



# Selective Chemoresistive Hybrid MOX/CNT based VOC and Methane Sensors



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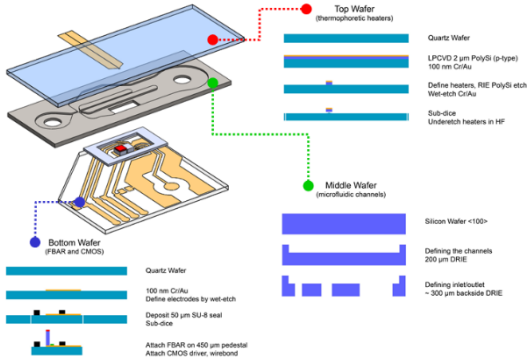


# Introduction to Air-Microfluidics

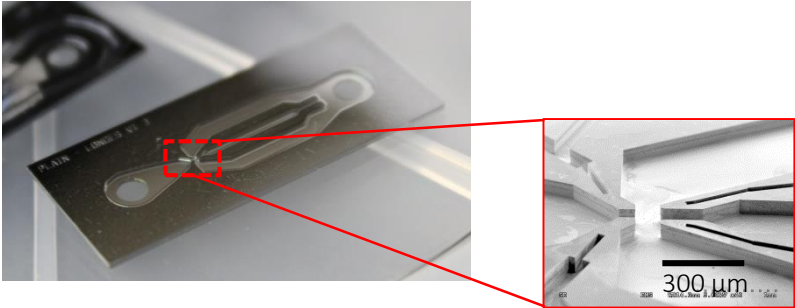
**Air-Microfluidics** is a multidisciplinary field, encompassing engineering, physics, chemistry, biochemistry, nanotechnology, and biotechnology, in which microfabricated systems use small volumes of fluids such as air and gas that are maneuvered through microchannels, or interact with microfabricated structures.



Kim et al., 2008



Paprotny et al., Sensors and Actuators A, Oct. 2013



Mahdavi pour et. al, AAAR 2014

# Air-Microfluidics Group (AMFG)



**Mission:** To conduct research in the use of micro electro mechanical systems (MEMS) technologies for reducing the size, cost, and power requirements of air-quality and gas sensors.

**Founded in 2012**

**UIC** UNIVERSITY OF ILLINOIS  
AT CHICAGO



Argonne  
NATIONAL LABORATORY

**Core Scientific Team:**

***Prof. Igor Paprotny (UIC)***

Prof. Alan Feinerman (UIC)

Prof. Rachael M. Jones (UIC/SPH)

Prof. Richard M. White (UCB)

Prof. Lisa Brosseau (UIC/SPH)

Dr. Ralu Divan (ANL)



[http://www1.ece.uic.edu/~paprotny/AMFG\\_index.html](http://www1.ece.uic.edu/~paprotny/AMFG_index.html)

**Semi-annual workshops (next one October 4<sup>th</sup> 2018 UIC)**

# Selected AMFG Projects

PM Badge: Wearable MEMS PM Sensor



Wearable Respirable PM Sensors

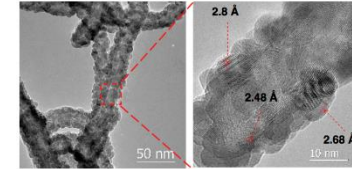
Nanostructure-based Unipolar Charger (PM)

**Opto Air-Microfluidics**

Dust Monitors for Underground Coal Mines

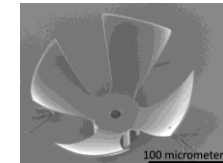


Nanomaterial-based Methane Sensors



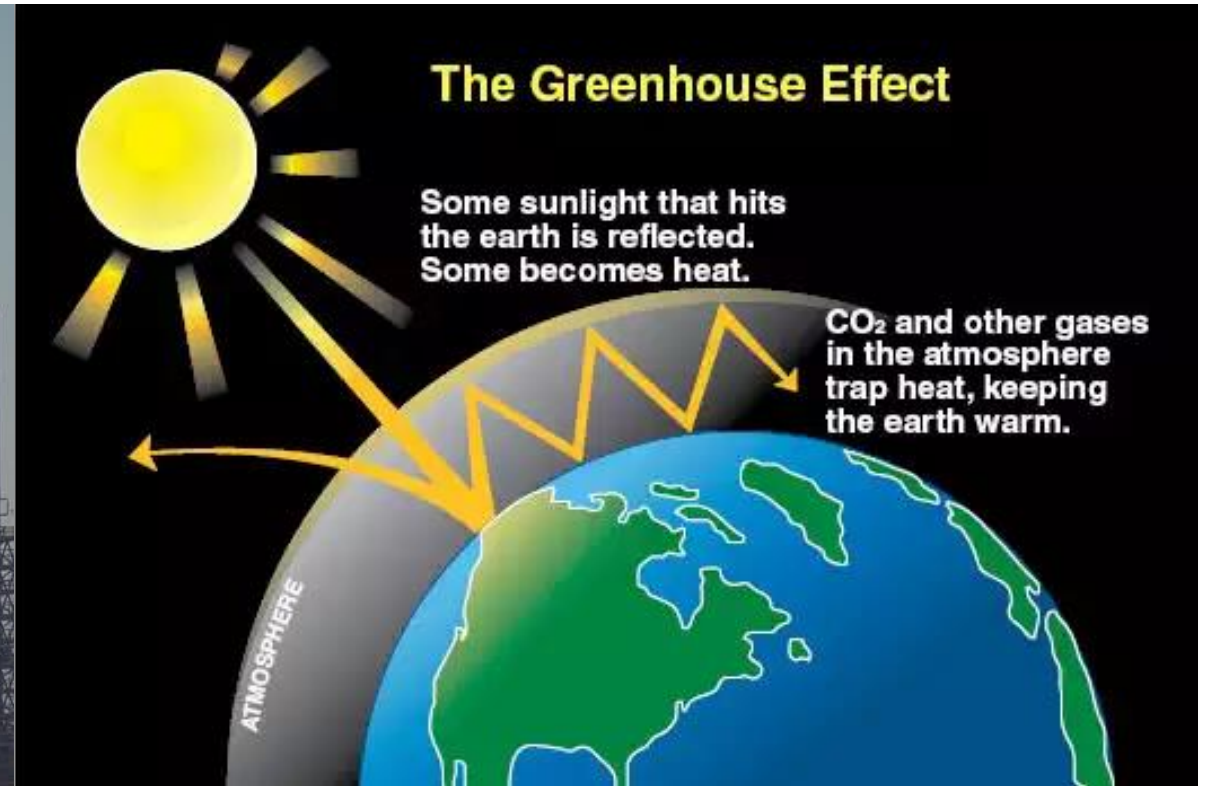
CNT-based VOC Sensors

MEMS Microfliers



**Bio-Aerosol lab-on-a-chip**

# Importance of Gas Detection



- Gas sensors are used widely in industry, health fields, residential homes, and protecting the ozone layer
  - Working with or just being around gases can be hazardous to our health

