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

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

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

Research and Innovation Needs of SIG3

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Vice-Chair, MC member

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ESF provides the COST Office through a European Commission contract

SIG3: Guidelines for Best Coupling Air Pollutants and Transducer

CONCLUSIONS

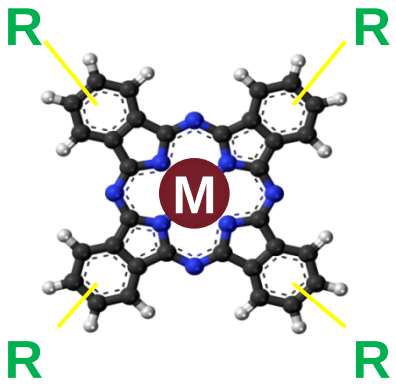
From Cambridge meeting in dec. 2013

Suggested R&I Needs for future research to Action WGs/SIGs General Assembly

- **Research directions as WGs R&I NEEDS for Action TD1105:**

- Coupling air pollutants to transducers generally overlooked
- Detecting pollutants at required levels (e,g, ppb for toxic gases, detection of nanosized PM)
- Sensing materials based inks for fully printed sensors
- Appropriate testing of sensors under realistic conditions to speed up development time.

Scientific approach for sensor development



Metallophthalocyanines

- π-electron delocalization
- High aromaticity
- Easy functionalization at periphery

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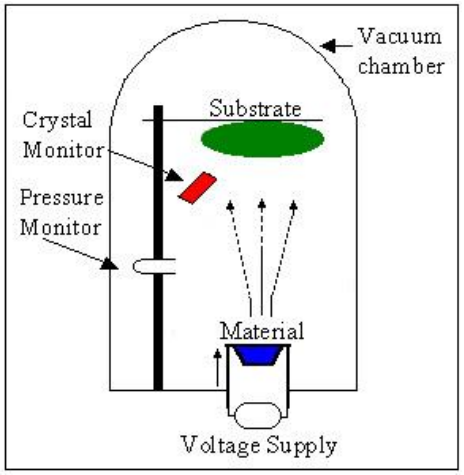
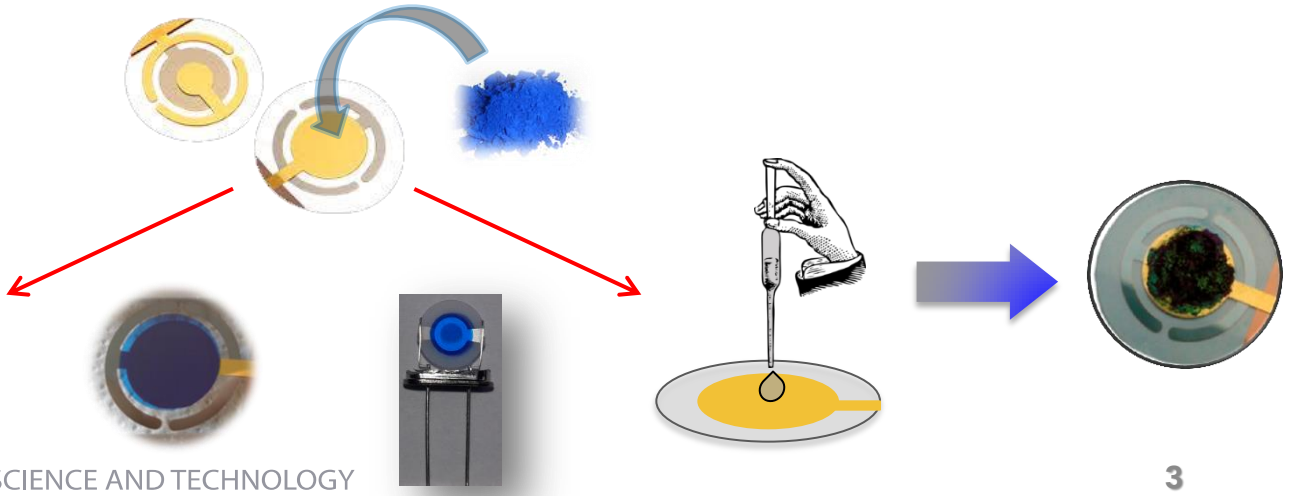
Aromatic properties ⇒ **pi-stacking interactions with analytes**

Processability ⇒ **Compatible with several transducing modes**

Nature of interaction ⇒ **Quartz Crystal Microbalances**



Thermal evaporation



Phthalocyanines: effect of peripheral groups

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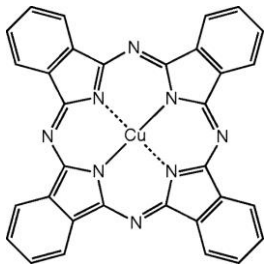
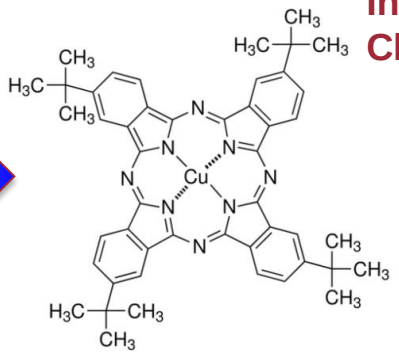
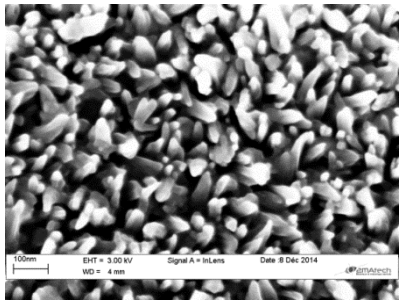
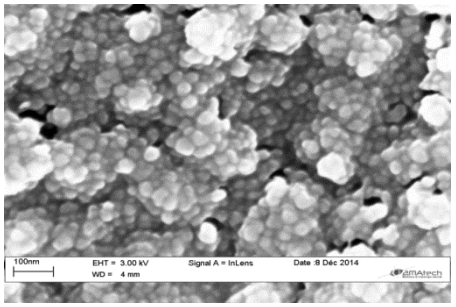
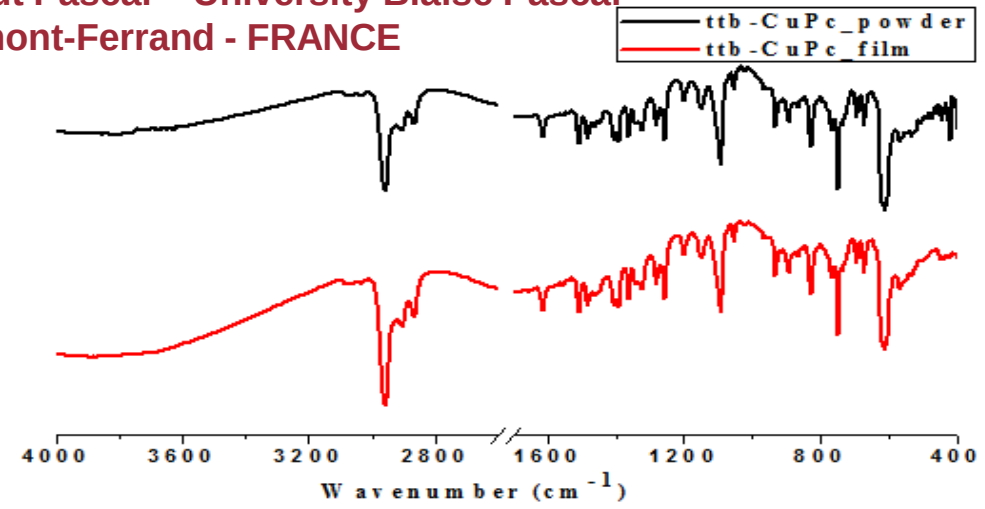






