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

COST Action TD1105

WGs and MC Meeting at LINKOPING, 3 - 5 June 2015

Action Start date: 01/07/2012 - Action End date: 30/06/2016

Year 3: 1 July 2014 - 30 June 2015 (***Ongoing Action***)

Sensors for indoor air-pollution monitoring

Speaker
Organization
Logo

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ESF provides the COST Office through a European Commission contract

ACKNOWLEDGEMENTS

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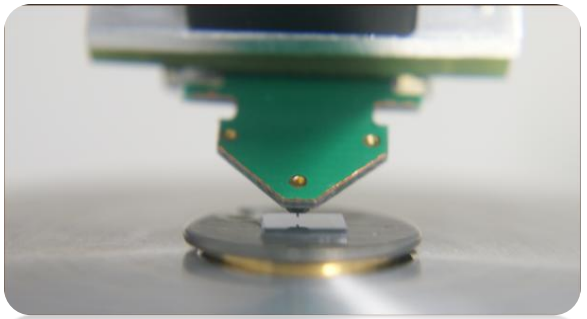

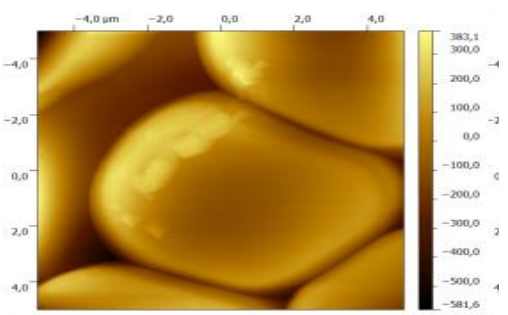

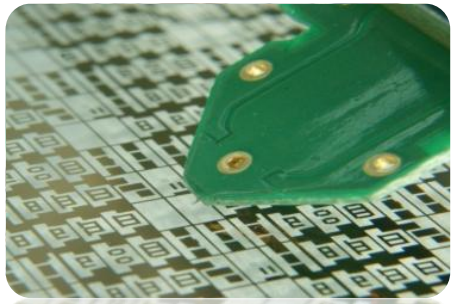

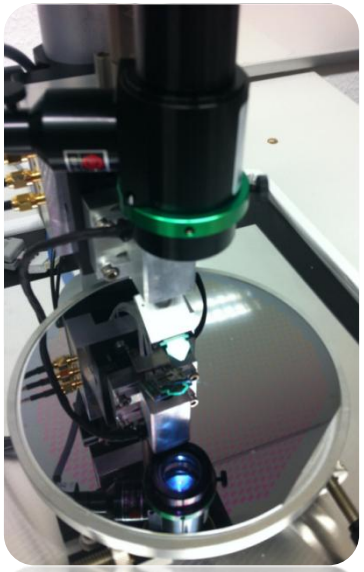

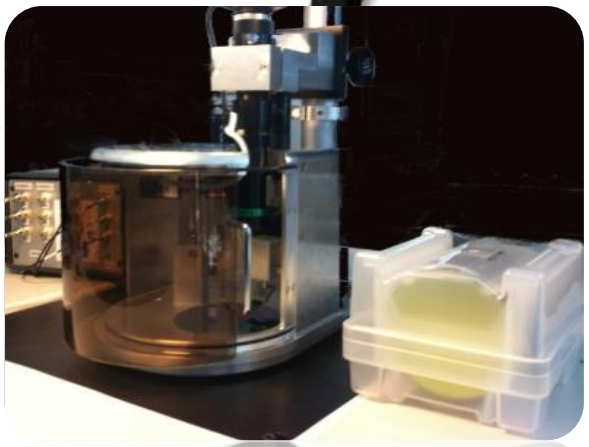

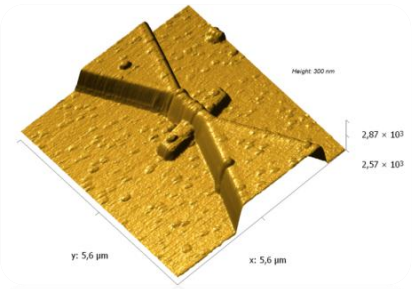

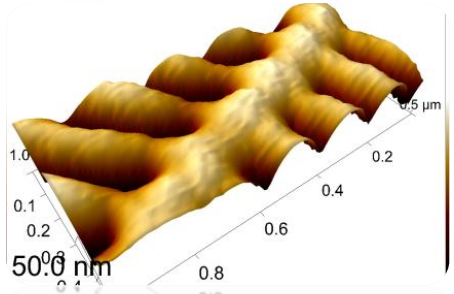

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Cleanroom Class 1000: 1300 m²

Cleanroom Class 100: 700 m²

Research Know-How 40 Departments

3 People focusing on IAQ-Sense

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Air pollution is present in any confined environment (buildings, vehicles) from outdoor and indoor sources and accumulating

Impact: health, comfort, quality of work

Are people aware of it? No, the pollution is mainly hidden.

Do control equipments exist?
No, there is no powerful and affordable sensing device on the market for real time monitoring of VOCs (*Volatile Organic Compounds*).

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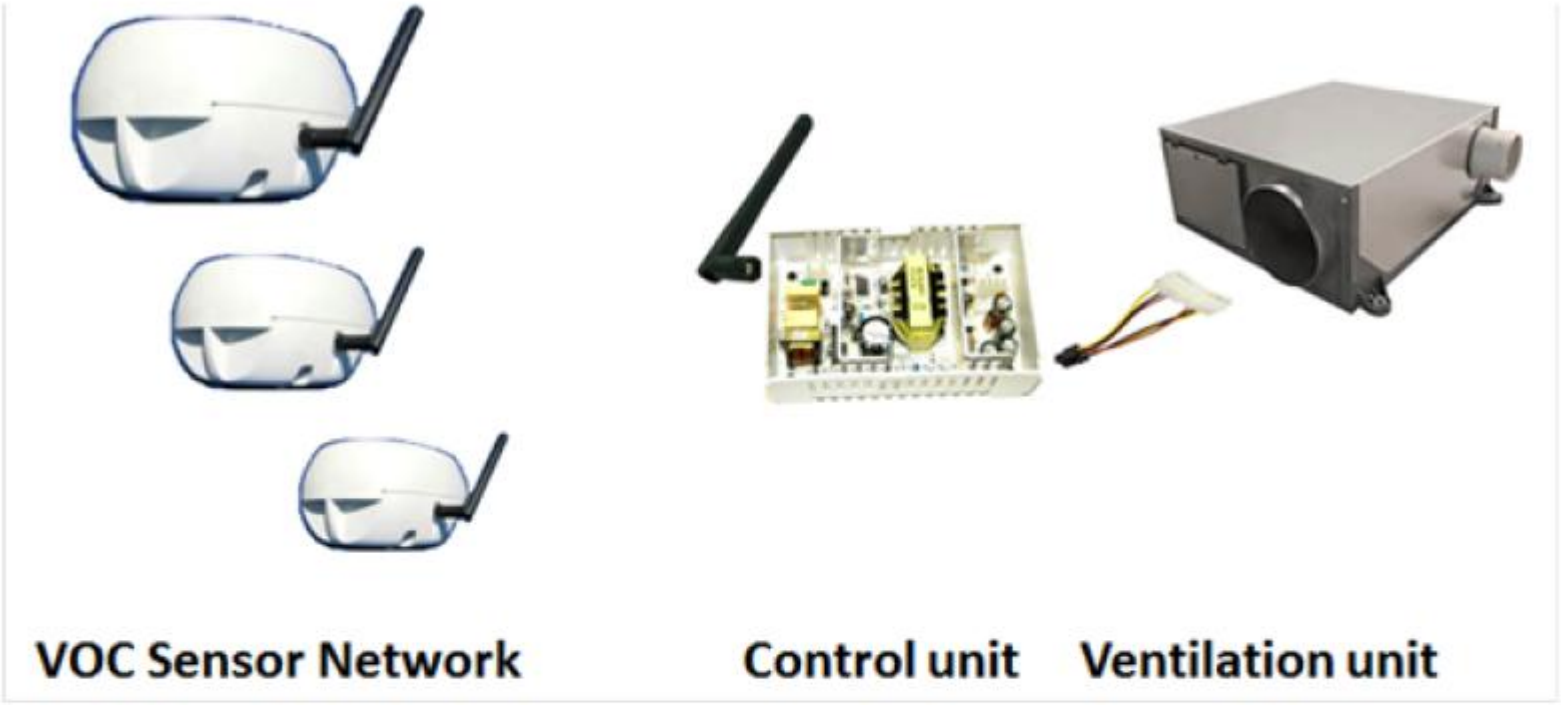

Local and distant smart data and control

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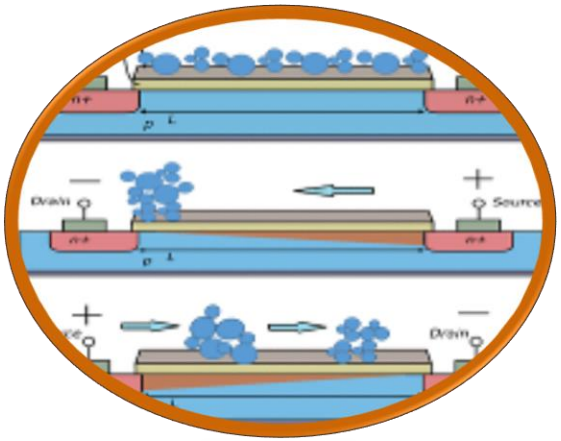
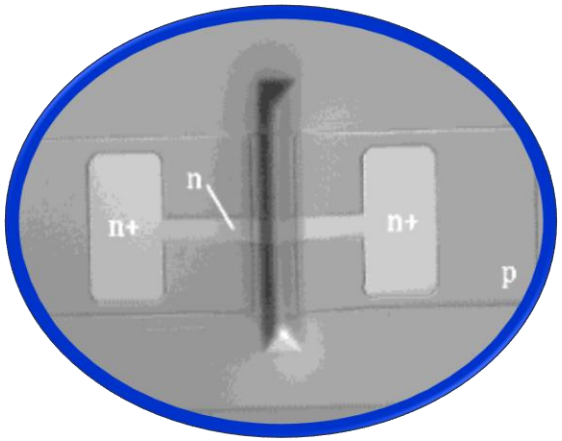
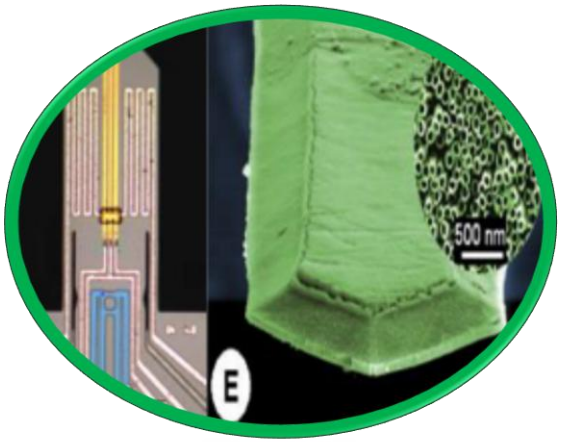
Three Groundbreaking Sensor Concepts of IAQSense: three different operation principles



Surface mobility of absorbed gas ions



Detection of Volatile Organic Compounds (VOCs) at low concentration in gaseous streams by ionic liquids



Functionalization with Nano-Tubes with high chemical affinity (selectivity)

