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

## COST Action TD1105

## WGs and MC Meeting at Cambridge, 18-20 December 2013

## AFFORDABLE NANOSENSORS FOR ENVIRONMENTAL MONITORING


**Xavier Vilanova**

WG1 Member

**University Rovira i Virgili / Spain**



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# AFFORDABLE NANOSENSORS FOR ENVIRONMENTAL MONITORING

This talk reviews the research activities of the URV group and comprises:

- Carbon black sensors
- Resistive carbon nanotubes sensors
- Resistive low-dimensional metal oxide sensors
- Flexible substrate sensors
- Resonant sensors functionalised with carbon nanotubes or zeolites

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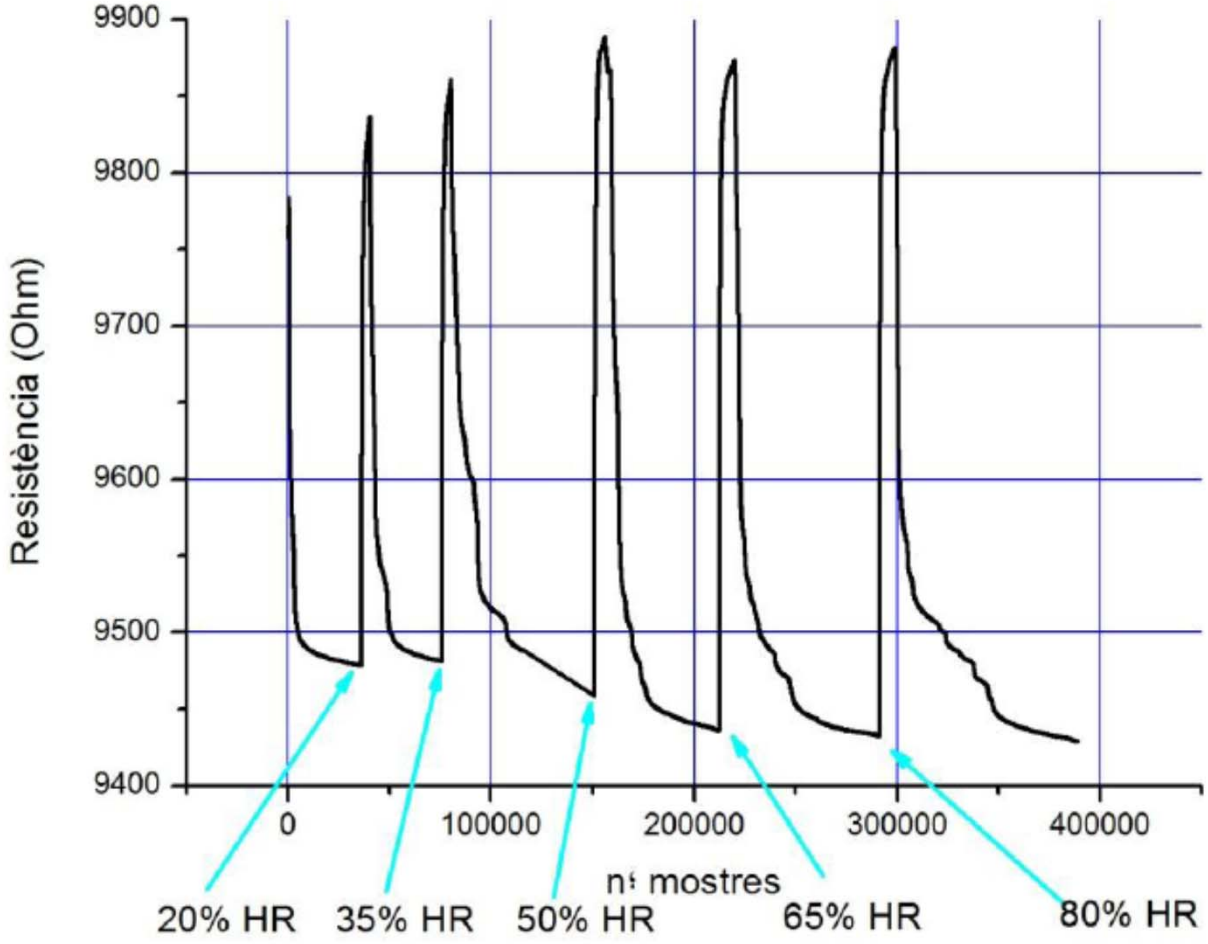
# Micro/nano gas sensors using carbon black

- **Humidity sensors based on carbon black nanoparticles**





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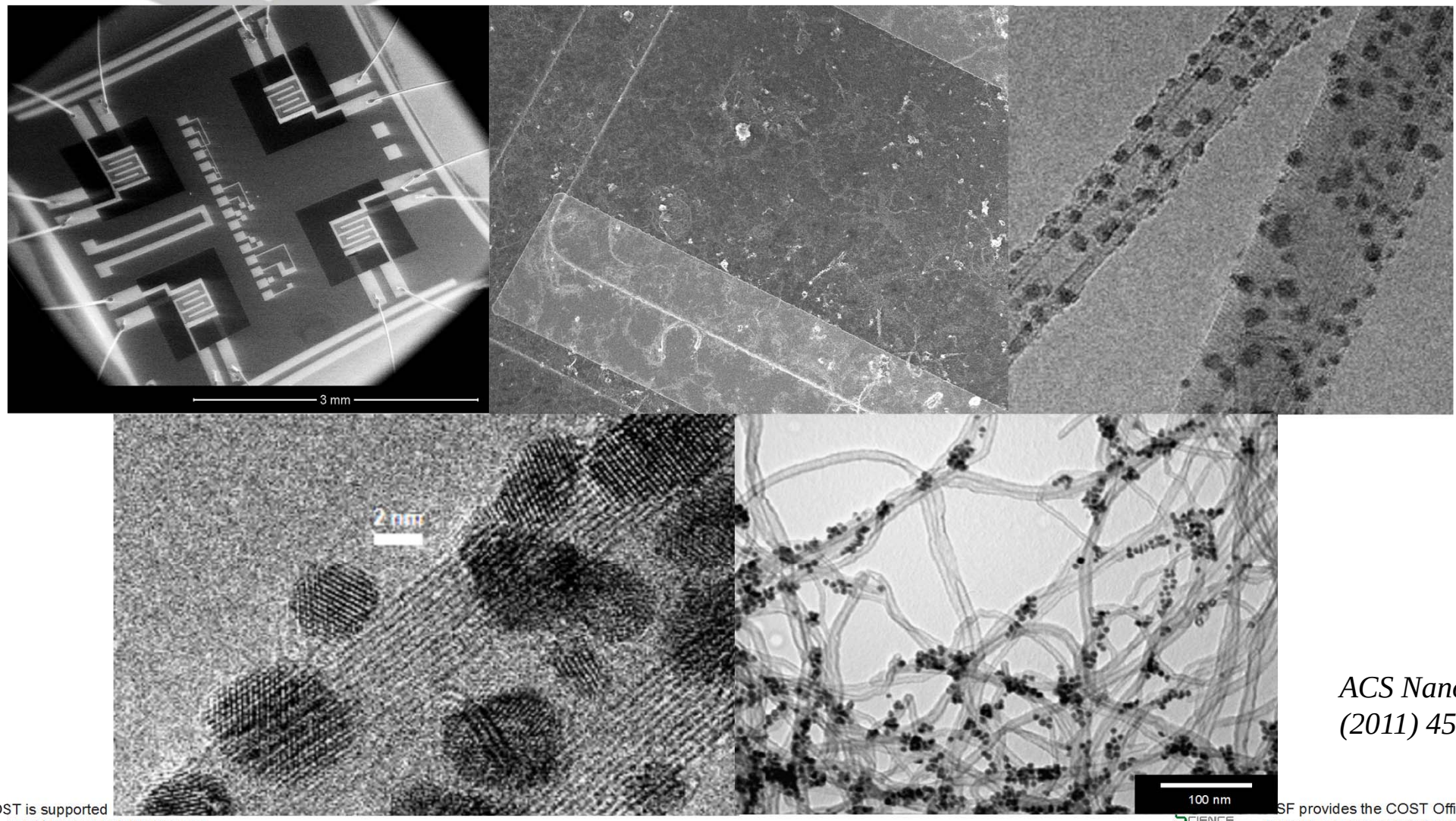
# Micro/nano gas sensors using MWCNTs

- **Gas sensors based on plasma-treated, metal-decorated MWCNTs and graphene**




*ACS Nano, 5 (2011) 4592*

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# Micro/nano gas sensors using MWCNTs