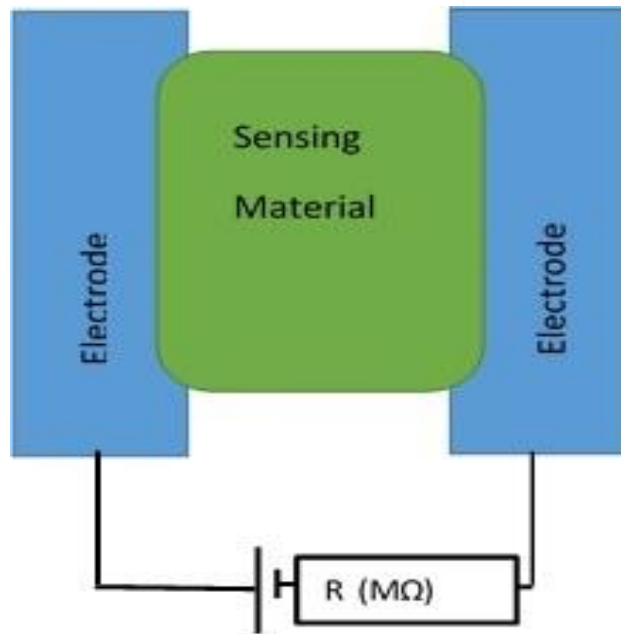
<sup>1</sup> "Smoke from a Chimney on Polluting the Environment." *Smoke From A Chimney On Polluting The Environment Stock Footage Video 736273* | Shutterstock. Web. 12 Sept. 2017.

<sup>2</sup> "What is climate change", *Department of Ecology, State of Washington*. Web. 24 July 2016.

# Chemoresistive Methane Sensors Using Nanomaterials

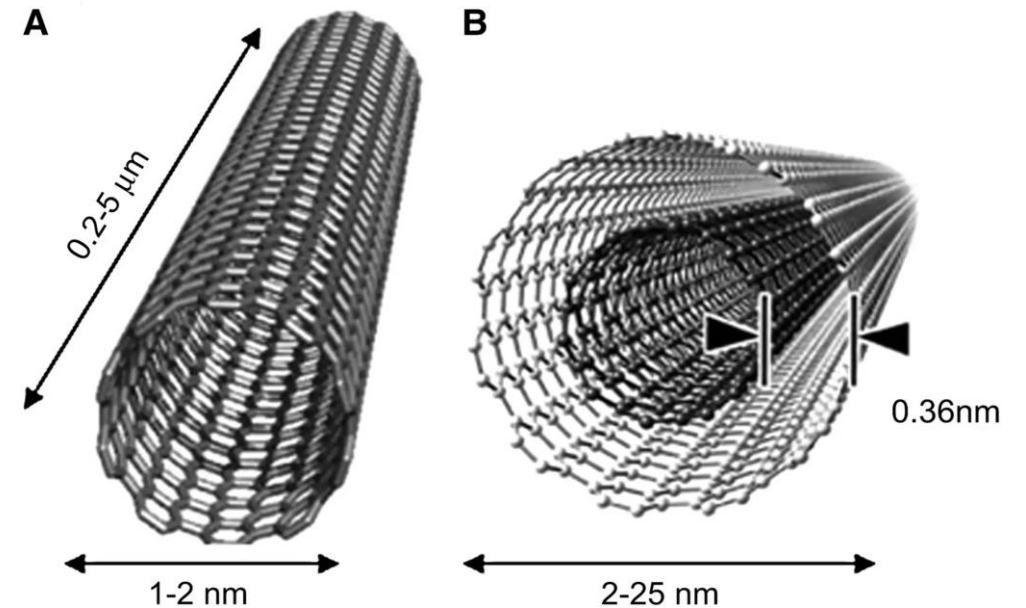
## Chemoresistive Sensors:

- High sensitivity (Change of Resistance)
- Low cost to produce
- Simple to fabricate



