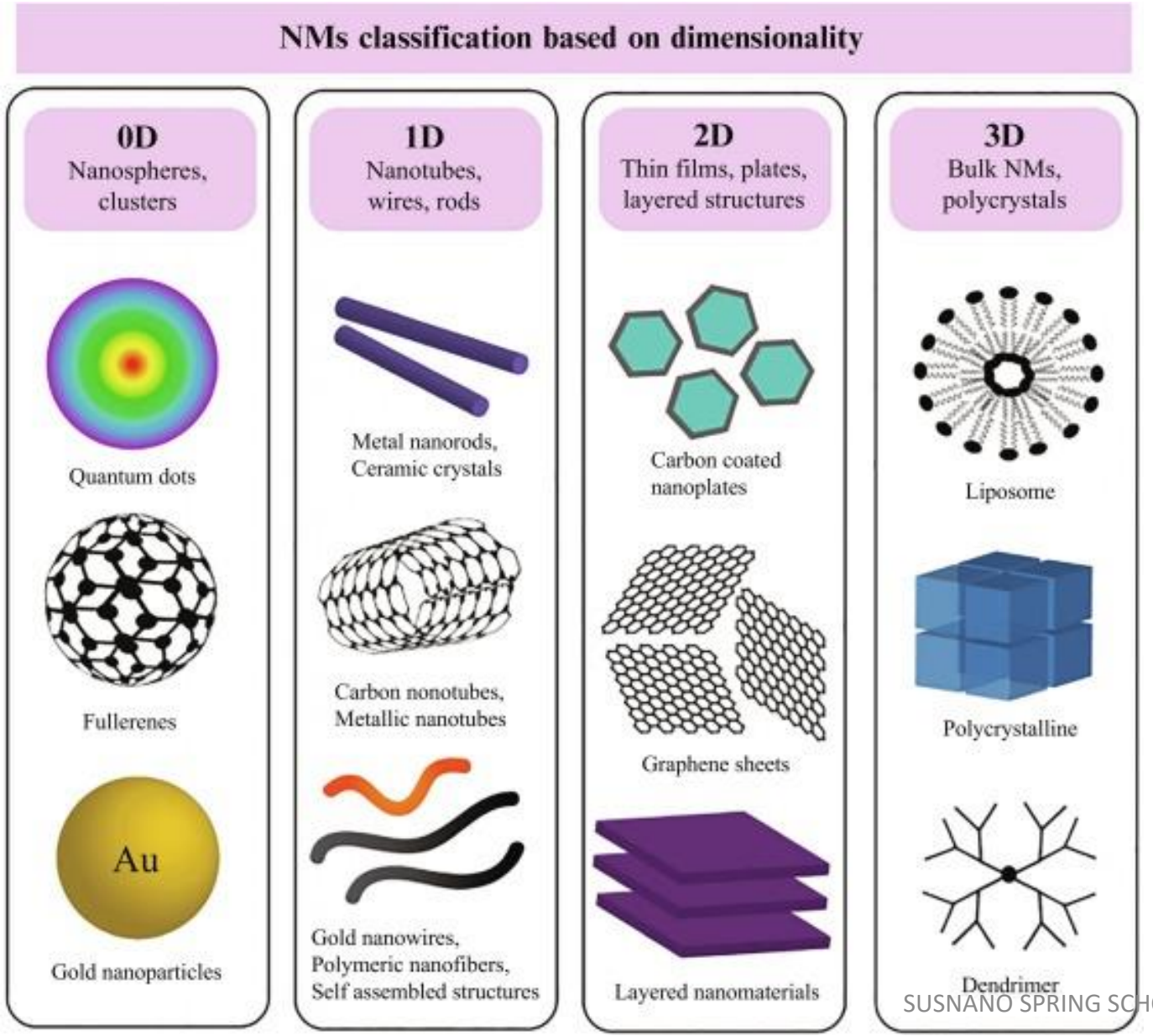
- Resolution (dots per inch)
- Color management
  (from RGB to the nozzle)
- Drop volume vs printed drop diameter
- Substrate type selection
  (glossy, matte, etc.)
- Real line/shapes dimensions vs design



Substrates

- **Impermeable** (solid, flexible, deformable)
  - ➢ **Surface energy control**
  - ➢ **Priming**
- **Semi-absorbent** (absorbent coating, reduced pore size, etc.)
  - ➢ **Nanomaterial filtration/ accumulation**
  - ➢ **Solvent separation**
  - ➢ **Post-print diffusion**
- **Absorbent** (paper, textile, fiber-based, etc.)
  - ➢ **Single fiber decoration**
  - ➢ **Nanomaterials penetration**

Nanoinks



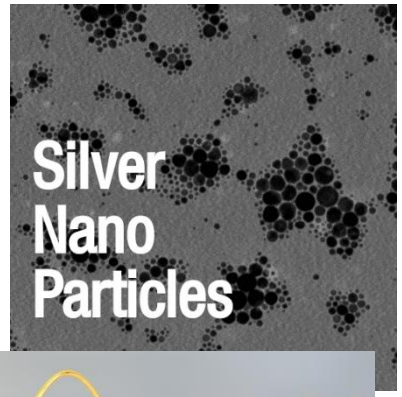
Nanoinks requirements:

- **Dimension** < 500 nm
- Water dispersion (70% water)
- Viscosity: 1-5 thermal; 5-40 piezo (mPa·s or cP)
- Surface tension: 30-60 (mN/m)
- **Stable in solution** (ideally > 6 months)

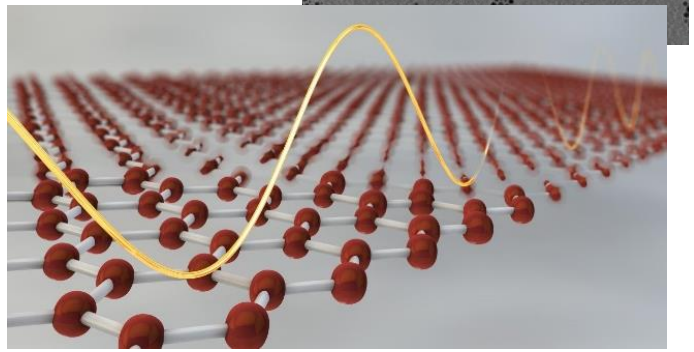
But there is a hidden actor….

