

Towards Disposable Sensors and Analytical Instruments for Gas Detection

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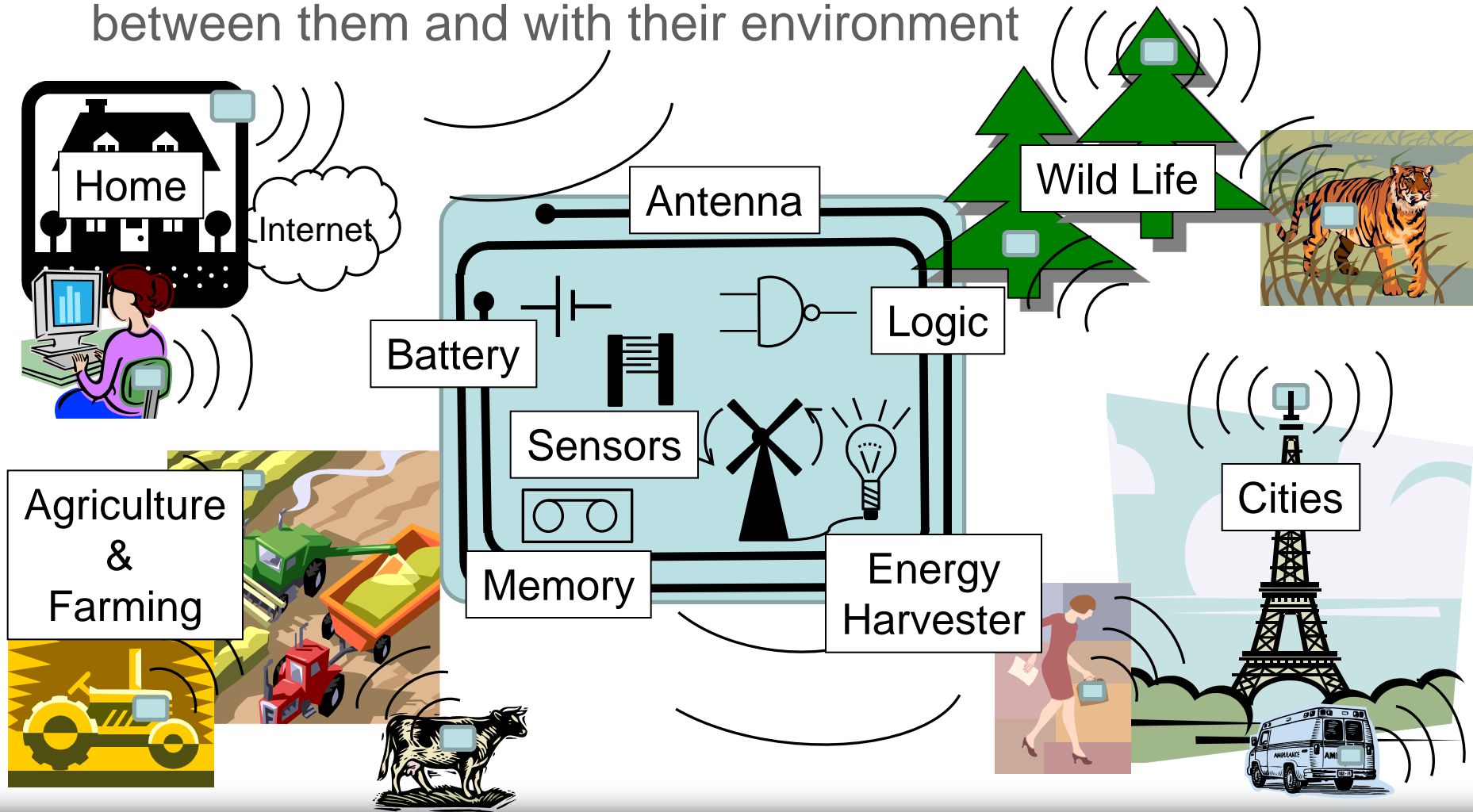
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Motivations

- The internet of things: Smart objects that can interact between them and with their environment

