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

## COST Action TD1105

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# RFID PASSIVE AND SEMI-PASSIVE TAGS FOR ENVIRONMENTAL MONITORING: CURRENT RESULTS AND FUTURE PROSPECTS


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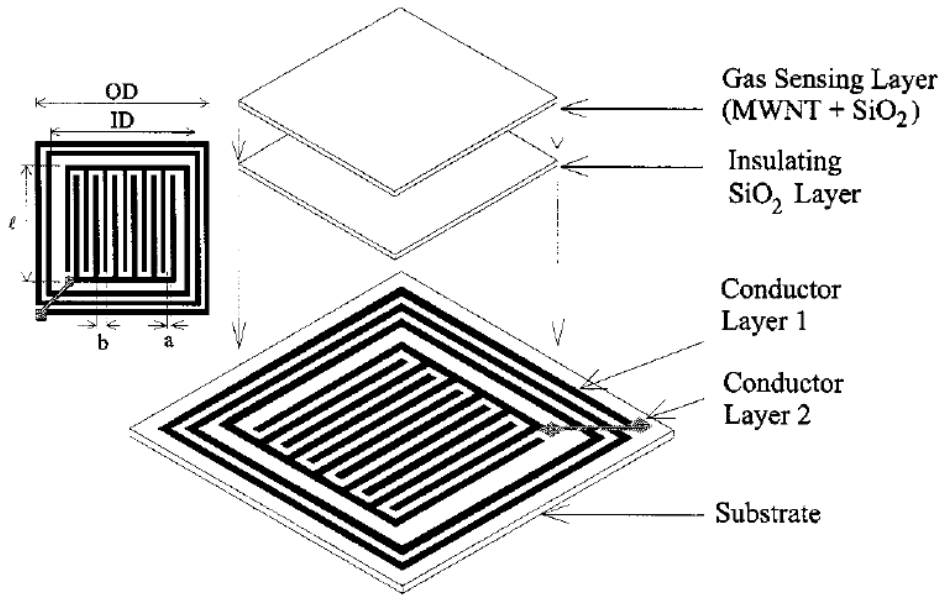
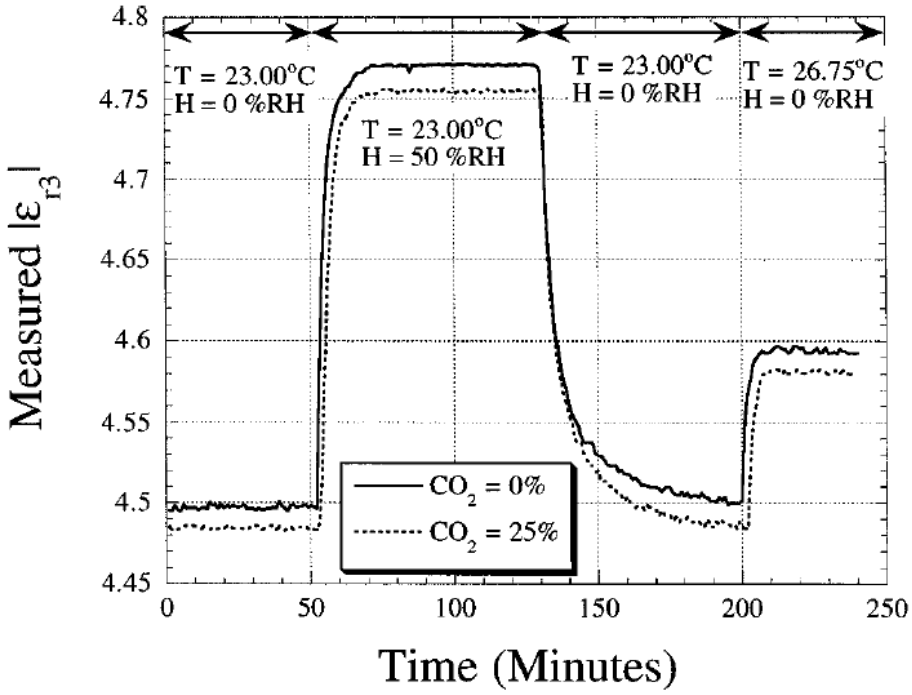
# Semi-passive or passive tags with gas sensing capabilities



