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

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Abstract: Heated Exhaust Gas Oxygen Sensors are used to detect the emissions of the everyday vehicle. Applying a voltage to these sensors simulates the conditions that the sensor is under when in a vehicle. Experiments show that when a voltage is applied for a long enough time, blackening occurs around the electrodes. By performing voltage treatments, it is possible to define the conditions that cause blackening. It is also possible to see the changes in the structure of the Yttria Stabilized Zirconia (YSZ) by cutting the sensor and looking at it under a Scanning Electron Microscope. Looking at the cut sensor under an optical microscope allows for the design of the sensor to be examined and measurements to be taken.

Keywords: Heated Exhaust Gas Oxygen (HEGO) Sensor, Yttria Stabilized Zirconia (YSZ), Platinum Electrode, Sensor Side, Heater Side, Blackening

1. Introduction

Heated Exhaust Gas Oxygen (HEGO) sensors are used to detect the oxygen emissions from engines. These sensors help to optimize air-fuel ratio within the engine. The correct air-fuel ratio helps to prevent engine misfire and wasted fuel. HEGO sensors are composed of platinum electrodes encased in an Yttria Stabilized Zirconia (YSZ) electrolyte. When a large voltage is applied to this YSZ, it becomes blackened. Blackening is caused by a strong chemical reduction, or when oxygen is taken from the lattice structure [3,4]. Using an optical and a Scanning Electron Microscope, this change in the lattice structure or blackening can be readily observed.

2. Experimental Procedure

Bosch Heated Exhaust Gas Oxygen (HEGO) Sensor samples were placed in the sensor housing. Ten samples were examined; heat as well as voltage applied to each one as shown in Table 1. The heat was applied using a regulated DC power supply, where the voltage was applied using a single output programmable DC power supply. After the voltage treatment, the samples were cut using a low speed saw. The samples were then examined using X-Ray Diffraction, a Scanning Electron Microscope, and an optical microscope at various magnifications.

Table 1: Voltage, Temperature, and Time of Voltage Treatments for 11 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

3. Results and Discussion

Figure 1 displays Sample 6, the first of two samples that were blackened. The right side of the hole is the sensor side, and the left is the heater side. It is apparent that the blackening starts at the heater electrodes and radiates out towards the sensor electrodes. The most significant results achieved were comparing the treated samples to the raw sample. As more samples were treated and examined under the optical microscope, the orientation of the electrodes in the zirconia became clearer. It was noted that at fraction 1 of the sensor, there are 2 platinum electrodes on the heater side, but at fraction 8, there are 4. After the samples are treated, the hole size increases, as shown in Figures 1 and 2. The size difference from figure 1a to 1b is large. In figures 2a and 2b, there is no noticeable difference in size. Figure 4 shows that the counts of YSZ are significantly less in the blackened sample. Figure 5 shows the structural changes seen when looking at YSZ that is not blackened, and also YSZ that is blackened.

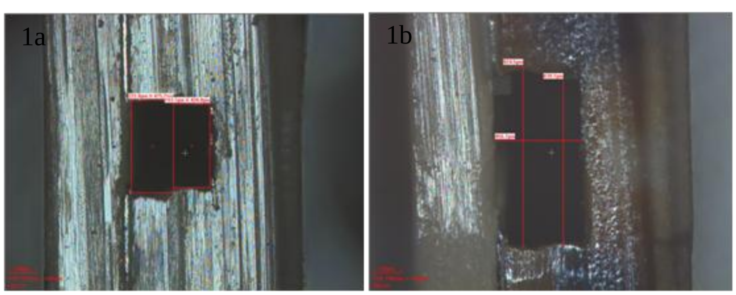

Figure 1 a) and b): Sample 6, fractions 1 and 8 respectively: Noting the difference in hole size as well as color.

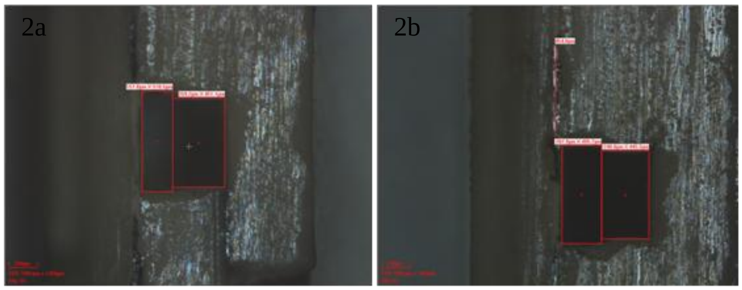

Figure 2 a) and b): Sample 2 (Raw sample), fractions 1 and 8 respectively. There is no noticeable difference in the size of the hole.

