A Study and Evaluation of Meat Freshness using Tin Oxide Nanomaterial e-Nose Sensor

The Angelo King Institute for Economic and Business Studies

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Objectives

Determine the effect of AMF on SnO_2 nanomaterial synthesis via the Horizontal Vapor Phase Crystal Growth (HVPG) technique

- morphological structure
- optical property
- electrical property
- fabrication of gas sensor substrate for meat spoilage detection

Objectives

Gas sensing ability of the SnO_2 nanomaterials (optimized) for meat spoilage detection, operated at room temperature was investigated

- determine the freshness of meat via electrical measurement technique
- Identify components of meat odor (headspace) using GCMS
- Correlate GCMS result with sensor response

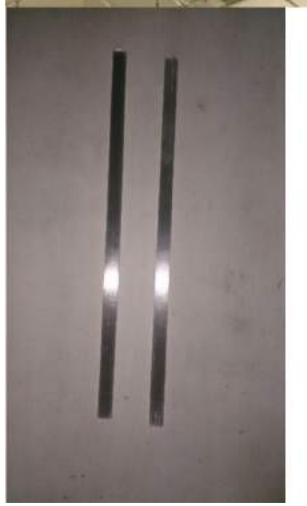

METHODOLOGY

Preparation

Sealing and cleaning of tube

Loading 50 mg SnO_2 Powder

Evacuating to 10^{-6} Torr and full sealing of tube



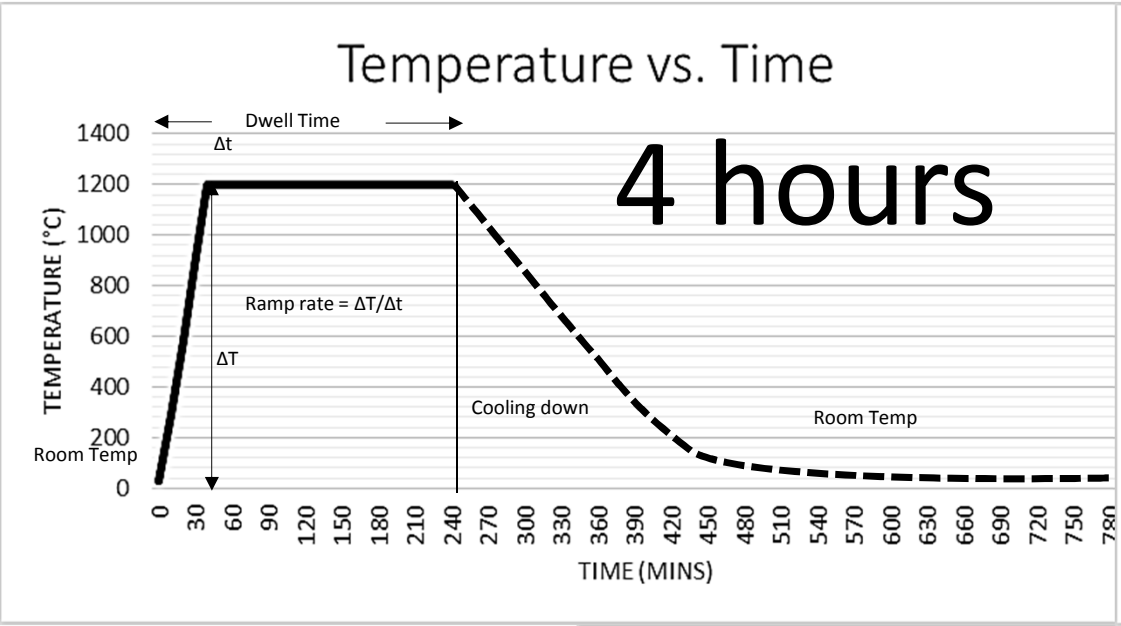
Fabrication

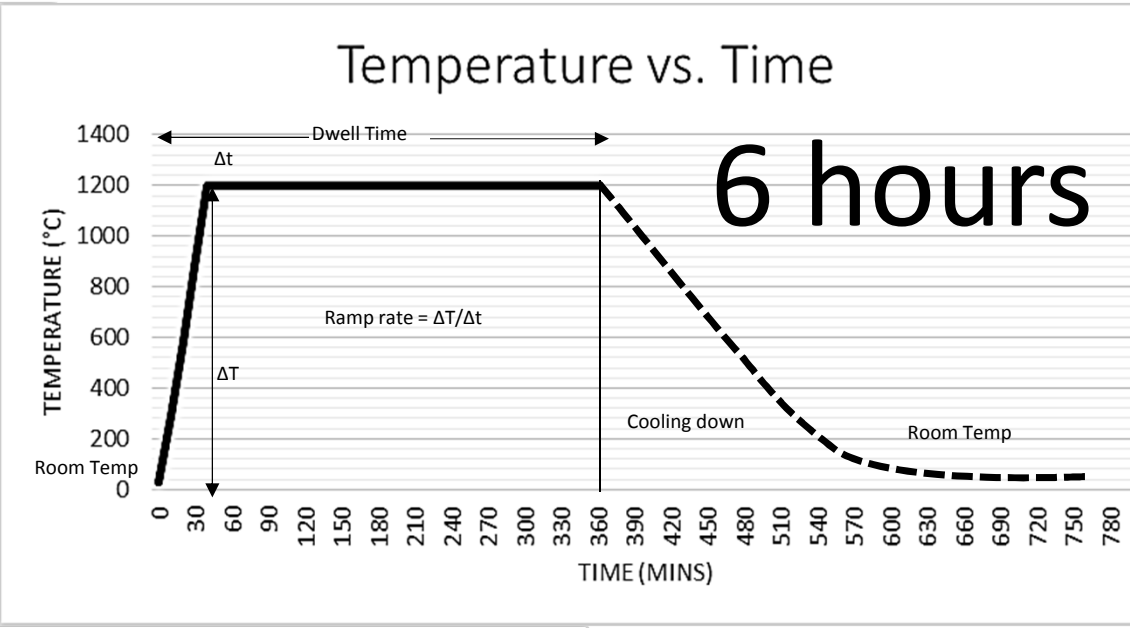
W/o AMF

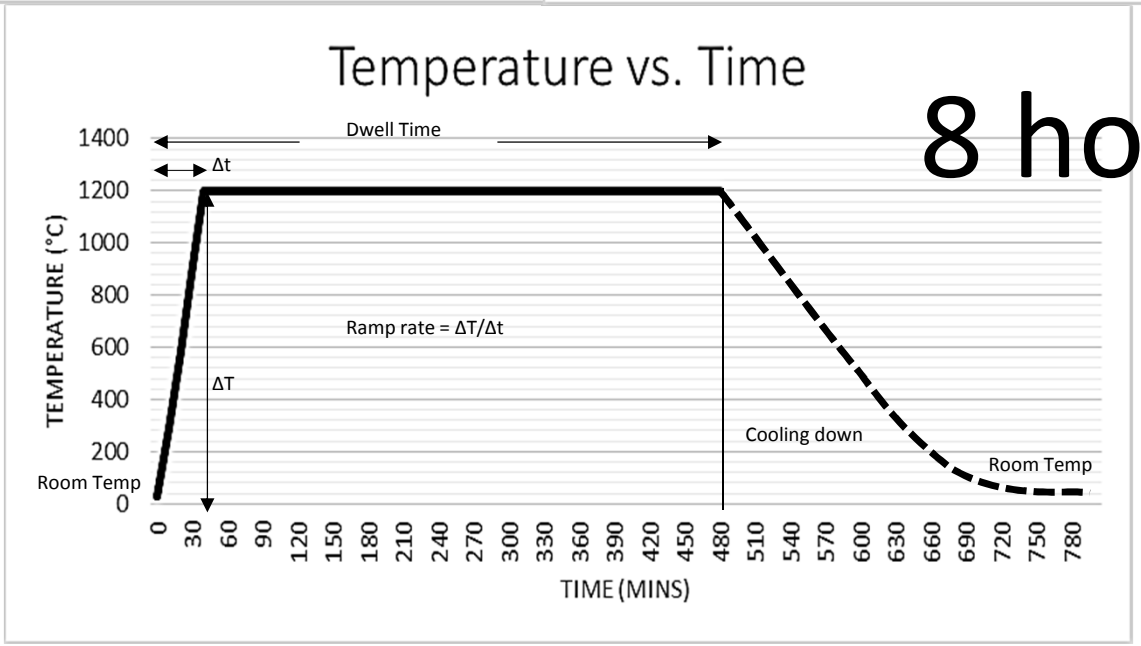
With AMF

Growth temp.:
1200 °C.

Dwell time: 4, 6, 8 hours
Ramp time: 40 mins


Temperature vs. Time
Dwell Time
Δt
4 hours
Ramp rate = ΔT/Δt
ΔT
Cooling down
Room Temp
Room Temp
TEMPERATURE (°C)
TIME (MINS)


Temperature vs. Time
Dwell Time
Δt
6 hours
Ramp rate = ΔT/Δt
ΔT
Cooling down
Room Temp
Room Temp
TEMPERATURE (°C)
TIME (MINS)