## Using Nano Materials (MWCNTs):

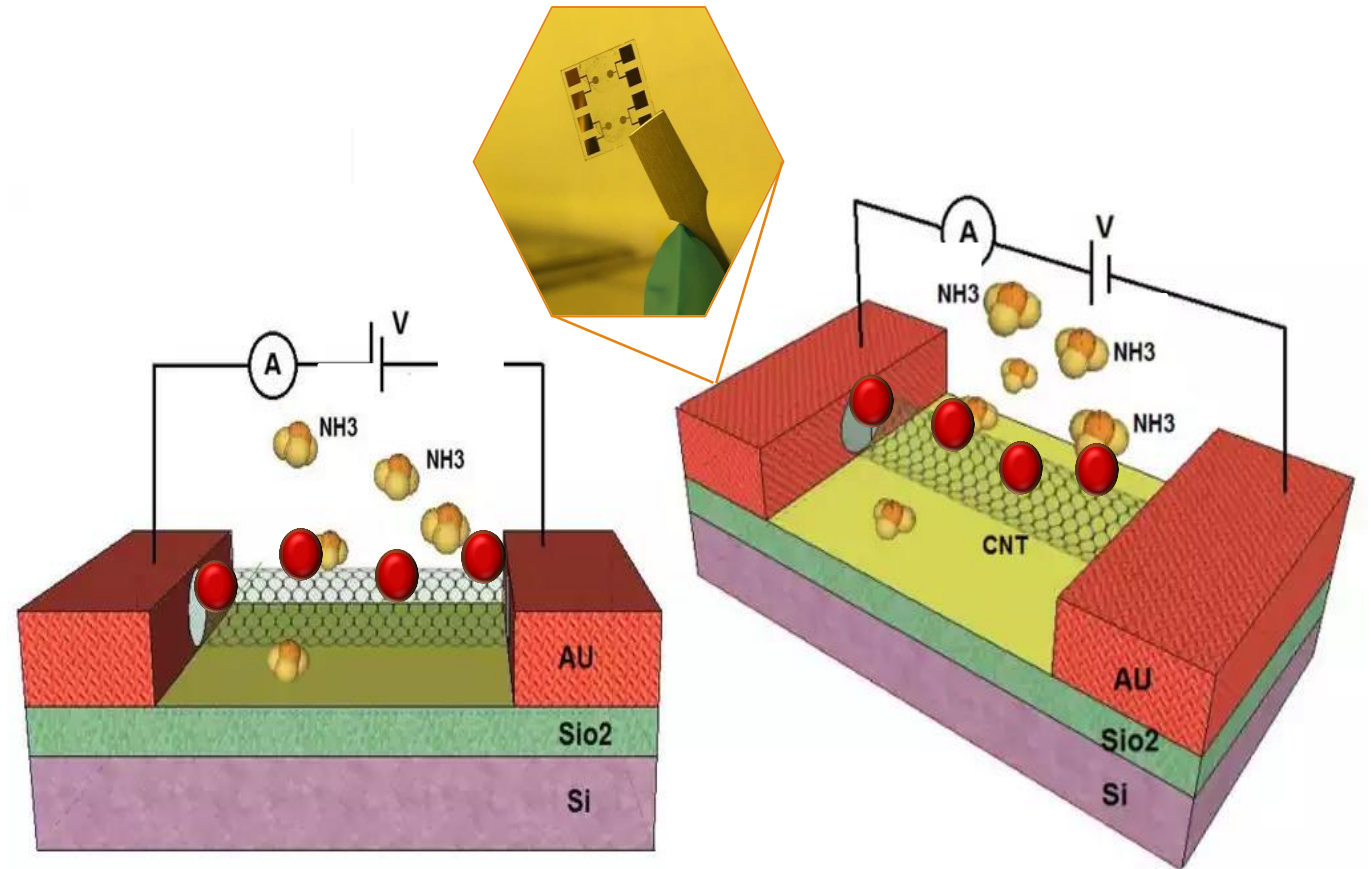
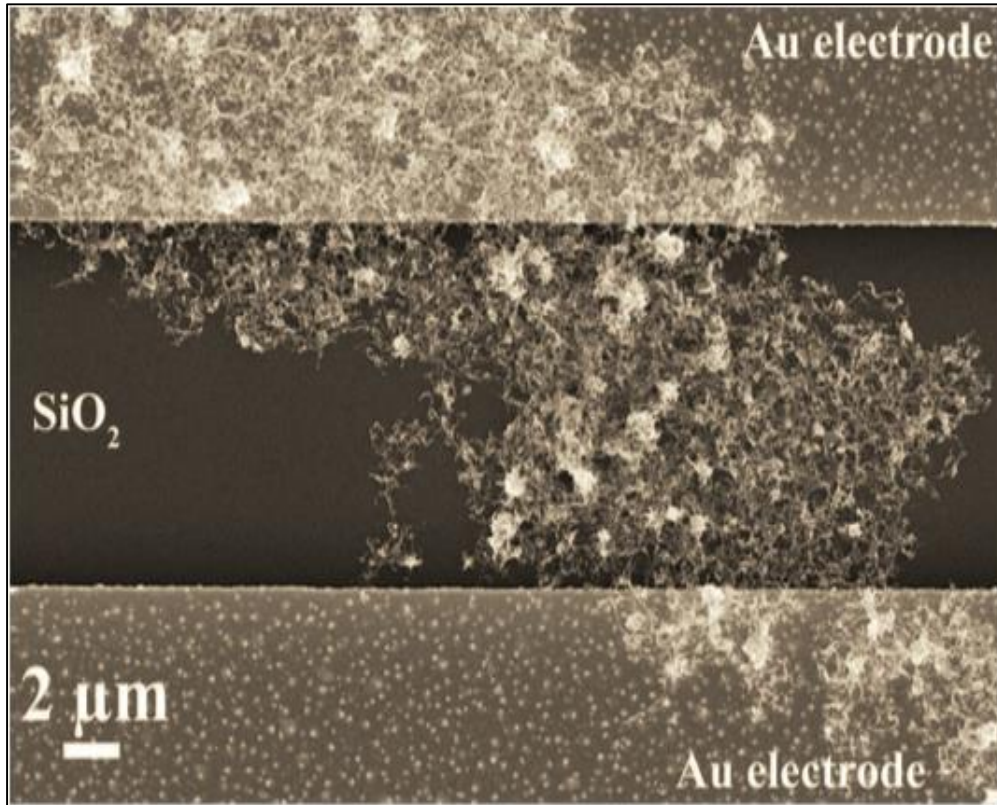
- High surface-to-volume ratio
- High sensitivity without the need of heat



<sup>1</sup>"Chemiresistor." *Chemiresistor - HowlingPixel*, howlingpixel.com/wiki/Chemiresistor. Web. 24 Sept. 2017.

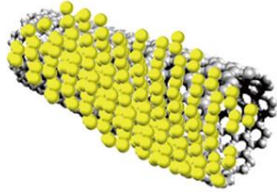
<sup>2</sup>Berger, Michael. "Functionalization of Carbon Nanotubes Is Key to Electrochemical Nanotechnology Devices." *Functionalization of Carbon Nanotubes Is Key to Electrochemical Nanotechnology Devices*. N.p., n.d. Web. 25 July 2016.

# Chemiresistive CNT-based Sensors



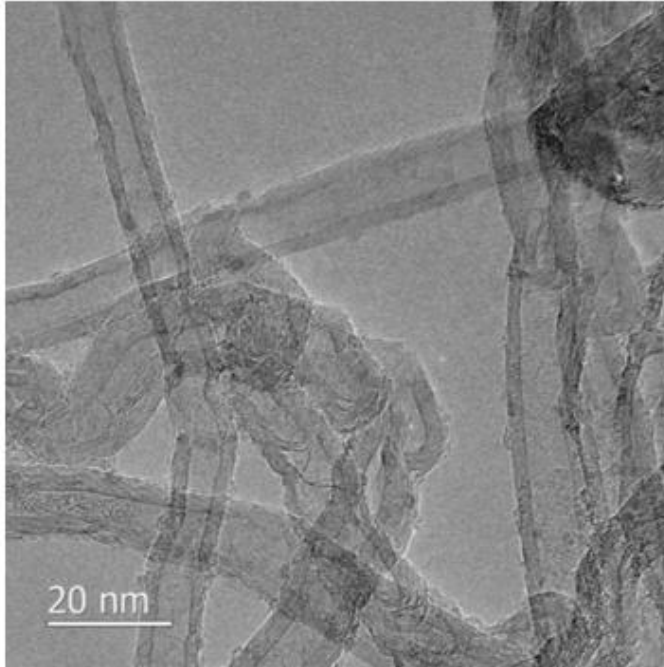
## Chemi-R Sensors Based on Composite MWCNT/ZnO

