European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

Final Meeting at PRAGUE (CZ), 5-7 October 2016

New Sensing Technologies for Air Quality Monitoring

Action Start date: 01/07/2012 - Action End date: 15/11/2016 - EXTENSION: 15/11/2016

DISPOSABLE SENSORS AND INSTRUMENTS FOR AIR QUALITY MONITORING

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Danick Briand

WG2 member

EPFL-LMTS / Switzerland

Danick.briand@epfl.ch

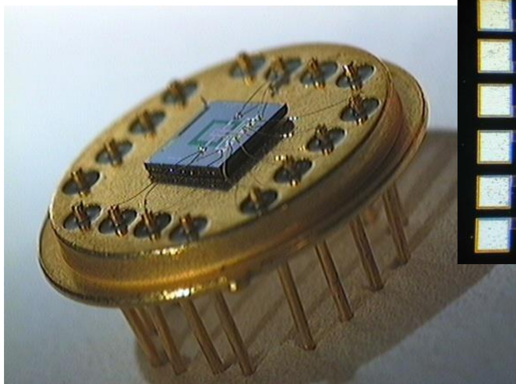
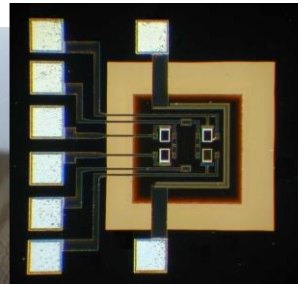
cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir
European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

COST is supported by the EU Framework Programme

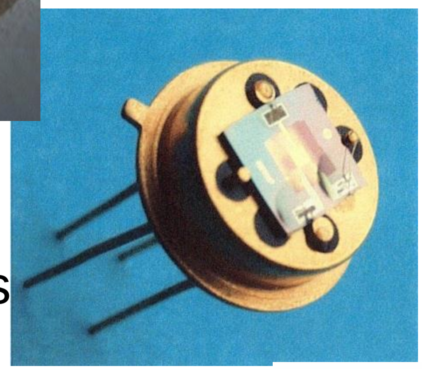
European Science Foundation ESF provides the COST Office through a European Commission contract

Advanced gas sensing technologies

GasFETs

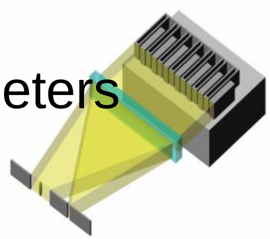
Micro-calorimeters



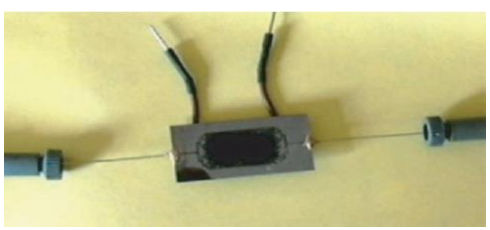
ARCoptix
Switzerland

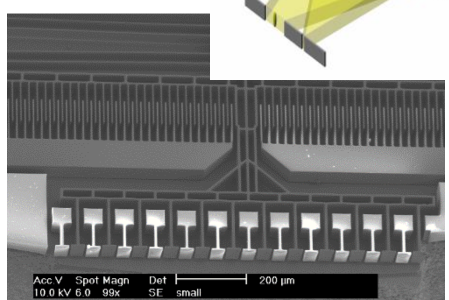
Ecole Nationale
Supérieure des Mines
SAINT-ETIENNE

Micro-spectrometers

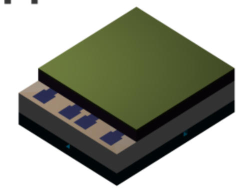


Gas preconcentrators

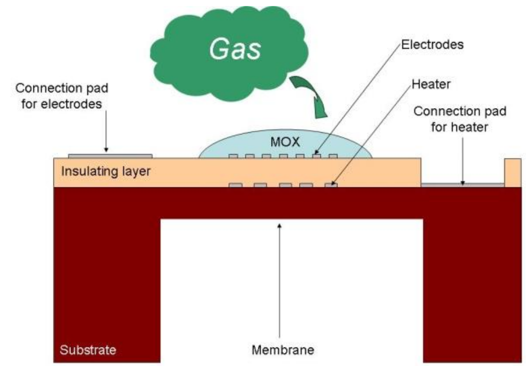


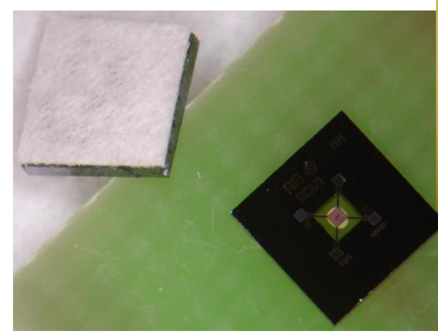
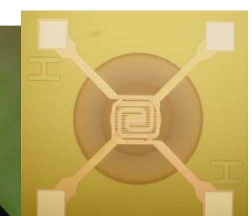


AppliedSensor



Metal-oxides



Green manufacturing

Disposability: plastic, paper, biodegradable materials

flexible

source: Plasticlogic

foldable

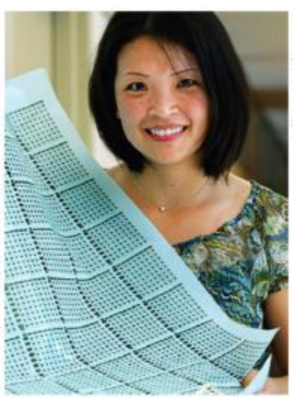
source: Swedish ICT

conformal

source: SEMICONWEST 2012

large area

source: Princeton University

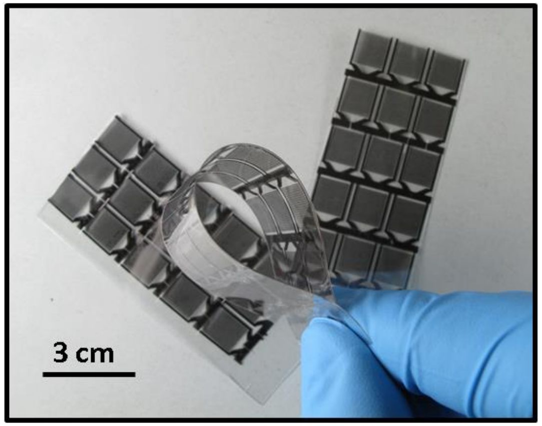


lower costs

source: GSA

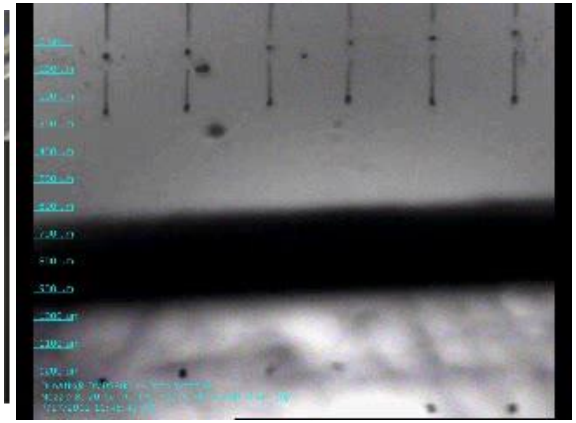
Green manufacturing

Localised patterning of materials outside cleanroom



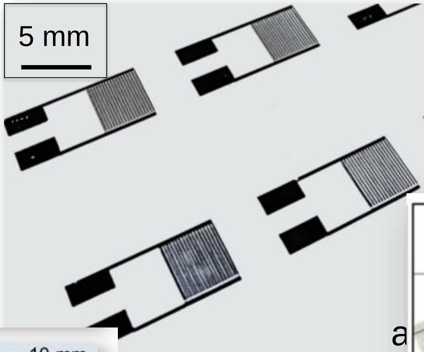
EPFL-EnviroMEMS

- Large area manufacturing on foil (S2S, R2R)
- Additive processes, i.e. printing
- Environmentally friendly materials
  - Water based inks
  - Recyclable substrate (PET, Paper, PLA…)

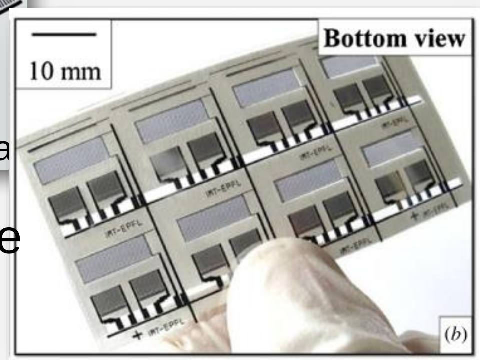


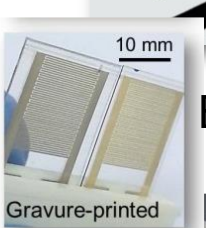
Smart sensing systems on foil

- Foil-based sensors

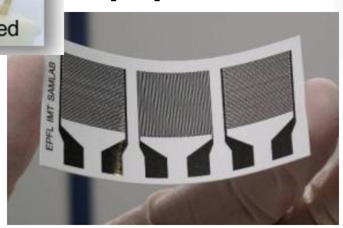


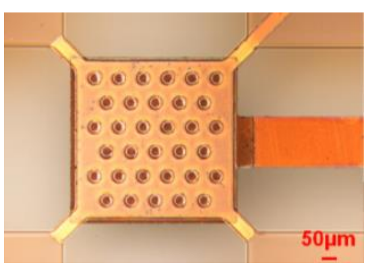
Printed and encapsulated
chemical / physical