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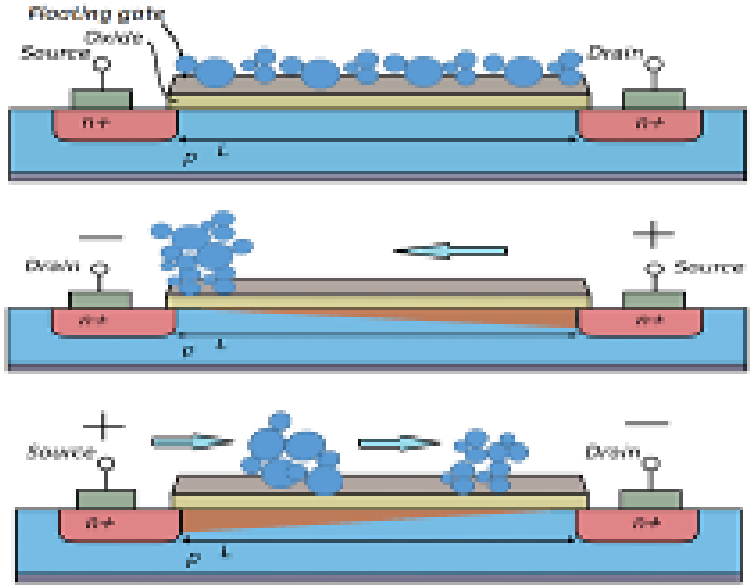
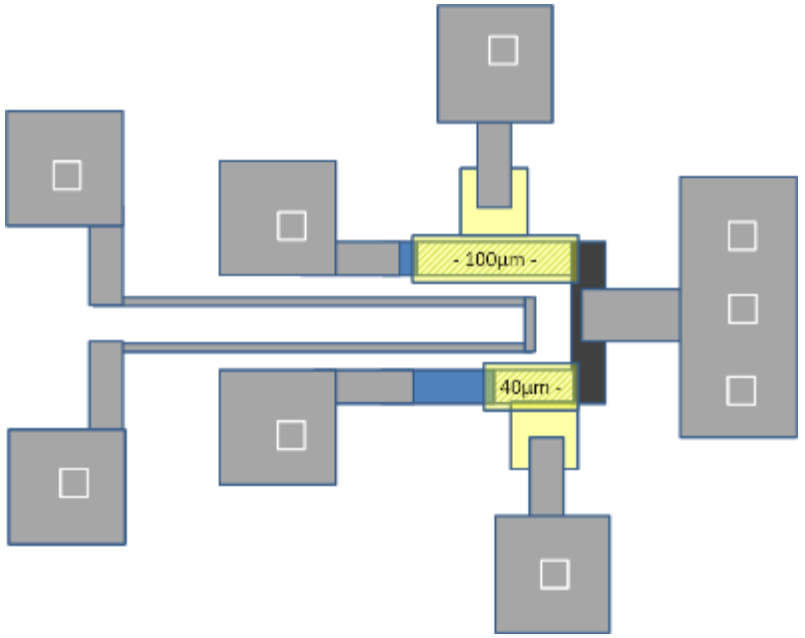
T2.1.1 Technology-Type 1





- Multigas sensing of Ions (Ion Mobility Spectrometer)
- Long-term ppb detection of key air components
- Functionalized layer collecting bio-pollutants

Source: Nanotechnology based gas multispectral sensing system for enviromental control and protection; Part B IAQSense

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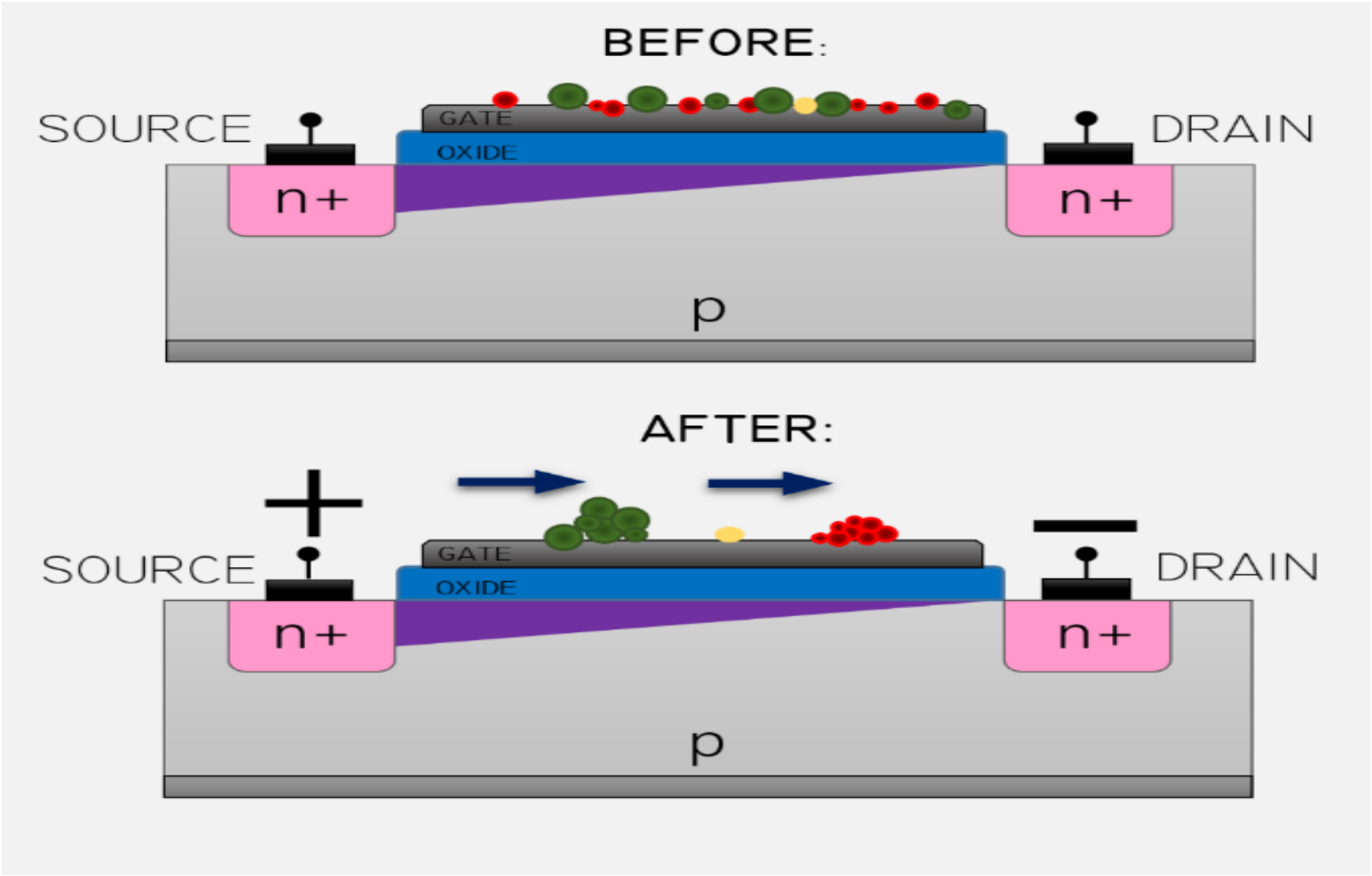
Principle of operation



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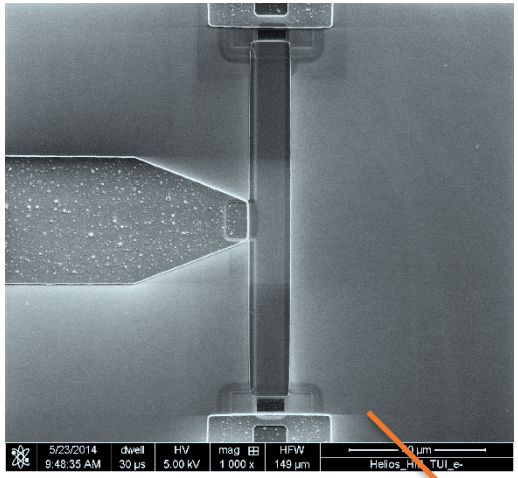
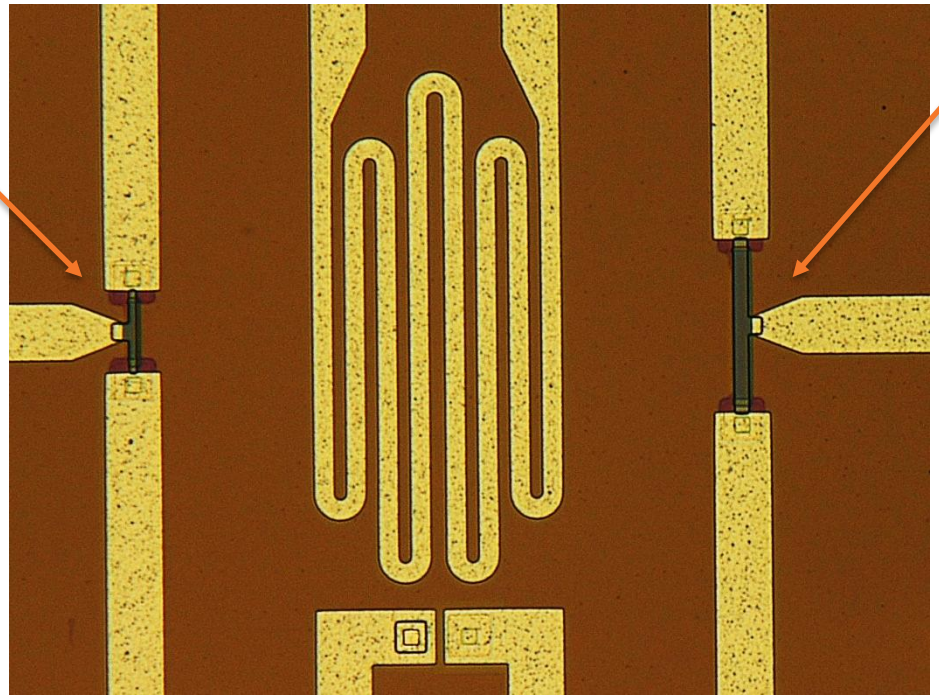
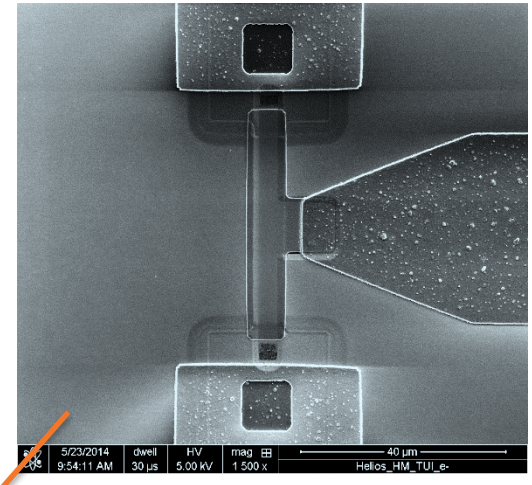
Realization: CMOS & MEMS mixed technology







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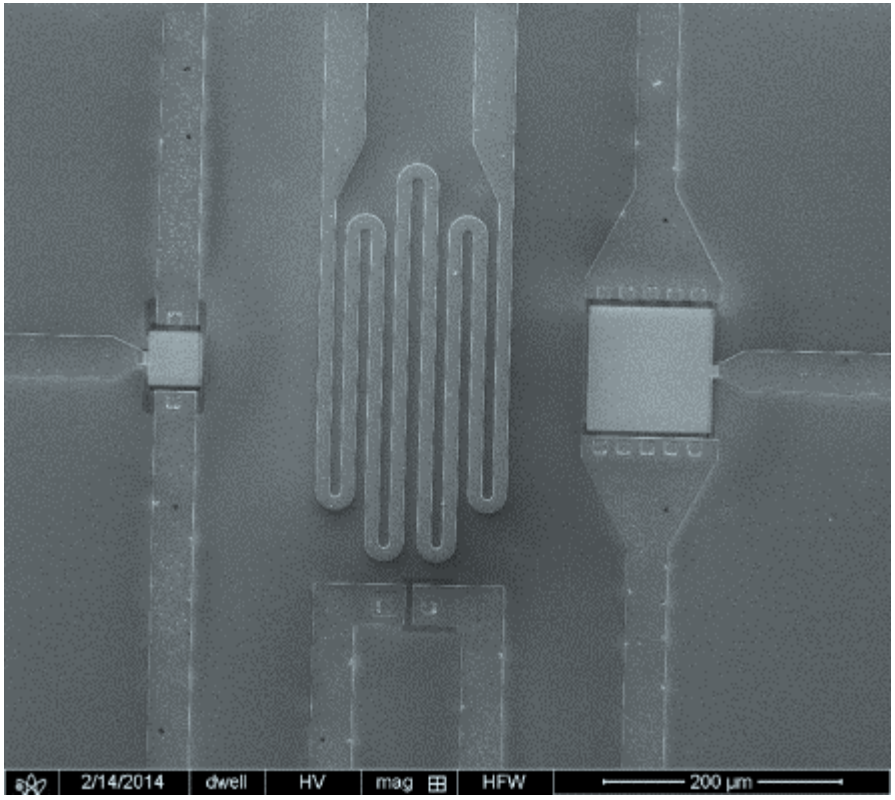

