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Study on Carbon Monoxide Detector using Conventional and Plasma-Treated Gas Sensor

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Abstract: Air pollution is one of the major concerns around the world. This is because air pollution will decrease the air quality of the surrounding which will weaken the immune system if exposed to long term. This paper focuses on the effect of plasma treatment using atmospheric pressure plasma on the sensing layer of the MQ-7 gas sensor which is made of tin (IV) oxide (SnO_2). Two similar experiments are conducted to ensure the experiments are credible. One of the MQ-7 gas sensors will undergo plasma treatment using atmospheric pressure plasma needle jet (APPNJ), which will be named as plasma-treated MQ-7 gas sensor, and it will be used to detect the concentration of carbon monoxide with a conversional MQ-7 gas sensor. By the end of this paper, the carbon monoxide concentration detected by conventional and plasma-treated MQ-7 gas sensors is compared. The data show that the conventional MQ-7 gas sensors detected more carbon monoxide in the presence of smoke compared to plasma-treated MQ-7 gas sensors. The sensitivity of the MQ-7 gas sensor decreases after undergoing plasma treatment.

Keywords: Plasma Treatment, MQ-7 Gas Sensor, SnO_2, Atmospheric Pressure Plasma

1. Introduction

Today, as the advancement of science and technology increasing day by day, the same can be said with the pollution. To date, pollution is still one of the main concerns of the world, especially air pollution. The main reason that so much attention is given to air pollution is because it will decrease the air quality of the surrounding. Low air quality will affect the health of the people living around the area. This is because long term exposure to air pollution will weaken the immune system.

Plasma was discovered by Sir William Crookes on Friday, 22 August 1879 [1]. Plasma, known as one of the fourth stage of matter, is a mixture of gas such as atoms, molecules and ions after gain or lose electrons. Plasma treatments are used to alter the surface properties of a wide range of materials using plasma. In this project, one of the MQ-7 gas sensors have undergone plasma treatment. The effect

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of plasma treatment towards the MQ-7 gas sensor is determined by identifying the carbon monoxide concentration detected by conventional and plasma-treated MQ-7 gas sensor.

2. Materials and Methods

This section will present the materials and methods used for this project. The materials used for this project are Arduino UNO, MQ-7 gas sensor, laptop, LED, Arduino Software (IDE), Microsoft Excel and PLX-DAQ. The block diagram and flow chart will show the overall system for this project.

2.1 Materials

Arduino UNO is a microcontroller board which is based on ATmega328P. The word "UNO" is one in Italian [2]. SnO_2, also known as tin (IV) oxide is the sensing layer of the MQ-7 gas sensor. It makes detection through a method of cycling low and high temperature. Low temperature is when it is heated by 1.5V while high temperature is when it is heated by 5.0V. At low temperature, it will detect carbon monoxide while at high temperature, it will clean the gas absorbed during low temperature. MQ-7 is very sensitive to carbon monoxide and the sensitivity can be changed with using a simple circuit [3].

LED, which mean light emitting diode, is a special diode which will give out light when current pass through [4]. Arduino Software (IDE) or also known as Arduino Integrated Development Environment is a software which allows user to write coding and upload to the Arduino board easily [5]. Microsoft Excel is used to collect and record the data sent by PLX-DAQ from the sensors in this prototype. Microsoft Excel also able to plot graphs of the data collected easily [6]. Parallax Data Acquisition Tool, or PLX-DAQ for short is an add-on software or an extension for Microsoft Excel. This software allow real life data from the sensors to be easily collected and record in Microsoft Excel [7].

2.2 Methods

2.2.1 Block diagram

The block diagram of the project is as shown in Figure 1. One of the MQ-7 gas sensor was put inside plasma machine so that sensing layer, SnO_2 is treated. The argon gas meter was set at 45sccm while the voltage was set at 220V during the treatment to produce stable plasma gas. The Arduino UNO which acts as the microcontroller will be connected to both conventional and plasma-treated MQ-7 gas sensor. The Arduino UNO is then connected to the laptop, which have Arduino Software (IDE), Microsoft Excel and PLX-DAQ installed. Both MQ-7 gas sensors are used to detect the carbon monoxide in the air while Microsoft Excel is used to collect and record the data.

