Structural Analysis of Bosch Heated Exhaust Gas Oxygen Sensors after Voltage Treatments

Regina Blackman[1], Arwa Alshowaier[2], Erica P. Murray[2]

[1]Department of Chemistry, Francis Marion University

[2]Institute for Micromanufacturing, Louisiana Tech University

Outline

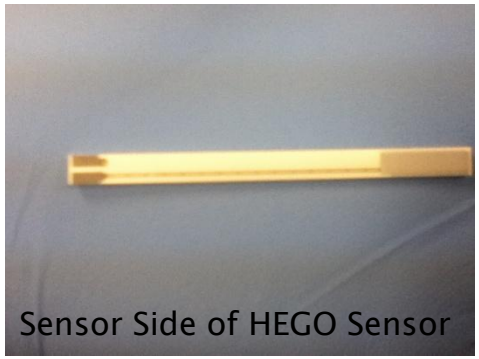
- Background
- Purpose of Research
- My Role During This Summer
- Procedure
- Results
- Conclusion
- Remaining Work

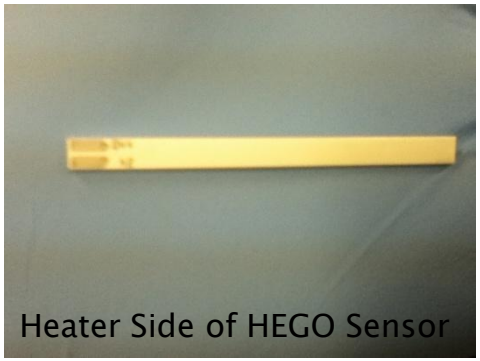
Background

- Heated Exhaust Gas Oxygen (HEGO) Sensors detect oxygen emissions from engines
- Help to optimize air-fuel ratio within the engine
- If the oxygen level is:
  - Too high – may lead to engine misfire
  - Too low – leads to wasted fuel

HEGO Sensors

- Composed of platinum electrodes encased in an Yttria Stabilized Zirconia (YSZ) electrolyte
- Two sets of electrodes
  - Heater electrodes
  - Sensor electrodes
- Vent in the center of the electrodes


Sensor Side of HEGO Sensor


Heater Side of HEGO Sensor

HEGO Sensor Research

- Blackening
  - Caused by a strong chemical reduction or when oxygen is taken from the lattice structure
  - Occurs when a large voltage is applied to the YSZ
- Change in the lattice structure can be observed using:
  - Optical Microscopy
  - Scanning Electron Microscopy (SEM)
  - X-Ray Diffractometry (XRD)