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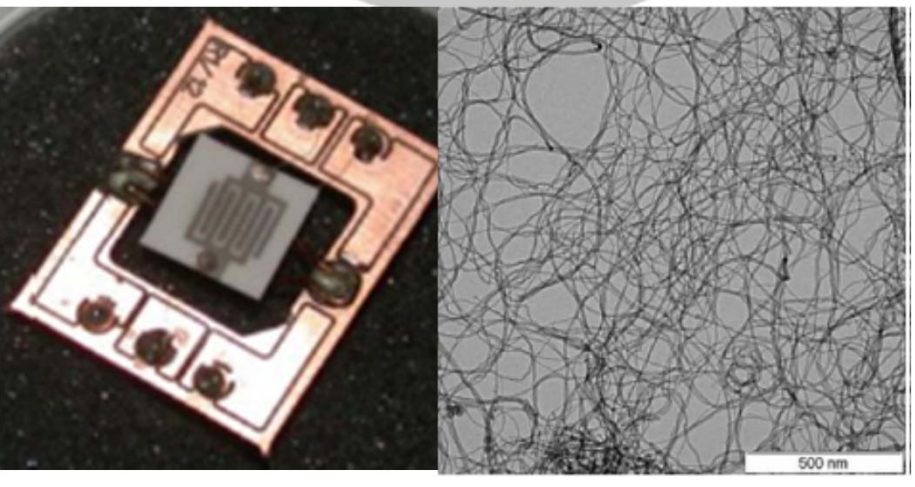
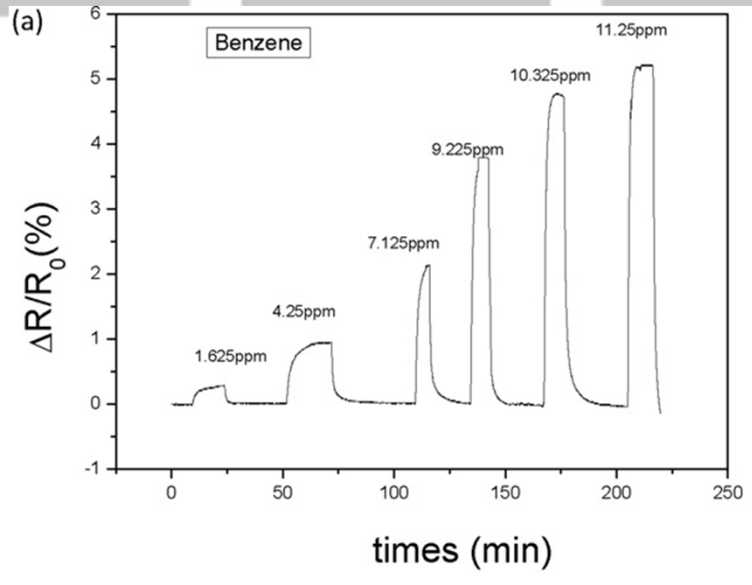
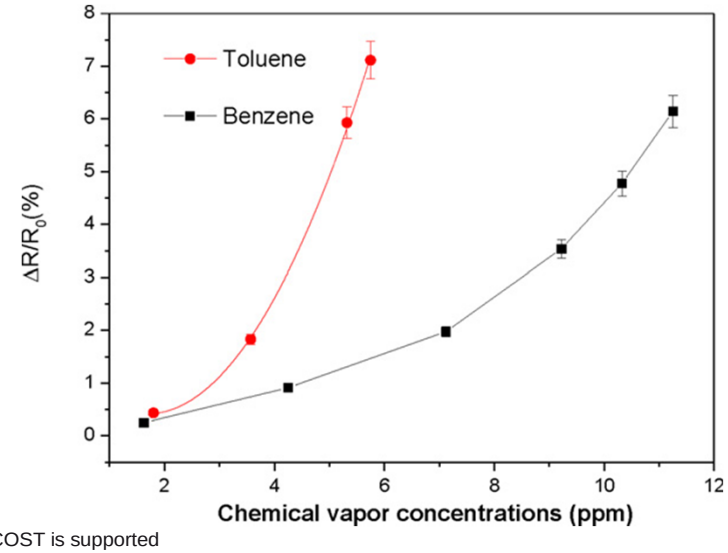
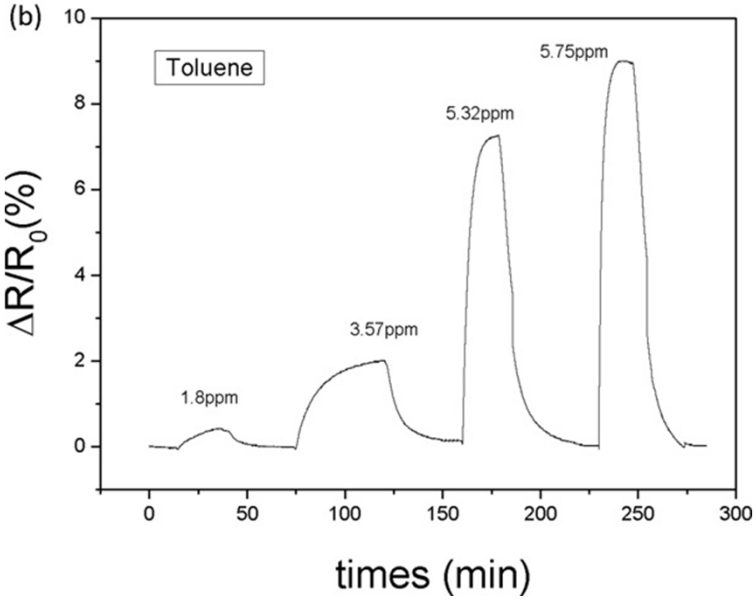





**Room temp.**




*Sensors and Actuators B 182 (2013) 344– 350*

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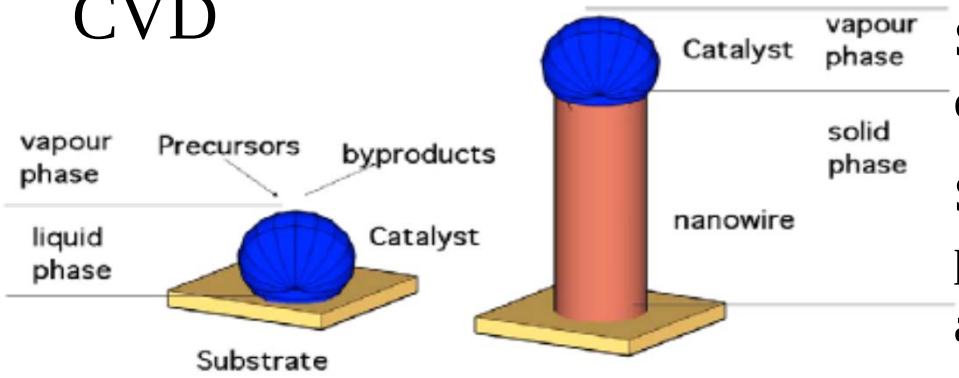
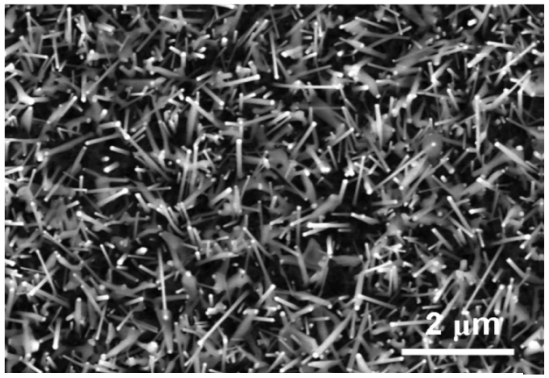
# MOX NW sensors *VLS (catalyzed)*