2.2.2 Flowchart

The prototype will work as shown in the flowchart in Figure 2. First of all, both conventional and plasma-treated MQ-7 gas sensor will be detecting the carbon monoxide in the air. Both sensors are calibrated so that the sensor will be operating accurately and give accurate results. The concentration of carbon monoxide detected by both MQ-7 gas sensors will be recorded and shown in Microsoft Excel.

There are 4 LED which are connected to both sensors, 2 red and 2 blue LED. A red and a blue LED are connected to each MQ-7 gas sensor. Either red or blue LED will light up at a time, depending on the concentration of the carbon monoxide detected by the MQ-7 gas sensor. If the concentration of carbon monoxide is higher than the limit set, which is 15 ppm, then the blue LED will be lit up while red LED will not light up. If the concentration of carbon monoxide is higher than the limit set, then the blue LED will not light up while the red LED will light up.

Both sensors are put in the enclosed environment and the Microsoft Excel will start collecting the data. Then, a burned paper is put into the enclosed environment to create an environment with smoke. Finally, the burned paper is removed.

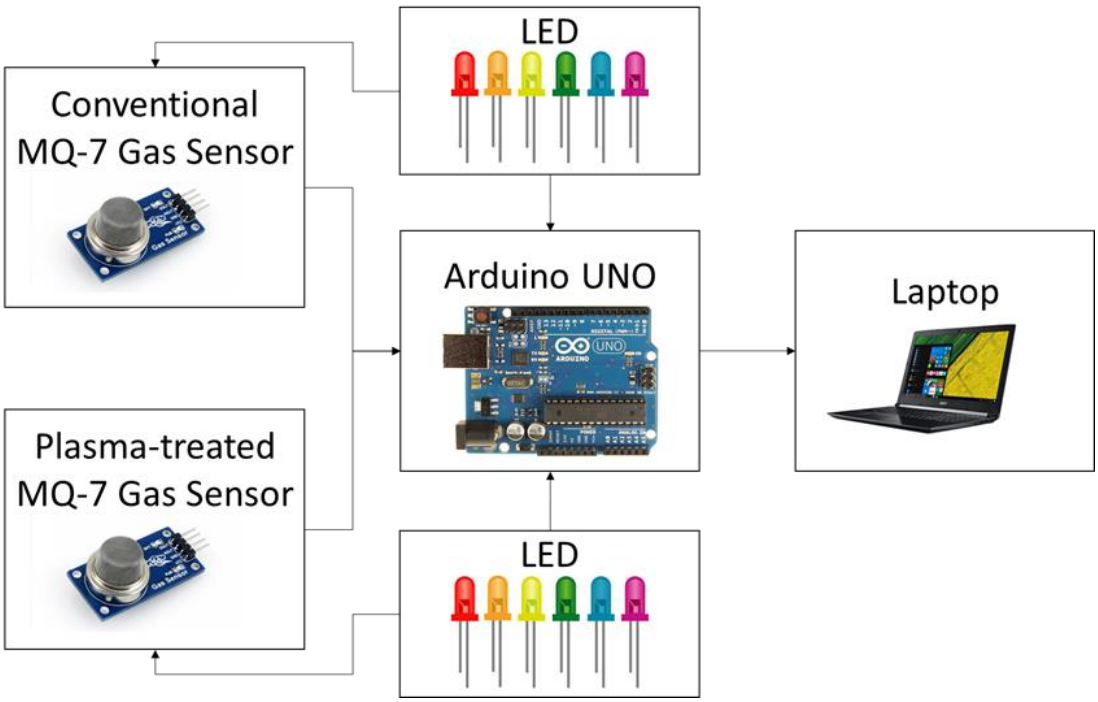

Figure 1: Block diagram of the project

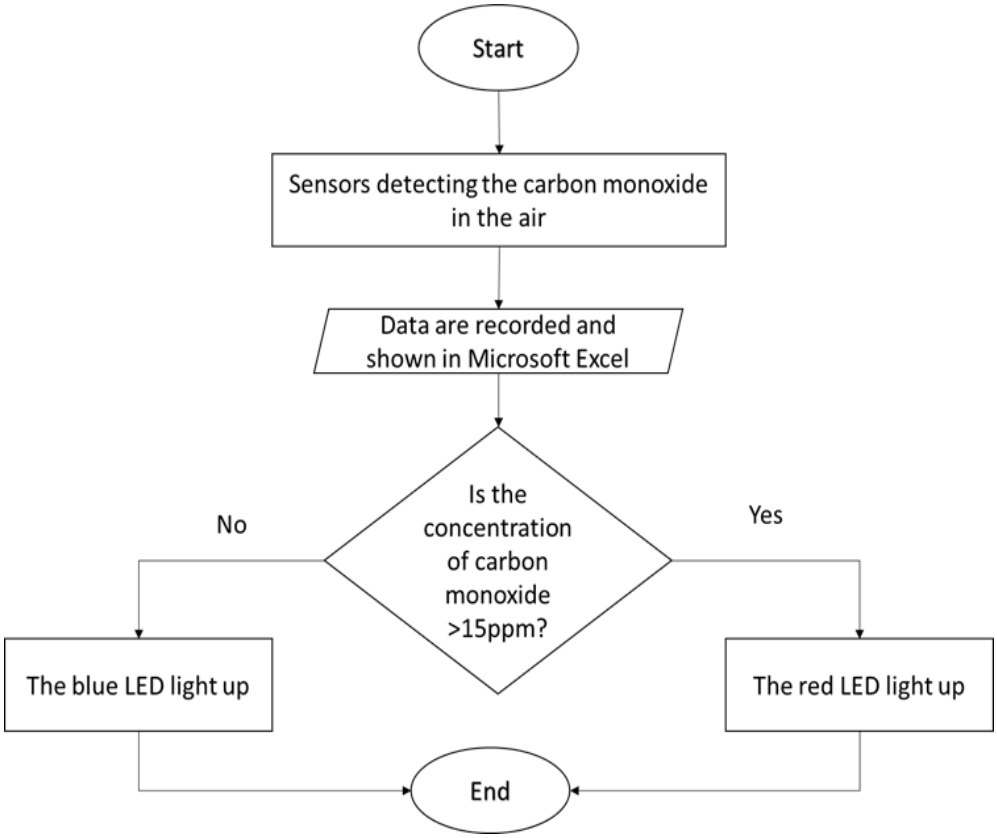

Figure 2: Flowchart of project

2.2.3 Plasma surface treatment

The sensing layer, SnO_2 of one of the MQ-7 gas sensors have undergone plasma treatment [3]. The MQ-7 gas sensor was put inside the plasma machine for treatment. The argon gas meter was set at 45 sccm while the voltage was set at 220 V during the treatment to produce stable plasma gas. The plasma gas was produced and aimed at the sensing layer of the MQ-7 gas sensor as shown in Figure 3 for 10 s. After the treatment, no noticeable changes can be seen in the sensing layer of the MQ-7 gas sensor with the naked eye.