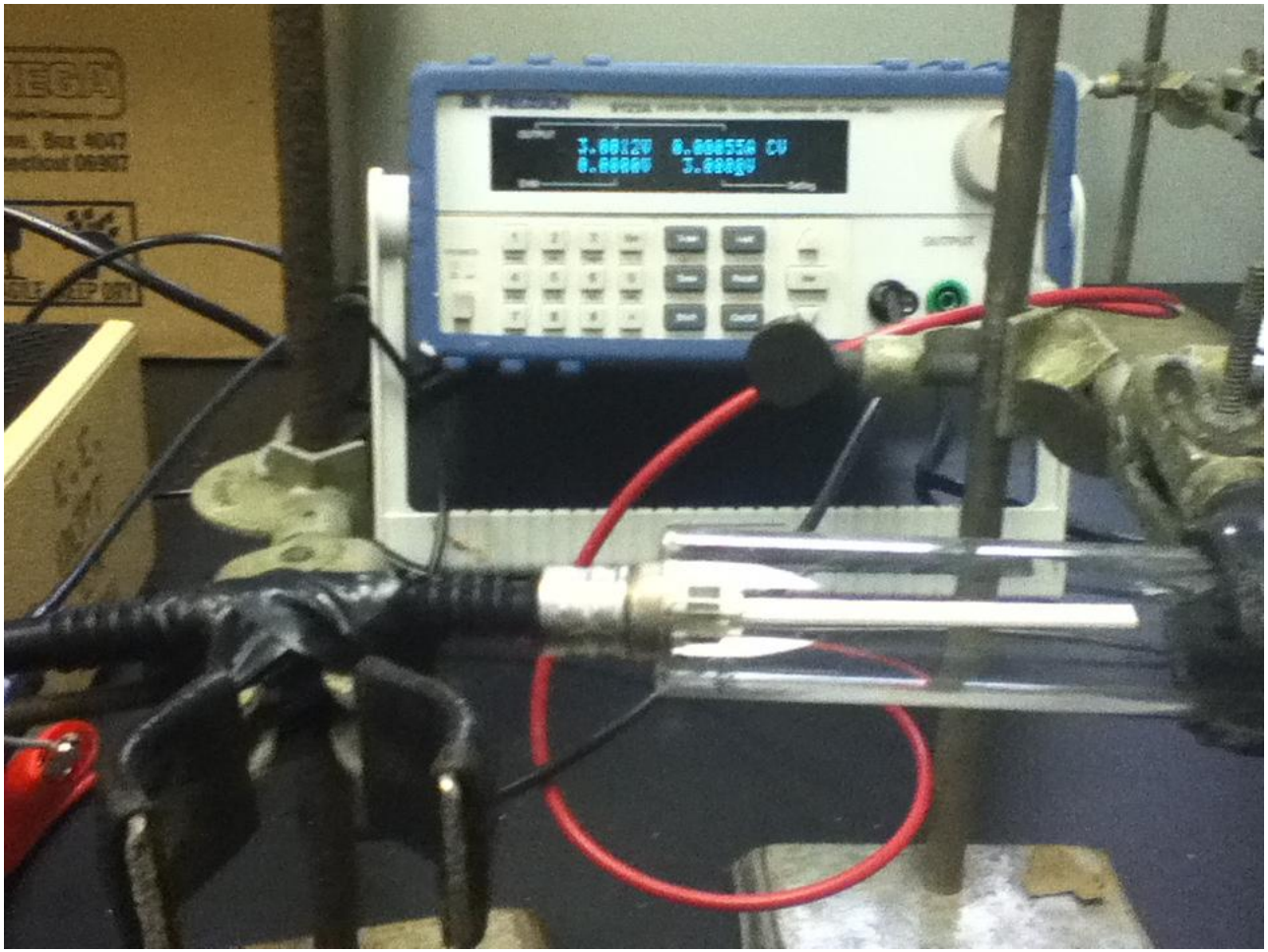
Purpose of Research

- Define the parameters and optimal operating conditions of the Bosch HEGO Sensors
- By observing the voltage treated sensors, it is possible to understand what leads to the blackening phenomenon.

My Role

- Analysis of YSZ structure after voltage treatments
- Finding the “hot spot” on the HEGO sensors
- Determining the temperature of the sensor at each voltage applied to the heater
- Defining conditions for future experiments

Setup



Procedure

- Found hot spot and temperatures using thermocouple
- Applied a voltage across heater and sensor for various amounts of time
- Cut sensor with low speed saw
- Examined using SEM, XRD, and optical microscope

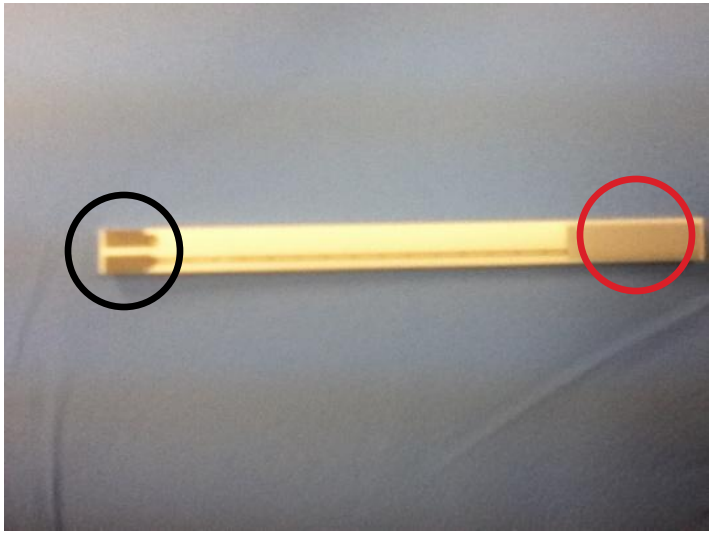
Sample Conditions (highlighted rows indicate blackened samples)