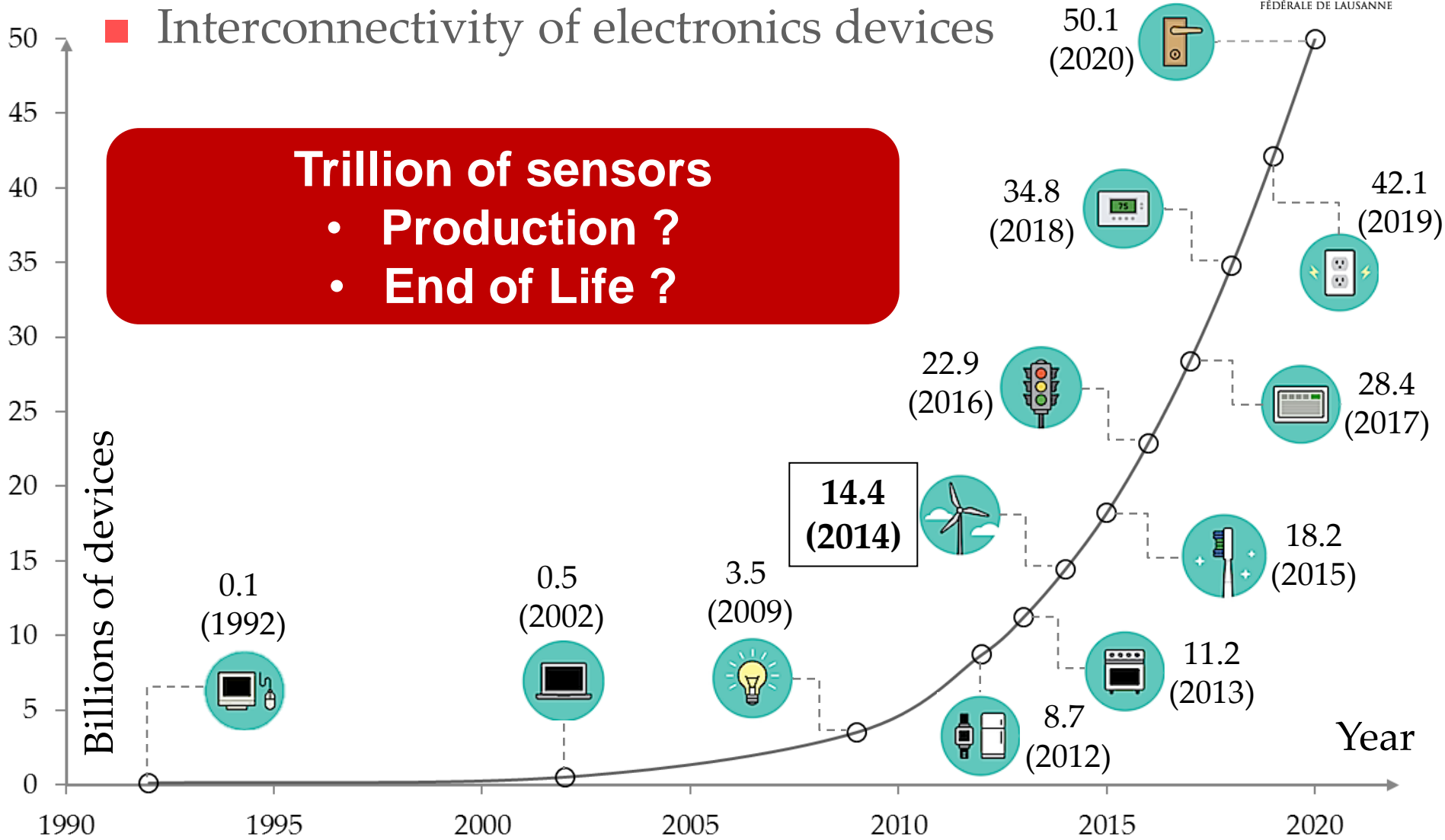


Motivations

■ Interconnectivity of electronics devices

Trillion of sensors

- Production ?
- End of Life ?



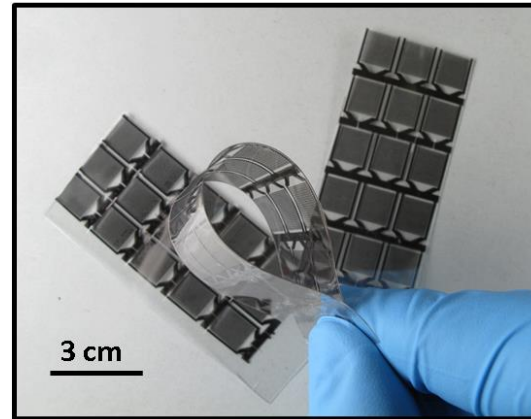
Source: images from The Connectivist and data from Cisco

Outline

- Technology shift
- Printed sensors and systems
- Polymeric analytical instruments
- Biodegradable sensors technology
- Conclusion

Technology shift

Flexible and printed sensors



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



Printing electronic devices

- Why use plastic and paper flexible substrates?



flexible

source: Plasticlogic



foldable

source: Swedish ICT



conformal

source: SEMICONWEST 2012

large area

source:
Princeton
University



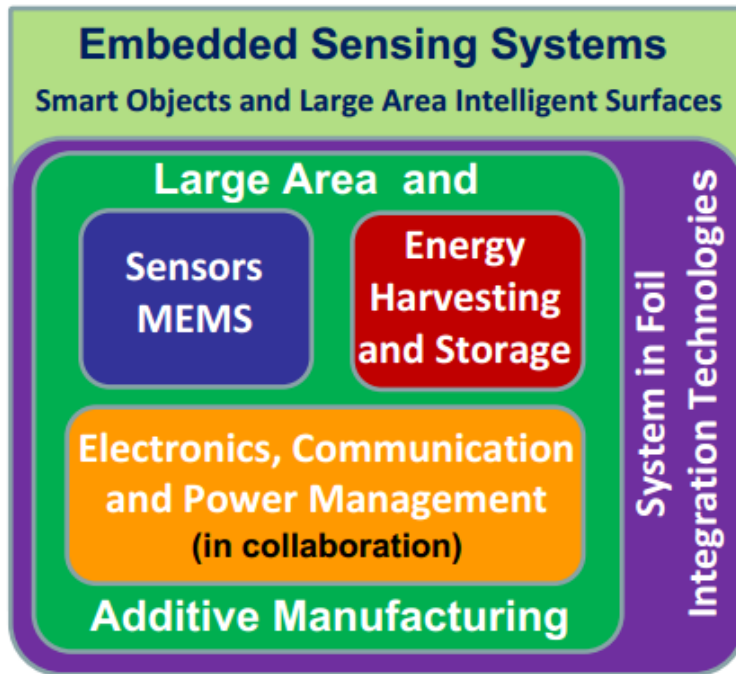
lower costs

source: GSA



Smart sensing systems on foil

Energy autonomous smart labels

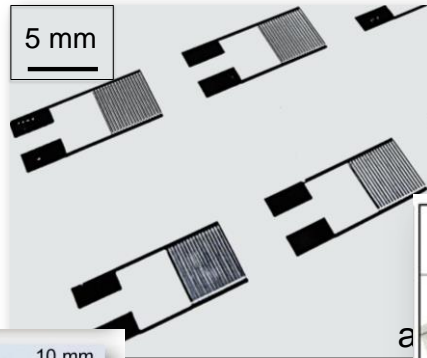


- On foil using additive manufacturing
- ➔ Integrating 'nano' and bio materials
- Low environmental impact
- ➔ Disposable / reusable electronics
GREEN electronics
- Ultimately ➔ Biodegradable

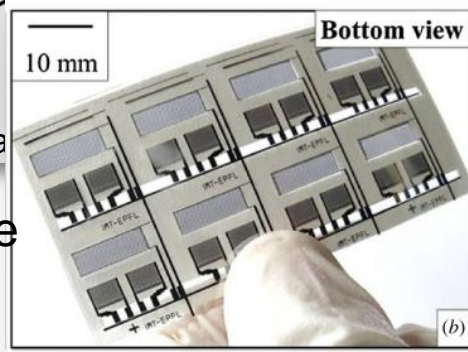
From imperceptible to **Disappearing electronics**

Smart sensing systems on foil

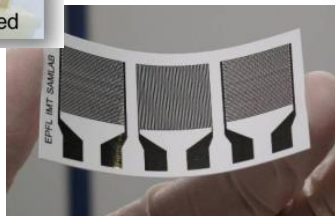
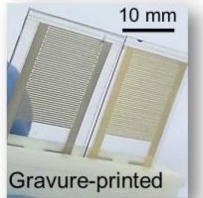
■ Foil-based sensors



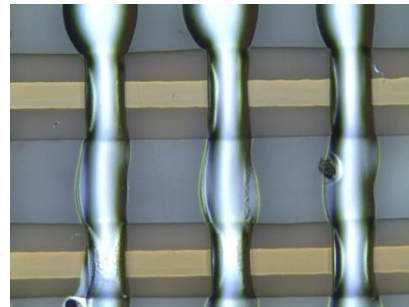
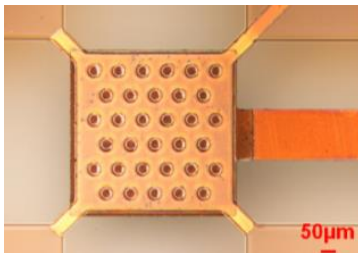
Printed and encapsulated
chemical / physical



