

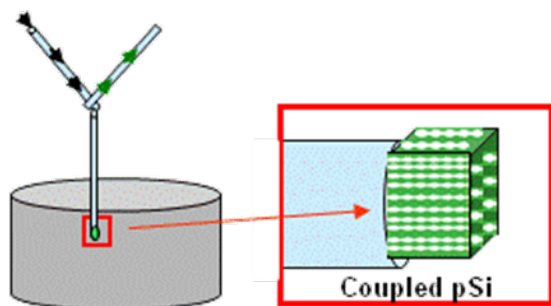
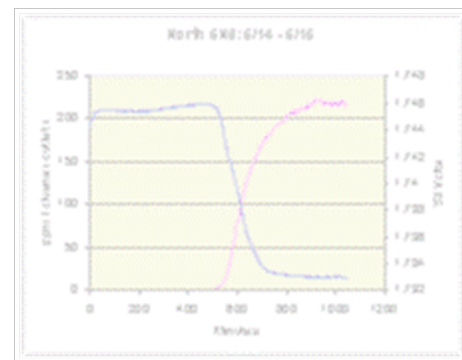
# National Personal Protective Technology Laboratory

Sensor Development for ESLI

&

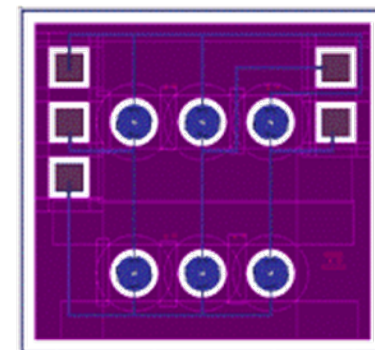
Application to Chemical  
Detection

Jay Snyder- NIOSH



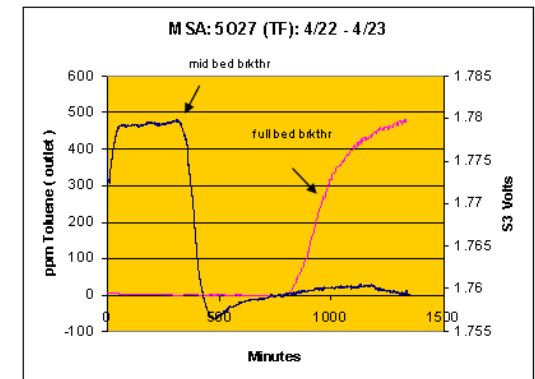
412-386-6775

[JSnyder@cdc.gov](mailto:JSnyder@cdc.gov)

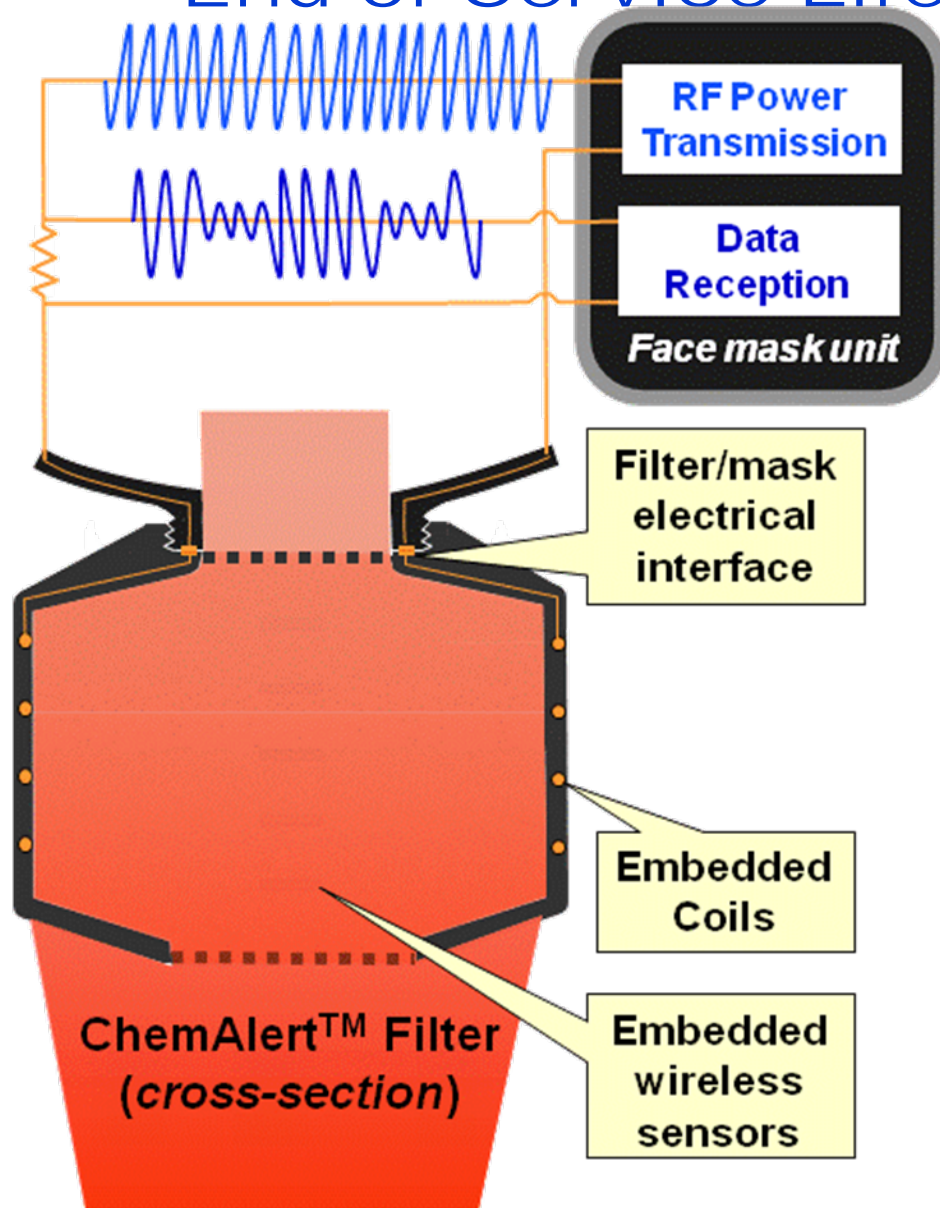


# Presentation Outline

- Current and Future Electronic System Work
- Current and Future Optical System Work