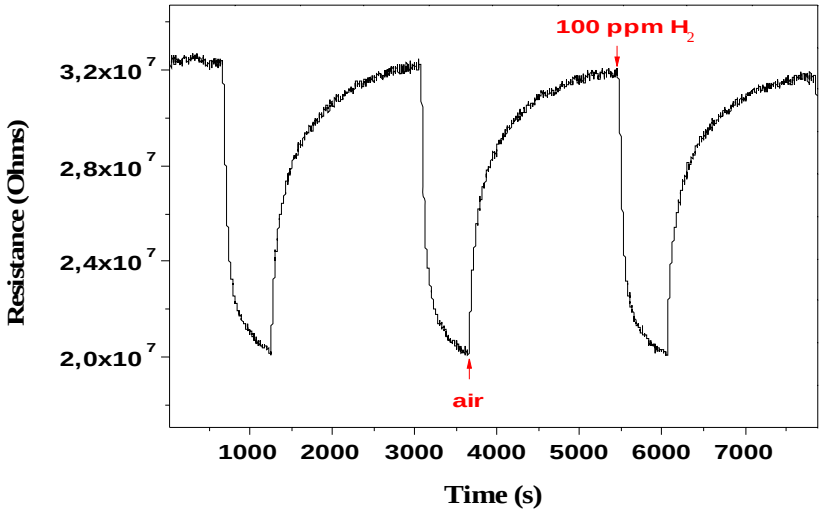
## CVD

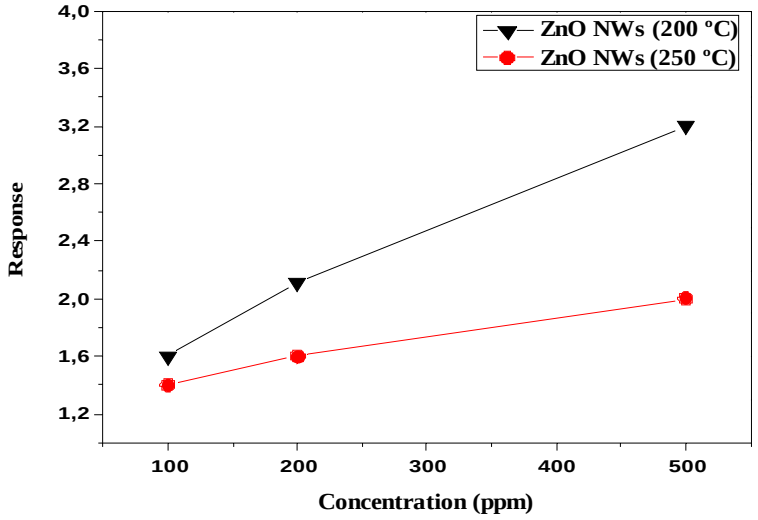



ZnO grown by CVD (900ºC) on $SiO_2$ substrates using Au NP as catalyst.

Substrate conditioning: Au NP prepared by sputtering + annealing. *IMCS 2014*

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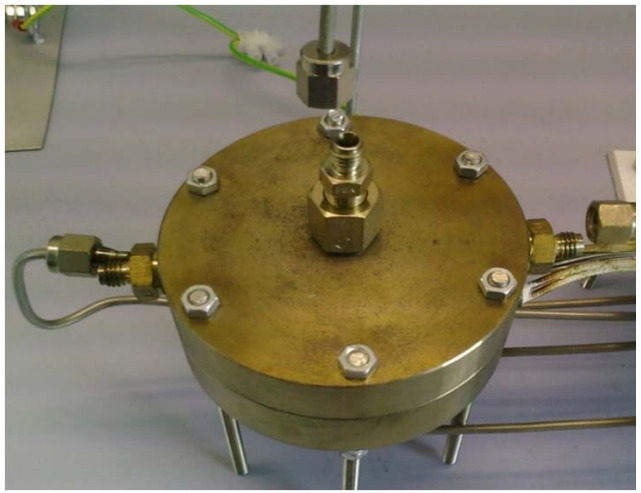
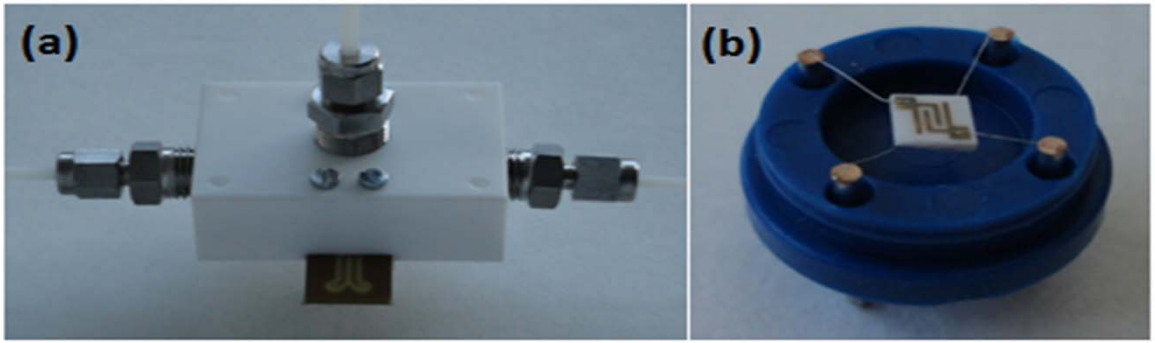
# MOX NW Sensors: Aerosol-Assisted CVD (VS)



Hot wall AACVD reactor




(a) AACVD cold wall reactor, (b) Alumina gas sensor

**Deposition time: 45-60 min**
**Precursor : 150 mg**
**T °C used : up to 500 °C**

**Deposition time: 15-20 min**
**Precursor : 50 mg**
**T °C used : up to 600°C**

**Doped nanowires  growth in a single step**

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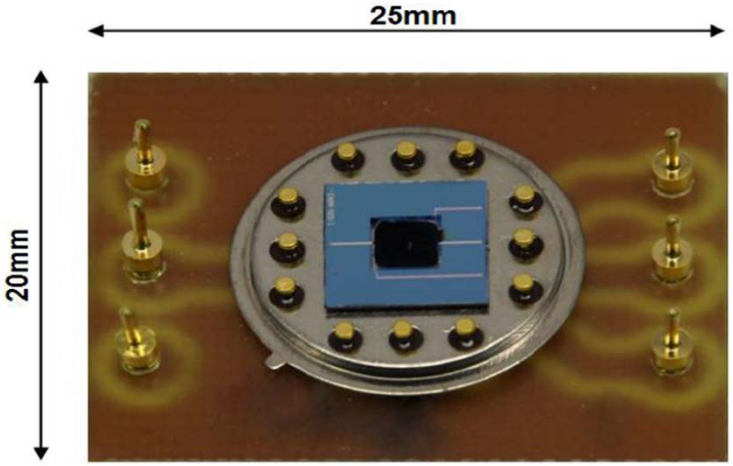
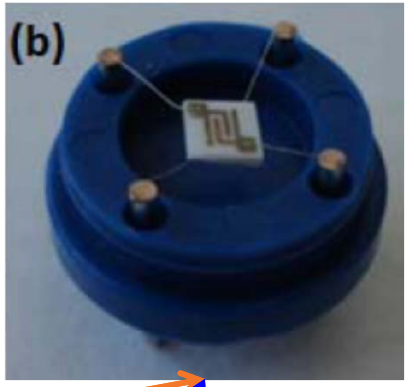
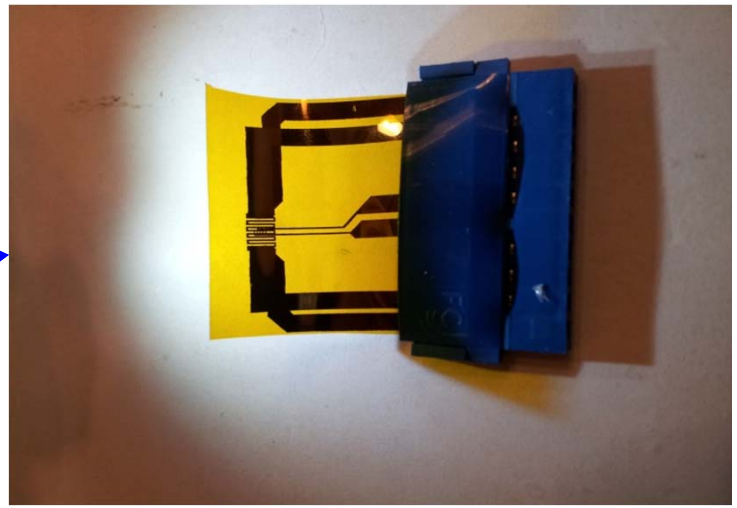
# MOX NW Sensors: Aerosol-Assisted CVD (VS)