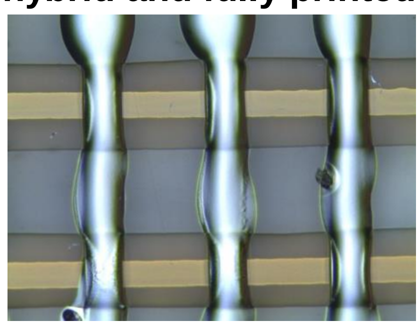


Biodegradable
paper / PLA

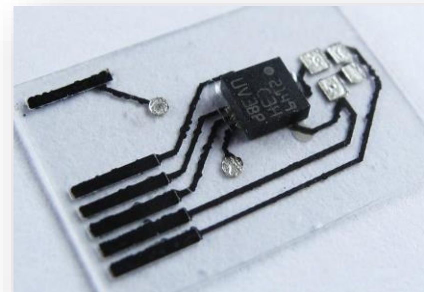




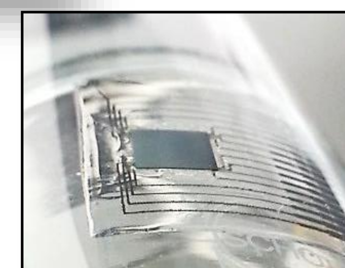
MEMS bridges
hybrid and fully printed



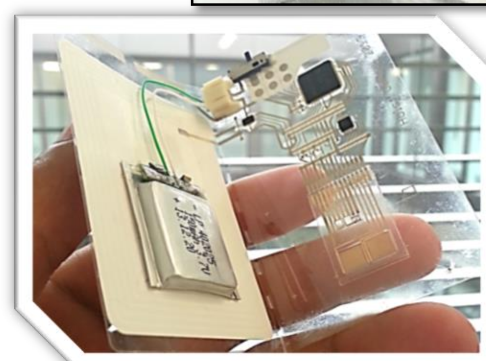
- Integration of components on foil



SMD and bare dies on PET



Foil to foil integration

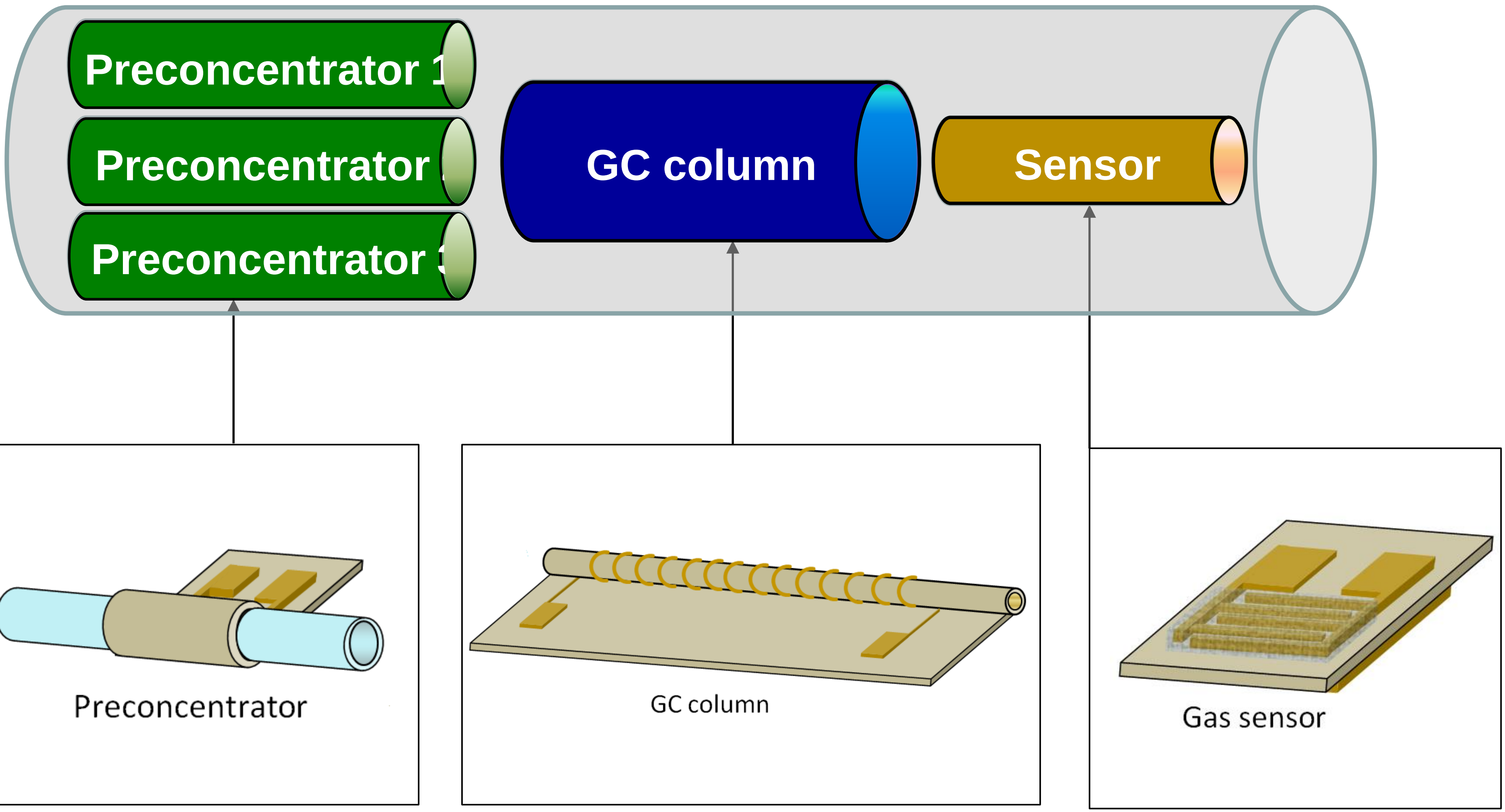


Outline

- Polymeric analytical instruments
- Printed sensors
- Biodegradable sensors technology
- Conclusion

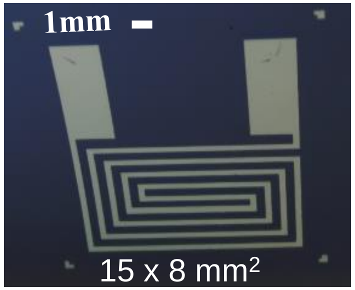
Analytical instruments

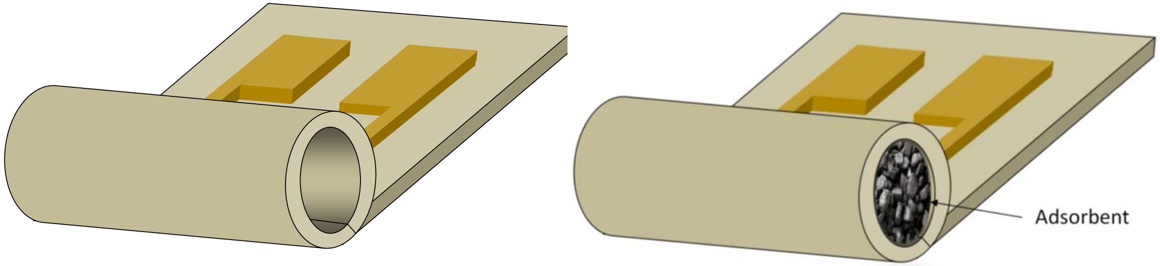
- Architecture of our foil micro-analyzer



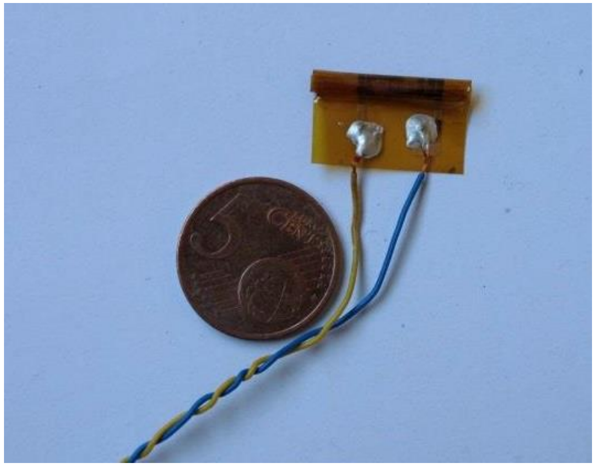
Tubular gas preconcentrator

- **Rolling up of printed micro-hotplates**





Schematic view of the rolling up and filling of a printed Gold micro-hotplate



Picture of a rolled micro-hotplate with electric wires

Materials

- **Ceramic glue:** sealing the rolled up micro-hotplate
- **Adsorbent:** carbopack B and Tenax polymer
- **Glass fibers:** plugging inlet and outlet of rolled device
- **Conductive adhesive**: Connection with electric wires

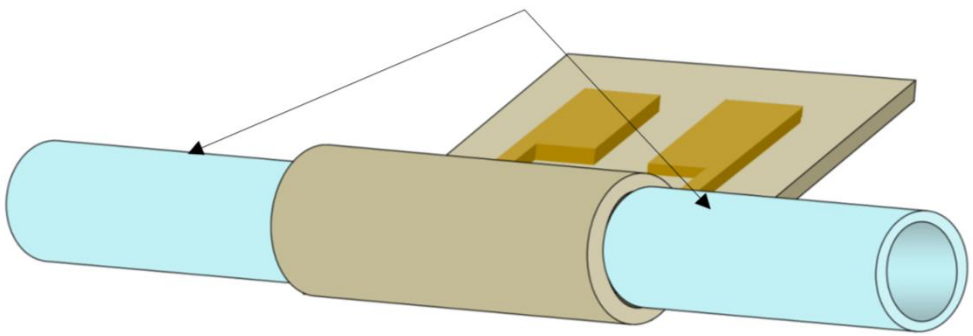
FGP can welcome arious adsorbents

i.e. targeting different gases.

