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Aligned ZnO nanorod arrays for sensor applications

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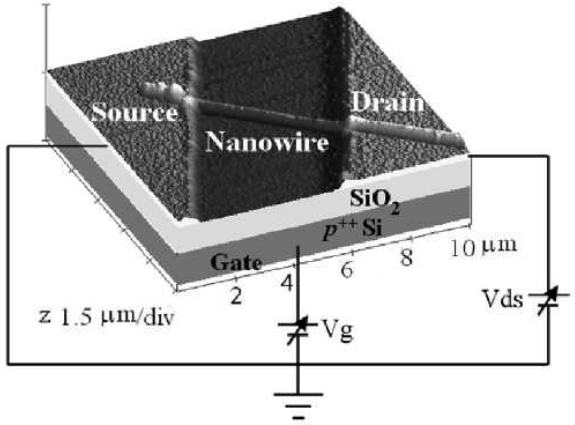
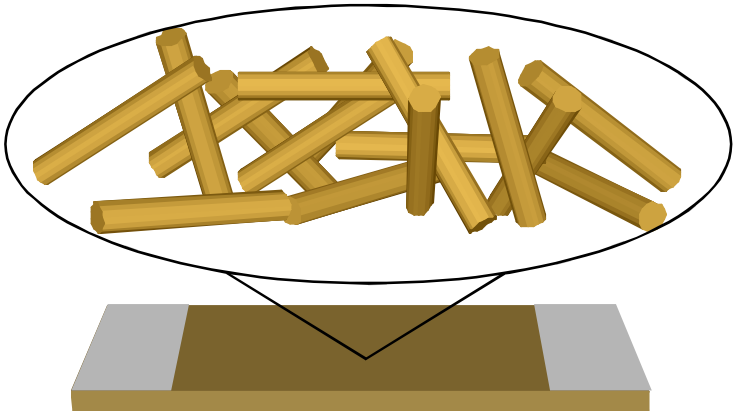
Acknowledgements:
Sandia LDRD, Sandia Truman Fellowship

Motivation/Objectives

Nanostructured materials offer high surface area to volume ratios





Individual nanorod FET devices

- High Sensitivities
- RT operation
- Difficult to fabricate

Nanostructured Films

- Easy to fabricate
- Operated at high temperatures (>150ºC)

Fan & Lu, IEEE Trans. Nanotechnology, 5, 393, (2006).

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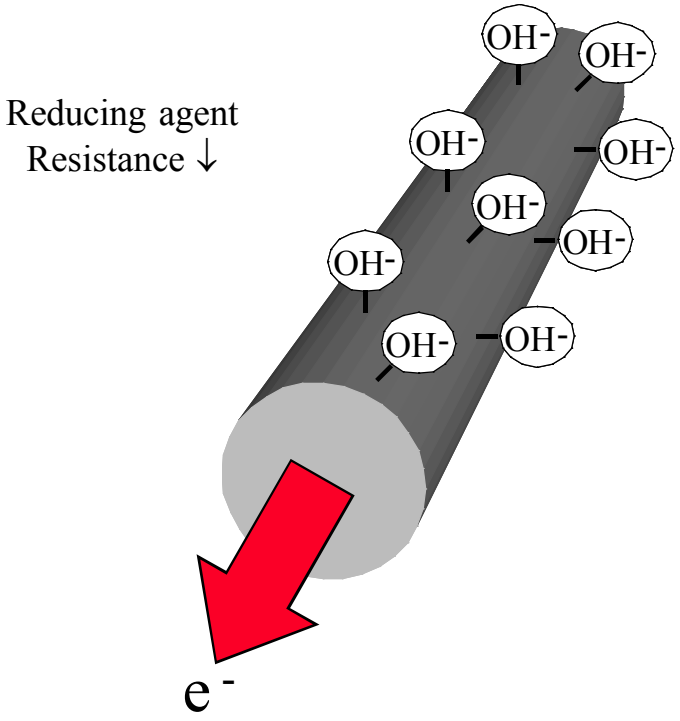
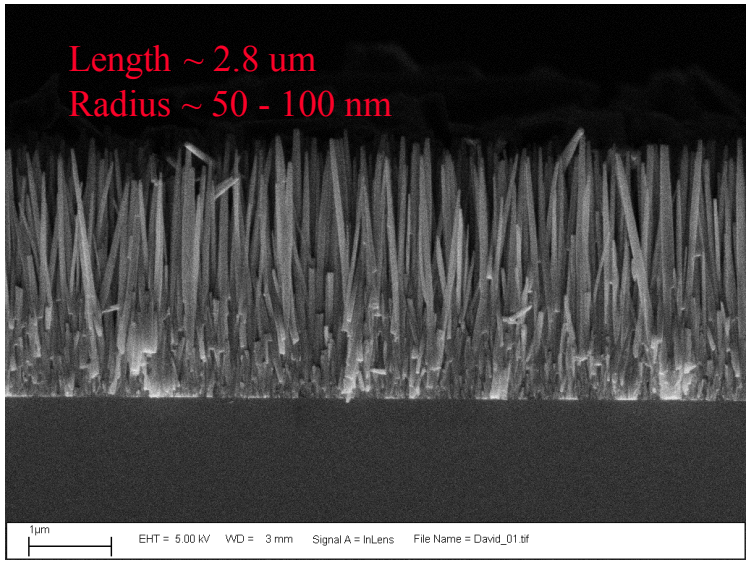
ZnO Nanostrucutred Sensors

Mechanisms of Resistive Oxide Sensors

- Chemisorbed oxygen species on surface bind conduction electrons
- Reducing species react with oxygen and releases electrons



Nanostructured ZnO



- Growth on silicon wafers
- Solution growth at 92.5°C
- Harvested via ultrasonic dispersal

Details on growth technique:

Z3.8 11:15 Wednesday

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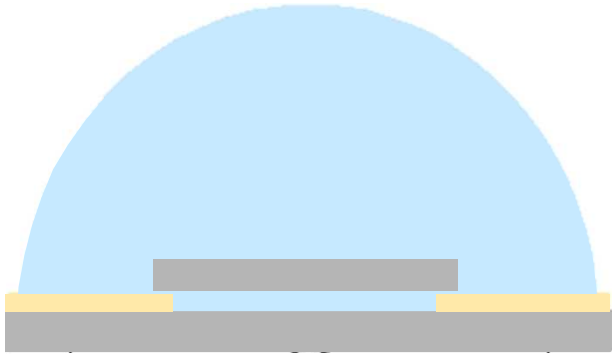
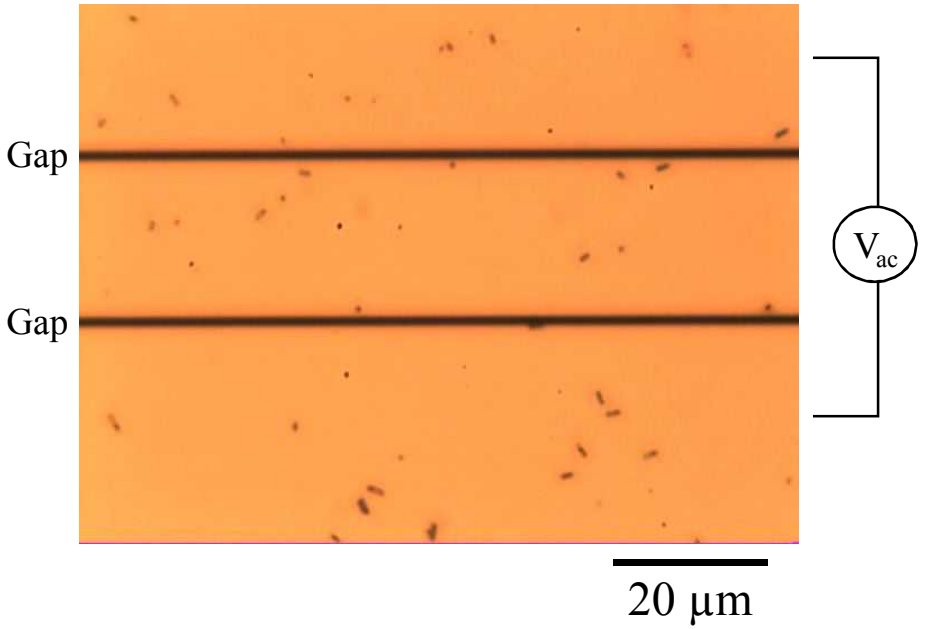
Dielectrophoretic Assembly of Nanorods

Dielectrophoresis (DEP) - motion of uncharged particles in non-uniform electric field



Interaction of E-field with induced dipole



Deposition parameters:

- Dielectric medium
- Electric field (AC frequency and voltage)
- Solution concentration
- Deposition time

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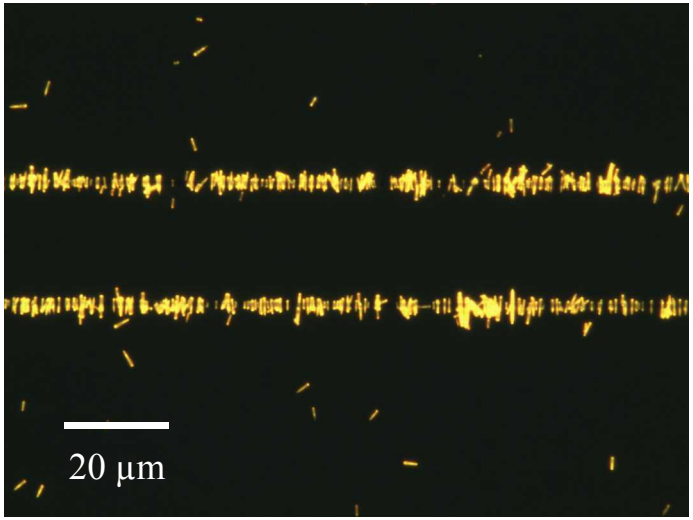
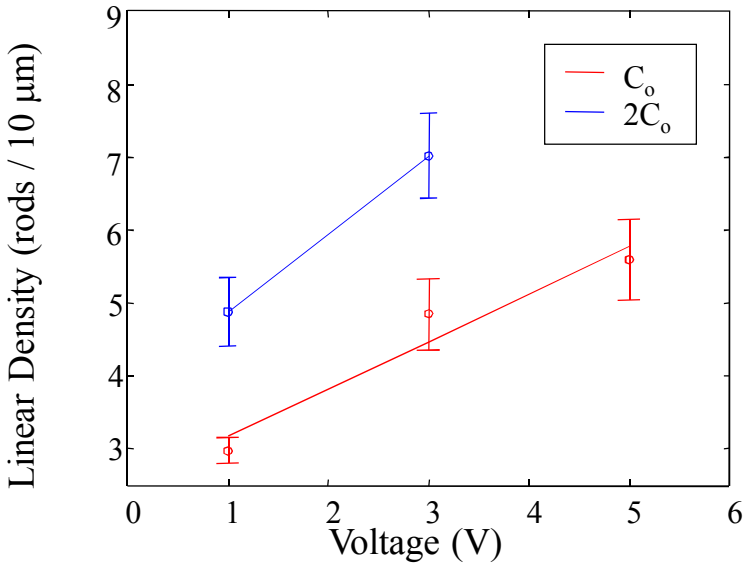
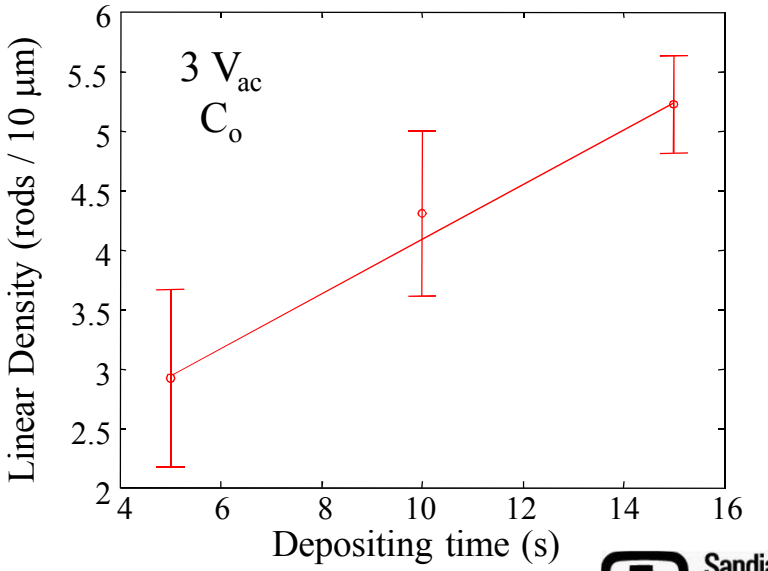
Deposition Parameters