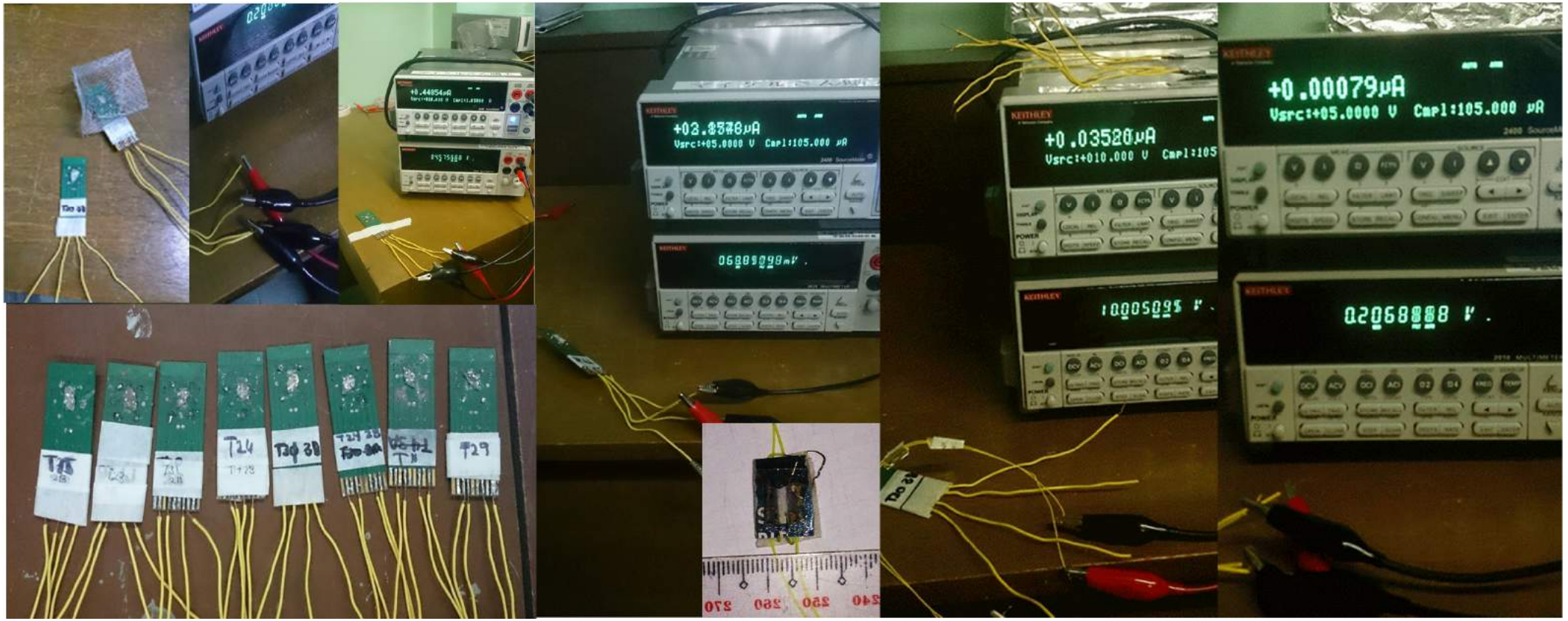

Temperature vs. Time
Dwell Time
Δt
8 hours
Ramp rate = ΔT/Δt
ΔT
Cooling down
Room Temp
Room Temp
TEMPERATURE (°C)
TIME (MINS)

Characterization/ Parametric Analysis

SEM	EDX	IV	Photoluminescence

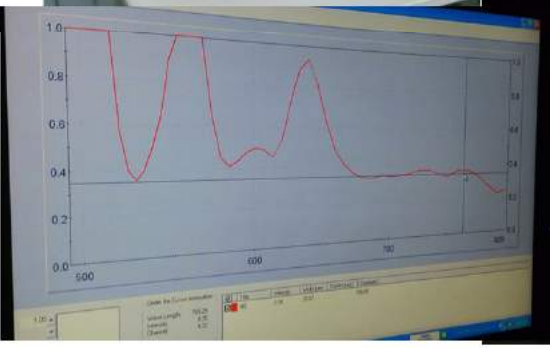
Characterization/ Parametric Analysis

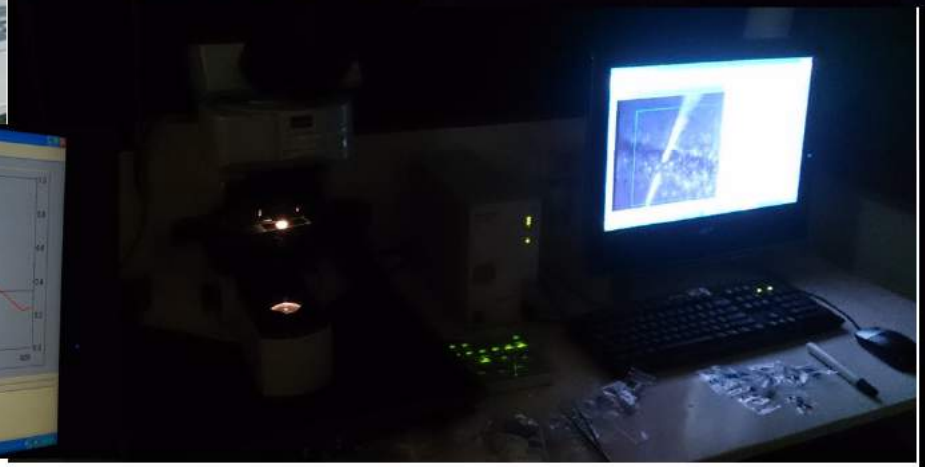
SEM	EDX	IV	Photoluminescence

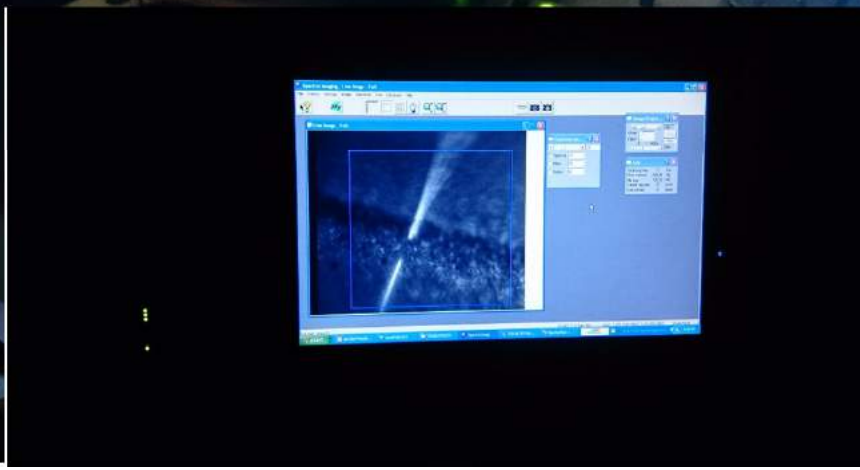


Characterization/ Parametric Analysis

SEM	EDX	IV	Photoluminescence



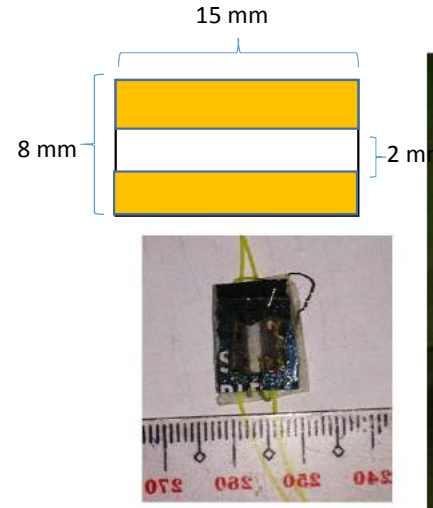


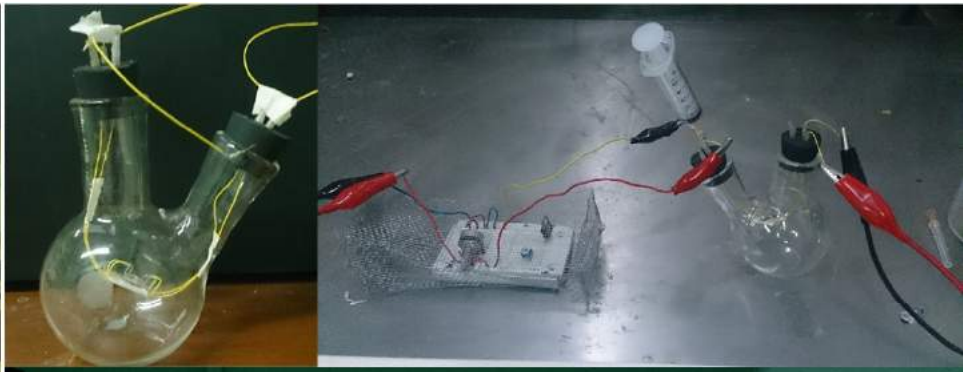


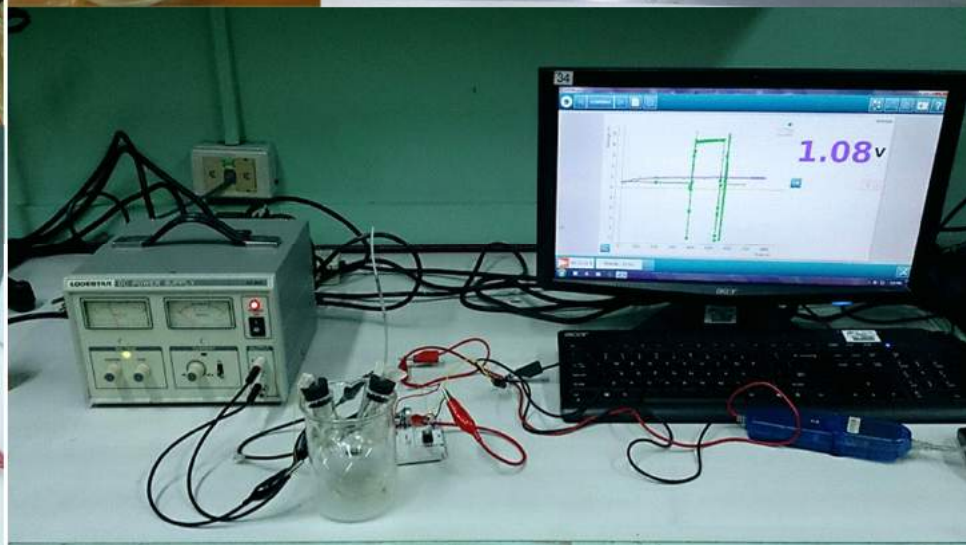
Gas Sensing Test/ Analysis

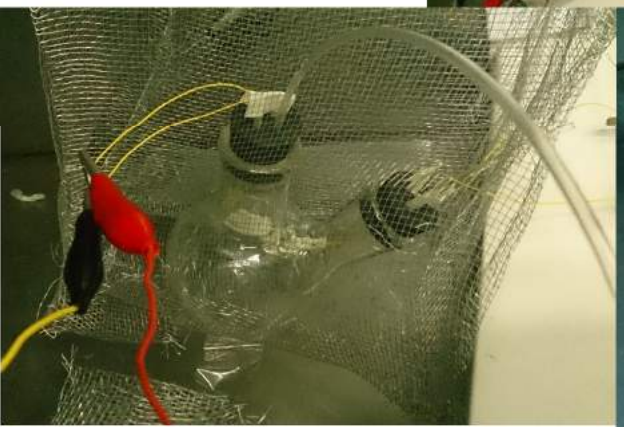
SnO_2 Sensor Substrate

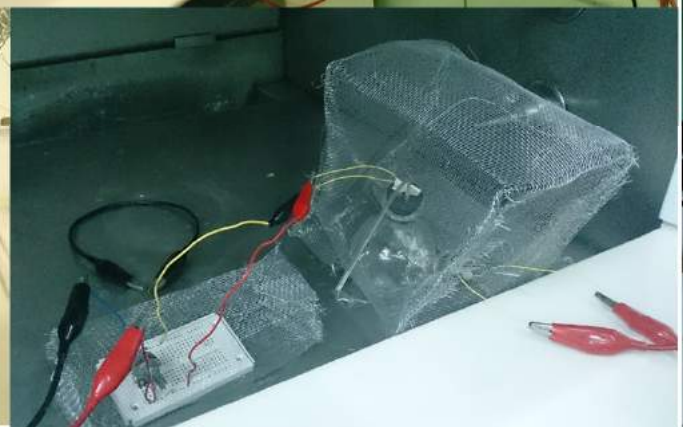
SnO_2 Sample, electrodes, Power Supply, Voltmeter