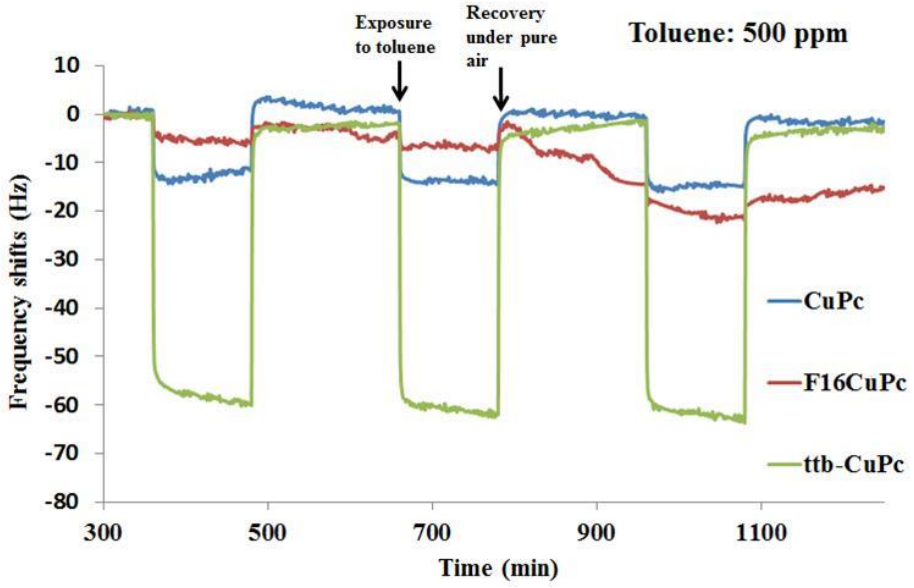




Same results with ttb-ZnPc

Strong influence of peripheral groups on gas/material interactions

Higher sensitivity to BTX



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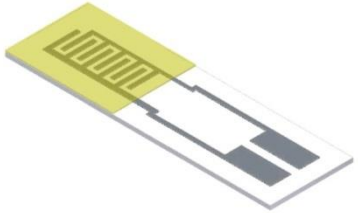
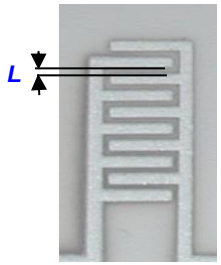
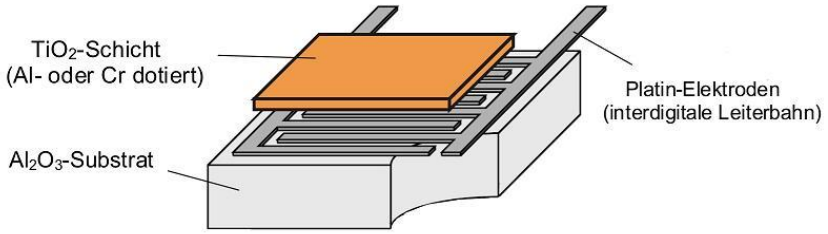
Applied Sensor Electrode Configurations

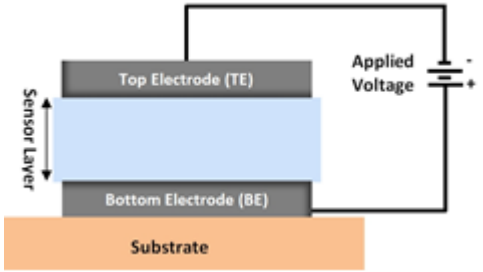
- Pt-InterDigital sensor Electrode (IDE)



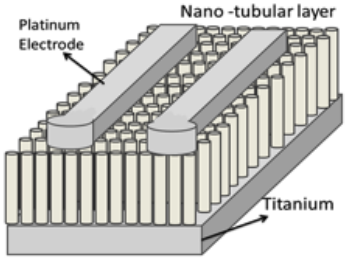


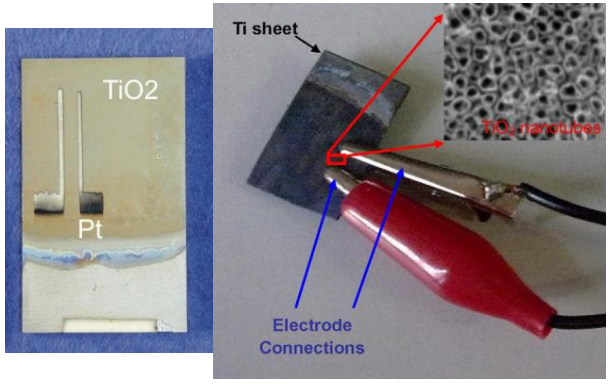


- Pt Top Bottom Electrode (TBE)



- // Pt sputtered Electrode (PE)





