Micro-Preconcentrator Devices for Gas Sensing

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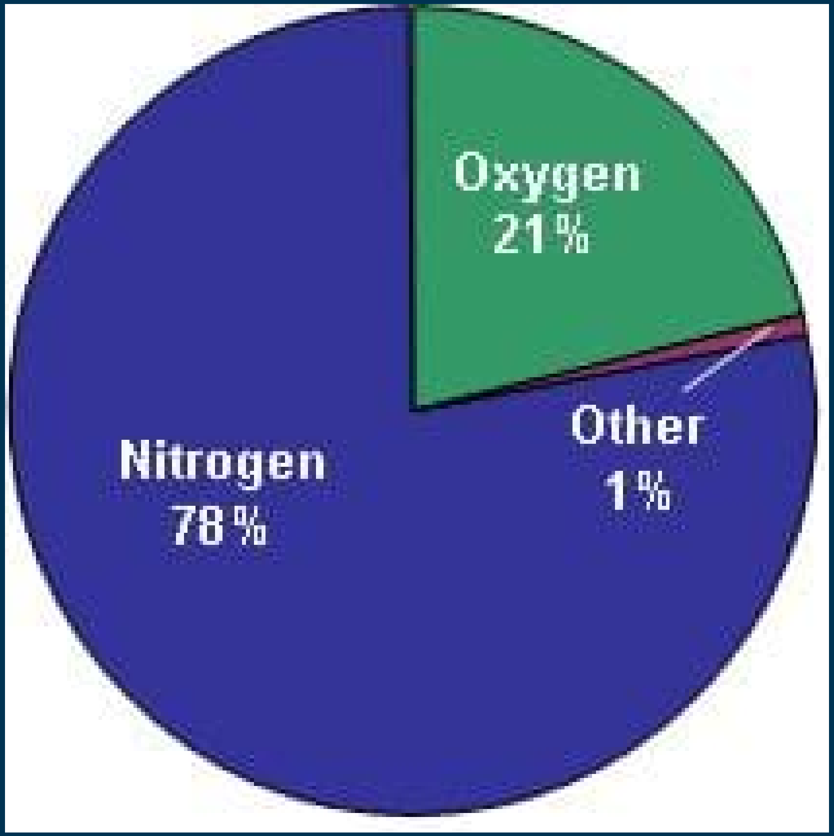
Common Gasses

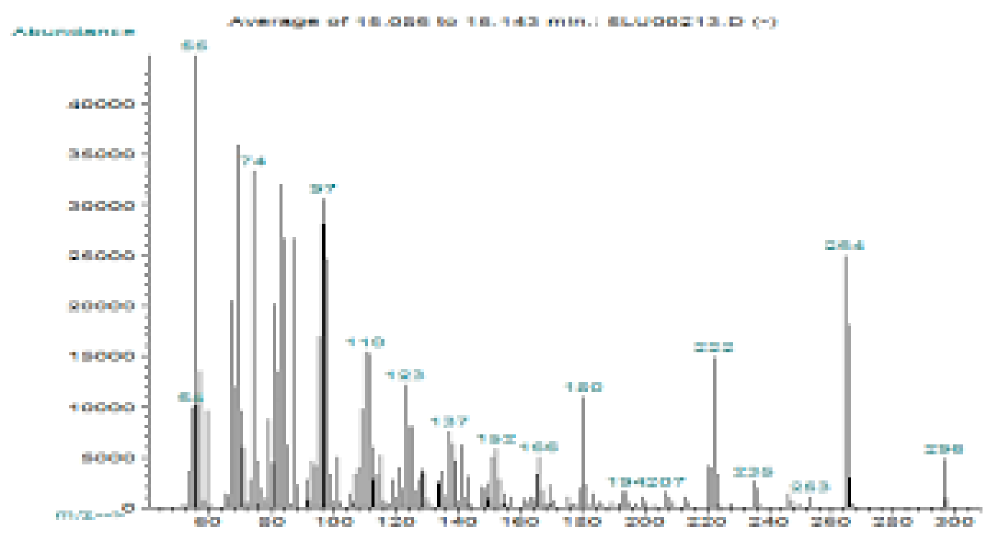


Combustible Gas	Lower Explosion Limit		
	ppm (vol.)	ppm(m)	Volume Fraction
Butane	1.6	0.8	1.6×10^{-6}
Ethane	3.0	2.9	3.0×10^{-6}
Ethylene	2.7	2.8	2.7×10^{-6}
Hexane	1.1	0.4	1.1×10^{-6}
Isobutane	1.8	0.9	1.8×10^{-6}
Isopentane	1.4	0.6	1.4×10^{-6}
Methane	5.0	9.0	5.0×10^{-6}
Pentane	1.5	0.6	1.5×10^{-6}
Propane	2.1	1.4	2.1×10^{-6}
Propylene	2.4	1.7	2.1×10^{-6}

Table 2. Lower Explosive Limit for Combustible Gases and Vapors as Per ISO 10156.