Resolution
Speed
XY control/step
Plate temperature
Number of inks

Printers



Post-treatments
Thermal annealing
Optical sintering
Others

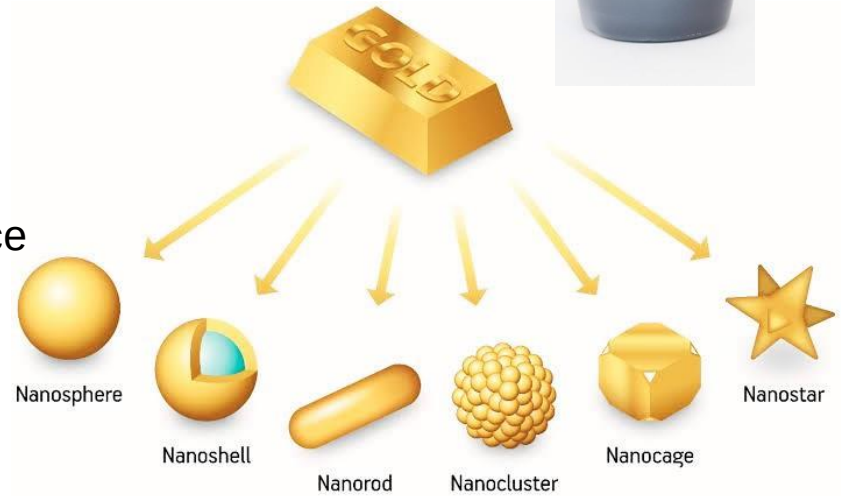


Substrates

Rigidity
Flexibility
Deformability
Sintering
Texture

Inks

Quantity/price
Printability
Clogging
Stability



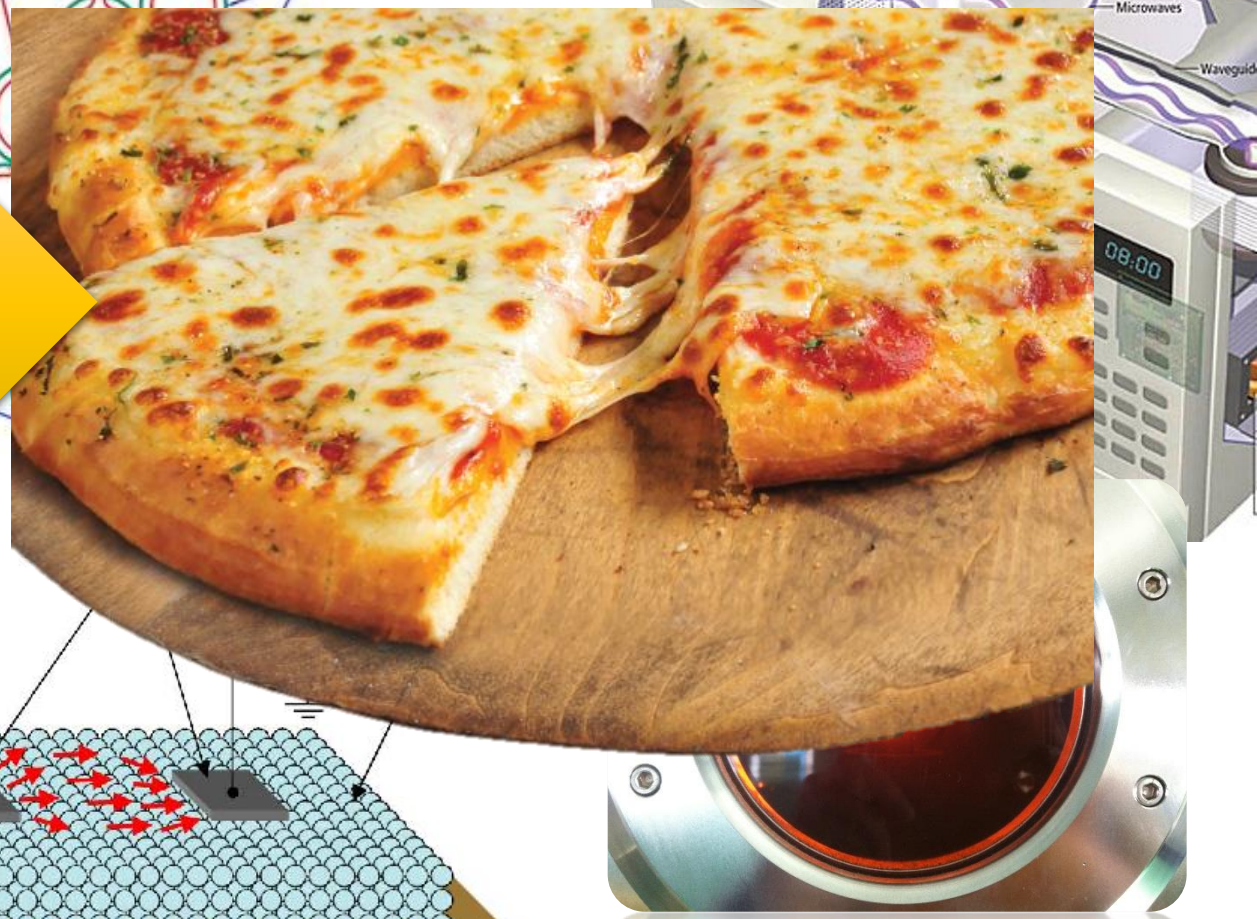
The hidden actor: post-treatments

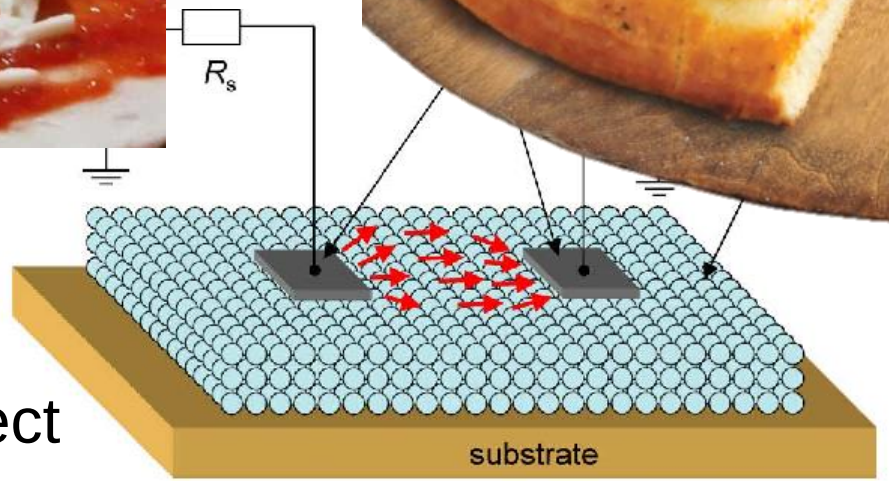
Thermal

Optical

Electrical

Microwaves, plasma, etc.