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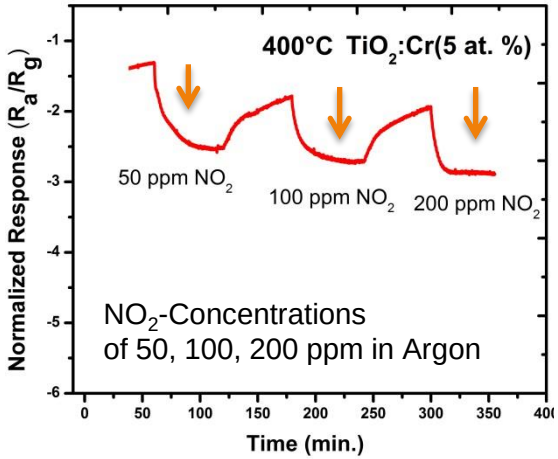
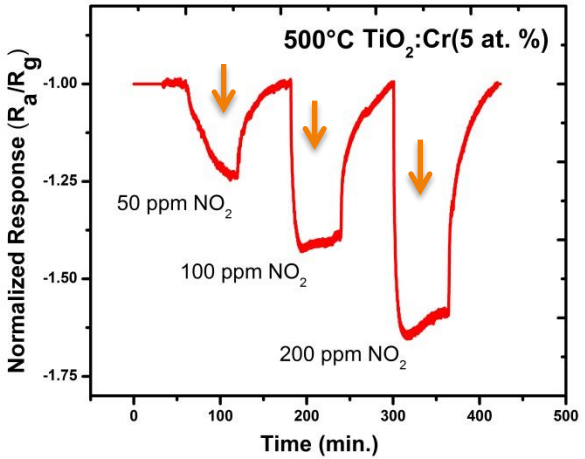
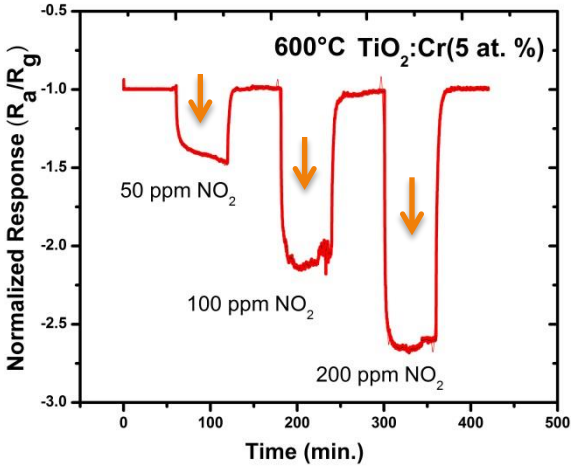
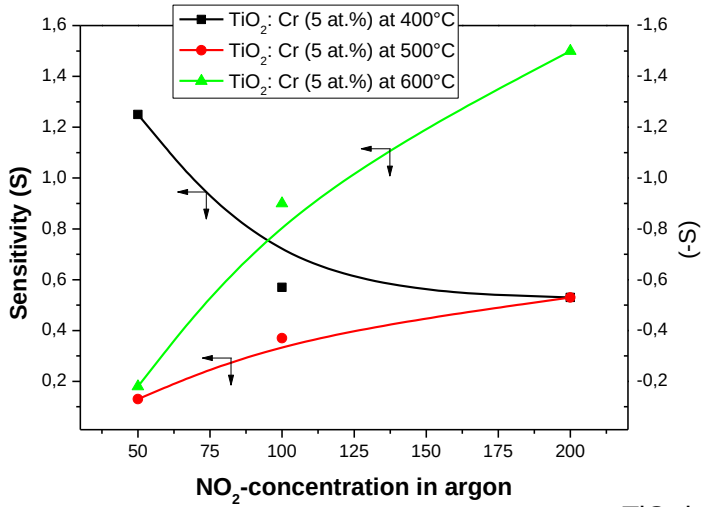
NO_2-response of TiO_2:Cr-layer sputtered on IDE









- NO_2-response is improved by doping sputtered TiO_2 with 5 at.% Cr (TiO_2:Cr) at temperatures above 400°C
- Sensor response has low resolution with concentration at 400°C

⇒ Best sensor response is achieved above 500°C

- TiO_2 layer thickness is 1.5 µm

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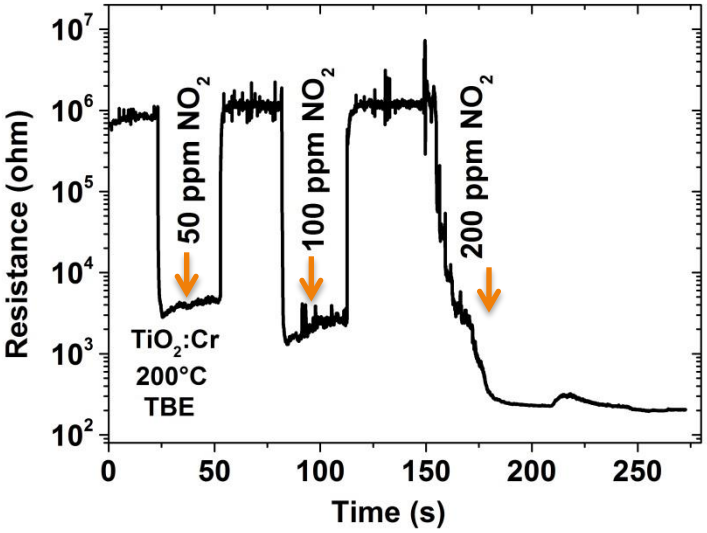
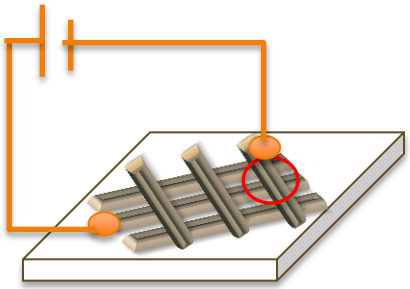
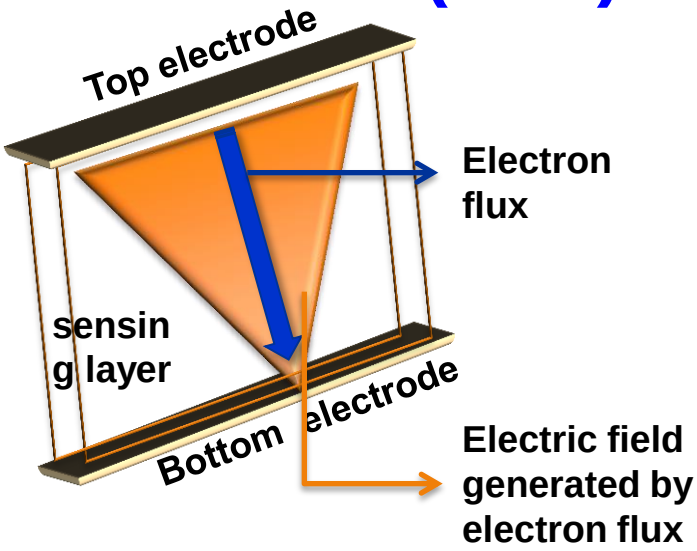
NO_2-response of TiO_2: 2.2 at.% Cr-layer sputtered between Top-Bottom Electrode (TBE)







- NO_2-response of TiO_2 with 2.2 at.% Cr (TiO_2:Cr) sputtered between TBE yields good sensor response with high sensitivity at temperatures as low as 200°C
- The sensitivity for 50 ppm NO_2 is a factor of $5X10^2$ higher than that achieved with same sensor material on IDE
- The baseline-resistance decreases on exposure to NO_2-concentrations above 200 ppm.
- The investigation to understand the cause of this and similar phenomena is under way.