Existing Technology

- Low detection threshold
- Accurate quantitative analysis
- Large equipment, high power demand

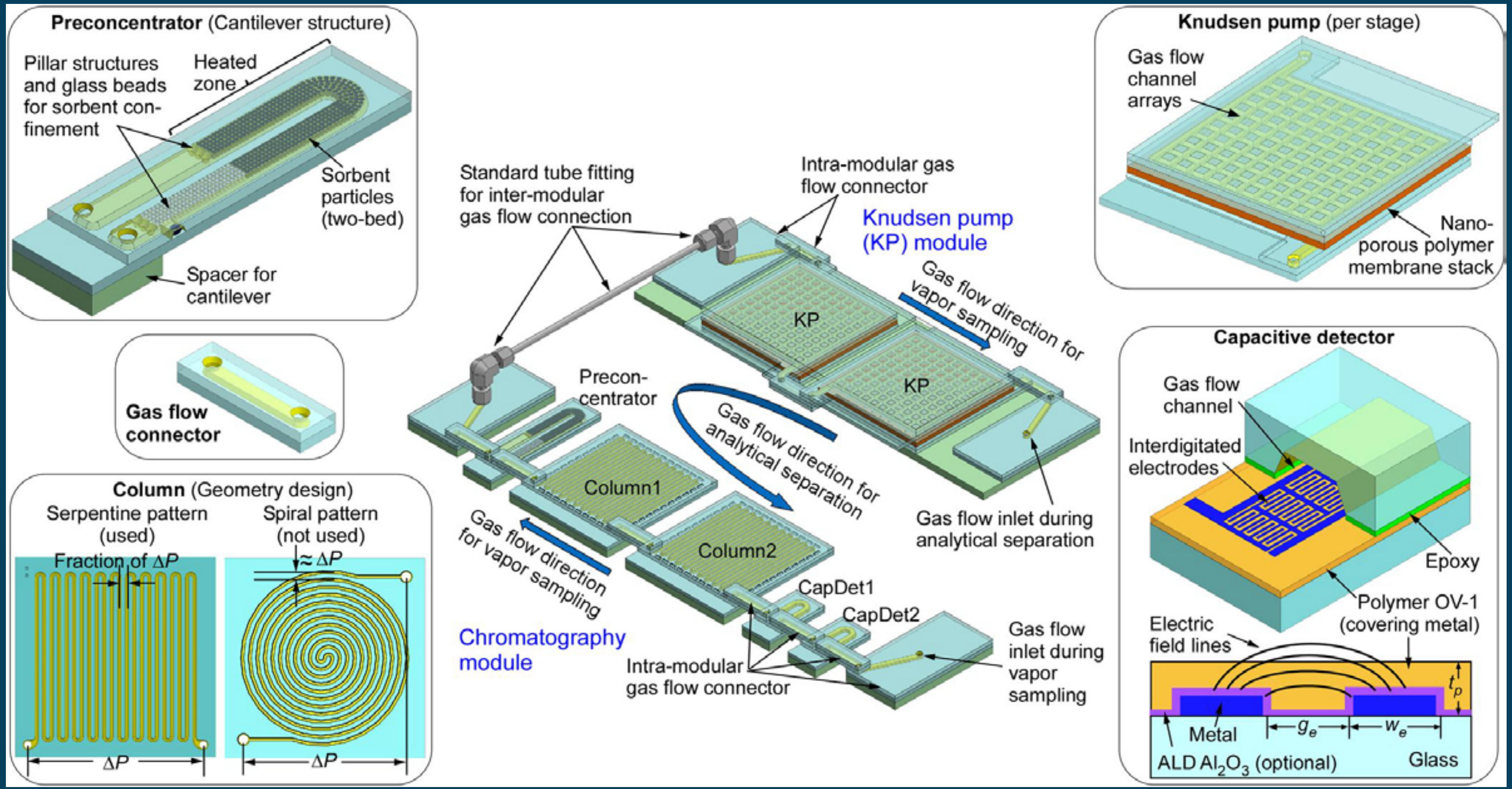


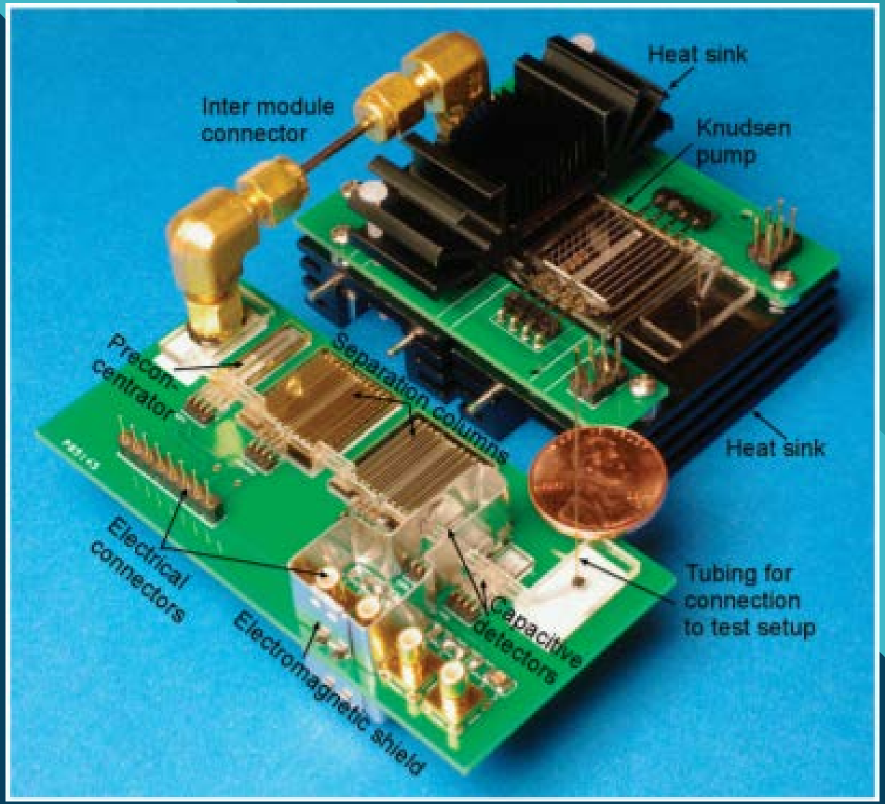
Scale of Measurement

Gas Sensing Applications