Ultrasonicate samples in H_2O or EtOH 15 min

- Deposit at 10 MHz
- Voltage
- Solution concentration
- Deposition time

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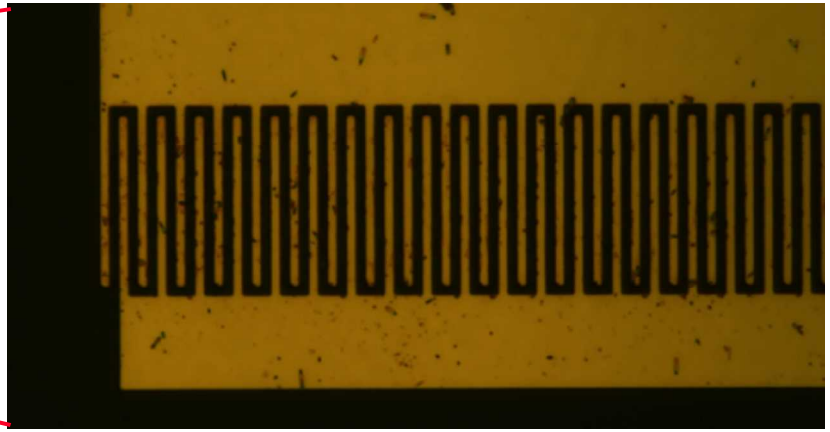
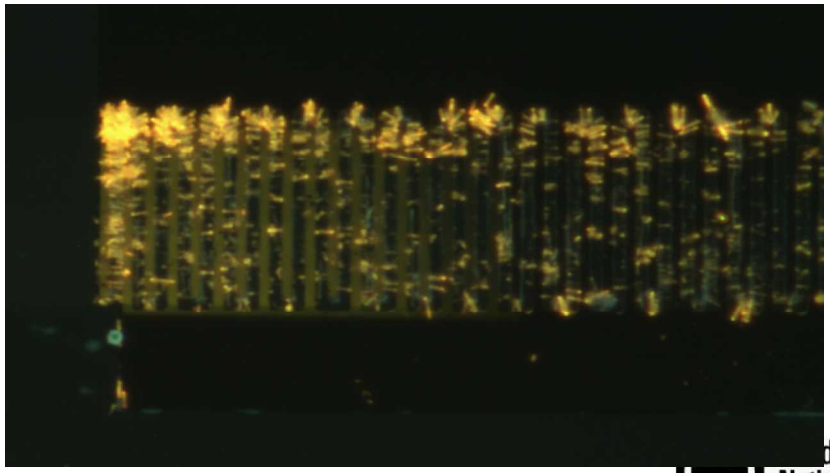
Structured Sensors