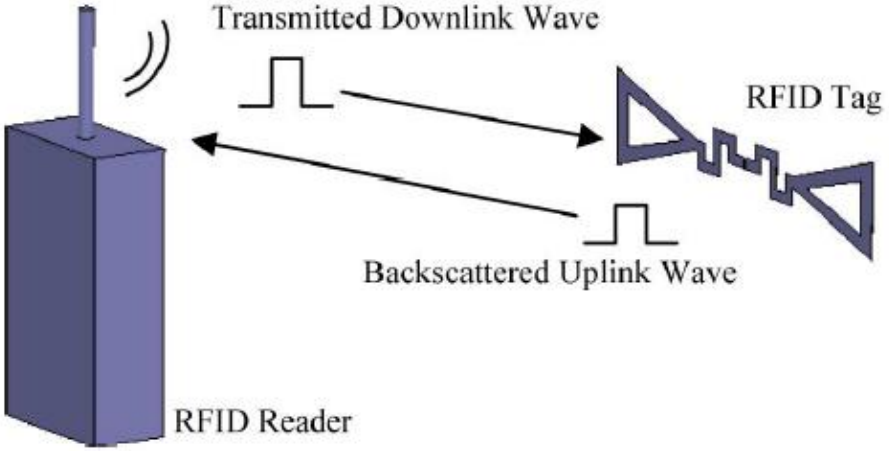




Fully passive tag, but an impedance analyzer needed to estimate permittivity. A coil antenna placed at few cms of the tag. $CO_2$, $NH_3$ (irreversible response), $O_2$ and $H_2O$ detected. Operated at frequencies outside the standard RFID band.

C.A. Grimes et al., IEEE Sensors Journal (2002) 82.

# Semi-passive or passive tags with gas sensing capabilities

M.M.Tentzeris et al., IEEE Antennas and Wireless Propagation Letters 8 (2009) 653.



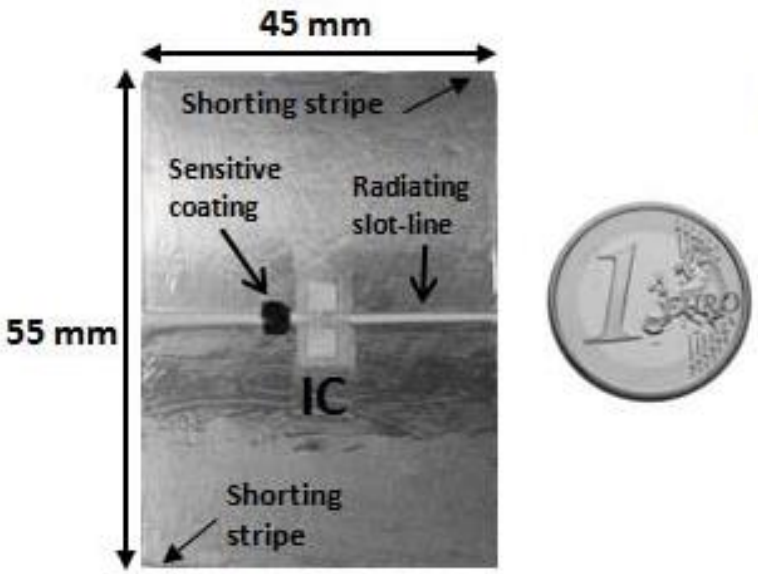

Photograph of the conformal tag with a SWCNT film in the center.

Passive tag, but no actual gas sensing measurements performed either in ‘wired’ or wireless mode! Designed for the European UHF RFID band.

CNT buckypaper monopole for detecting ammonia (wireless mode tested for conc. > 20%)

M.M.Tentzeris et al., IEEE Trans. Microwave Theory and Tech. 59 (2011) 2674.