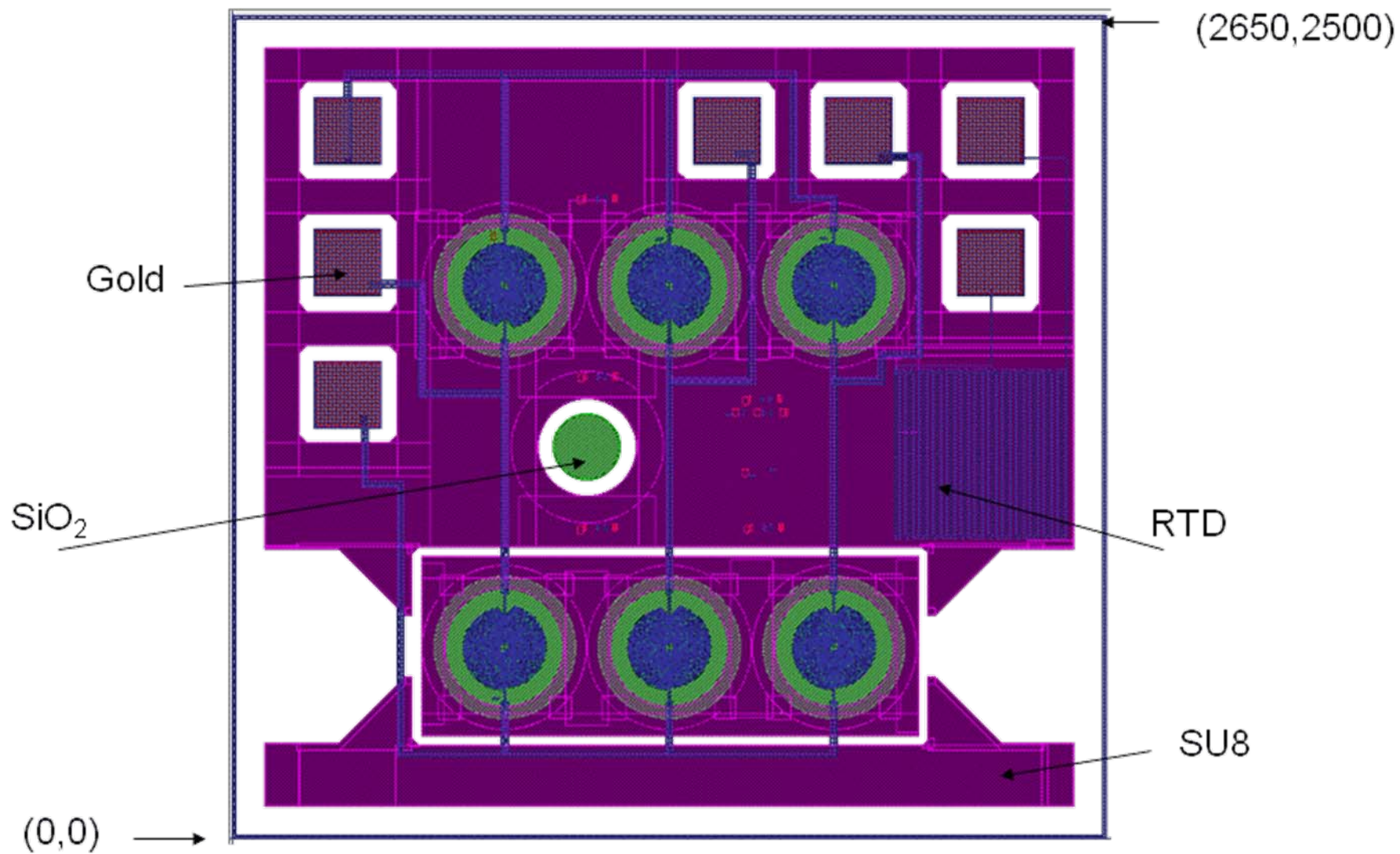


# End-of-Service Life Detection System





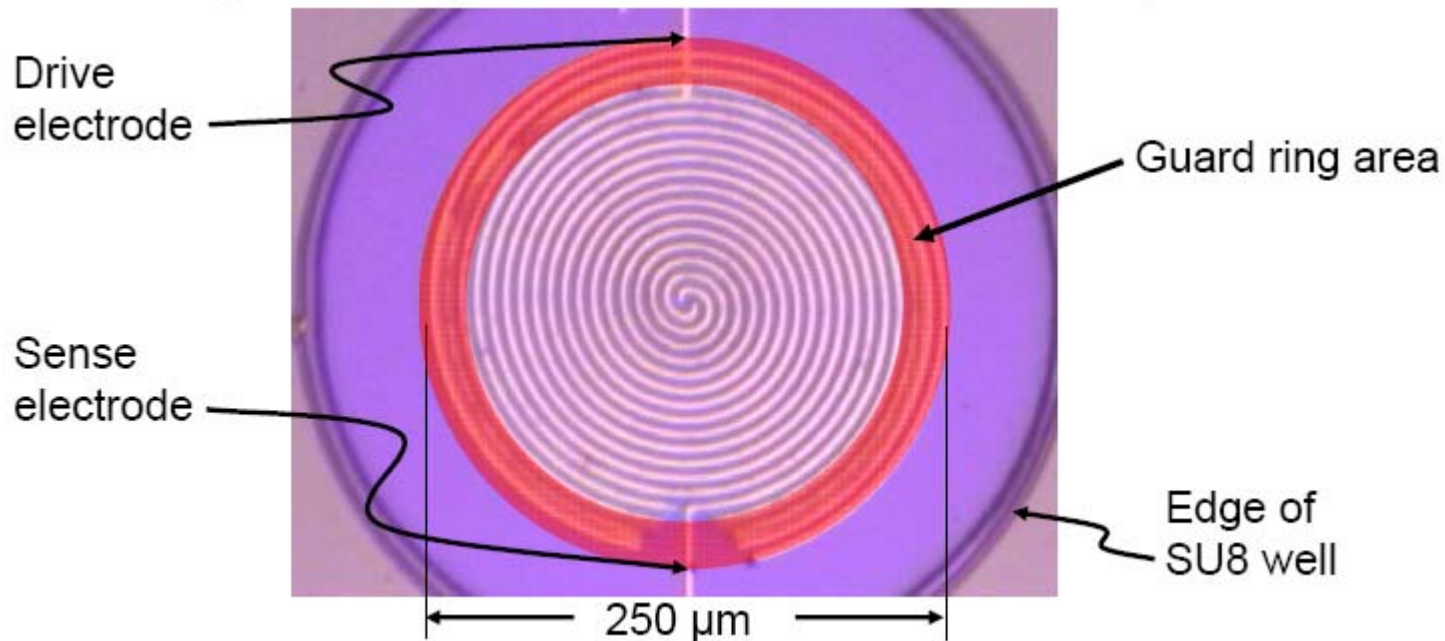
## Generation V – Embedded T sensor.