Assembed on interdigitated electrodes with 2 μm gaps

Deposition parameters 10 kHz, 10 V_{ac}, 10 minutes

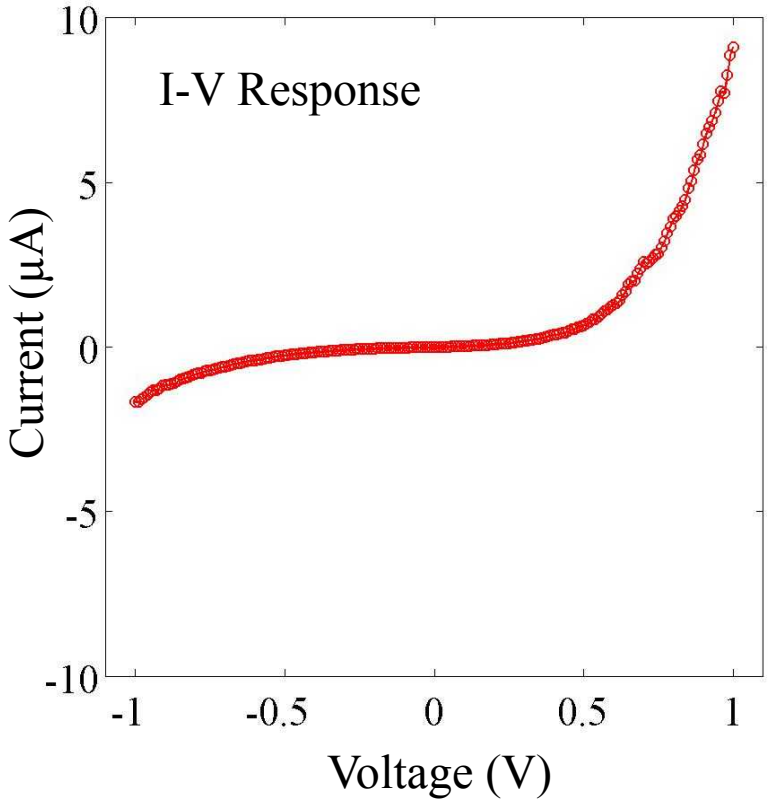
Densities ~ 1.5 rods / 10 μm

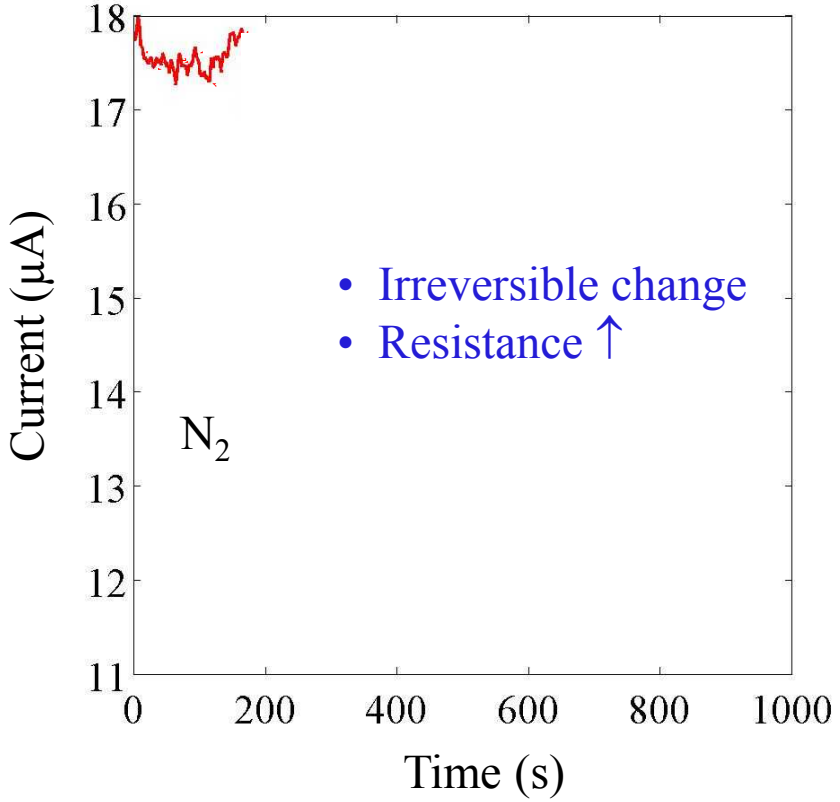




Structured Sensors Response

Placed in test fixture, flow rate 10 sccm
Bubble N_2 through ethanol well
Apply bias (0.2 V), measure currents (Keithley 6487)





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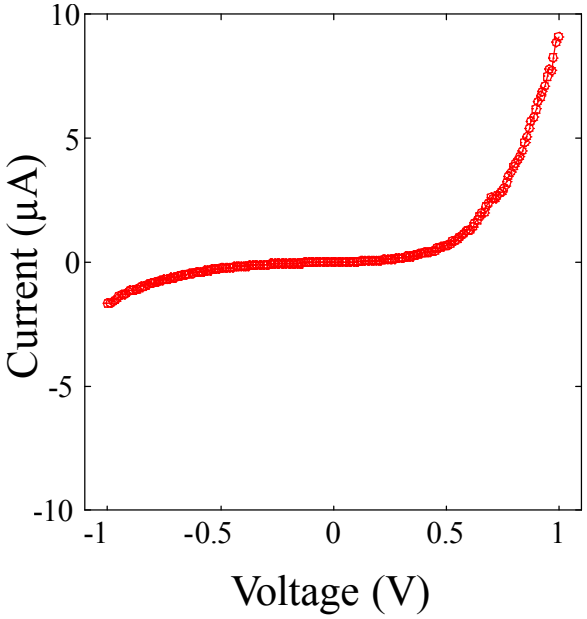
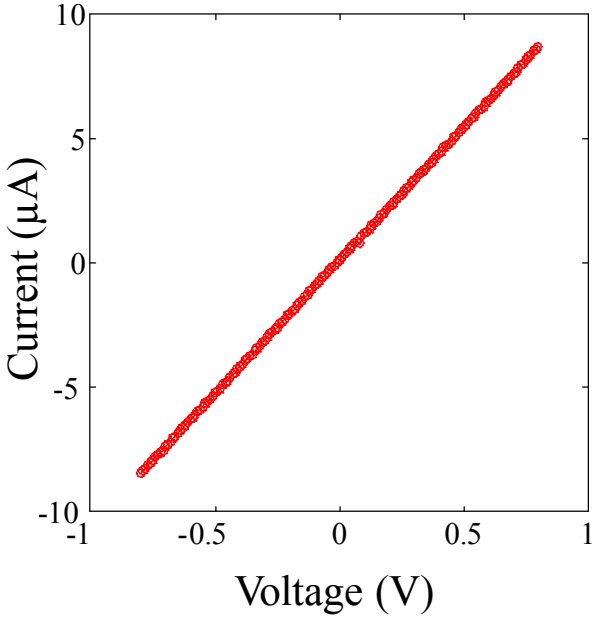
I-V Curves on Structured Sensors