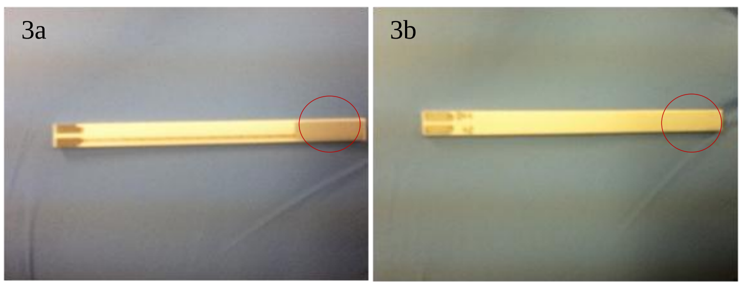

Figure 3 a) Sensor Side and b) Heater Side of a Bosch HEGO sensor. The outlined area is where the blackening occurs (Fraction 8). The opposite end is where the sensor is placed in the housing (Fraction 1).

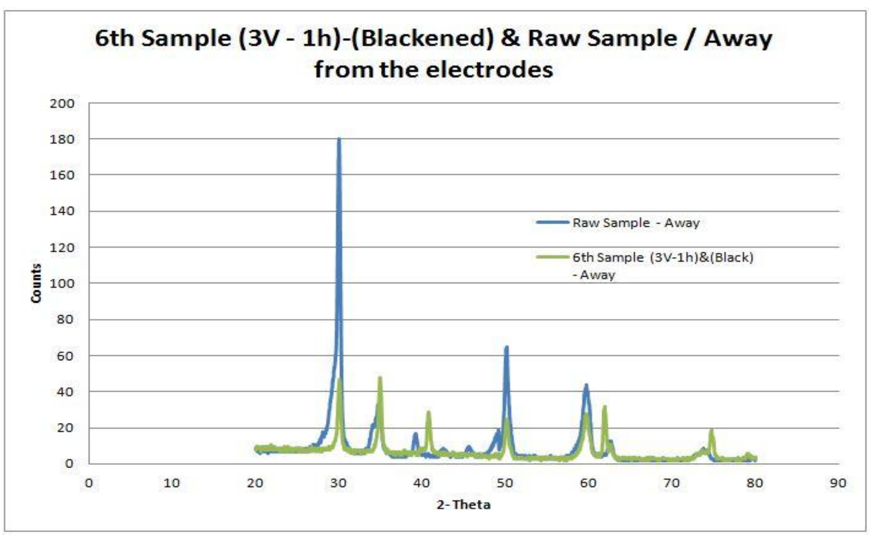

Figure 4: XRD plot comparing the Raw Sample and the Blackened (6th) Sample

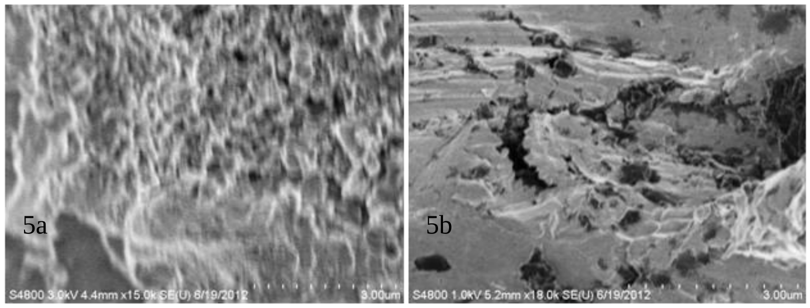

Figure 5: a) SEM image of heater electrode of sample 6, fraction 6 (not blackened) at 3μm. b) SEM image of heater electrode of sample 6, fraction 8 (blackened) at 3μm. The structural changes are easily seen.

4. Conclusion

The oxygen that is removed from the lattice structure may affect the functionality of the HEGO sensors. Further research on this will help to define the conditions under which the YSZ becomes blackened. Of the 10 samples that were treated, only two were blackened. From this, it is easy to define the upper threshold of the parameters. When the sensor was treated at 3V, there were signs of blackening, occurring faster and more spread out when the temperature was raised from 400°C to 700°C. Also, the images from the optical microscope help to determine where the blackening is occurring. The blackening is affecting the area around the sensor electrodes. It starts on the inside of the heater electrodes and is blackened through to the opposite side of the sensor electrodes.

5. Acknowledgments

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6. References

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