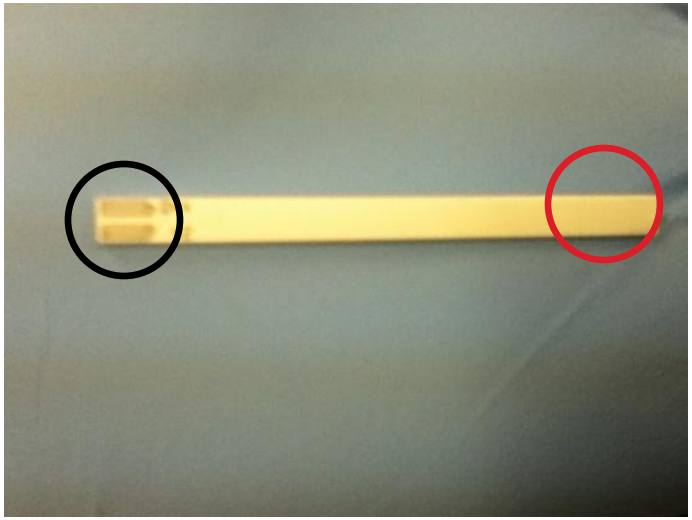
Sample Number	Voltage (V)	Temperature (°C)	Time Period (hrs)
1	2	400 (9 V)	4
2	Raw Sample (No Voltage Treatment)		
3	2	400 (9 V)	2
4	2	400 (9 V)	3
5	2	400 (9 V)	4
6	**3**	**400 (9 V)**	**1**
7	**3**	**700 (18 V)**	**0.333**
8	2	750 (20 V)	4
9	2.8	750 (20 V)	1
10	2.6	750 (20 V)	3.5
11	2.9	750 (20 V)	2
12	2.9	750 (20 V)	12.5
13	2.9	750 (20 V)	24

Results

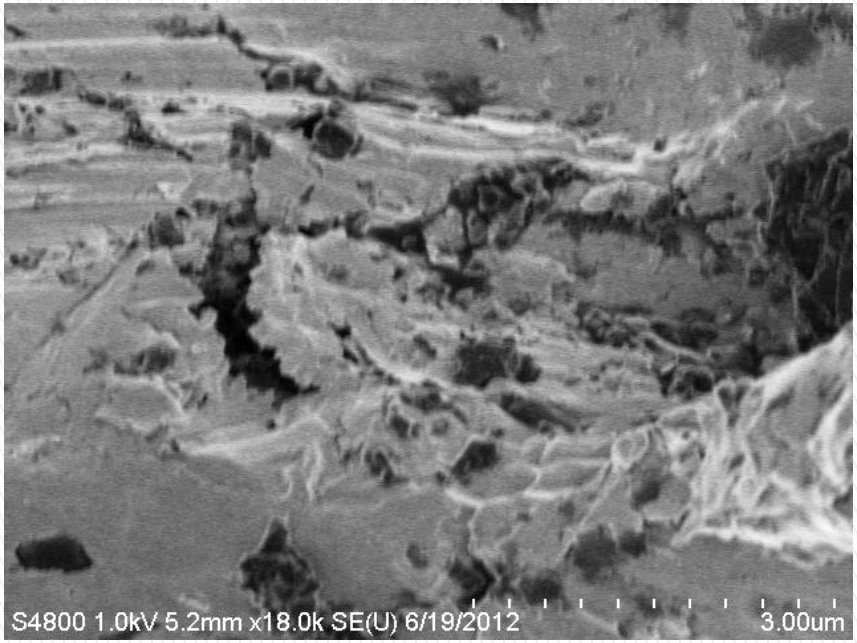
- Most important fractions of the sensor were 1 and 8
- Fraction 8 was at the sensor's "hot spot"
  - Voltage is applied here
  - Blackening occurs at the hot spot
  - Size of vent increased
- Increase in vent size noticed when comparing fraction 8 with fraction 1
- Samples were also compared to raw (untreated) sample