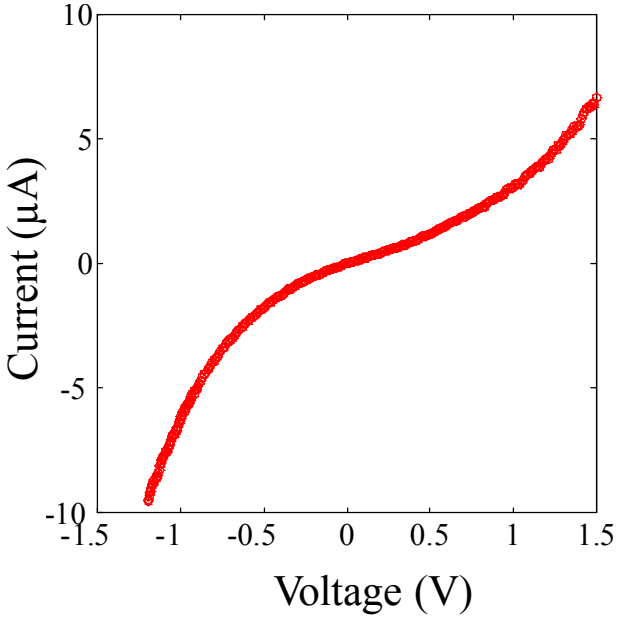
As fabricated



Post exposure



After heating



- At high concentrations condensing solvent on electrodes
- Interaction creating ohmic connections
- Dominated by electrode effects

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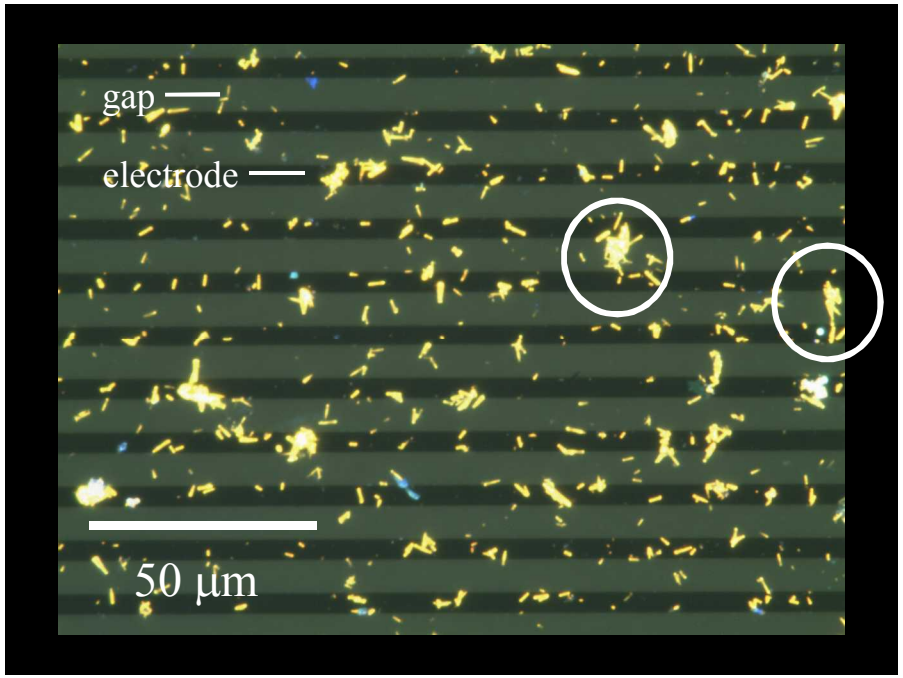
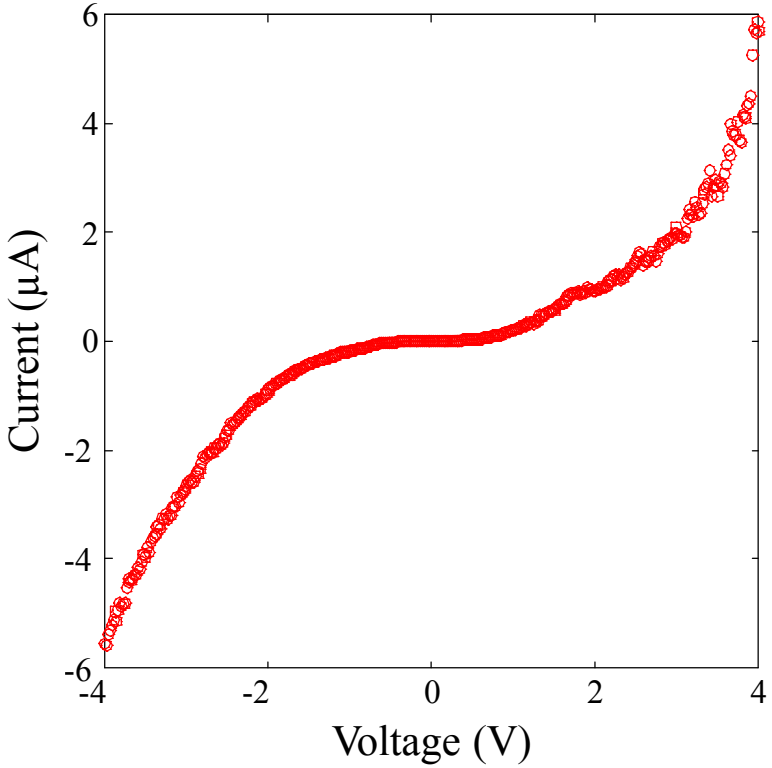
Random Network Sensors