# Semi-passive or passive tags with gas sensing capabilities

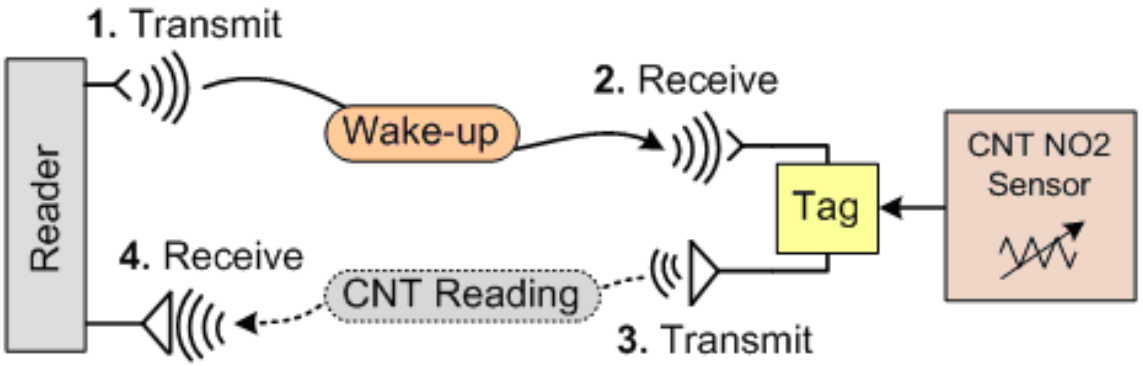


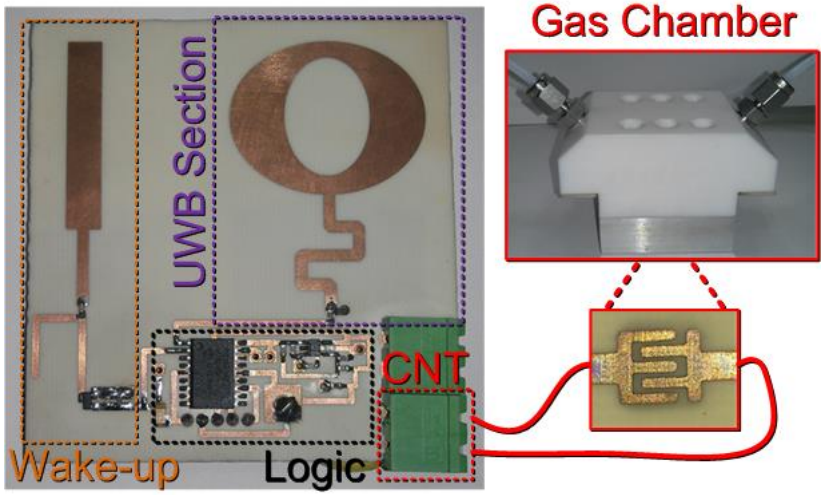

| Sensor no. | Sensitive coatings | |
|---|---|---|
| 1 | **Pedot:PSS** | *poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate)* |
| 2 | **SWCNT** | *Single Wall Carbon Nanotubes* |
| 3 | **Carbon black** | |
| 4 | **Phthalocyanine** | |
| 5 | **Polypyrrole** | |
| 6 | **ZnO Nanorods** | *Monocarboxytetraphenylporphyrin functionalized ZnO nanorods* |
| 7 | **MnTPPS** | *Manganese-Tetra-(sulfonatophenyl)porphyrin* |
| 8 | **PDAC** | *poly diallyldimethylammonium chloride* |
| 9 | **Doped PSS** | *Doped poly(styrenesulfonate)* |

Passive tag, wireless detection of ethanol, ammonia, octane and moisture at very high concentrations (50, 80 and 100%). UHF (840-960 MHz) band was used.