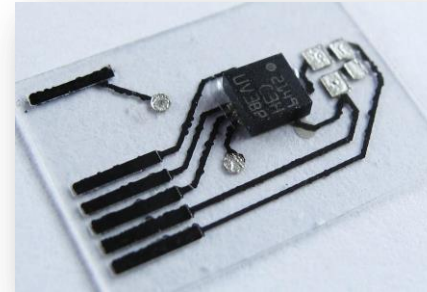
Biodegradable
paper / PLA



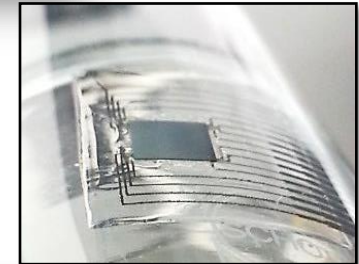
MEMS bridges
hybrid and fully printed



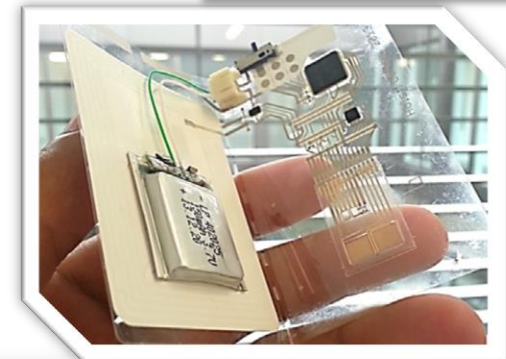
■ Integration of components on foil



SMD and bare
dies on PET

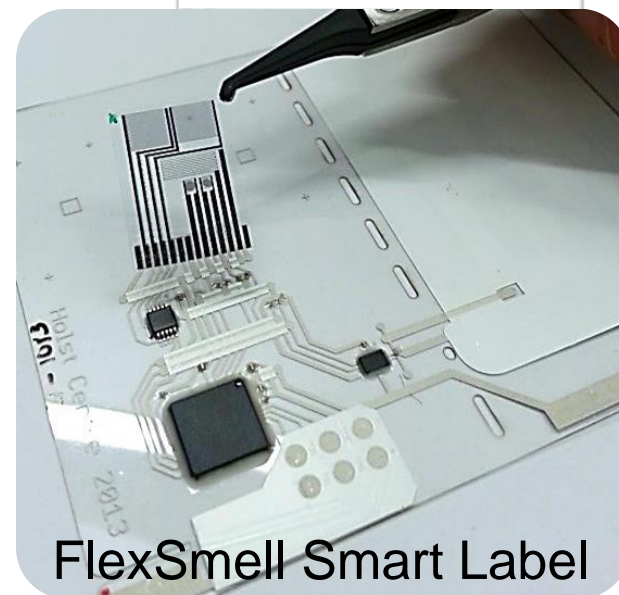
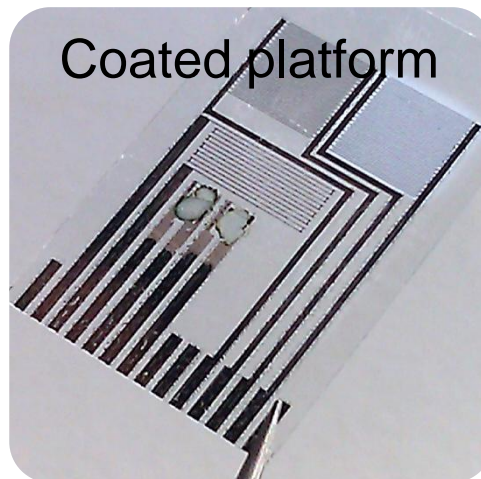
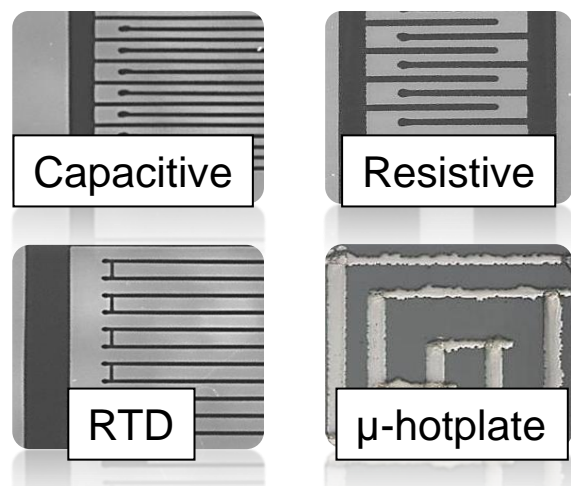


Foil to foil
integration



Smart sensing systems on foil

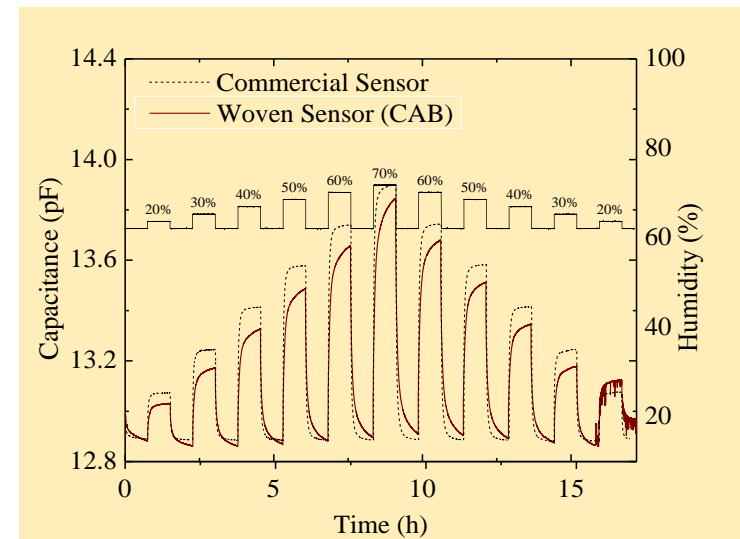
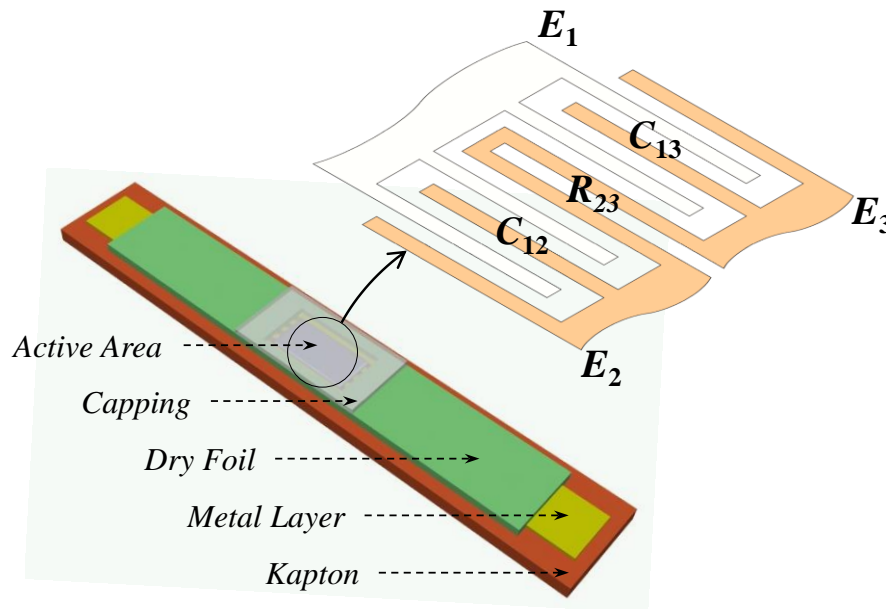
- Fully printed multi-sensor platform
- Integration to a RFID label (hybrid)