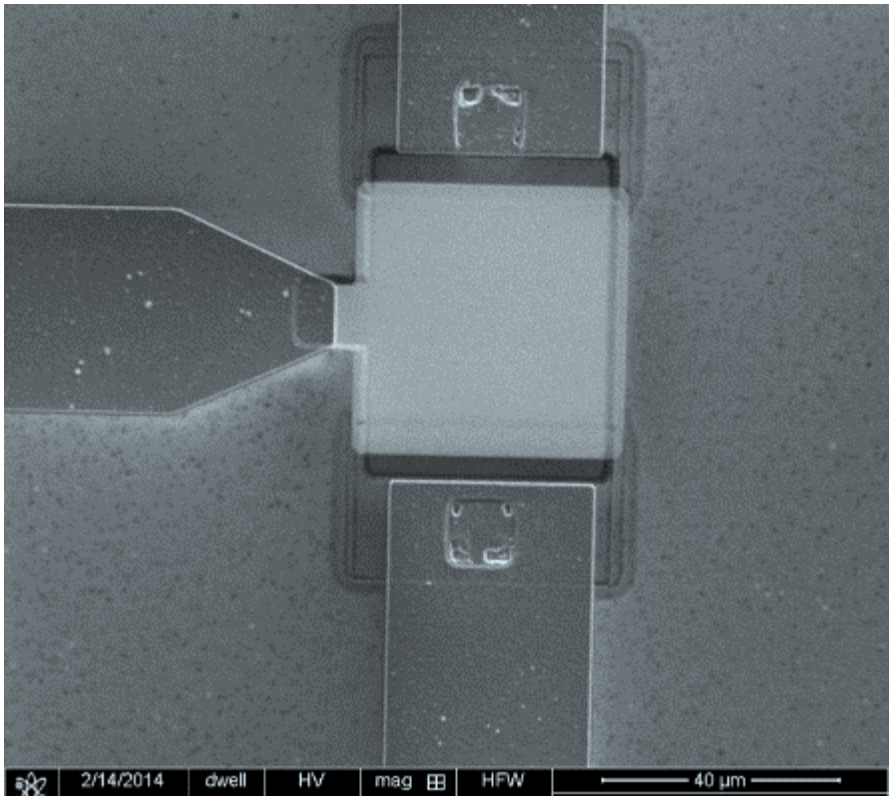

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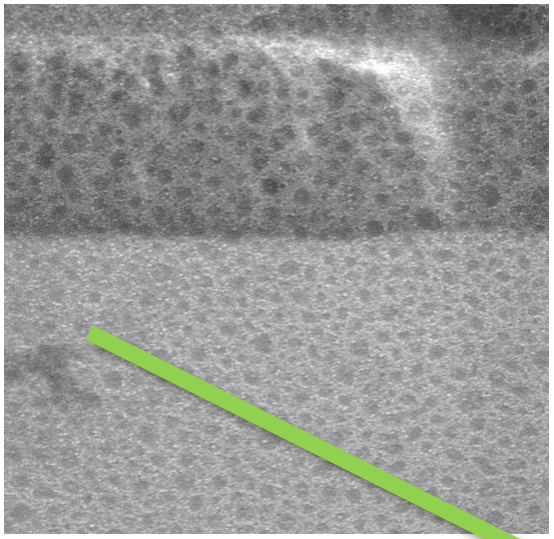
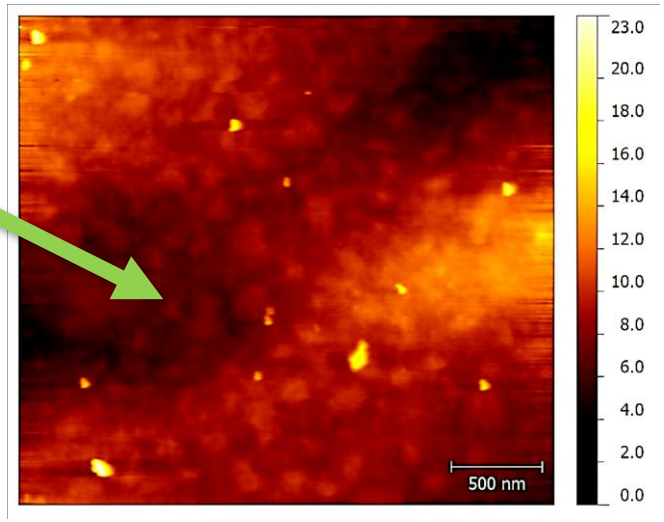
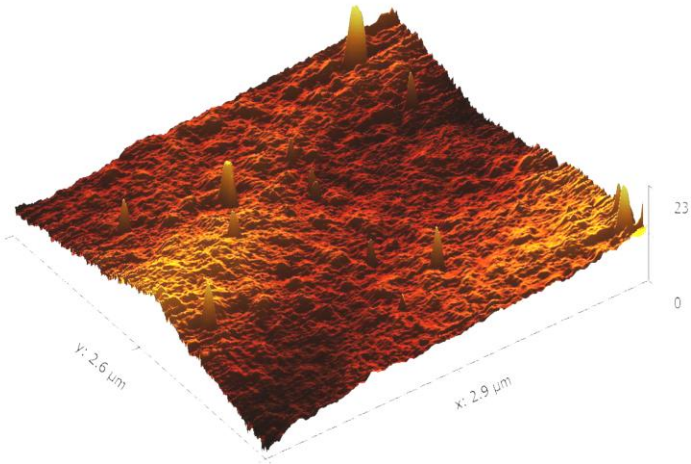
Developing of SnO Gate technology



Challenge:

- high porosity





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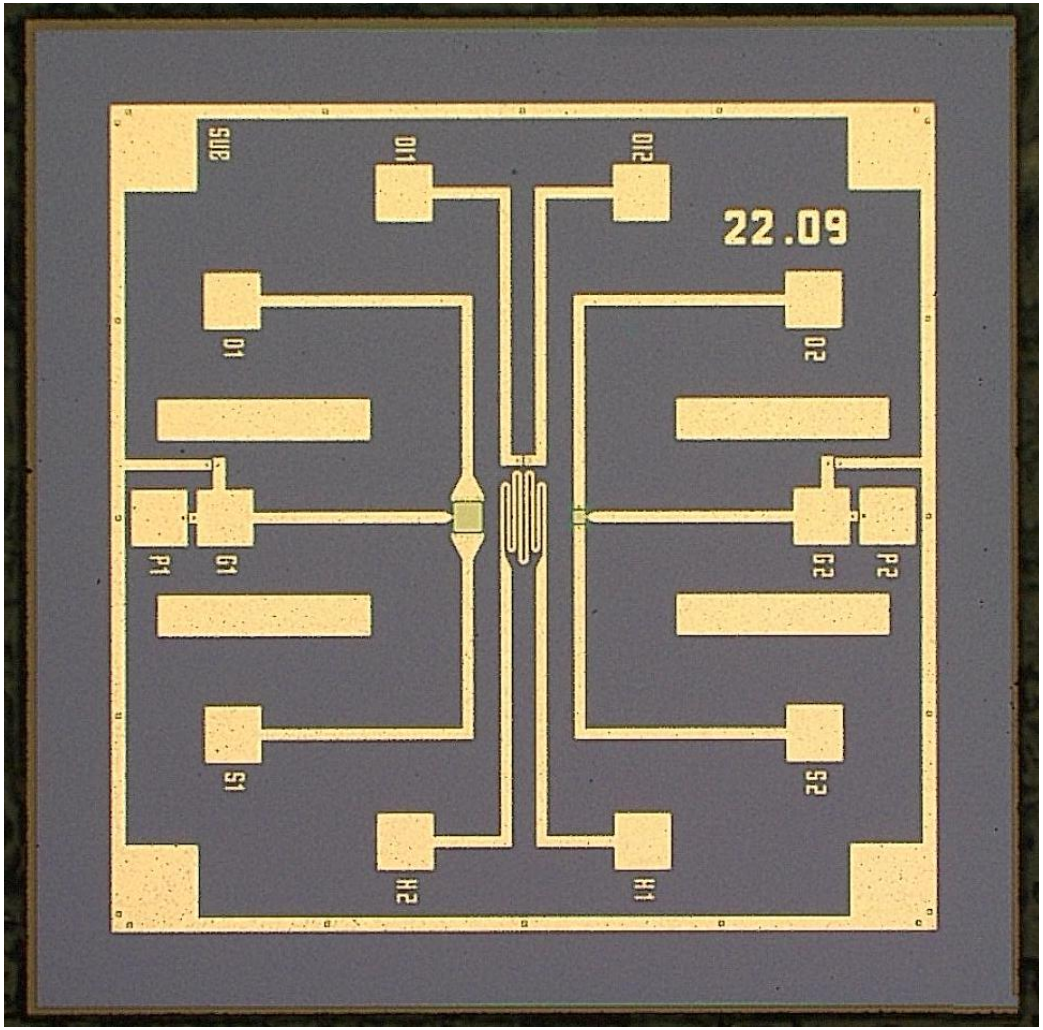
Realization: CMOS & MEMS mixed technology



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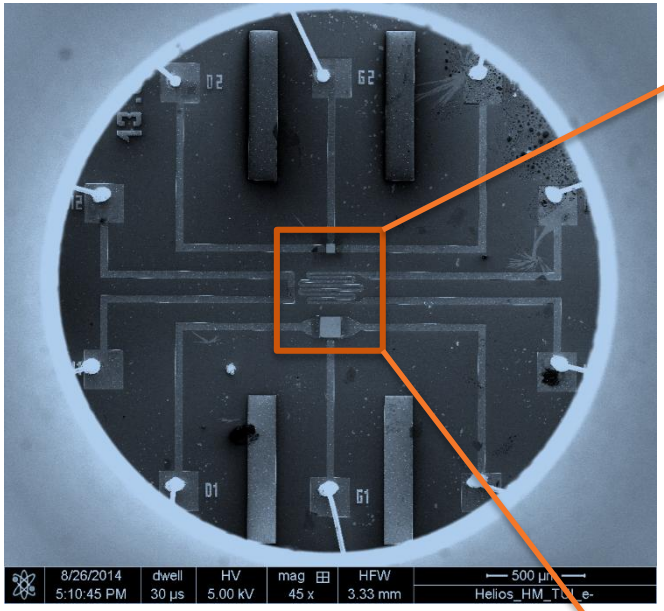
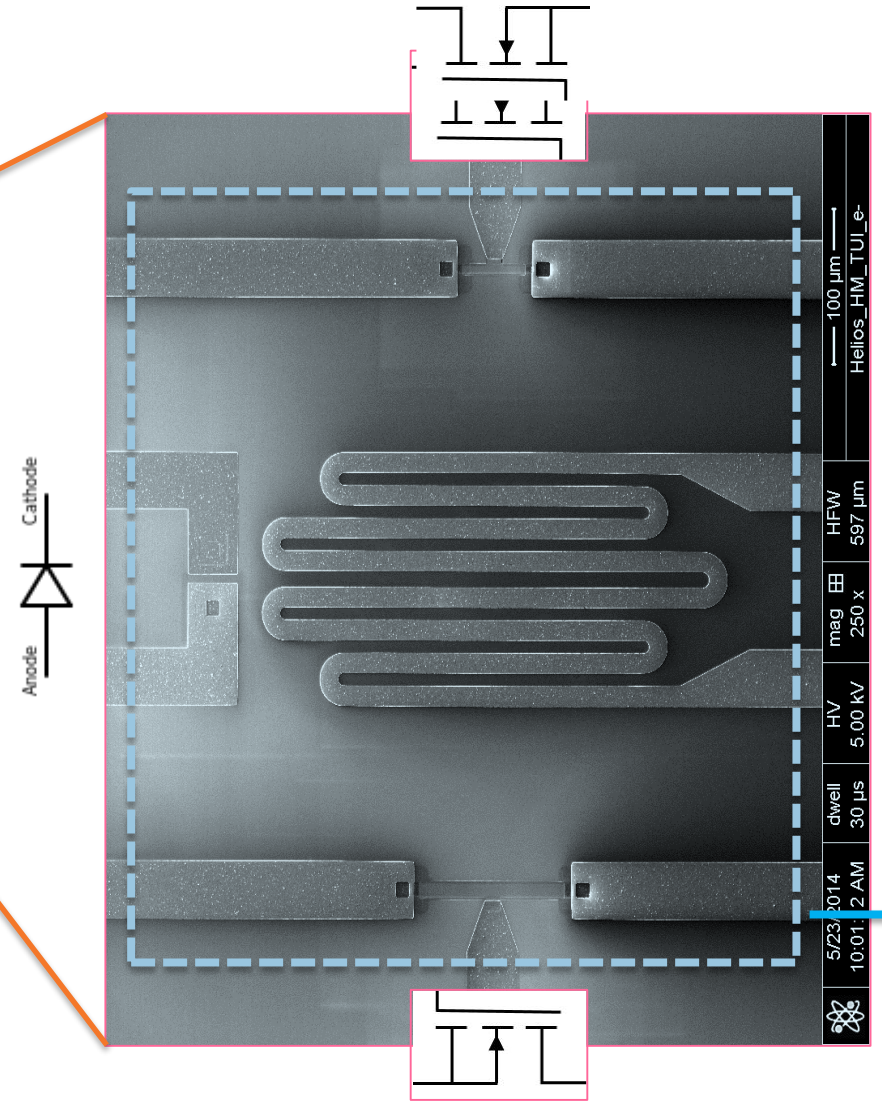
Realization: CMOS & MEMS mixed technology