### Synthesis

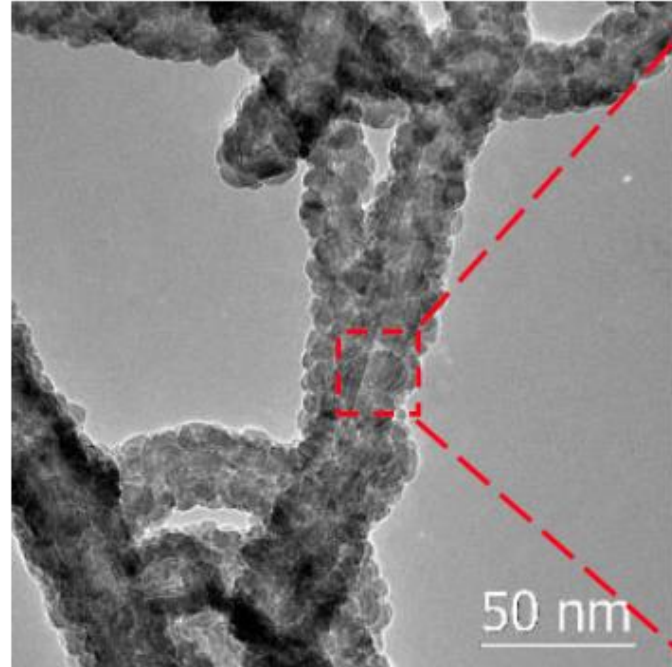


### ▶ ALD selective surface functionalization

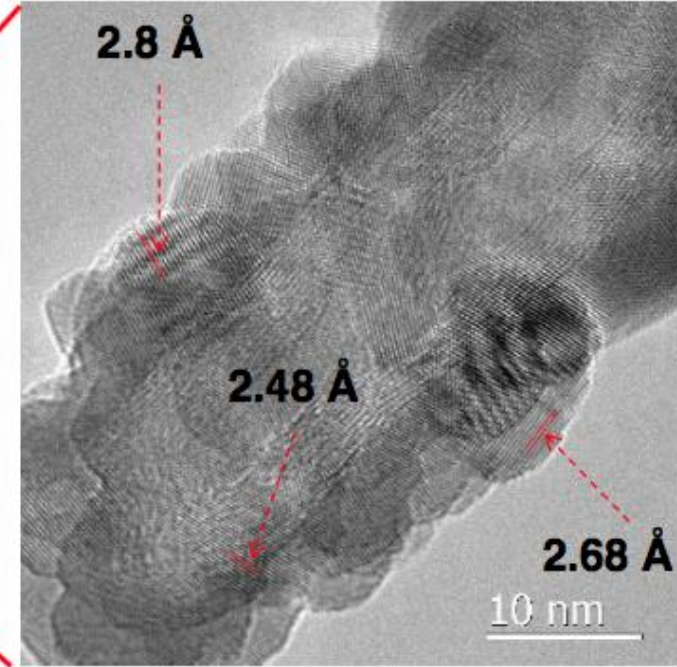
- ▶ Precisely control thickness at sub-nanometer level.
- ▶ Preserves high homogeneity and conformity.
- ▶ Agnostic to the complexity of the substrate.
- ▶ Conformal deposition of oxide coatings on MWCNTs.