HEGO Sensors

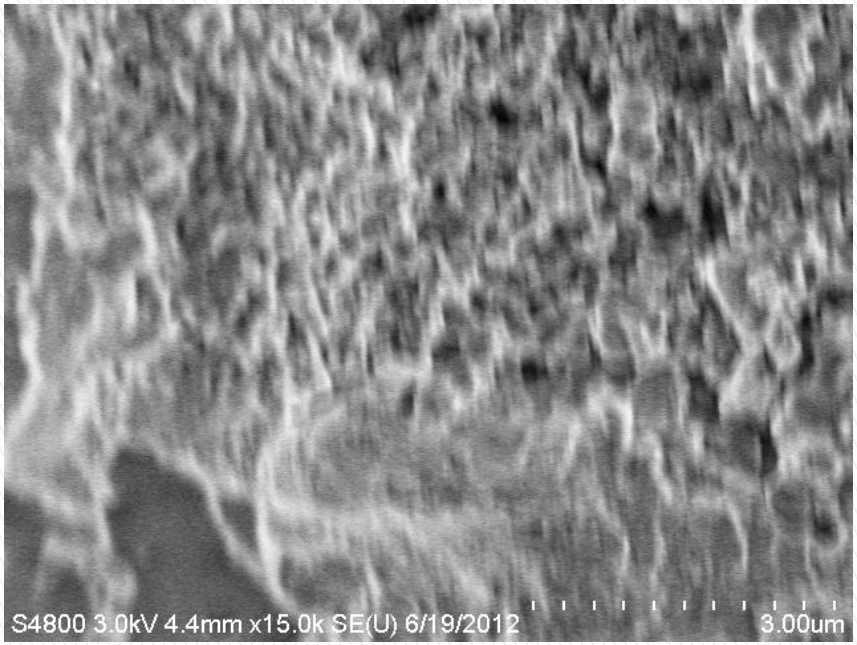




Sample 6 SEM

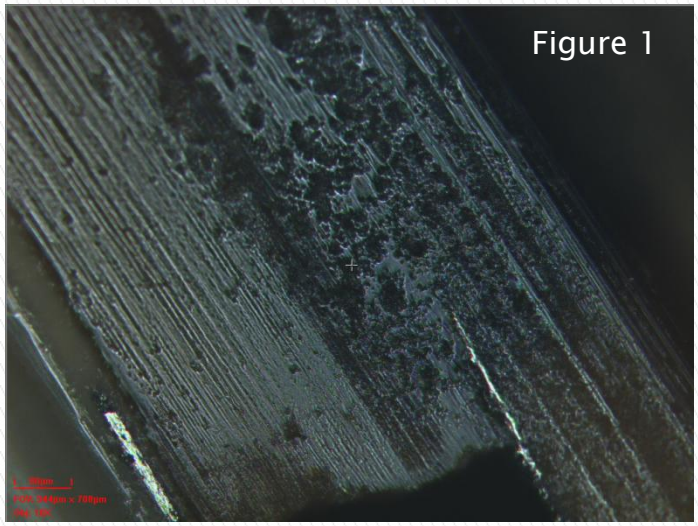


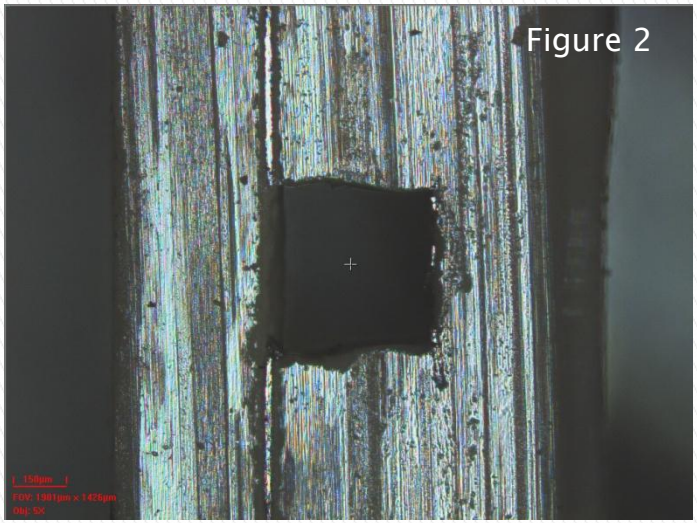
Fraction 8 (blackened portion of sample)