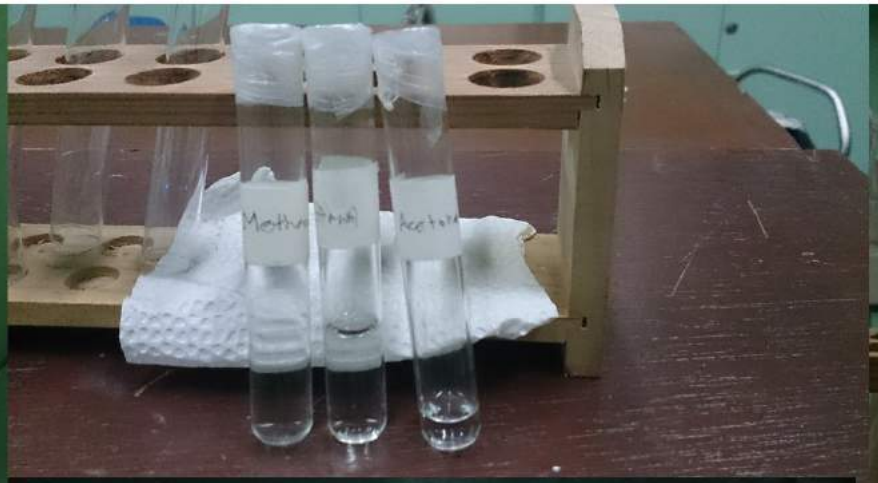


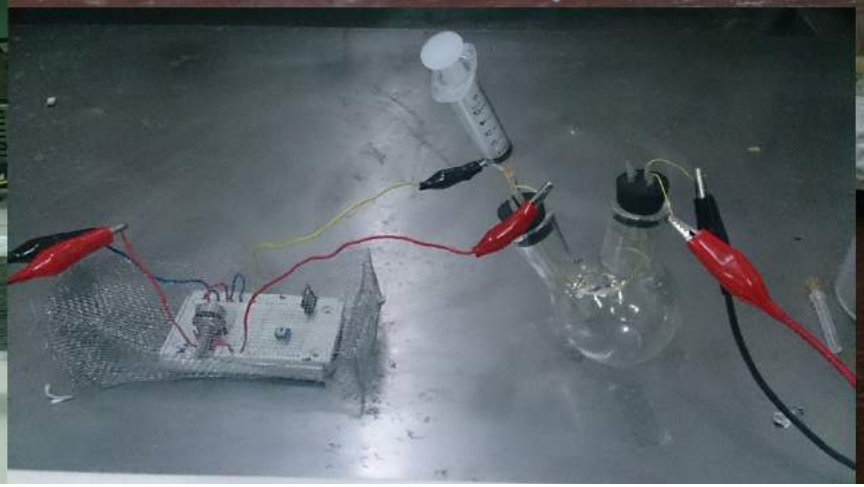


Gas Sensing Test/ Analysis

Reference Gas Test

CO_2, ethanol, methanol, acetone, Hydrogen sulfide





Gas Sensing Test/ Analysis

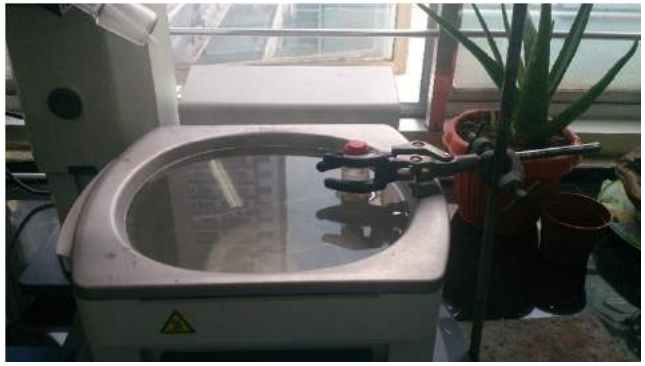
Meat Evaluation Set-up

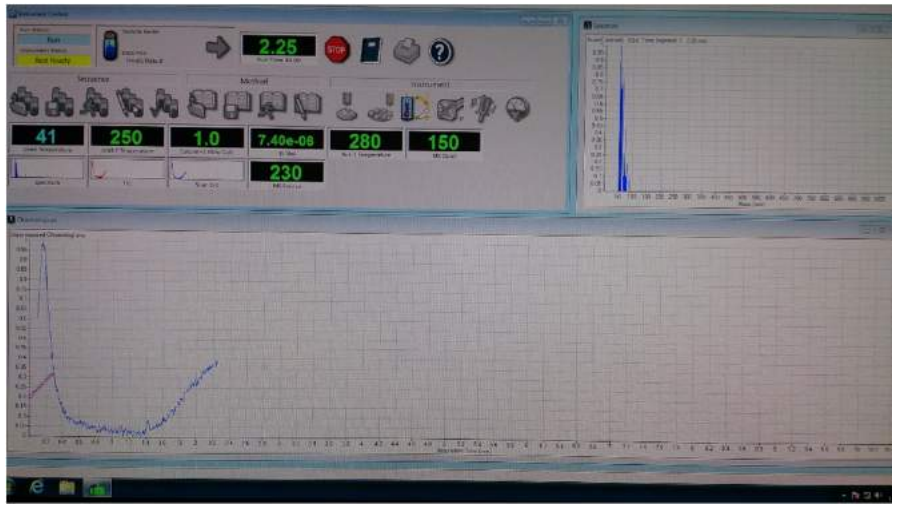
- Sample Handling
- Detection (SnO_2 sensor substrate)
- Data Acquisition