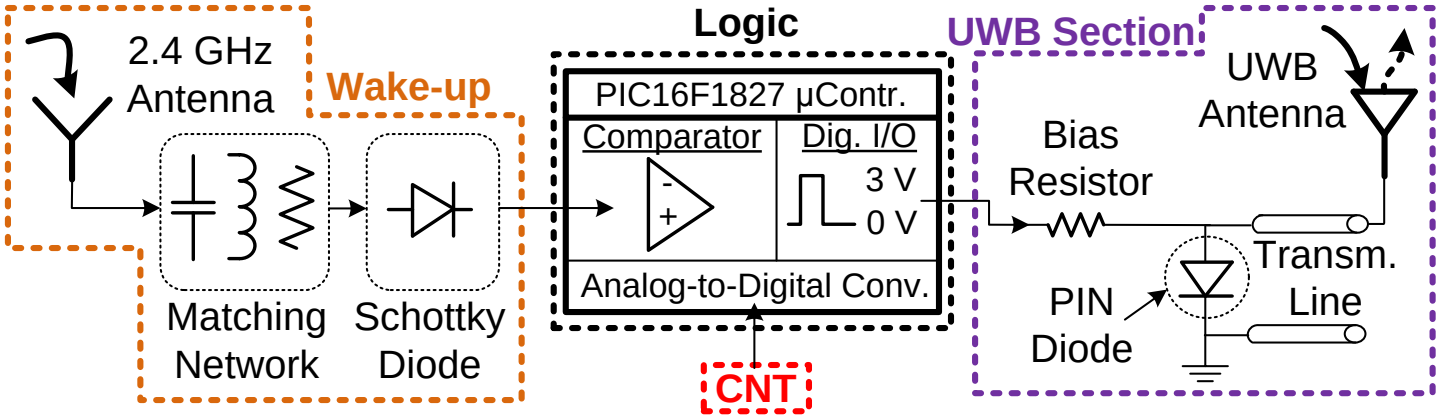
G. Marroco et al., IEEE Sensors Journal 14 (2014) 3616.

# Wireless $NO_2$ sensor: Set-up



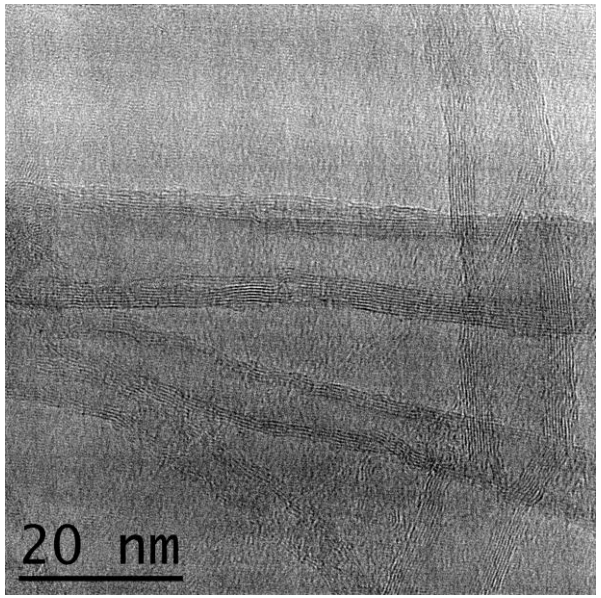

A commercial, low cost UWB reader is used. The Tag is semi-passive and employs a PIC16F1827 low-power microcontroller (with an embedded 10-bit ADC).






IEEE Antennas and Wireless Propagation Letters (2014) in press
Sensors and Actuators B 208 (2015) 444.

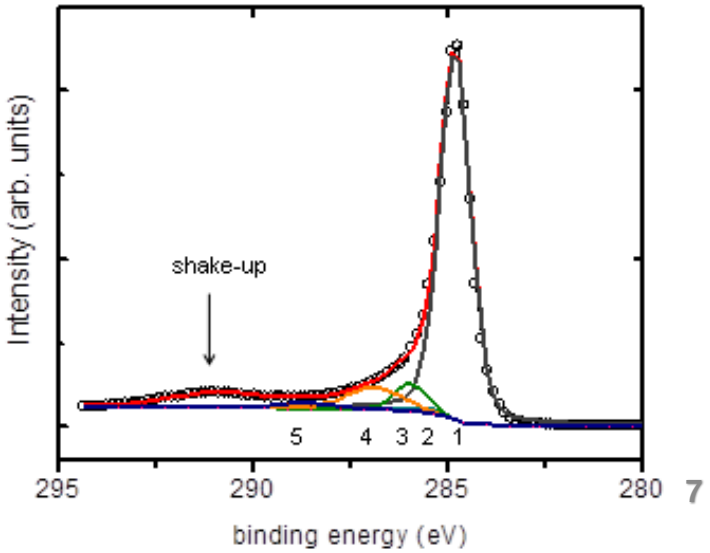
# Wireless $NO_2$ sensor: Gas sensitive material