- Pollutant monitoring
- Industrial safety
- Medical Applications
- Space Exploration

Developing Technologies





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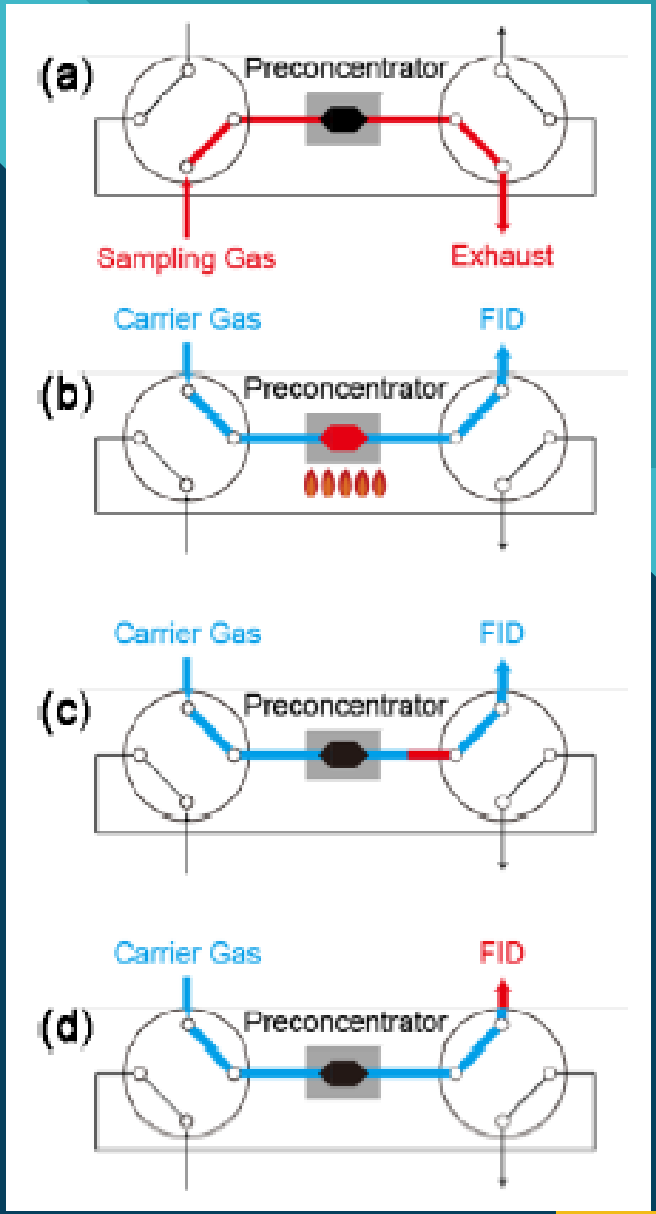
Micropreconcentrator Operation