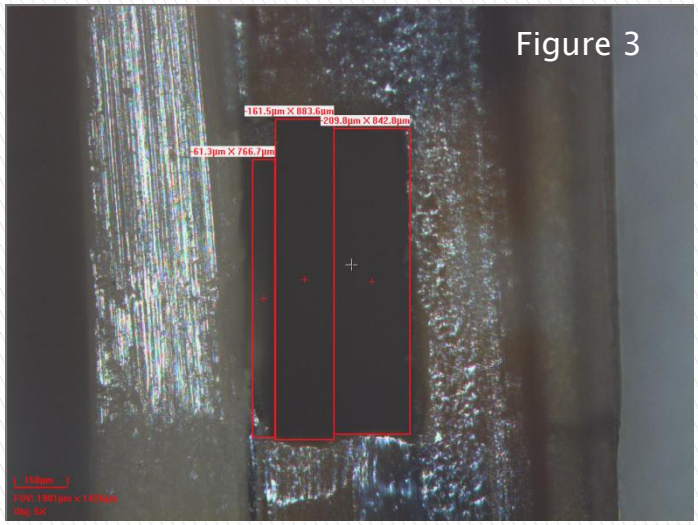


Fraction 6

Sample 6 Optical Microscope



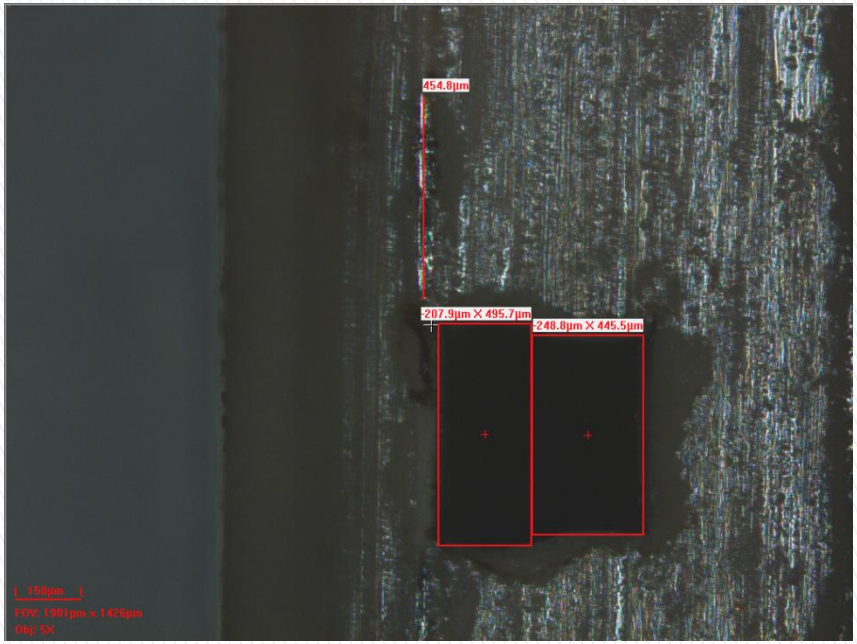




- Figure 1 displays blackening at fraction 8
- Figure 2 displays fraction 1
- Figure 3 displays the vent size at fraction 8