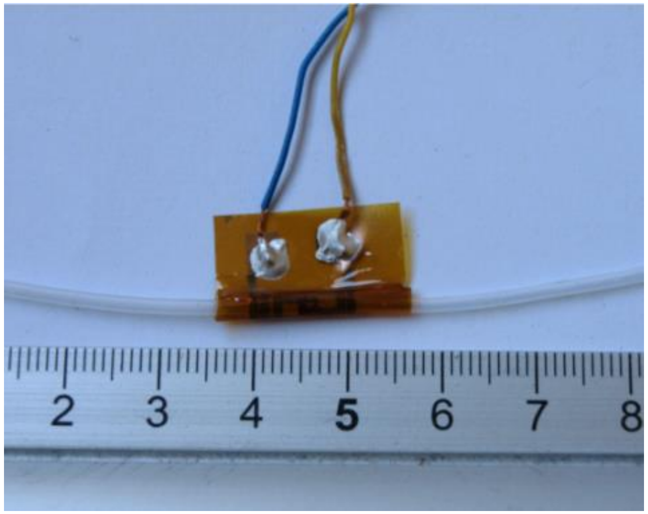
M. Camara et al., Sensors and Actuators B, 2016

Tubular gas preconcentrator

- Fluidic interconnects



Schematic view of FGP in its final stage with adsorbent and fluidic capillary



Picture of FGP in its final stage with adsorbent, fluidic capillary and electric wires

Materials

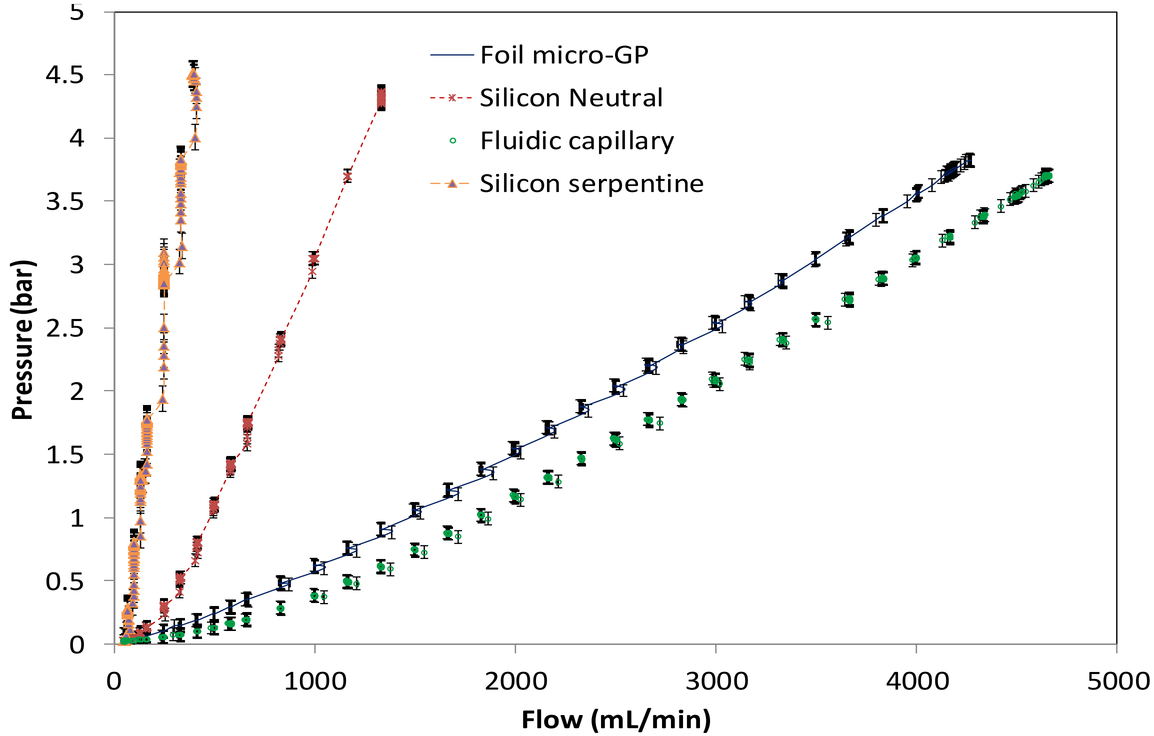
- **Teflon tubes:** fluidic capillaries of 2mm of internal diameter
- **Ceramic glue:** high temperature operating device

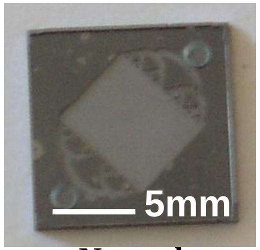
Inlet and outlet are adjustable during the rolling up for reaching high flow rates

M. Camara et al., Sensors and Actuators B, 2016

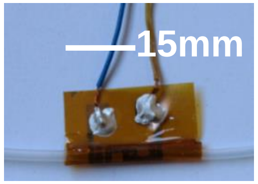
Tubular gas preconcentrator

- Fluidic characterisation

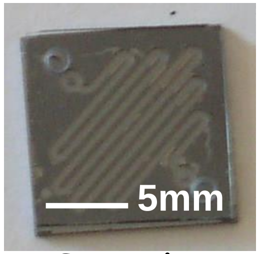




Neutral



Foil GP



Serpentine

Fluidic capillary

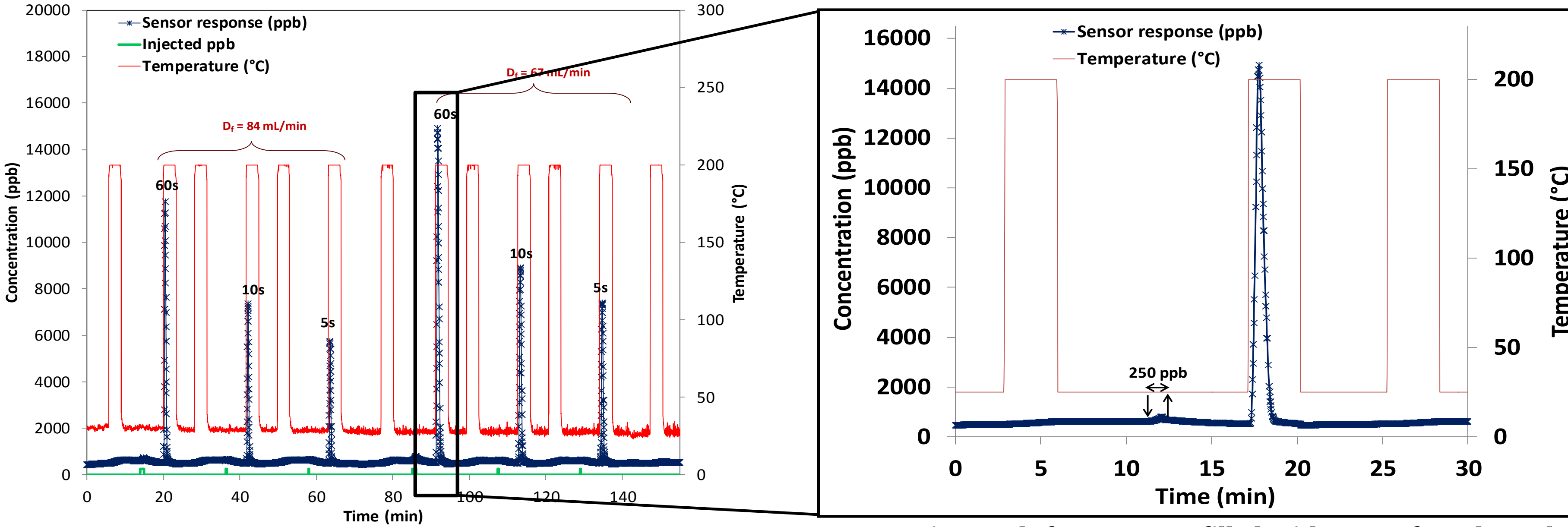
Flow Vs Pressure for a FGP filled with 1 mg of carbopack B compared with and two empty silicon GPs and metallic capillary, respectively.

The pressure drop observed with our FGP is mainly due to the metallic capillary used to connect the FGP to the test bench.

M. Camara et al., Sensors and Actuators B, 2016

Tubular gas preconcentrator

- **Preconcentration under benzene**



Six desorption peaks from a FGP filled with 1mg of Carbopack B when exposed to 250 ppb of benzene (60, 10 and 5s) and desorbed with flow rates (Df) of 83 and 66 mL/min, respectively