Direct growth of NWs on ceramic, micromachined silicon and flexible substrates

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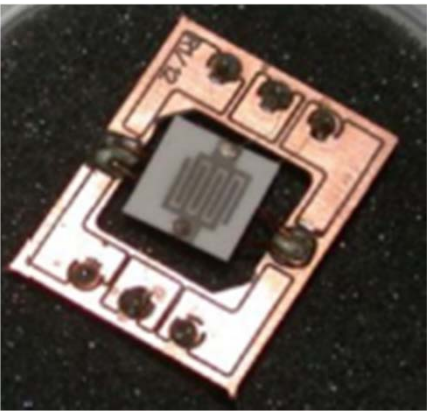
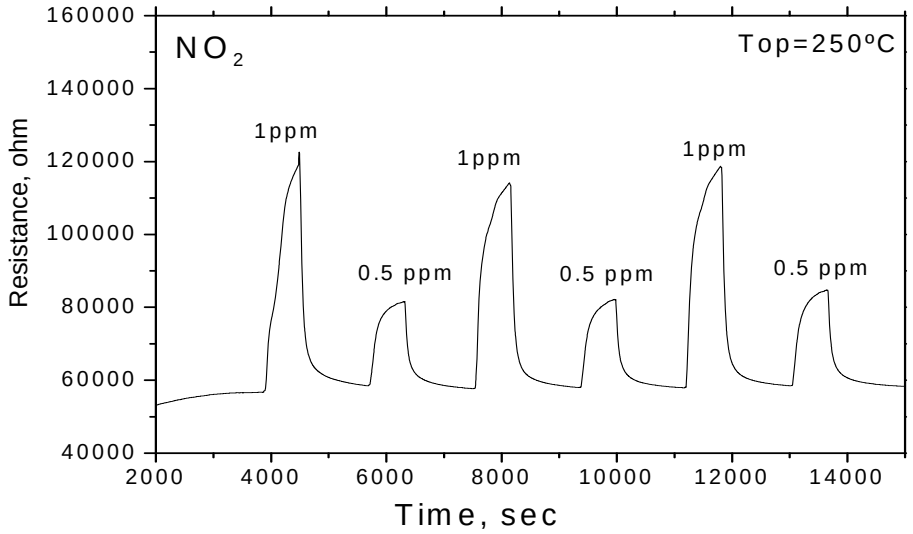
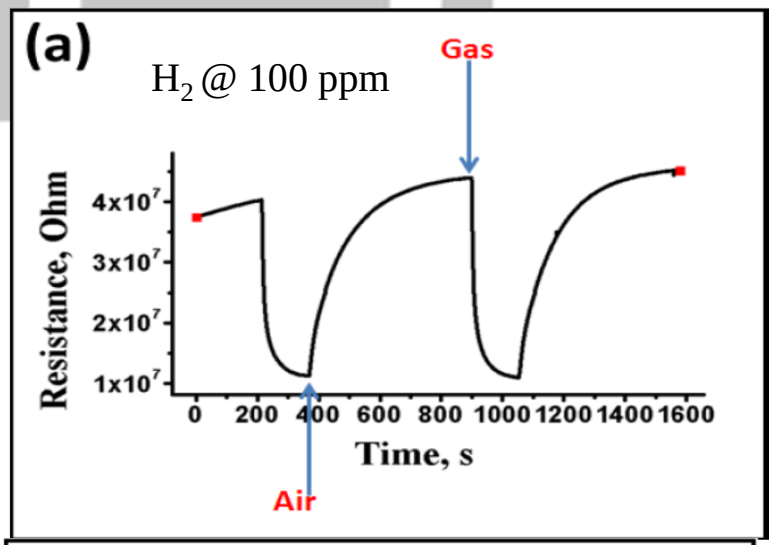
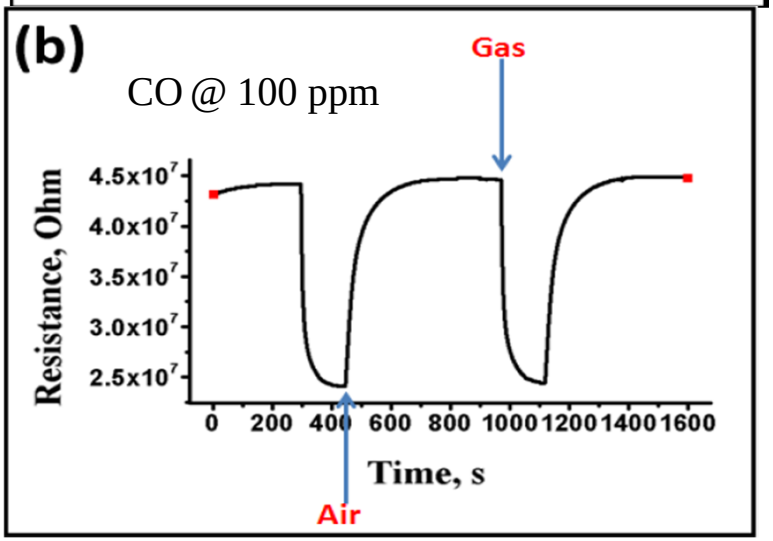
# MOX NW Sensors: Aerosol-Assisted CVD (VS)