Device/ Variable	Humidity	Temperature	Ammonia	μ-hotplate
Nominal value	3 pF (@ 40%RH)	500 Ω (@ RT)	100 kΩ - 1 MΩ	100 Ω
Sensitivity	0.5 fF/%RH	0.6 Ω/°C	0.0044 ΔR/ppm NH ₃	3°C / mW
Resolution	5 fF – 5 %RH	1.2 Ω - 2 °C	sub NH ₃ ppm	-

Smart textile

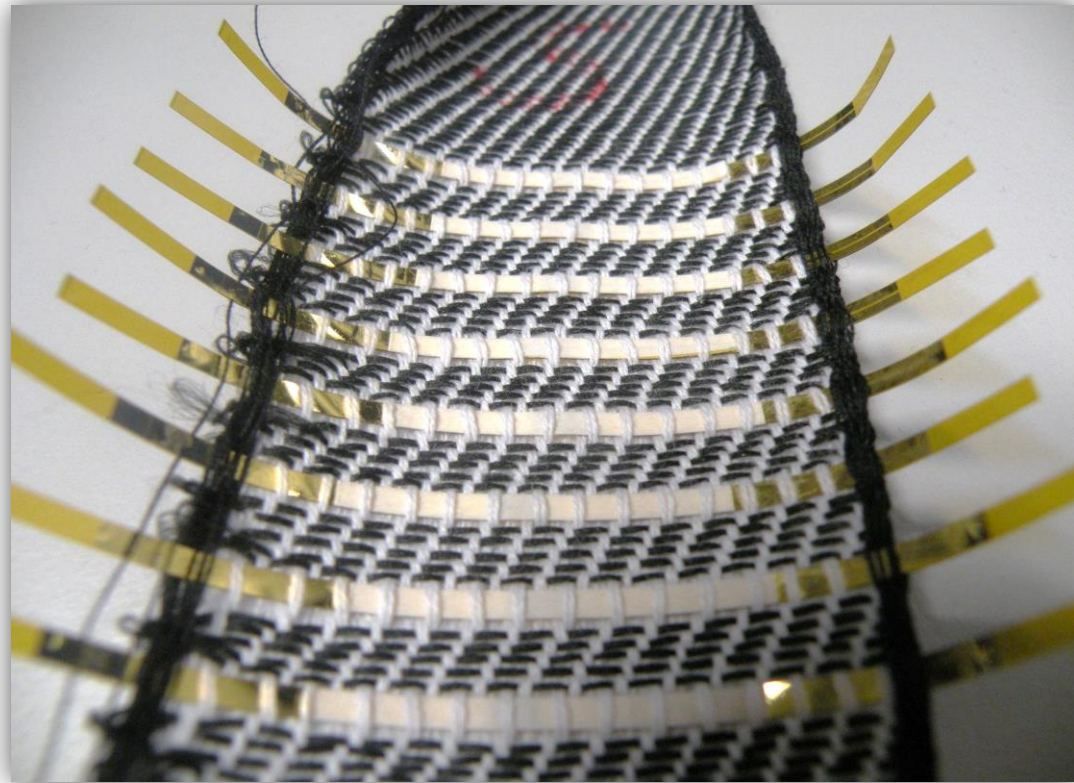
- Plastic stripes processed using printing techniques
 - Capacitive humidity and VOCs sensors
 - Resistive temperature detector



G. Mattana et al., Woven Temperature and Humidity Sensors on Flexible Plastic Substrates for E-textile Applications, IEEE Sensors Journal, vol. 13(10) (2013) 3001-3010.

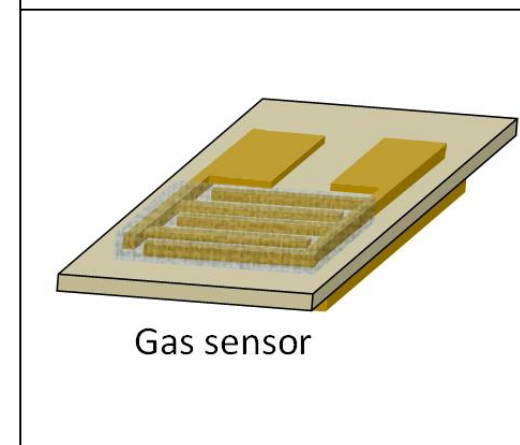
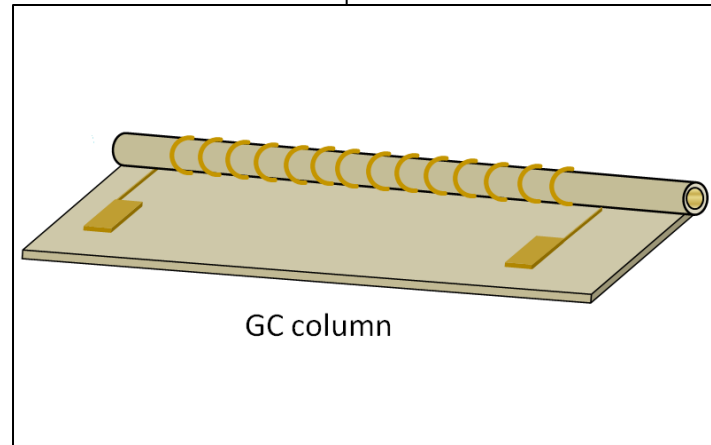
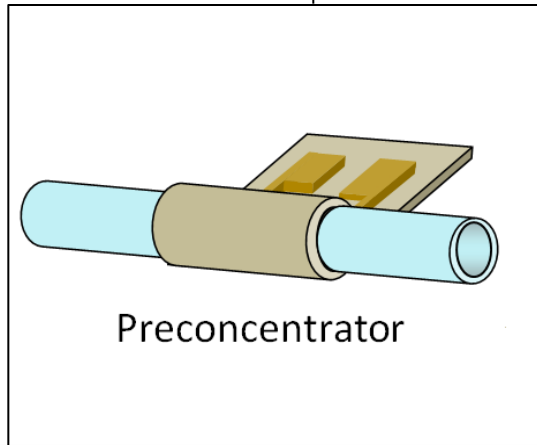
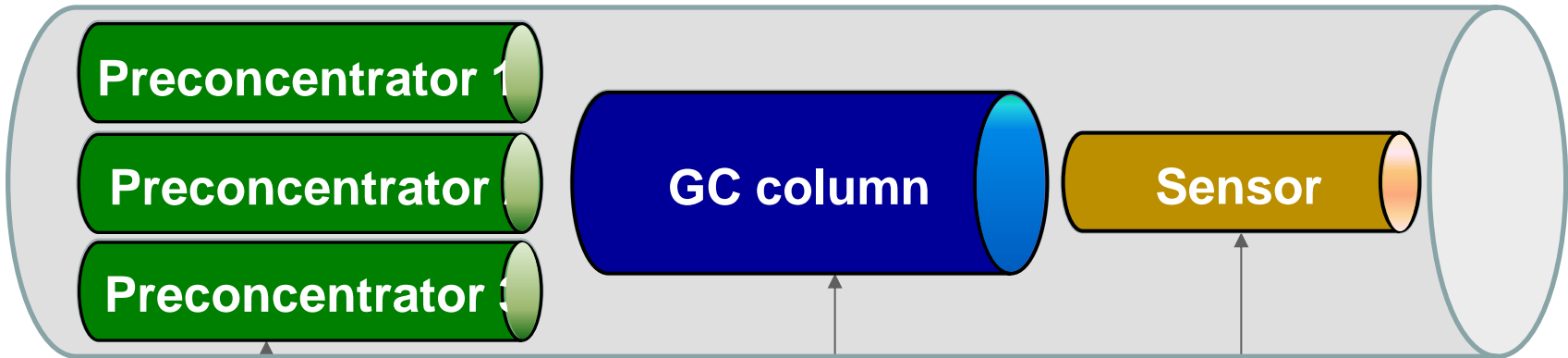
Smart textile

