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Optical Emission Spectroscopy Study using Plasma Jet System

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Abstract: Plasma is no longer an alien term used in various industries such as semiconductor, medical and many other industries. This project is done to observe, how the Optical Emission Spectroscopy method affects the plasma jet system. The spectrometer that gathers the spectrum emitted by the active plasma factorizes the plasma that is examined using Optical Emission Spectroscopy. The spectrum that is collected shows the characteristic of the plasma that is collected. The plasma is emitted using the Atmospheric pressure plasma needle jet (APPNJ). Then argon gas is flowed into the machine using a quartz tube and high voltage is supplied to the tube which is coated using copper foil. A neon transformer is used to step up the voltage as only high voltage can produce plasma. The composition of plasma is then emitted to justify the experiment as its effect of it will also be shown in comparison to the reading of the spectrometer. This project will be beneficial to the semiconductor industries as well as medical industries.

Keywords: Plasma, Spectrum, Optical Emission Spectroscopy

1. Introduction

In physics, a state of matter is one of the distinct forms in which matter can exist. One of the crucial states of matter is plasma. Plasma was coined by physicist Irving Langmuir in 1923 and is commonly referred to as the fourth form of matter after solid, liquid, and gas. Plasma is widely utilized in our daily life in items such as the fluorescent bulb, plasma television, cell phone, arc welding and more.[1] Plasma can be defined as ionized gas and it can be created by giving gas enough external energy. When a solid is being heated sufficiently that the thermal motion of the atoms causes the crystal lattice structure to break apart and usually a liquid is formed. If the heating process is continued to the liquid the atoms structured are vaporized and a gas is formed. Plasma occurs when a gas is heated enough and the atoms collide with each other and hit their electrons in the process. The reality is that an ionized gas has its own special properties because charge separation between ions and electrons gives rise to electrical fields [2]. Natural plasma and manufactured plasma are two types of plasma. Stars, interstellar particles,

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the sun, and a variety of other natural plasmas are examples [3]. In the meantime, artificial plasma can be produced by giving gas sufficient external energy for its atoms to ionize [3].

Artificial plasma is widely used in the semiconductor and medical industry such for cleaning, surface treatment of bio-material, living tissue and many more. The traditional method that has been used is low-pressure plasma, however, due to its disadvantages at some point, another method must be implemented, such as atmospheric pressure plasma.

2. Materials and Methods

2.1 Materials

The main criteria of this project will be the software and hardware used in this project. This project uses the Spectrasuite software to monitor the spectrum of plasma. To produce the plasma, we have the Atmospheric Pressure Plasma Needle Jet (APPNJ). The Optical Emission Spectroscopy set up as in Figure 1:

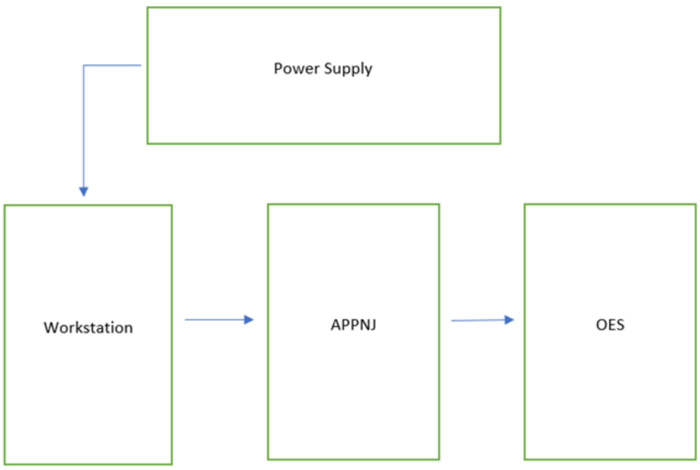

Figure 1: Block diagram of the project

2.2 Methods

The project first needs to be sorted into the objectives and its scope. Then reading through journals of literature reviews to collect information about this project. Next would be to proceed with a methodology that is set up for the experiment. Next will be to proceed with the APPNJ testing and collecting spectrum for this project. The project flow chart is shown in Figure 2.

2.3 Final set-up of the experiment

Figure 3 shows how the project is finally set up and how its run to obtain data using the optical emission spectroscopy method.