Joule effect

The hidden actor: post-treatments

…and strategies to “avoid” them (engineered substrates)

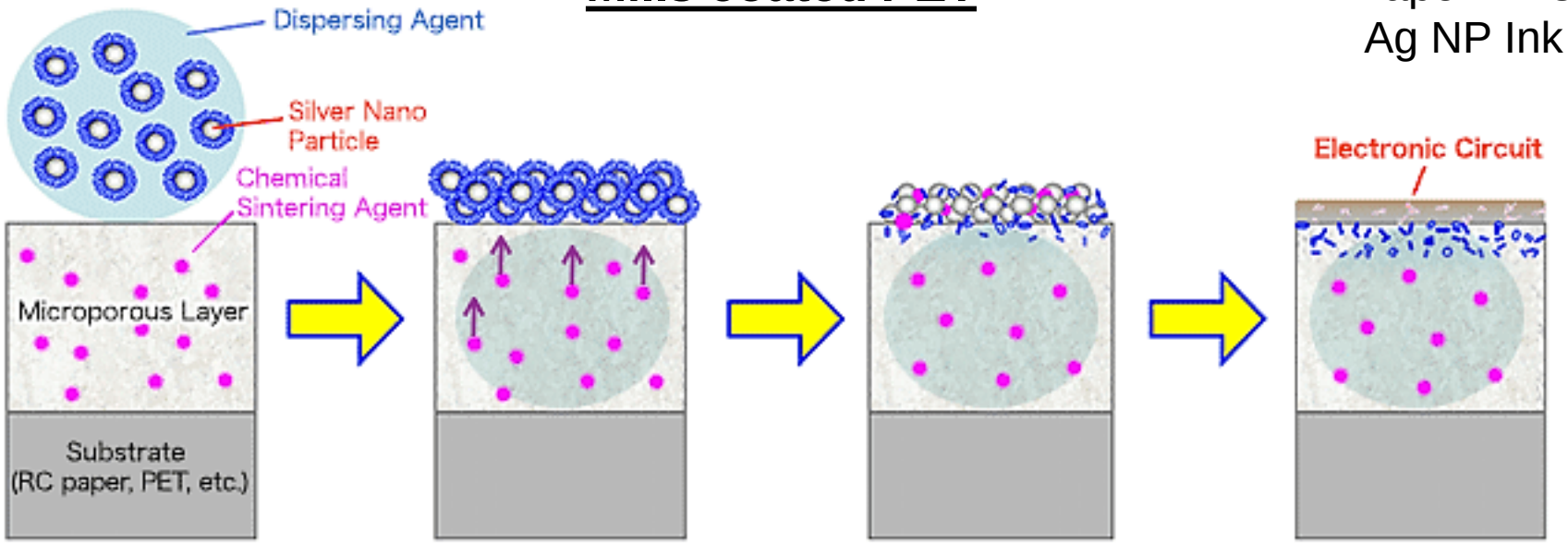
EPSON XP15000

+

Mitsubishi paper Mills coated PET

+

Mitsubishi Paper Mills Ag NP Ink

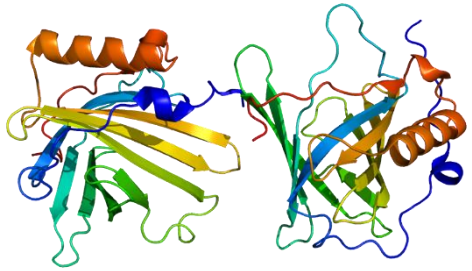


Rosati et al. Sens. & Act. B 2019; Rosati et al. Sens. And Biosens. Res. 2019; Rosati et al. Chemosens. 2019; Rosati et al. Bios. and Bioel. 2022; Yang et al. Biosens. and Bioel. 2022

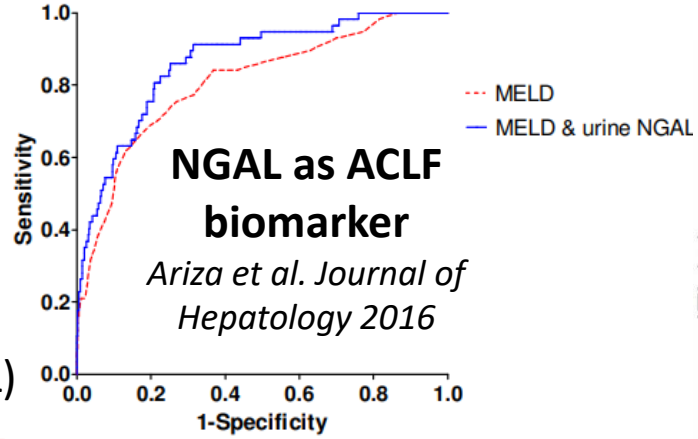
Are these AgNP devices really working?

NGAL detection for acute-on-chronic liver failure

Massimo Urban



Neutrophil gelatinase associated lipocalin (NGAL)



NGAL as ACLF biomarker

Ariza et al. Journal of Hepatology 2016

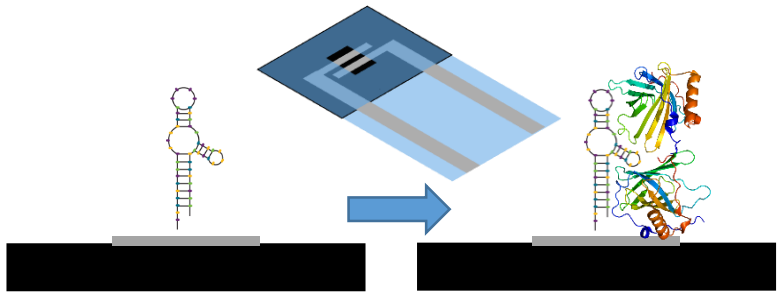
EF Clif
EUROPEAN FOUNDATION FOR THE STUDY OF CHRONIC LIVER FAILURE