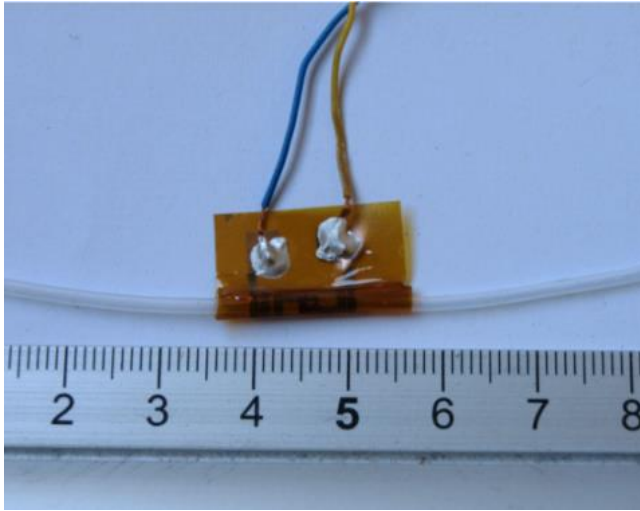
- Weaving of sensoric stripes



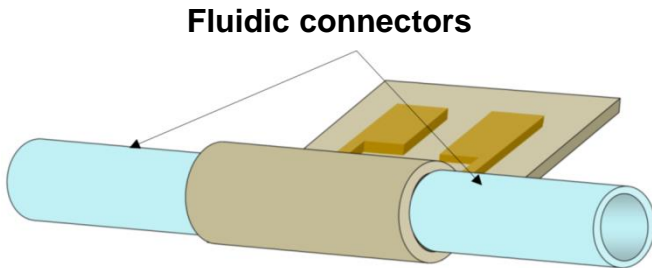
Analytical instruments

- Architecture of our foil micro-analyzer





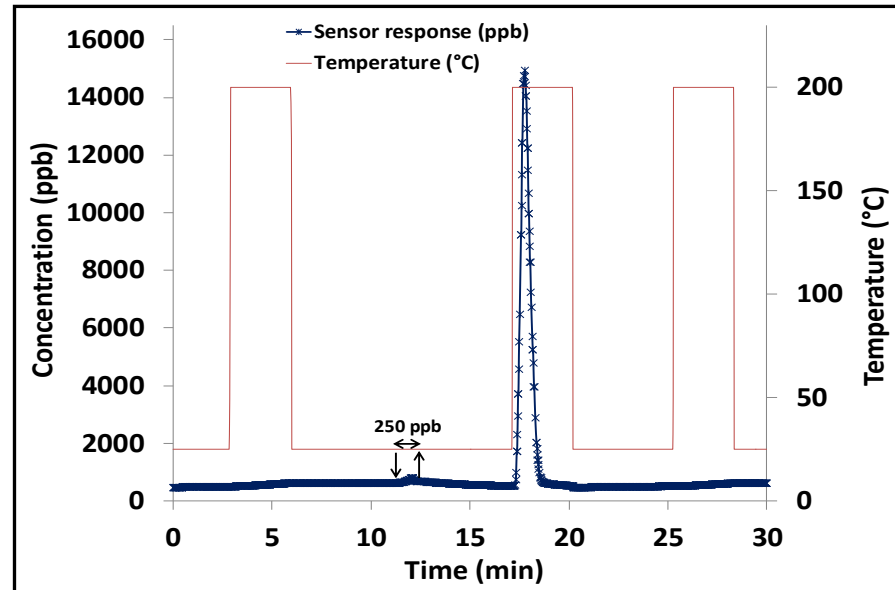
Picture of FGP in its final stage with adsorbent, fluidic capillary and electric wires



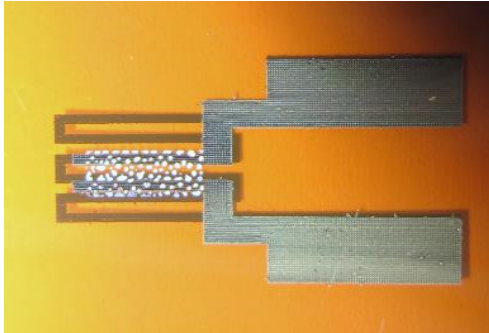
Rolling up of printed Au Heater on polyimide

