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

A Novel Concept of Environmental Camera through Volatile Organic Compounds Sensing

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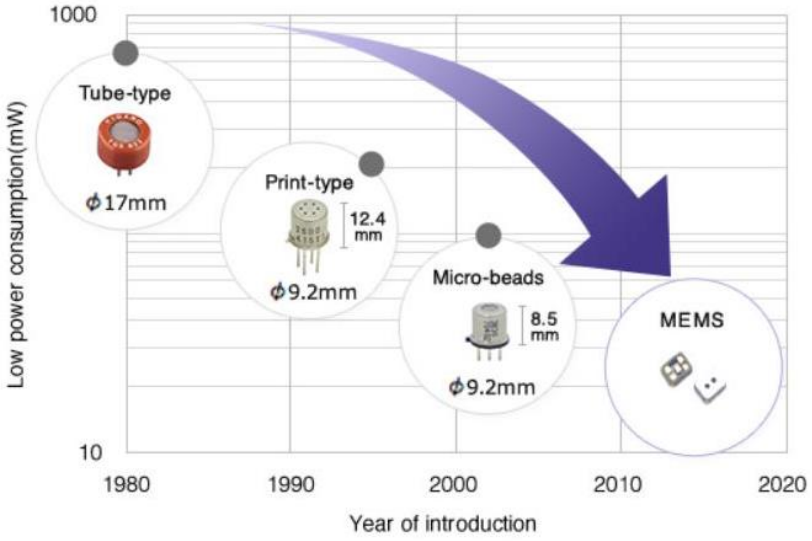
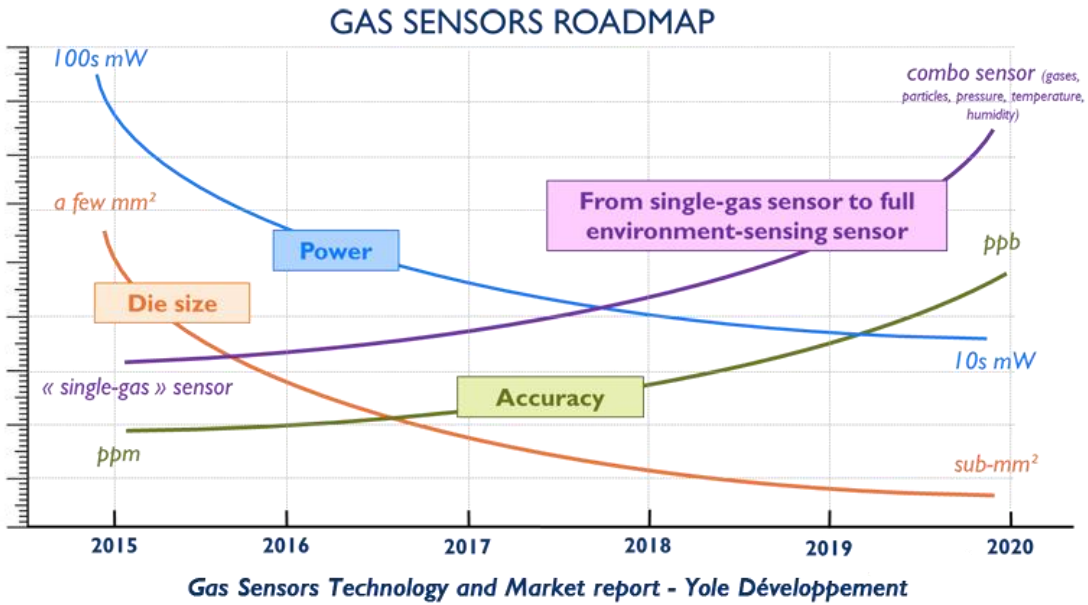
Miniaturized gas sensor roadmap