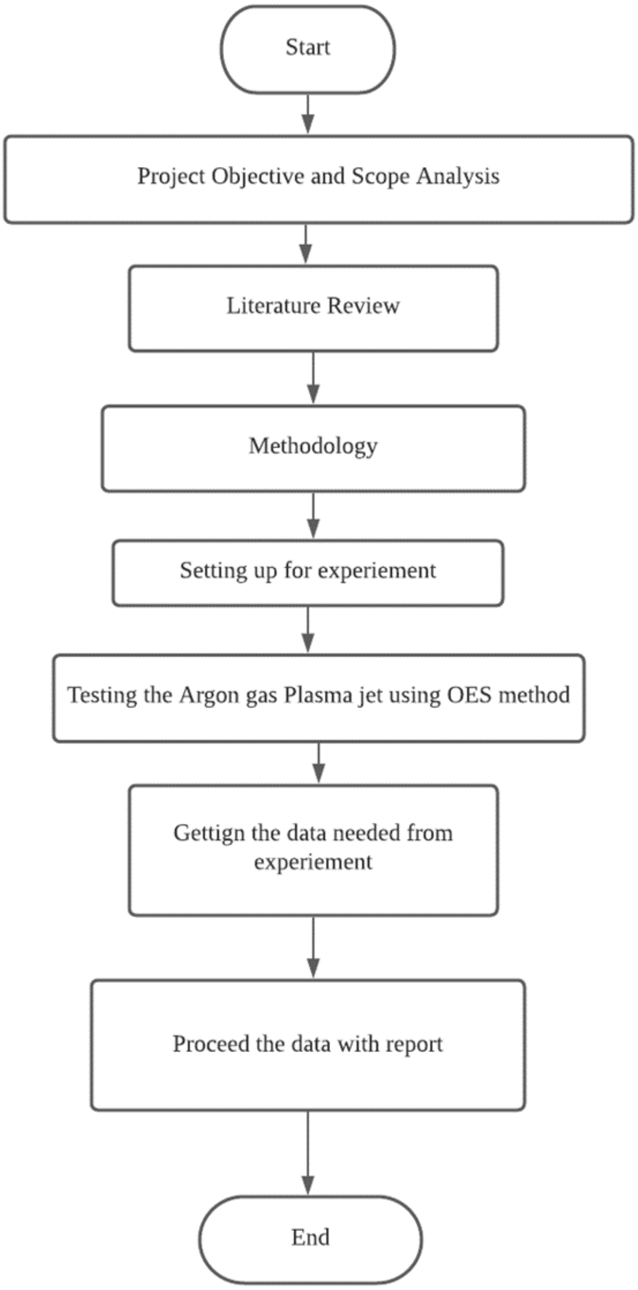

Figure 2: Flowchart of project

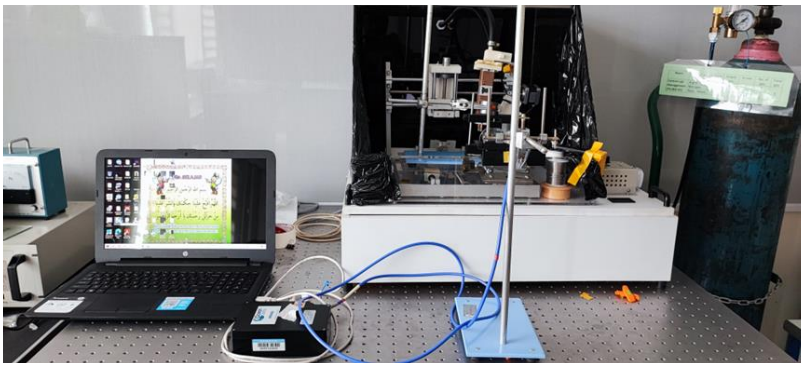

Figure 3: PC with Spectrasuite software, Ocean Optics

3. Results and Discussion

The optical emission properties of the tip of the plasma jet nozzle to fully understand the phenomenon. Figure 4 shows the emission of corresponding reactive gas from the APPNJ orifice at several different flow rates of Ar. The entire respective peak plasma emission was evaluated in Table 1 and Table 2.