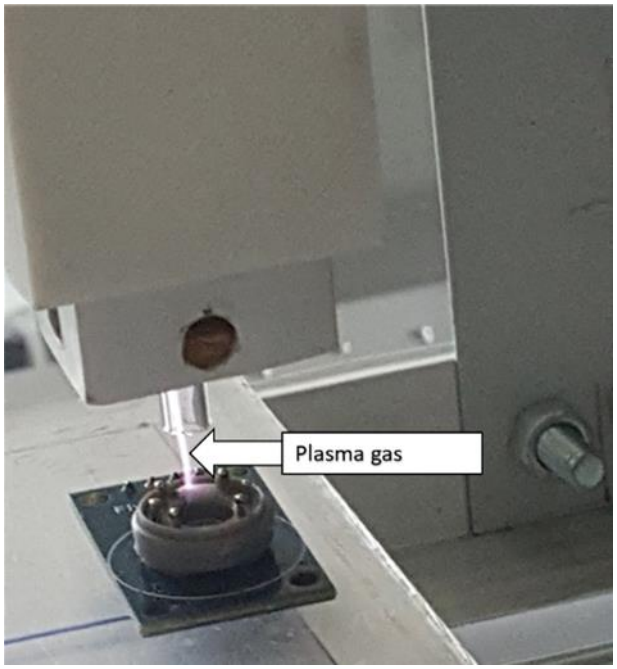

Figure 3: MQ-7 gas sensor undergoing plasma treatment

3. Results and Discussion

This section presents the data collected by both conventional and plasma-treated gas sensor and its analysis.

3.1 Results

Two similar experiments are conducted with a 3 week gap. The experiments are named Experiment 1 and Experiment 2 respectively. Experiment 1 is conducted on 28th May 2021 while Experiment 2 is conducted on 16th June 2021.

3.3.1 Experiment 1

Figure 4 shows the graph of carbon monoxide concentration detected by conventional and plasma-treated gas sensor against the time of Experiment 1. The blue line shows data of the conventional MQ-7 gas sensor while orange line shows the data of the plasma-treated MQ-7 gas sensor. The graph shows that the conventional MQ-7 sensors have detected higher carbon monoxide concentration compared to plasma-treated MQ-7 gas sensor. Despite the difference in concentration value of carbon monoxide detected by both sensors, the reading of carbon monoxide concentration increases when there was presence of smoke. When there was no smoke, the reading of carbon monoxide concentration decreases.

The LEDs of the prototype act as the indicator whether the concentration of the carbon monoxide detected by each MQ-7 gas sensor have exceeded the limit set, which is 15 ppm. The carbon monoxide

concentration of 15 ppm is set as a limit because inhaling carbon monoxide concentration surpass 15 ppm is bad for health. Figure 5 shows the indicator when there was no smoke while Figure 6 shows the indicator when smoke was present.

The red and blue LEDs on the left is connected to the conventional MQ-7 gas sensor while the red and blue LEDs on the right is connected to the plasma-treated MQ-7 gas sensor. When there was no smoke as shown in Figure 5, both sensors detected carbon monoxide concentration lower than 15 ppm. Thus, only blue LED lighted up for both sensors. When there was presence of smoke as shown in Figure 6, only conventional MQ-7 gas sensor detected carbon monoxide concentration higher than 15 ppm. This is why red LED of conventional MQ-7 gas sensor lighted up while blue LED of plasma-treated MQ-7 gas sensor remain lighted up.