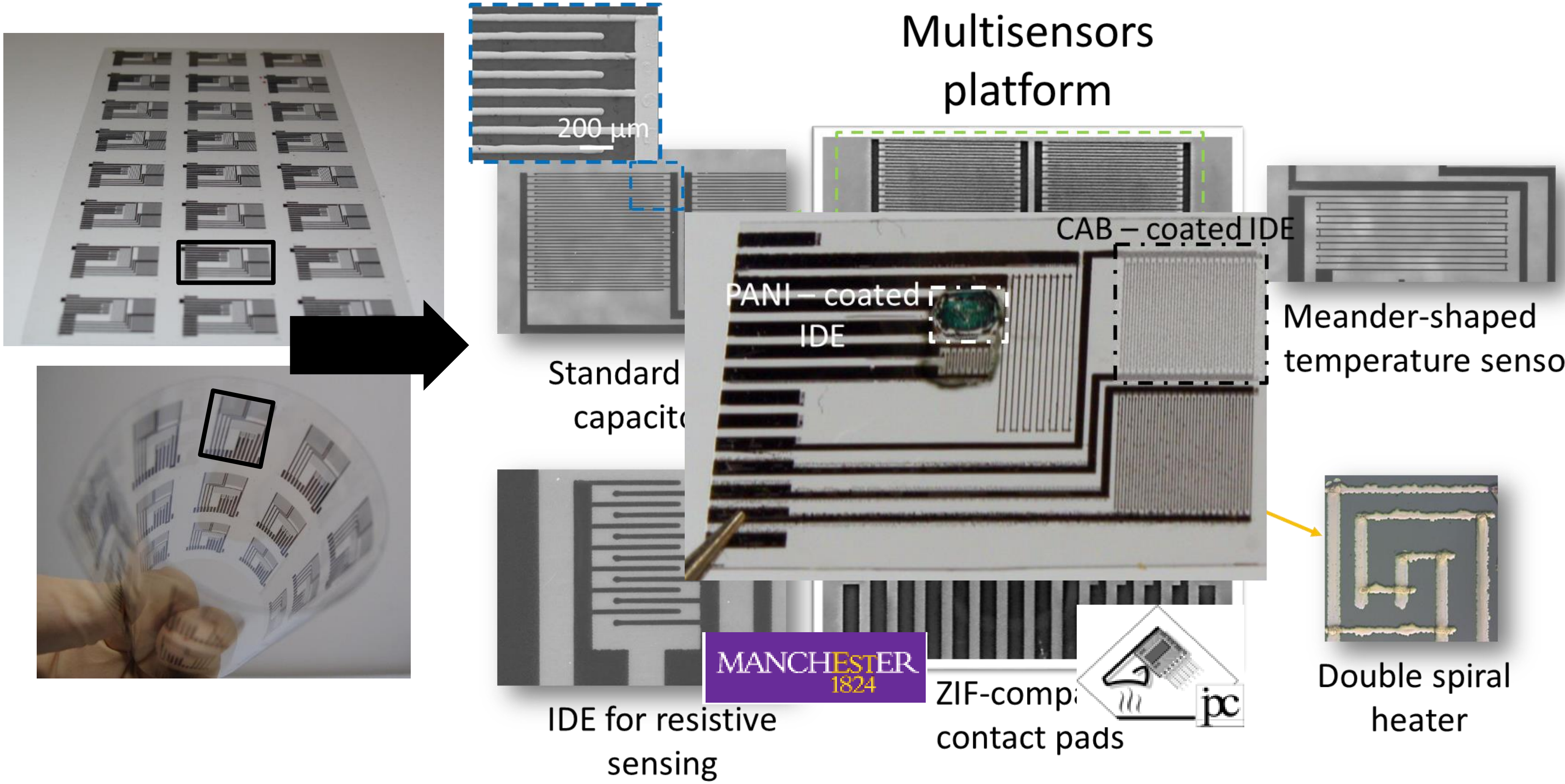
Desorption peak from a FGP filled with 1mg of Carbopack B when exposed to 250 ppb@1min of benzene (60, 10 and 5s) and desorbed with a flow rate of 66 mL/min

- **A PF of 56 is obtained for only 1 min of adsorption (for Silicon : 10 min)**
- **An adsorption time down 10s is also conceivable for lowering the duty cycle.**

M. Camara et al., Sensors and Actuators B, 2016

Multisensing platform: H_2O, T°C, gases

- Inkjet-printed gas multisensing platforms on foil: fabrication



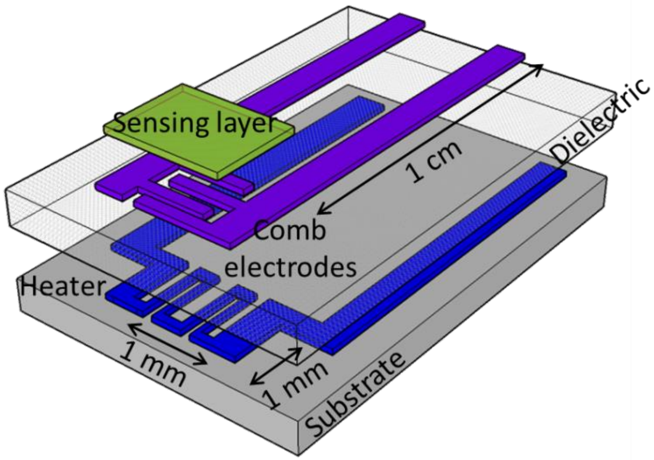
A. Vasquez-Quintero et al., FPE, 2016

Printed micro-hotplates

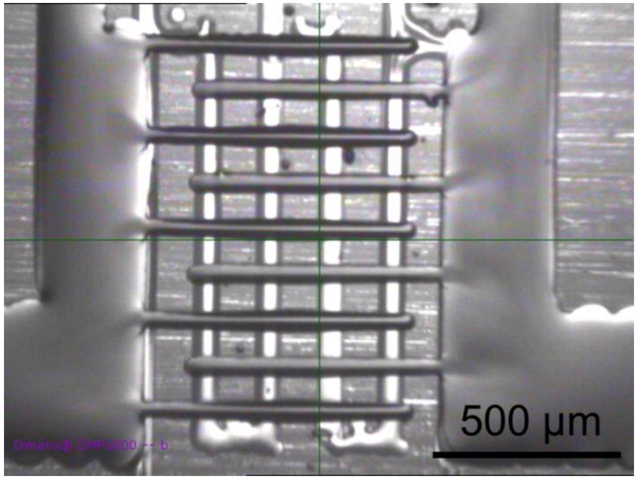
- **Design and fabrication**
  - – Printed Ag + electroplated Ni heaters
  - – Laminated 14 μm dry foil resist as interdielectric
  - – Printed Ag + electroplated gold electrodes
    - Heater resistance: 36 ± 3 Ω
    - Sensing area: 1 x 1 mm^2

Sensing layer:

- Polyaniline doped with poly (4-styrenesulfonic acid)
- Vapor-phase deposition polymerization



Schematic view of μ-hotplates.



Optical top view of μ-hotplates.

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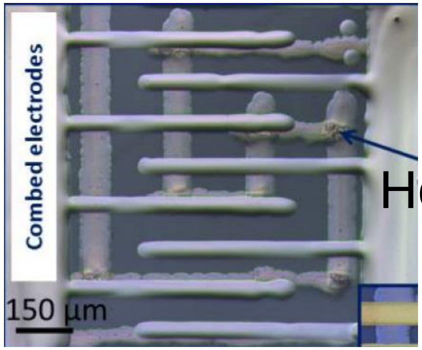
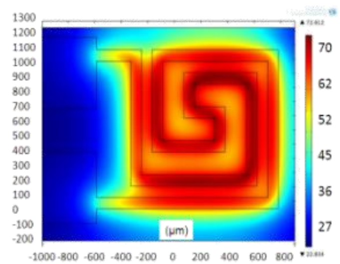
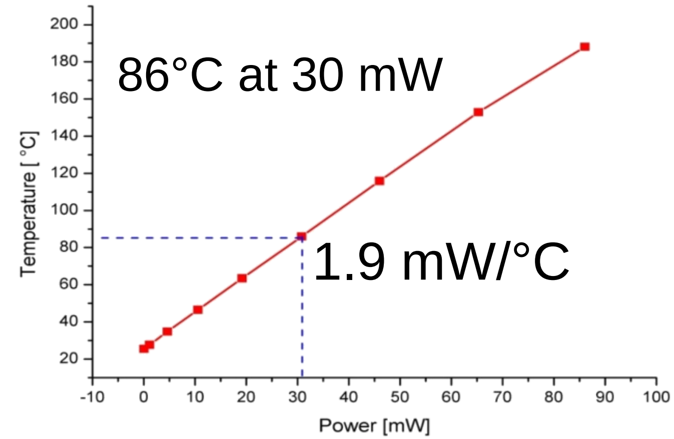
E. Danesh et Anal. Chemisty, 2015