Not pre-treated but functionalized



Pre-treated and ALD (ZnO) functionalized



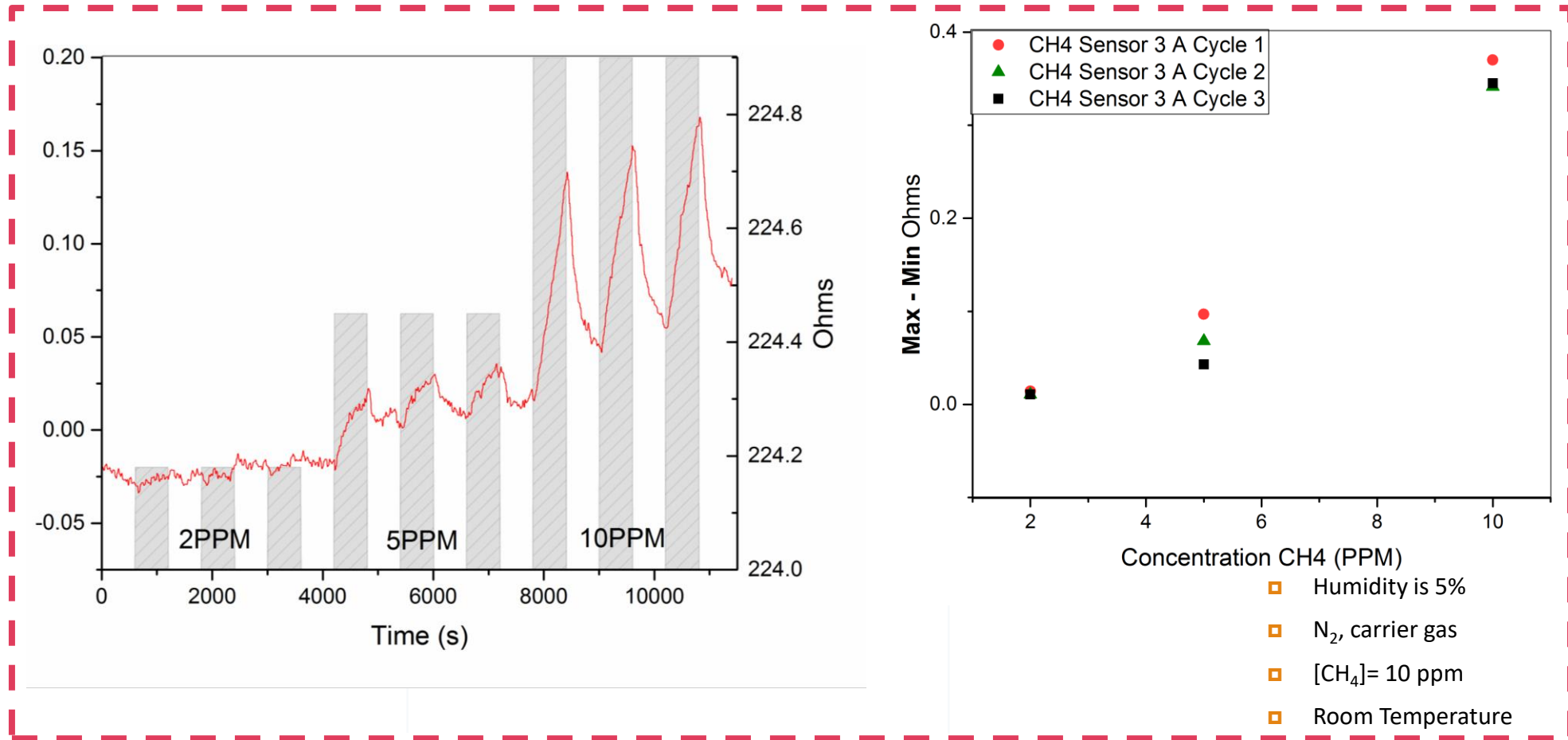


# Chemi-R Sensors Based on Composite MWCNT/ZnO

Sensing: methane 5 PPM

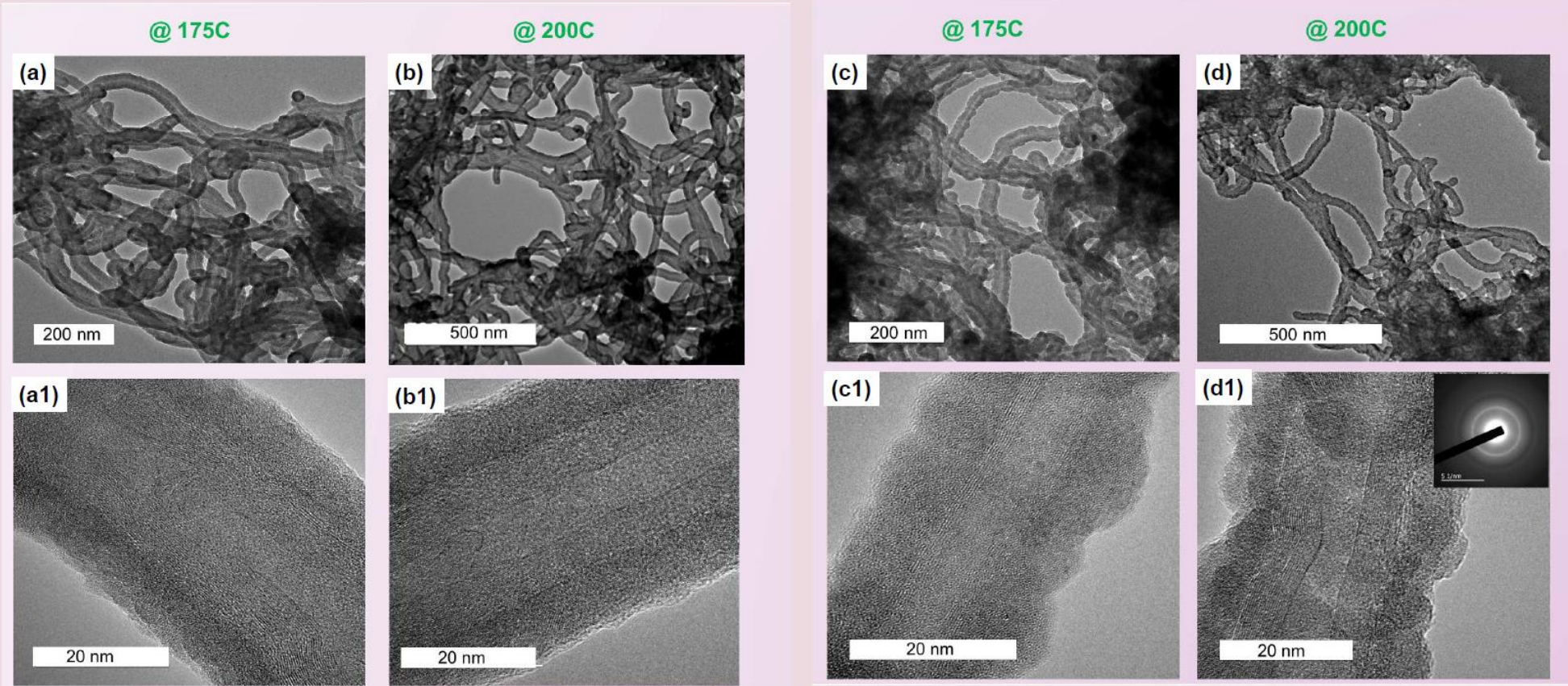
## Methane Calibration

▶ Modulation of the surface depletion layer width at the MWCNT/MOX interface



# Morphology-Dependent Sensitivity of MOX/MWCNT Sensors under Target Gases

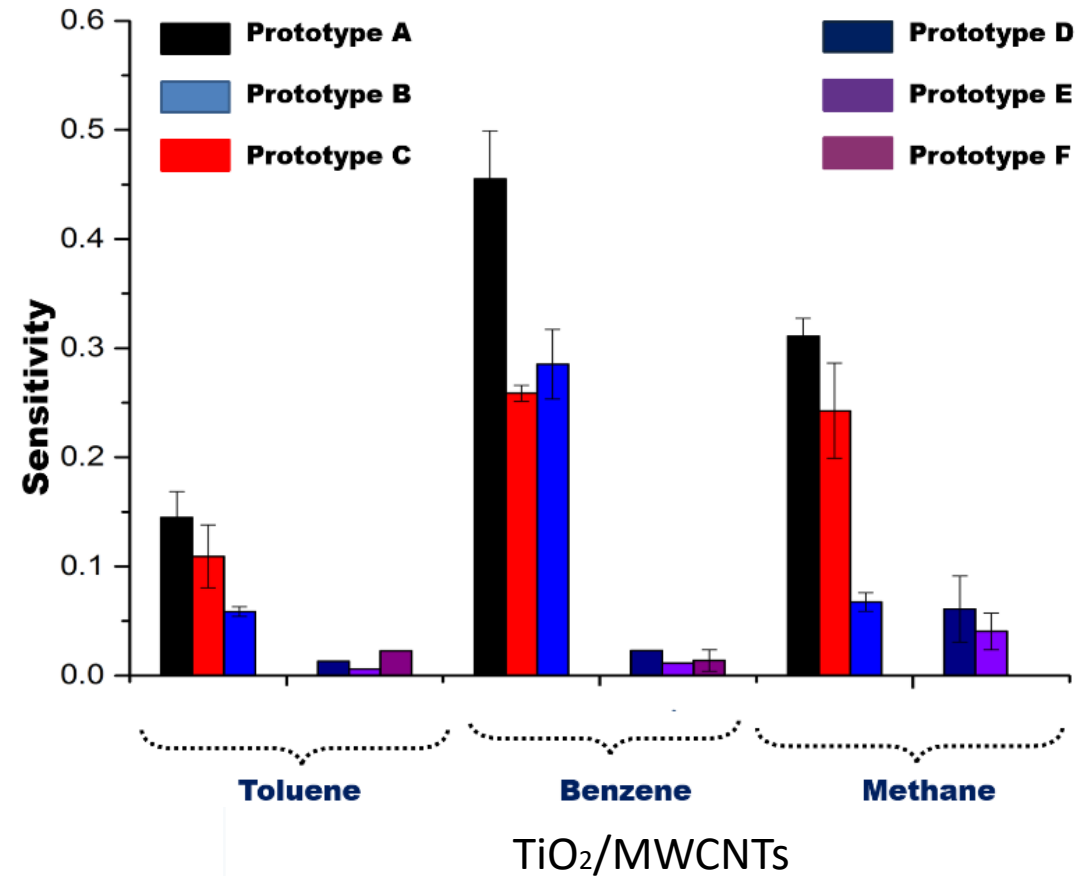
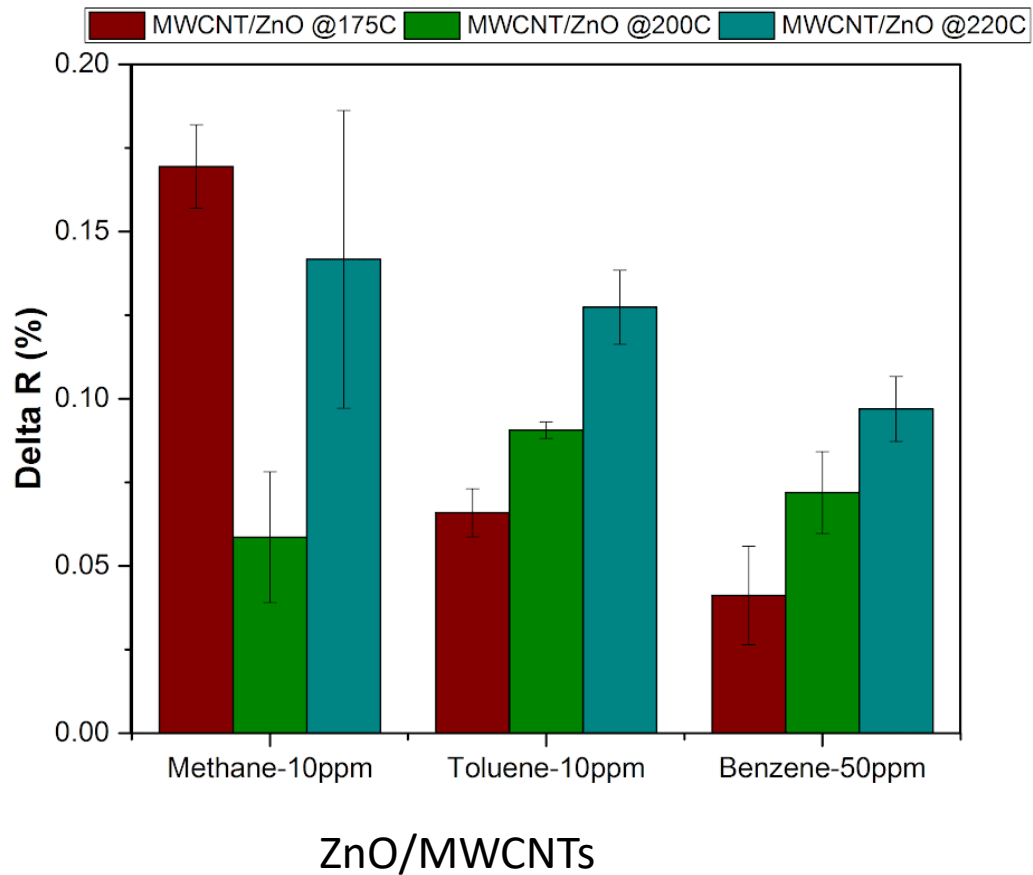