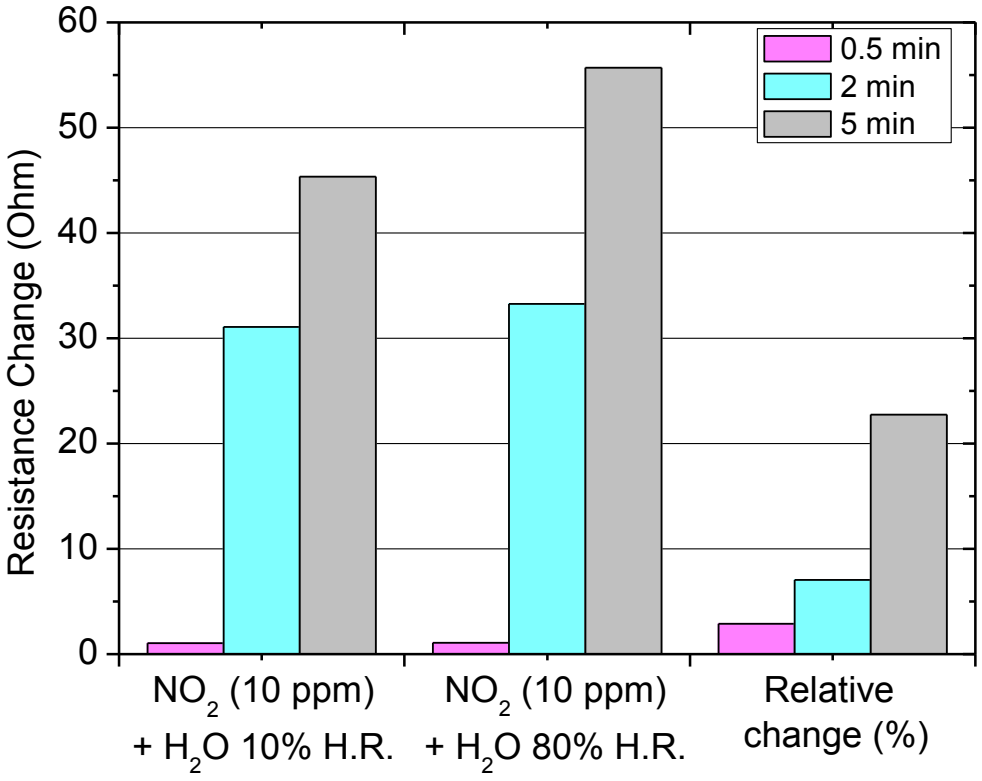

CVD-grown, oxygen plasma treated MWCNT (13.75 MHz, 15 W, 0.1 Torr)

| Treatment time (min) | Oxygen % | C-O % (hydroxyl) | C=O % (carbonyl) | C-O-O % (carboxyl) |
|---|---|---|---|---|
| 0.5 | 16.1 | 23.3 | 64.9 | 11.8 |
| 2 | 17.2 | 18.5 | 69.5 | 12.0 |
| 5 | 17.4 | 14.1 | 74.1 | 11.8 |

XPS C 1s core level spectrum recorded on plasma functionalized CNTs. (1) corresponds to the sp2 signal. (2) is attributed to the sp3 signal. (3), (4) and (5) at 288.9 eV correspond to hydroxyl, carbonyl and carboxyl groups, respectively.

