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

COST Action TD1105

WGs and MC Meeting at ISTANBUL, 3-5 December 2014

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

Integrated Nanosensors for Indoor Air Quality Applications

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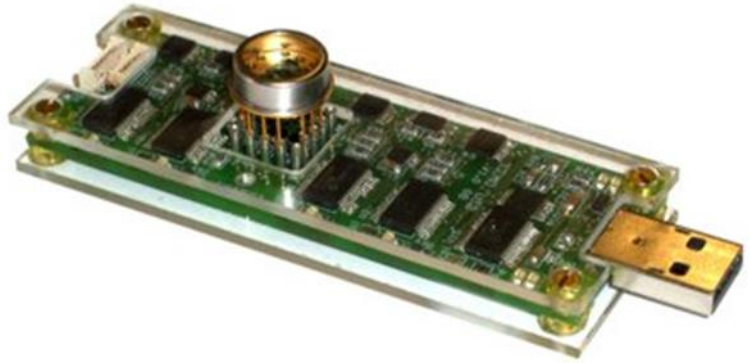
Acknowledge: J. Guilera, C. Fábrega, T. Andreu, F. Shao, F. Hernández-Ramírez (IREC) JD Prades (U. of Barcelona)

Scientific context and objectives in the Action

- **Background / Problem statement:**

Interest in detecting gases and determining their composition is huge and continuously increase over time (e.g. industrial emission control, household security and environmental monitoring).

BCC Research, Business Communications Company, Inc., estimates the global market for gas sensing devices reached 2.2 billion USD in 2014. Besides, market analyses show an annual growth rate of 6.7%, by reaching 3.5 billion by 2020. Therefore, it seems that the market for gas sensors is plenty of business opportunities.



Scientific context and objectives in the Action

- **Background / Problem statement:**

Since 1962 it has been known that metal-oxide materials interact with gaseous components from the surrounding ambient. Thus, development of gas sensing devices based on metal-oxides as SnO_2, ZnO, TiO_2, WO_3, Fe_2O_3 and In_2O_3 has been intensively investigated during last 50 years. In parallel, commercial gas sensors have been in the market for more than 3 decades.

The main advantage of this technology is the simplicity and low-cost of the device. However, classical metal-oxide sensors typically operate at an elevate temperature, which results in large power consumption. To put it bluntly, metal-oxide gas sensors are economic to purchase but not enough reliable.

Scientific context and objectives in the Action

- **Brief reminder of MoU objectives:**

Can nanostrustured metal oxide materials be one alternative for improving solid state gas sensors performance ? (increasing reliability and feasibility and keeping low cost)

One interesting option is to use NANOWIRES

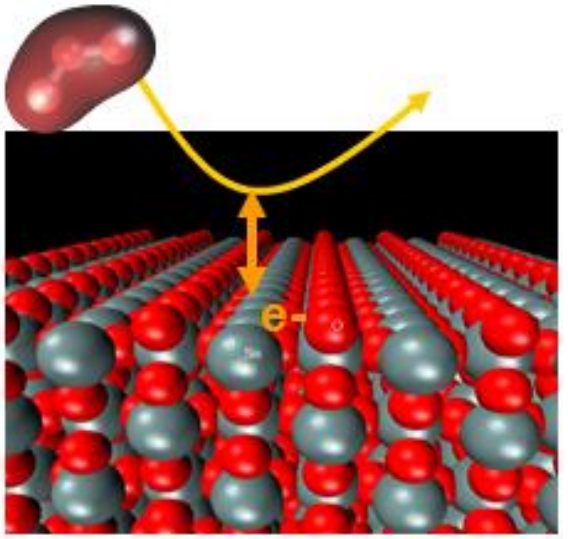
Why nanowires?

Surface-to-volume ratio increases So, surface phenomena dominate over the bulk

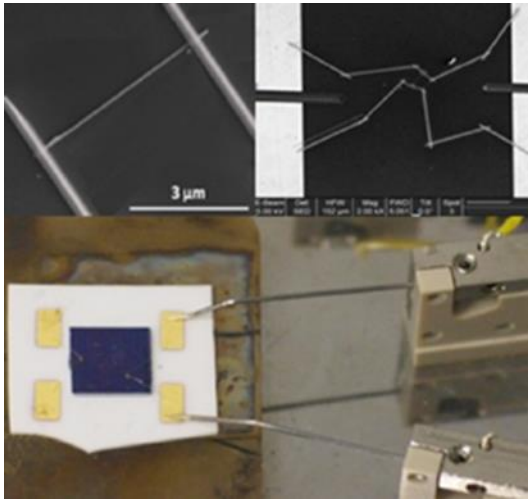
High stability derived from their high crystallinity

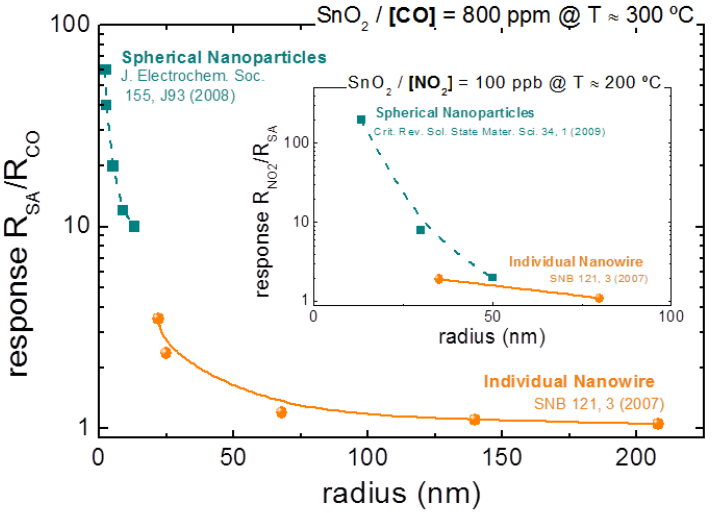
Grain boundary effects typical of standard film sensors are overcome