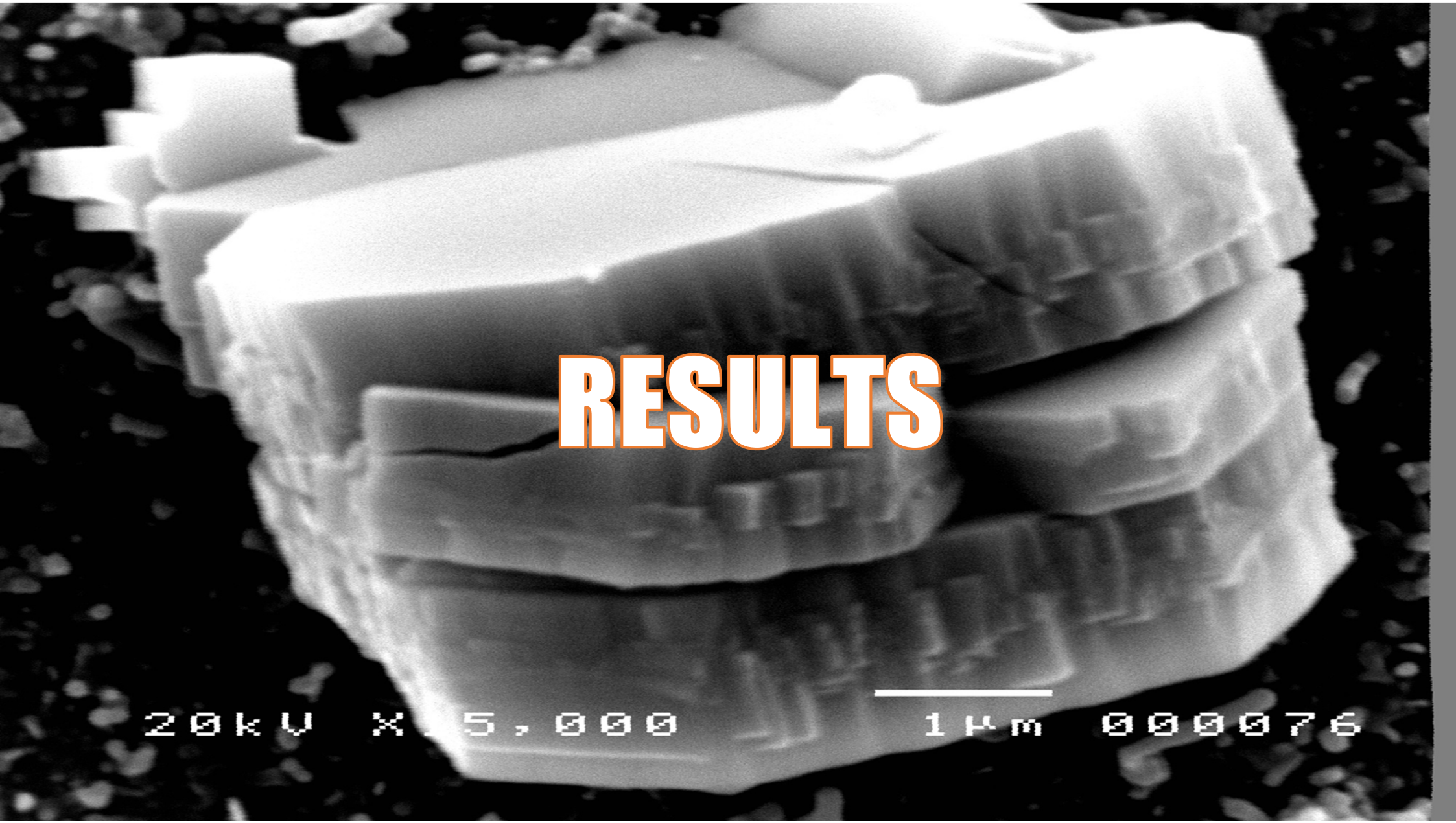
SPME-GCMS

Fresh and Spoiled Meat Samples

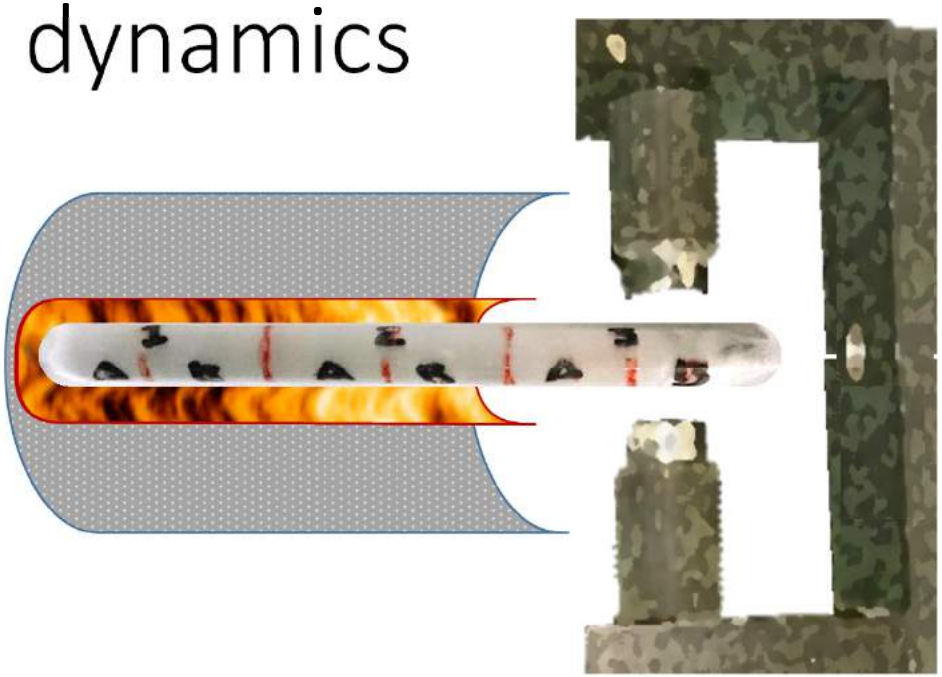
SPME fiber (50/30 µm DVB/Carboxen/PDMS coating)

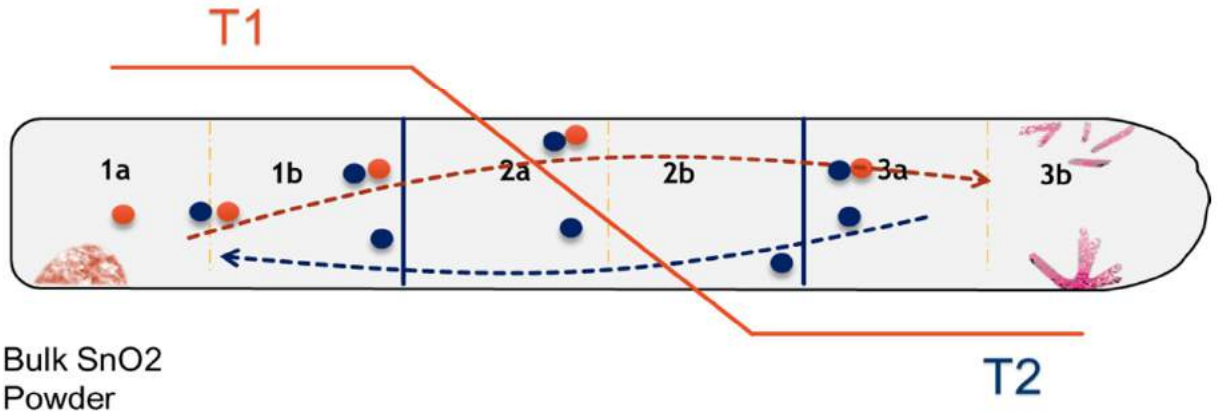





RESULTS
20kV X 5,000
1µm 000076

Experimental Setup and dynamics



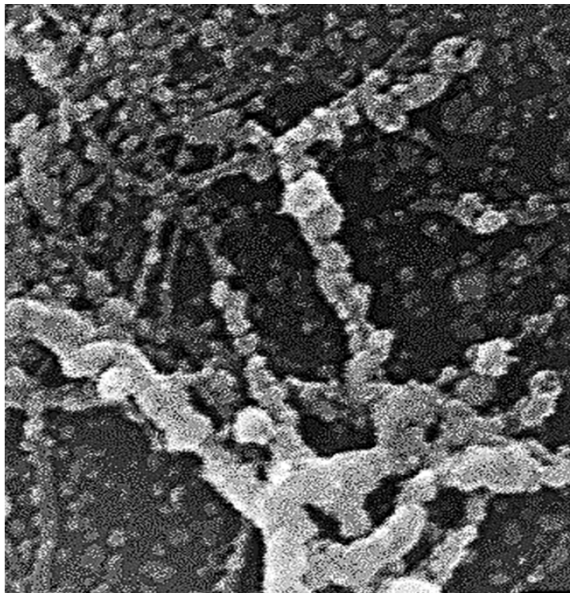


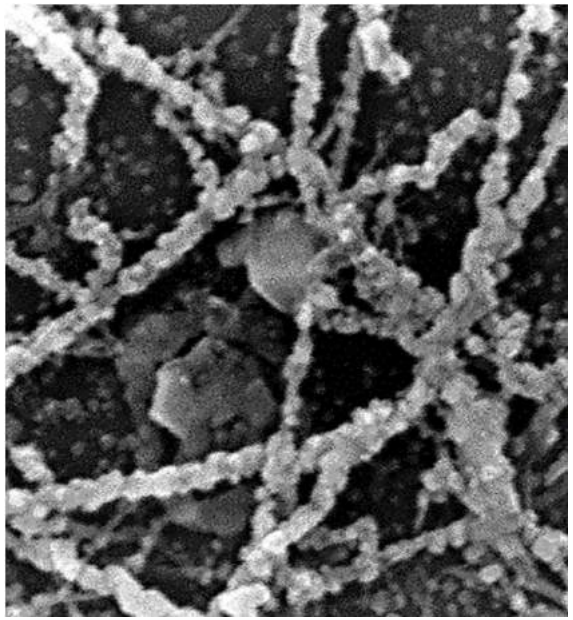
Bulk SnO_2
Powder

Nanowires preferred <90nm droplet size
(Das & Jayaraman, 2014)

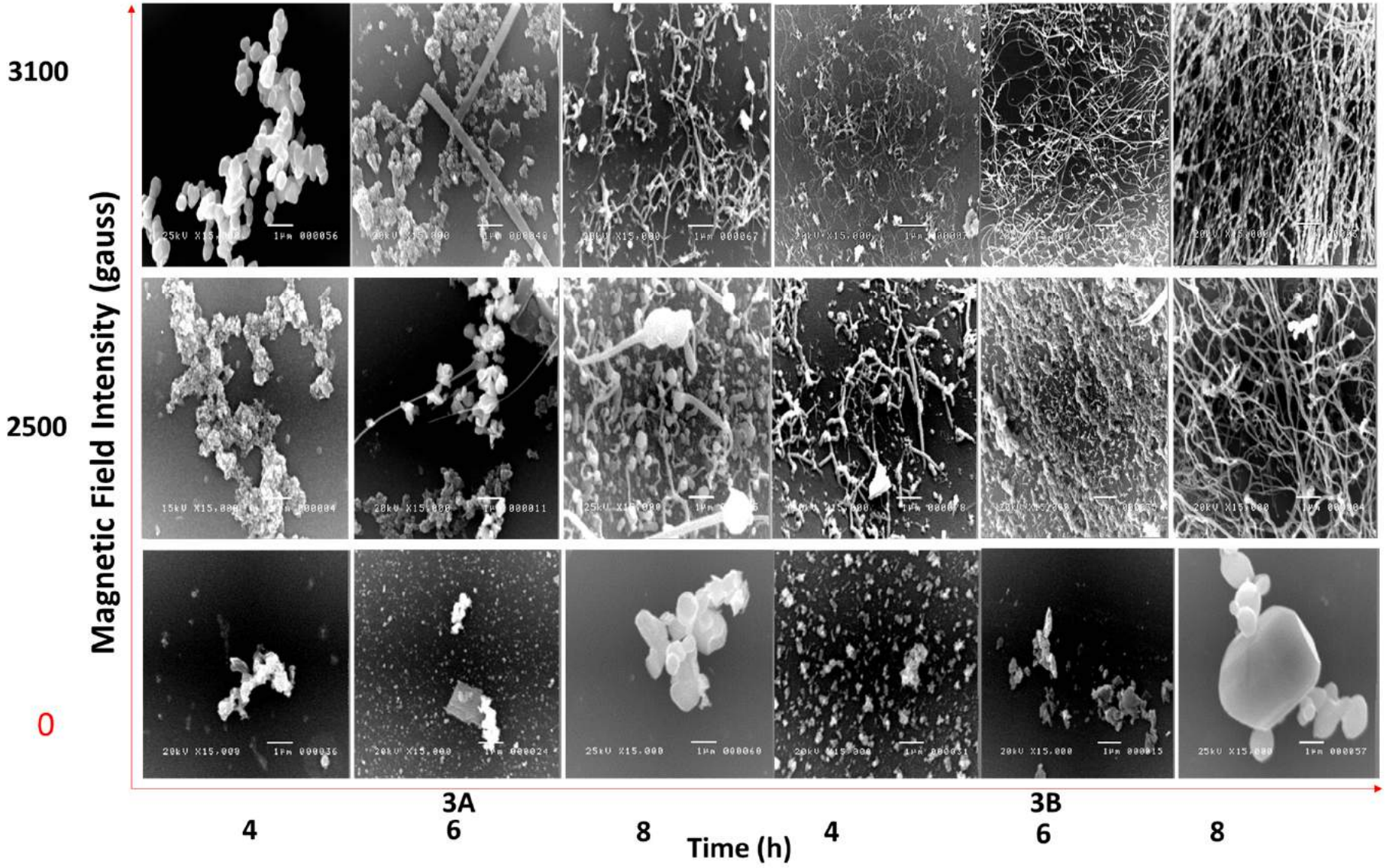
Chain formation of the nanoparticles was observed to compose the nanowires