- **Solid-state gas sensors based on metal oxide semiconductor**



- ✓ Micro/nano level gas sensor
- ✓ Integrated with other ICs on the same chip



Miniaturized gas sensor roadmap

- **Trends towards low-size, low-power consumption**

CAMBRIDGE CMOS SENSORS

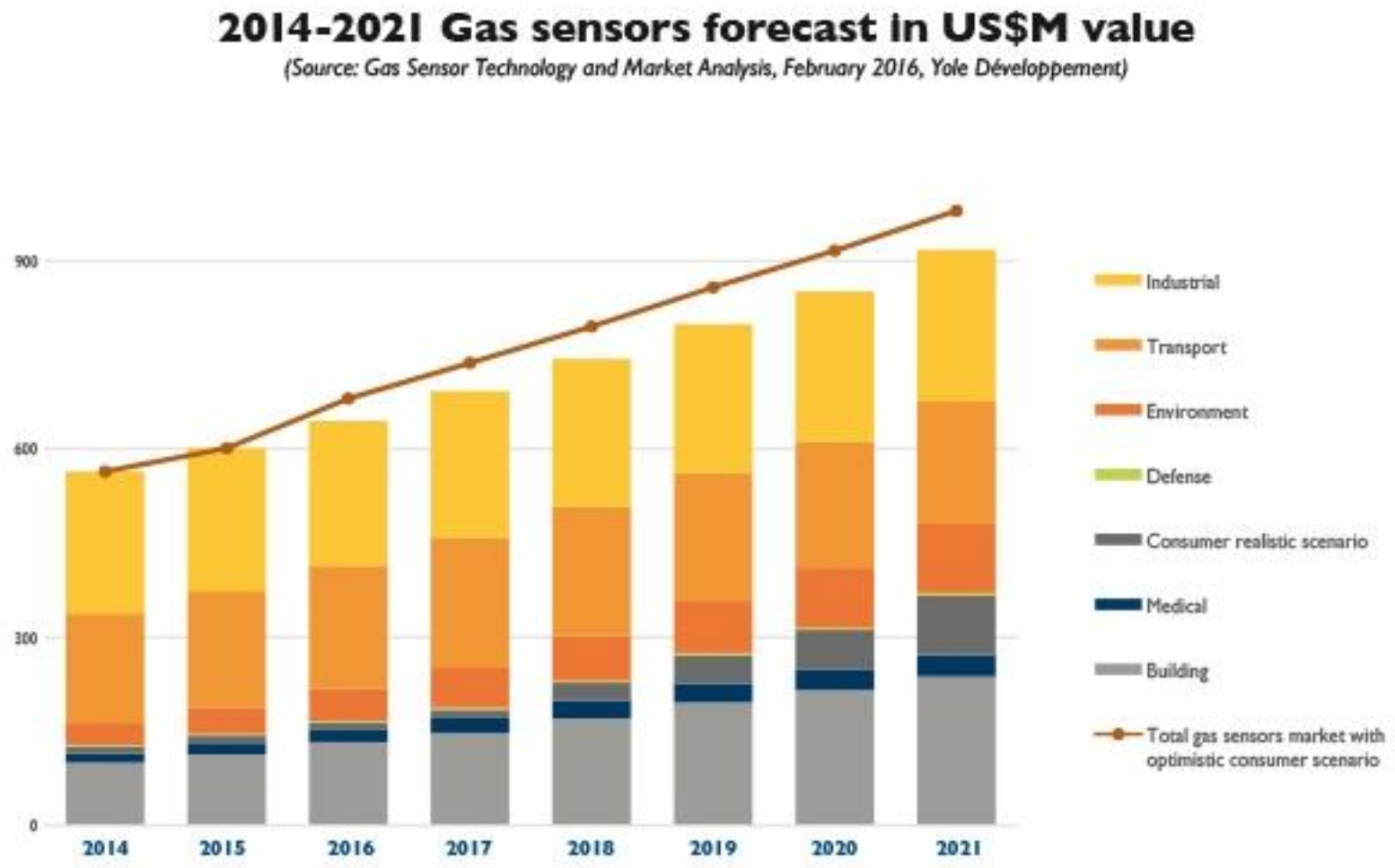
FIGARO

FIGARO ENGINEERING INC
World leader in gas sensing innovation

And beyond?

Market demand and development trends

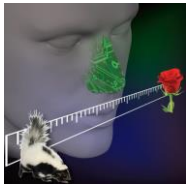
- **Expected market evolution**



Current and future applications of gas sensors

- **Towards new developments opportunities**

- ✓ Process control industries
- ✓ Life and working Environmental monitoring
- ✓ Fire detection
- ✓ Alcohol breath tests
- ✓ Poison gas detection
- ✓ Grading of agro-products like coffee and spices