Very low thermal inertia

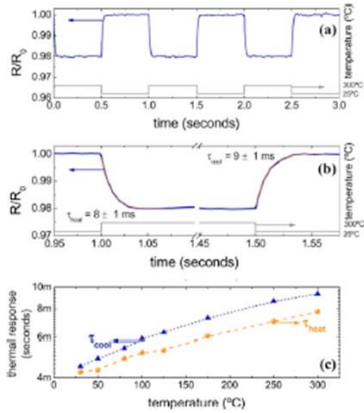


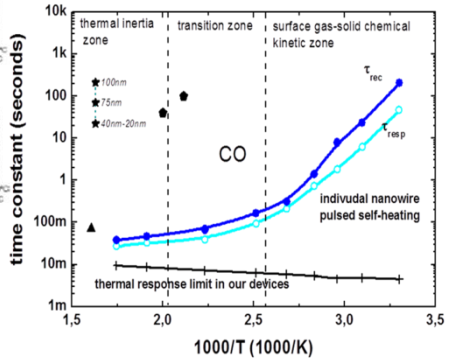
Current research activities





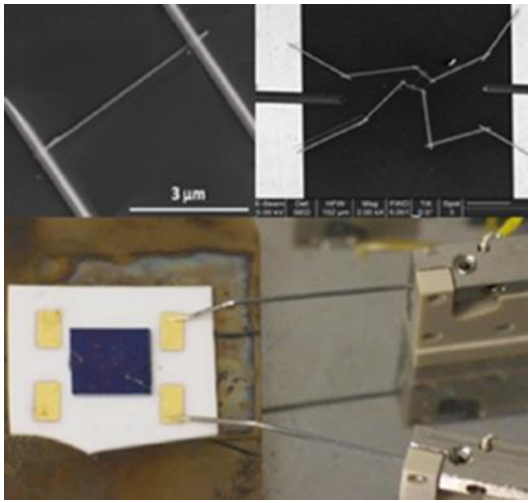
1.-Geometrical factors.

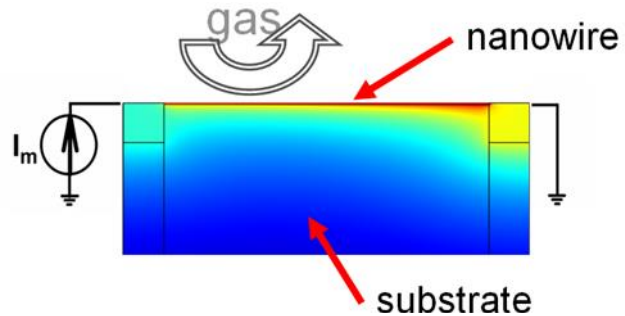


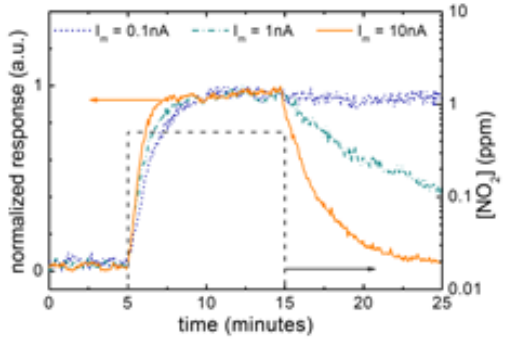


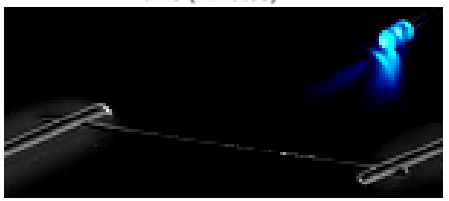
2.- Improved response and recovery time constants