-not seen in the control set-up of the same growth time and tube section

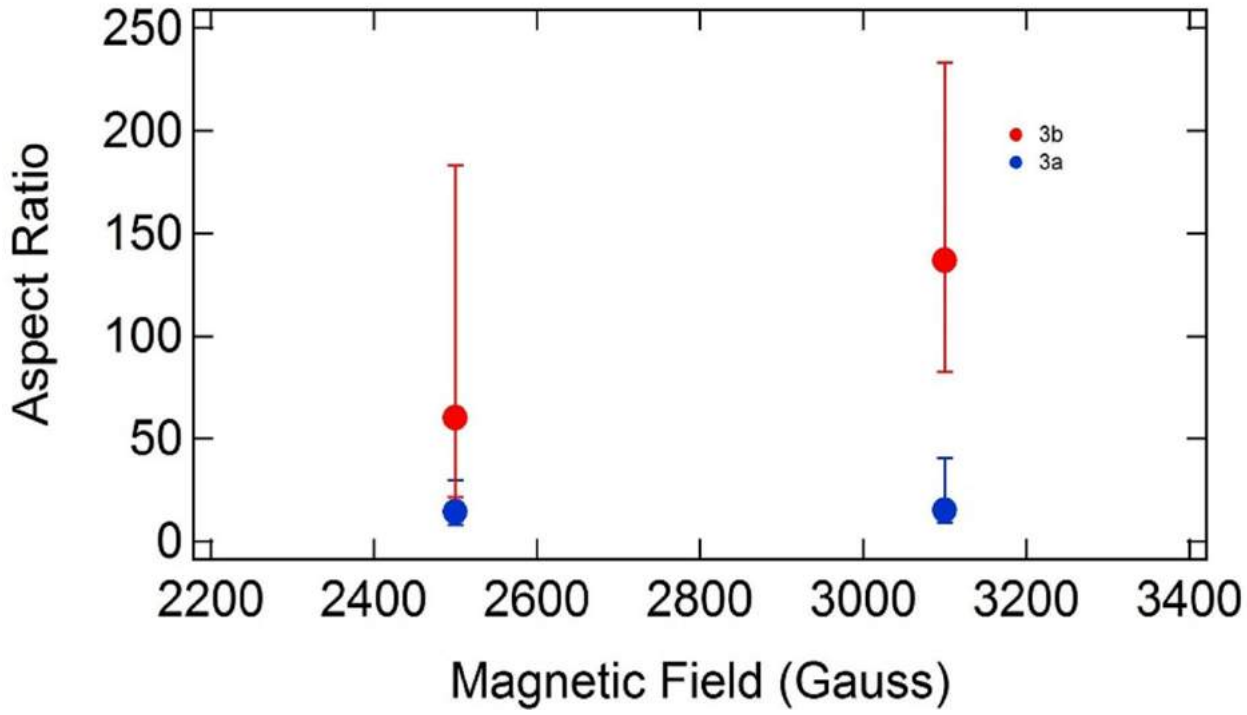


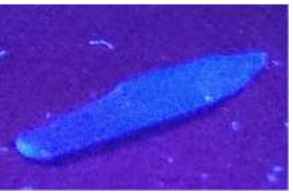


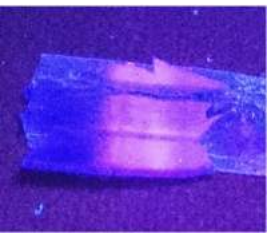
EFFECT OF APPLIED MAGNETIC FIELD ON SnO_2 MORPHOLOGY



Aspect Ratio of the Nanowires grown under different Magnetic Field intensity and position in the tube.

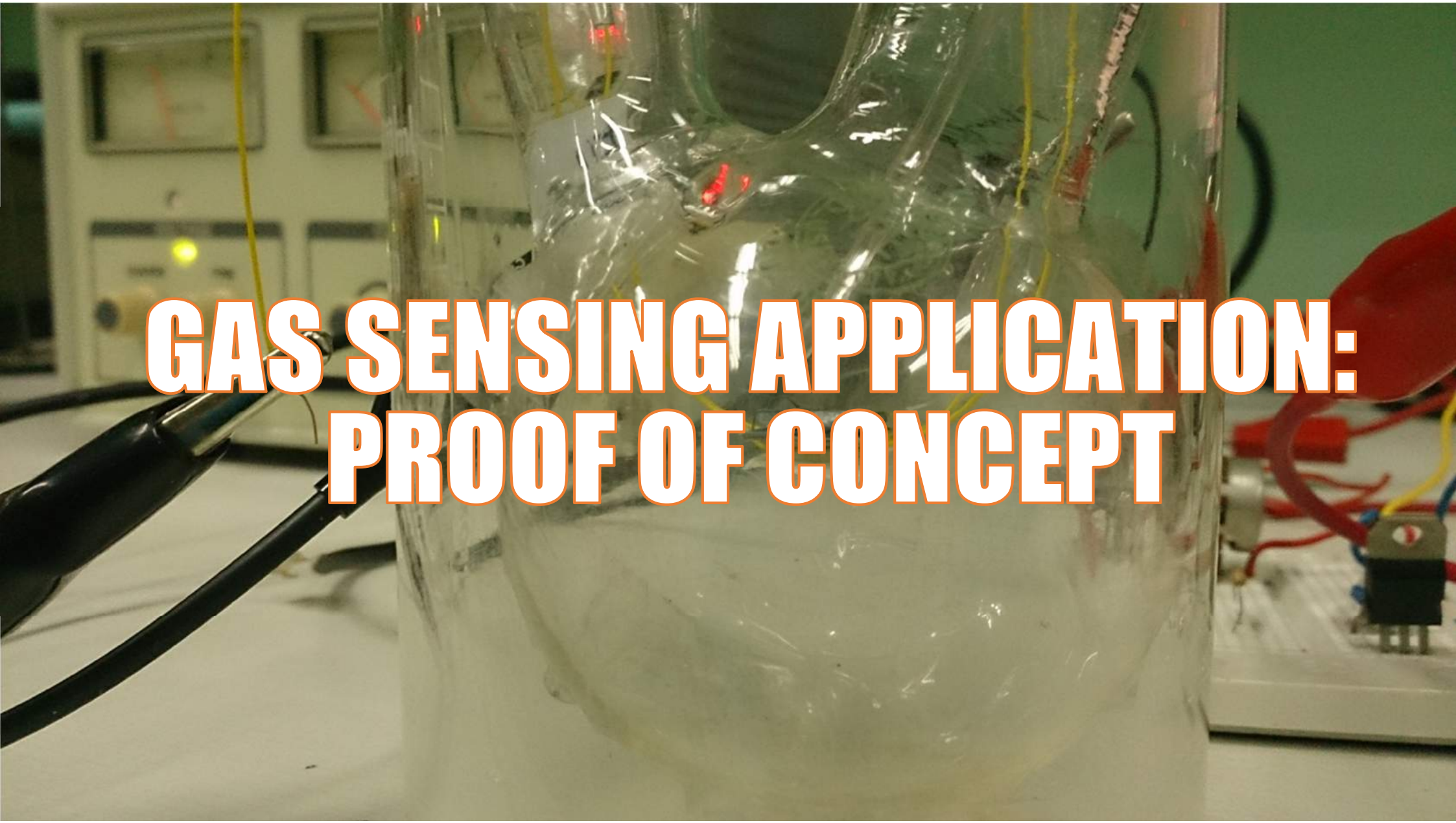




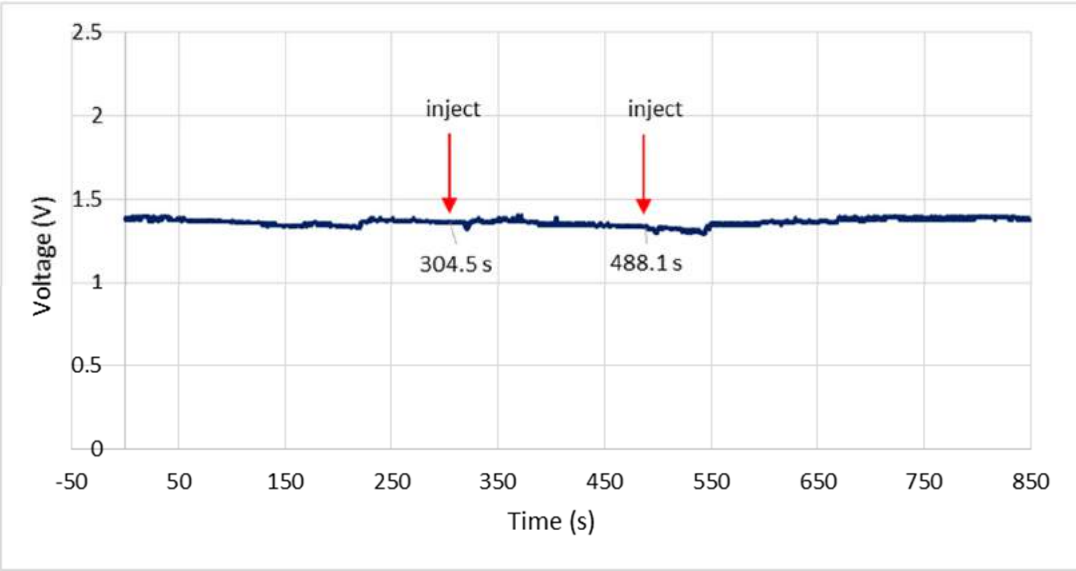


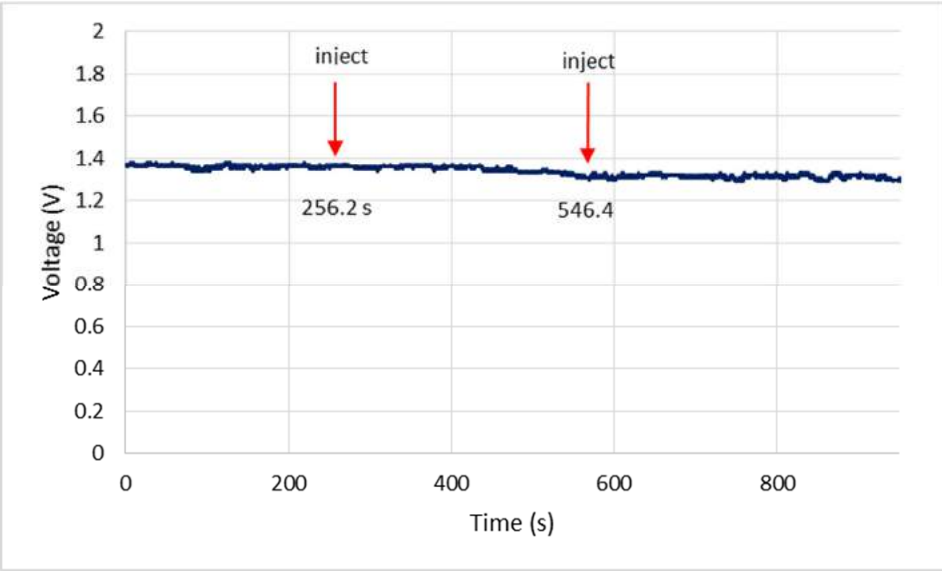
Setup		Wavelength Peak (nm)			Energy Gap (eV)		
Control	4 hours	483	565	660	**2.6**	**2.2**	**1.9**
	6 hours	430,	480		**2.9**	**2.6**	
	8 hours	429	480		**2.9**	**2.6**	
2500 gauss	4 hours	480			**2.6**		
	6 hours	479	571	680	**2.6**	**2.2**	**1.8**
	8 hours	470	540	635	**2.6**	**2.3**	**1.95**
3100 gauss	4 hours			653			**1.9**
	6 hours	468	653	720	**2.6**	**1.9**	**1.7**
	8 hours	469	560	715	**2.6**	**2.2**	**1.7**