Eurosensors 2015

Gas preconcentrator made by rolling up a printed hotplate on foil

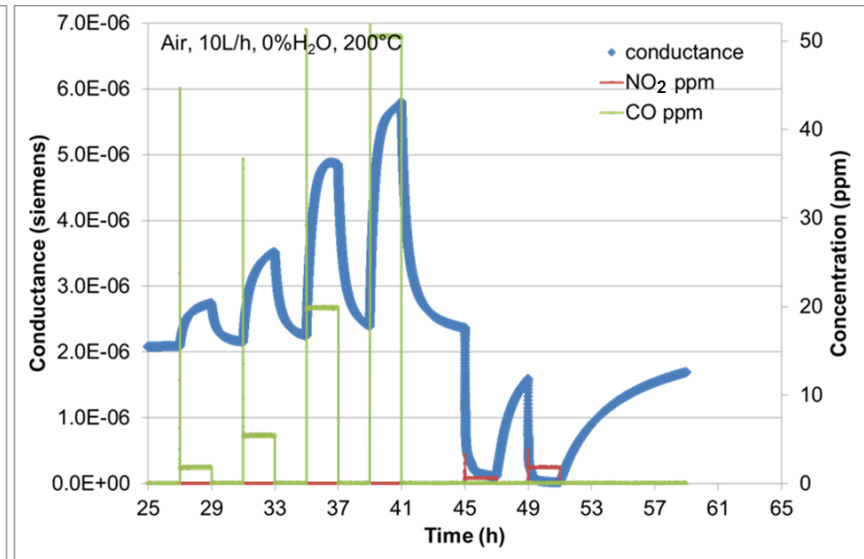
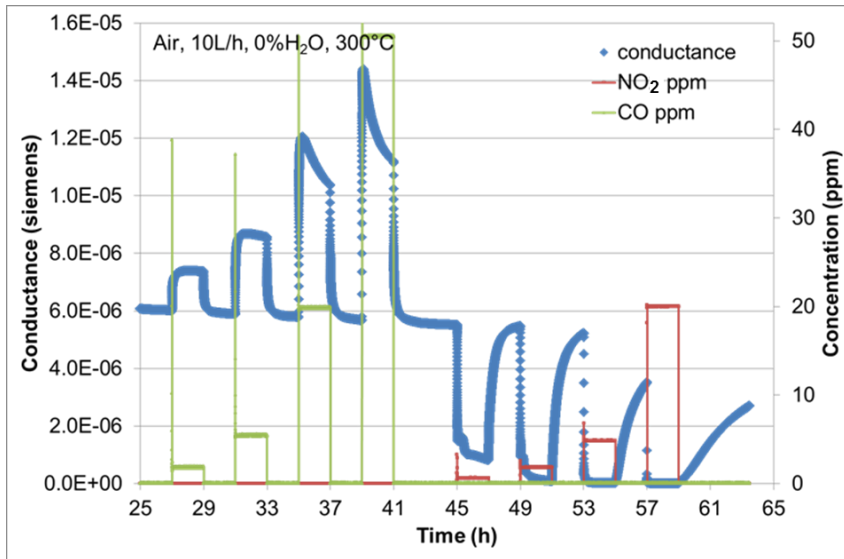


Desorption peak from a FGP filled with 1mg of Carboxpack B when exposed to 250 ppb@1min of benzene and desorbed with a flow rate of 66 mL/min



Eurosensors 2015

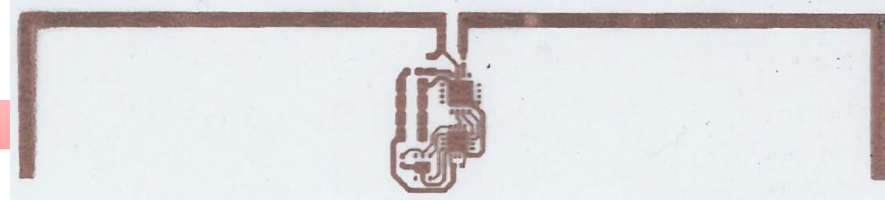
Inkjet printed SnO₂ gas sensor on plastic substrate



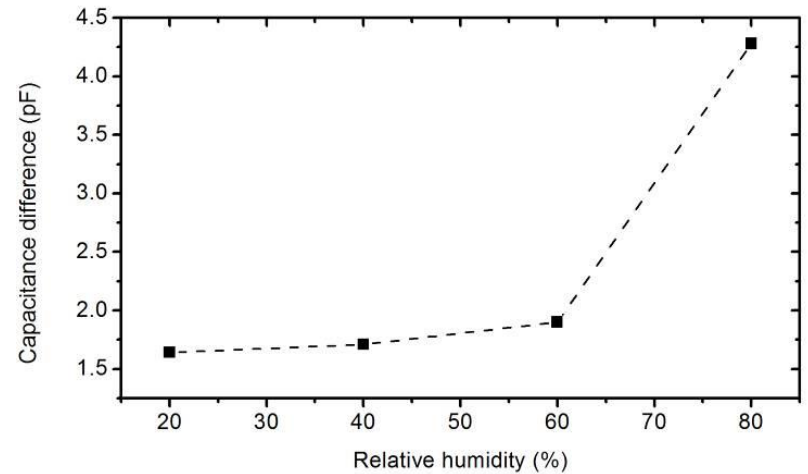
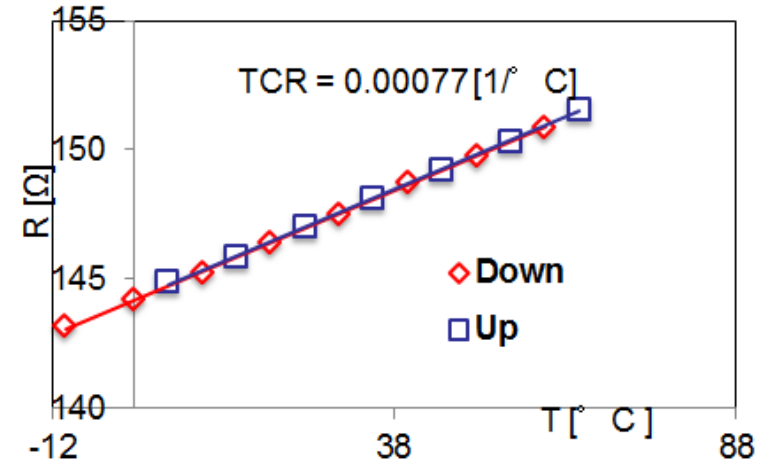
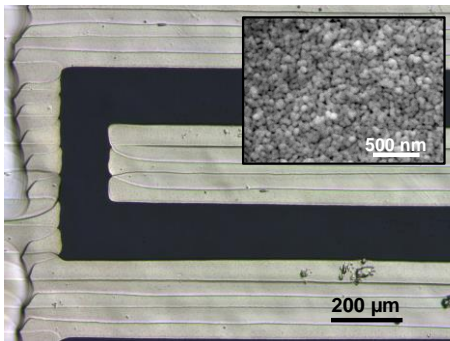
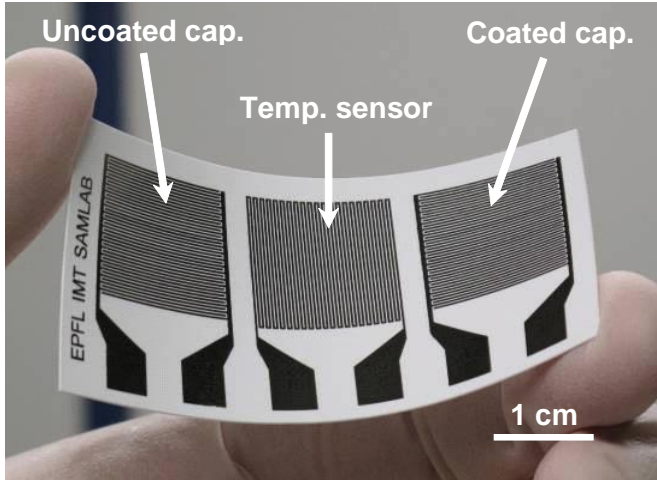
Evolution of the sensor conductance in dry air with CO and NO₂ injections at 300°C (left) and 200°C (right)