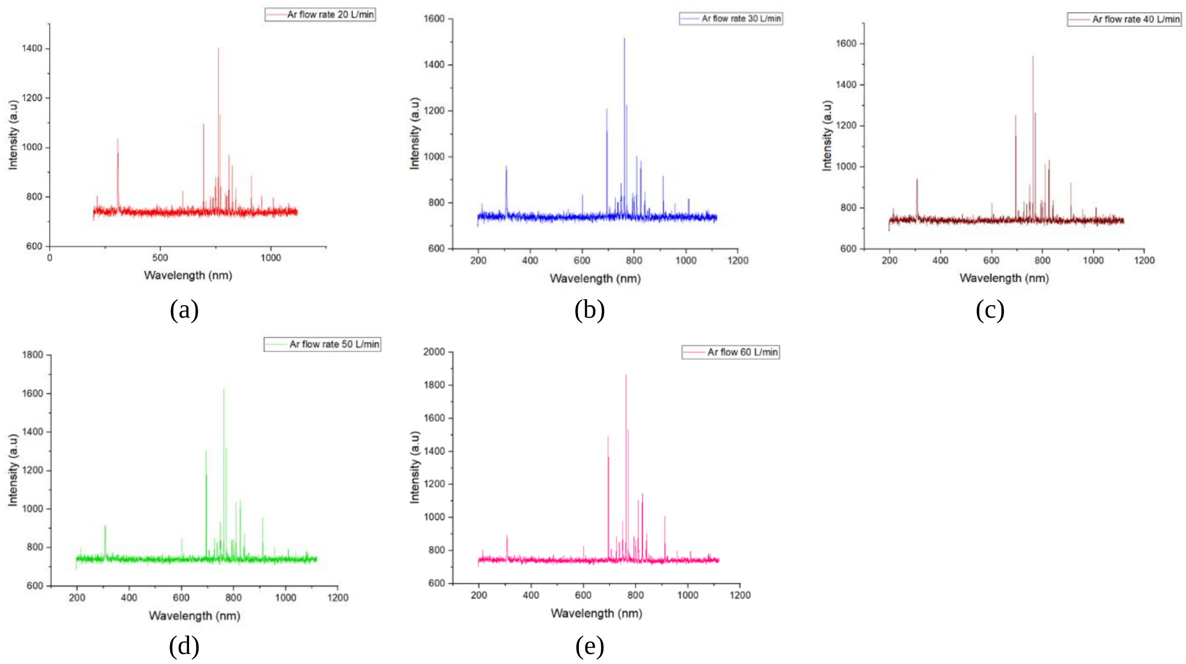

Figure 4: The spectral line of APPNJ of plasma with several Ar flow rate (a) 20 L/min, (b) 30 L/min, (c) 40 L/min, (d) 50 L/min, and (e) 60 L/min

Table 1: Intensity of corresponding Ar flow rate for plasma discharge

Ar flow rate	Ar II (761)(nm)	
	Intensity peak (a.u)	Wavelength of peak (nm)
20 L/min	1404	761
30 L/min	1518	761
40 L/min	1542	761
50 L/min	1625	761
60 L/min	1864	761

Table 2: Data intensity of Ar plasma emissions with regards to different Ar gas flow rate

Wavelength (nm)	Corresponding Element	Intensity				
		20 L/min	30 L/min	40 L/min	50 L/min	60 L/min
307	OH	894	897	929	948	1036
695	Ar I	1097	1210	1253	1301	1496
749	O III	871	887	892	934	947
771	Ar I	1135	1227	1264	1319	1532
825	Ar I	926	984	1033	1050	1146

The Ar reactive gas with regards to different gas flow rates is shown in Figure 5. From the graph, it is clearly seen that several reactive gases such as OH, O III, and Ar I also contributed to the APPNJ plasma discharge. The emission of APPNJ varied from 20 L/min to 60 L/min. However, the increase in Ar flow rate also is affected by several factors such as noise and the presence of other gases such as (Nitrogen) N2 and Oxygen (O2). The emission of Ar was the highest as it was a feeding gas. When the flow rate was 20 L/min, the emission of Ar was 1404 a.u. The emission kept increasing when the Ar flow rate increased by 10 until finally, the emission went up to a maximum of 1864 a.u. Table 4 shows the peak value of Ar during the increase in flow rate. The plasma wavelength is cross-checked using the NIST Database and the presence of Ar II is detected. Figure 2 justifies the purpose of the experiment by showing the flow rate affects the plasma intensity. Figure 5 shows the reading of plasma intensity affected by different elements present during the plasma emission. Other emissions such as hydroxides (OH) and oxygen (O) were also present in the Ar plasma emission, despite Ar II being the main species.