Membrane region

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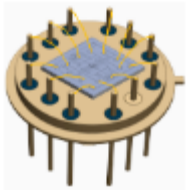
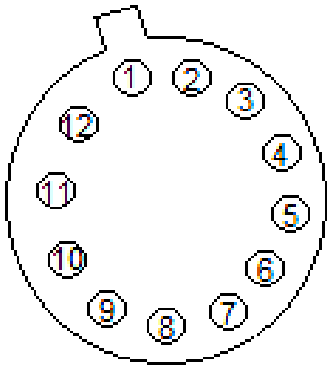
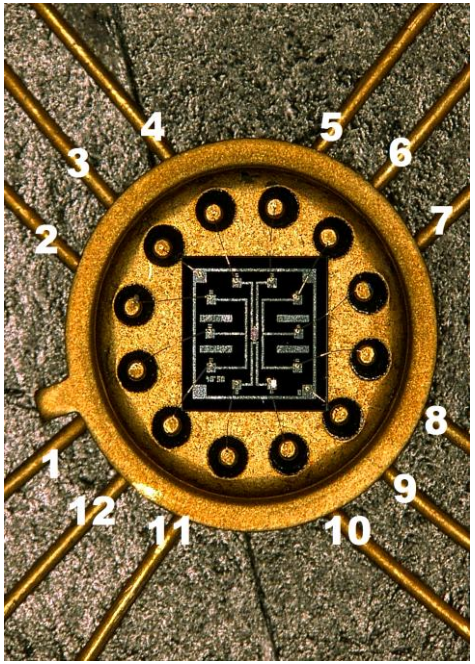
Realization: CMOS & MEMS mixed technology



PIN	DESCRIPTION	SIMPLIFIED OUTLINE	REALIZATION
1	G2 – T2 gate		
2	S2 – T2 source		
3	SUB- substrate connection		
4	H1 - heater contacts		
5	H2- heater contacts		
6	S1 – T1 source		
7	G1 – T1 gate		
8	D1 – T1 drain		
9	SUB- substrate connection		
10	DI1- temperature measurement diode-anode		
11	DI2- temperature measurement diode-cathode		
12	D2 – T2 drain		

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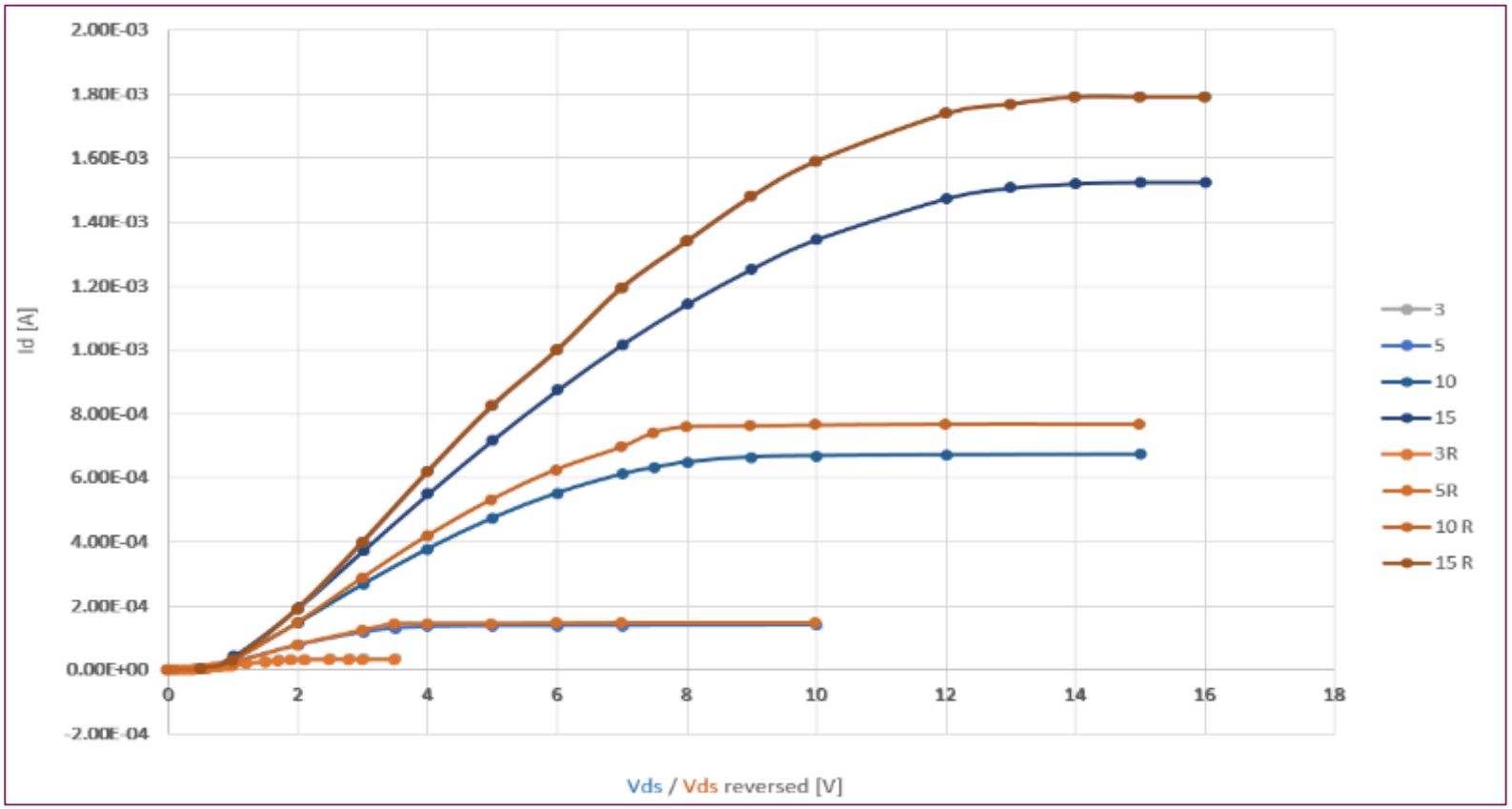

Comparison between output characteristics of transistor dependent on how S/D leads are connected, showing transistors symmetry. Orange- source lead connected as drain, Blue- source connected as a source.

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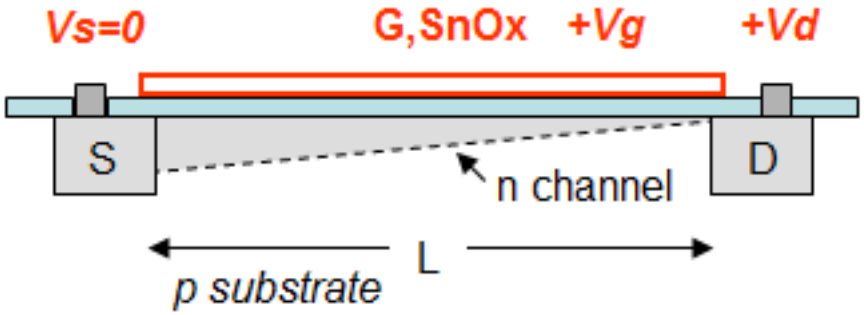
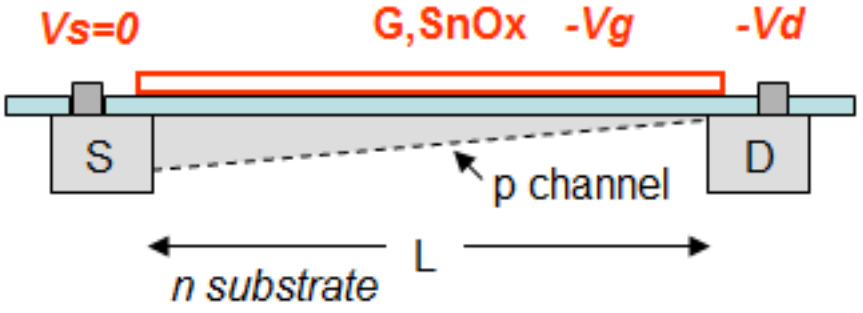
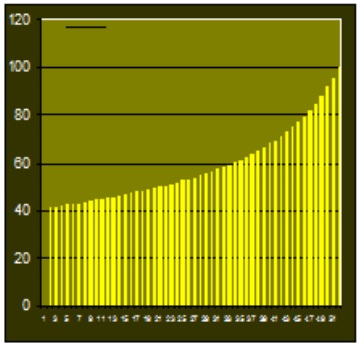
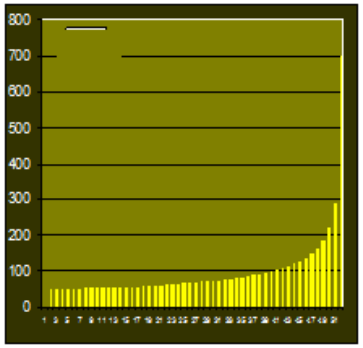
Realization: CMOS & MEMS mixed technology





a)





b)

Distribution of the resistivity of the channel along the length L of the channel (left edge – source, right edge – drain). a – non-saturated (triode) mode of operation, b- saturation)

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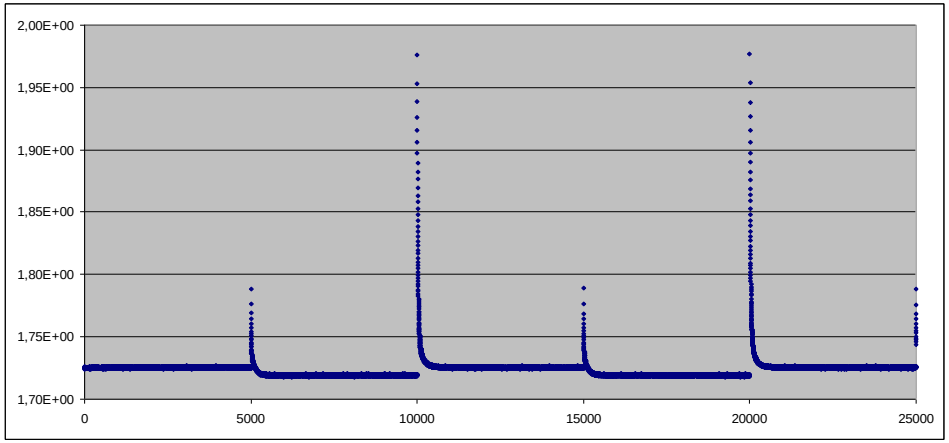
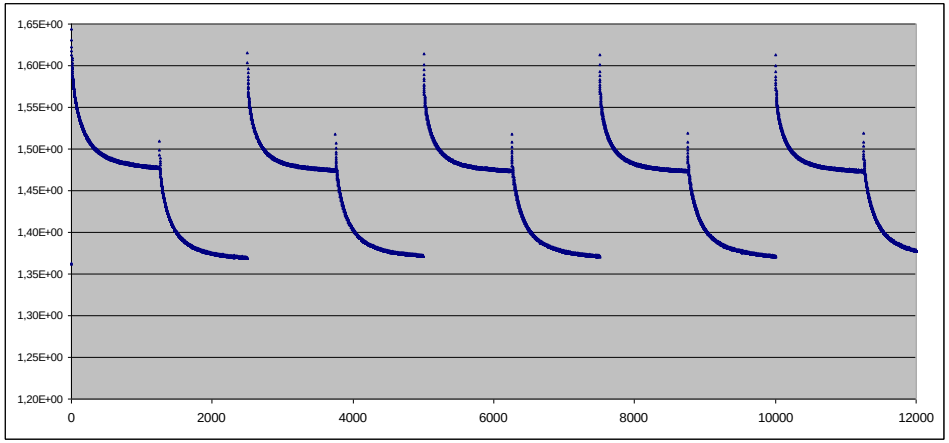
Response to ammonia



Response to room air , F =1Hz., Tdur = 500ms . Type D response with asymmetrical initial peaks (expected are symmetrical peaks).