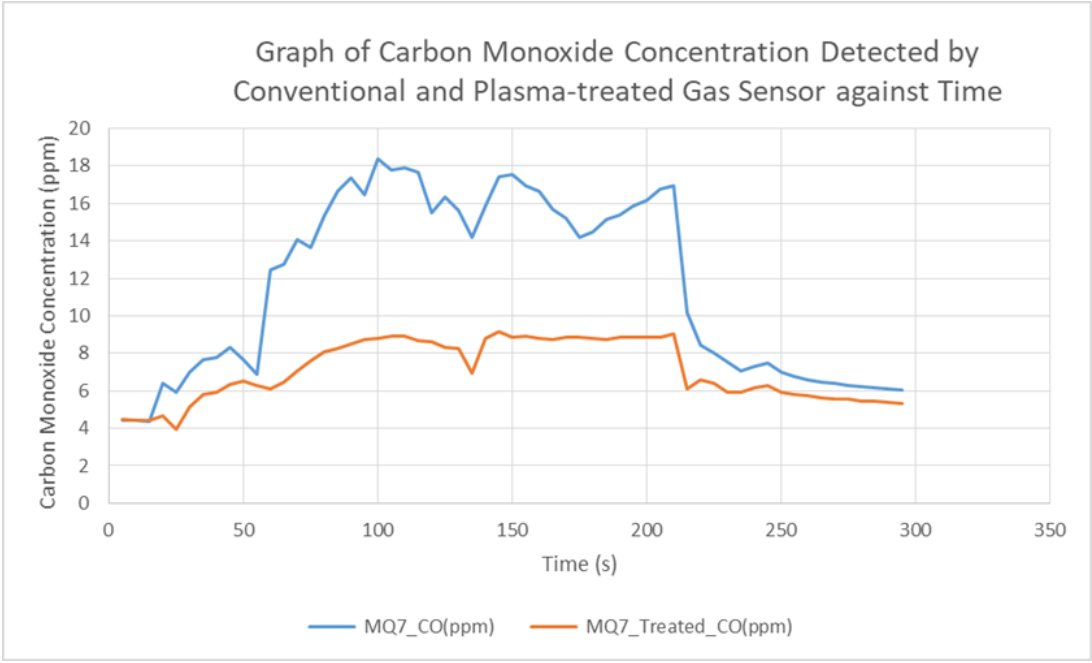

Figure 4: Data of Experiment 1

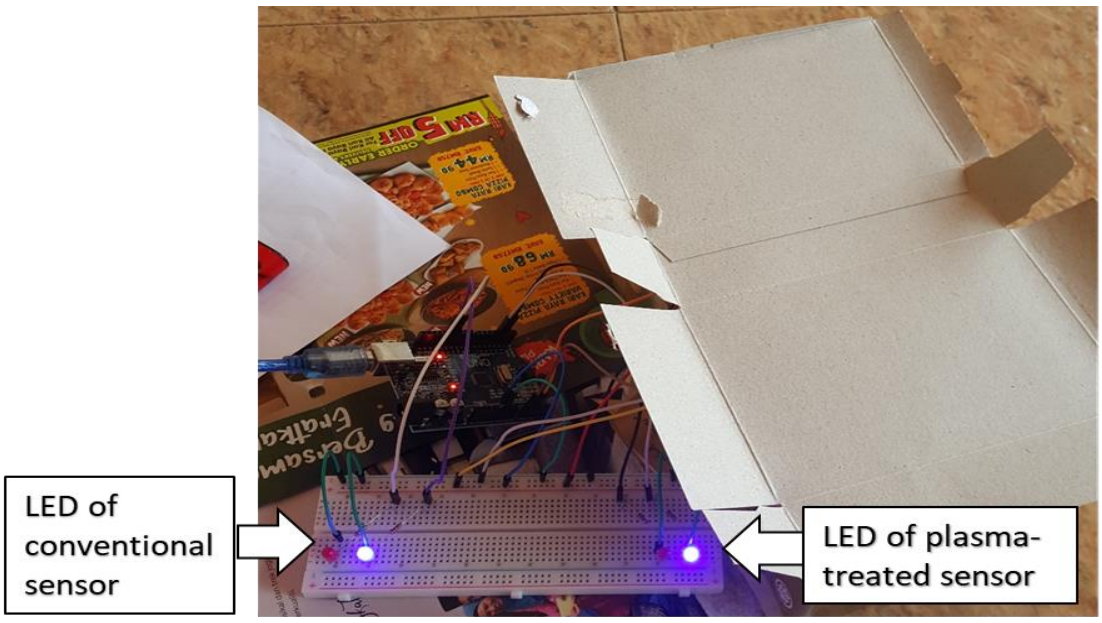

Figure 5: Indicator of Experiment 1 when there is no smoke

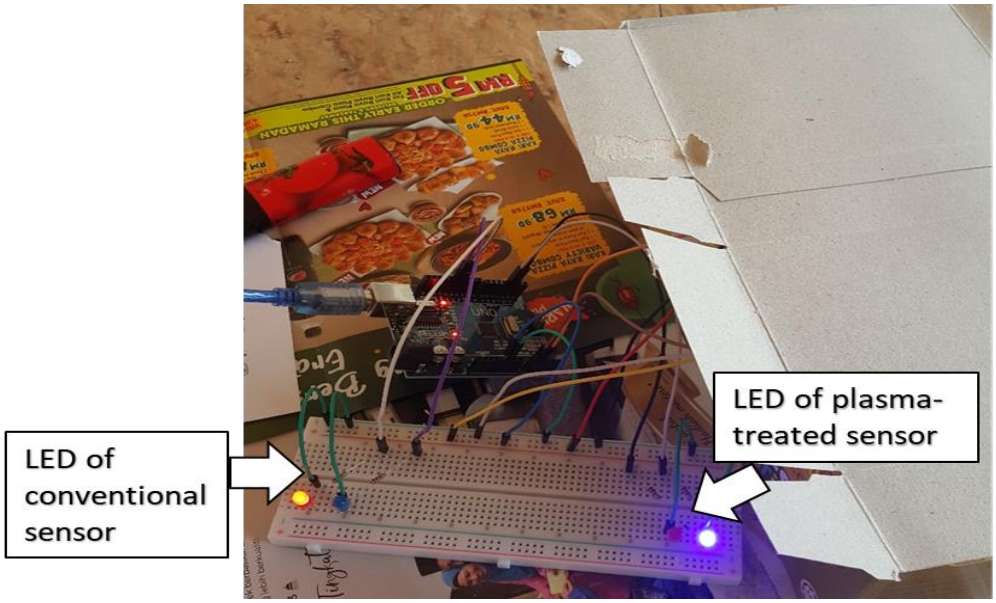

Figure 6: Indicator of Experiment 1 when there is presence of smoke

3.3.2 Experiment 2

Figure 7 shows the graph of carbon monoxide concentration detected by conventional and plasma-treated gas sensor against the time of Experiment 2. Similar to previous experiment result in Figure 4, the graph shows that conventional MQ-7 sensors have detected higher carbon monoxide concentration compared to plasma-treated MQ-7 gas sensor. The reading of carbon monoxide concentration increases when there was a presence of smoke and decreases when there is no smoke.

Similar with previous experiment, the red and blue LEDs on the left is connected to the conventional MQ-7 gas sensor while the red and blue LEDs on the right is connected to the plasma-treated MQ-7 gas sensor as shown in Figure 8 and Figure 9. Similar to the previous result, blue LED light up for both sensors as shown in Figure 8 when there is no smoke since both sensors detected carbon monoxide concentration lower than 15 ppm. Similarly, only red LED of conventional MQ-7 gas sensor lighted up as shown in Figure 9 when there is the presence of smoke since only conventional MQ-7 gas sensor detected carbon monoxide concentration higher than 15 ppm.