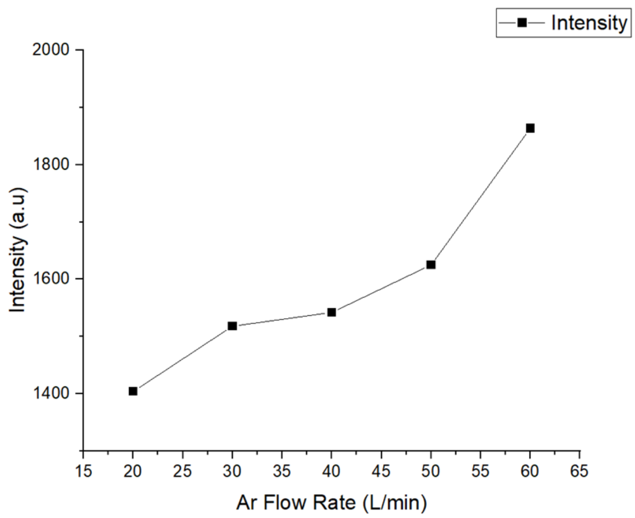

Figure 5: Graph shows how Ar flow rate affects Intensity of Plasma

The Ar reactive gas with regards to different voltage rate is shown in Figure 6. The emission of voltage varied from 140V to 220V. However, the increase in Ar flow rate also is affected by several factors such as noise and the presence of other gases such as (Hydroxide) OH and Oxygen (O_2). The emission of Ar was the highest as it was a feeding gas. When the flow rate was 140V, the emission of Ar was 1091 a.u. The emission kept increasing when the voltage rate increased by 10 until finally, the emission went up to a maximum of 1921 a.u. Table 3 shows the peak value of Ar during the increase in voltage rate. Table 4 and Figure 7 show the presence of other elements and the intensity reading of each element. The plasma wavelength is cross-checked using the NIST Database and the presence of Ar II is detected. Figure 7 graph shows the purpose of the experiment on how the voltage rate affects the plasma intensity. The voltage variation has more obvious effects on the OES spectrum of the plasma intensity.