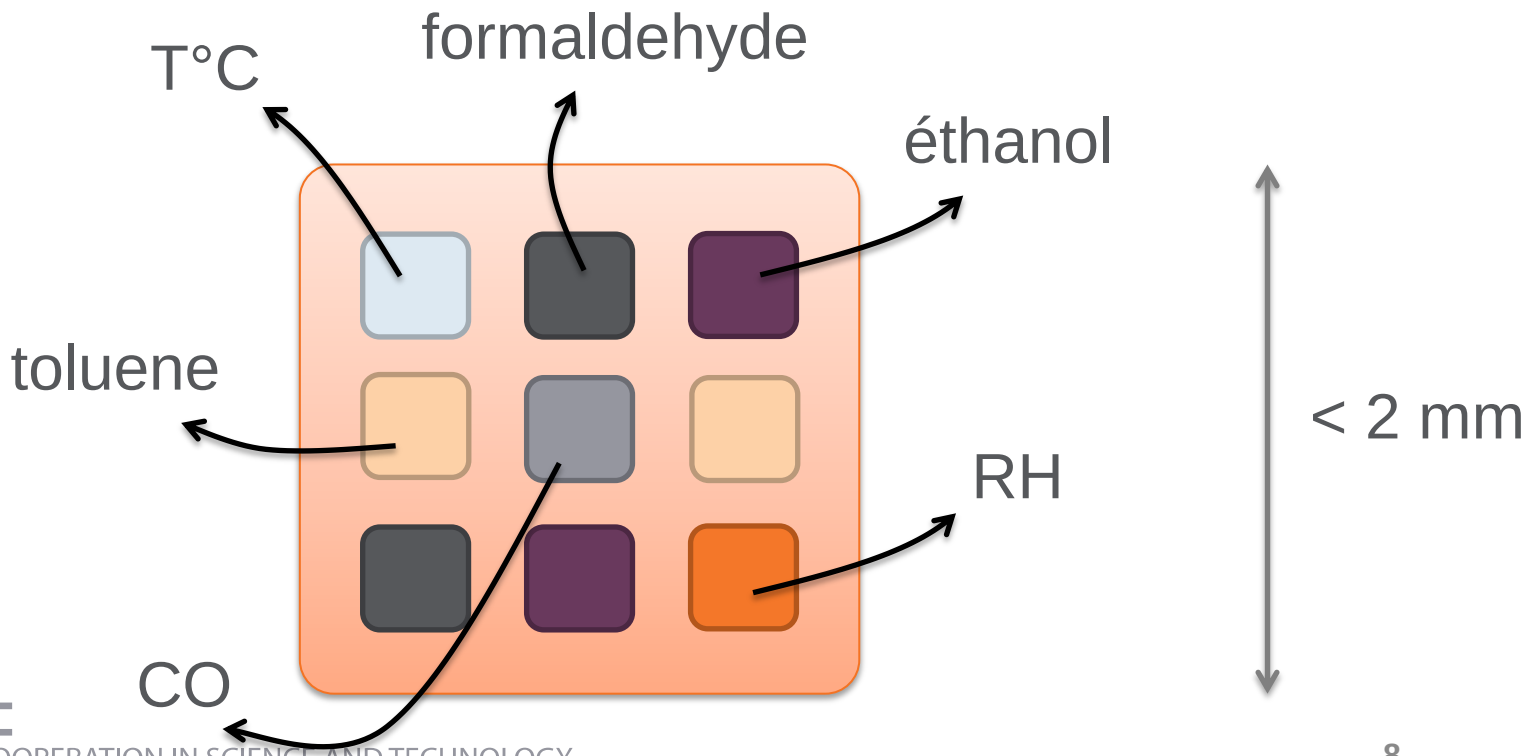
- ✓ Food process and storage
- ✓ Industrial emissions monitoring
- ✓ Medical diagnosis
- ✓ Underwater gas detection
- ✓ Smartphone & wearable devices
- ✓ Detection of hazardous explosives

Strategic marketing analysis

- **Internet of Things** and **smart sensing**
- **Radio connectivity** for remote control
- Request for **detecting the absence of specific compounds** through **increased selectivity**

A novel concept of environmental camera

- **CMOS-compatible** gas sensing platform
- **Multi-pixel** implementation
- Specific focus on **volatile organic compounds (VOC) detection**
- **Room temperature detection for ultra-low-power** consuming