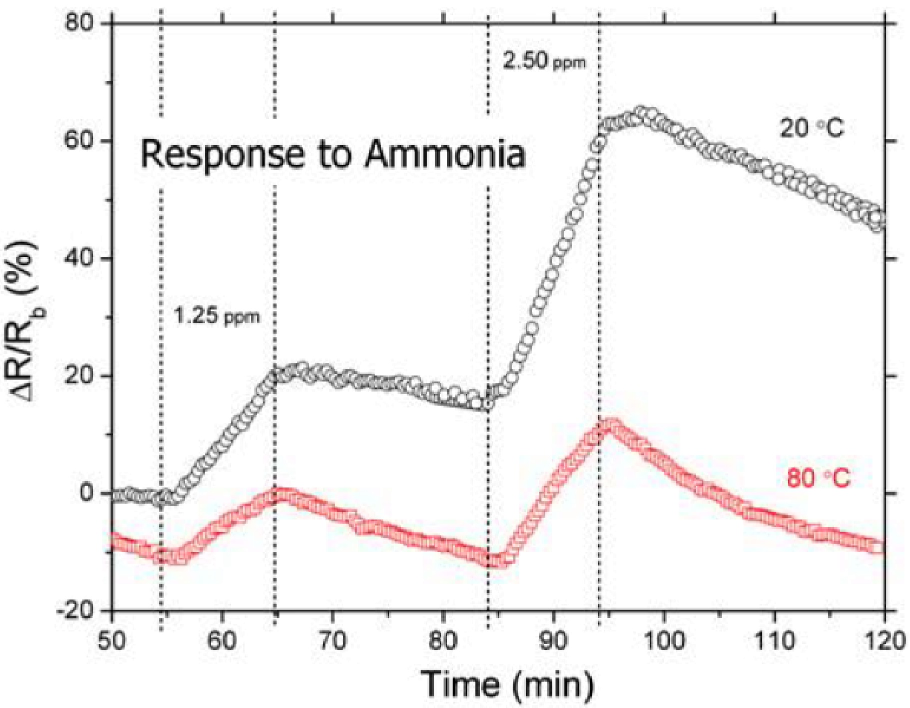
Chemoresistive NH_3 sensor



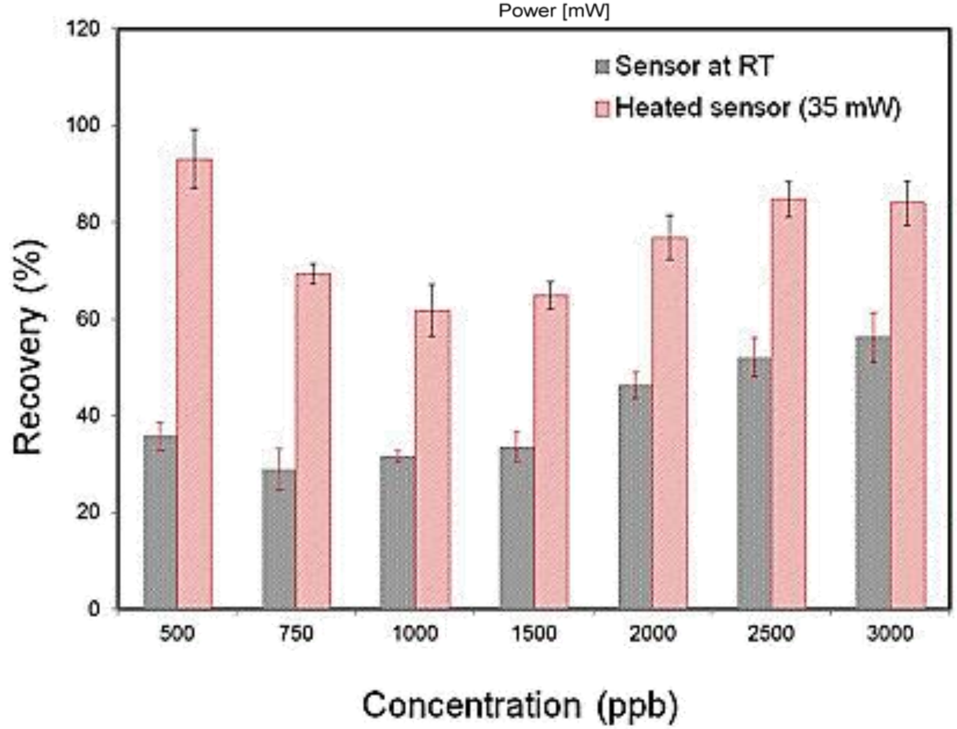
Value: 97 ± 7 Ω







E. Danesh, Analytical Chemistry, 2015



E. Danesh et Anal. Chemisty, 2015

Printing metal-oxide sensors on foil

- Printing of hotplate transducers
- Printing of metal-oxide films

Challenges

Polymeric foil have low Tg

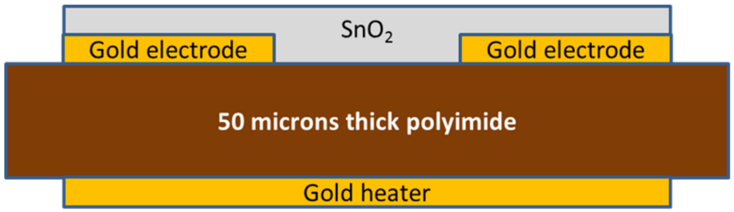
Printing resolution

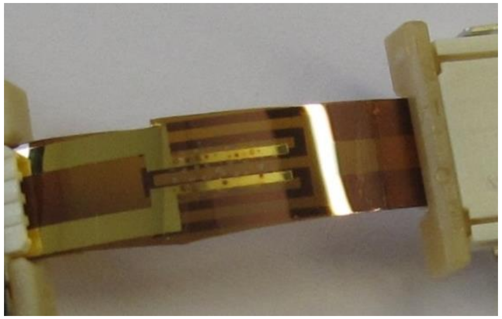
For higher temperature of operation:

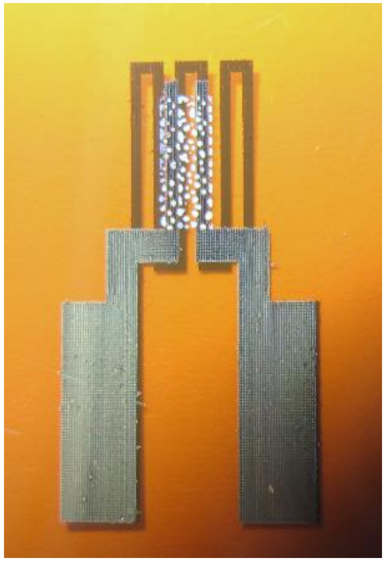
- **More stable metal: Gold**
- **Temperature resistant foil: Polyimide**