1. Sampling gas passed through preconcentrator
2. Preconcentrator heated with carrier gas
3. Gas tested for concentration
4. Concentration of original gas is determined from sampling gas



Shuji Takada *et al*. **2010**

Goals

Develop preconcentrator with

1. High preconcentration factor
2. Good mechanical and heat transfer properties
3. Carbon nanotubes (CNTs) adsorbent material

Summer 2018 Work

I. Design and Computational Work
   A. Low pressure drop
   B. High volume flow
   C. Even heat distribution
II. Fabrication
   A. Single Walled Carbon Nanotube (SWCNT) synthesis
   B. Microchannel fabrication

I. Design and Computational

Literature

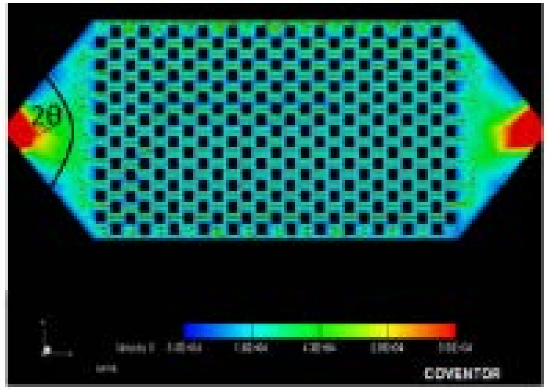


Fig. 1. CFD simulation of a preconcentration device with micropillars in the channel.

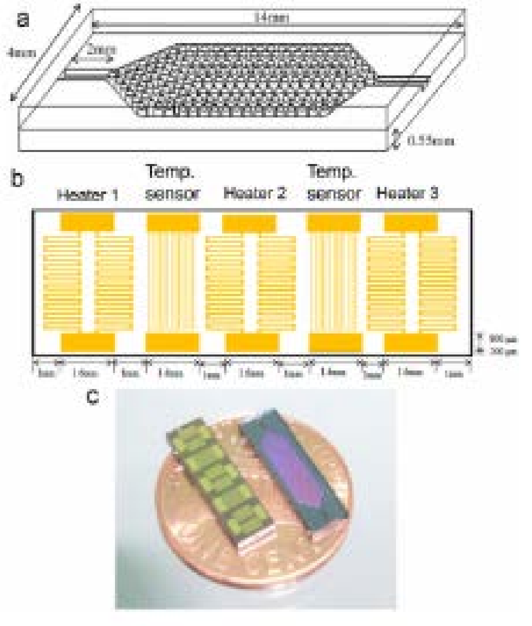
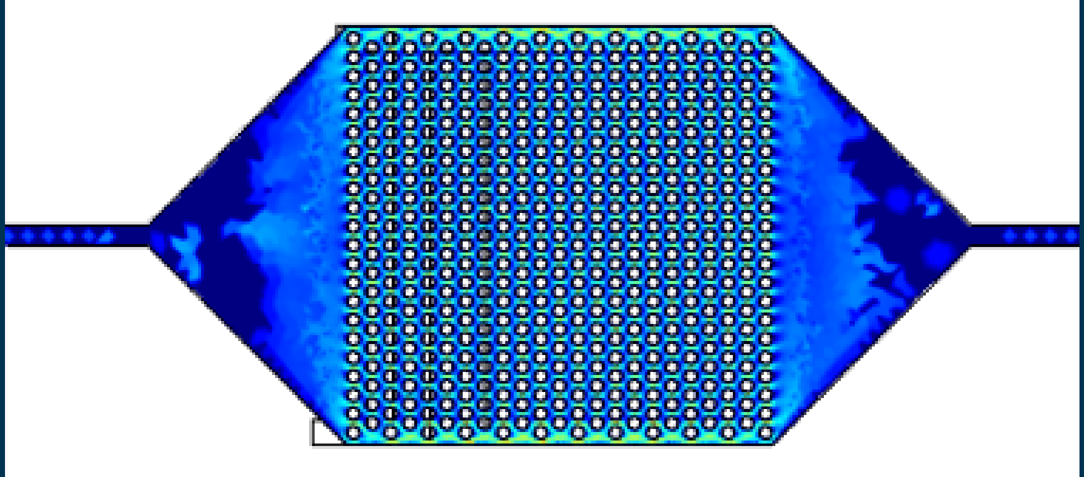