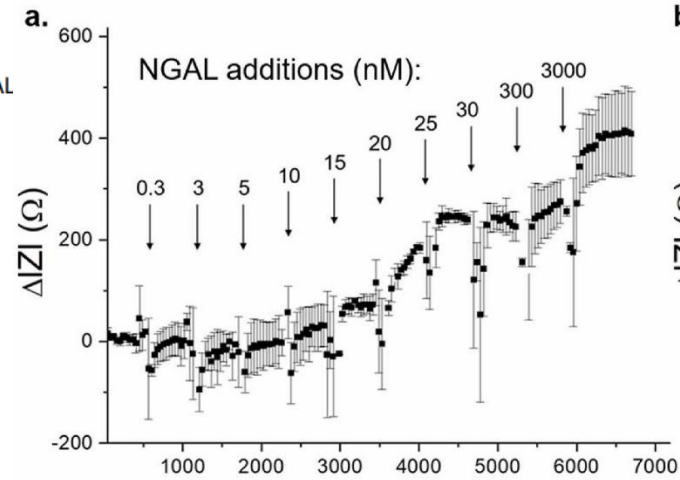
MICROB-PREDICT

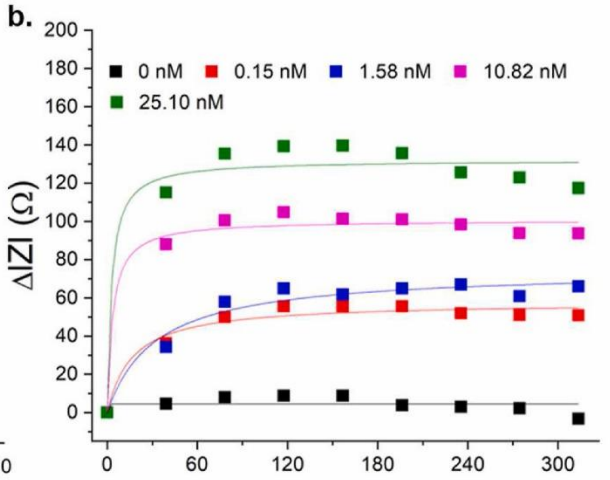
This study received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 825694.

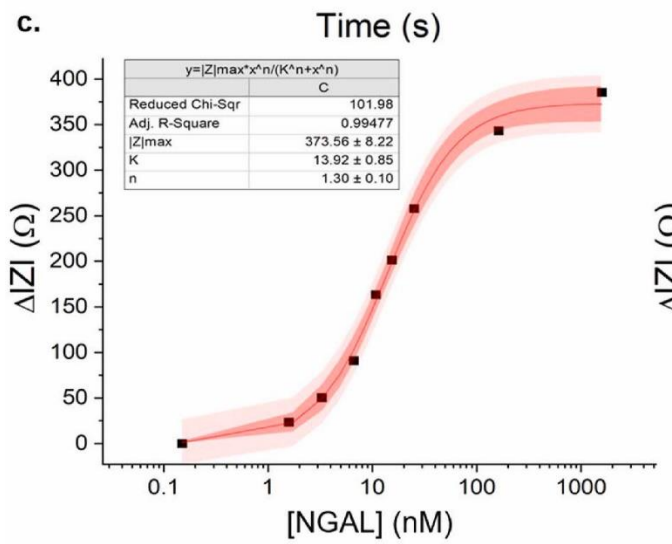
SCAN ME

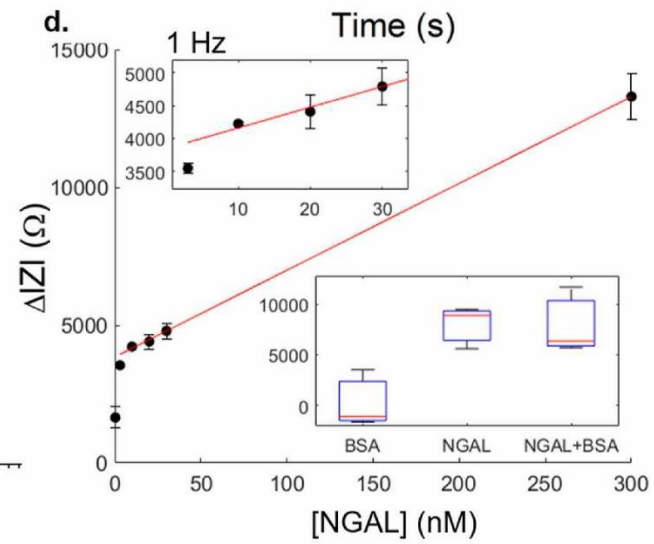
IDE AgNP label-free impedance-based device



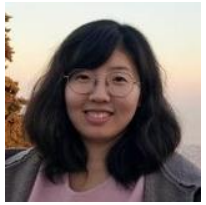








Rosati et al. Biosensors and Bioelectronics 2022

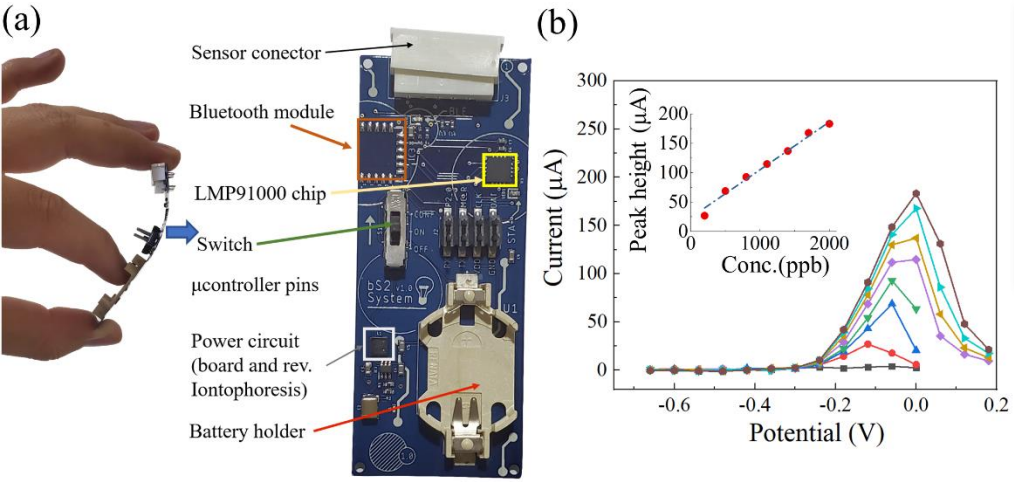


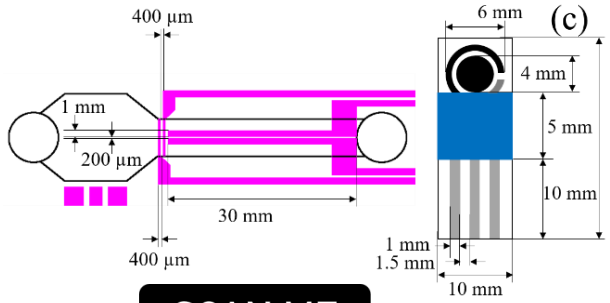
Qiuyue Yang

Are these AgNP devices really working?