GenV – May 29, 2007, rev July 12, 2007

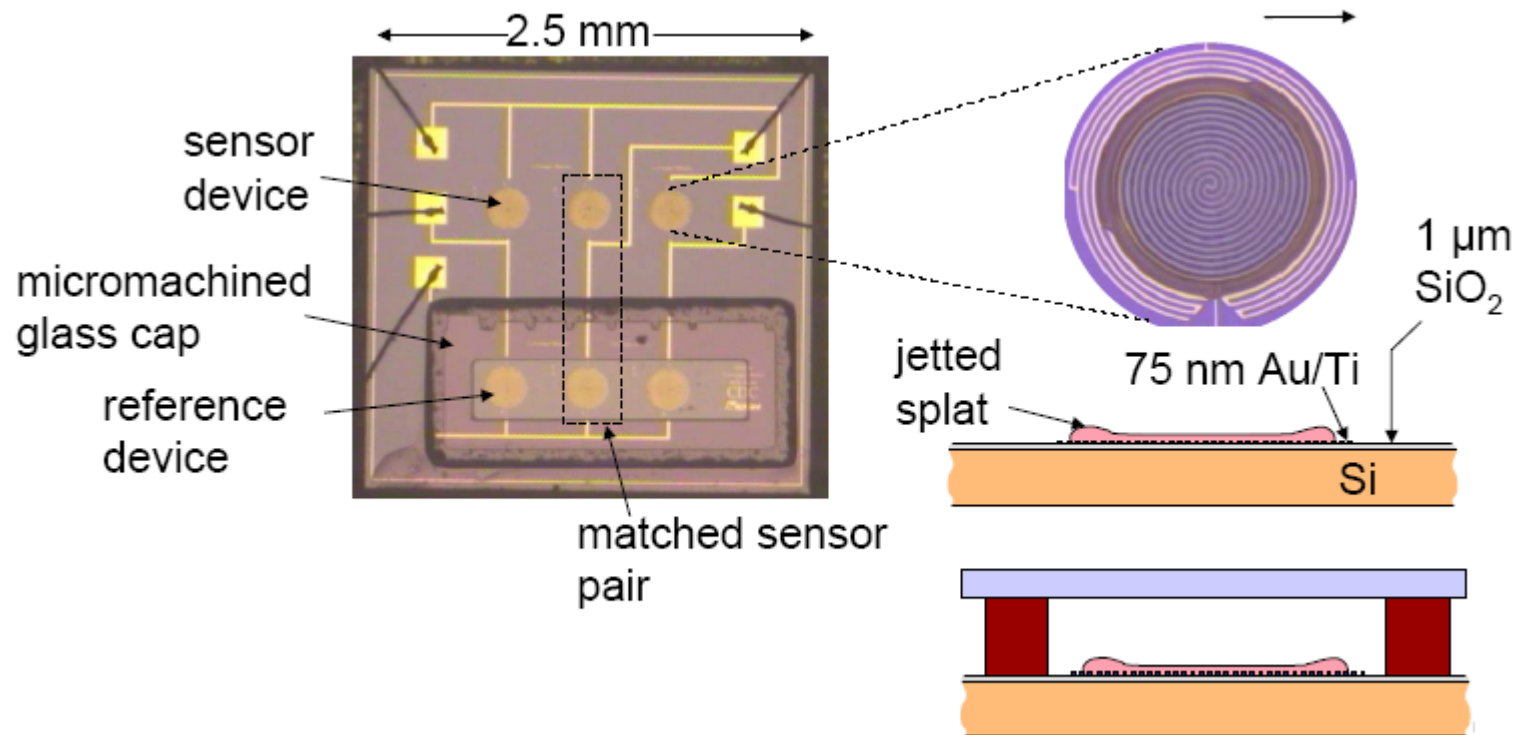
# Electrode Design

- **Spiral interdigitated gold electrodes**
  - Symmetric coverage of jetted splat
  - 3  $\mu\text{m}$ -wide traces, 4  $\mu\text{m}$  spacing, 75 nm thick
- **Sized to accommodate 30 to 60  $\mu\text{m}$  diameter nozzles**
- **Outer guard ring to achieve better uniformity**



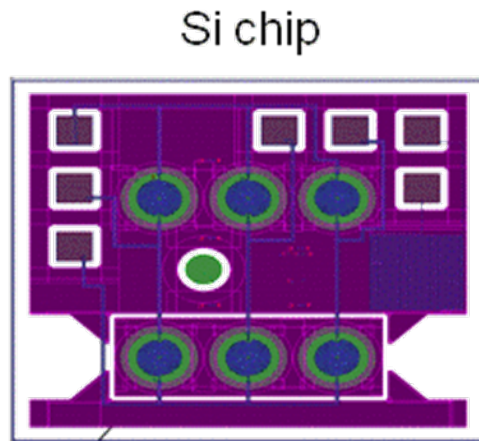
# Sensor Circuit Chip

- 3 chemiresistive sensor circuits
- Reference devices capped with glass/SU8 epoxy cap
- Sealed with low outgassing arathane