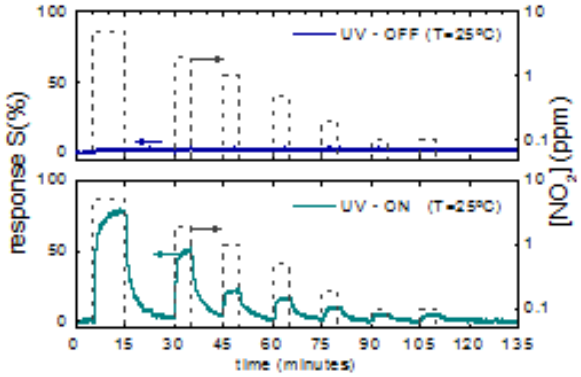
Current research activities







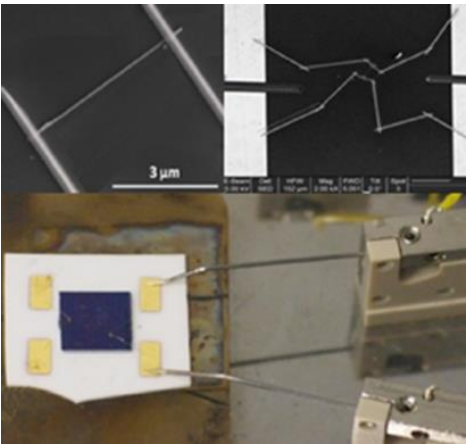


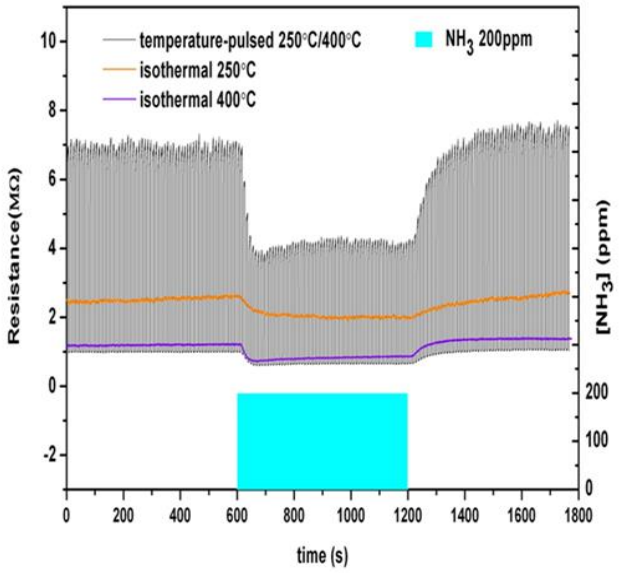


3.- SELF-HEATING

4.- Optical excitation

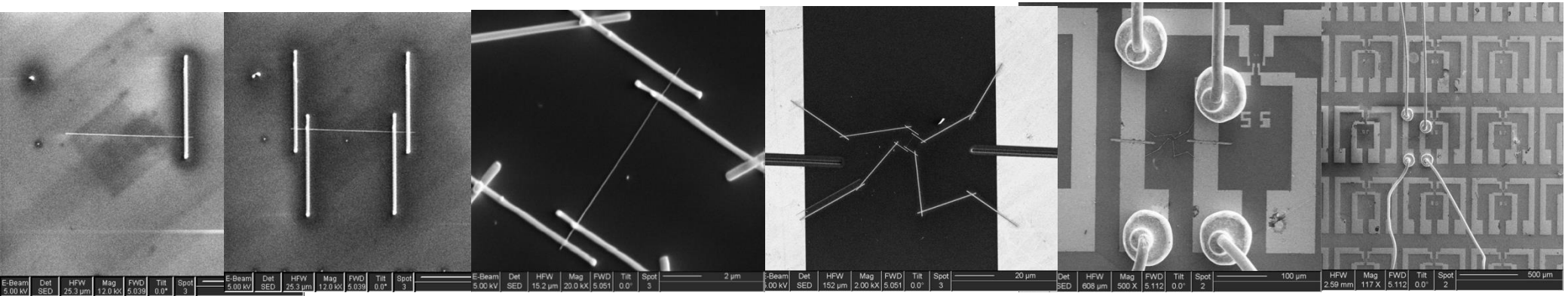
Current research activities





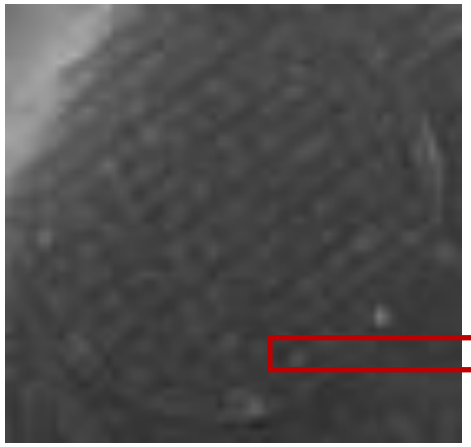
5.- Pulsed operation modes

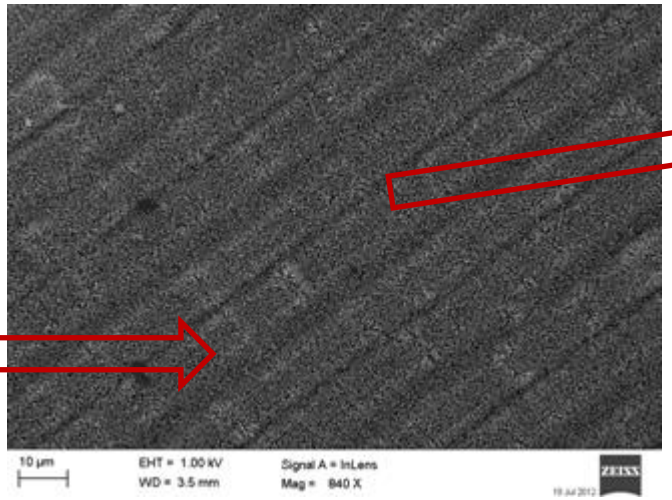
Non available nanowire manipulation tools for industrial fabrication of sensor