## MWCNT/TiO<sub>2</sub> Characterization: TEM analysis



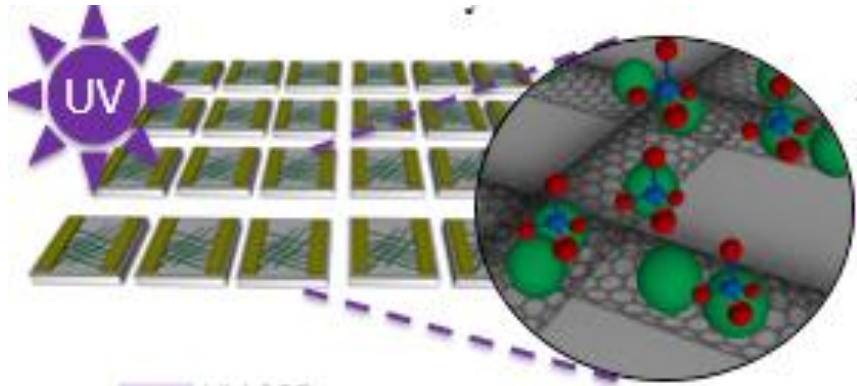
CNT-with O<sub>2</sub> plasma treatment-TiO<sub>2</sub>-270 cycles

CNT-without O<sub>2</sub> plasma treatment -TiO<sub>2</sub>-270 cycles

# Morphology-Dependent Sensitivity of MOX/MWCNT Sensors under Target Gases

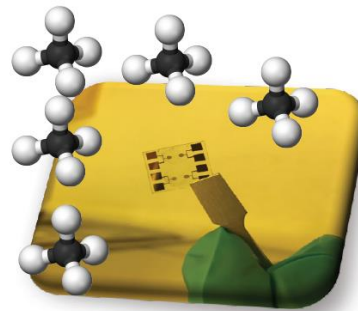
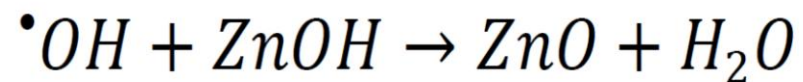
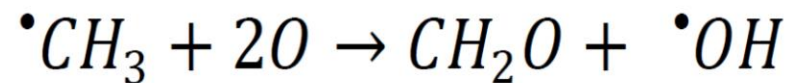
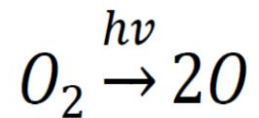
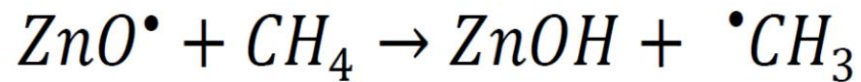
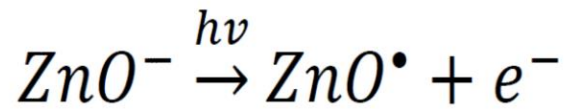