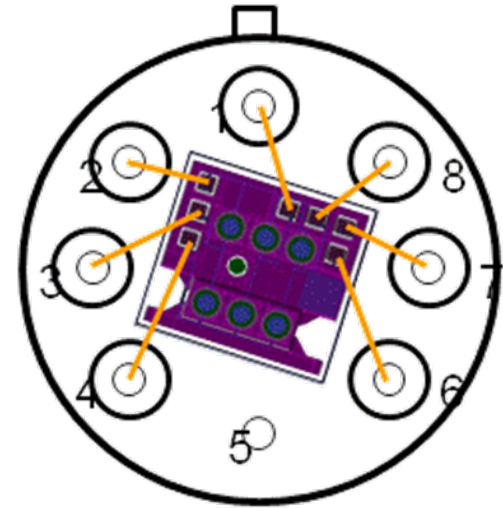




# Sensor Assembly

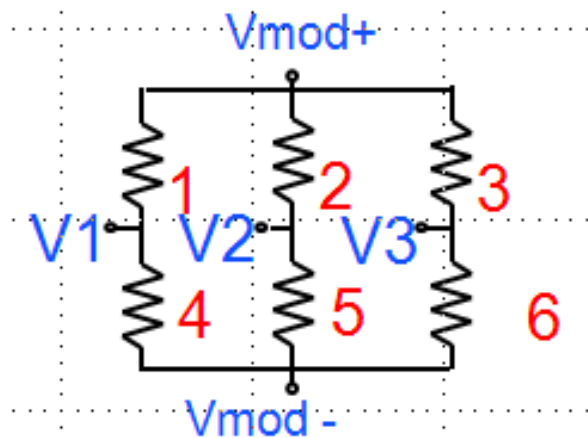


Cover glass



Sensor

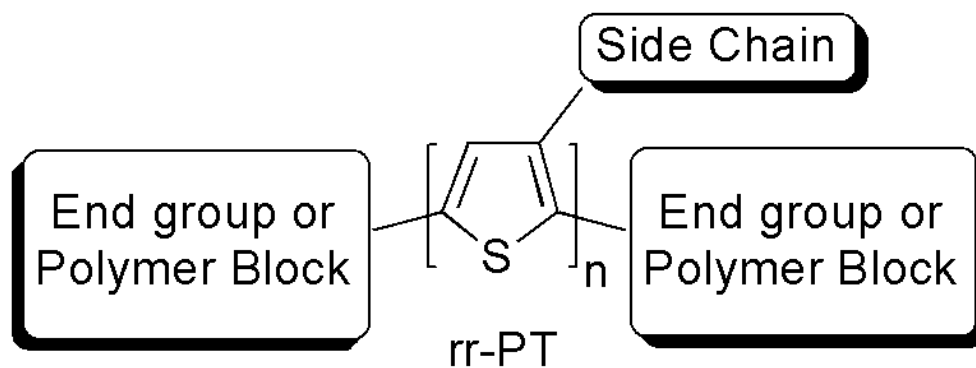
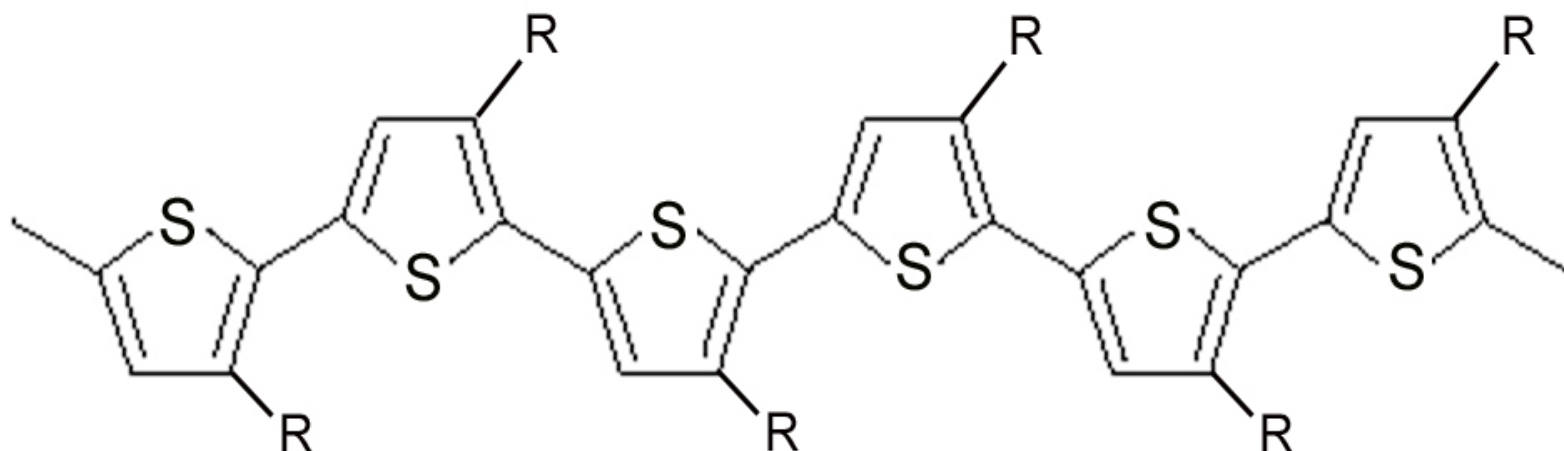
Equivalent circuit



TO-5



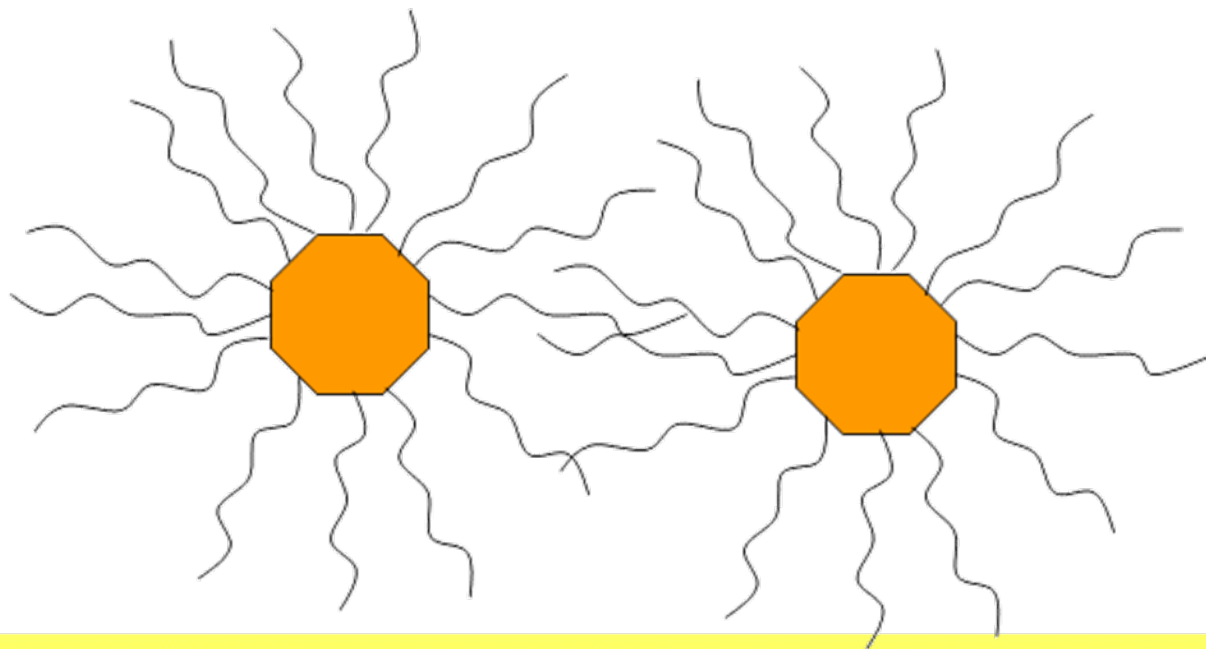
# Regioregular poly(alkylthiophene)





# What are Au-Monolayer Protected Clusters?

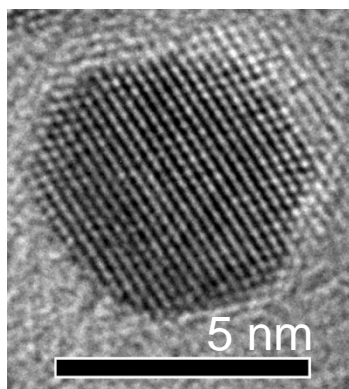
- **Composite material consisting of a cluster of gold atoms surrounded by a single layer of an organic molecule (thiol) bound to the metal through a sulfur atom:**



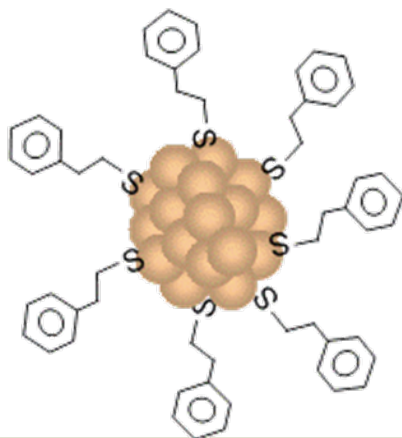
# Nanoparticle Terminology

## Nanoparticle:

- Solids in a size range of 1-100 nm in diameter (a general term).
- New phenomena not seen in atoms/molecules or bulk will emerge at this scale (*\*The exact size at which this happens depends both on the **system** and the **property** being considered*).