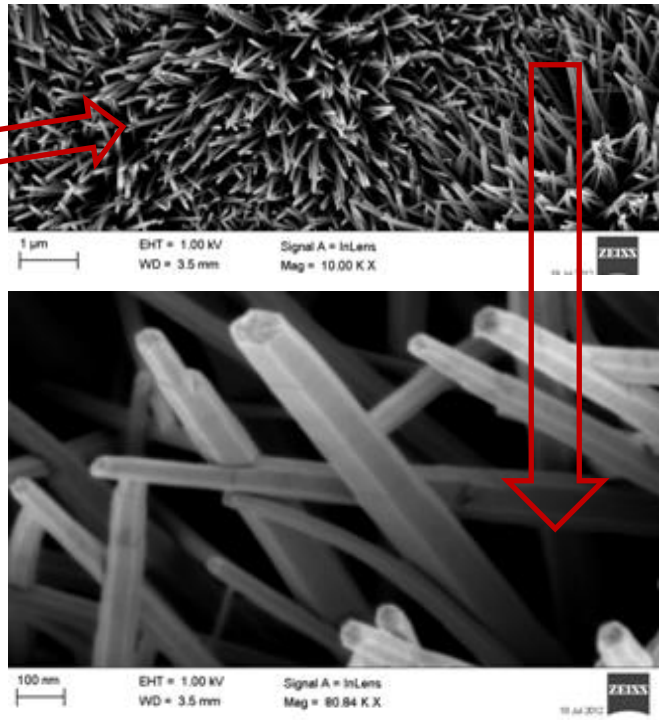


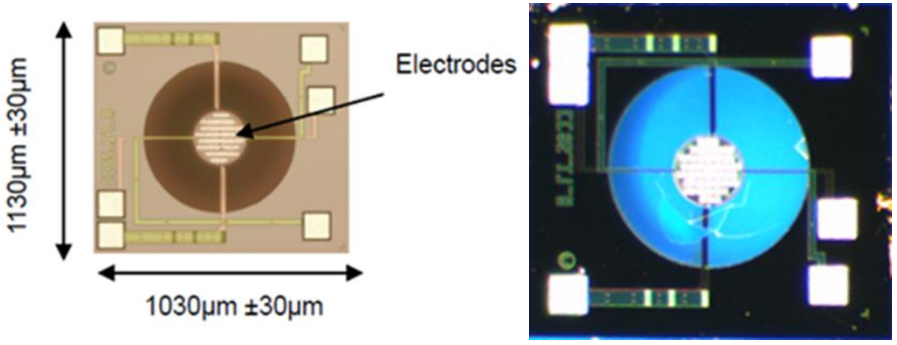
R&I Needs for future research

During these last year to implement nanowires as sensitive materials has been one of the major challenges.





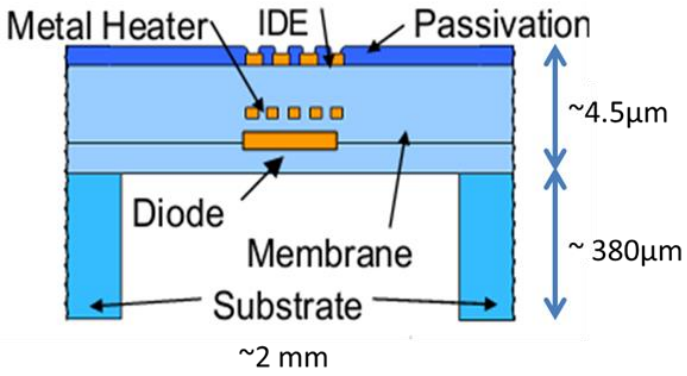


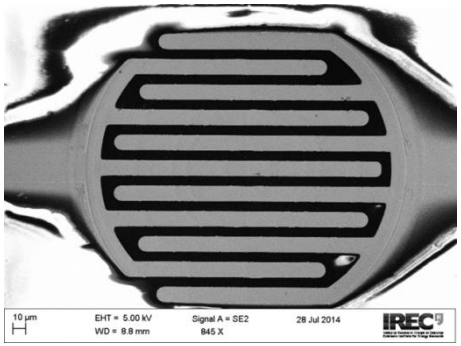


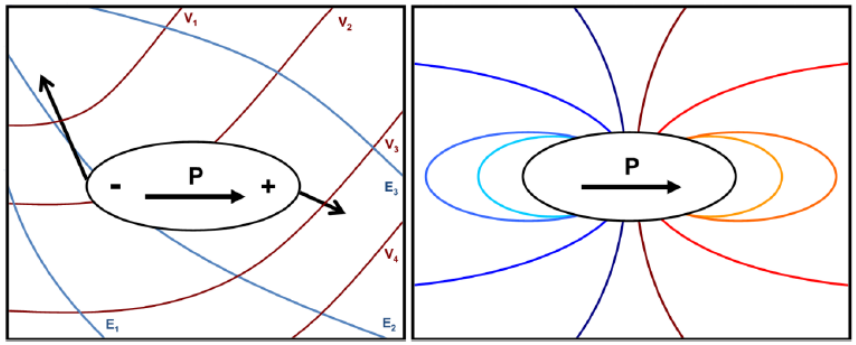
People use NW but they do not keep many of their properties !!!!.