Dry ~150 µL ethanol dispersed rods on IDE pattern
Gaps 10 µm





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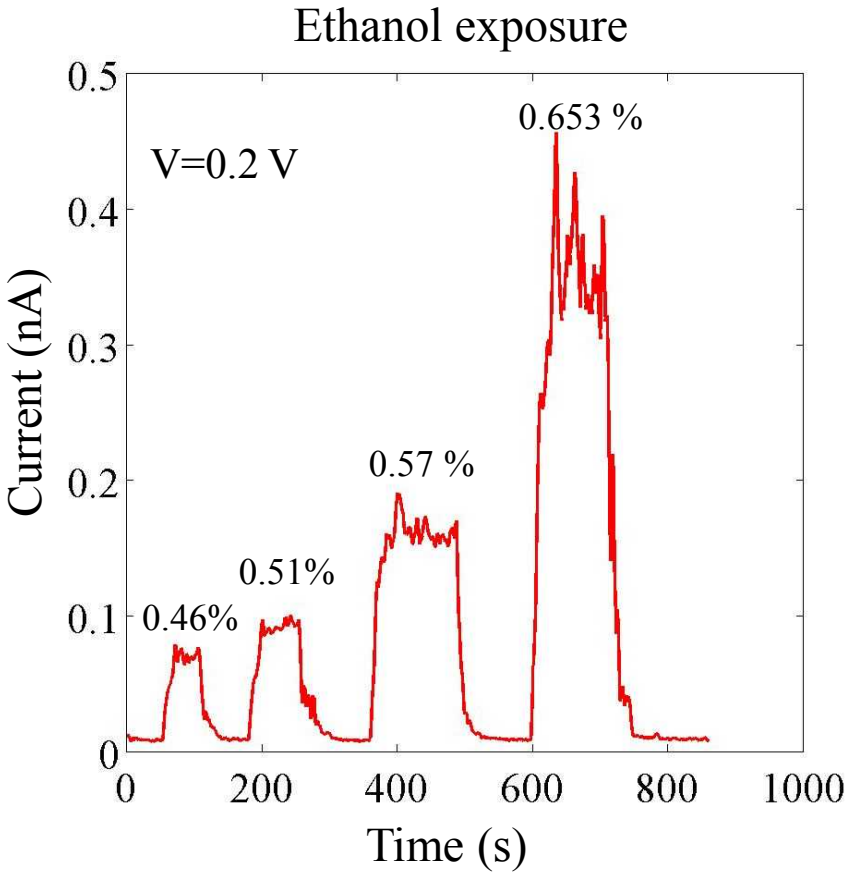
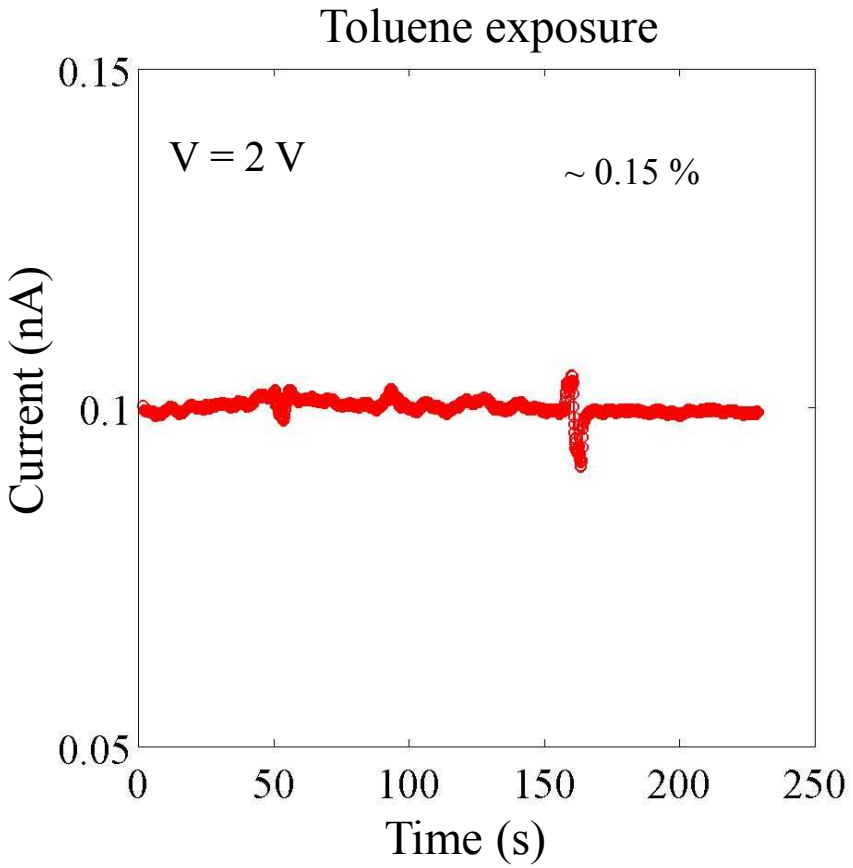
Random Network Sensitivity