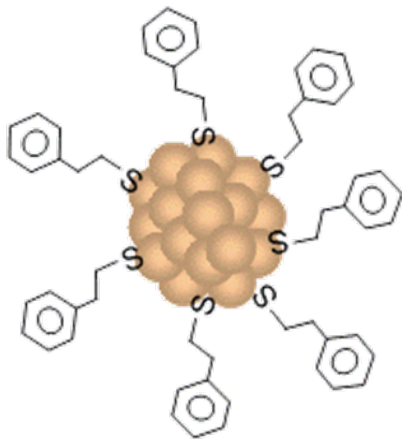


**Nanocrystal:** single crystalline nanoparticles (typically > 2nm to exhibit crystallinity (i.e. translational symmetry).



**Nanocluster or cluster:** individual molecular units that have **well-defined** structure (e.g. Au<sub>11</sub> and Au<sub>25</sub>), but are too small to be true crystals, with sizes ranging from subnanometer to ~2 nm). They are closely akin to molecules in terms of transport and other properties.

# Gold Nanoclusters for VOC sensing



## A New Type of Ultrasmall Gold Nanoparticles:

- These particles have well-defined composition and structure (e.g.  $\text{Au}_n$ ,  $n$ =the # of gold atoms);
- Too small to be true crystals (size ranging from subnanometer to 2 nm);
- New physiochemical properties that could benefit VOC sensing.

## Synthetic Challenges:

1. How to achieve the ultrasmall size (< 2nm)?

— Ultrasmall size effects electron quantum confinement (semiconducting gold nanoparticles)

2. How to achieve atomic monodispersity?

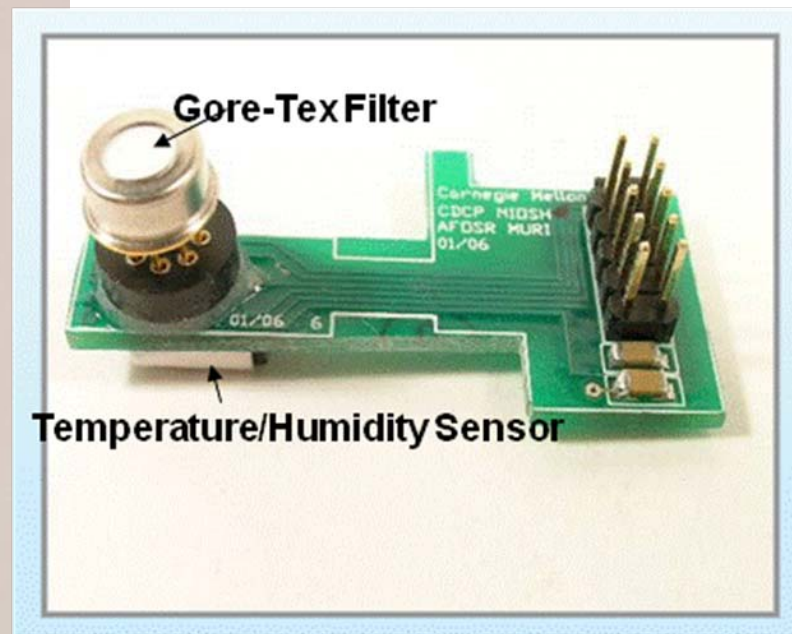
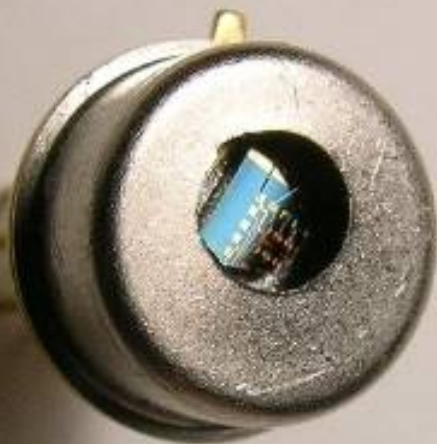
— Controlling the # of atoms in a particle via kinetic control (atomically monodisperse: the ultimate)



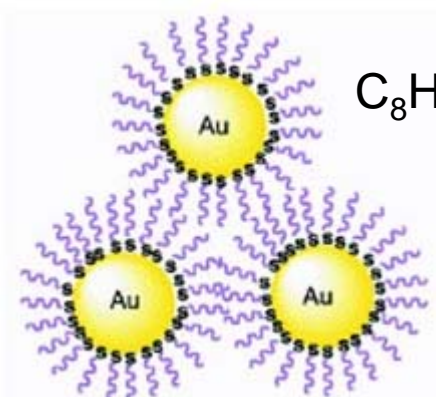
# MPC Properties

- **Easy to handle**
  - Air stable.
  - Soluble in organic solvents\*.
  - Can be coated on substrates by ink-jetting, dipping, spinning and spraying.
- **Can be modified**
  - Size and shape.
  - Functional end groups of organic monolayer.
  - \*Solubility determined by the nature of the monolayer.
- **Reusable**

# Complete TO-5 Package

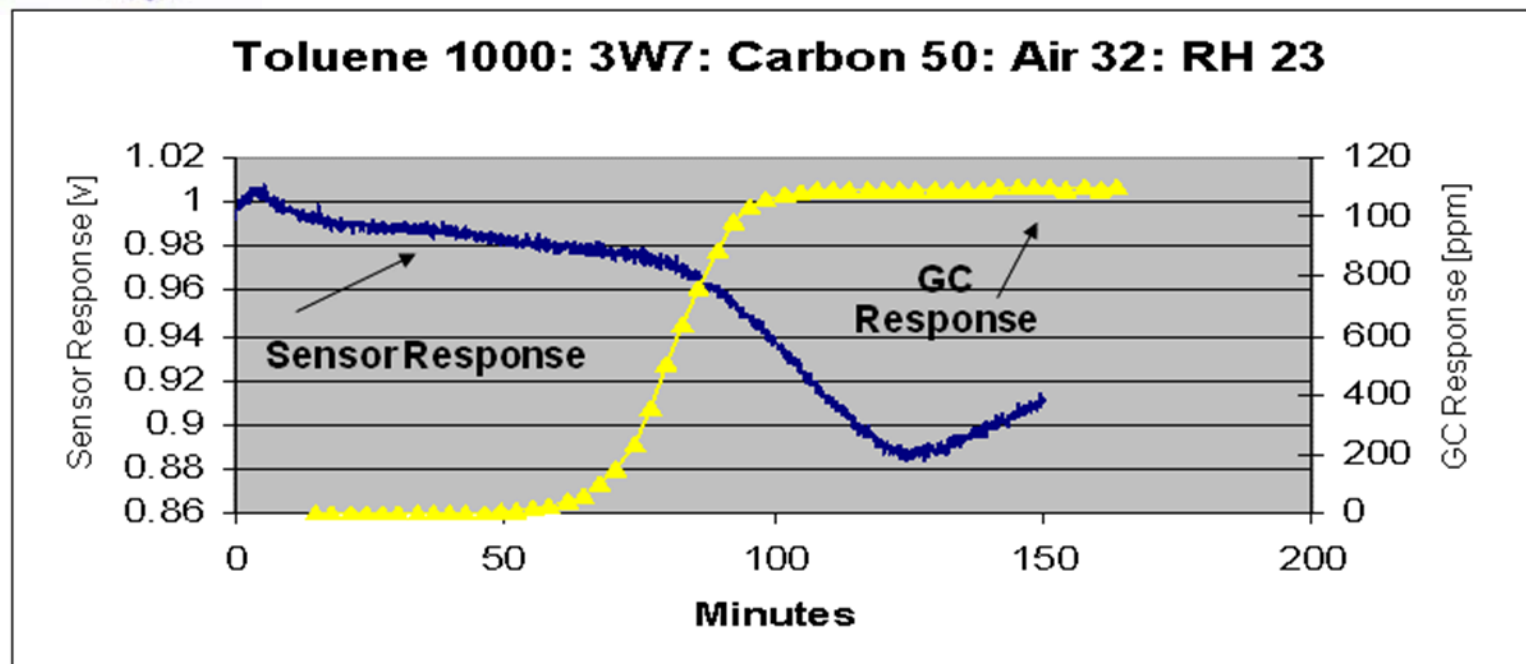
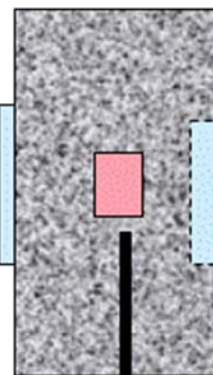