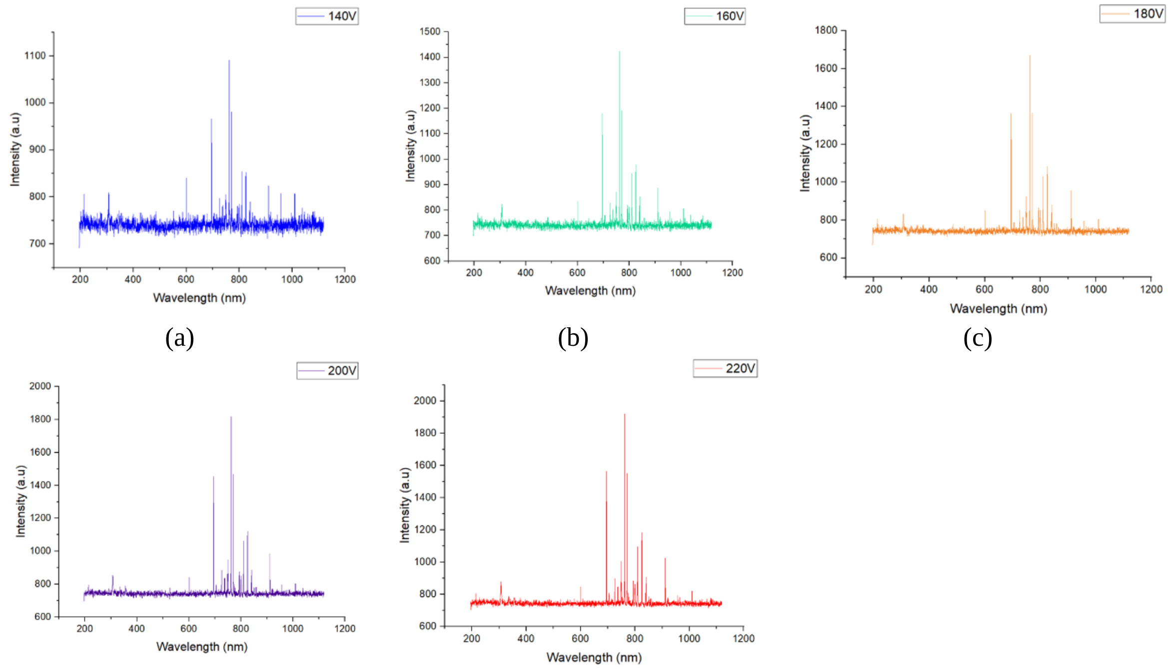

Figure 6: The spectral line of APPNJ of plasma with several Voltage rate (a) 140V, (b) 160v, (c) 180v, (d) 200v, and (e) 220v

Table 3: Intensity of corresponding plasma discharge for plasma discharge

Voltage rate	Ar II(761)(nm)	
	Intensity peak (a.u)	Wavelength of peak (nm)
140V	1091	761
160V	1425	761
180V	1670	761
200V	1820	761
220V	1921	761

Table 4: Data intensity of Ar plasma emissions with regards to different Voltage supply rate

Wavelength (nm)	Corresponding Element	Intensity				
		140V	160V	180V	200V	200V
307	OH	798	814	828	853	860

695	Ar I	967	1180	1364	1454	1565
749	O III	804	856	891	949	1005
771	Ar I	981	1191	1366	1468	1551
825	Ar I	837	980	1084	1123	1183

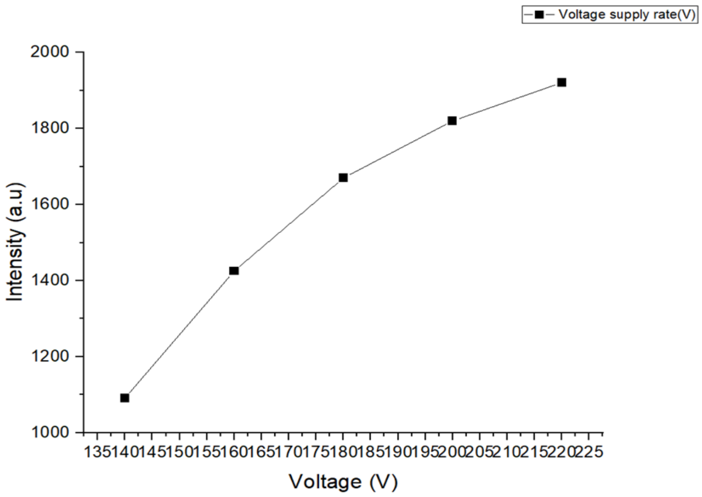

Figure 7: Graph shows how voltage rate affects the intensity of plasma

4. Conclusion

Optical emission spectroscopy results were further explained in the result and discussion part. The Ar gas flow and voltage rate were directly proportional to the intensity of plasma. To conduct the experiment, the plasma jet machine had to be first set up in a dark environment so that the noise can be reduced. The spectrometer was first calibrated using a laser in order to achieve the most suitable position for OES. The collimator lens was placed straight facing the plasma jet nozzle and then the optic fiber. After we are done with the calibration, the environment was made dark and after that OES was conducted. The results of both the plasma intensity and reading were obtained and discussed. The parameter that was varied flows or Ar gas from 20 L/min gradually increasing by 10 till 60 L/min. Another parameter that was varied is voltage by increasing 20 V each time. Starting from 140 V to a maximum of 220 V.

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References

[1] D. Merche, N. Vandencasteele, and F. Reniers, “Atmospheric plasmas for thin fi lm deposition: A critical review,” *Thin Solid Films*, vol. 520, no. 13, pp. 4219–4236, 2012.

[2] Atmospheric pressure plasma jet in Ar and Ar / H 2 O mixtures: Optical emission spectroscopy and temperature measurements (063504 (2010)). (2010). AIP Publishing. https://doi.org/10.1063/1.3439685

[3] Emission spectroscopy of an atmospheric pressure plasma jet operated with air at low frequency (No. 012048). (2015). IOP Publishing Ltd. https://doi.org/10.1088/1742-6596/591/1/012048.