Sensitivities $\left|\frac{\Delta R}{R_c}\right|$ ~ 35 @ 0.65%

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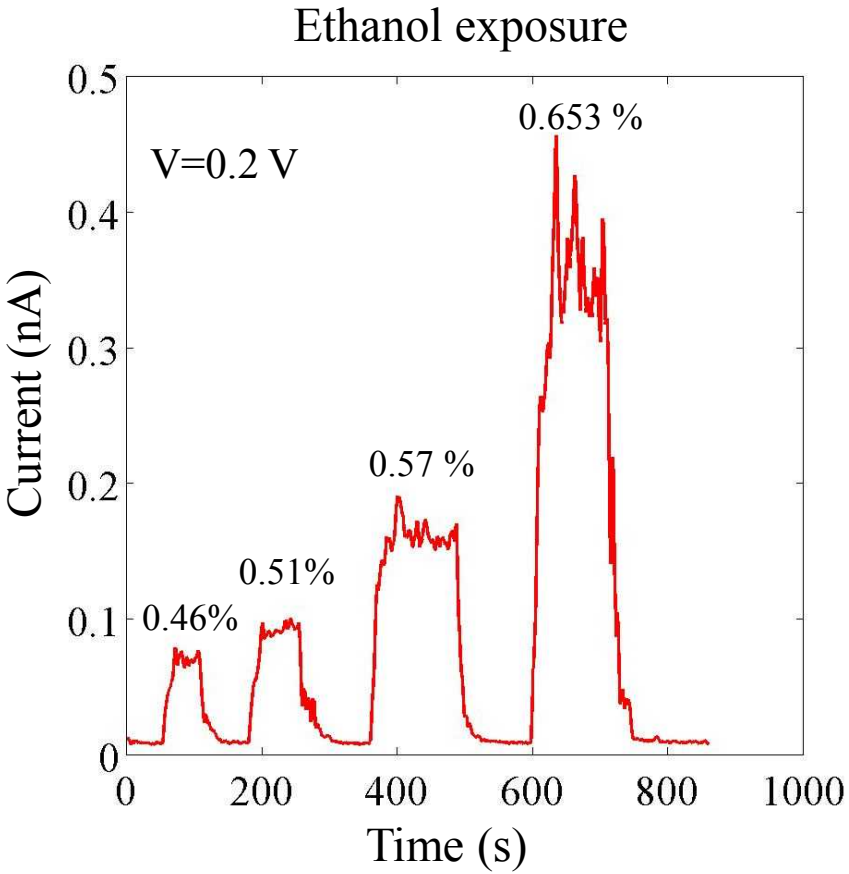
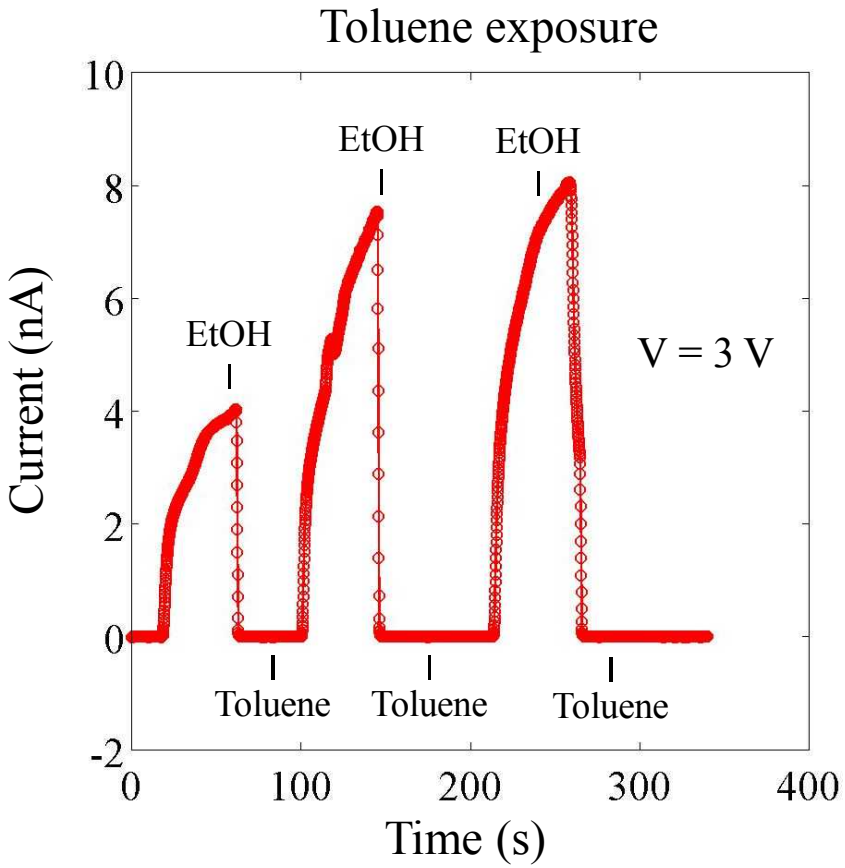
Random Network Sensitivity





Sensitivities $\left|\frac{\Delta R}{R_c}\right| \sim 35 \text{ @ } 0.65\%$

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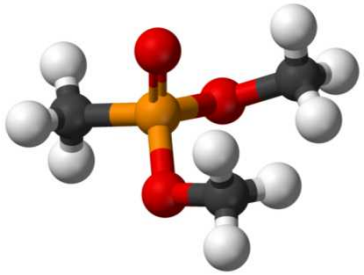
Random Network Sensitivity

Dimethyl methylphosphonate (DMMP)