- TiO_2 layer thickness is 1.8 µm

VOC SENSING PROPERTIES OF HYBRID NANOSTRUCTURES

Cleaning of FTO substrate

Hydrothermally Fabrication of TiO_2 nanorods on FTO

Polymer Coating on TiO_2 nanorods by spin coating

Sensor Device Fabrication of Heterostructures

Gas Test Measurements

Acetone (10 min.)
Isopropanol (10 min.)
Methanol (10 min.)

1 ml TnBT (HCl:Water)
150°C
18 h

Polymer P(S-*co*-CMS-C_{60}) (P3) **in chloroform**
2000 rpm
60 sec.

Au contacts
150 nm

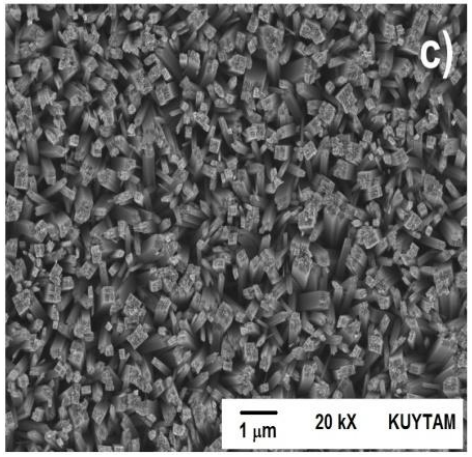
I-V
I-t

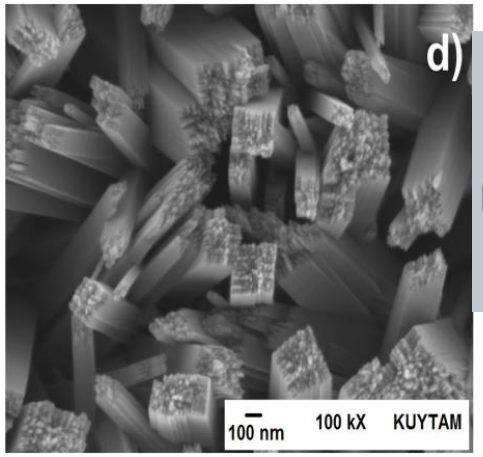