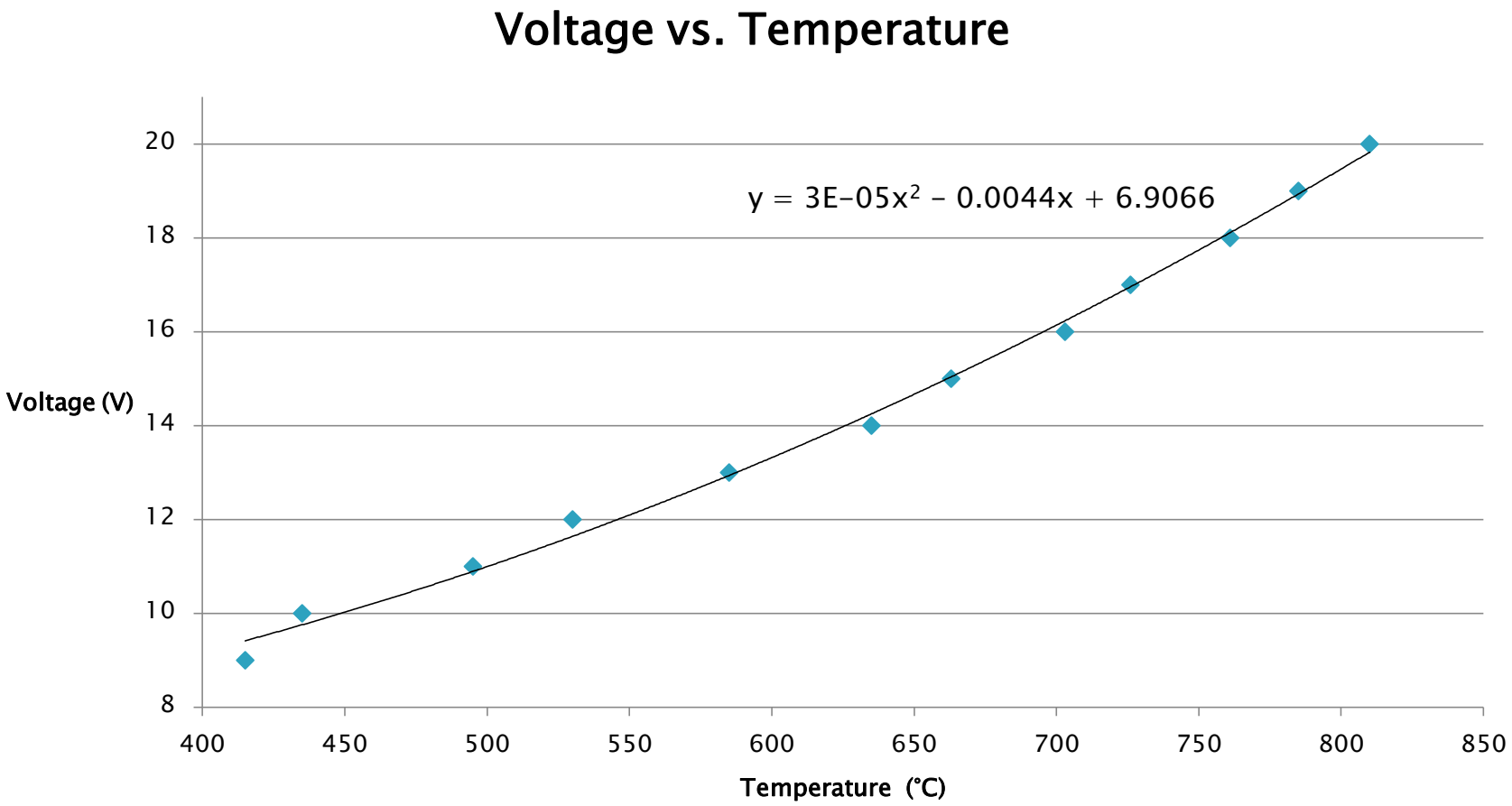
Raw Sample Optical Microscope

Fraction 1

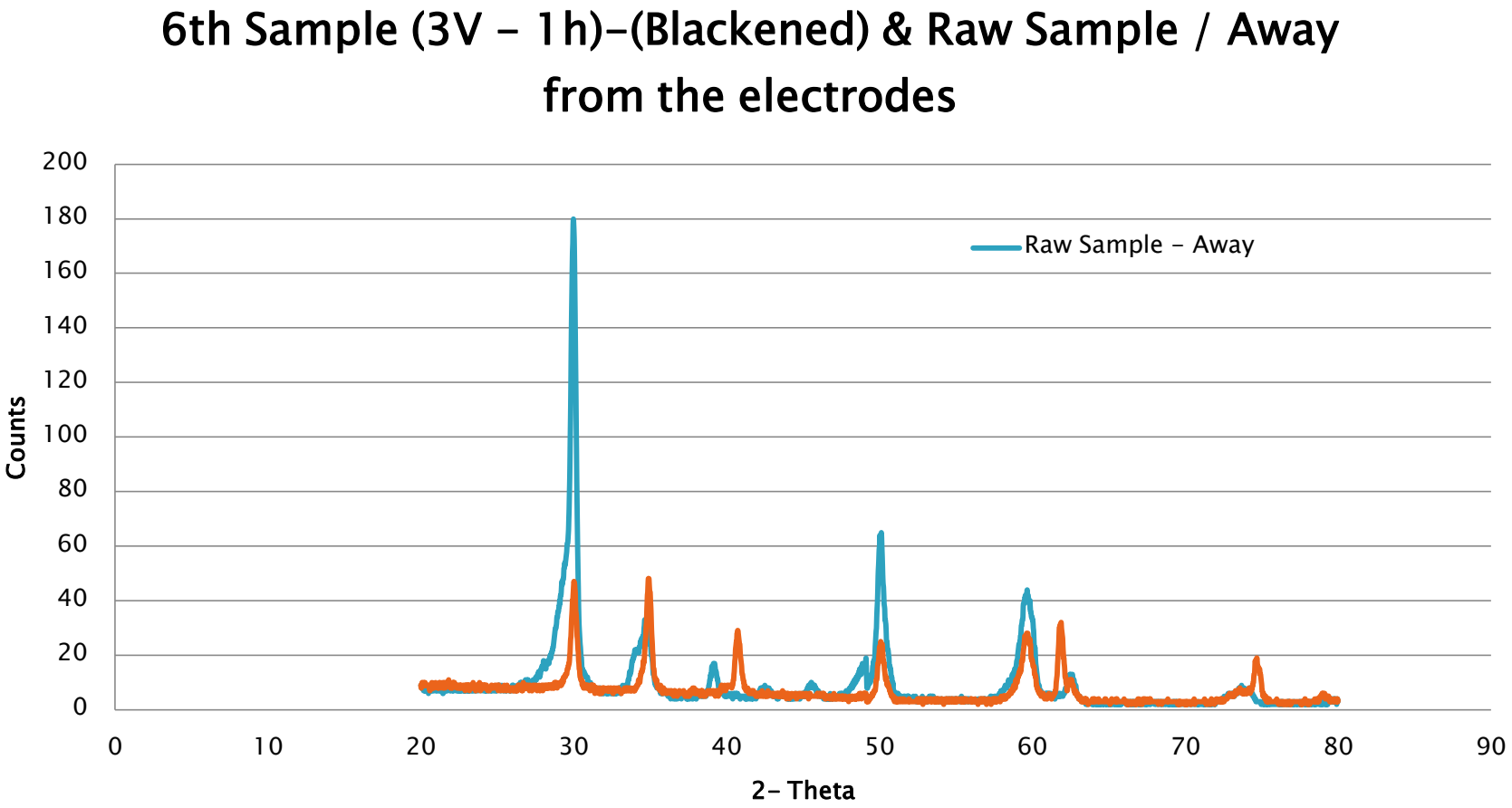


Fraction 8

Thermocouple Data



XRD


6th Sample (3V – 1h)–(Blackened) & Raw Sample / Away from the electrodes
Raw Sample – Away
Counts
2– Theta
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
60
70
80
90

Conclusion

- Blackening may affect the functionality of HEGO Sensors
- Of 12 treated samples, only 2 were blackened
- Upper threshold of parameter seems to be 3V
- Temperature helps to speed up the blackening
- Microscopy images show more about the structure of the sensors

Future Work

- Further examination using the optical microscope
- Determining the cause of the expanding hole
- Discovering what happens to the YSZ when the hole expands
- Determining the parameters of the HEGO Sensor

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