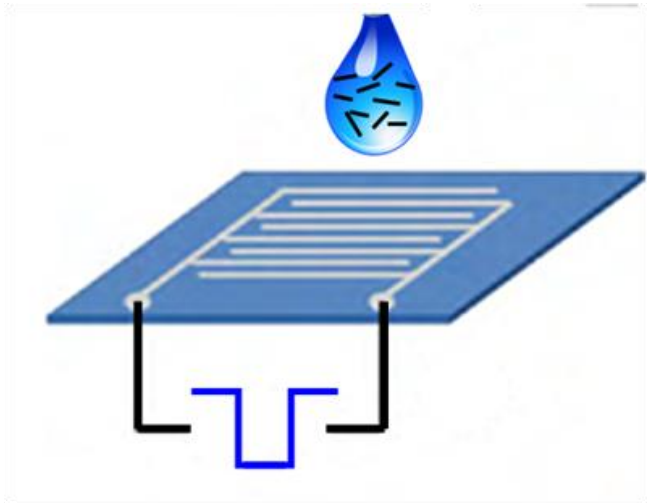
R&I Needs for future research

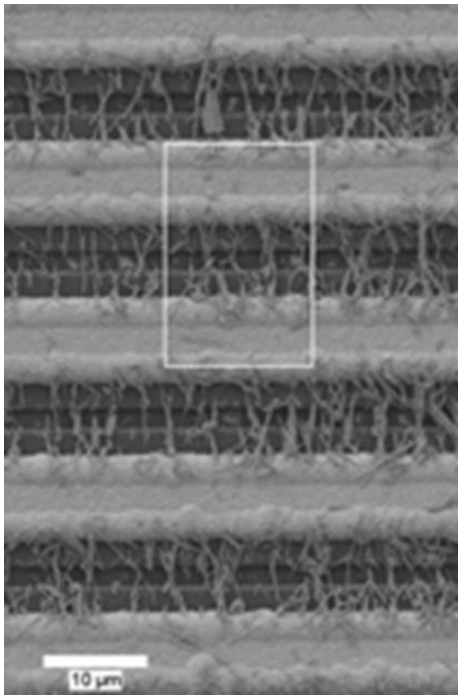
To look for new alternatives for facilitating the incorporation of nanowires as effective sensing materials with their described properties: Dielectrophoresis











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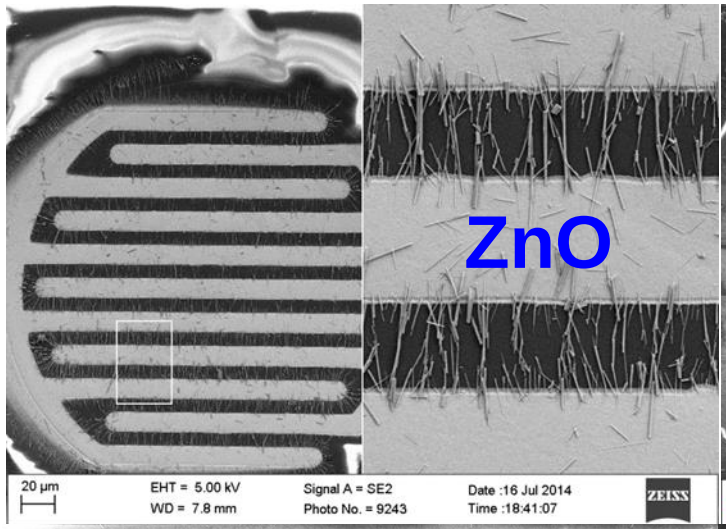
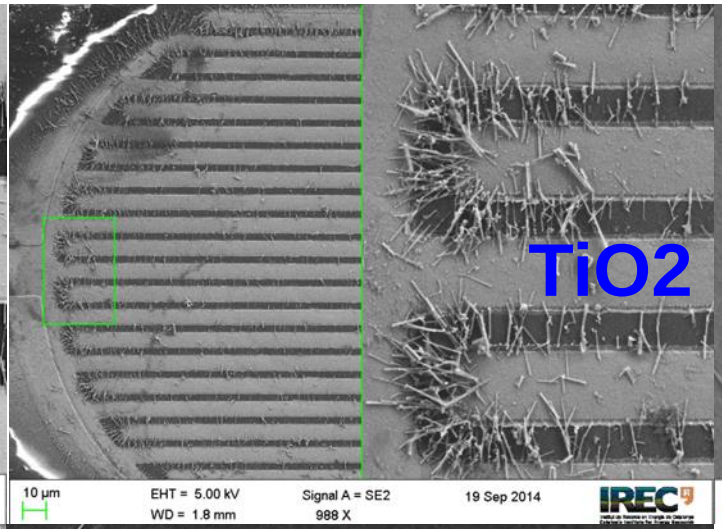
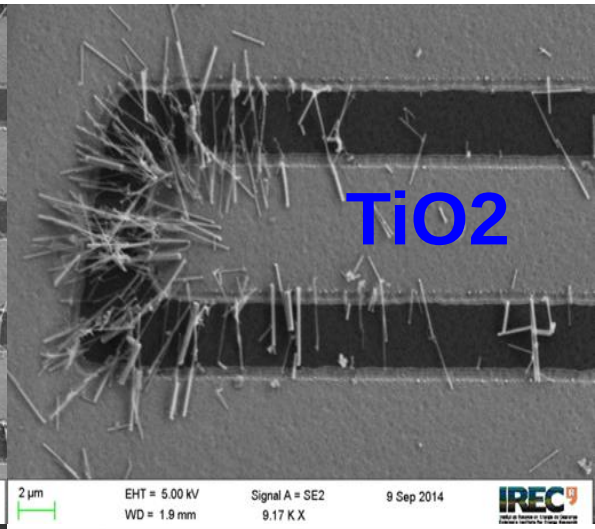
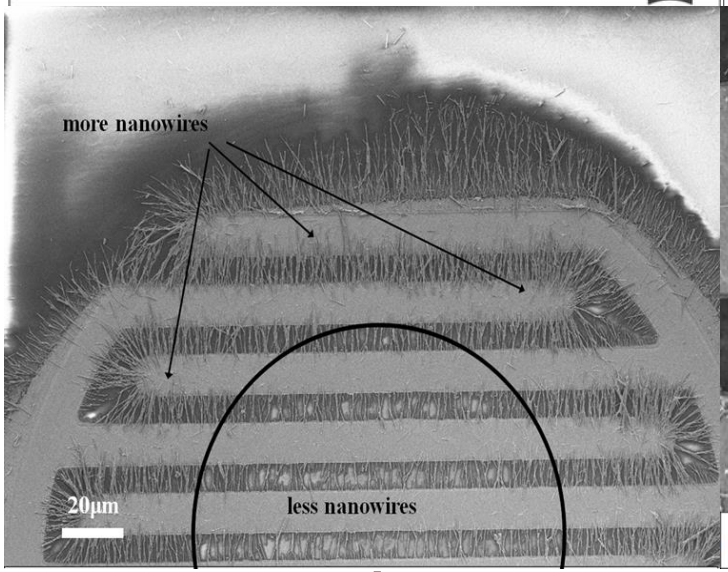
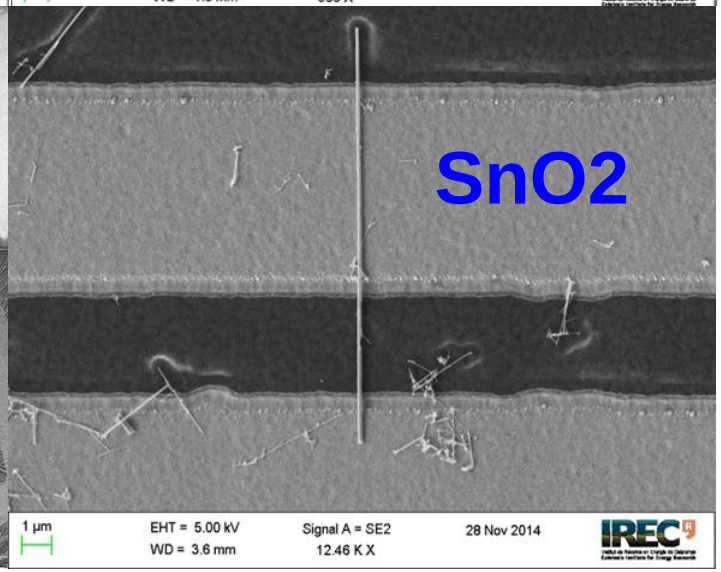
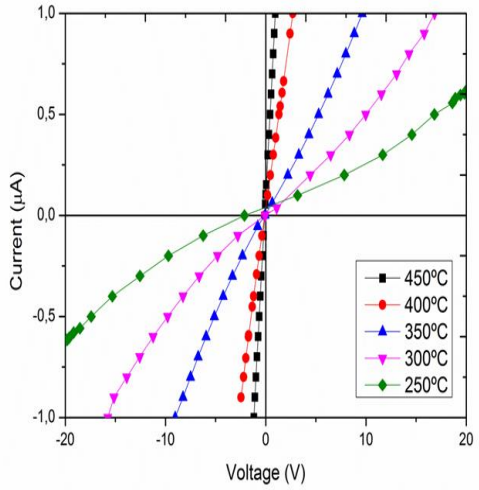