# Performance of a MPC



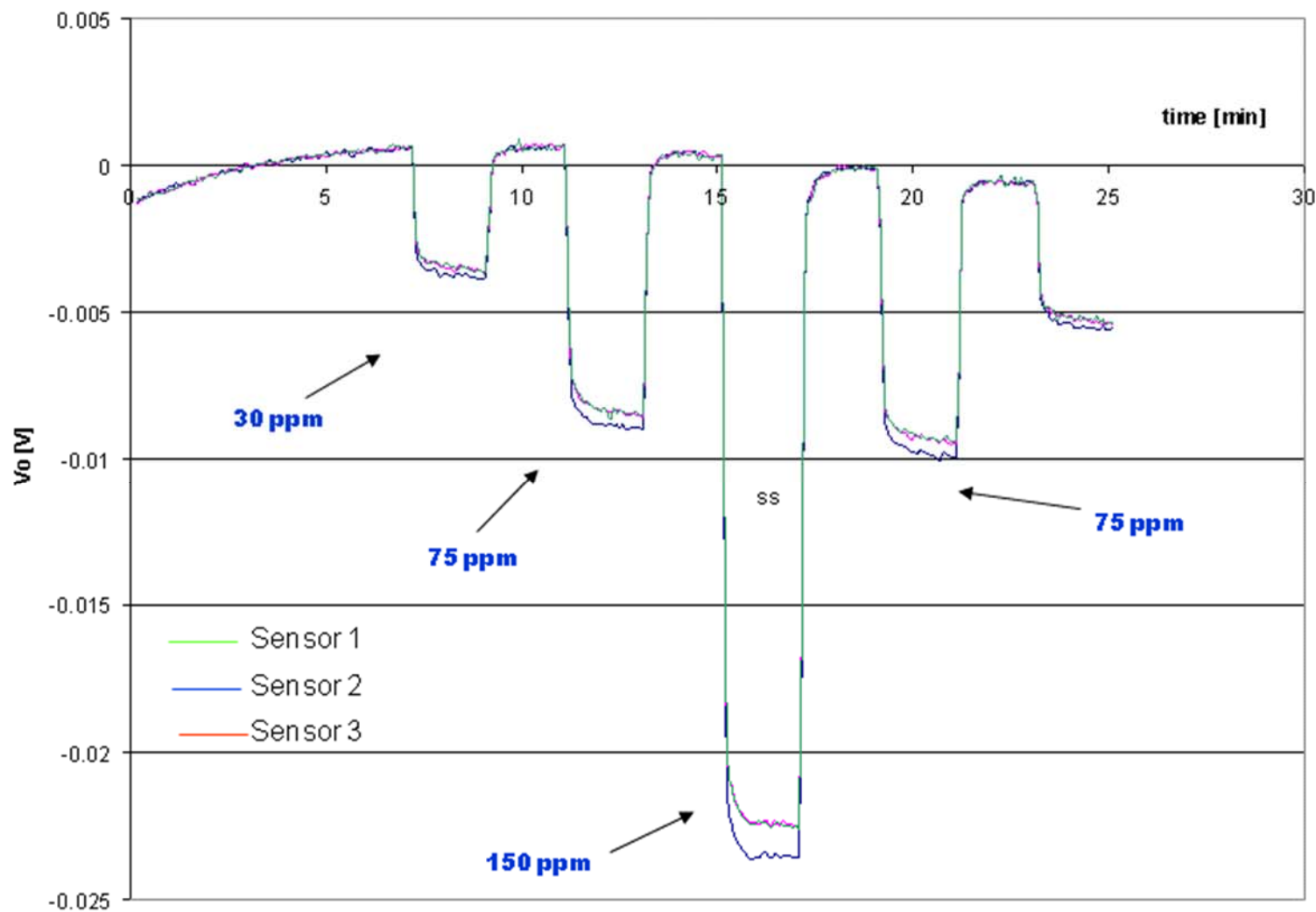
$\text{C}_8\text{H}_{17}\text{SH}$   
(C8)