Response to ammonia , F =40Hz., Tdur = 12,5ms .

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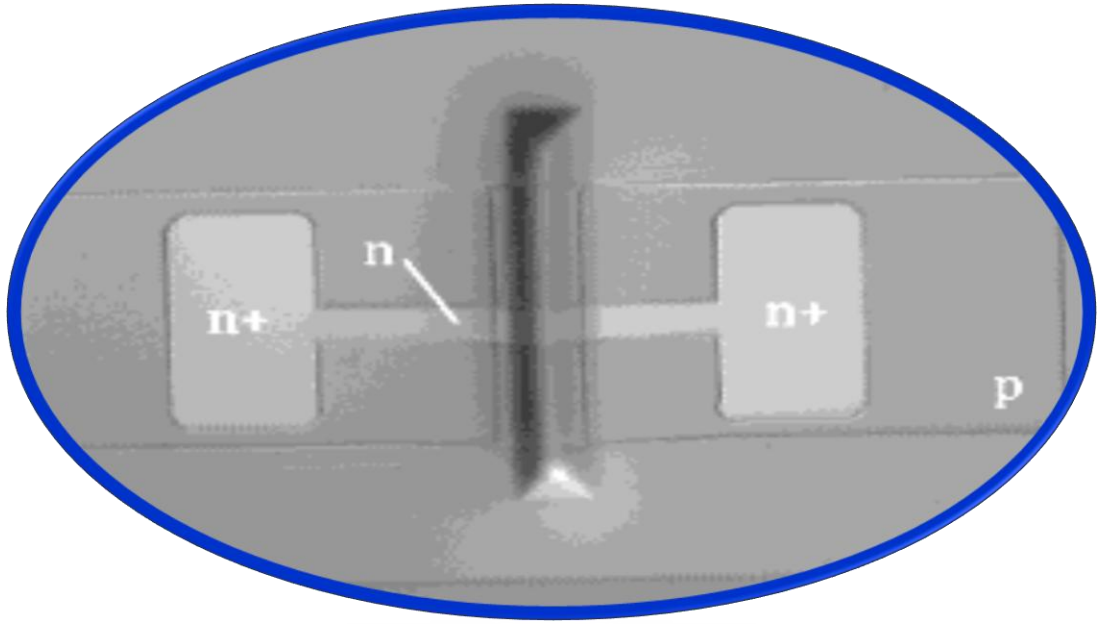
Detection of Volatile Organic Compounds (VOCs) at low concentration in gaseous streams by ionic liquids



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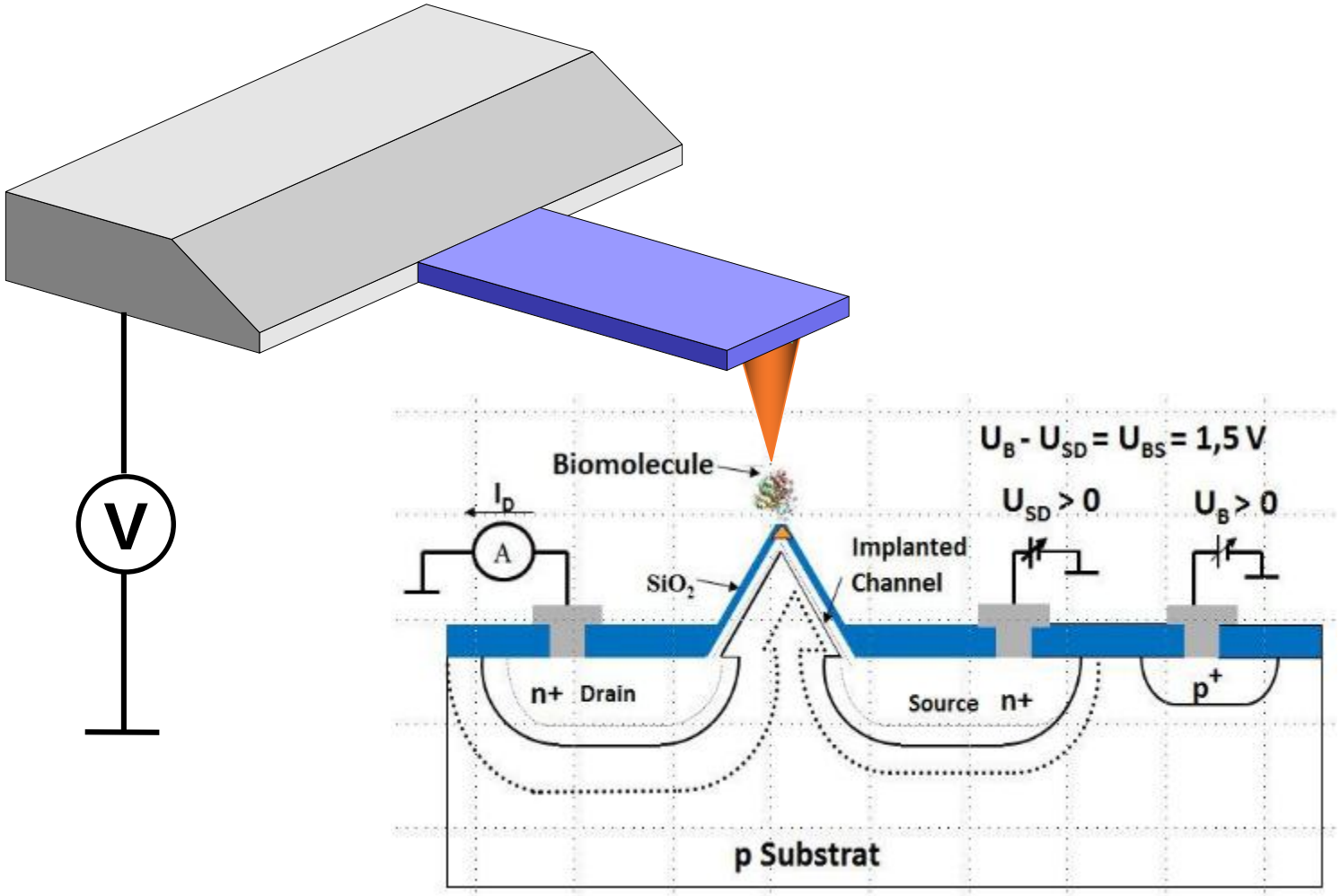
Measurement setup



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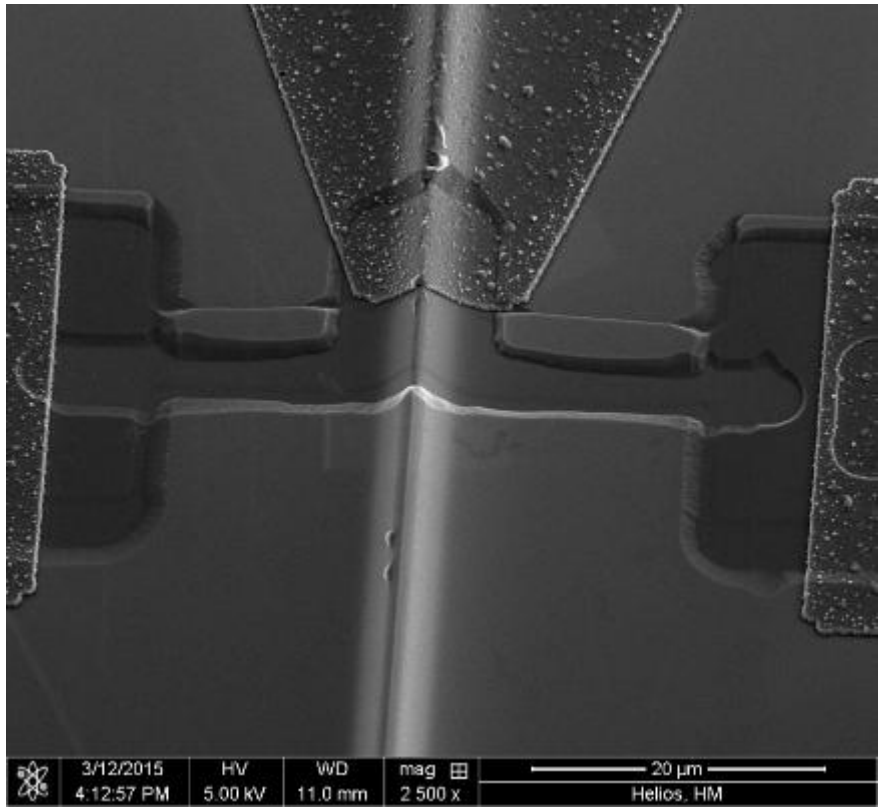
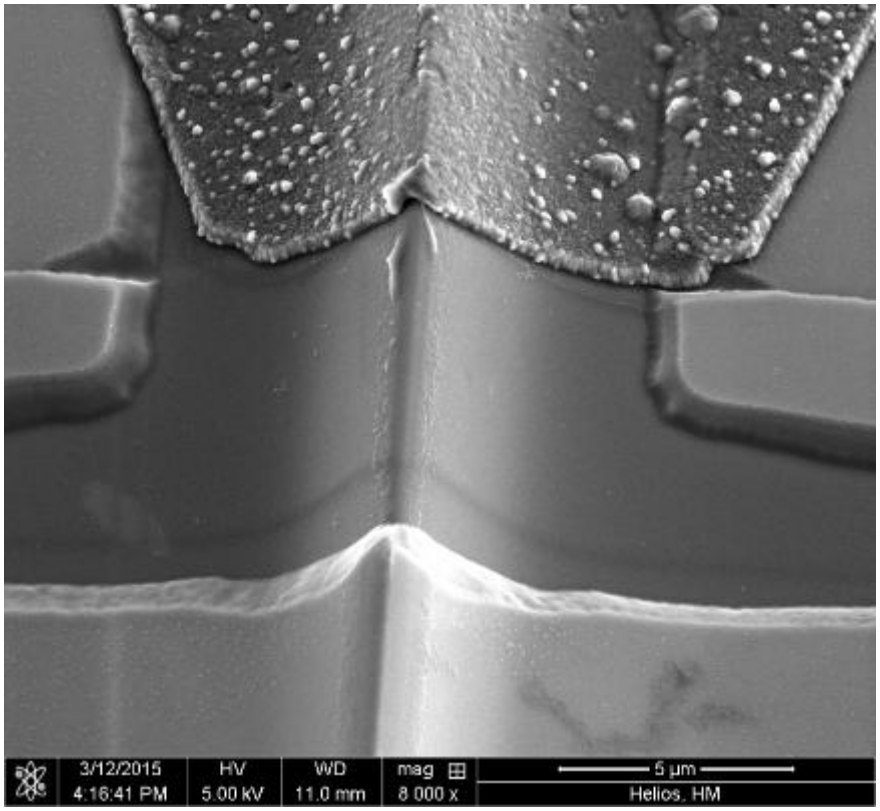
SEM images of manufactured Tip-Transistors