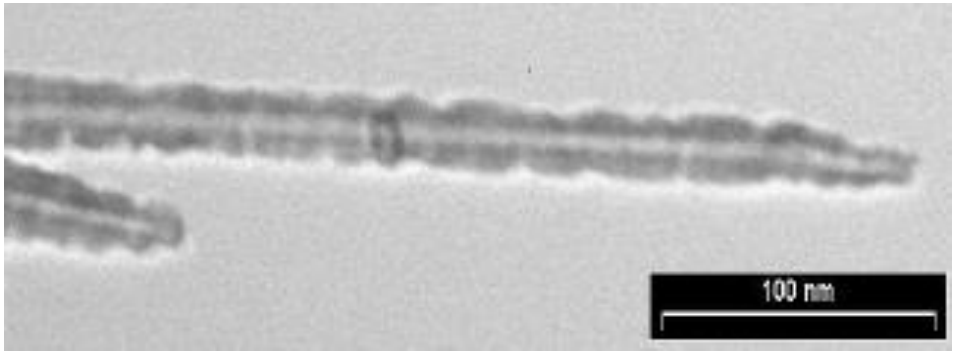


# Wireless $NO_2$ sensor: Results (wireless mode)



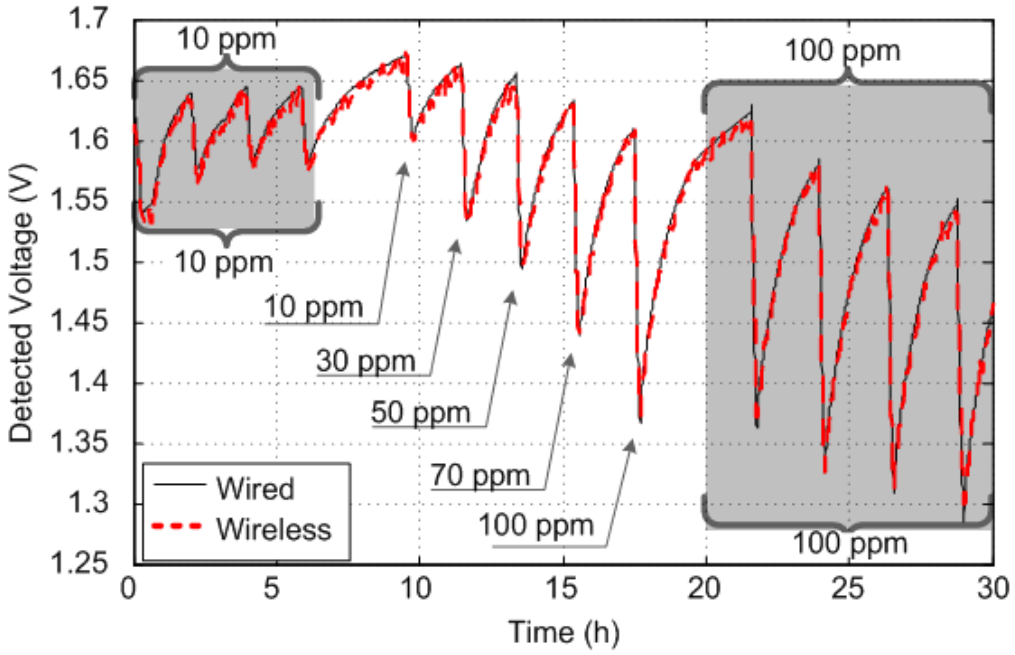

Detection of nitrogen dioxide under different humidity backgrounds. Effect of the duration of the oxygen plasma treatment in humidity cross-sensitivity of CNT sensors

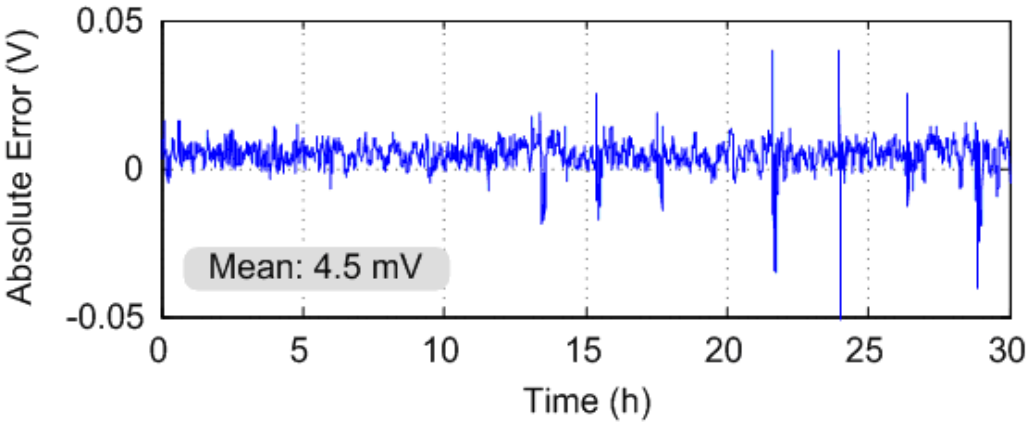
**2 min treatment is a good trade off between $NO_2$ response and moderate $H_2O$ cross-sensitivity**




Low-resolution TEM image of a multiwalled carbon nanotube treated by an oxygen plasma (0.1 Torr, 15 W, 5 min).