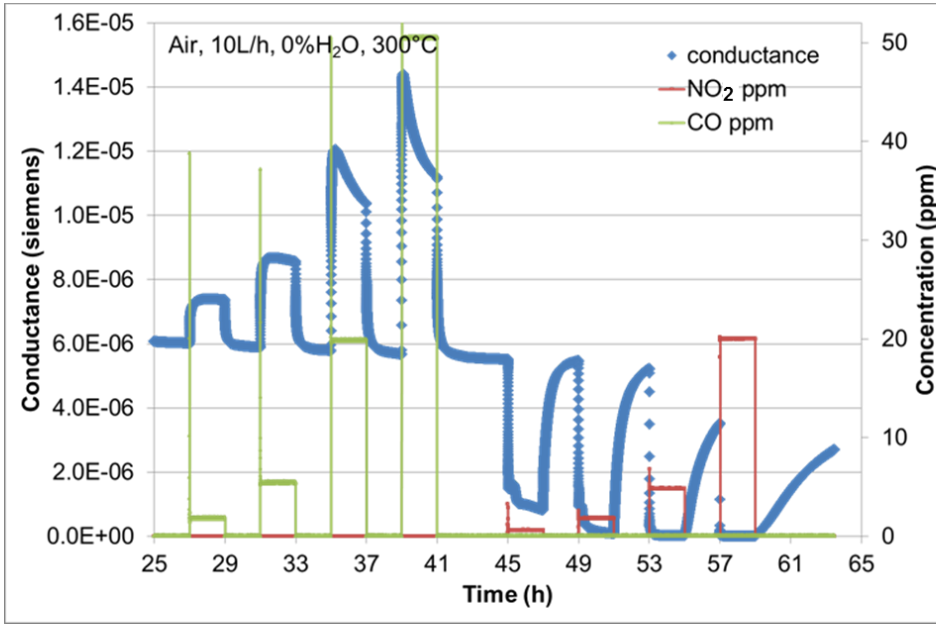
Fully printed SnO_2 sensor

- **Gold printed transducer on Upilex (PI) foil**







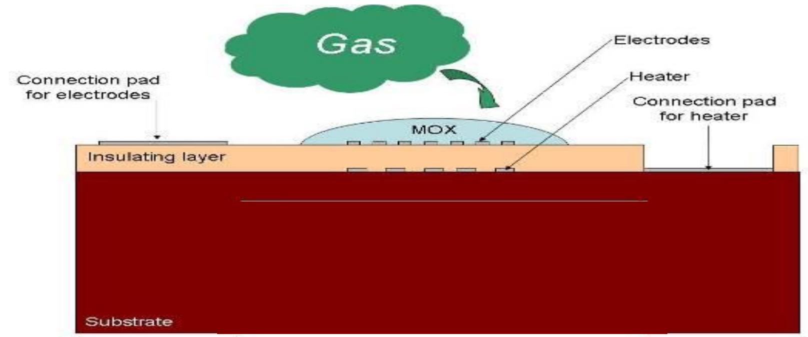


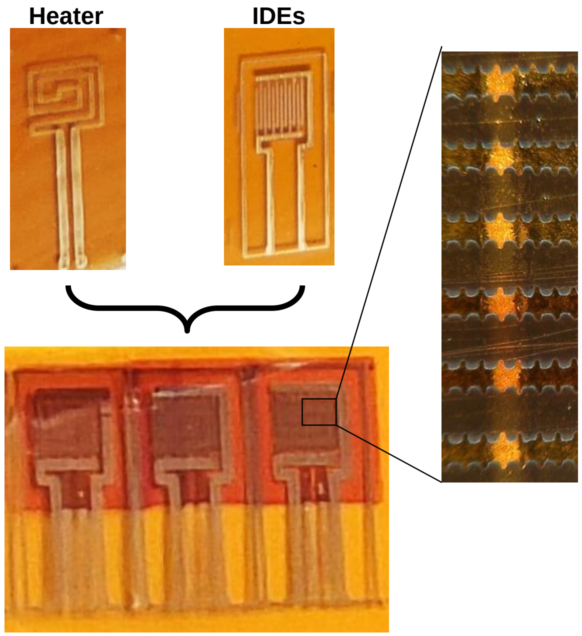
Responses to CO and NO_2

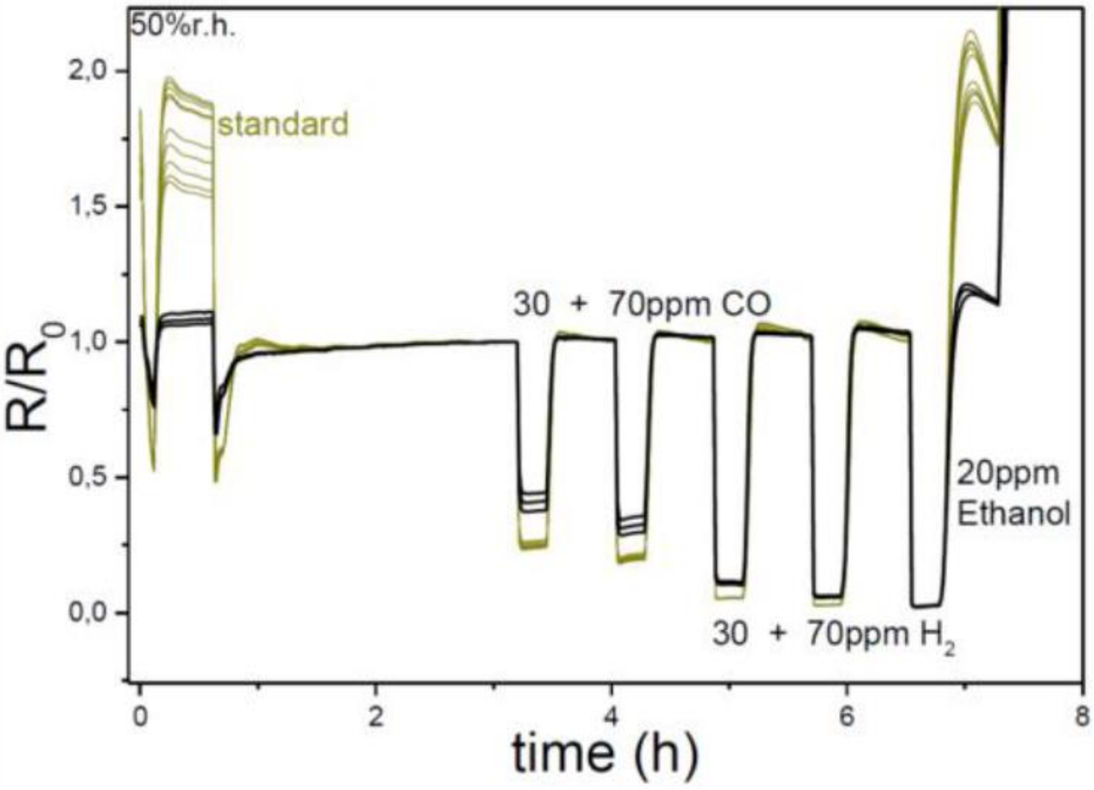
M. Rieu, Sensors and Actuators B, 2015

Fully printed SnO_2 sensor

- **Stack of printed layers**
  - Inkjet SnO_2 and WO_3 NPs

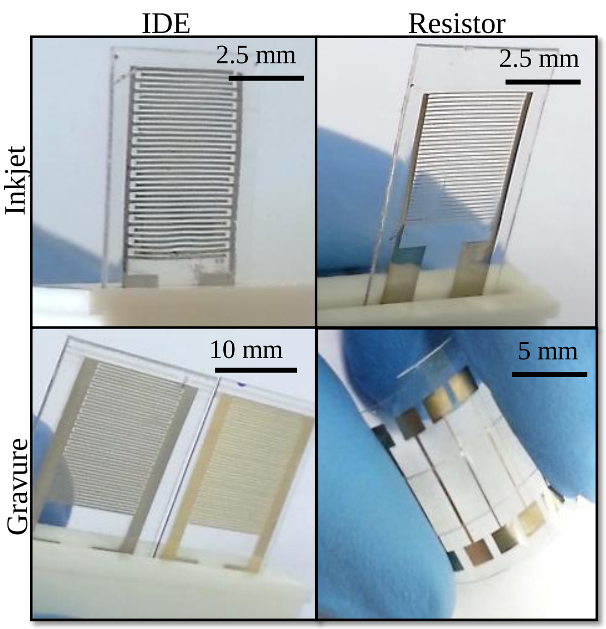


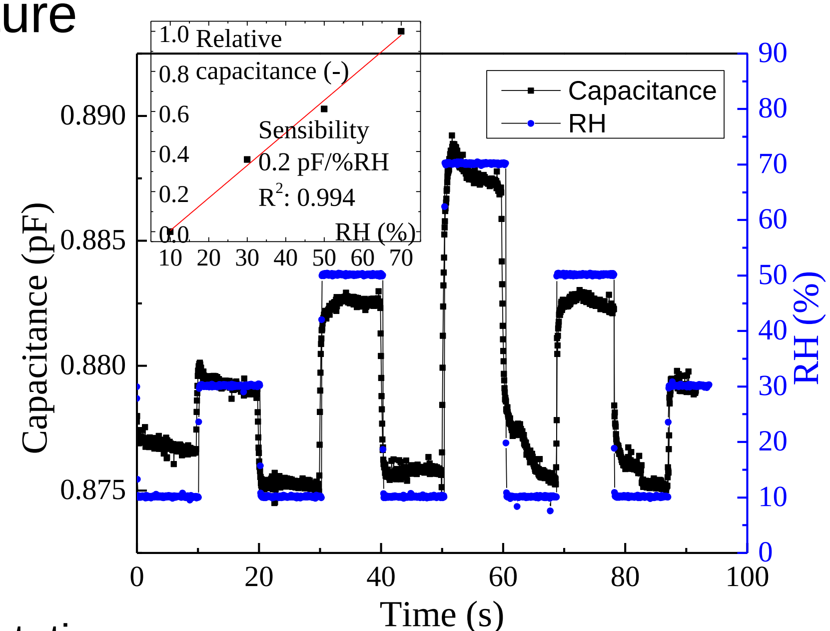




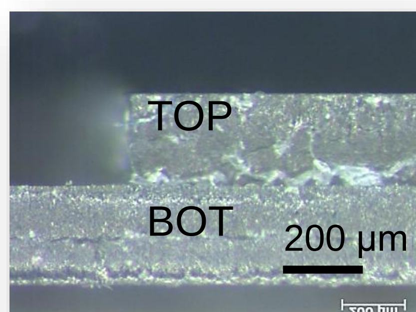
Biodegrable sensors

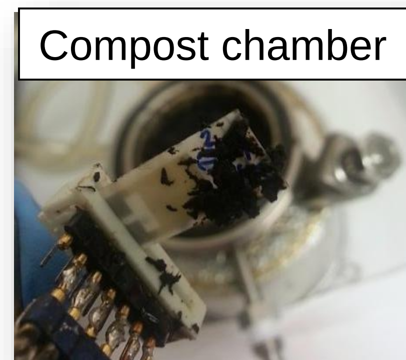
- On biodegradable substrates low Tg (56°C) poly lactic acid (PLA) → detection of humidity and temperature
  - Printing of Ag and Au inks
  - Photonic sintering





Encapsutation by lamination

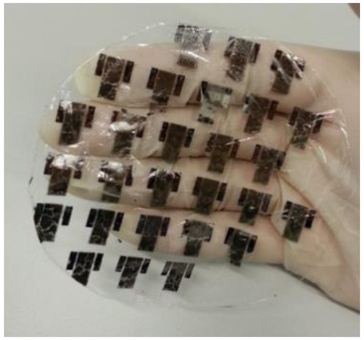




G. Mattana et al., Org. Electronics (2015)

Biodegrable sensors

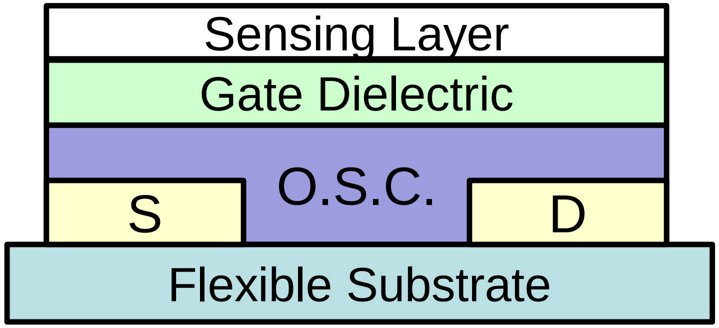
- Printed organic TFTs on poly lactic acid substrate