Biodegradable sensors

- Inkjet printing on paper substrate



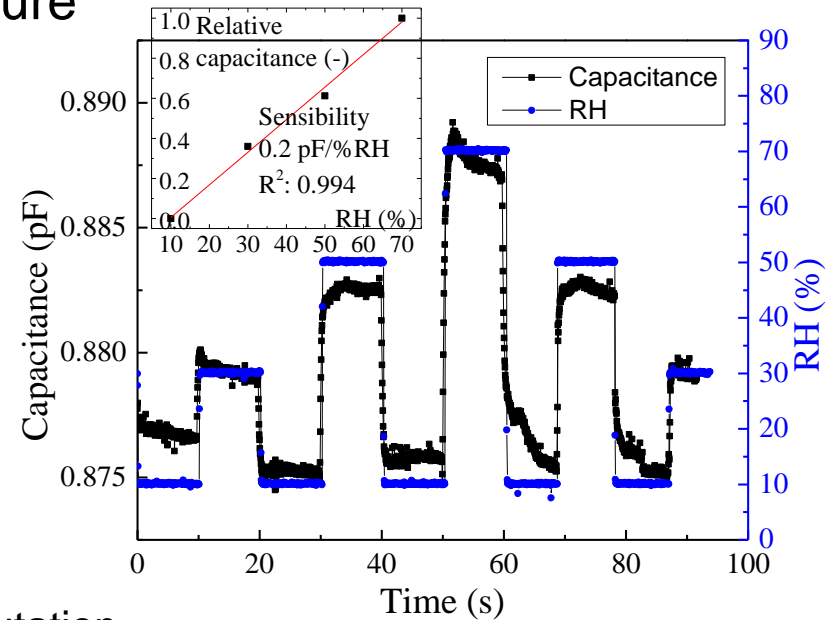
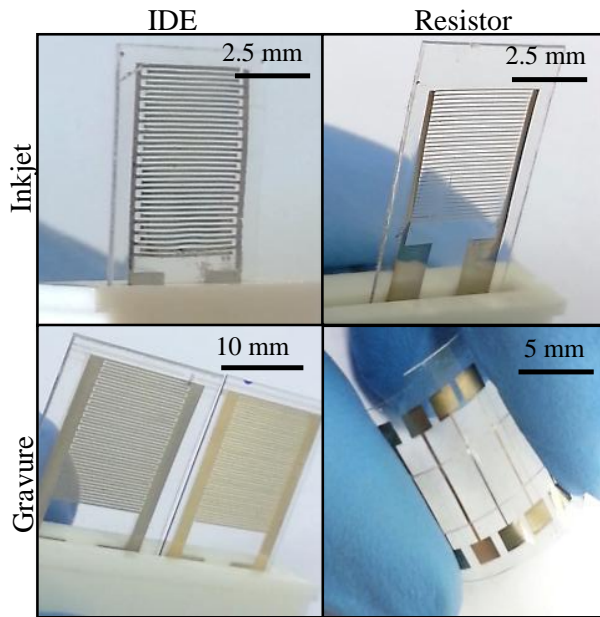
Printed copper circuit board and antenna



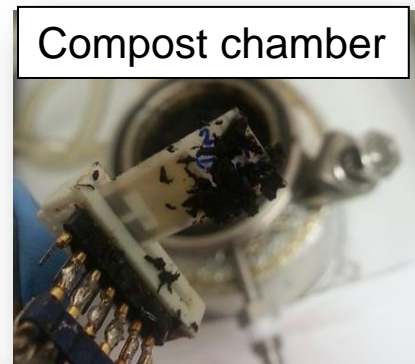
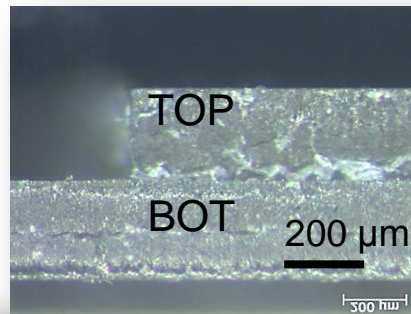
J. Courbat et al., Transducers 2011 / G. Mattana et al., E-MRS 2012 / D. Briand et al., LOPEC 2012

Biodegradable sensors

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



Encapsulation
by lamination



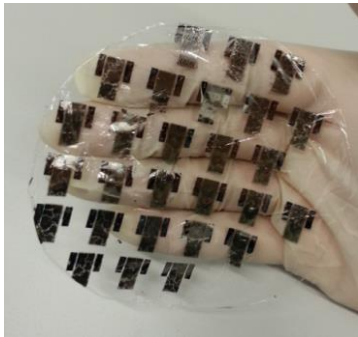
A. Vásquez Quintero et al., Proc. of the MEMS 2014 conference, pp. 532-535.