Working Temperature

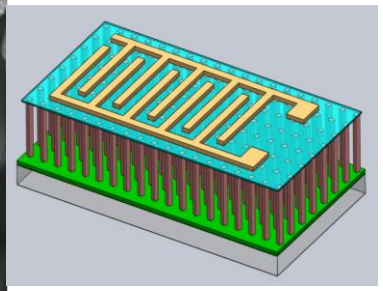
Different Gas Concentration

• VOC SENSING PROPERTIES OF HYBRID NANOSTRUCTURES ZZOZTURK

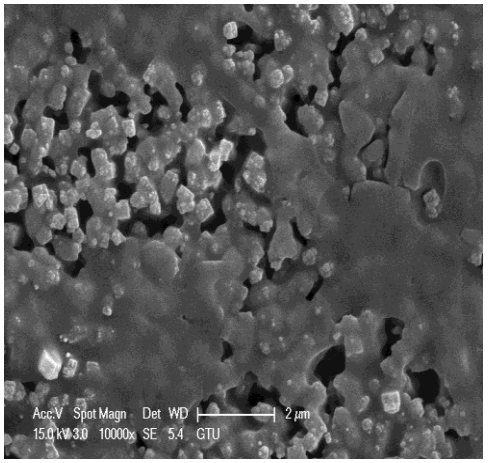
TiO_2 nanorods



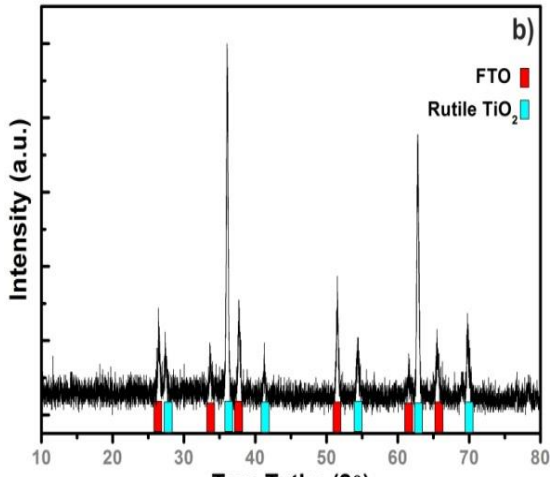


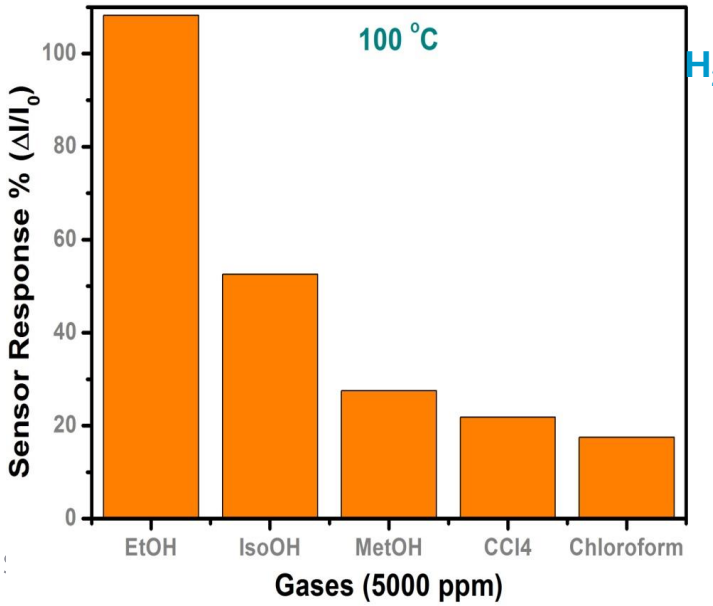


Polymer/TiO_2 nanorods

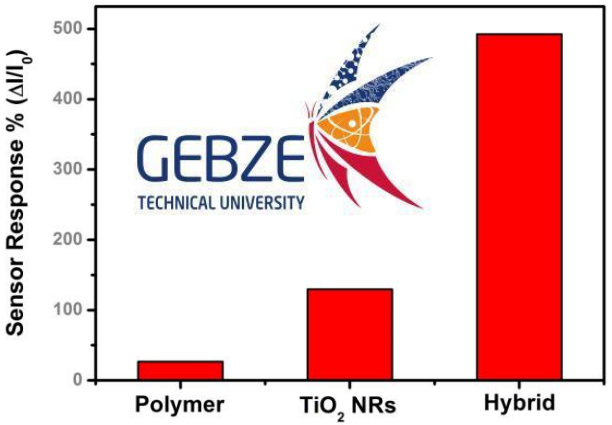


VOC Sensing Properties of Heterostructures





H_2 Sensing Properties Heterostructure



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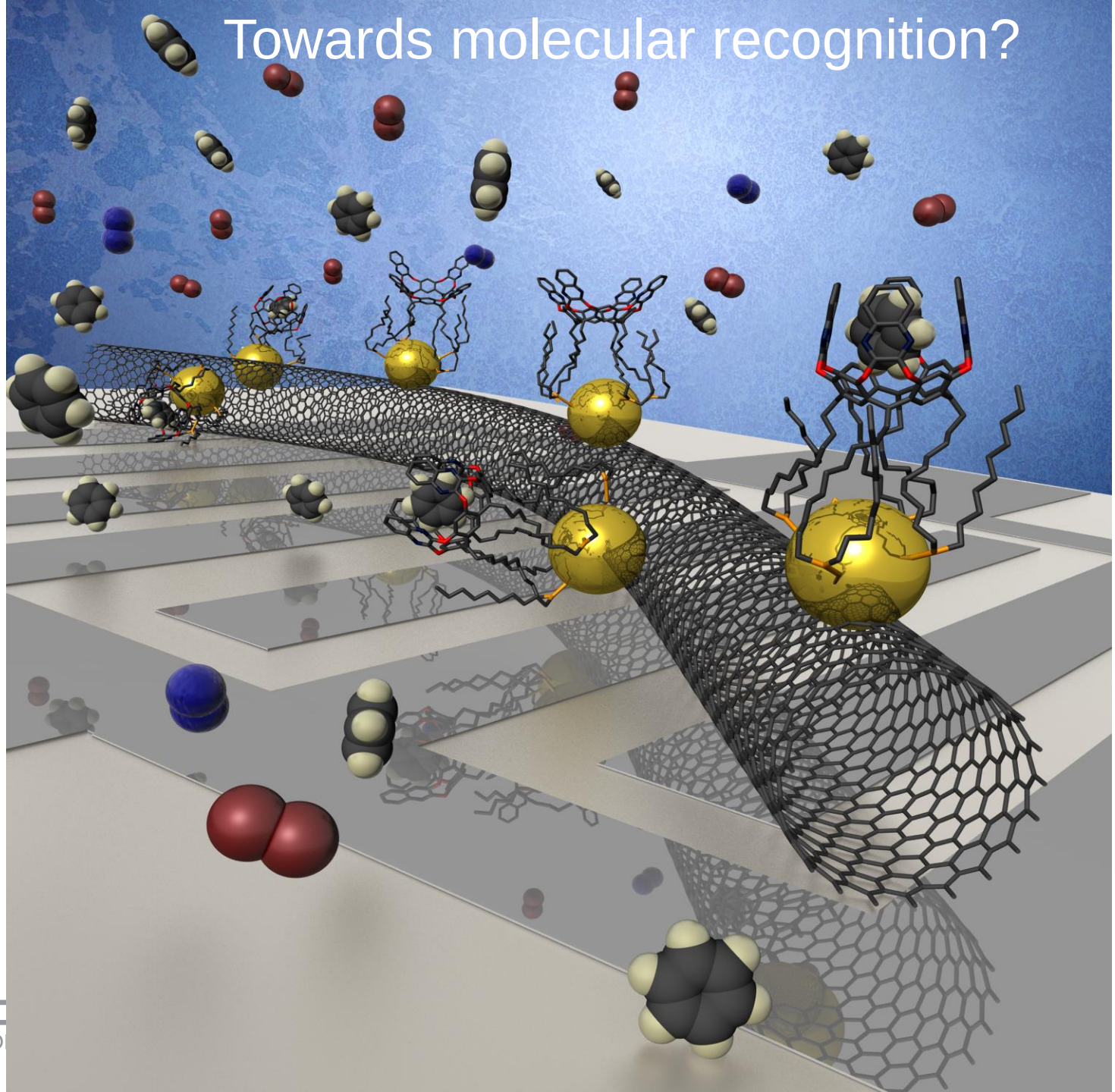
Towards molecular recognition?