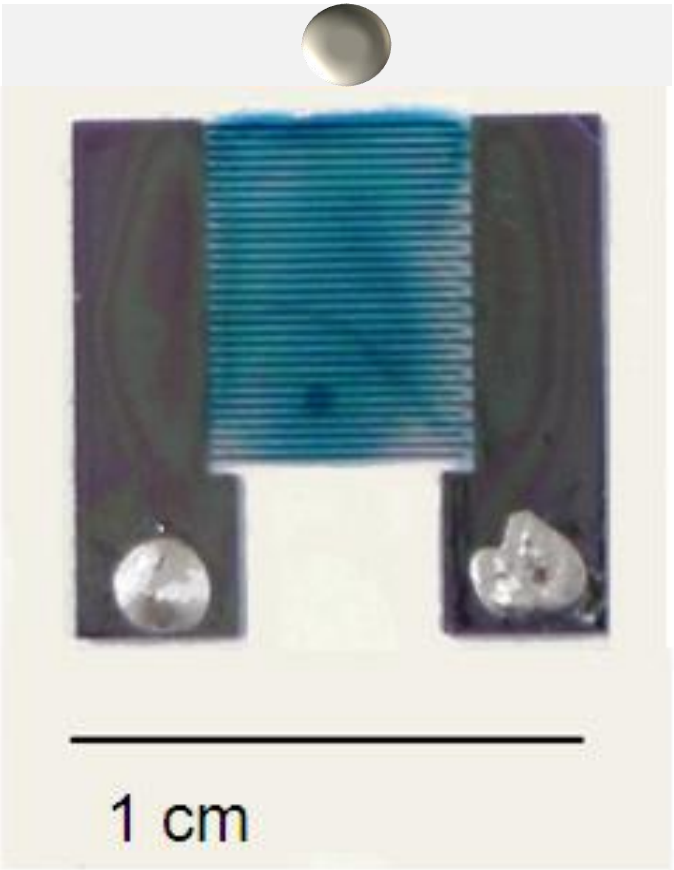


Transistors

- Thin film & electrochemical

- PLA as substrate & gate dielectric



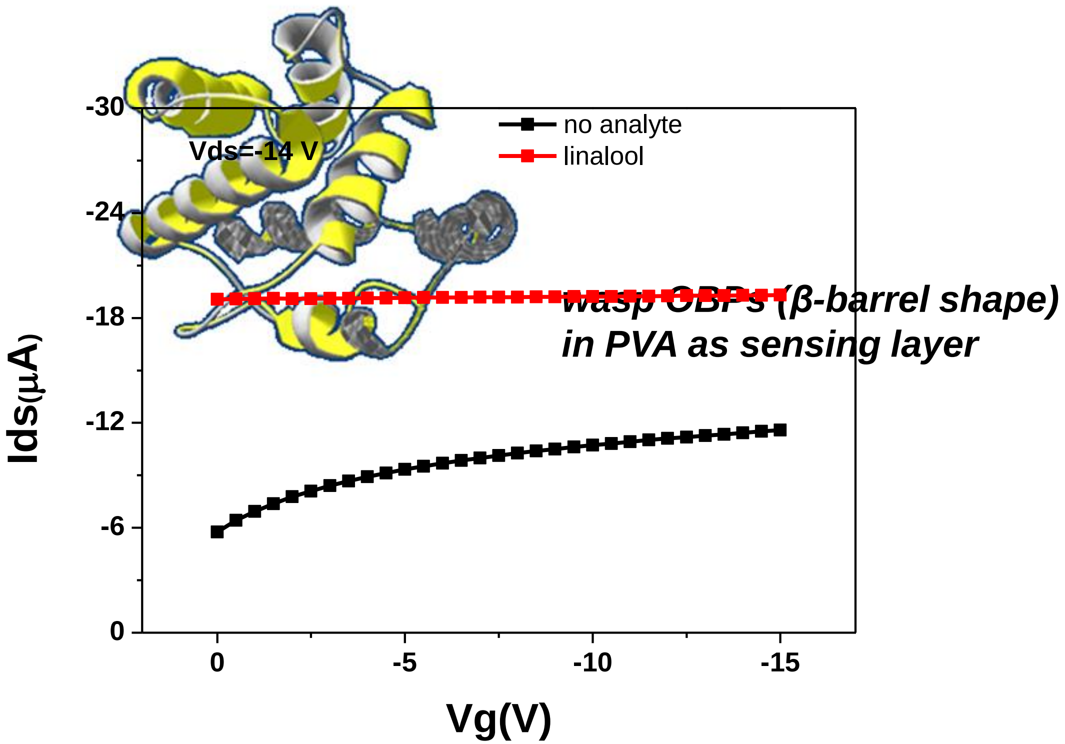


Collaboration with Prof. K. Persaud, UMAN, UK

G. Mattana et al., Org. Electronics (2015)

Biodegrable sensors

- Gate functionalisation with odorant binding proteins



Ids – *Vgs* curves acquired before and after exposure to saturated vapours of the analyte (ambient conditions).

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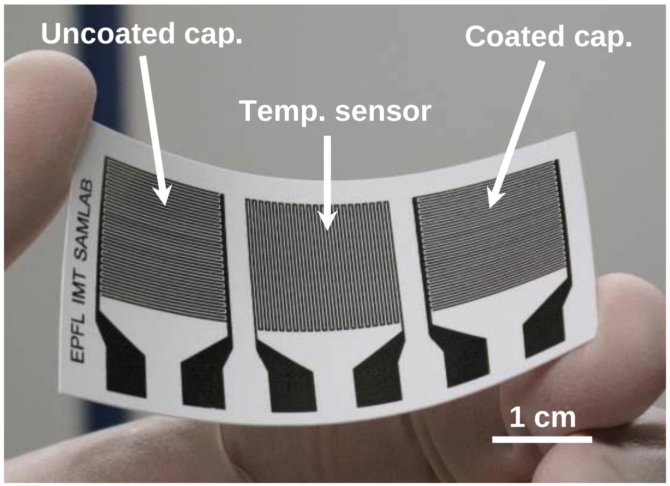
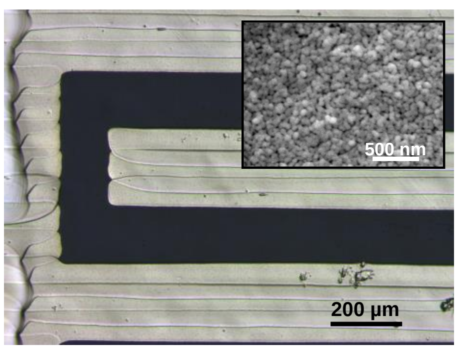
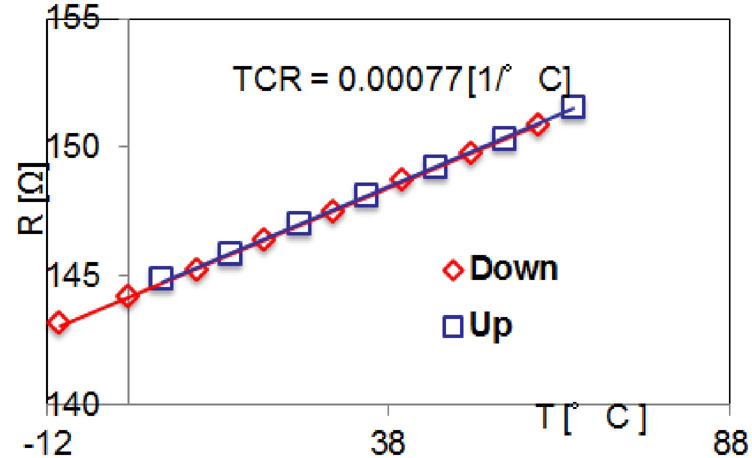
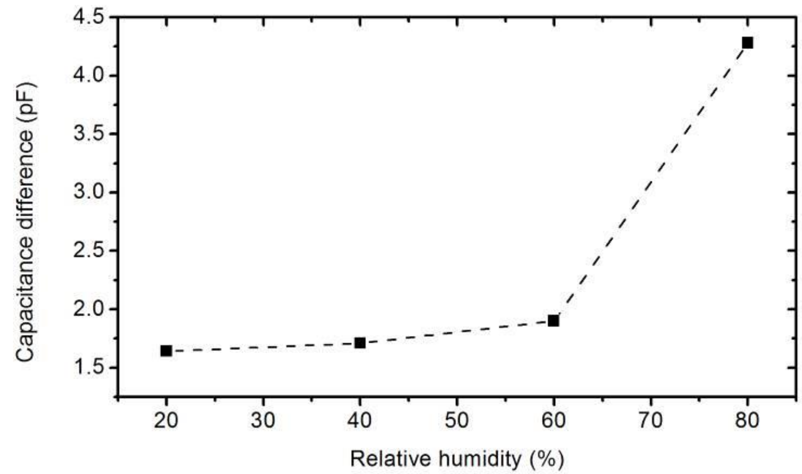
Biodegrable sensors

- Inkjet printing on paper substrate







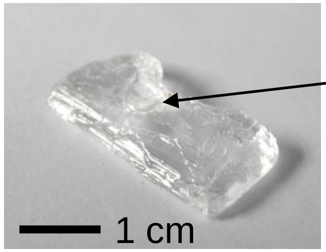


J. Courbat et al., Transducers 2011 / G. Mattana et al., E-MRS 2012 / D. Briand et al., LOPEC 2012

Biodegrable sensors

- Rochelle salt / paper composite piezoelectric material

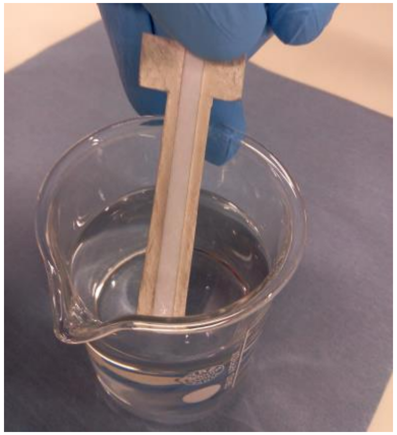
Piezoelectric constant	30-290 $pC.N^{-1}$



Potassium sodium tartrate ↔

Food additive E337

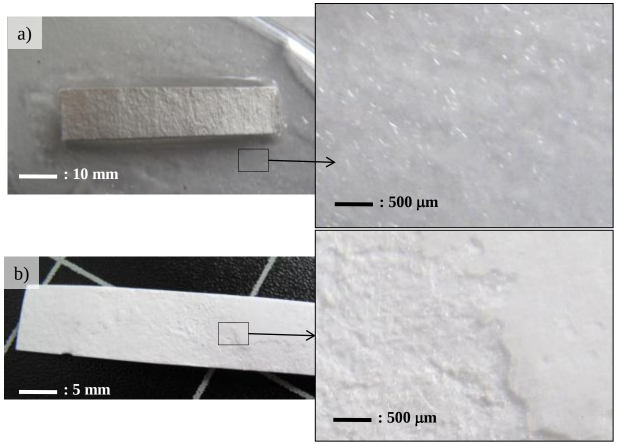
- Massive production
- Low cost
- Water soluble
- Environnemental/Bio compatibility



Solution processed

- Biocompatible

- Biodegradable



E. Lemaire et al., Sensors and Actuators A, 2016

Conclusions

- Polymeric and printed sensing components for environmental monitoring were presented

Benefits:

- **Potentially low-cost**
- **Flexible**
- **Towards green tech i.e. manufacturing + end of life**

Suitable for disposable sensors

- **Smart cards**
- **Reusable smart labels**
- **Single use / distributed preconcentrators**
- **Towards micro-analytical instruments**