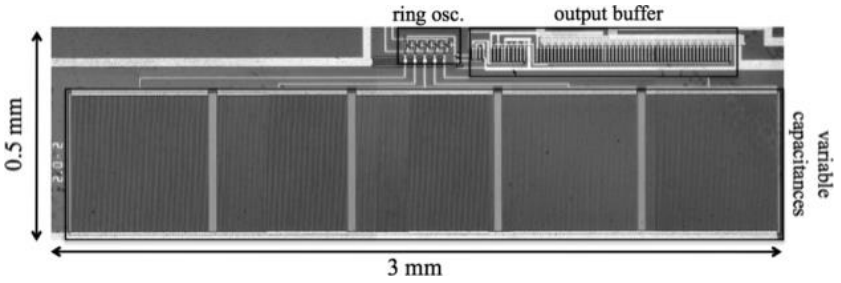


Improvements of new generation gas sensor

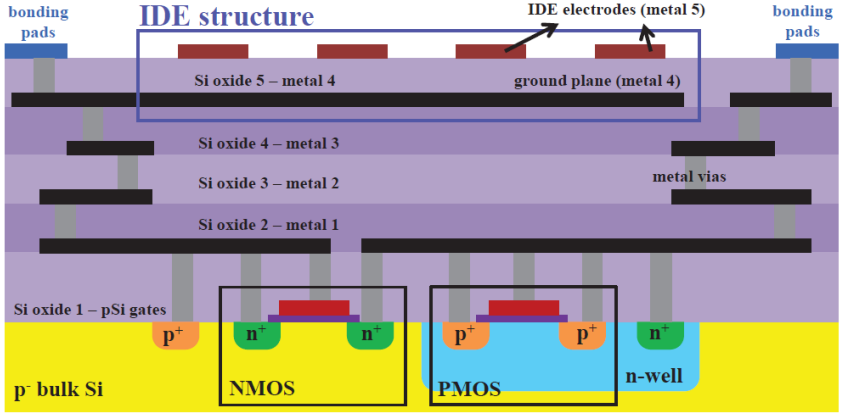
- **System-on-chip** to support **multi-gas detection**
- **Increased selectivity**
- **Higher sensitivity**
- **Ultra-low-power consumption < 100 µW**
- **Low-cost < 5 €**
- **Smaller size < 10 mm³**
  - ✓ Lower cost
  - ✓ Less material required
  - ✓ Easier mass production
  - ✓ Less manufacturing cost

Previous works @UCL

- **Integrated sensors based on interdigitated microelectrodes**

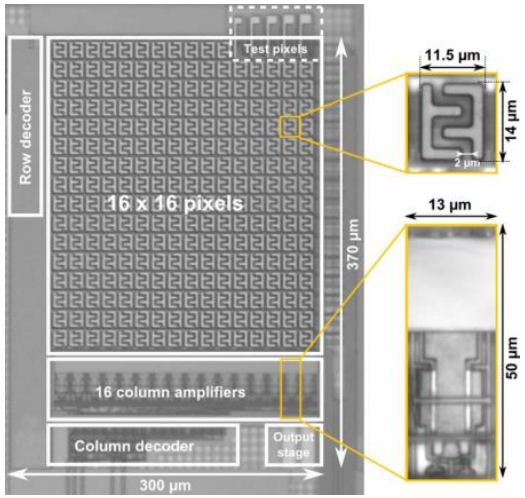


N. André et al., IEEE Sens. J., 2012



S. Druart, PhD thesis, 2013

- **Integrated sensor array**



N. Couniot et al., IEEE Trans Biomed Circuits Syst, 2015

SMALL
Sensors, Microsystems and Actuators Laboratory of Louvain

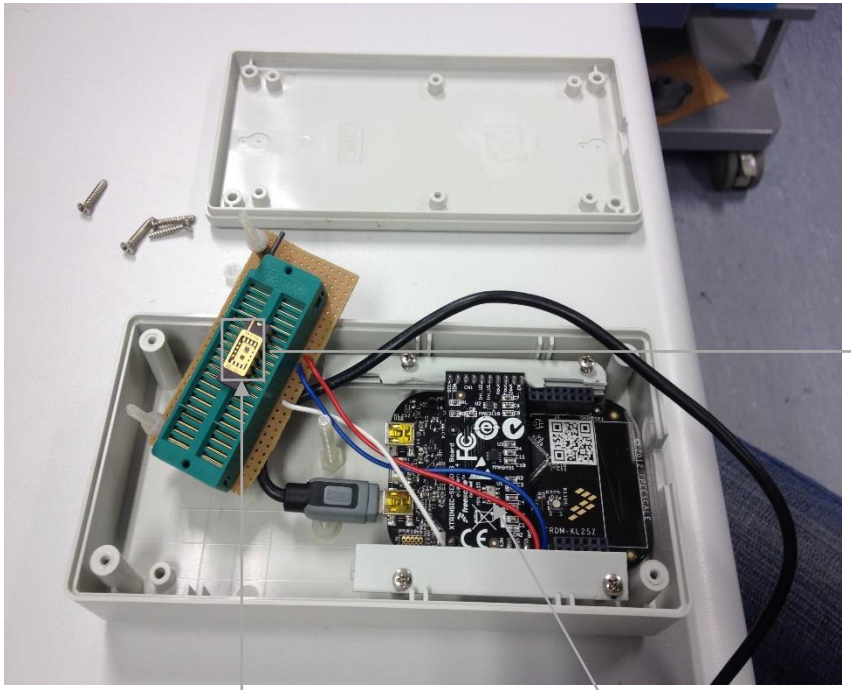
winfab

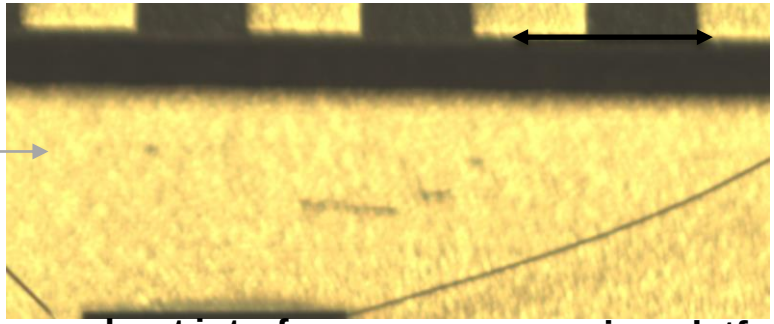
welcome

Previous works @UCL

- **Humidity sensor based on ALD-synthesized Al_2O_3 sensing layer**

Portable system = Micro-hotplate + Read-out circuitry + Freescale KL25Z® + Acer® Netbook