Set-up		Resistance ($R_{AB,CD}$) Ω	Resistivity (ρ) Ωm
Control	4 hours	3.46×10^{8}	**3.92×10^{3}**
	6 hours	1.18×10^{9}	**1.34×10^{4}**
	8 hours	8.68×10^{9}	**9.83×10^{4}**
2500 gauss	4 hours	3.16×10^{7}	**359**
	6 hours	9.53×10^{7}	**1080**
	8 hour	1.62×10^{7}	**183**
3100 gauss	4 hours	1.26×10^{7}	**142**
	6 hours	3.12×10^{6}	**35**
	8 hours	8.21×10^{5}	**9.31**

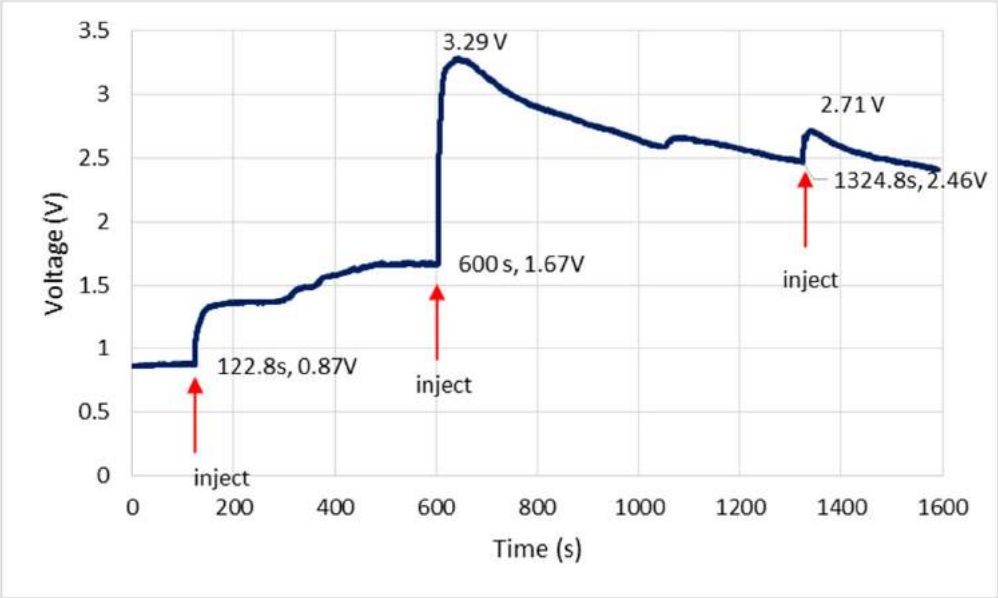

GAS SENSING APPLICATION:
PROOF OF CONCEPT

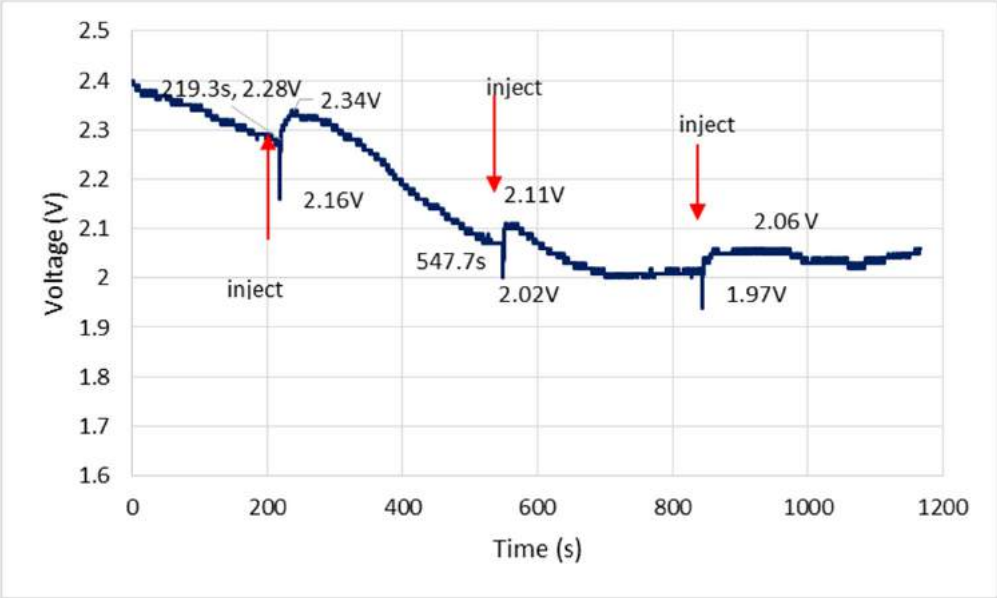
SENSOR RESPONSE TO FRESH PORK AND BEEF SAMPLES



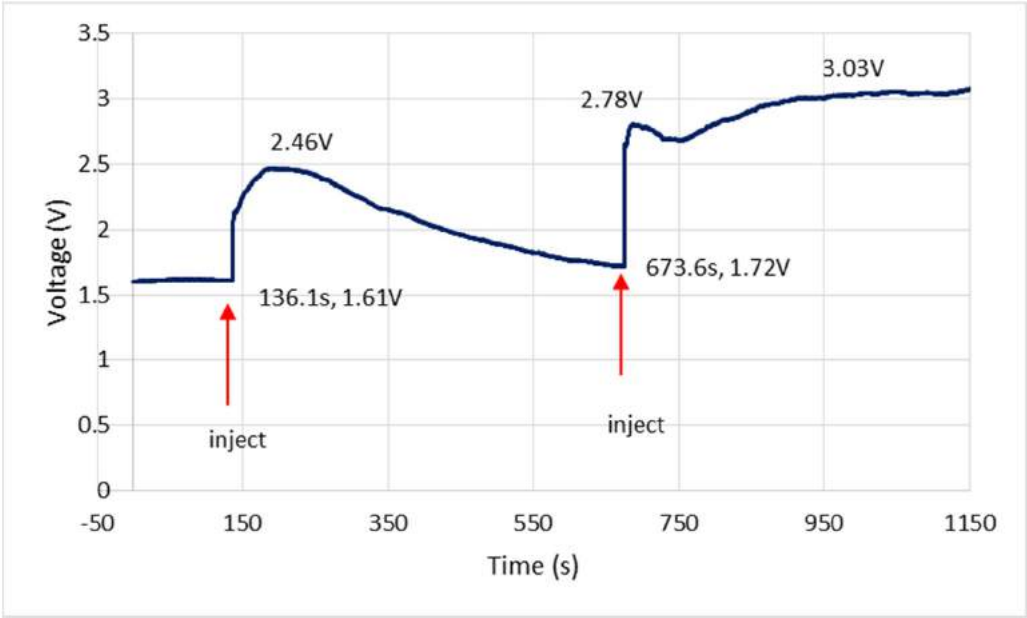


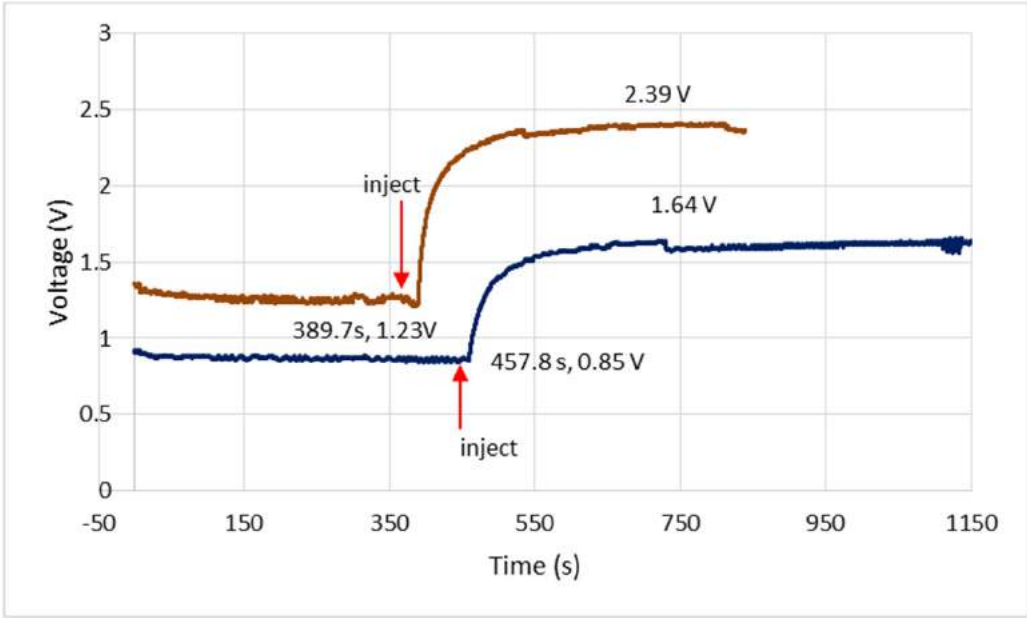
SENSOR RESPONSE TO SPOILED (24H) PORK AND BEEF SAMPLES