Fig. 1. Design diagram of device: (a) fluidic channel; (b) heater and temperature sensor and (c) device photo.

Sloped inlet and outlets with microposts to increase surface area and distribute the gas flow and trap adsorbent, along with integrated heating element for thermal desorption

Our Design

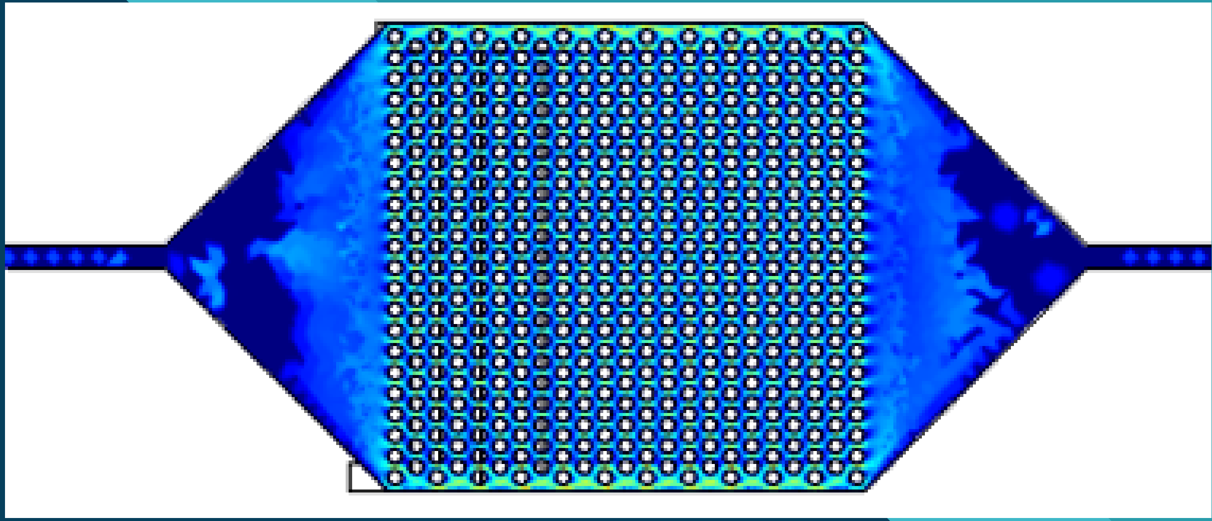


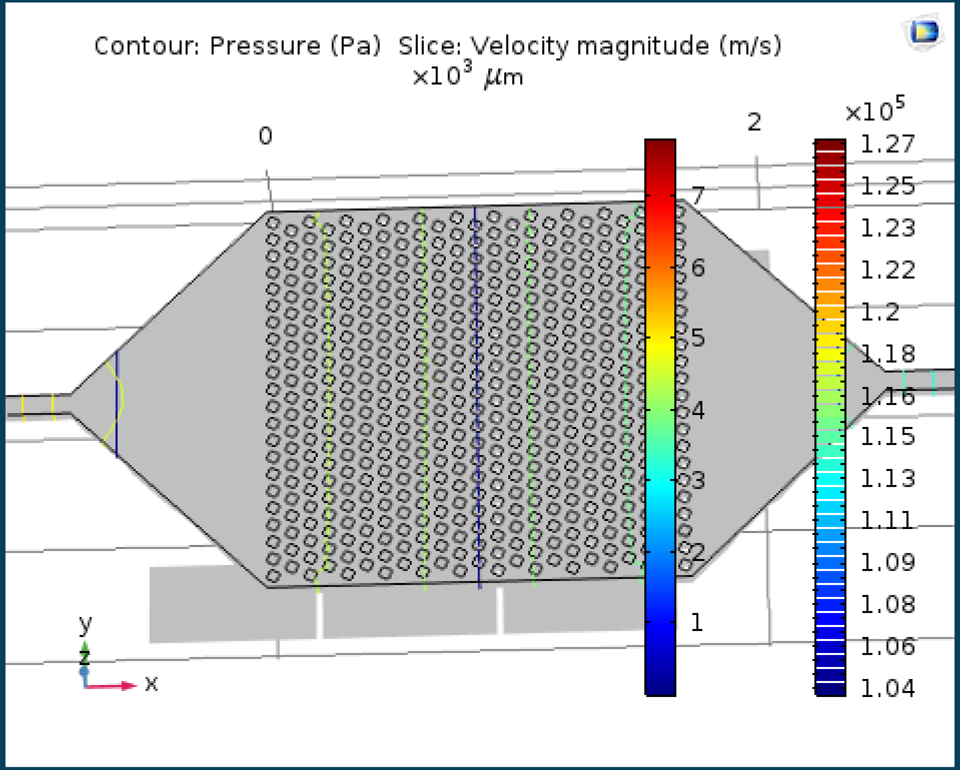