# UV Photo-activation



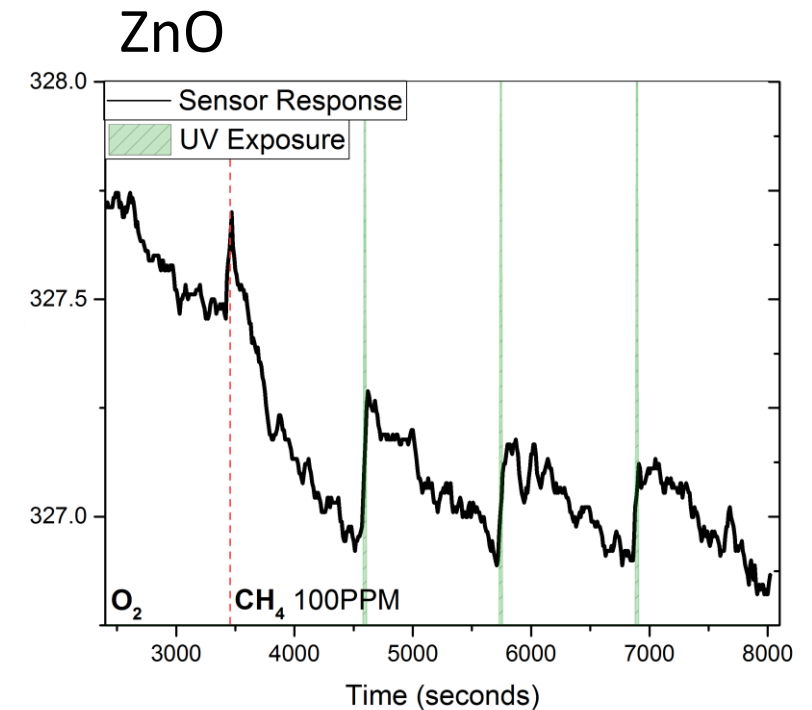
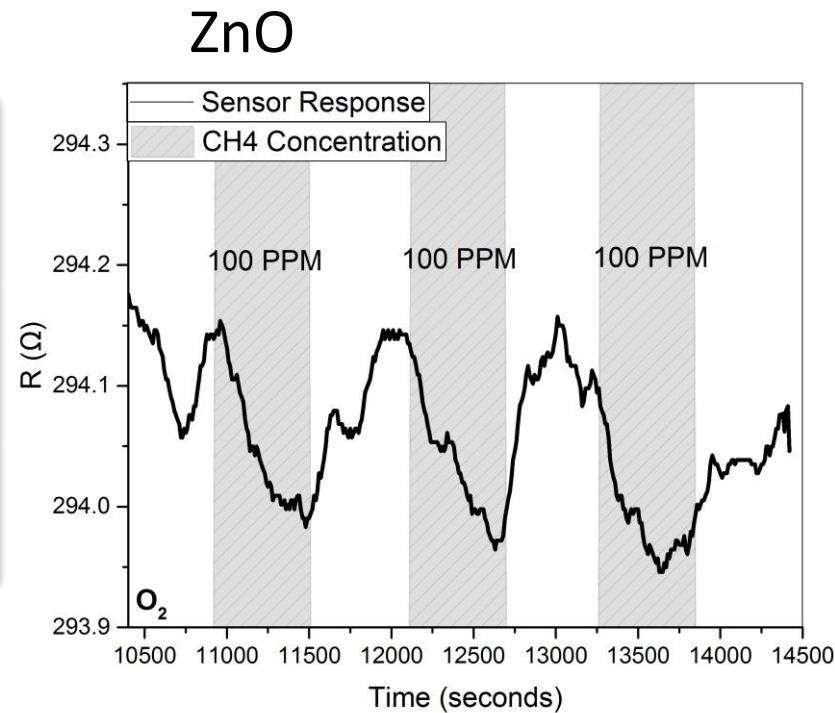
## **Advantages of UV Photo-activation:**

- High sensitivity
- Faster response and recovery time
- Long term stability
- Achieve selectivity with different UV intensities
- Low power operation

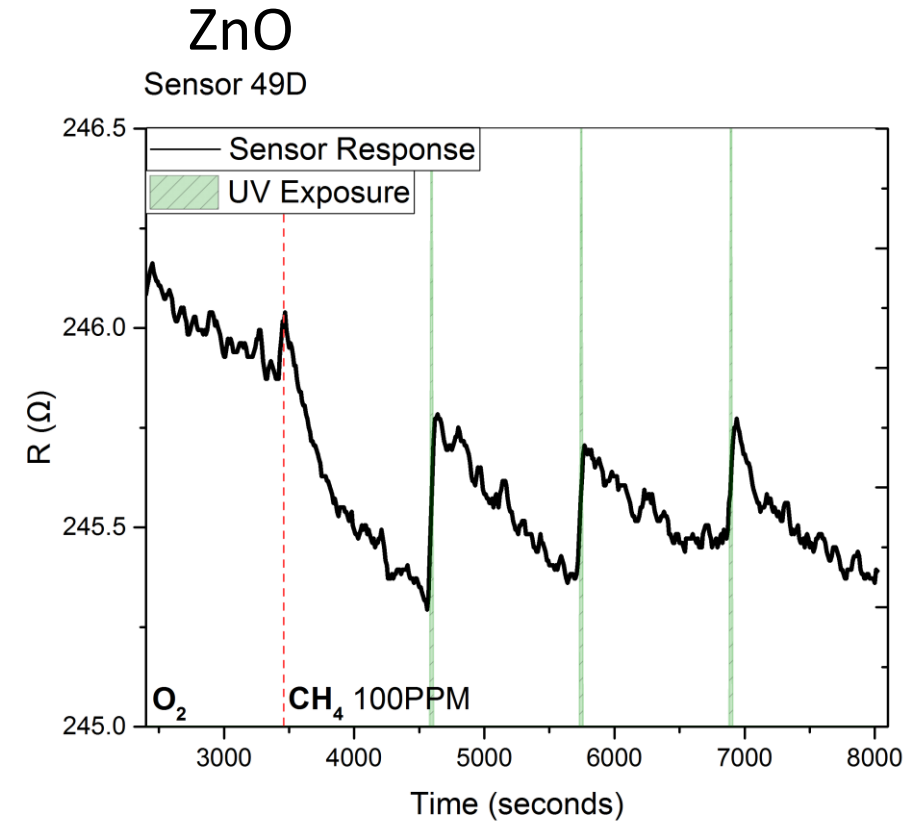
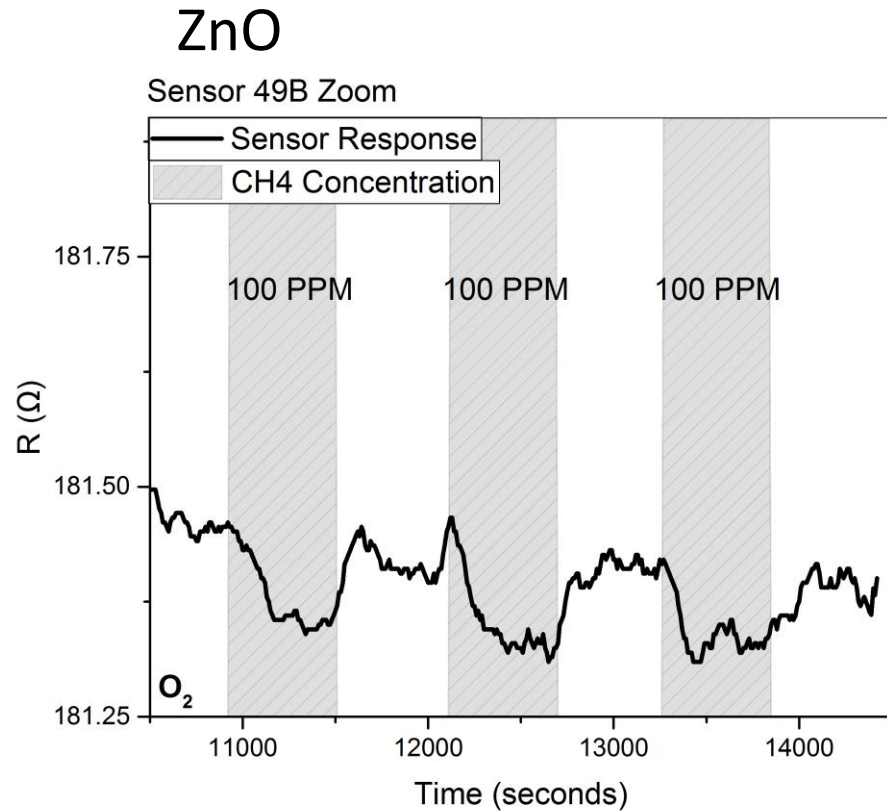