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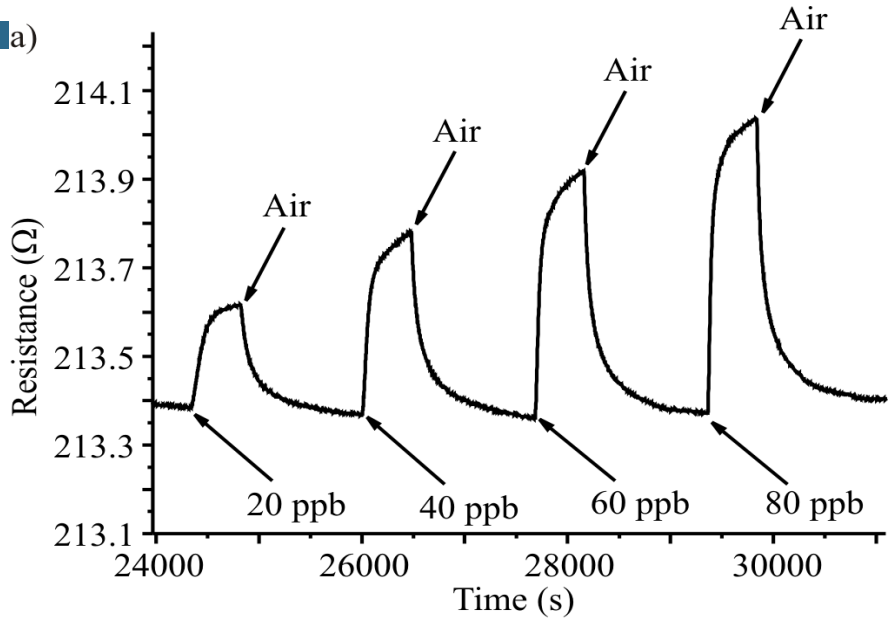
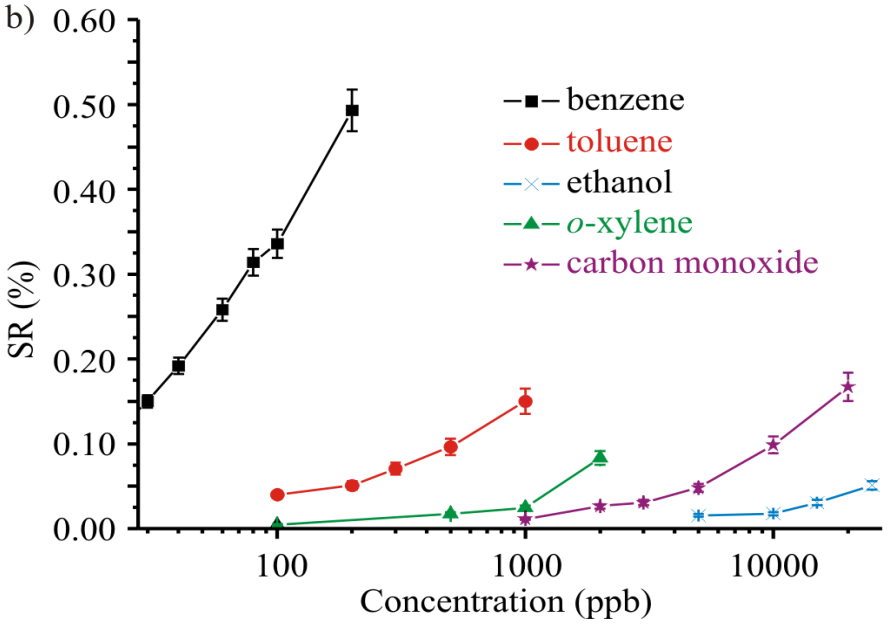
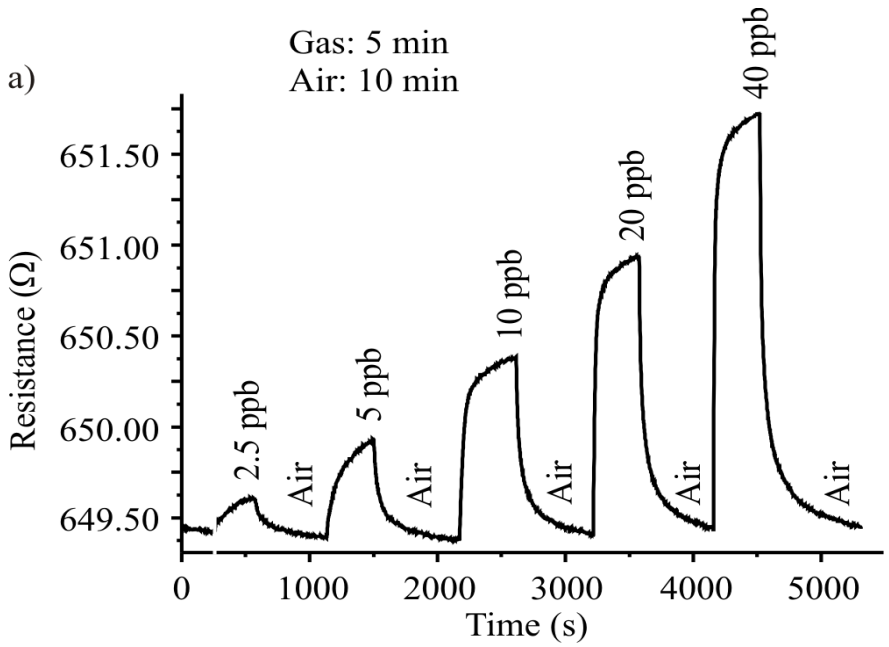
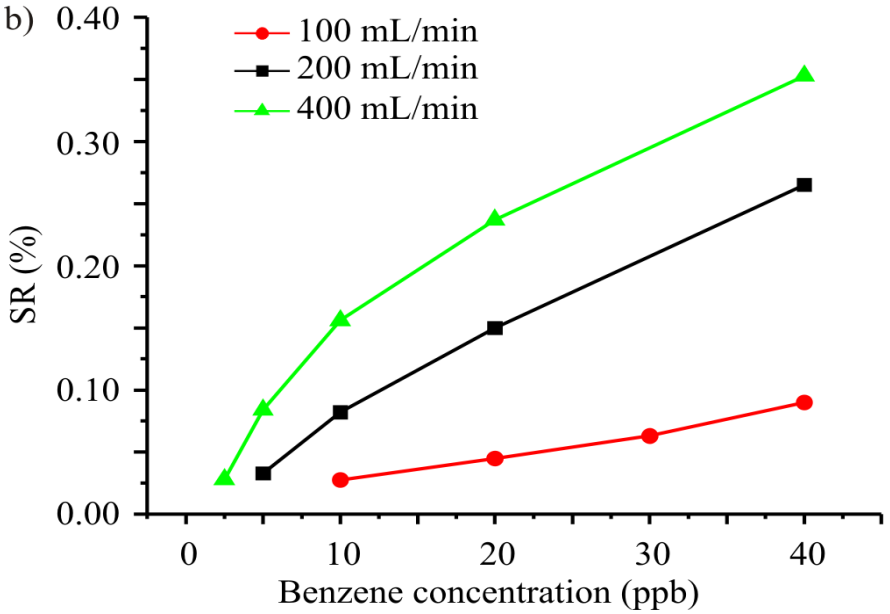
Detection results