read-out interface = ring oscillator

sensing platform

Our %RH sensor

MLP315 T sensor on Freescale board

Previous works @UCL

- **Aveiro real-time monitoring experience**

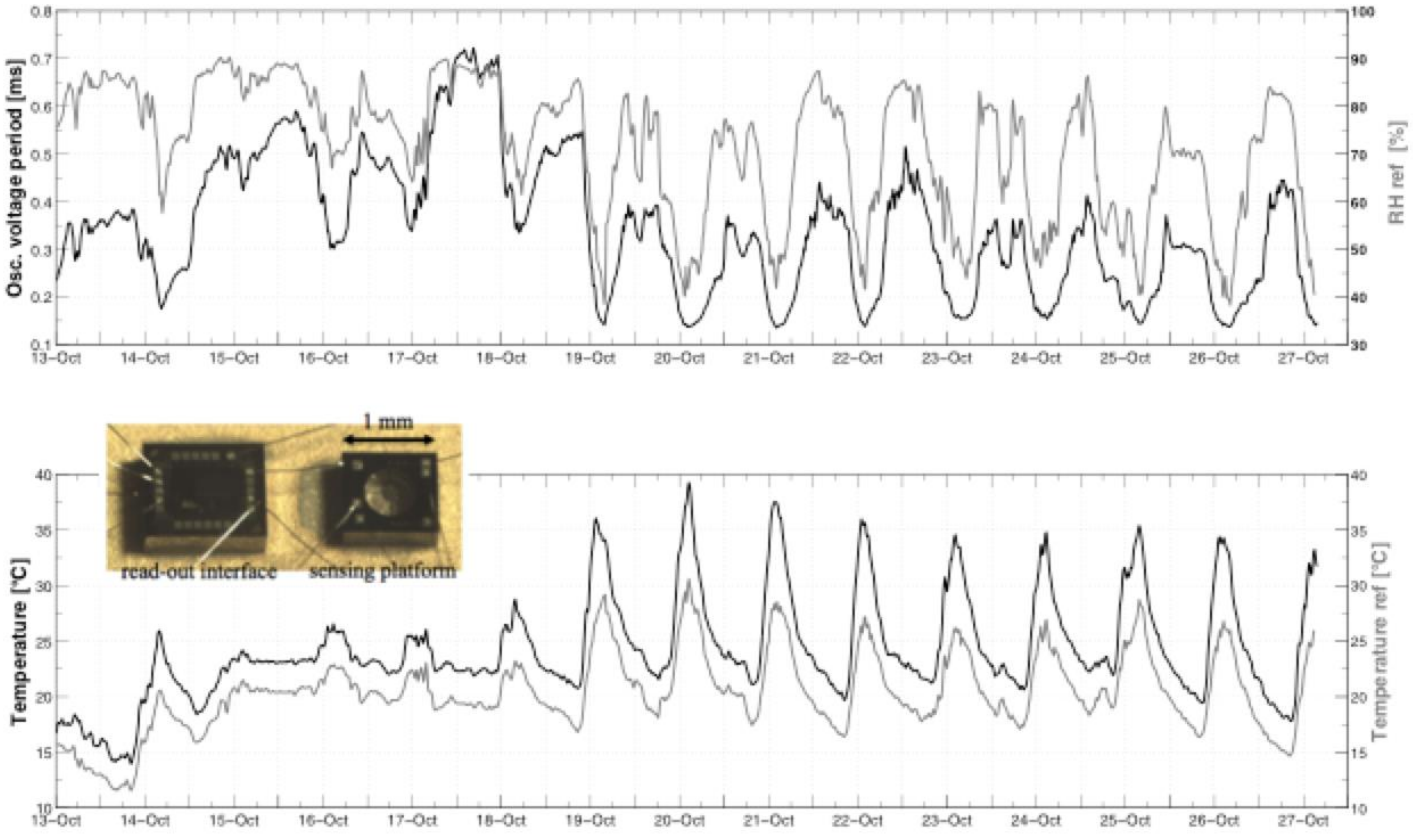
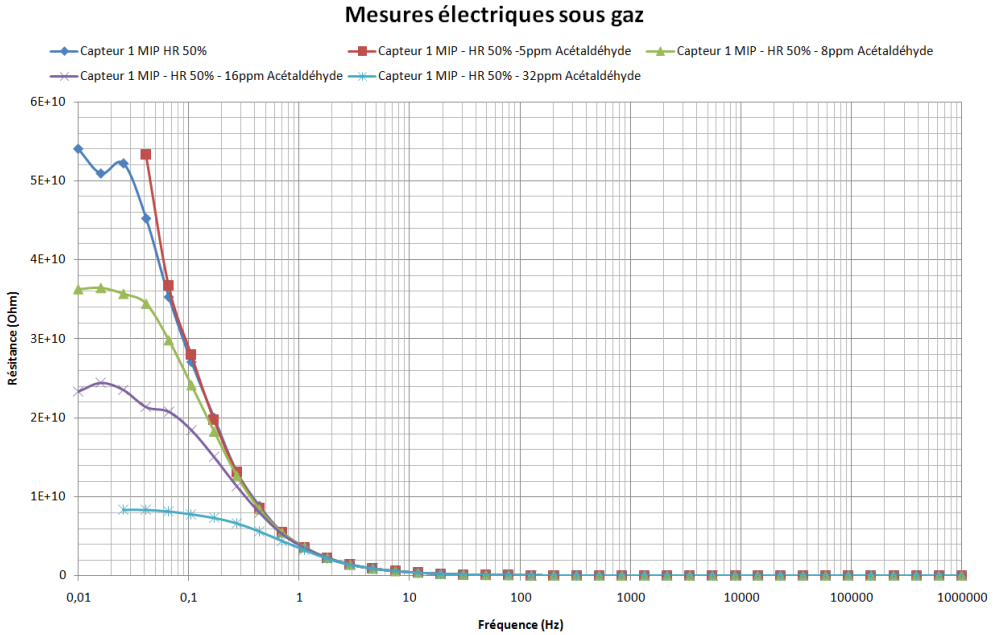
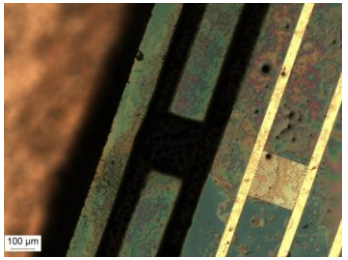