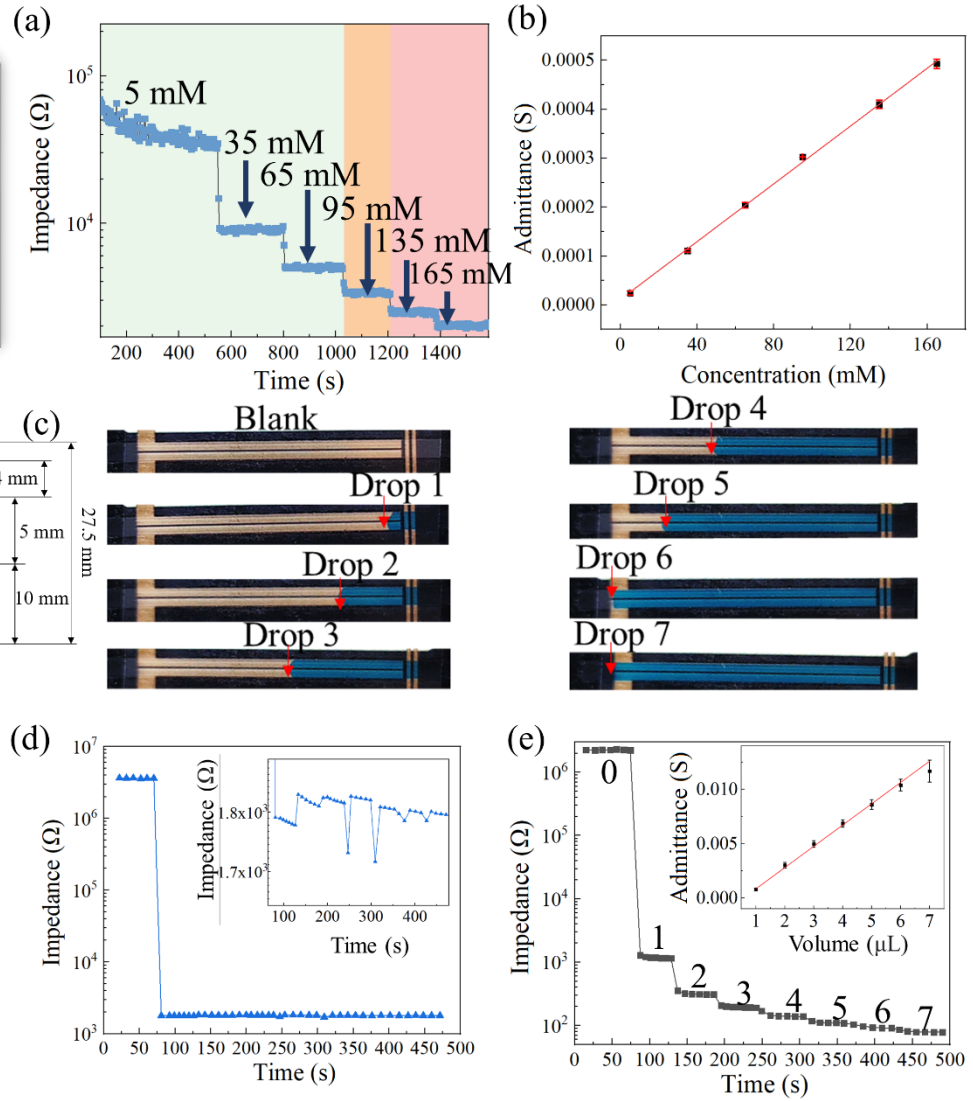
Wearables for heavy metals detection in sweat

Vernalyn Abarintos





SCAN ME



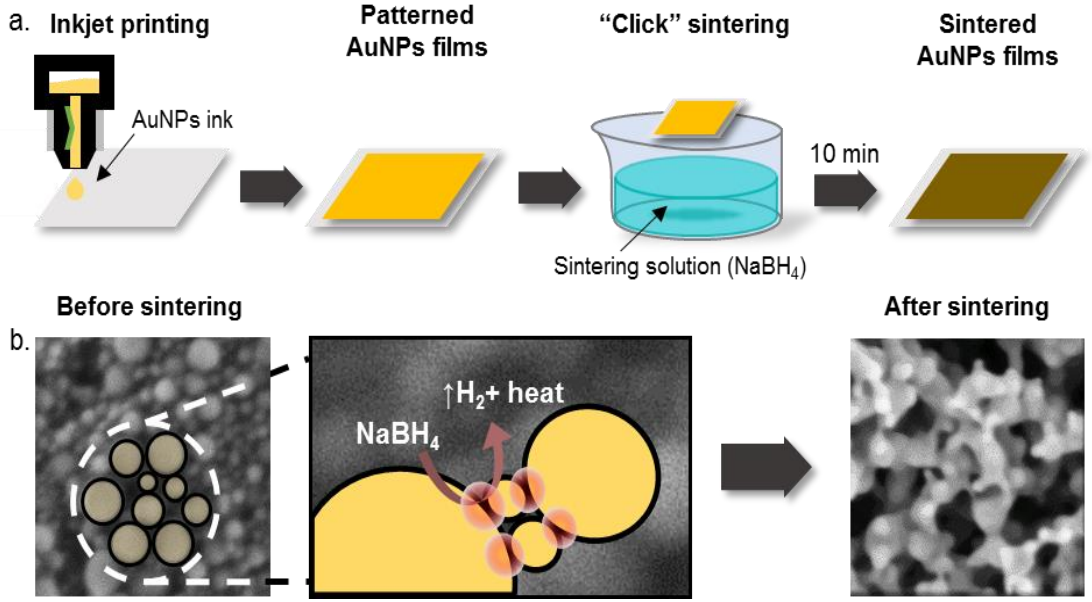
Yang et al. Biosensors and Bioelectronics 2022