Au-$WO_3$ NWs

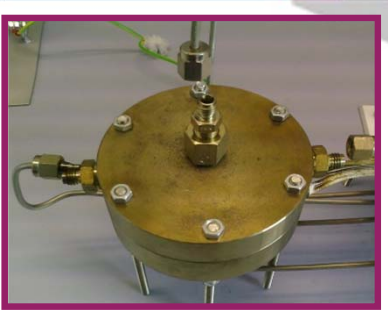


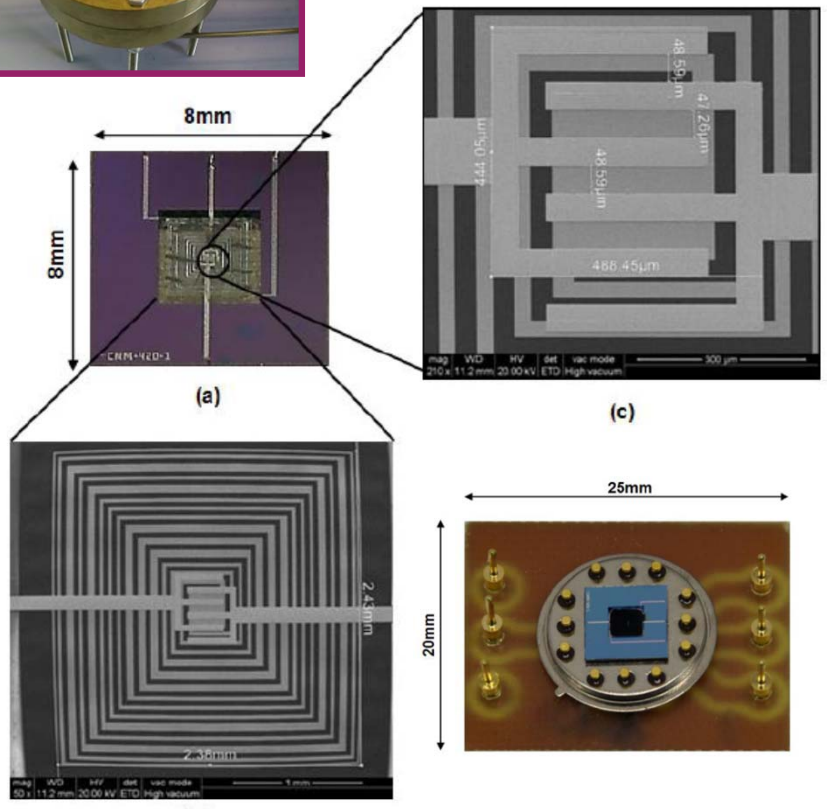



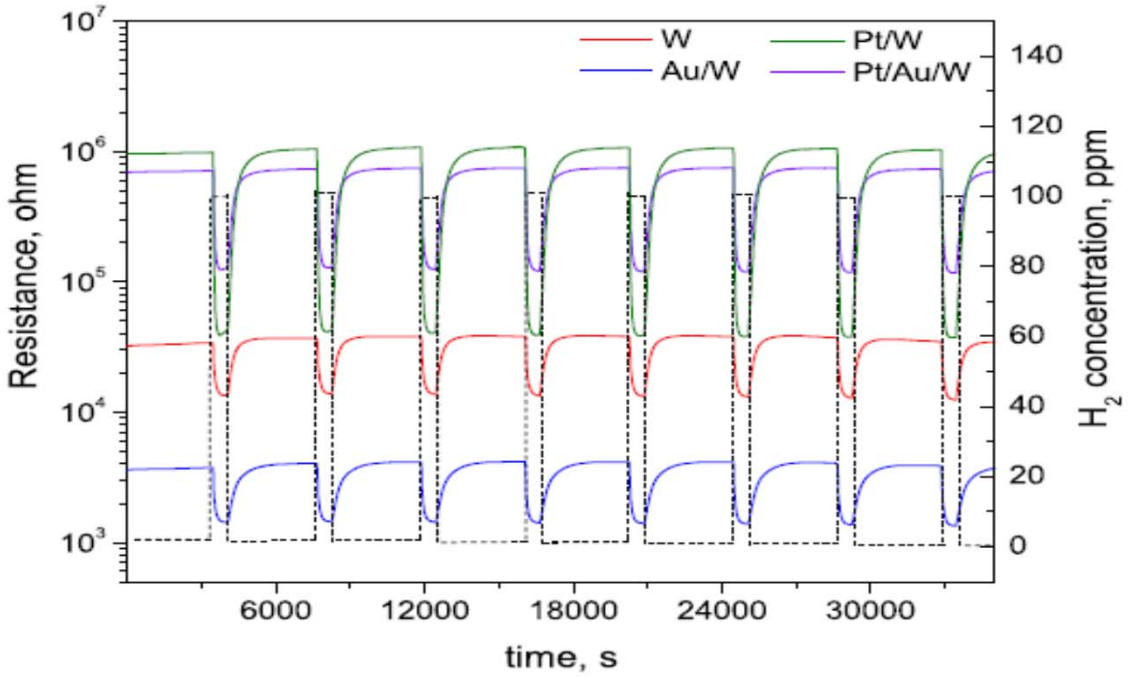

Pt-$WO_3$ NWs, operated at 250ºC

*Sensors and Actuators B 161 (2012) 406*
*Int. J. Nanotechnology, 10(2013) 455-469*
*Thin Solid Films, 548 (2013) 703-709*

# MOX NW Sensors: Aerosol-Assisted CVD (VS)






Film resistance changes towards hydrogen 100 ppm at 250 ºC.

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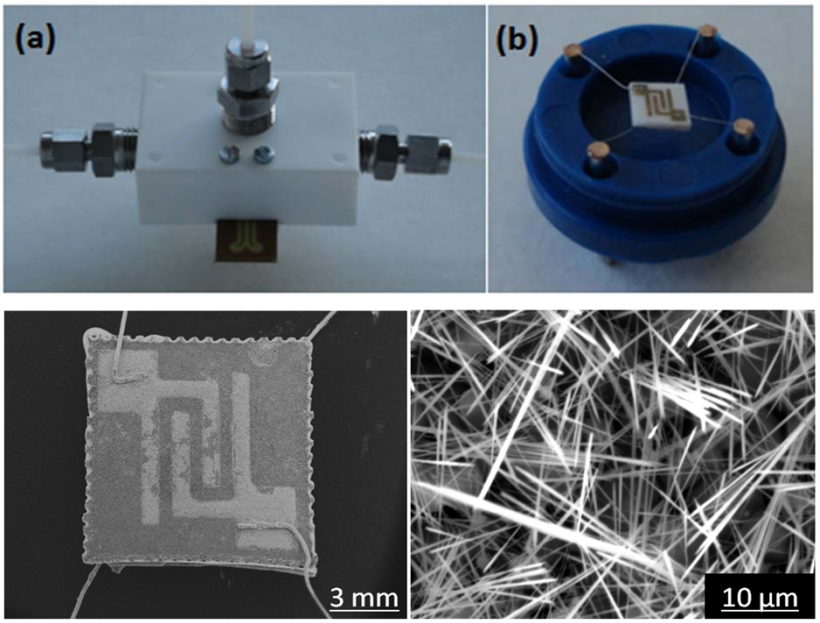
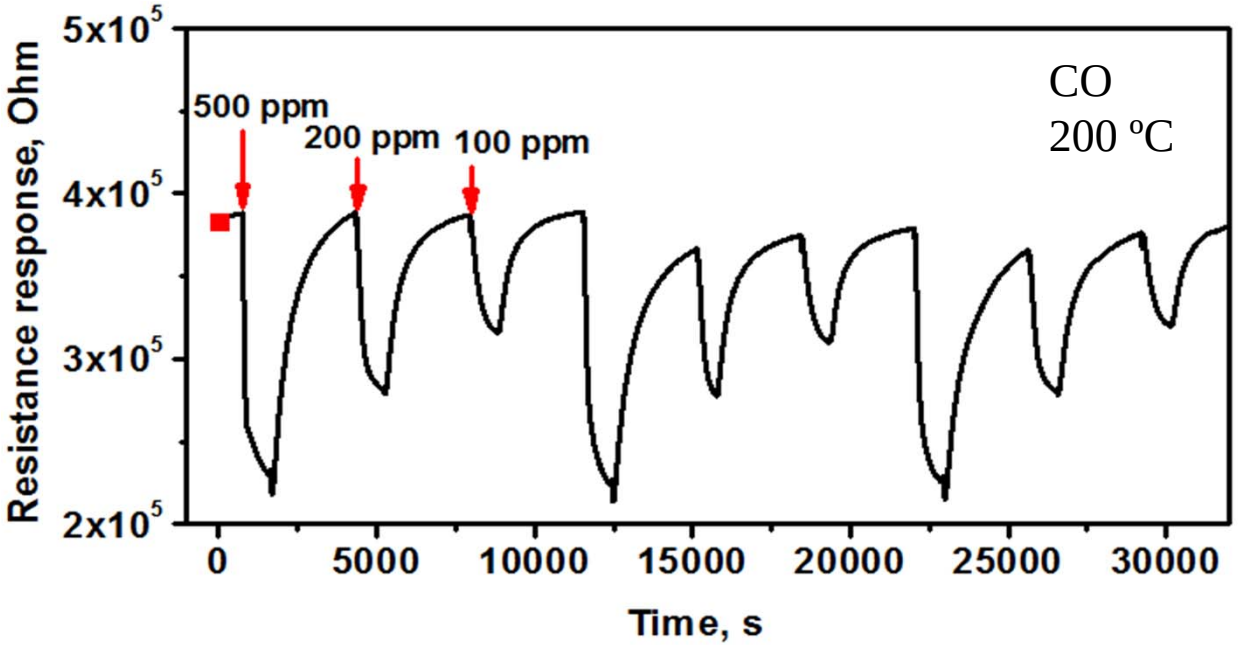
# MOX NW Sensors: Aerosol-Assisted CVD (VS)

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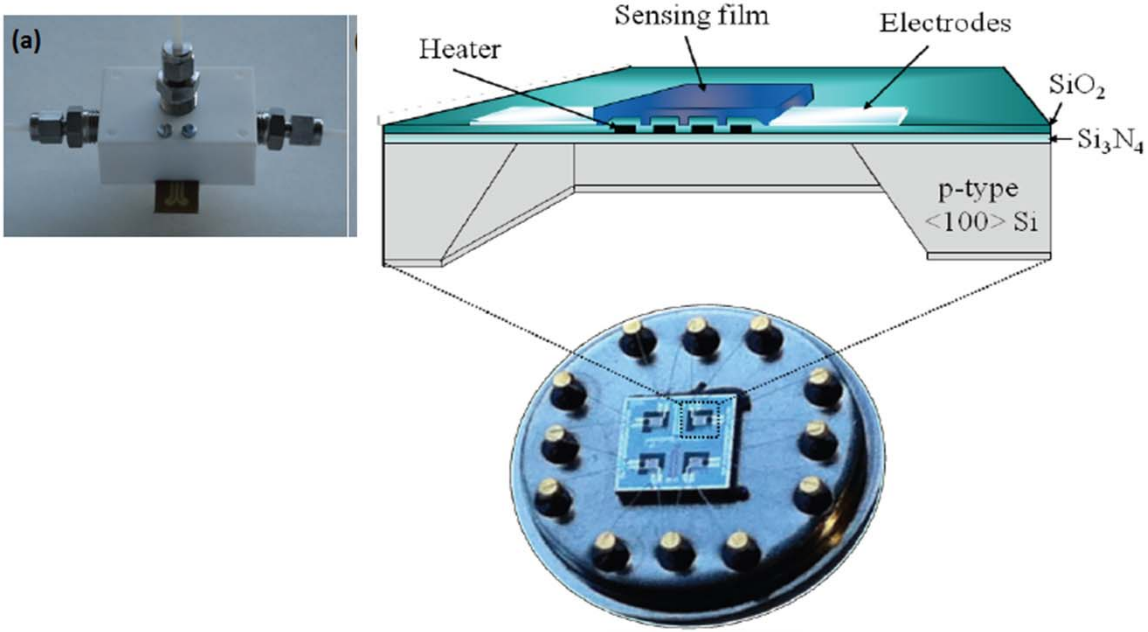