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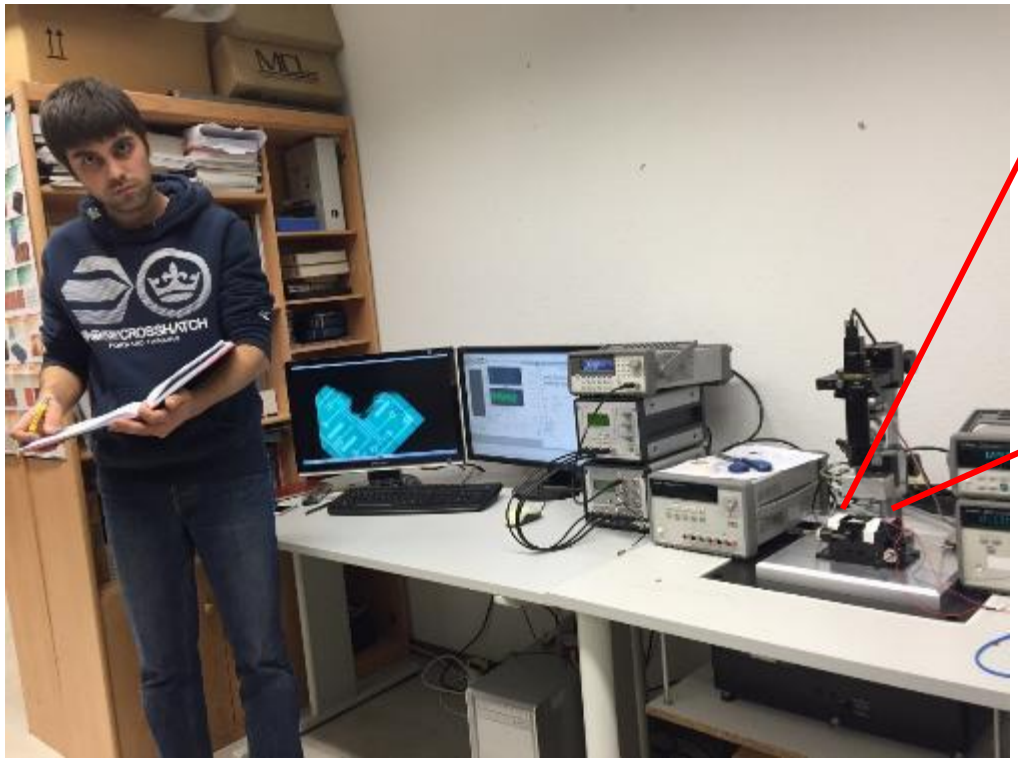
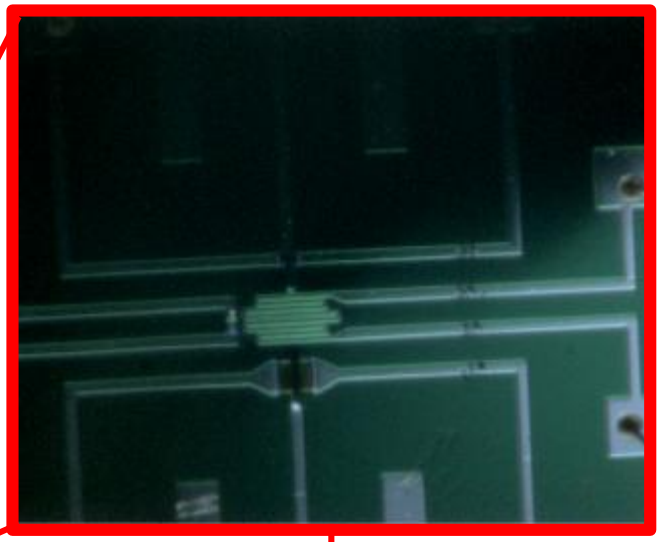
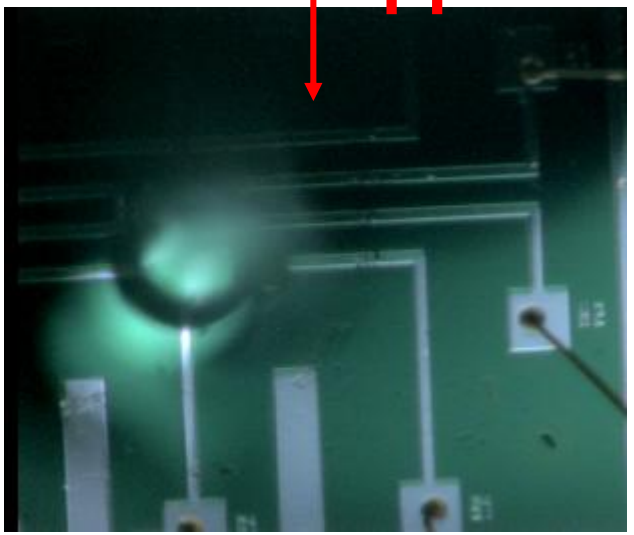
Measurement setup





Approach



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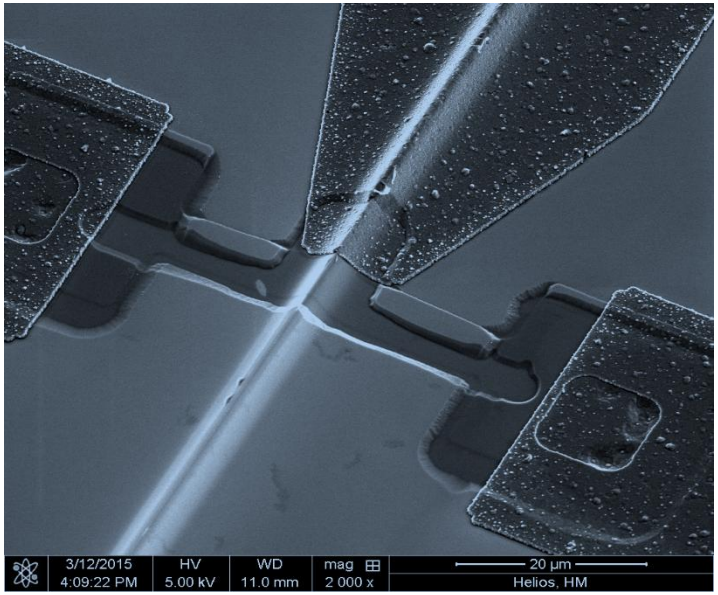
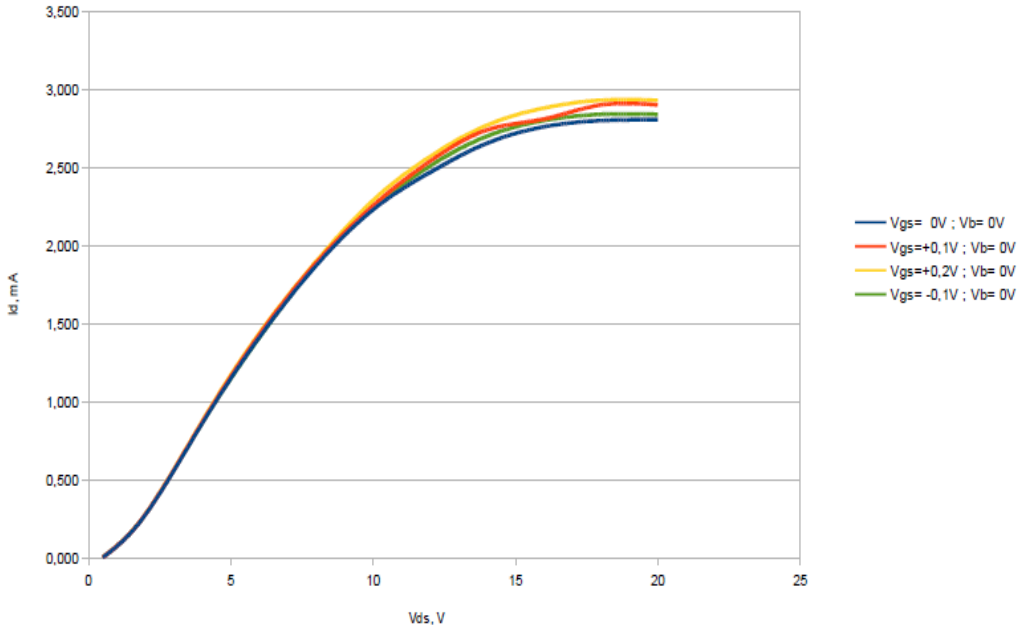
Measurement setup





The figure was recorded with external gate electrode in contact.

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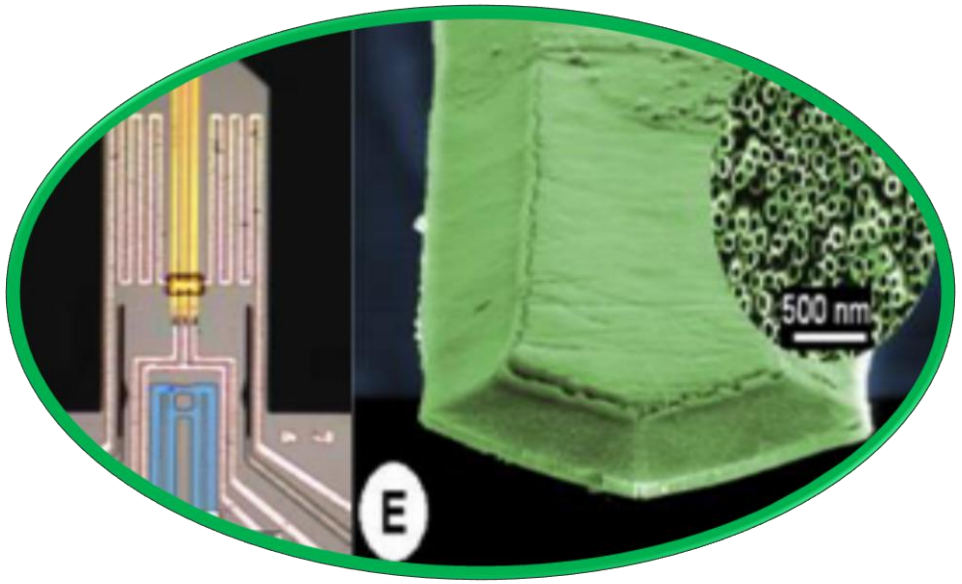
Functionalization with Nano-Tubes with high chemical affinity (selectivity)



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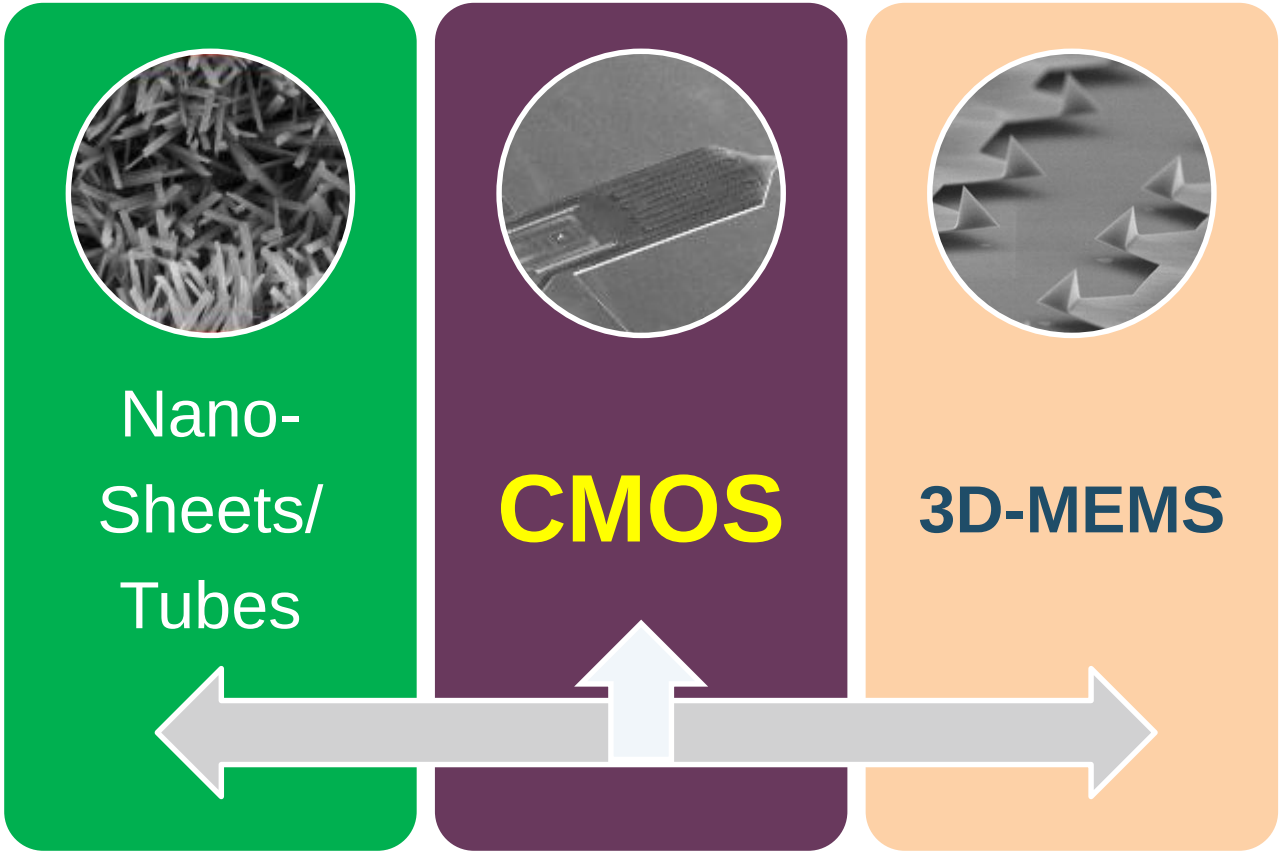
Challenge: Integration Issues



Has never been done before!