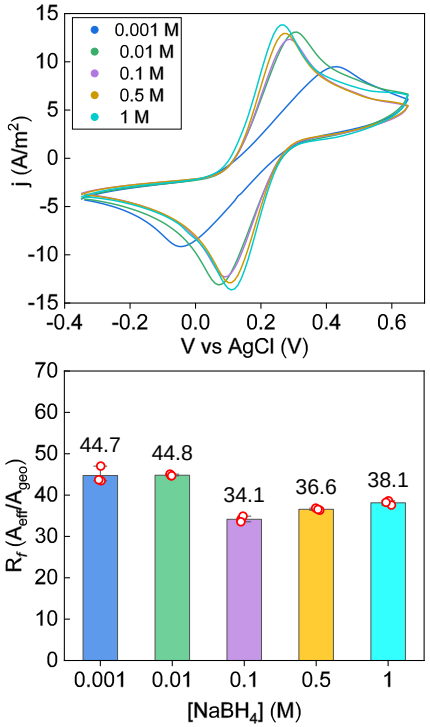
SCAN ME

The hidden actor: post treatments

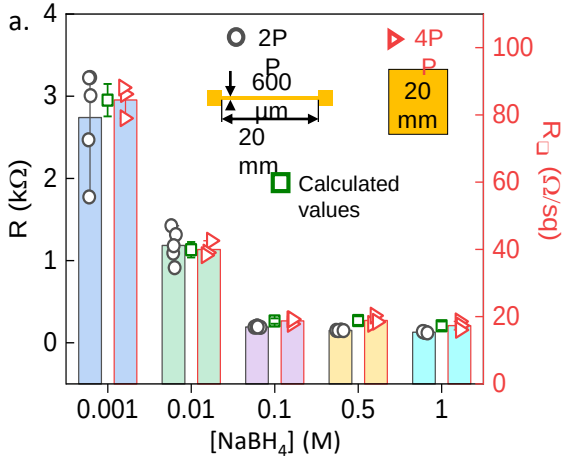
…and strategies to “avoid” them (click sintering)

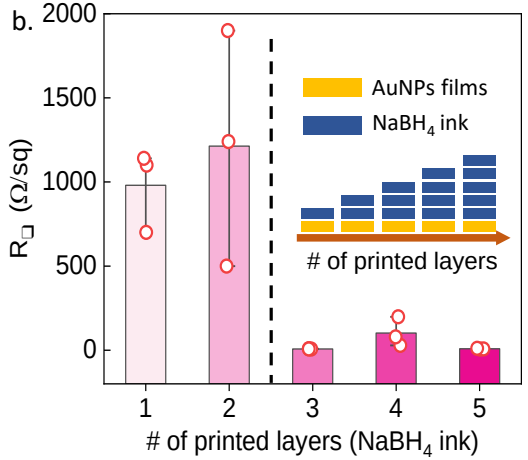
Massimo Urban

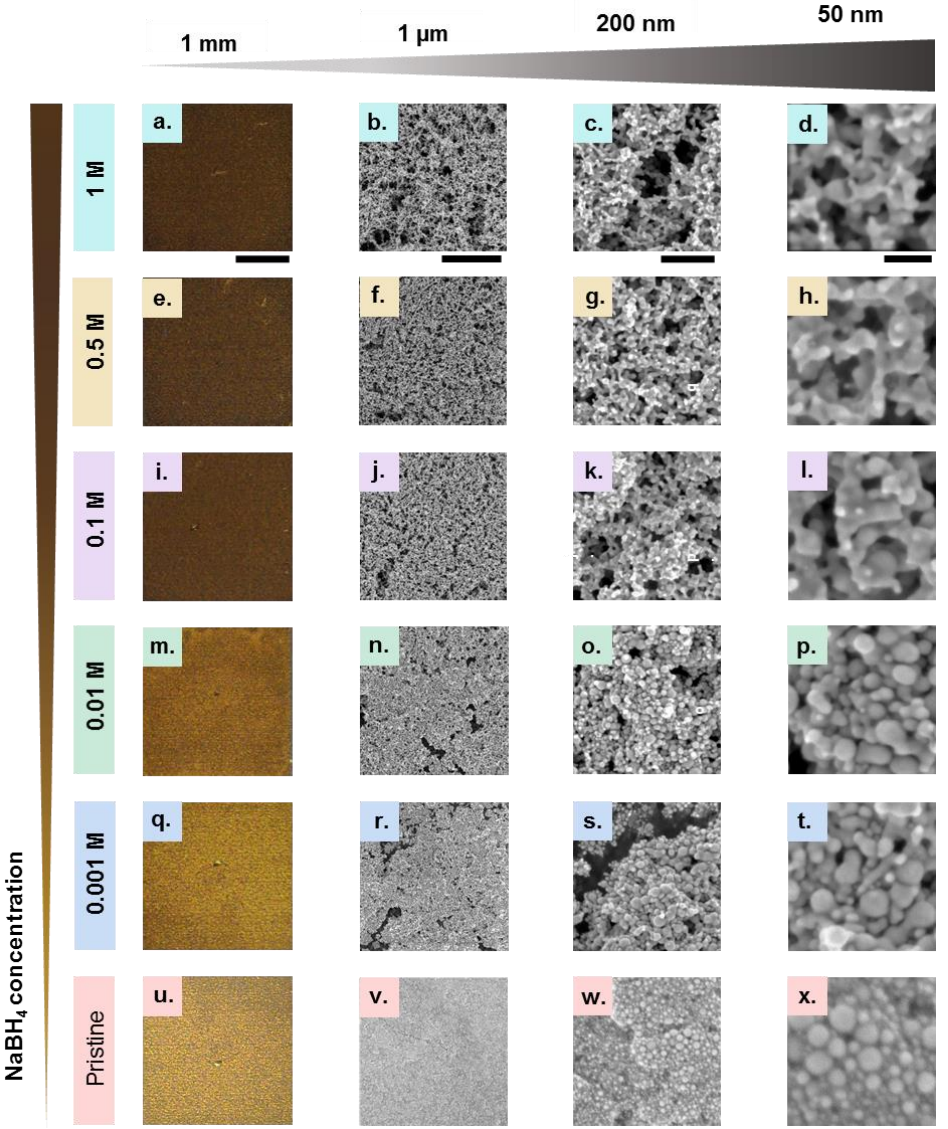




Unique control of nanoporosity, the conductivity, and the electrochemical characteristics.