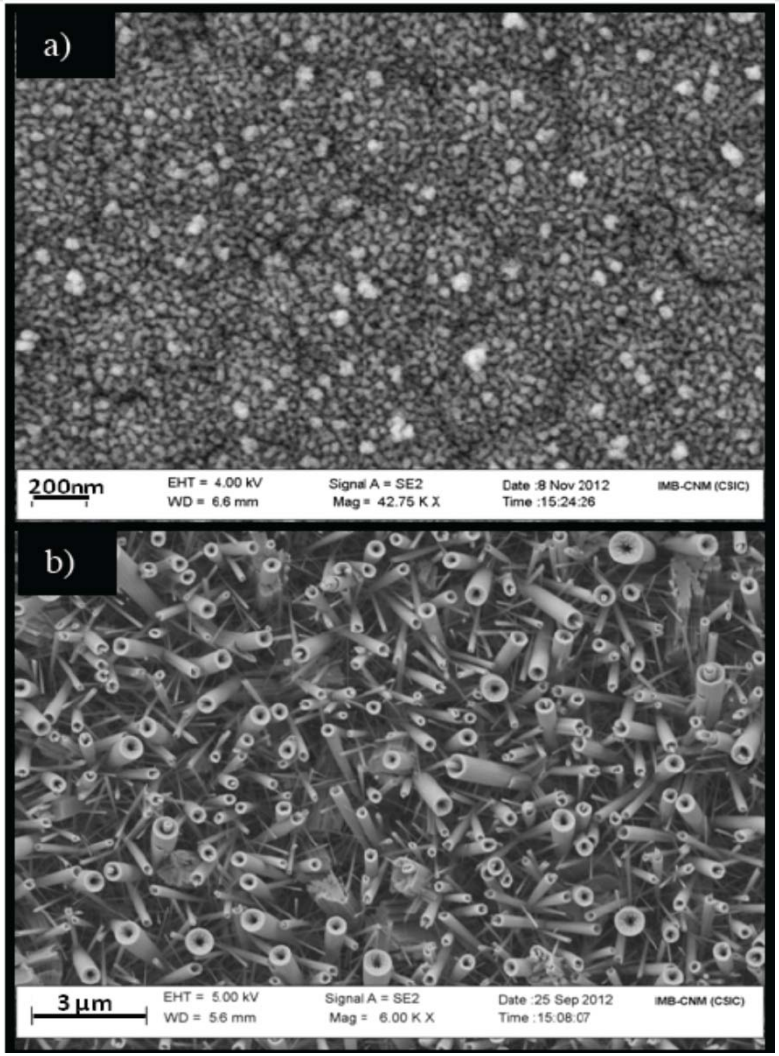


Direct growth of nanomaterials onto micro-hotplate transducers using the integrated heating element to reach and keep reaction temperature during growth.

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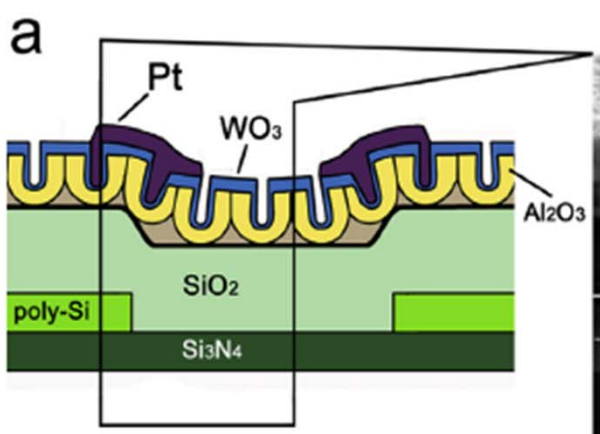
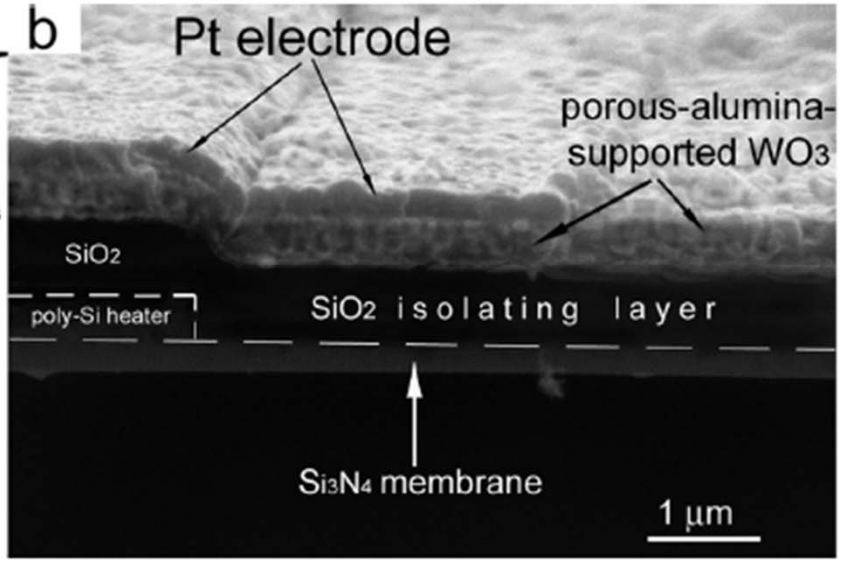
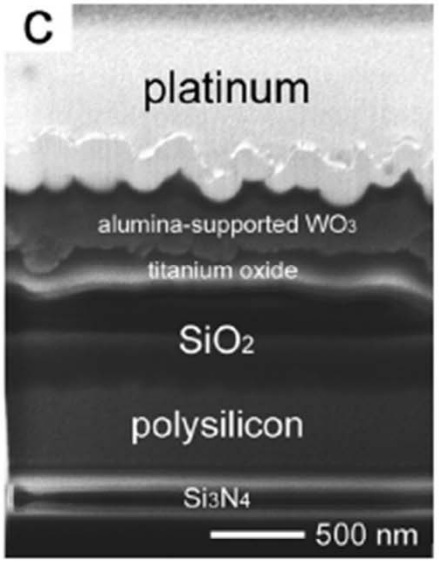
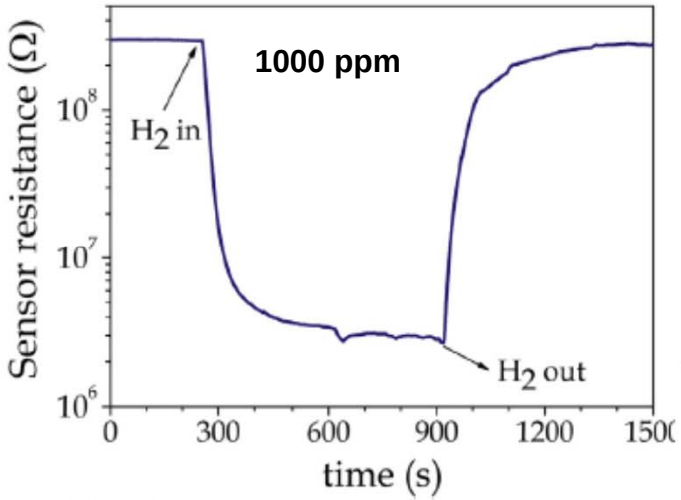
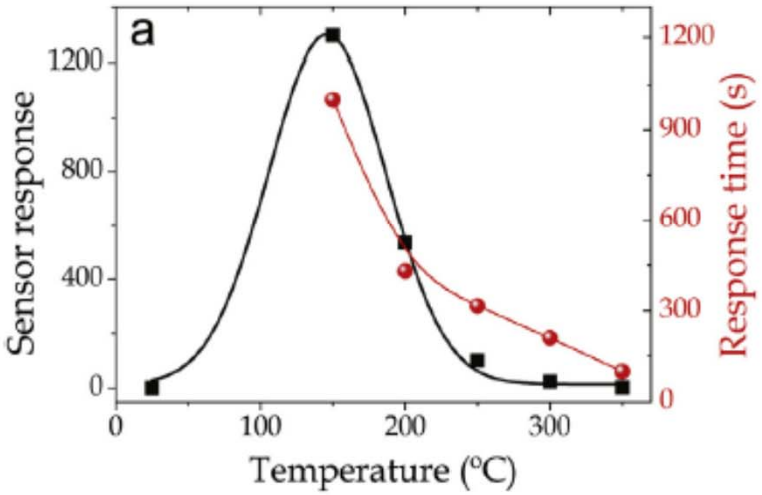
# MOX nanotubes by smart anodization