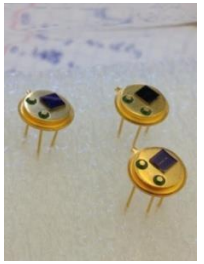
Fig. 2. Temporal distribution of the sensor oscillating voltage frequency and temperature from the UCL/CCMOSS datalogging. Inset: System-in-Package with readout interface and %RH sensor

Selective gas sensing at room temperature

- **Conductive and conjugated polymers:** PPy, PAni, PVP, etc.
- **Molecularly Imprinted Polymer (MIP) technology**
  - ✓ **Higher selectivity**
  - ✓ **Room temperature operation, no microheater is needed**







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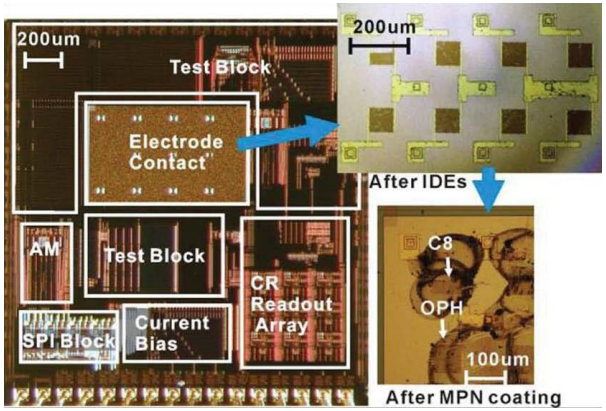
MATERIALS R&D CENTRE

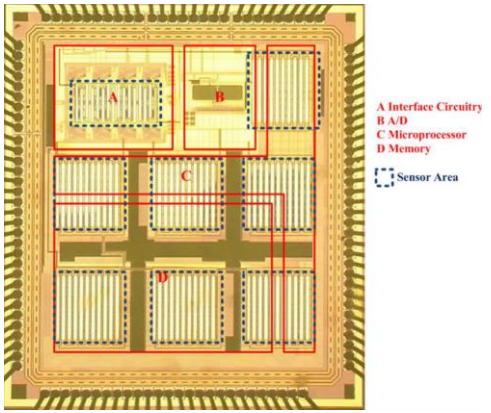
cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Selective gas sensing at room temperature