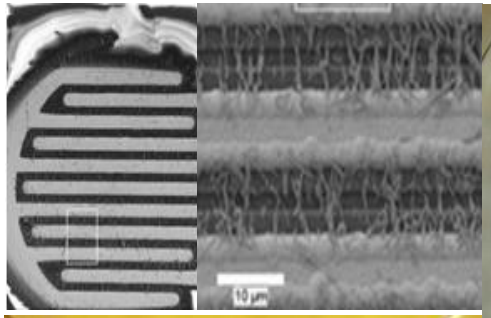


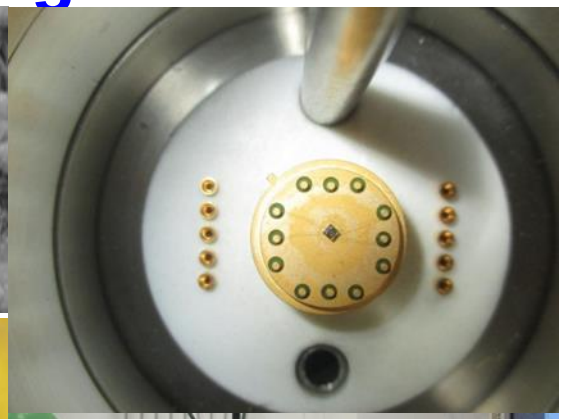


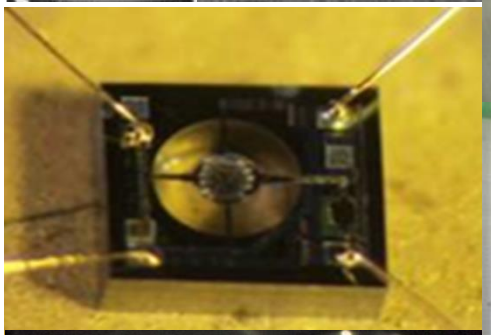


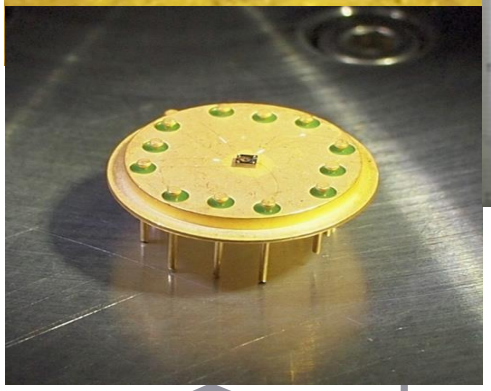
R&I Needs for future research

Results – SnO2 gas sensing by self-heating in multiwire integrated sensors

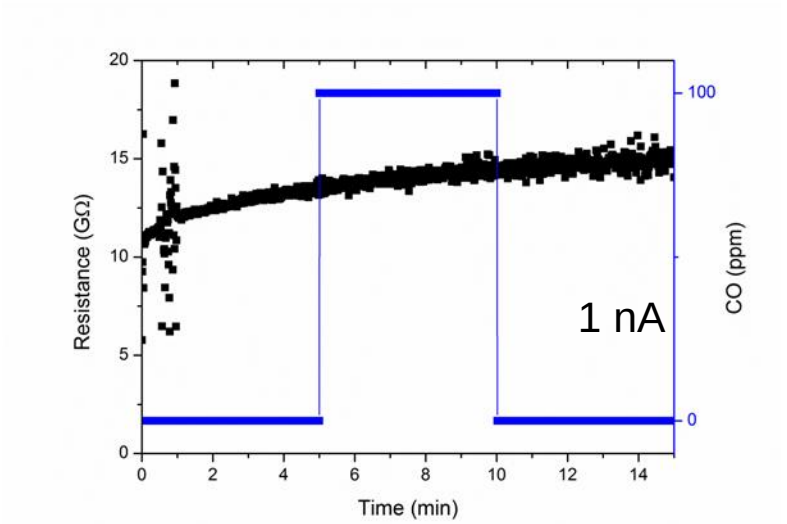


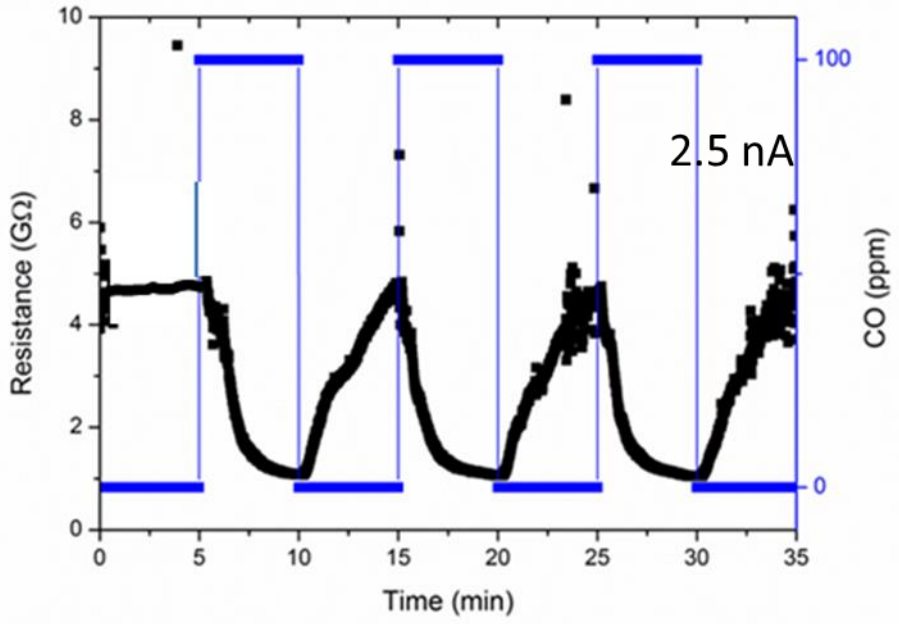






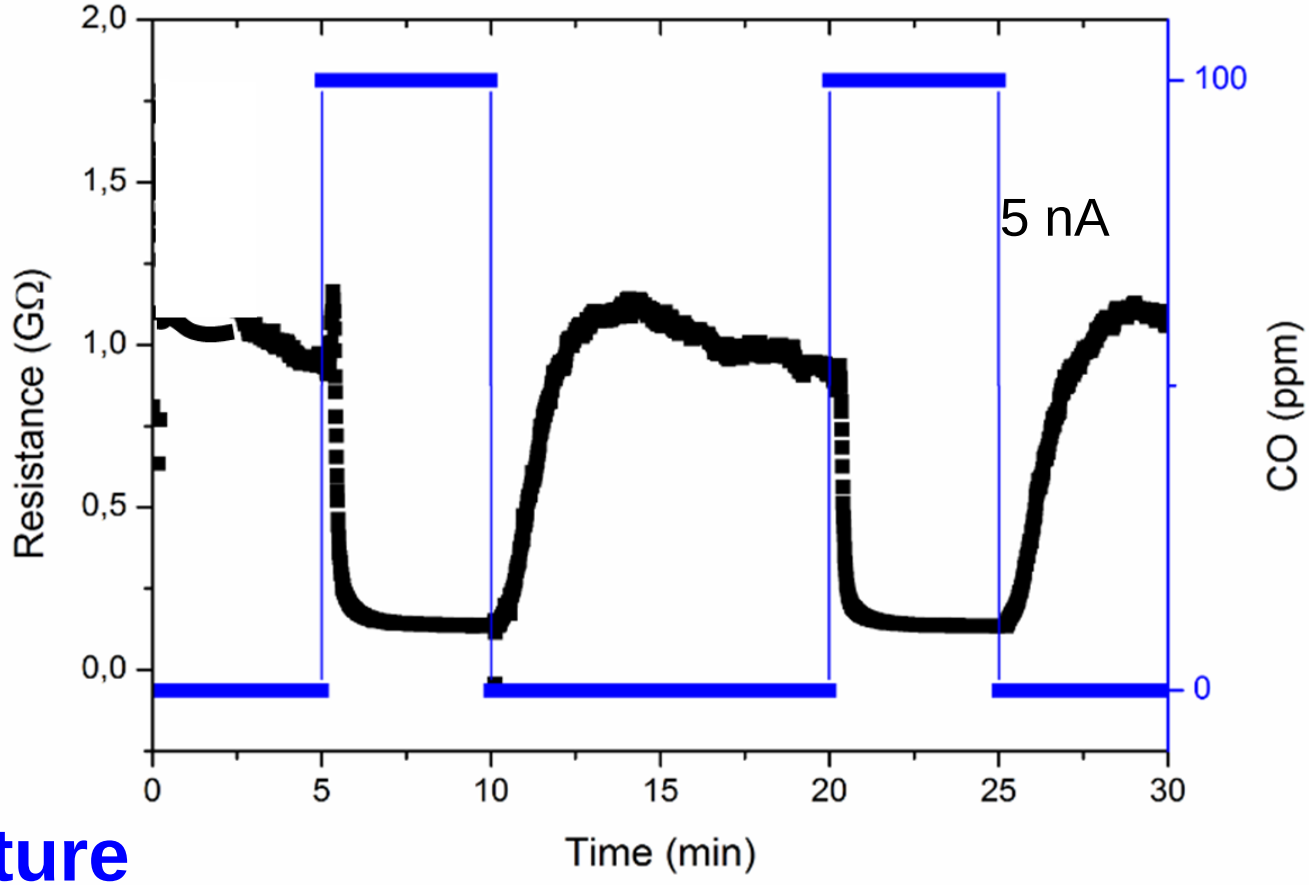
Room temperature





R&I Needs for future research

Results – SnO2 gas sensing by self-heating in multiwire integrated sensors



Room temperature

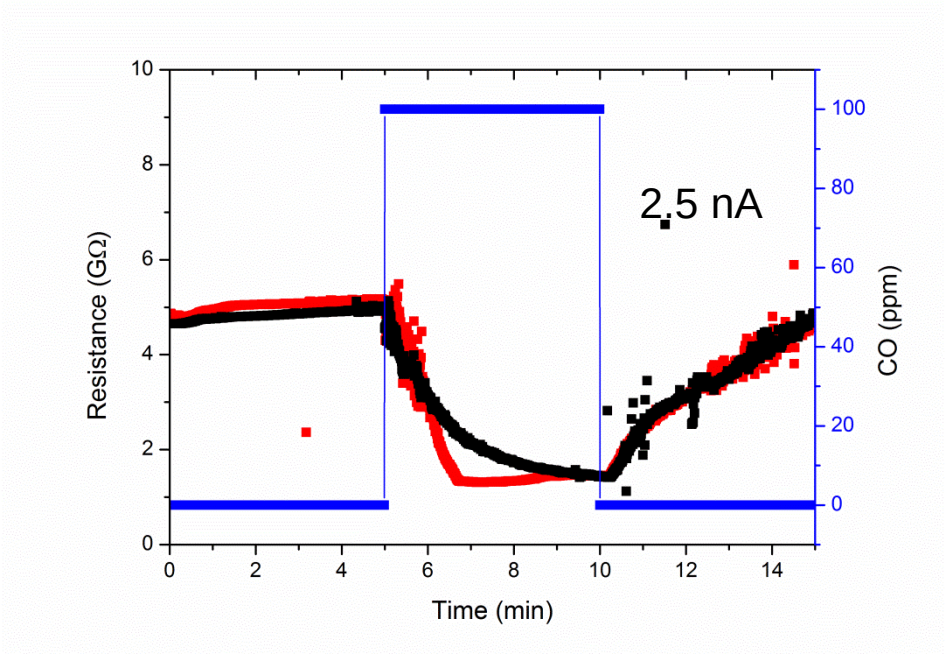