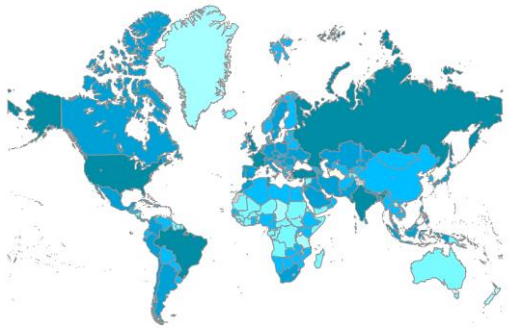
Urban et al. Small 2023 (patent pending)

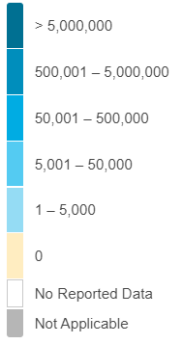
SCAN ME

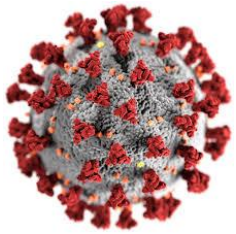
Are these AuNP devices really working?

Proteins and RNA detection for virus and bacteria

COVID19 genes multiplexed detection on a single electrode



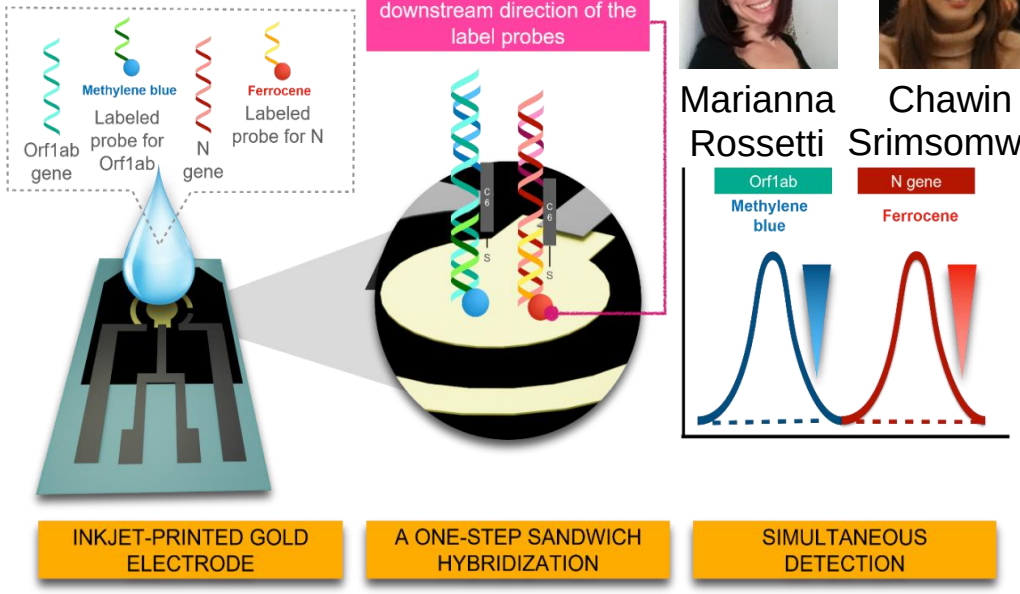




CHEM CHULA

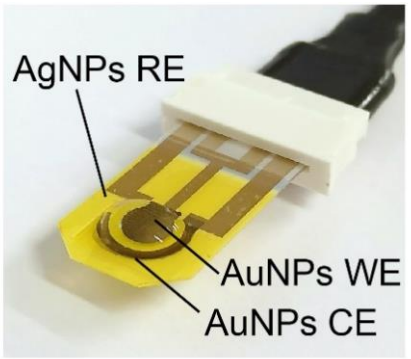
Marianna Rossetti

Chawin Srimsomwat

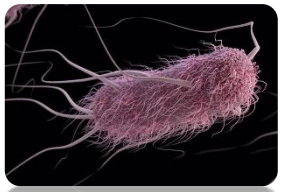


Click-sintered AuNP and AgNP inkjet devices

Massimo Urban



E.Coli and S.Aureus genes detection with a CRISPR-based electrochemical system

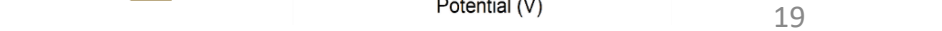


Angela Gilda Carota

Andrea Bonini

Prof. Fabio Di Francesco

Marianna Rossetti



Rossetti et al. Bios. And Bioel. 2024

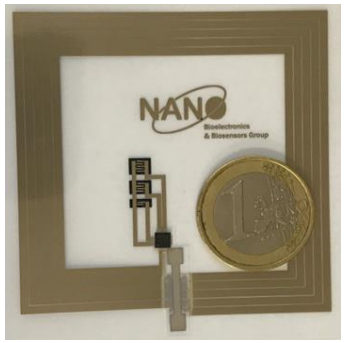
Results presented at the 33rd Anniversary World Conferenece on Biosensors (Seul, Korea)

How can we make these devices more impactful?

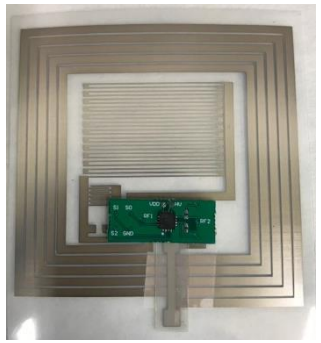
NFC antennas and chips for battery-less wireless smartphone systems