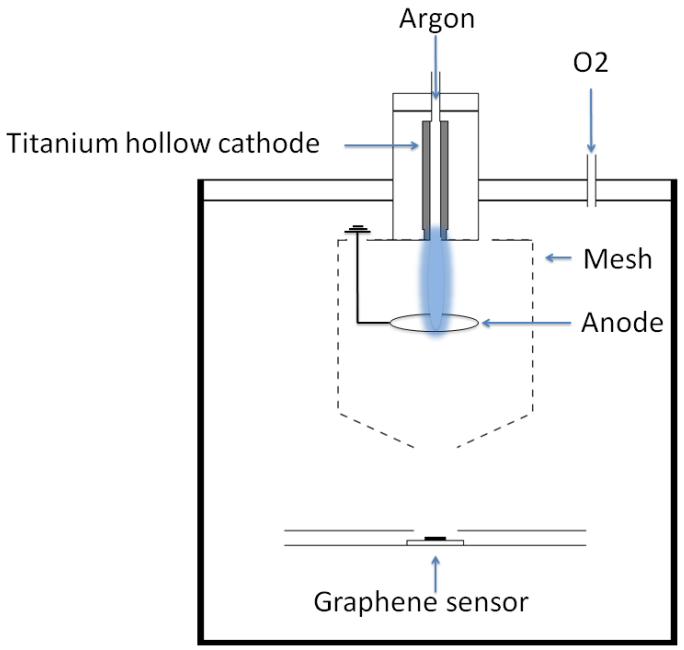


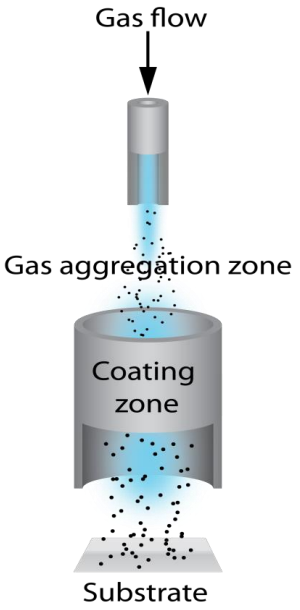




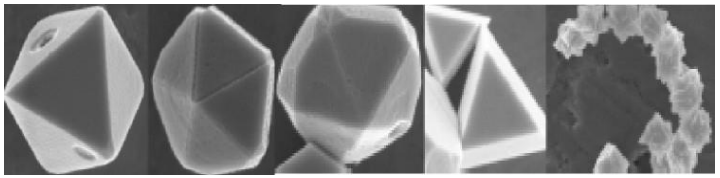
Designed Nanoparticles by Pulsed Plasma Hollow Cathode Sputtering

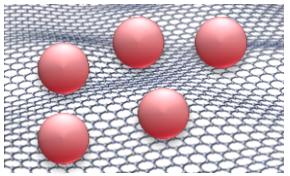
It is expected that decoration with different metals or metal-oxide nanostructures will allow careful targeting of selectivity to specific molecules





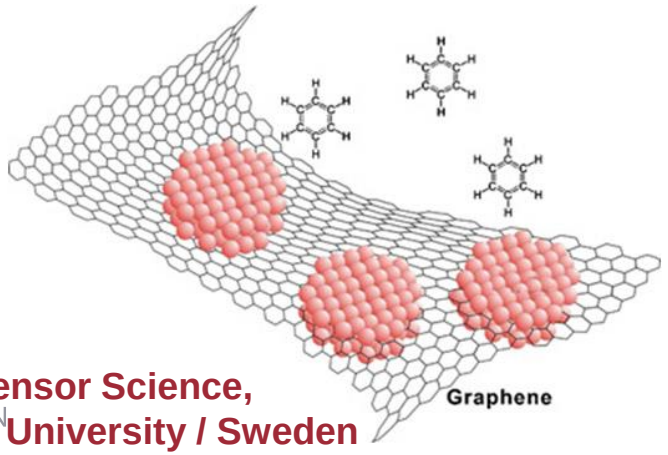
- ❑ Hollow-cathode based nanoparticle sputter process
- ❑ Highly reproducible thin film deposition technique
- ❑ Scalable

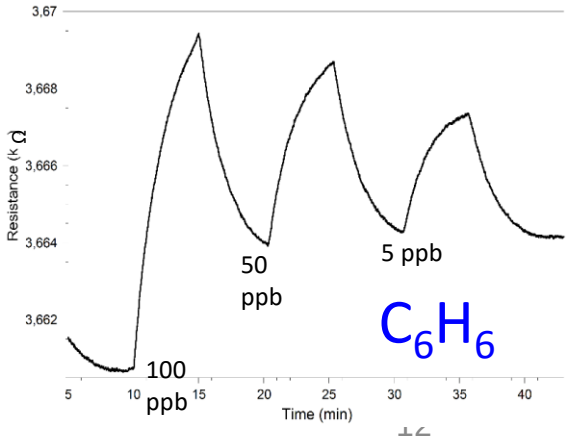




Ø > 50 nm

R. Gunnarsson, P&CP, IFM, LiU





- ❑ Utilize MOx sensitivity and selectivity, with EG as ultra-sensitive transducer
- ❑ TiO_2 and FeO NPs allow enhanced sensitivity towards formaldehyde and benzene