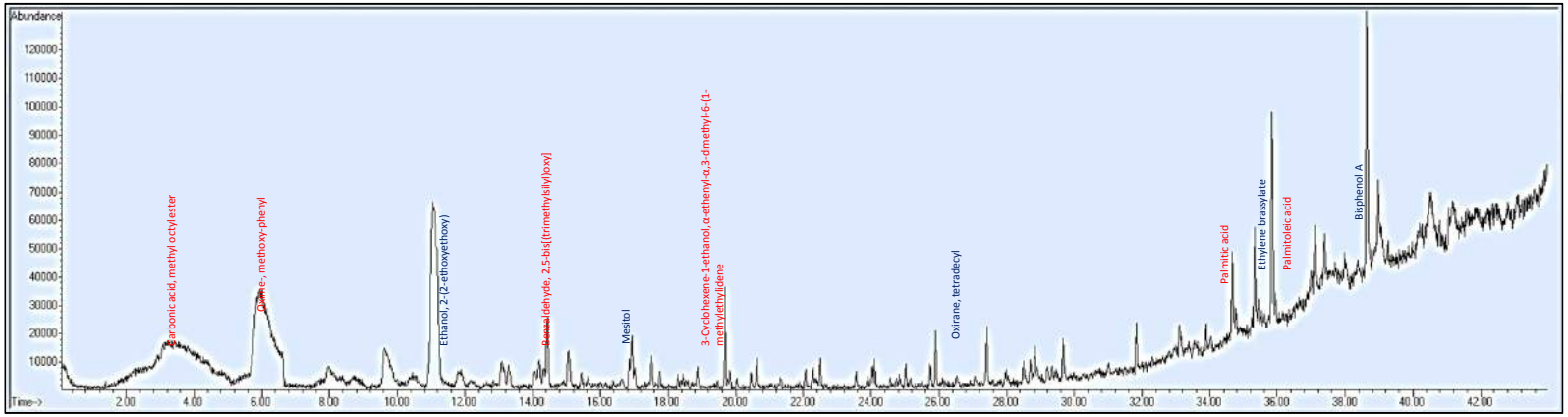


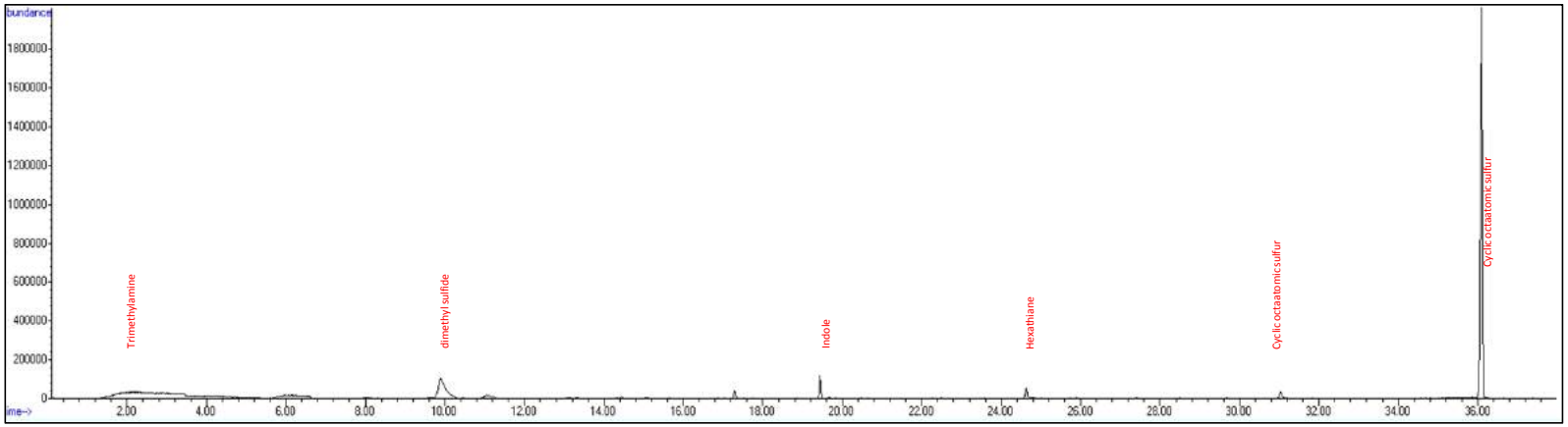
SENSOR RESPONSE TO SPOILED (36H) PORK AND BEEF SAMPLES





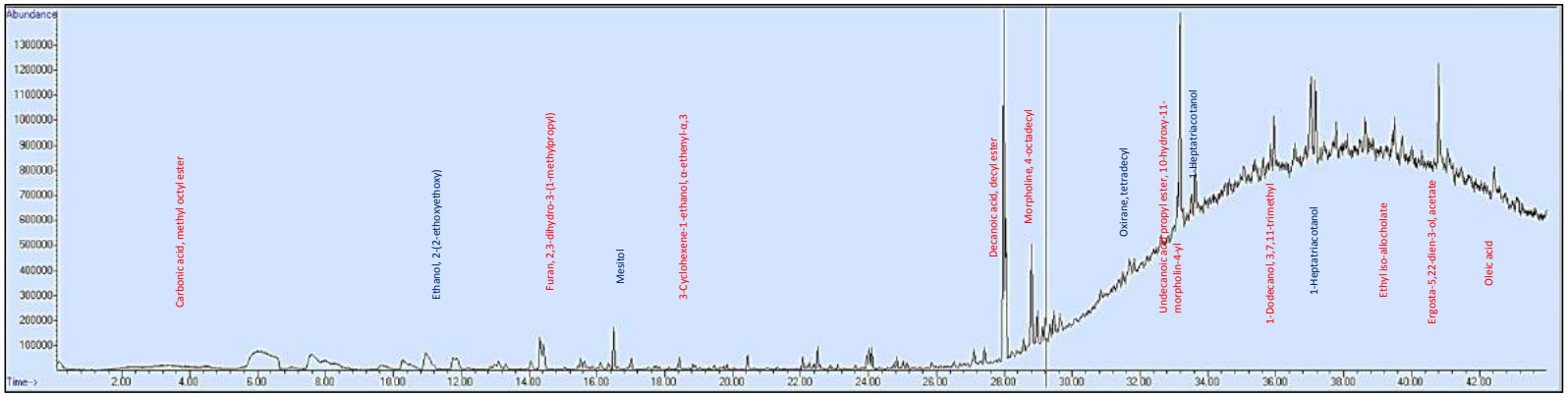
GAS CHROMATOGRAPHY MASS SPECTROMETRY –PORK (FRESH VS. SPOILED)

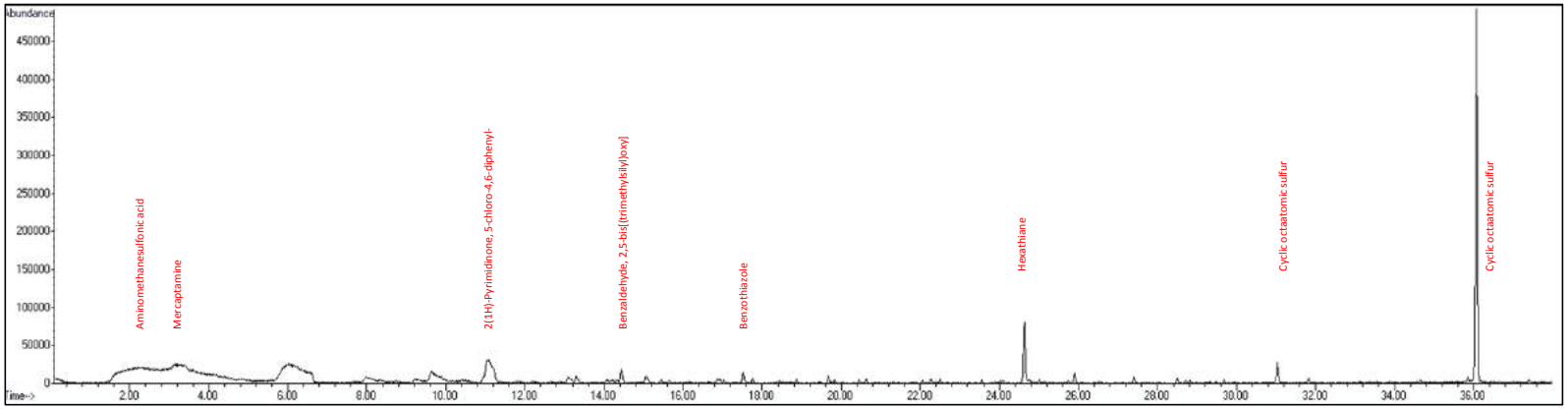




Sulfur compounds

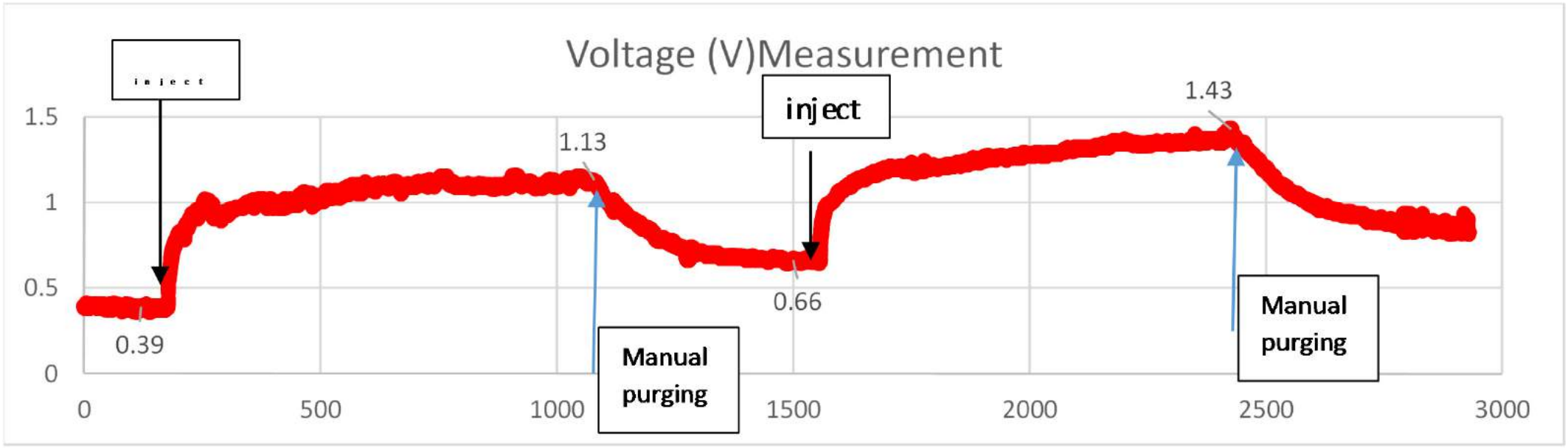
GAS CHROMATOGRAPHY MASS SPECTROMETRY –BEEF (FRESH VS. SPOILED)