# Preliminary Data: UV Degassing using Methane

- UV of wavelength 365nm (3.3968 eV)
- UV illumination for 12 sec
- Multiple illuminations at 20 minutes interval
- Synthetic air (20.8% O<sub>2</sub>) used as Carrier Gas with RH fixed at 2%

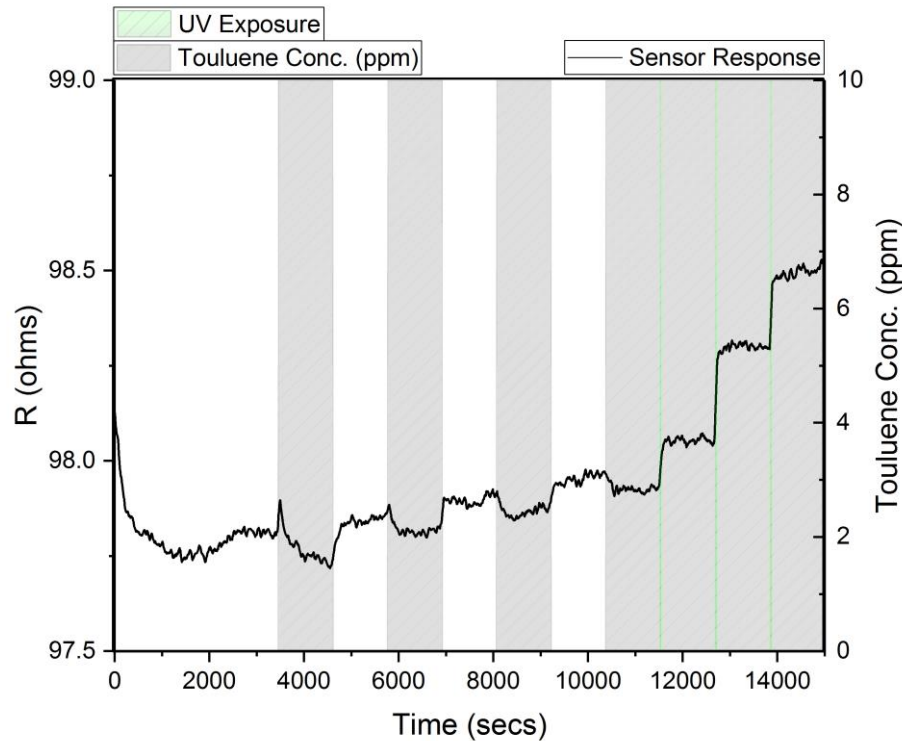


# Preliminary Data: UV Degassing using Methane Contd...



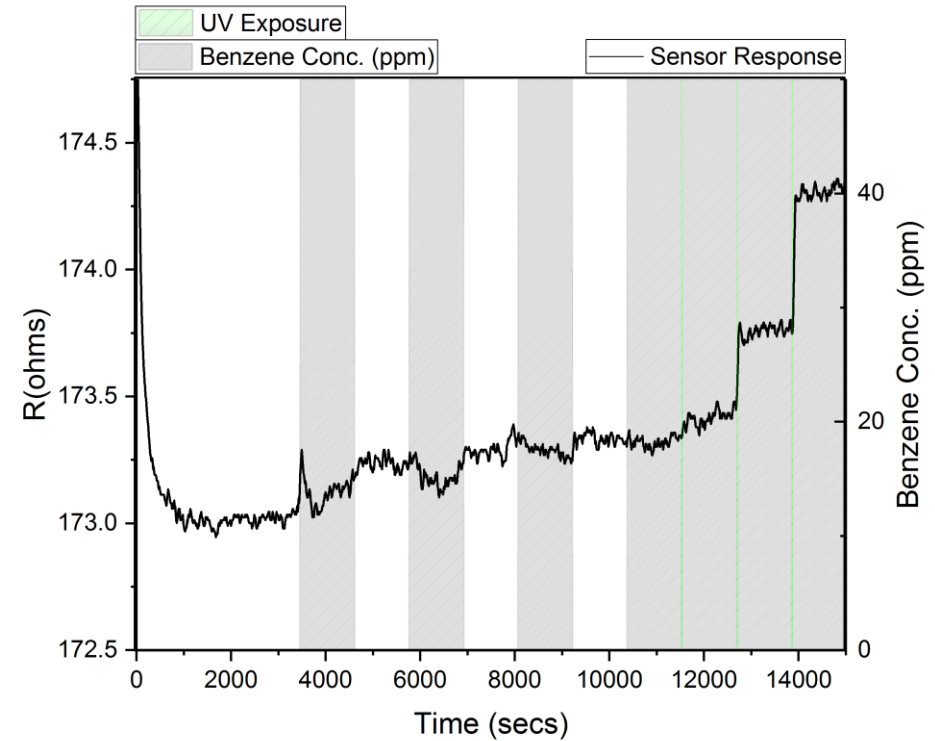
# Preliminary Data: UV Degassing of VOC Sensors

ZnO



Toluene 10ppm

ZnO



Benzene 50ppm



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<http://www1.ece.uic.edu/~paprotny/>