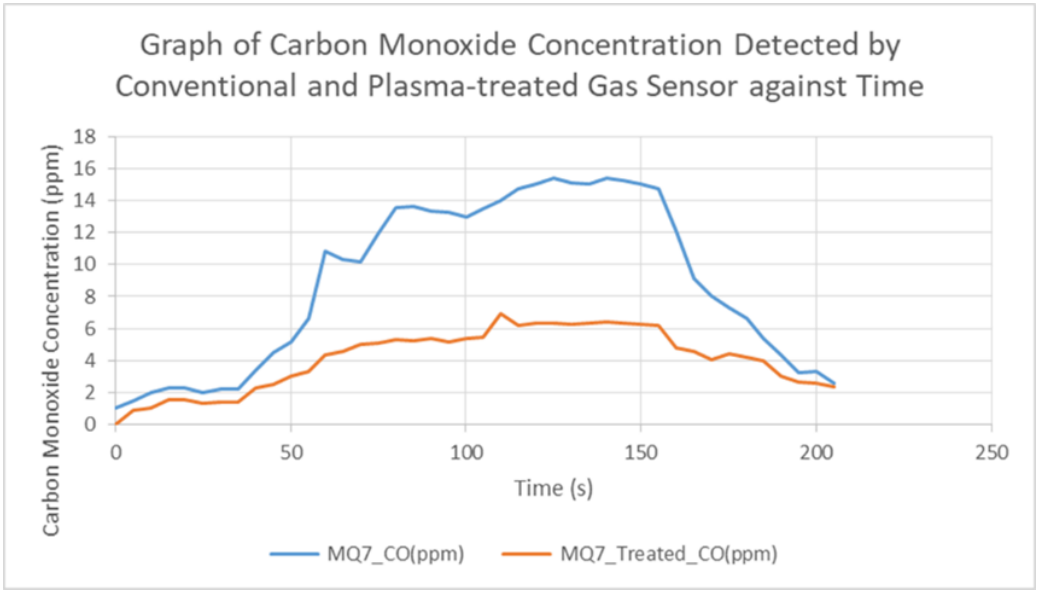

Figure 7: Data of Experiment 2

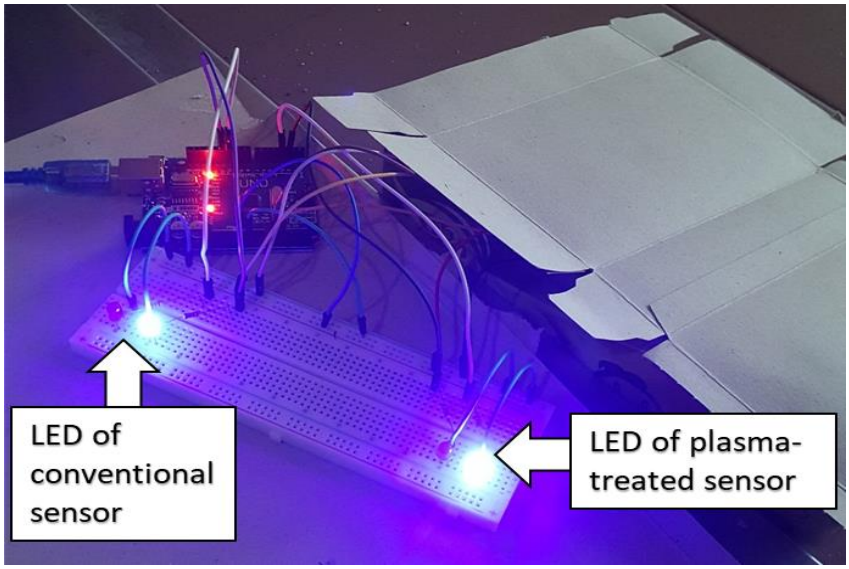

Figure 8: Indicator of Experiment 2 when there is no smoke

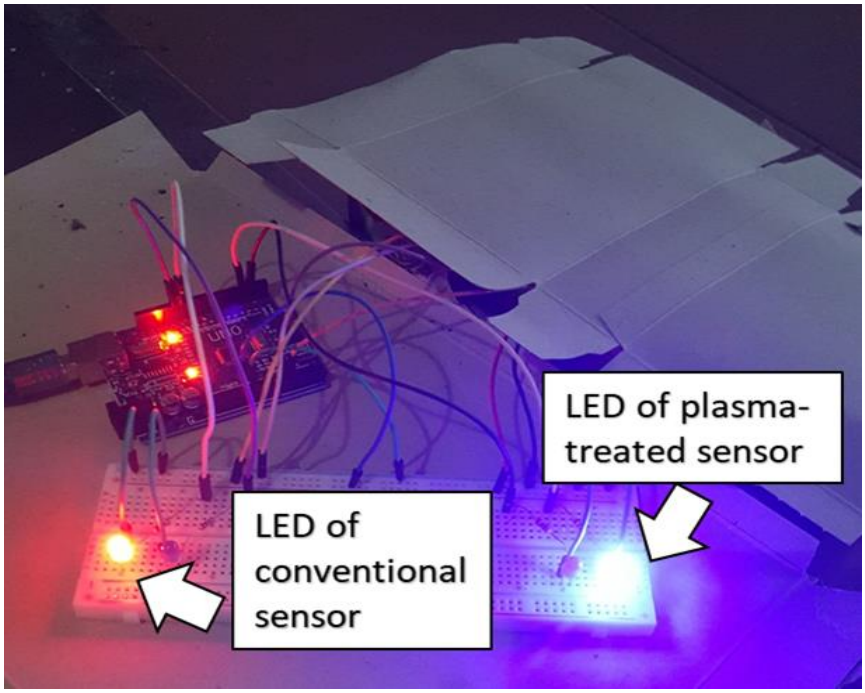

Figure 9: Indicator of Experiment 2 when there is presence of smoke

3.2 Discussions

The experiments of the prototype have successfully conducted and the result is obtained by collecting data of both MQ-7 gas sensors in Microsoft Excel and observe the colour of LED that light up for each sensor in both experiments. The data collected from both sensors are compared to determine the difference in sensitivity of the sensor before and after plasma treatment. Figure 4 and Figure 7 show that the sensor which is not treated by plasma have higher sensitivity compared to the sensor which have undergone plasma treatment.

Despite the difference in sensitivity, both sensors are able to detect the increase and decrease of carbon monoxide concentration easily. When the experiment of the prototype started, the sensors started to detect the carbon monoxide concentration in the air and the data were recorded in Microsoft Excel.

Since the surrounding was clean air, both sensors detected concentration of carbon monoxide lower than 15 ppm and blue LED of both sensors lighted up as shown in Figure 5 and Figure 8.

The graphs in Figure 4 and Figure 7 show that there is an increase of carbon monoxide concentration when there was presence of smoke. However, only conventional MQ-7 gas sensor was able to detect carbon monoxide concentration more than 15 ppm. This is why only the red LED