Alternating 50 micron diameter cylindrical posts with sloping inlets and outlets

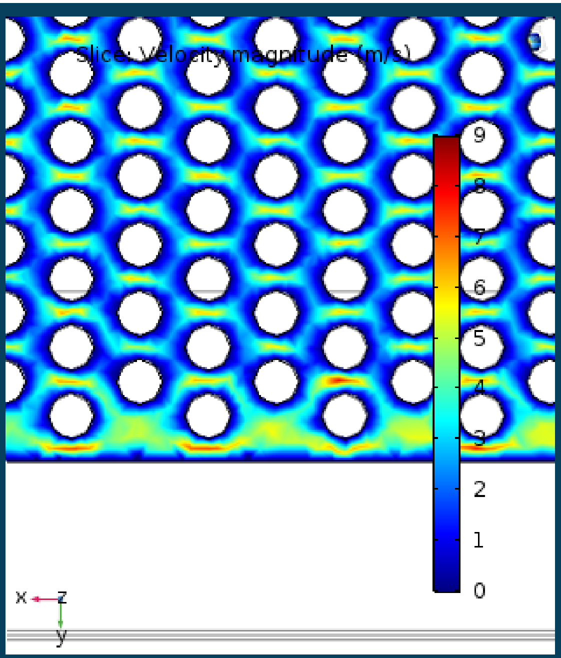
Left: Mingxiao Li *et al.* 2012
Right: Ming-Yee Wong *et al.* 2012

I. Design and Computational

- Computational Analysis with COMSOL Multiphysics showed even gas flow through the device
- FEM also showed low pressure drop (~3 psi)