Acknowledgements

The EnviroMEMS team: PhDs, Post-docs, Master, and interns

cost
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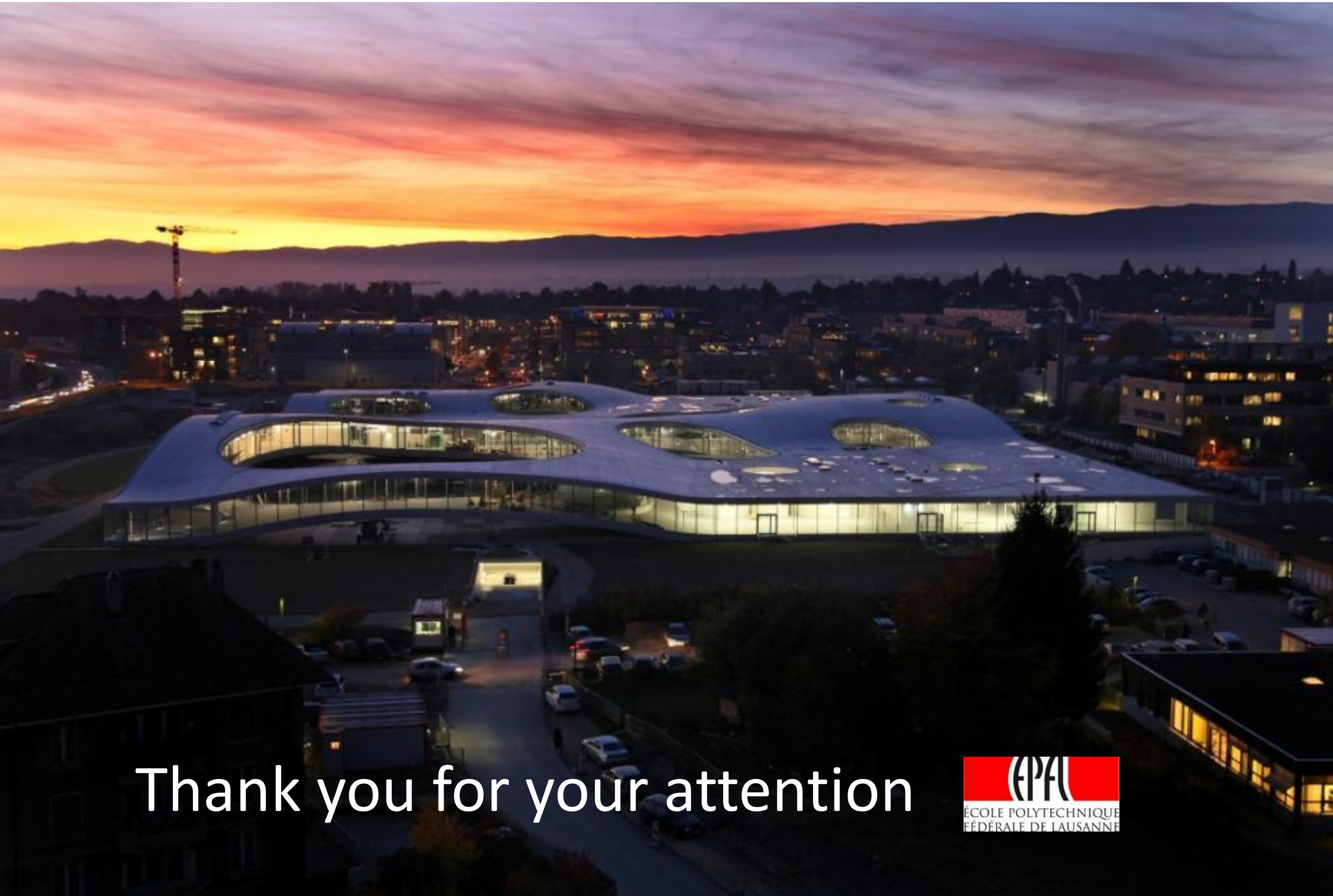
European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

Funding: GOSPEL EU Network of Excellence, FP6

FlexSmell, ITN, FP7

SNIFFER, FP7


Thank you for your attention
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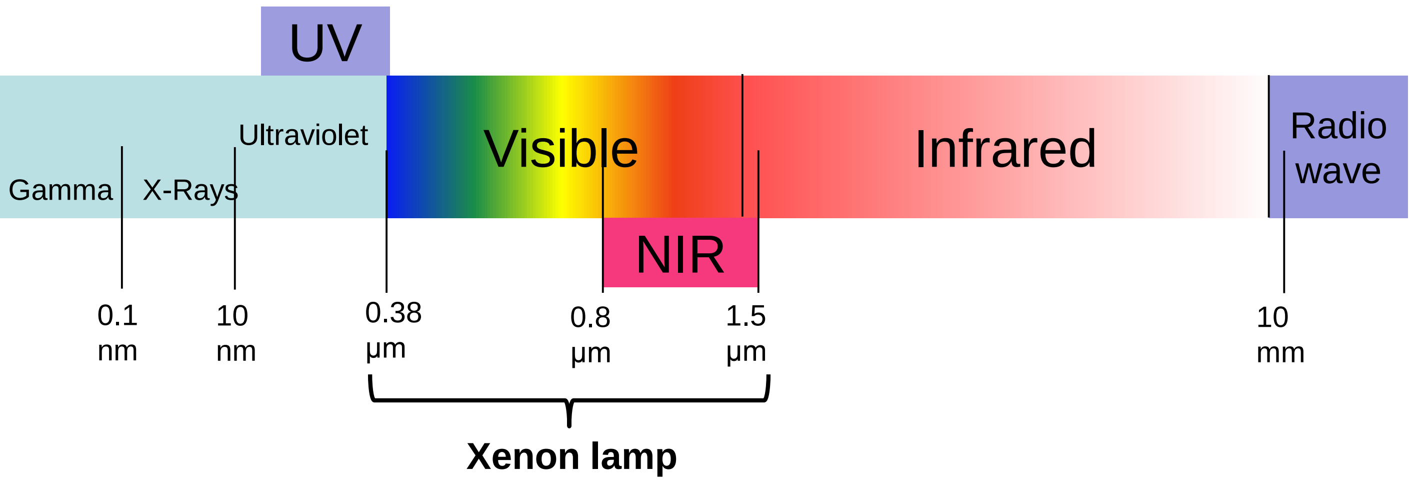
FÉDÉRALE DE LAUSANNE

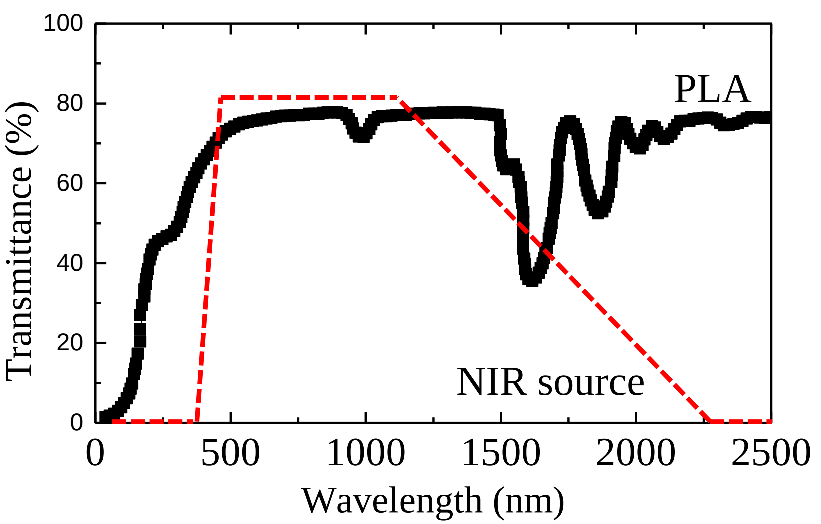
Photonic flash sintering



Novacentrix

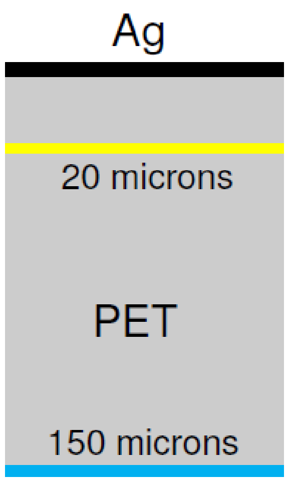
Photonic flash sintering (Xenon lamp)

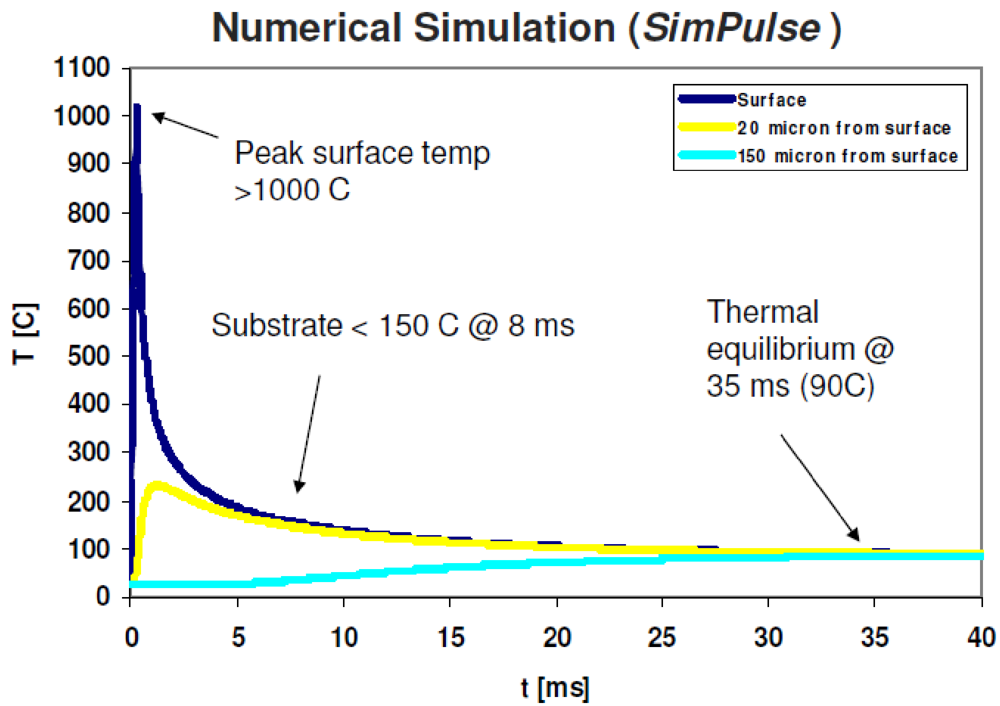
- 200 – 1500 nm
- Flash duration controlled by pulses (µsec)
- Energy: 3000-5000 mJ/cm^2
- Absorption of metal much higher than substrate: Substrate remains at low T°C



Photonic flash sintering

- On transparent polymeric substrates
  - Photonic sintering (1 to 5 J/cm^2)





Conditions:
1 μm Ag on 150 μm(6 mil)
Radiant exposure: 1 J/cm²
Pulse length: 300 μs

- High temperature processing removes excess solvent and enhances sintering.
- Substrate is undamaged.
- Pulse conditions (>10 parameters) are carefully tuned to each material application.