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RESONANCE BASED MICROMECHANICAL CANTILEVER FOR GAS SENSING

The principle used in this type of sensors is to literally catch gas molecules and to weigh them by measuring the shift in resonance frequency.

The chemical sensor consists of two key components:

- **a sensitive layer and the transducer (the cantilever). The sensing layer is the critical component and responsible for selectively capturing the CO_2 gas molecules and the cantilever which acts as the transducer converts the mass into a dynamic shift in the resonant frequency.**
- **The Molecular Weight of CO_2 is 44 g/mol. The mass change is detected by measuring resonance frequency shifts while actuating the cantilever (dynamic mode).**

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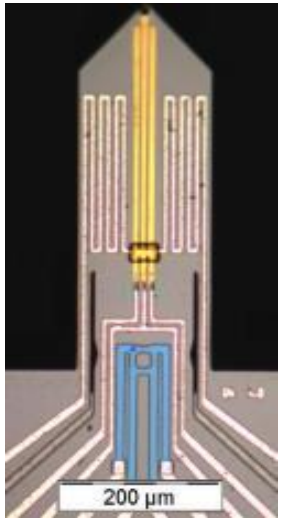
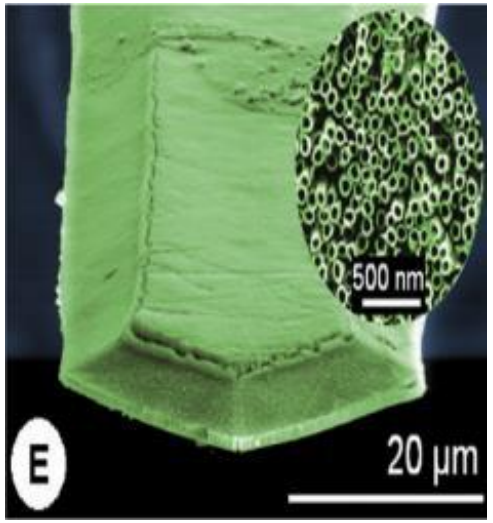
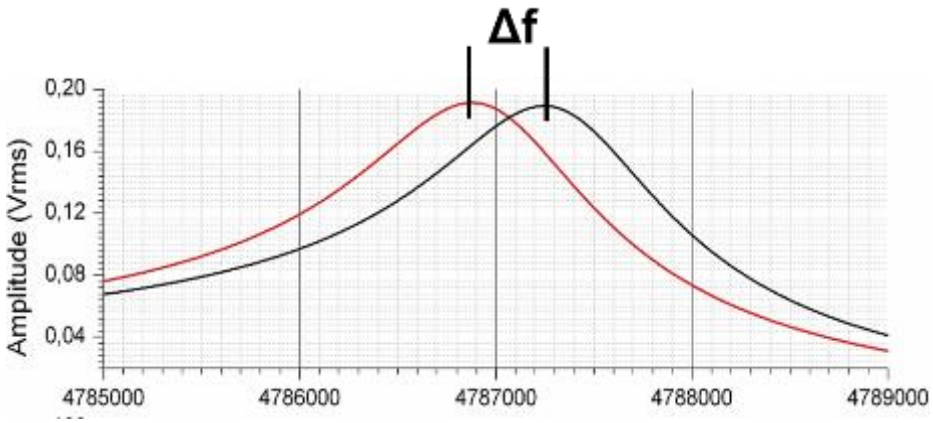
Technology-Type 3 - mass-sensing -







$$\Delta f = -\frac{f_r}{2m_0}\Delta m$$

$$f_r = \frac{1}{2\pi}\left(\frac{1.875}{l}\right)^2\sqrt{\frac{EI}{\rho A}},$$

- Specific sensing of molecules by mass
- Functionalized cantilever detecting ppb/ppt traces of hazards

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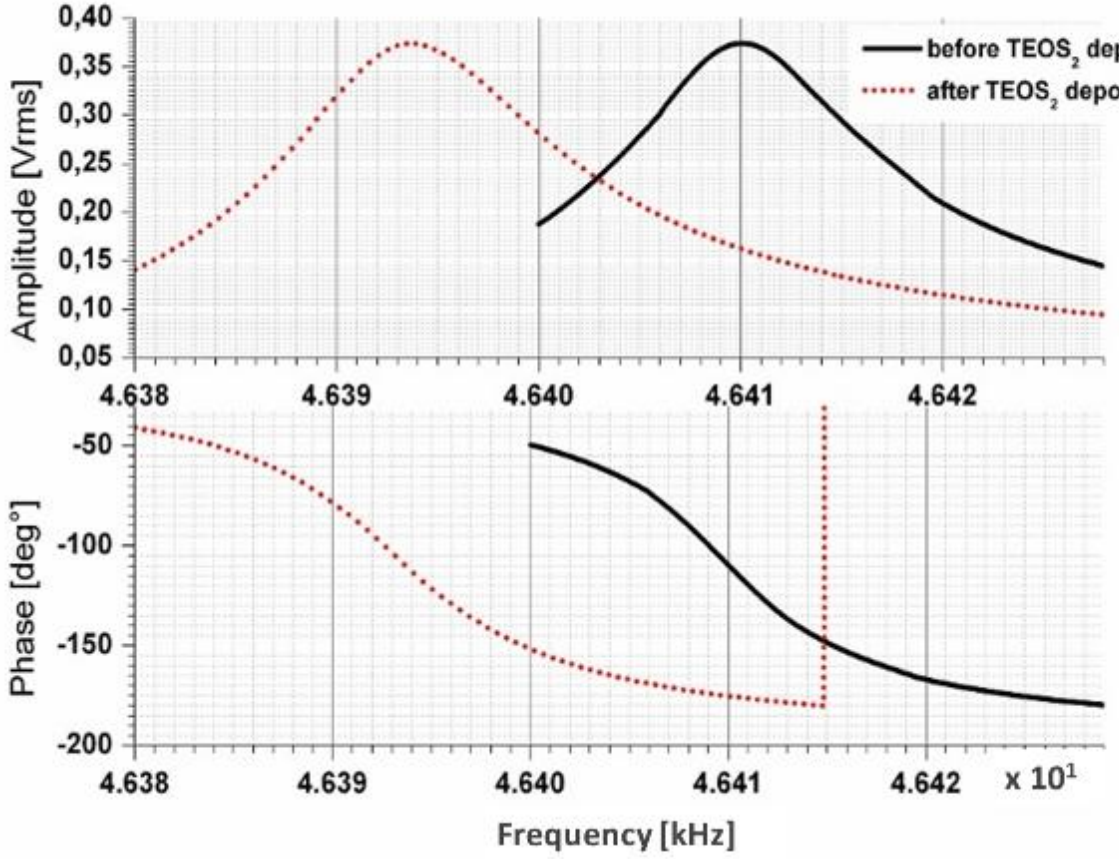
Concept of read-out electronics (piezoresistive cantilevers)



- **The developed electronic and cantilever (Mikrosystemi & nano analytik) have to show f_{Res} change with a change of the mass**
- **Therefore a test setup has been realized for depositing mass (TEOS) on the Cantilever and showing the f_{Res} before and after**

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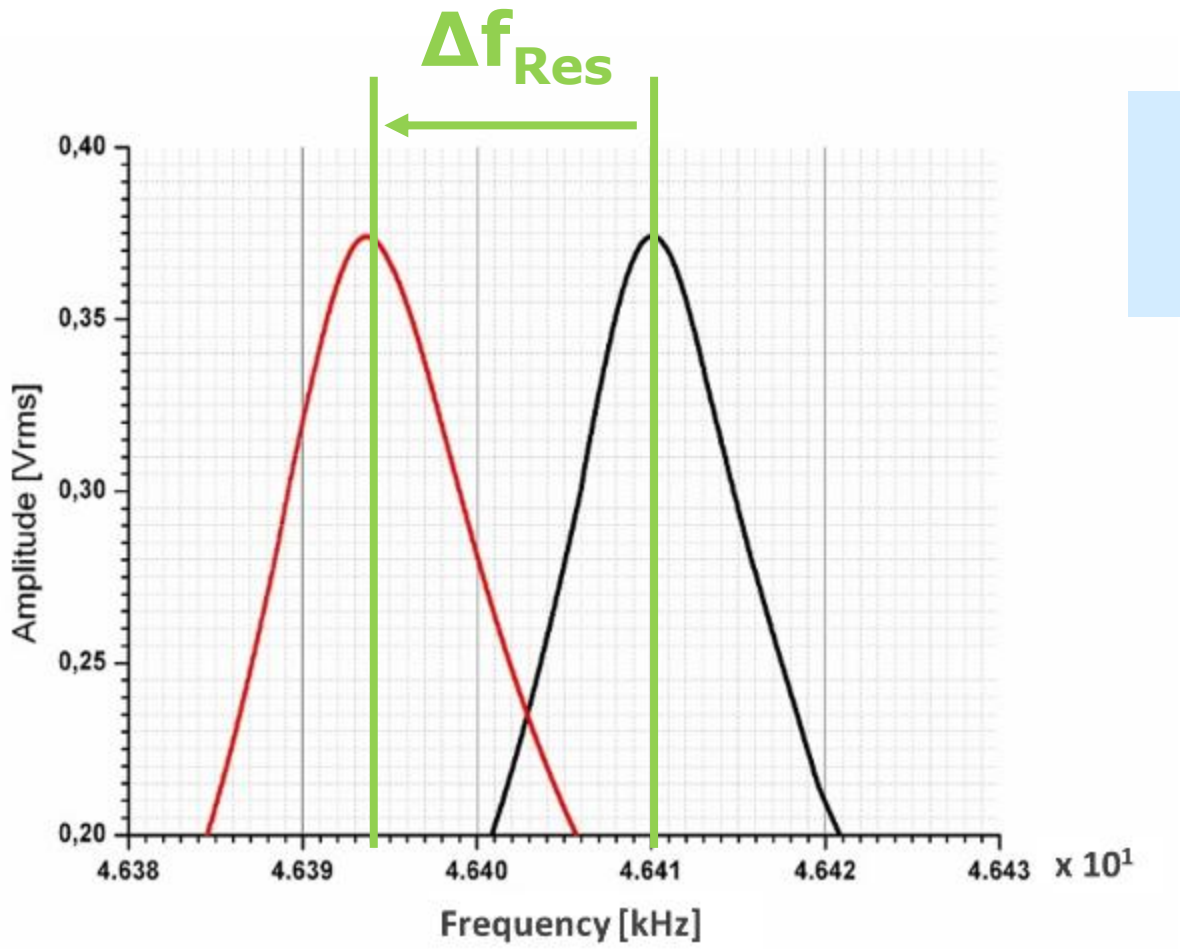
Concept of read-out electronics (piezoresistive cantilevers)