II. Fabrication

1. Photolithography of back side

2. Metallization and lift-off

3. Photolithography of top side

4. Deep etching of silicon

5. Sputtering CNT catalyst and liftoff

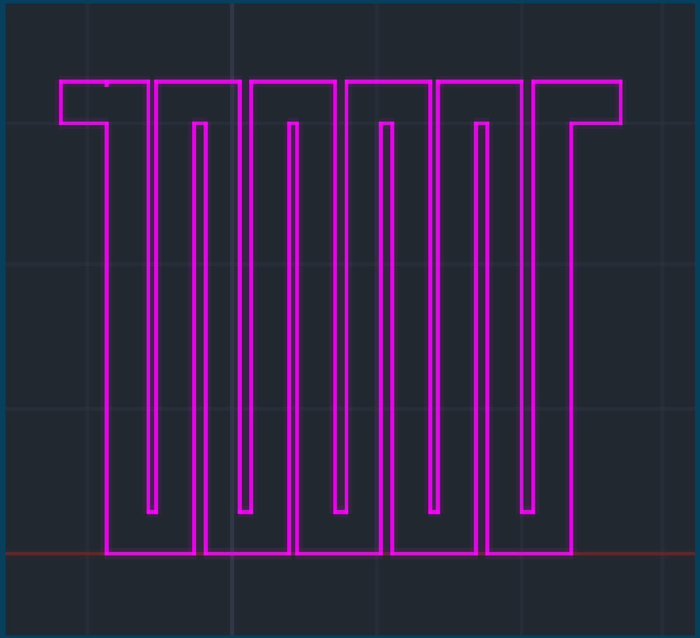
6. PECVD growth of CNTs

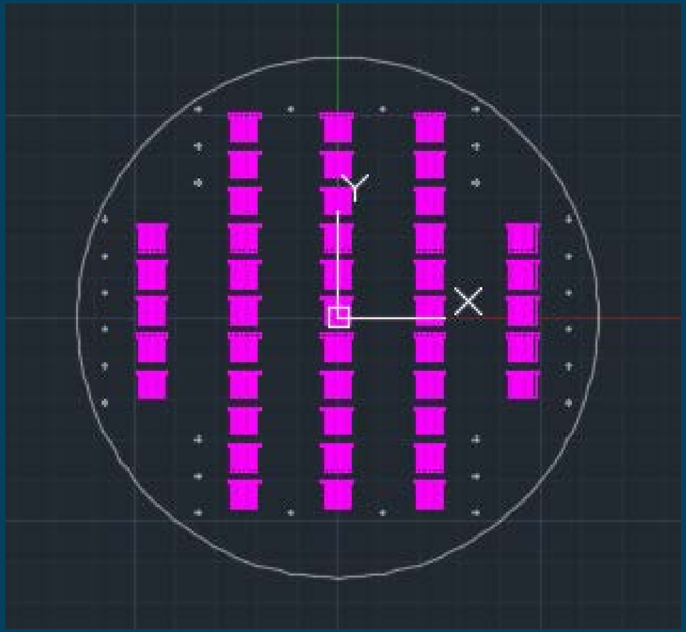
7. Bonding with another wafer

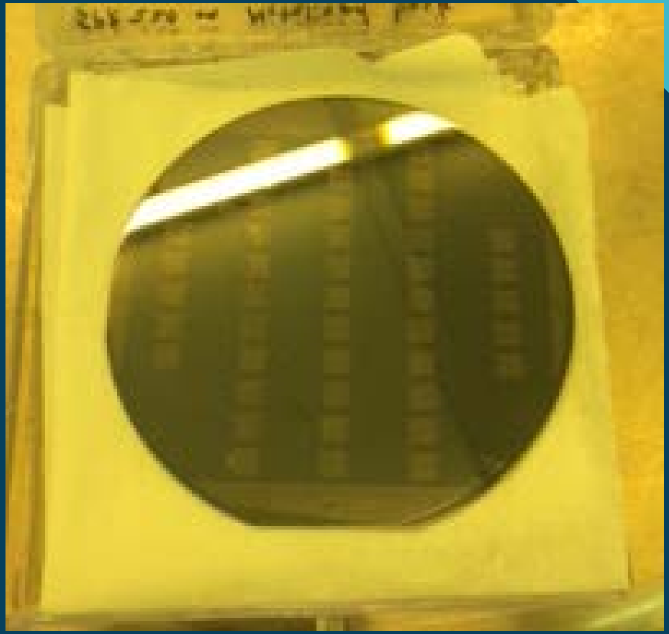
8. Dicing and testing

Resistive Heating Element

- A negative photoresist was exposed with the MLA 150 Maskless aligner
- 300 nm Au with 15 nm Ti adhesion layer was deposited with E-beam deposition
- Excess metal was removed using a liftoff procedure