1000 ppm  
Toluene





# MPC Sensor Response to Toluene in Air

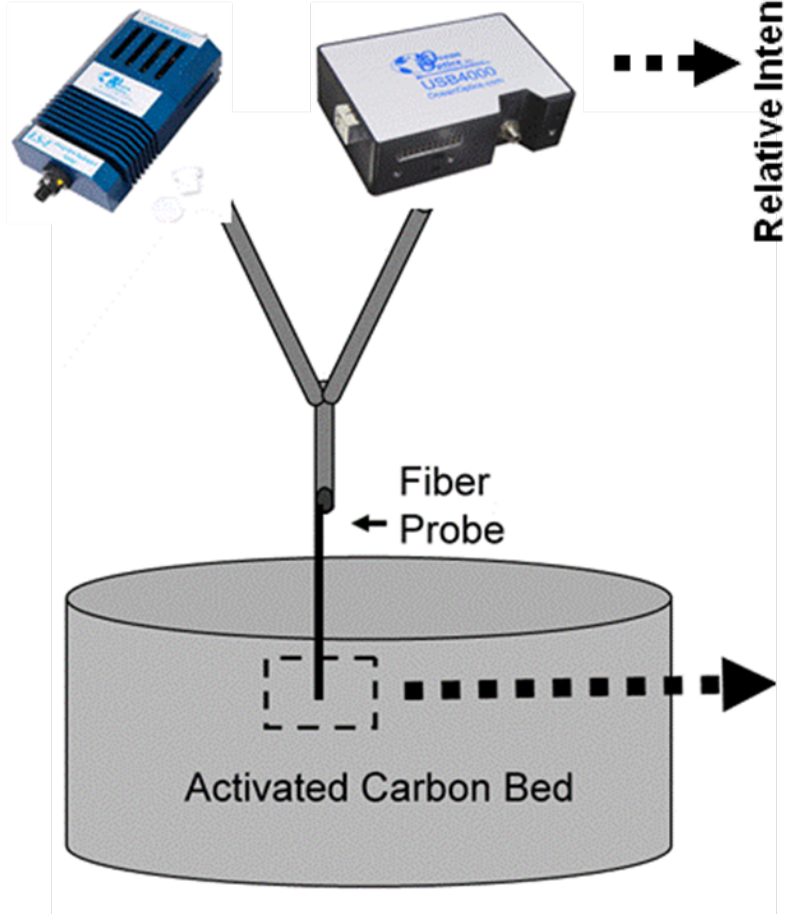


**3F7NRL-  
C8  
Sensor**

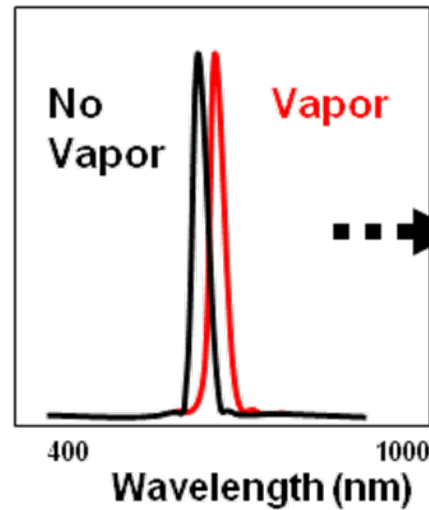
# Optical Fiber Sensing Scheme

Light Source

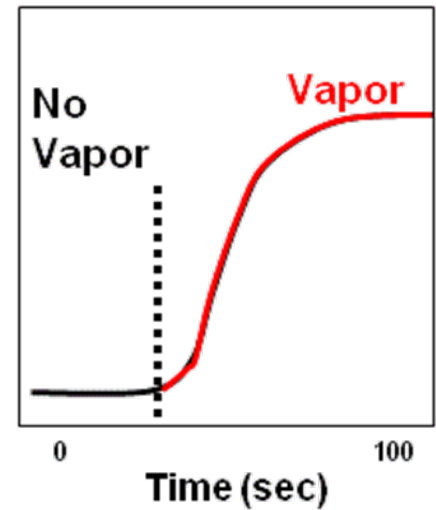
CCD Spectrometer



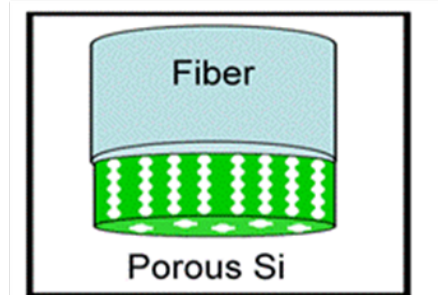
Relative Intensity



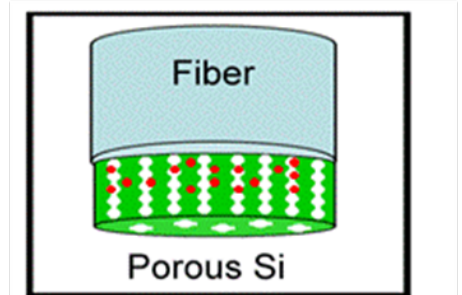
Peak Position



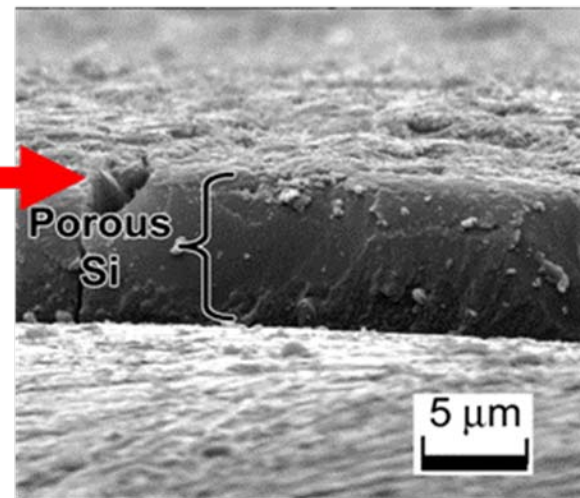
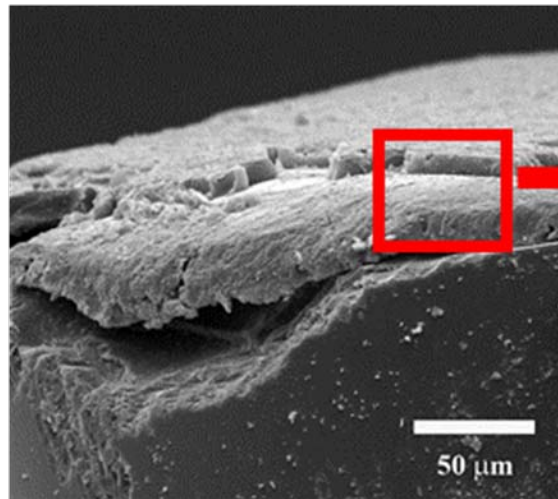
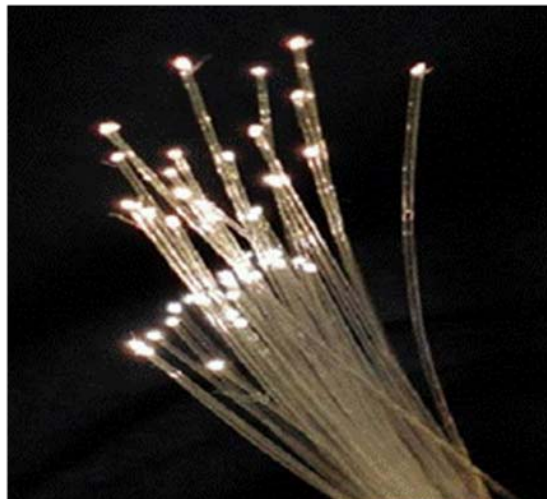
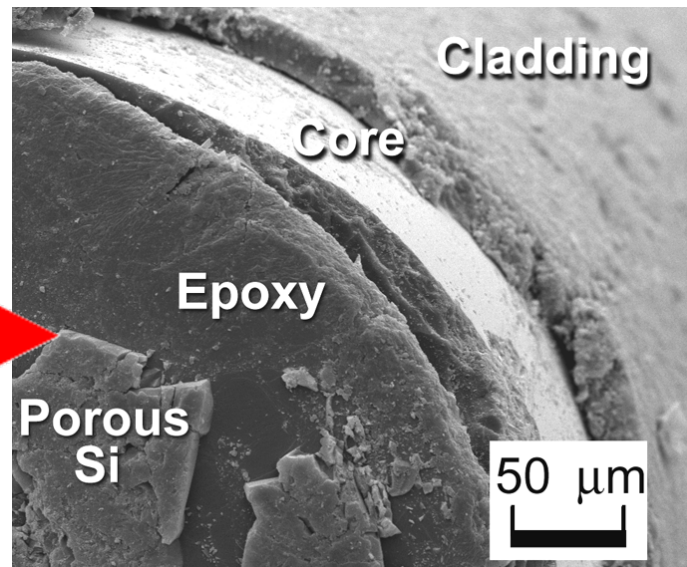
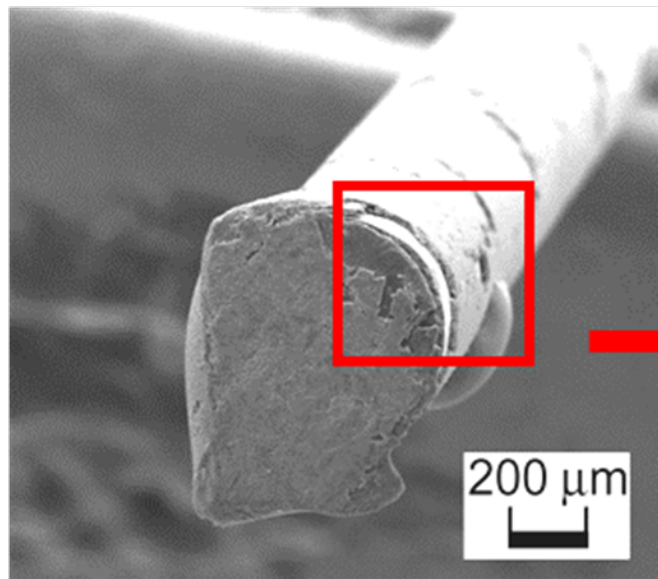
No Vapor