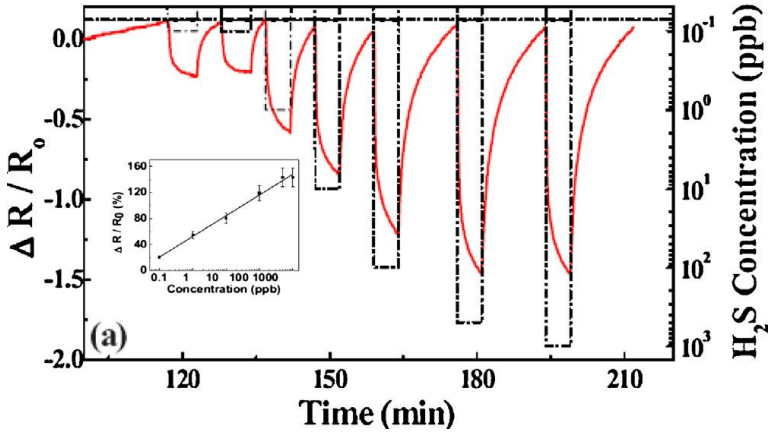
- **State-of-the-art examples of polymer-based gas sensors array**



X. Mu et al., IEEE Sens. J, 2012



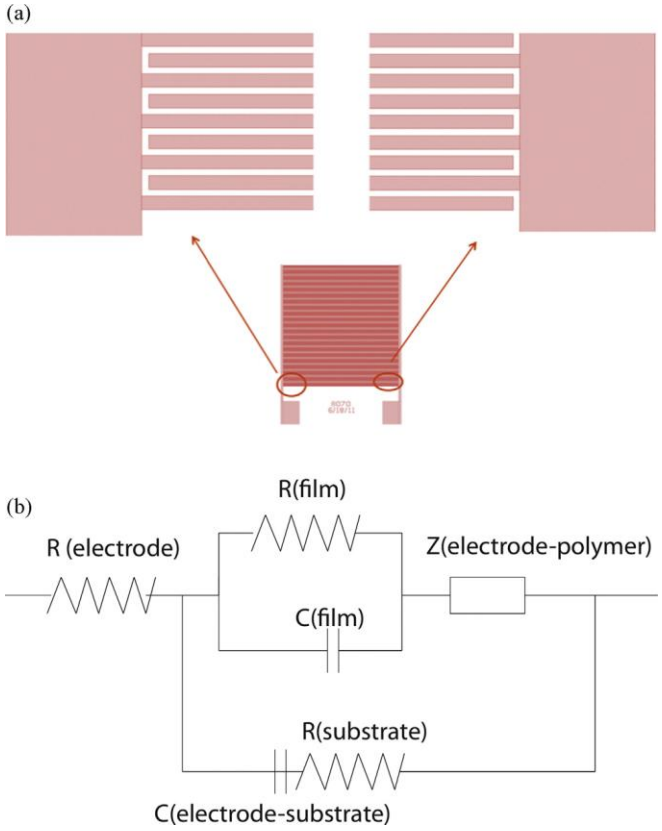
K.-T. Tang et al., Proc. IEEE Biomed. Circ. Syst., 2011



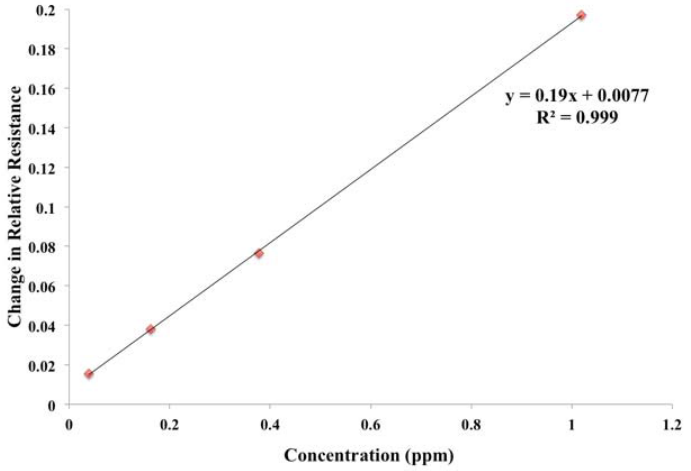
I. Fratoddi et al., Sens. Actuator B-Chem, 2015