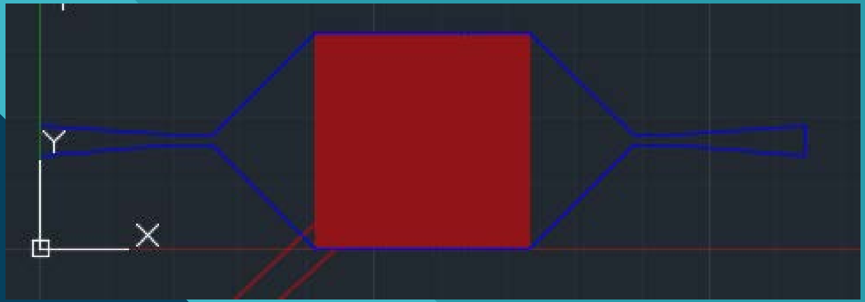


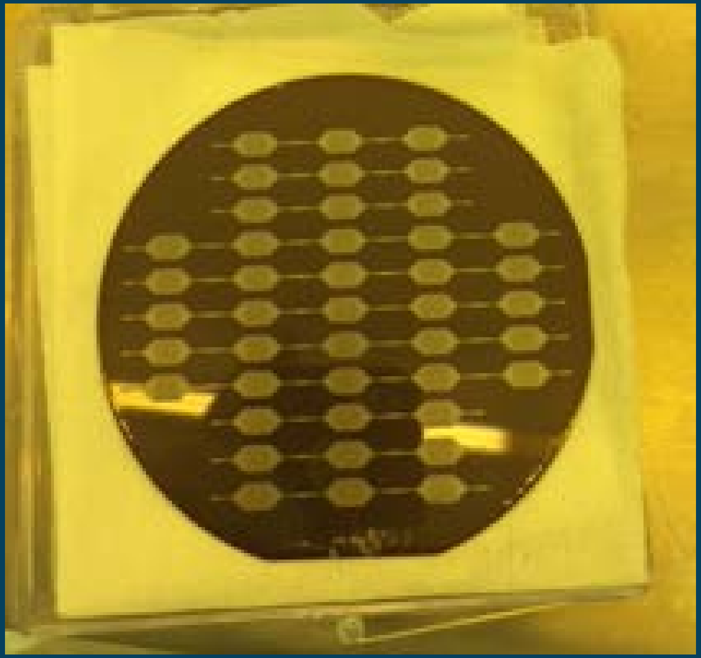


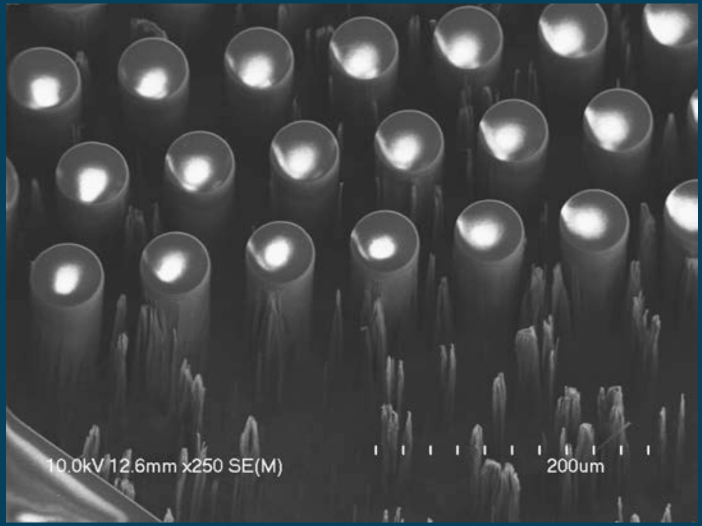


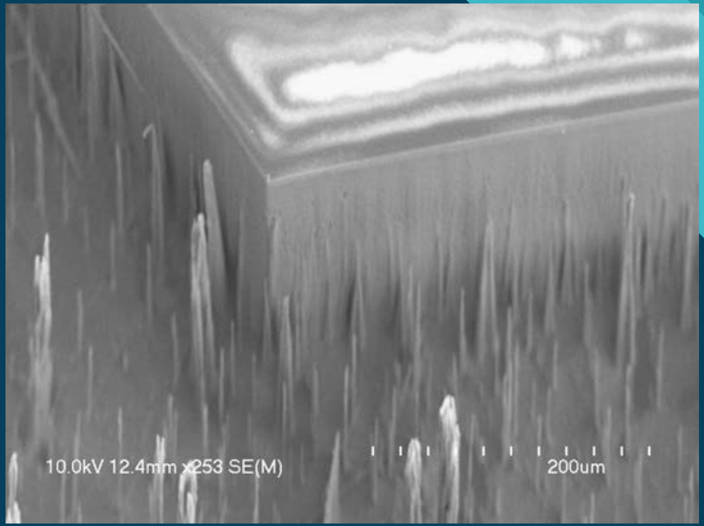
Channel Etching and Sputtering

- Thick photoresist
- Deep Reactive Ion Etching used to make a deep channel
- Sputtered film was used to deposit CNT catalyst









Further Work

1. Characterize the CNTs performance as an adsorbent
2. Test the performance of the preconcentrator
3. Integrate the preconcentrator into a sensor array

Questions?