Vapor

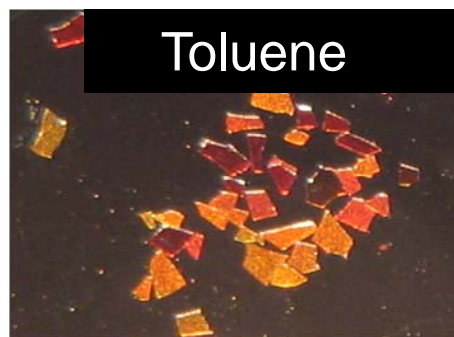
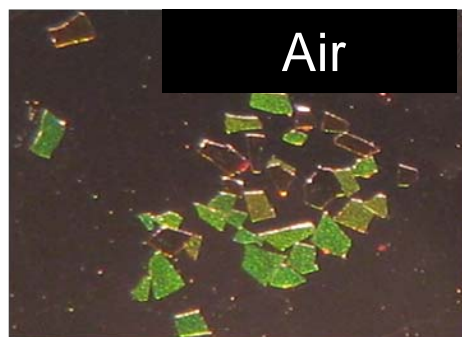
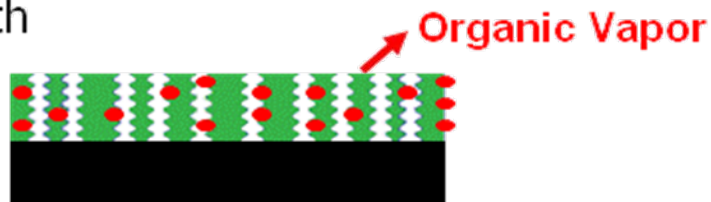
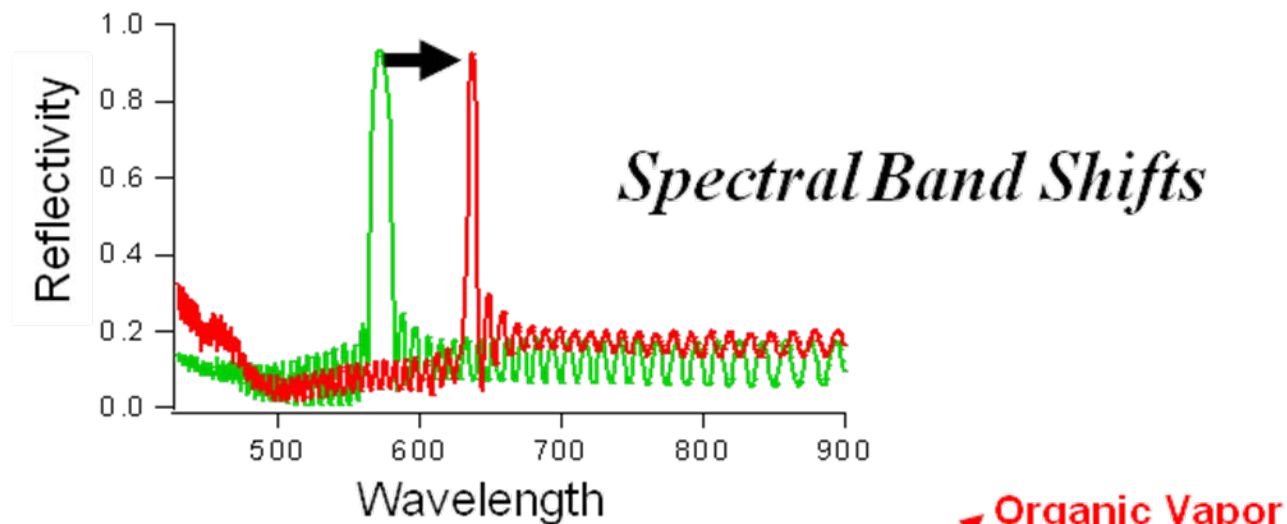


# Attachment to Optical Fiber





# General Sensing Scheme



**Vapors:**  
ppm to ppb  
sensitivity

# Conclusions

- **NIOSH and its partners have made great progress toward ESLI for organic vapor respirator cartridges.**
- **Prototype electronic sensor systems have been inserted into commercially available cartridges.**
- **Optical based ESLI systems have completed proof of concept testing.**

# Summary

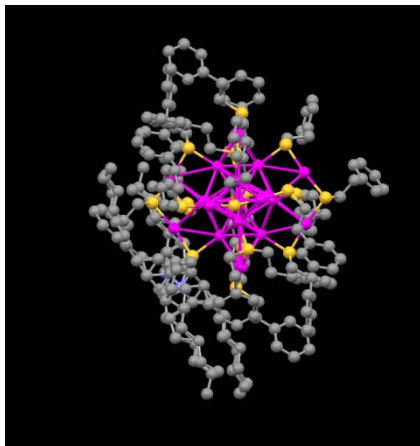
- **Many ESLI design parameters still need to be optimization and continued development is underway.**
- **Application to commercial chemical detection is possible.**

# Disclaimer

Visit Us at: <http://www.cdc.gov/niosh/npptl/>

## ***Disclaimer:***

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Thank you