R&I Needs for future research

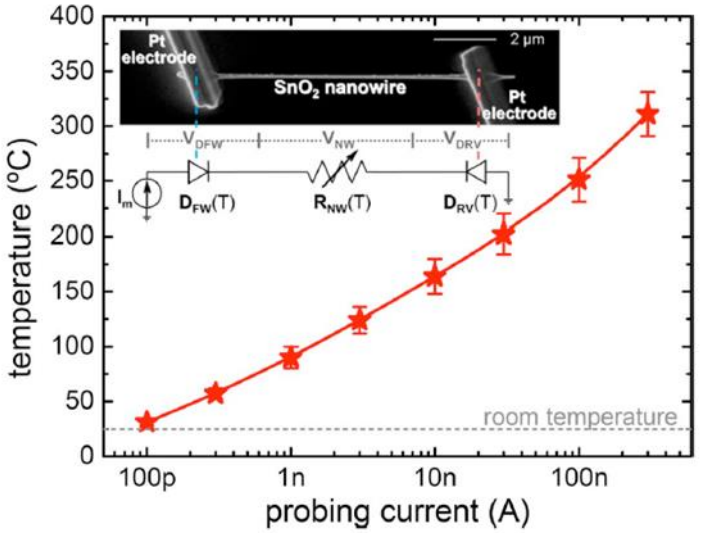
Results – SnO2 gas sensing by self-heating in multiwire integrated sensors

Similar behavior is observed in SnO2 by using:

-An external heater (13.7 mA) and low probing current (1nA) (red)

-Without external heater (0 mA) and with 2.5 nA. (black)





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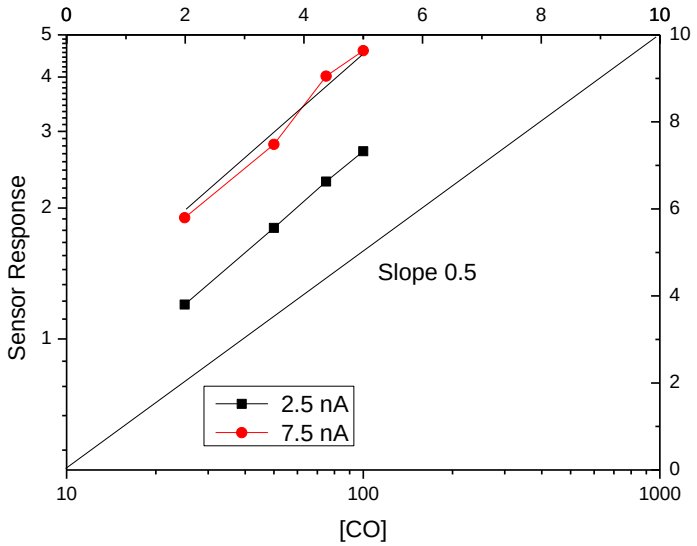
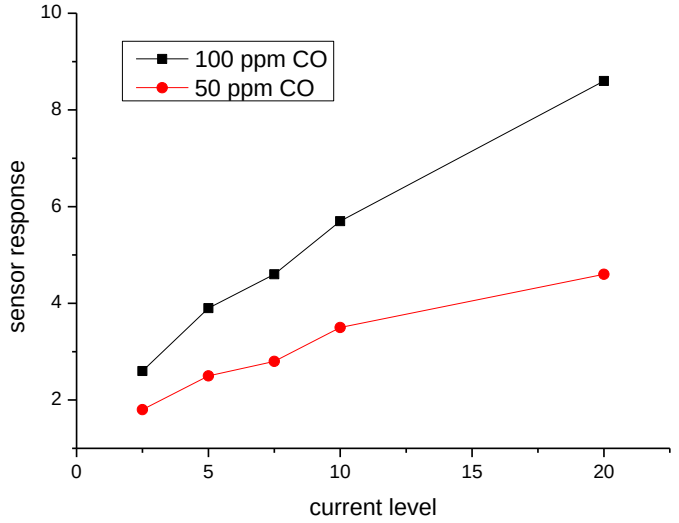
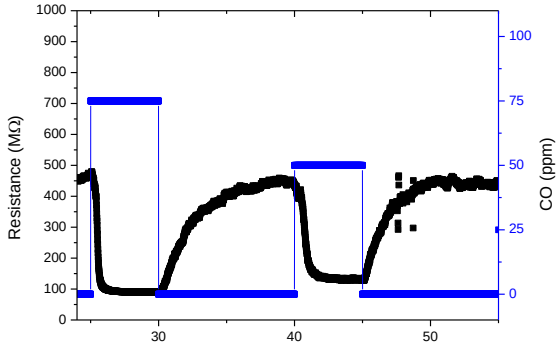
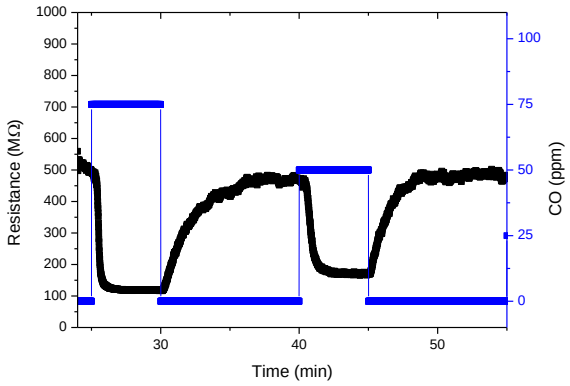
Results – SnO2 gas sensing by self-heating in multiwire integrated sensors