$$\Delta f = -\frac{f_r}{2m_0}\Delta m$$

Δm ≈ 3,4 x10^{-17}g

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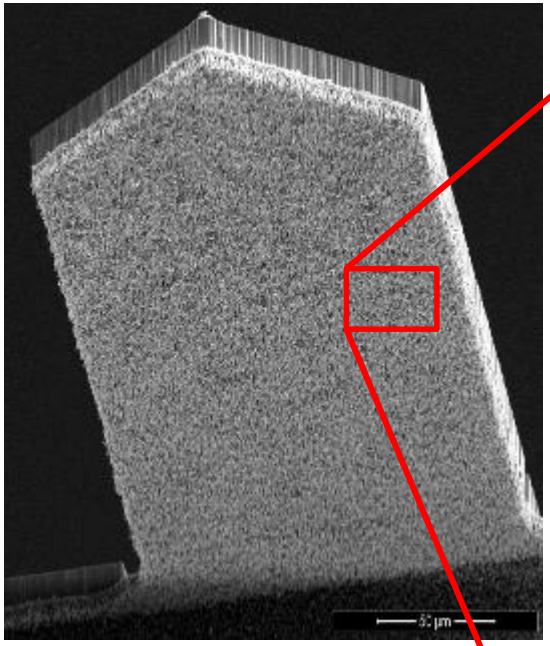
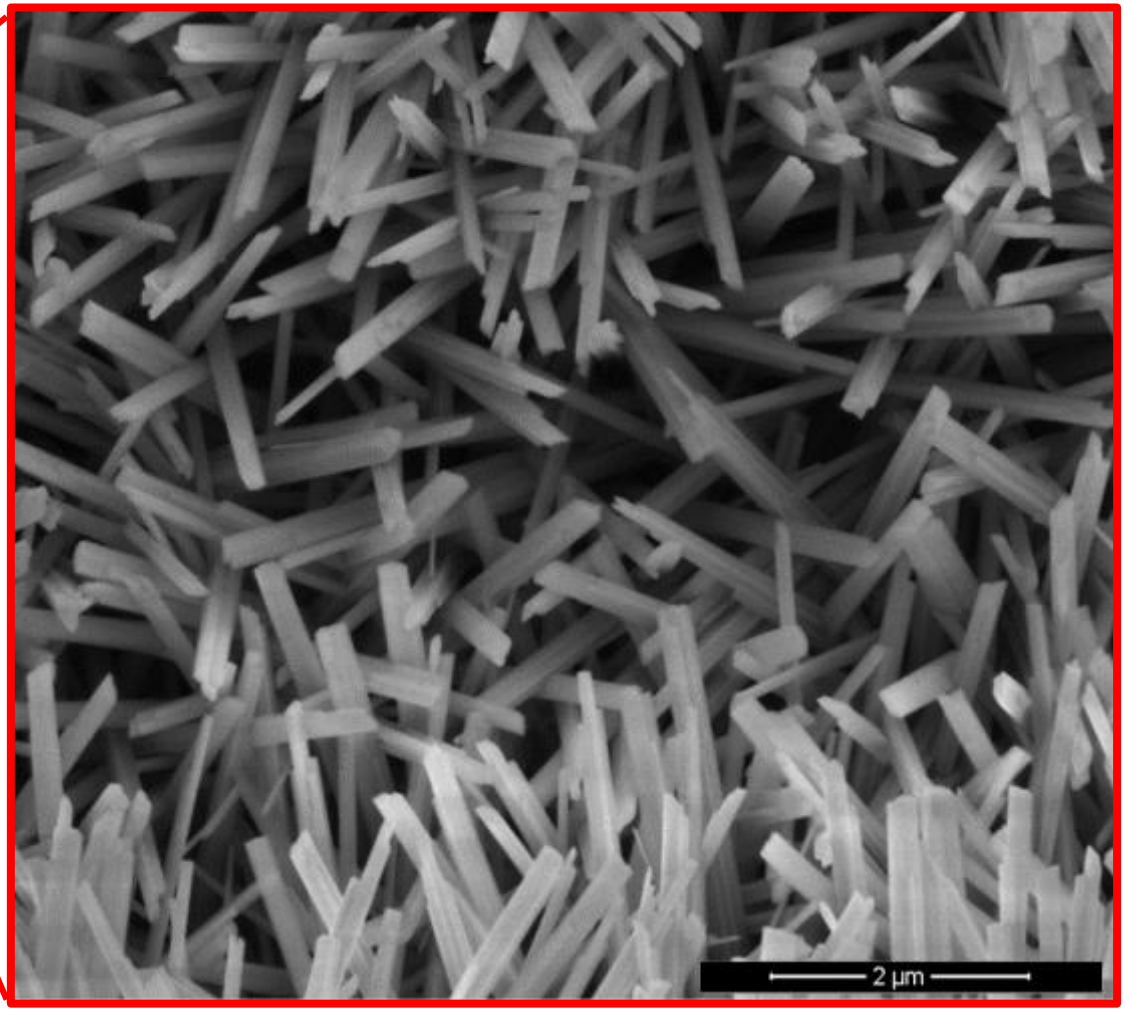
Process scaling to wafer level

(membranes for piezoresistive cantilevers -> etching)





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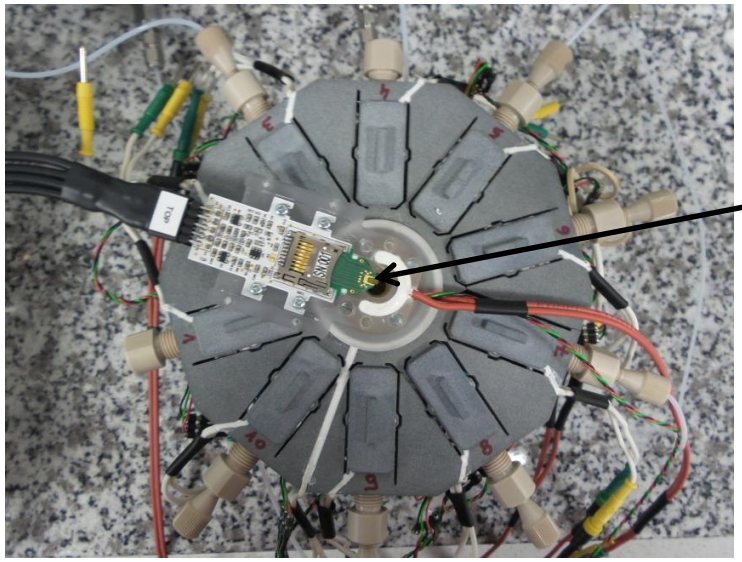
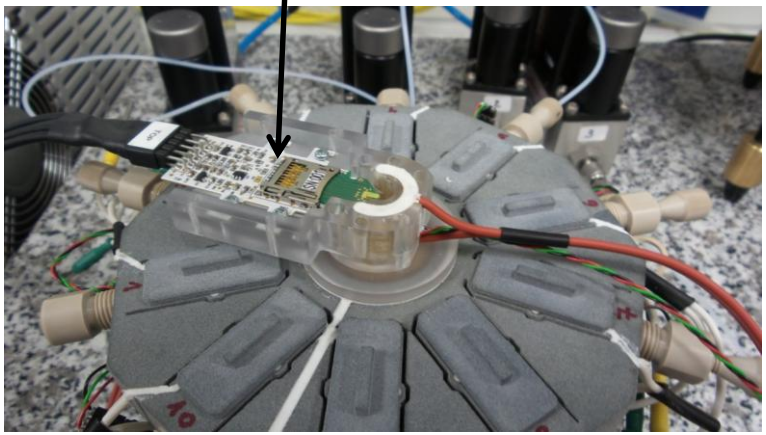
Development of the detection device at ISL

Principle of the device



na - Piezoresistive cantilever with PSB card



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Detection results

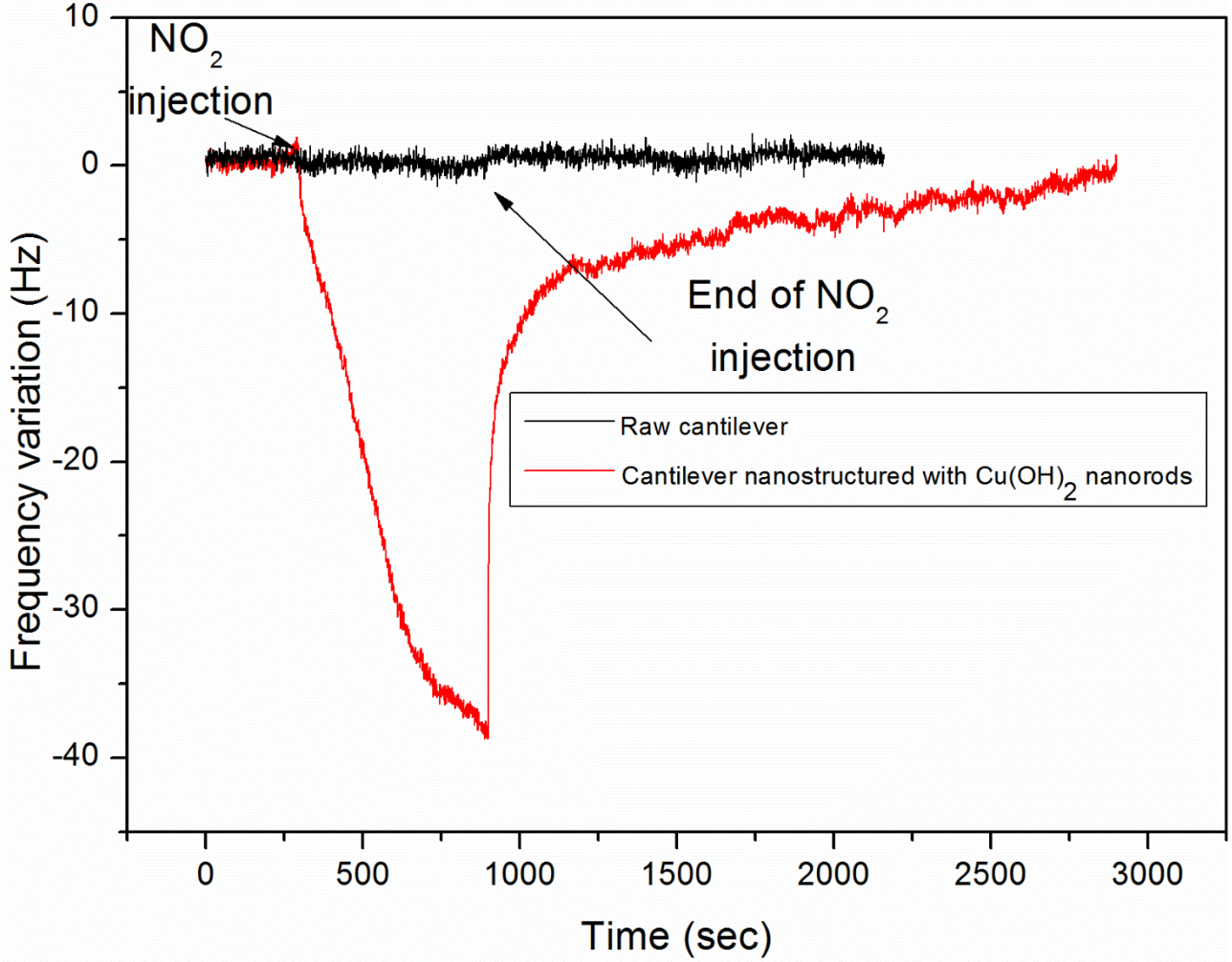
Detection of 20.0 ppm of NO_2

Baseline : Air flow of 125 mL/min
NO_2 flow 125 mL/min

Cantilever temperature : 55°C
NO_2 temperature : 40°C

Detection of NO_2 with nanorods

No detection of NO_2 with a raw cantilever



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Scientific context and objectives

Two major impacts have been identified:

- Respiratory illness
- Sick Business Syndrome (connected to work efficiency and absenteeism at work).

Most of the standards (example ISO 16000-xx or EN 717-1) are based on sampling and lab analysis.

European Lung Foundation - Respiratory illness cost in Europe 102 billion e/year (17.7 billion is related to Asthma)

WHO Europe (World Health Organisation) - European cost of Sick Business Syndrome 0.8 to 1.7 billion e/year.

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Suggested Needs for future research

- Sensor arrays based on different measurement principle (Cross sensitivity minimization is the key issue)
- Long term monitoring of liquid and non liquid media
- Particle detection and consequences for the organism
- Functionalization sensing systems
- Sensor integration

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Outlook

- Crosslinking of projects for developing synergies
- Crosslinking of existing know-how for a European strengthening
- Facilitating access to technology bases
- Referencing of measurement results
- Setting up realistic (measurable / affecting) standards

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Thank you for your attention.

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