Biodegradable sensors

- Printed organic TFTs on poly lactic acid substrate

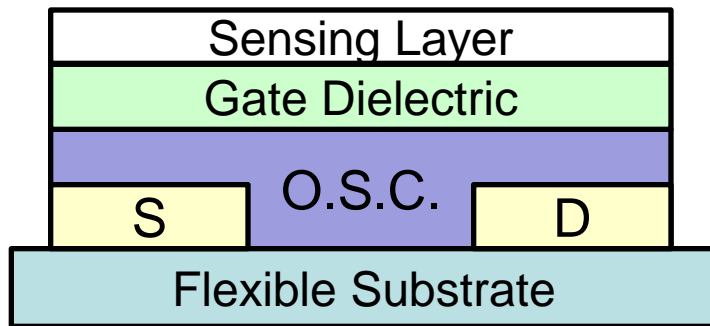


Collaboration with Prof. K. Persaud, UMAN, UK

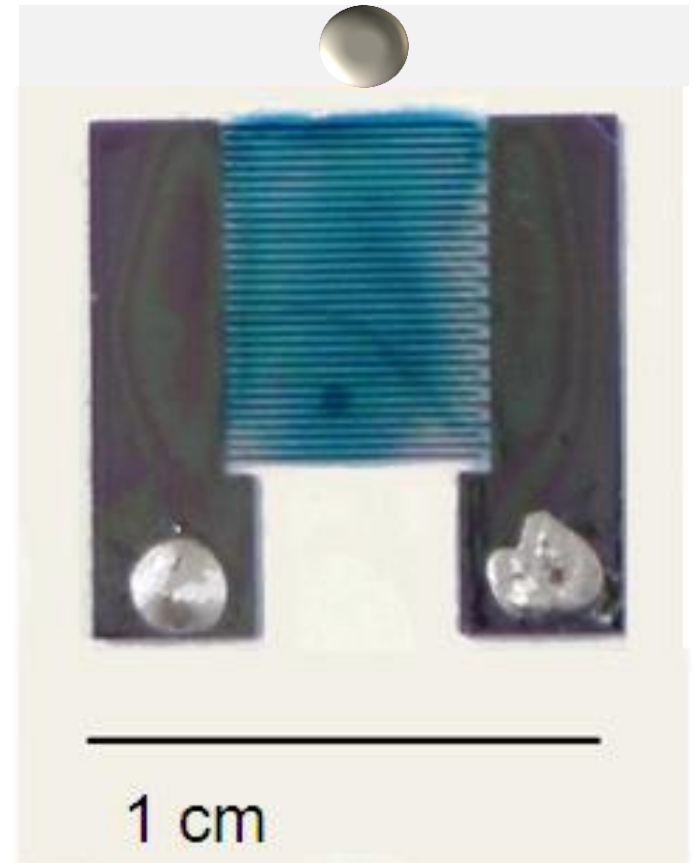


Transistors

- Thin film & electrochemical
- PLA as substrate & gate dielectric

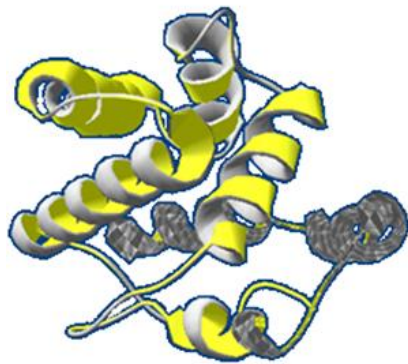


G. Mattana et al., Org. Electronics (2015)

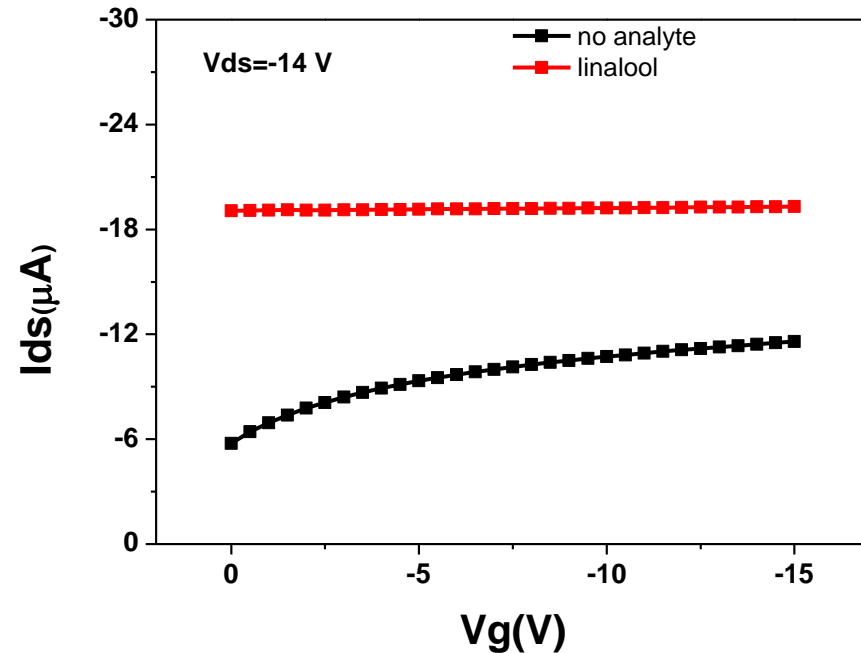


Biodegradable sensors

- Gate functionalisation with odorant binding proteins



*wasp OBPs (β -barrel shape)
in PVA as sensing layer*



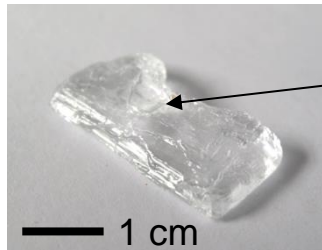
Ids – *Vgs* curves acquired before and after exposure to saturated vapours of the analyte (ambient conditions).

Biodegradable sensors

- Rochelle salt / paper composite piezoelectric material

Piezoelectric constant

30-290 $\mu\text{C}\cdot\text{N}^{-1}$



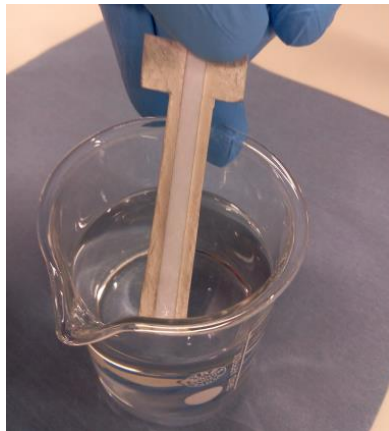
Potassium
sodium
tartrate



Food additive E337

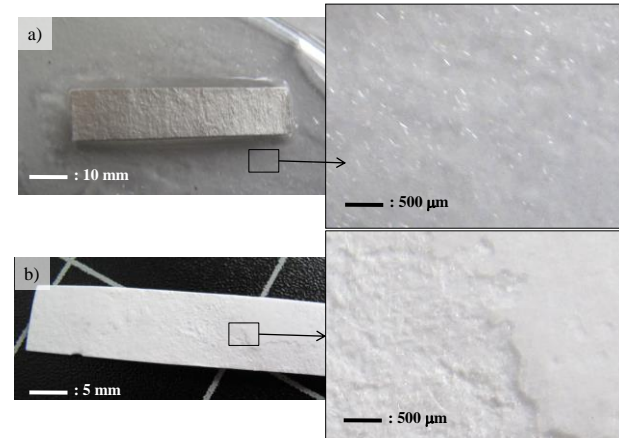
- Massive production
- Low cost
- Water soluble
- Environmental/Bio compatibility

Eurosensors 2015: Green paper-based piezoelectric material for sensors and actuators



Solution processed

- Biocompatible
- Biodegradable



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 ...

Acknowledgements

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



Funding: GOSPEL EU Network of Excellence, FP6



FlexSmell, ITN, FP7



Nano-Tera.ch, Swiss Confederation Program
evaluated by the SNSF



Thank you for your attention