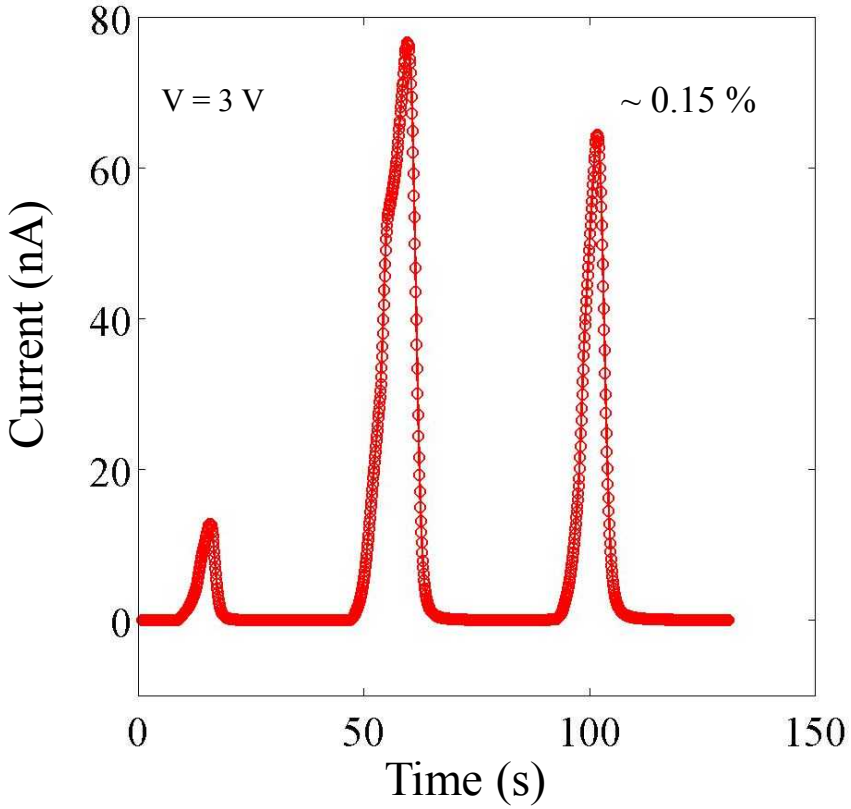
$C_3H_9O_3P$



Flame retardant, anti-foaming agent, stabilizer

Simulant Sarin nerve gas

DMMP Headspace Exposure



Sensitivities $\left|\frac{\Delta R}{R_c}\right|$ ~ 300 @ 0.15%

http://en.wikipedia.org/wiki/Image:Dimethyl-methylphosphonate-3D-balls.png

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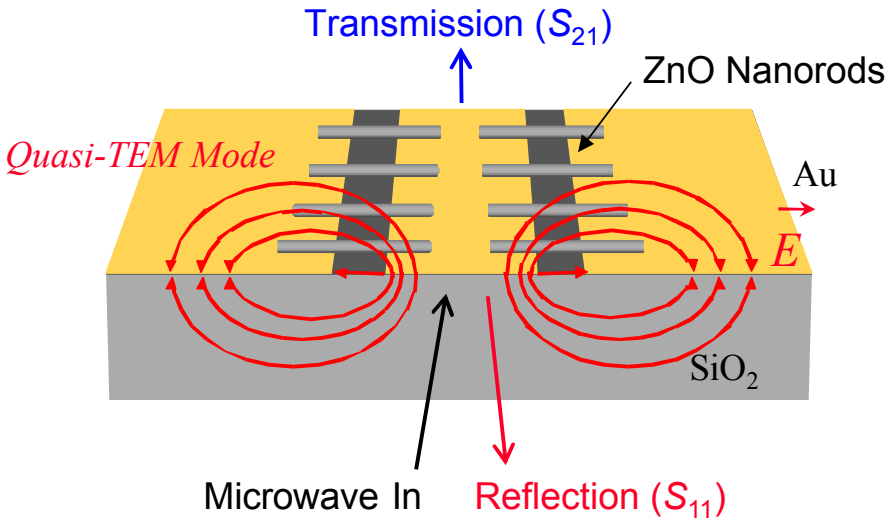
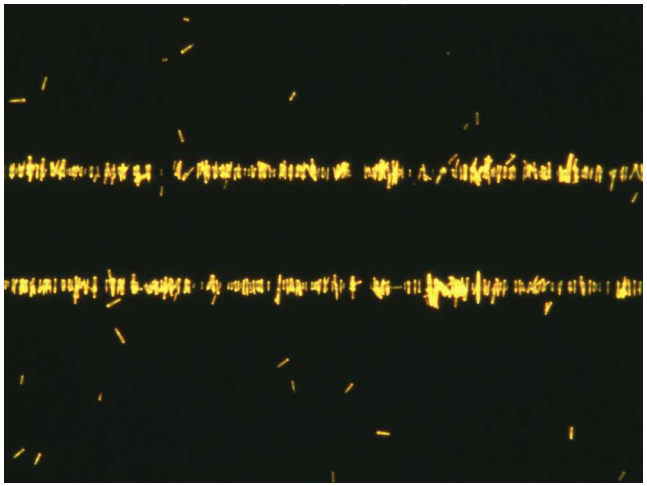
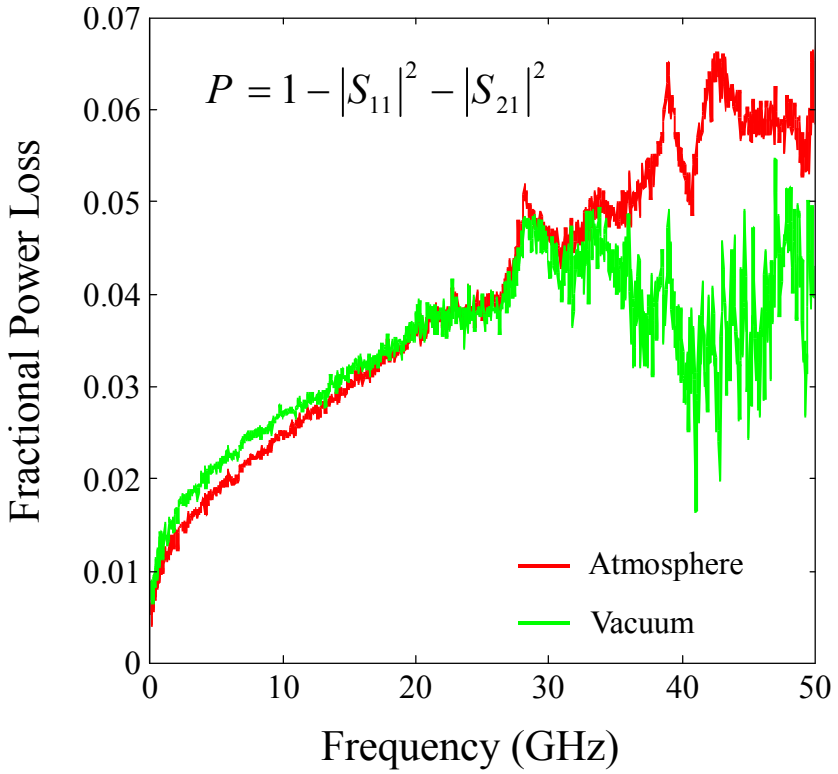
High Frequency Measurements

Assemble on Coplanar Waveguide (CPW) Platform







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Conclusions/Future Work

Successfully deposited ZnO nanorods on electrode structures

Investigated structured electrodes as sensors

Random unstructured networks showed good sensitivity to EtOH and DMMP at room temperature

Work on structured sensors → Figure out fouling mechanism
Low concentrations
Higher temperatures

High frequency sensor properties

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The End

stuff