cost EUROPEAN COOPERATION IN SCIEN

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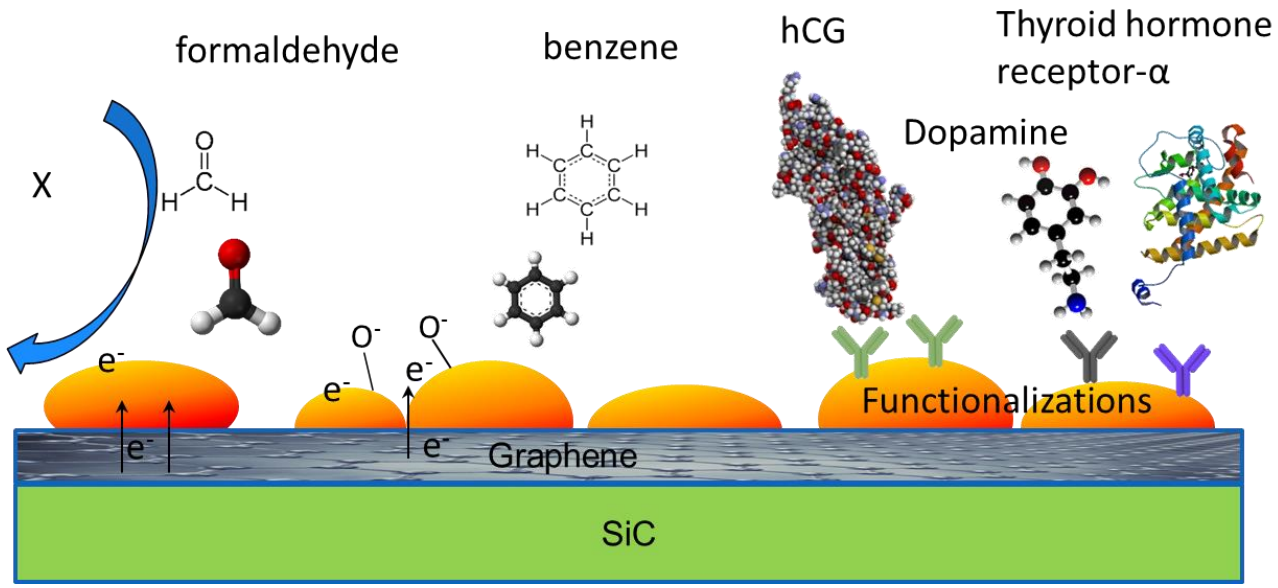
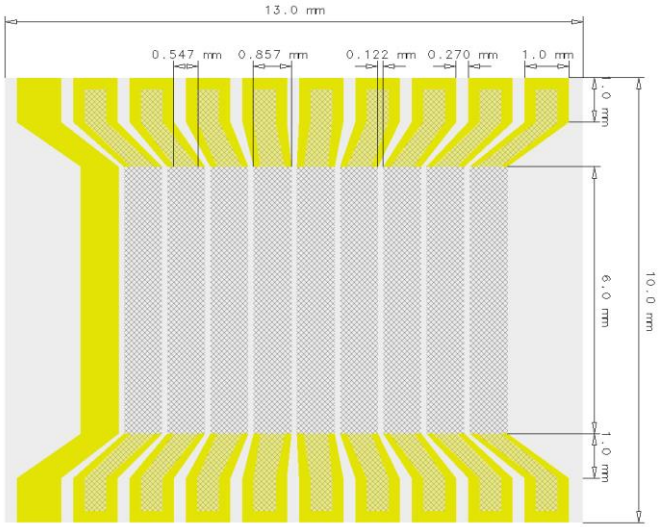
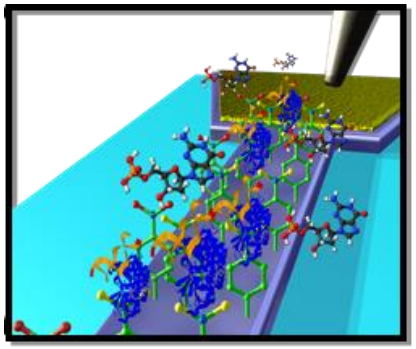
Epitaxial Graphene sensor platform







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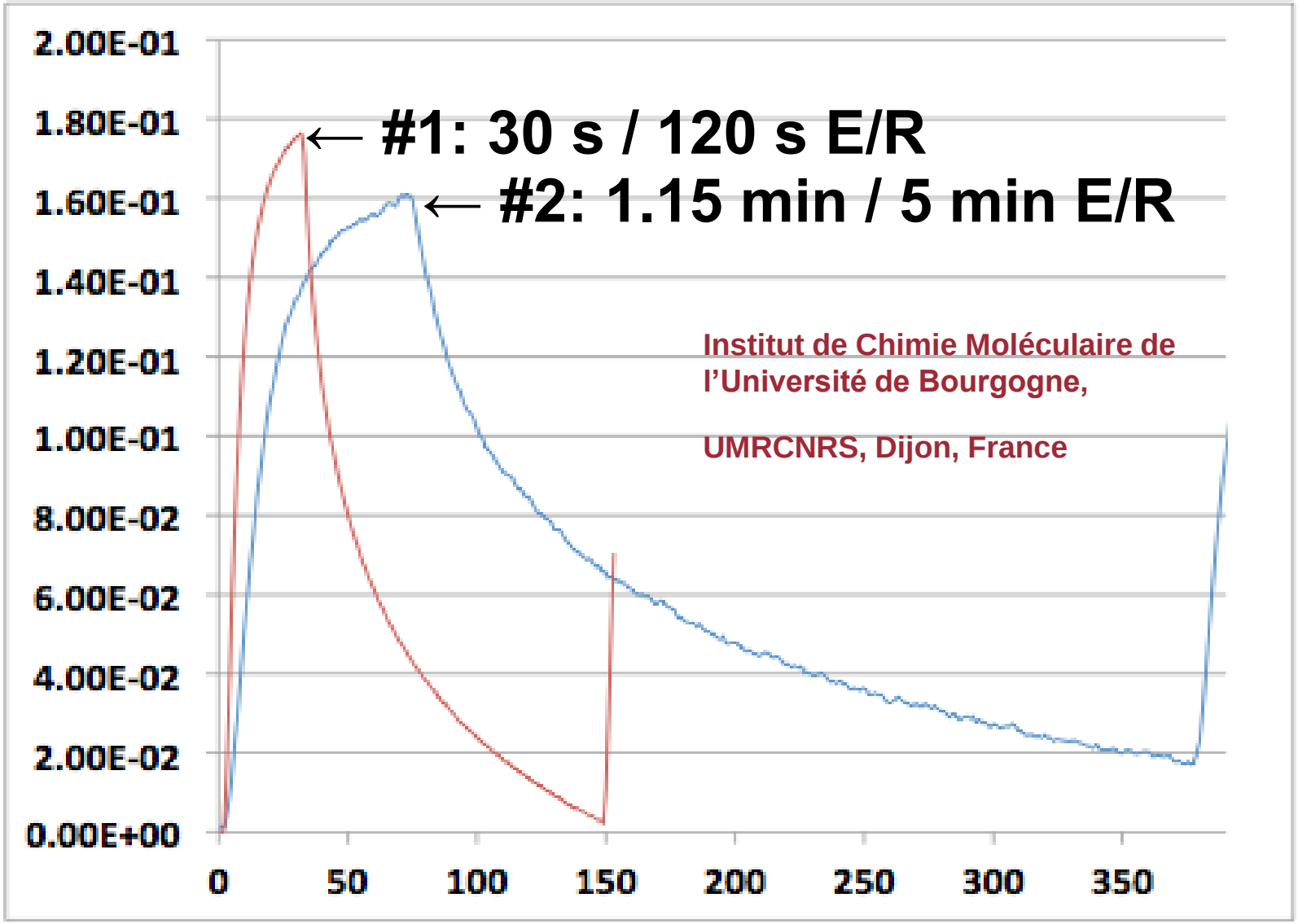
Sensor Relative Response
2.00E-01
1.80E-01
1.60E-01
1.40E-01
1.20E-01
1.00E-01
8.00E-02
6.00E-02
4.00E-02
2.00E-02
0.00E+00
0
50
100
150
200
250
300
350
Time (s)
← #1: 30 s / 120 s E/R
← #2: 1.15 min / 5 min E/R
Institut de Chimie Moléculaire de l'Université de Bourgogne,
UMRCNRS, Dijon, France