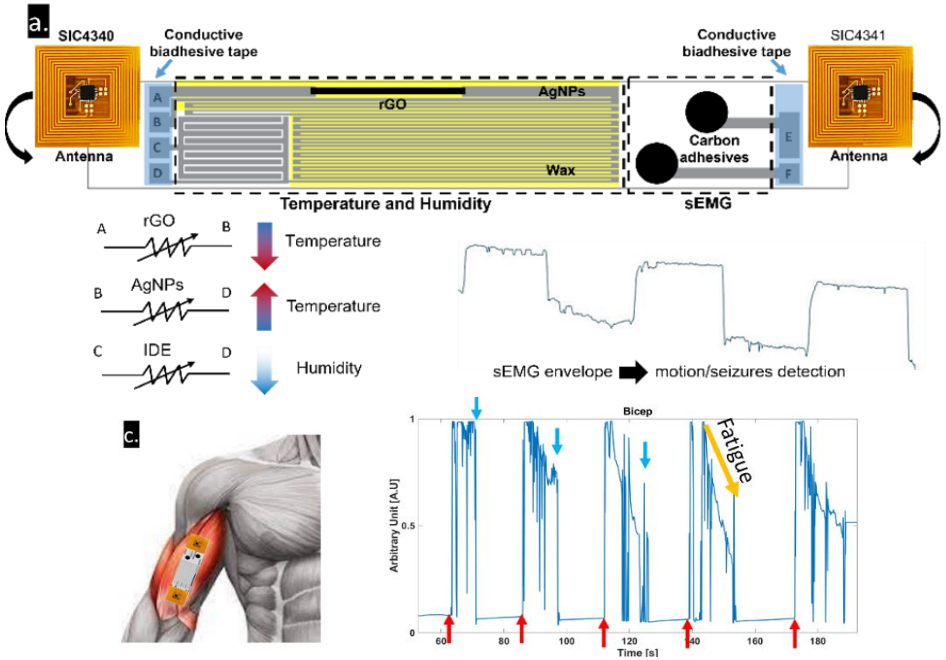
Gabriel Maroli

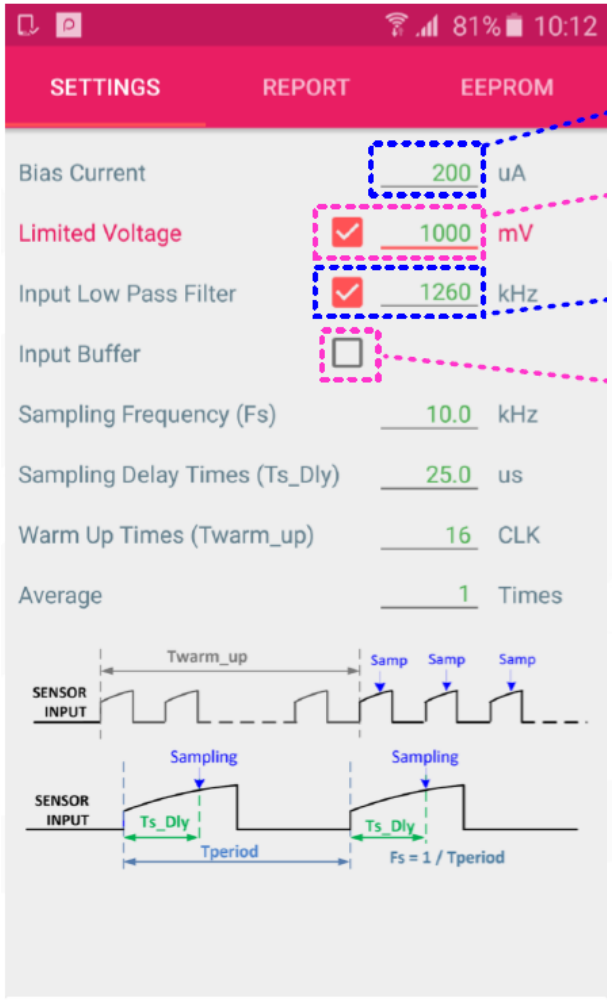
3 channels IDE

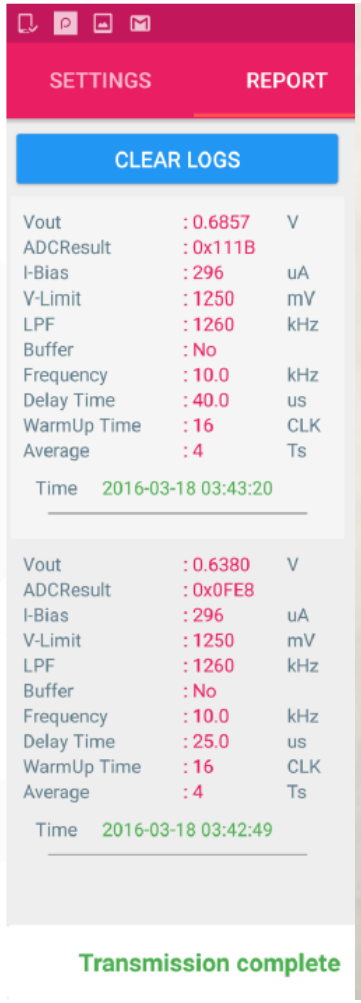


Temperature and humidity sensors

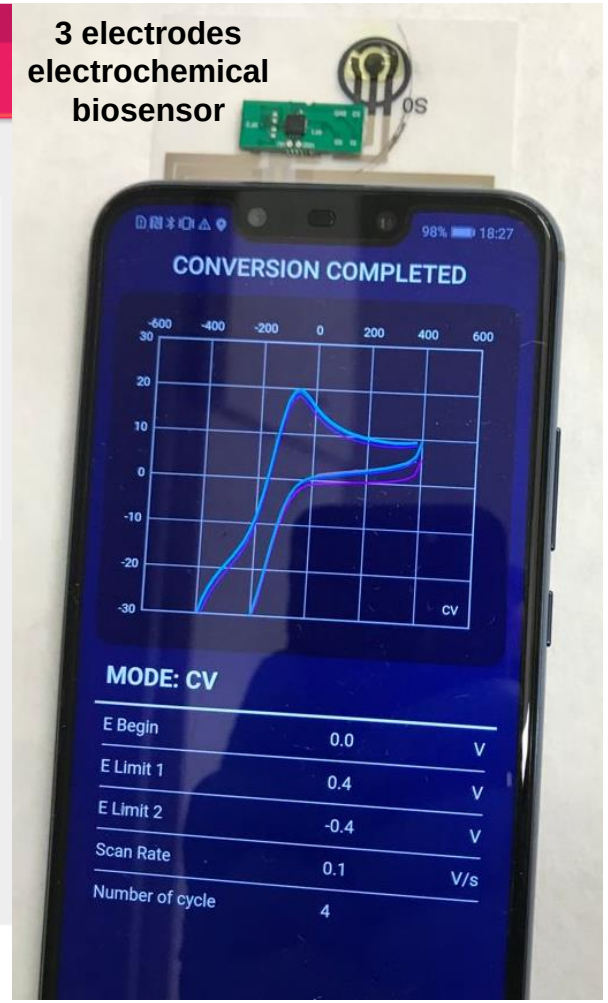








3 electrodes electrochemical biosensor



Manuscript submitted (accepted with maj.rev. In Bios. and Bioel.)

Conclusions

Ubiquitous

Democratic

printing

Need-precise

Consumer printers have potential for the controlled and scaled fabrication of bisoensing devices

Proper knowledge and appropriate reverse engineering of the printers allow obtaining important features

NFC antennas, smartphone readout, and simple DIY microfluidics combined with inkjet printed devices are the basis of a **paradigm change** taking the **fabrication out of the company**, **to the people**

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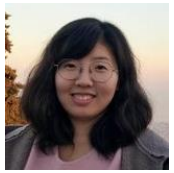
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Emerging Printed Electronics Research Infrastructure (EMERGE)

Thanks for your attention!

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