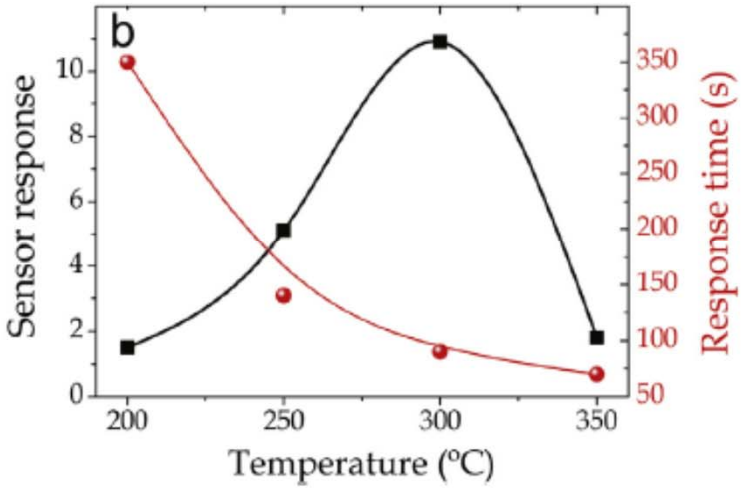



*International Journal of Hydrogen Energy 38 (2013) 8011*

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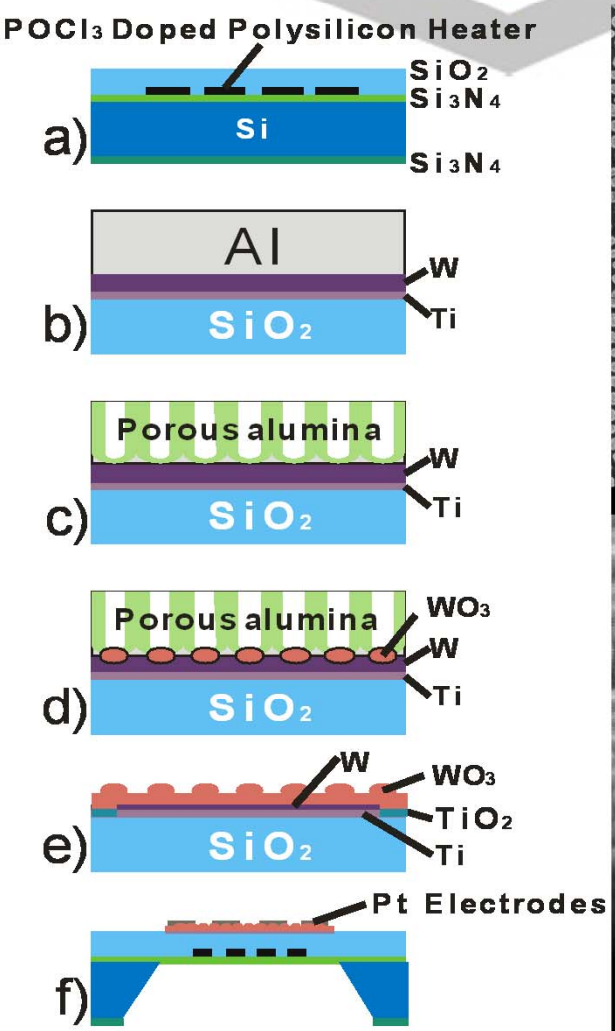
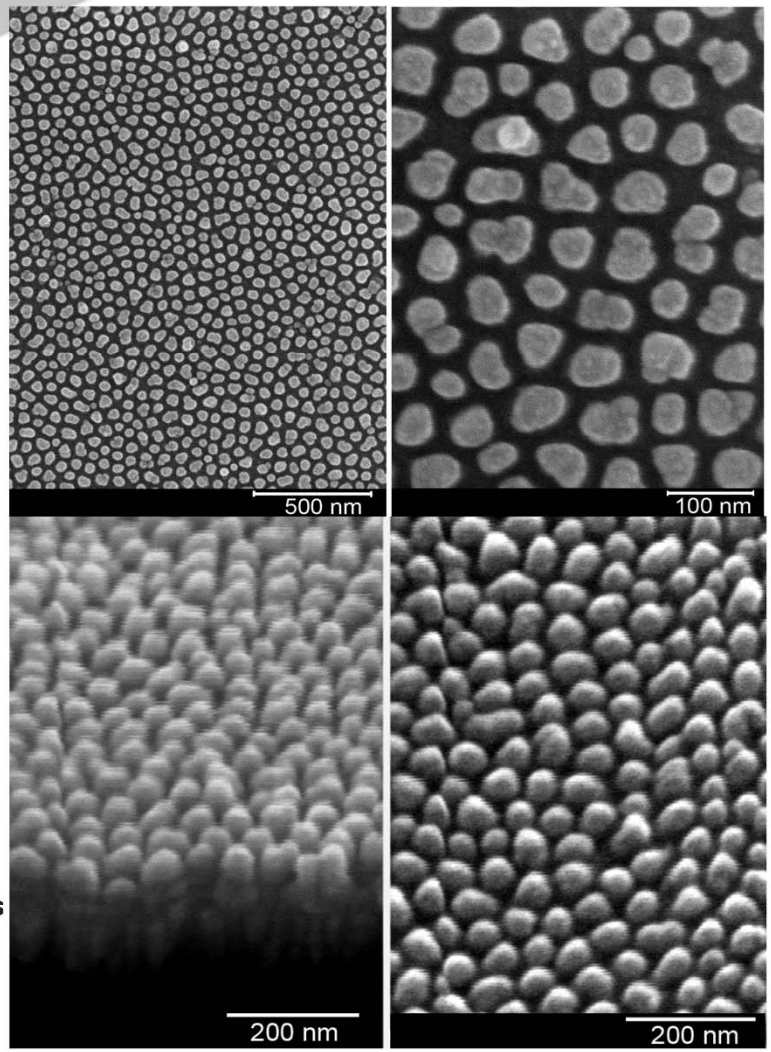
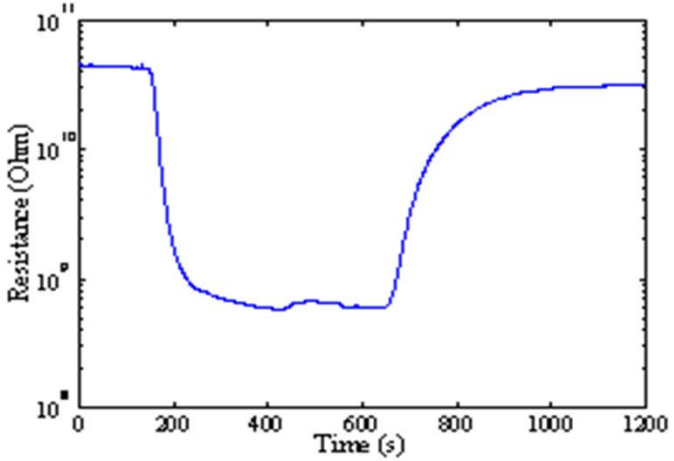
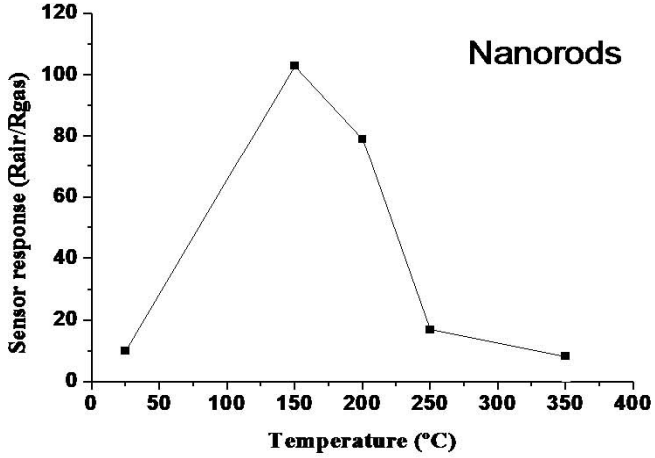
# MOX nanorods by smart anodization

- Gas microsensors based on smart anodisation (tungsten oxide, titania or niobia)