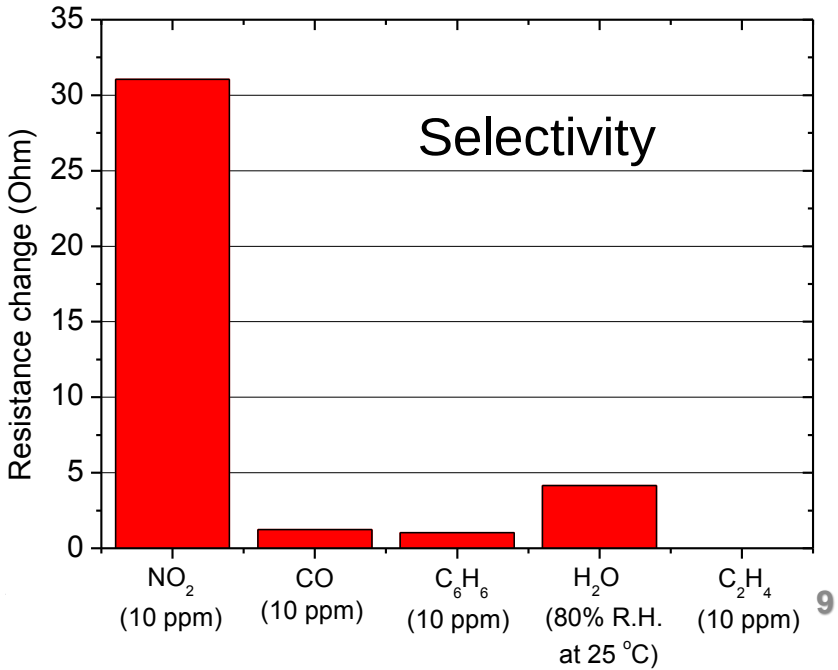
# Wireless $NO_2$ sensor: Results (wireless mode)




Wired (black solid line) and wireless (red dashed line) measurements of the CNT-based $NO_2$ sensor. The sensor is operated at room temperature (i.e., 25ºC) both in the response and the recovery phases.

Evolution of the absolute error between the wired measurement (taken as reference) and the wireless measurement.



# Conclusions

- Most of the systems use narrow-band signals, which are prone to suffer interferences from other systems such as WiFi, Bluetooth or cellular phones and work only at low reader-to-tag distances.
- Passive tags are able to sense extremely high concentrations of toxic gases.
- Instead, UWB is known for being robust to interferences from other systems, permits to localize the physical position of the tags within an area, and works at long reader-to-tag distances (up to 8.5 m).
- The sensor is normally in a low-power mode (20 nA) until it is woken (325 μA) by the reader. For a typical situation of 12 measurements per hour and a 1000 mAh battery, the expected lifetime of the tag is about 10 years.

# Outlook

- There are still important technological barriers that limit the implementation of smart and autonomous systems with sensing capabilities. These obstacles are related to (i) sensor performance, (ii) power consumption and (iii) size of the system as a whole.

- For the particular case of CNT sensors, stability and cross-sensitivity of the gas sensitive material remains a major challenge.

# Acknowledgements


- This work is supported in part by MINECO under grant no. TEC2011-28357-C02-01, AGAUR grant 2013FI_B1 00060, The European Science Foundation via COST Actions MP0901 ‘NanoTP’ and TD1105 ‘EuNetAir’, The Belgian Fund for Scientific Research (FRS-FNRS) under FRFC contract “Chemographene” (convention no. 2.4577.11) and Catalan Institution for Research and Advanced Studies under the ICREA Academia Award


## Thank you for your attention