Selective gas sensing at room temperature

- **State-of-the-art example with formaldehyde detection**



S. Antwi-Boampong and J. J. BelBruno, Sens. Actuator B-Chem, 2013

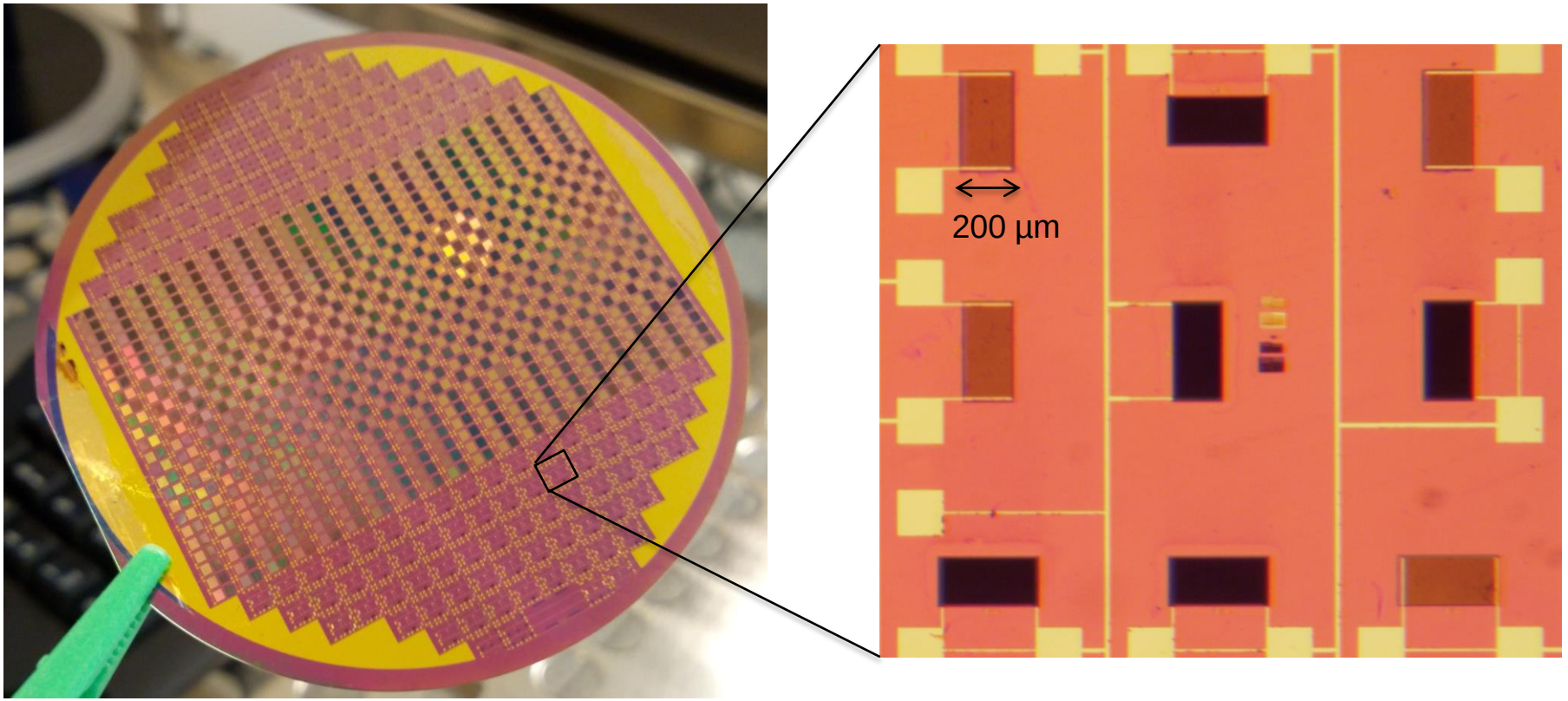


Molecule	Unimprinted Layer (A Relative R/ppm)	Imprinted Layer (A Relative R/ppm)
Water	6.8×10^{-7}	No response
Methanol	1.6×10^{-8}	7.4×10^{-7}
DCM	1.9×10^{-7}	1.2×10^{-8}
Chloroform	2.1×10^{-7}	1.9×10^{-8}
Acetone	1.9×10^{-6}	5.5×10^{-8}
Toluene	8.6×10^{-7}	1.2×10^{-6}
Ethanol	2.0×10^{-6}	8.8×10^{-7}
Formaldehyde	6.9×10^{-5}	2.5×10^{-5}

S. Antwi-Boampong et al., IEEE Sens. J., 2014

Multi-pixel integration @UCL

- **CMOS front-end interface** development
- **Functionalization** of the sensor array **at wafer level**



Market-oriented research and valorization

- **Ultra-low-power CMOS gas sensing platform**: transducer and front-end interface
- First development towards **selective volatile organic compounds detection**

VOCSens

Selective sensing

SCAN ME

Your environmental camera

What's next?

- Need for **novel selective sensing materials:**
  - ✓ **CMOS compatible**
  - ✓ **Operating at room temperature**
  - ✓ **"Highly" sensitive**
  - ✓ **Easy to integrate**, especially at wafer scale
  - ✓ **Low-cost**
- Functionalization ways **towards mass production**

⇨ Conductive polymers, MIP, etc. + nanomaterials?

⇨ Carbon nanotubes, graphene, etc. combined with MOX or polymers?

What's next?

Ready to fill the gap?

Acknowledgements

- **Team and partners:**
  - Dr. Thomas Walewyns, UCL/ICTM/ELEN, Spin-off project leader
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  - Dr. Driss Lahem, Materia Nova, Scientific partner

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