*Sensors and Actuators B, 149 (2010) 352*

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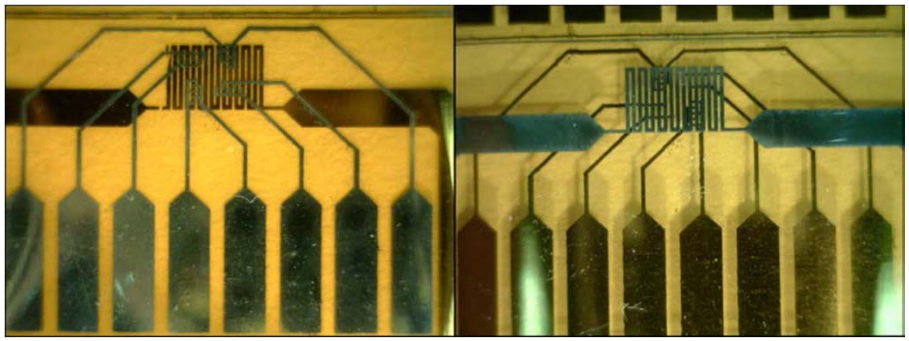
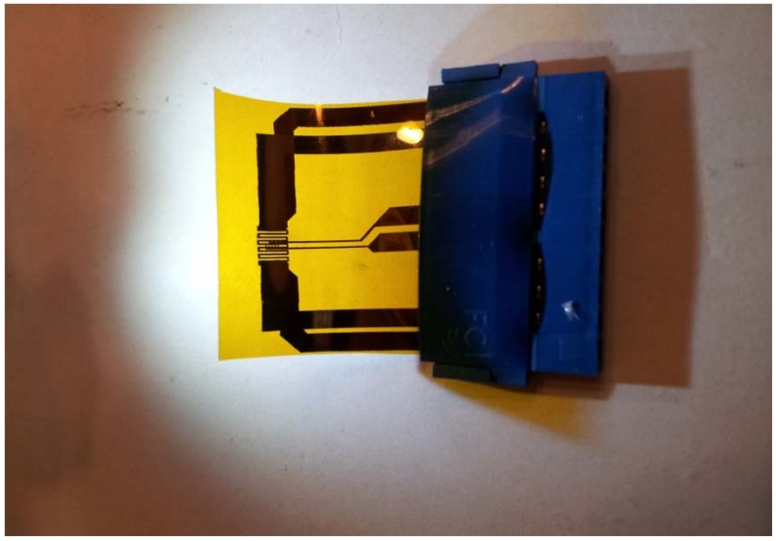
# Nanomaterials on flexible substrates: sensors on fabrics



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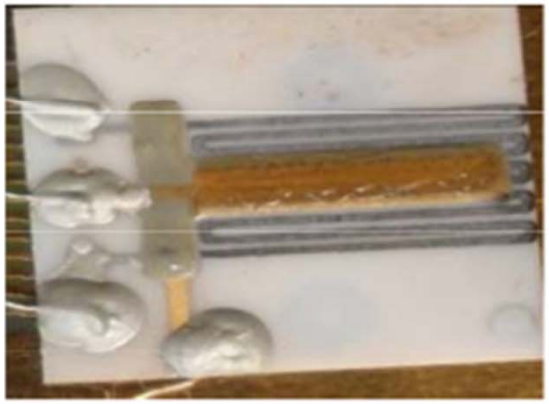
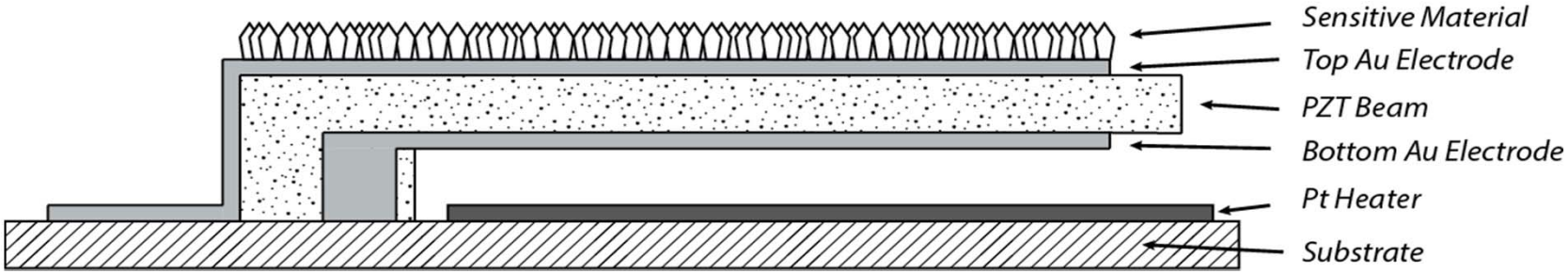
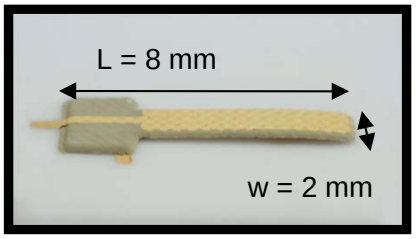
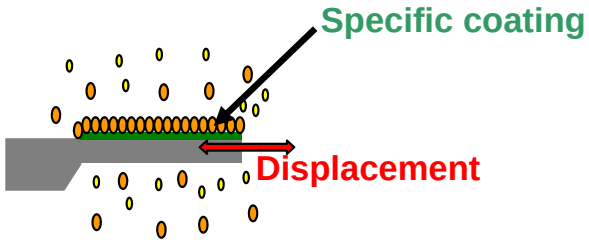
# Screen-pinted resonant sensors using CNTs and zeolites

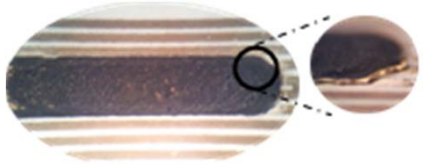
PZT cantilever





Surface functionalisation with CNTs /zeolites

Resonant frequency maximum at 65-70 kHz

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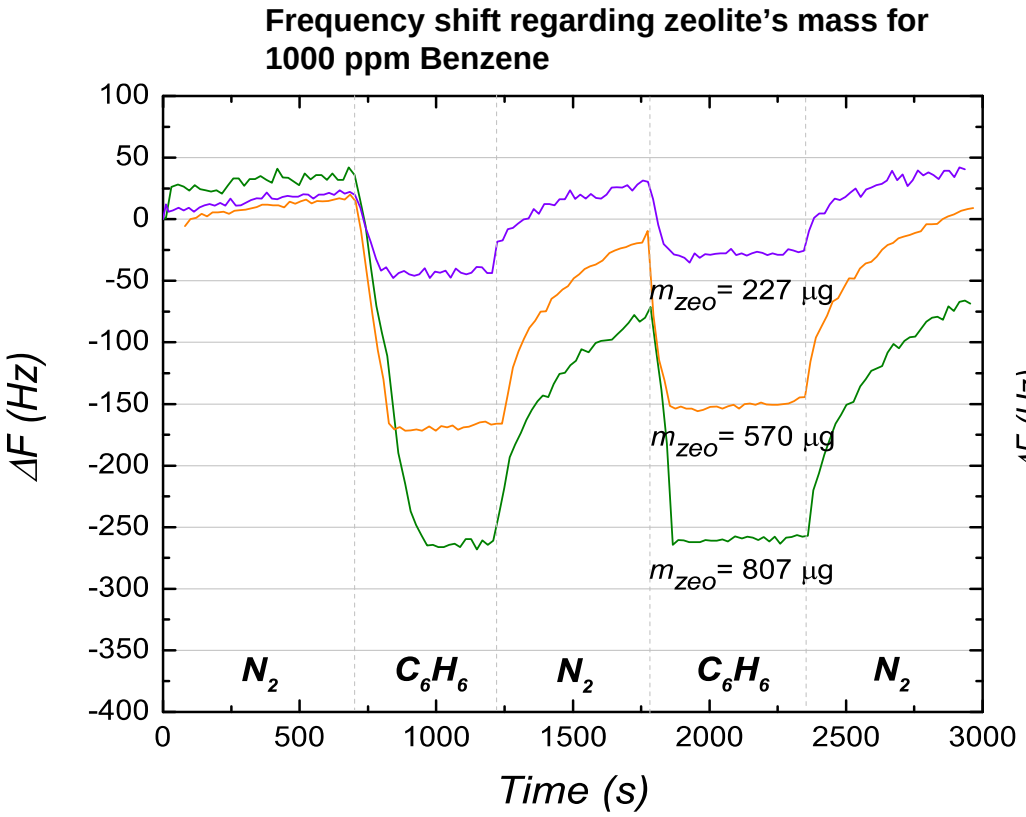
# Screen-pinted resonant sensors using CNTs and zeolites





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# Conclusions

- AA-CVD leads to highly stable low-dimensional MOX sensors (drift below 8% in 12 months)
- Resistive CNT sensors show *ppb* LOD for aromatics
- Smart anodization techniques are compatible with MEMs for the integration of MOX nanotubes and nanorods
- MOX and CNTs can *easily* be integrated in flexible substrates
- Our resonant sensors still less sensitive than our resistive sensors

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