of conventional MQ-7 gas sensor lighted up as shown in Figure 6 and Figure 9. The blue LED of plasma-treated MQ-7 gas sensor in Figure 6 and Figure 9 remains lighted up since the plasma-treated MQ-7 gas sensor did not detect carbon monoxide concentration surpass 15ppm.

Conclusion

Based on the result from both experiments, it can be said that the sensitivity of the MQ-7 gas sensor decreases after undergoing plasma treatment. The plasma gas consists of argon molecules, oxygen molecules, nitrogen molecules, argon atoms, oxygen atoms, nitrogen atoms, argon ion, oxide ion and nitride ion. The oxygen molecules, oxygen atoms and oxide ion might have covered the sensing layer of the MQ-7 gas sensor after the plasma treatment.

Sensing layer of the MQ-7 gas sensor, SnO_2 is a chemiresistor which changes its resistance according to the carbon monoxide in the surrounding. Since the sensing layer of the plasma-treated MQ-7 gas sensor have covered by oxygen molecules, oxygen atoms and oxide ion, the sensing layer will not able to detect the carbon monoxide easily. This makes the free electrons will not be able to break free despite there is carbon monoxide, which causes the resistivity of the sensing layer remain high.

Thus, the conductivity of the plasma-treated MQ-7 gas sensor becomes lower than the conventional gas sensor in the presence of carbon monoxide. Moreover, the plasma-treated MQ-7 gas sensor can no longer detect carbon monoxide concentration more than 15ppm, which is dangerous to the health of people.

Acknowledgements

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