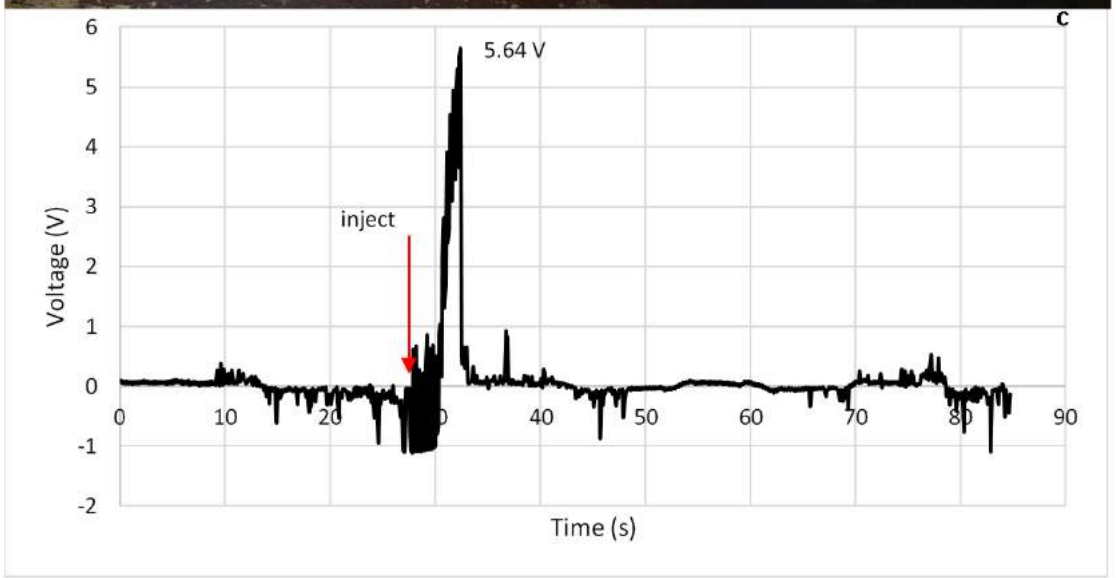


Sulfur compounds

REFERENCE TEST- Hydrogen sulfide (H_2S)



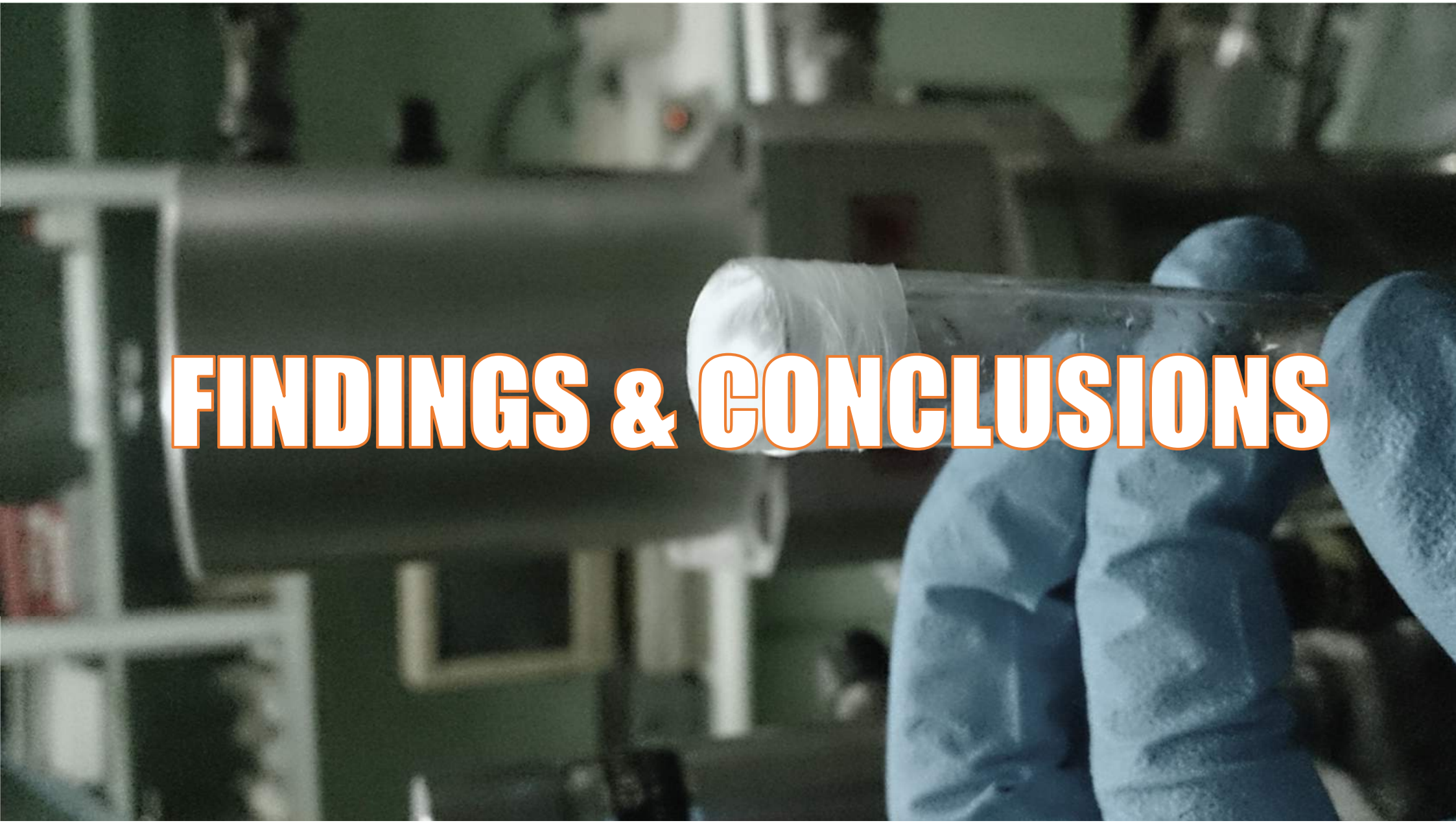
PROTOTYPE: MEAT FRESHNESS EVALUATION



LED indicator lights up when it reaches the voltage range identified/calibrated for spoiled meat head space

Home video
First prototype
8-10s response time

Sensitivity improved in succeeding prototypes


FINDINGS & CONCLUSIONS

FINDINGS

We found that length of nanowires was significantly enhanced by the application of magnetic field. The aspect ratio, as well as, as the density of the fabricated nanowires increased with increasing magnetic field.

FINDINGS

- Longer growth time, 8 hours- greater density of nanowires
  AMF and temperature gradient (greater influence) – responsible for nanowire formation

FINDINGS

- Without AMF - blue light emission giving an energy gap around 2.6 eV – 2.9 eV

- With AMF –distinct red light emission with greater area of luminescence in the 3100 gauss AMF set-ups, giving an energy gap around 1.7 eV– 1.9 eV with lower energy gap for longer growth time, 8 hours.

FINDINGS

- Without AMF - values of the resistance and resistivity were found to increase with increasing growth time.

- With AMF –decrease in the resistivity of the sample was observed as the AMF intensity and the growth time increased

FINDINGS

- Both the sensor substrates did not show a response for the FRESH MEAT HEADSPACE.

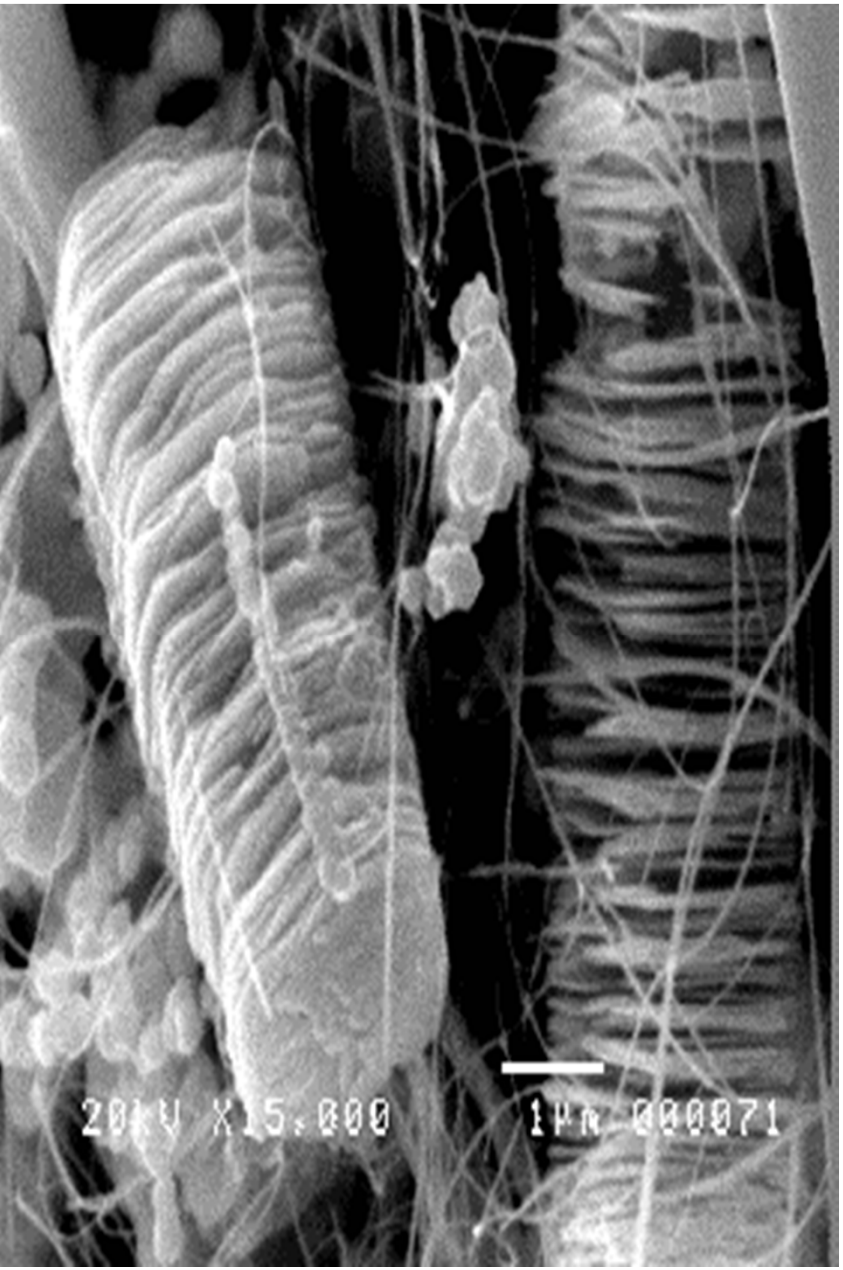
  Response was recorded in the SPOILED MEAT HEADSPACE (pork and beef).

FINDINGS

- Headspace of spoiled pork and beef was found to be largely composed of sulfur compounds.
- sensor is primarily responsive to sulfur compounds found in the odor of spoiled meat. Although the CO_2 gas produced by bacteria's cellular respiration could also be contributory

CONCLUSION

- we demonstrated that magnetic field could be used as a key parameter to control the morphology of metal oxide nanomaterials grown via HPVG technique.
- Now, we are using the magnetically enhanced metal oxide nanowires to develop highly sensitive gas sensors



THANK YOU!