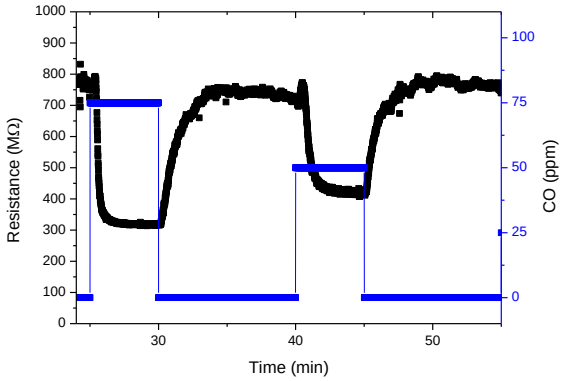




Temperature estimated in the range 100-150ºC

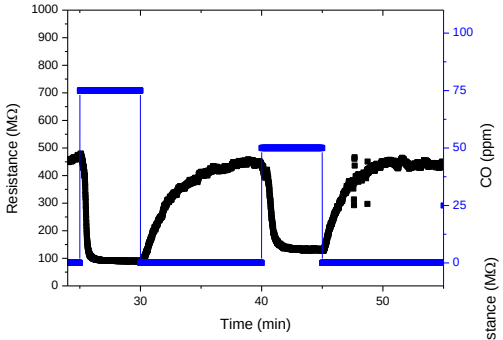


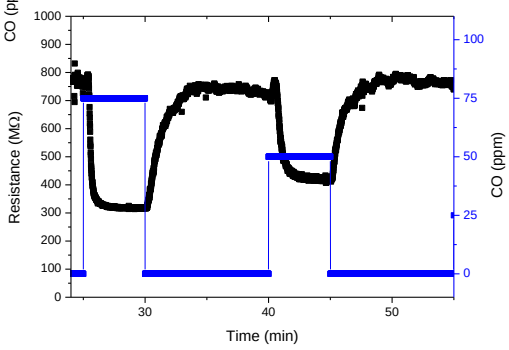


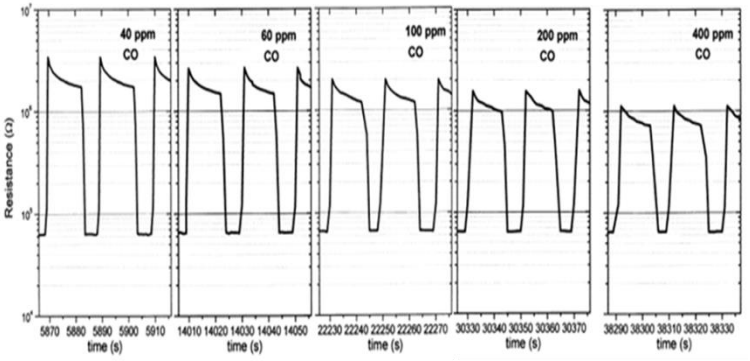


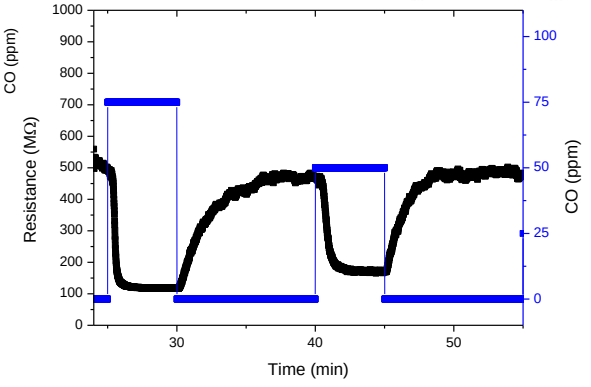
Improved integrated gas sensing based on self-heating of multi nano wires

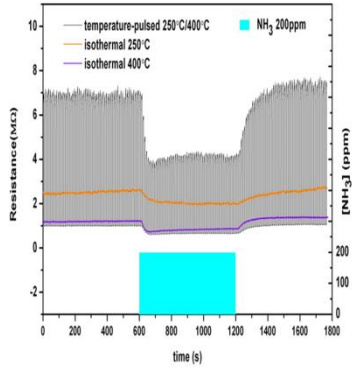
- As heater is not needed this approach can be used on any type of substrate and not more hotplate are needed.
- Sensor resistance range can be controlled or selected according density of NW's
- Sensor response level can be controlled or selected according NW's geometrical parameters (diameter, lengths)
- Sensor response o recovery time constant can be improved using current pulses
- Sensor selectivity can be improved using pulsed working modes instead isothermal operation modes.
- Optical excitation can also be used for sensor selectivity improvement
- Methodology is reliable and feasible to be industrially implemer











Conclusions

Multiples individual nanowire Integrated in SOI-CMOS based hot plates for gas sensors have been fabricated by DEP alignment giving direct response for a low cost high volume production solid state integrated gas sensor. This proof of concept has been achieved.

It allows to maintain the properties of the individual nanowires with many advantages, although still technological improvements need to be done for optimizing the overall powerful performances based on:

1.-Self-heating

2.-Sensitivity control (diameter control)

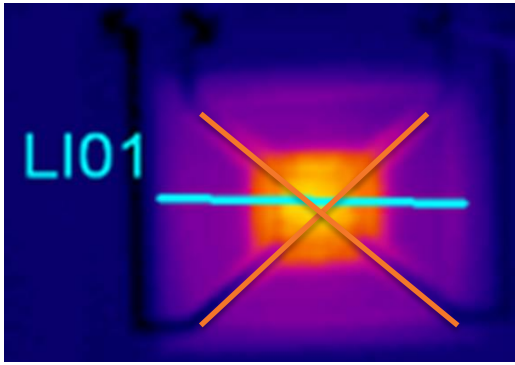
3.-High porosity avoiding any problem due to the gas difussion. So, very high response and recovery time only limited by the surface chemical processes.

4.-Possibility to fully illuminate the sensing bulk of the sensing nanowires avoiding non-uniform optical absorption such as it happens using layers.

5.- Possibility of working on the base of pulsed modes taking advantages of the SOI hotplate suitable up to 600ºC

It avoids the heater problem for develop sensor on advanced new substrate with low power consumption.

It opens a new via for NW integrated gas sensor fabrication



Acknowledge:

J. Guilera, C. Fabrega, T.Andreu, F. Shao, F. Hernández-Ramirez And J.D. Prades

Projects:

EU: Soi-Hit, Wirox,Nanos4

Nano-en esto

Patrons:

THANKS FOR YOUR ATENTION
ANY QUESTION?

Amb el finançament de: