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A Study in Plasma Characteristics and Plasma–Ion Propulsion

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Abstract: In the present work, I have established and diagnosed some of the basic characteristics of plasma, such as relation between discharge voltage and pressure, plasma under external magnetic field and several related experiments which comprise the present work. Also, a simple and innovative model of an ion-propulsion engine has been developed for diagnostics and future demonstration purposes.

Keywords**:** Plasma, Electric discharge, Paschen's curve, Magneto plasma, Ion propulsion

1. INTRODUCTION

Plasma, being the fourth state of matter, provides the solution to many of our problems ranging from energy crisis to industrial applications and space exploration [1, 2, 3, 4]. An extensive research has been going on since many years in research labs in India and abroad as scientists have developed the potential applications of Plasma which range from plasma processing of materials to space explorations to even solving the future energy crisis by means of fusion.

2. PLASMA CHARACTERISTICS AND ION-PROPULSION

This project was carried out in collaboration with the Institute for Plasma Research, Gandhinagar where I was mentored by Mr. K.K. Mohandas. The main purpose of this project was to understand the physics of plasma and get a better appreciation of its applications in various industrial and scientific explorations.

2.1 Objectives

The following studies and objectives have been performed in the project:

1) To establish a relation between gas pressure and voltage in a discharge tube.

2) To observe the anomalies in gas pressure values after the electric discharge.

3) To observe and record the Paschen's curves plotted for gas discharge.

4) To map the magnetic field of the available magnets in the apparatus.

5) To measure the gas pressure and voltage values necessary for discharge under magnetic field.

6) To develop an ion-propulsion engine model worthy of providing experimental data as well as for future demonstrations.

The above-mentioned objectives have been performed under various conditions of the concerned parameters related to the experiments. So, the present article provides the outline of my work.

2.2 Figures for Plasma characteristics

Fig. 1 is the schematic diagram of the used set-up where AC signal is applied to the DIMMER-STAT.

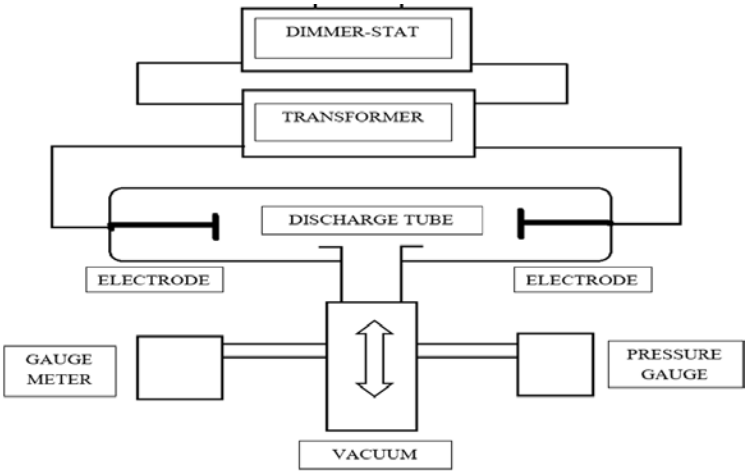


Figure 1. Block diagram of the apparatus set up.

The result of Objective-1 is shown in Fig. 2, which displays a piece-wise linear relation between Discharge voltage and Pressure corresponding to my data sets.

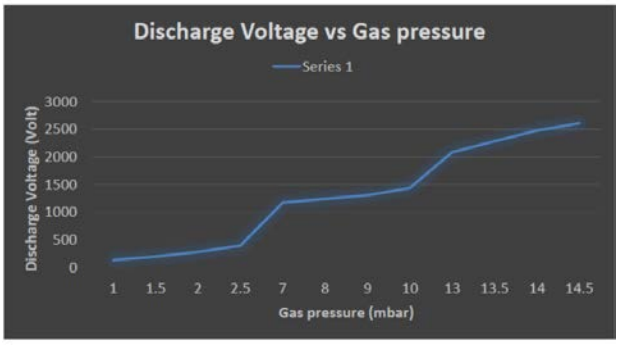


Figure 2. Relation between Discharge voltage and Pressure

The result of Objective-2 is shown in Fig. 3, which establishes that increase in voltage after discharge leads to a small increase in pressure values.

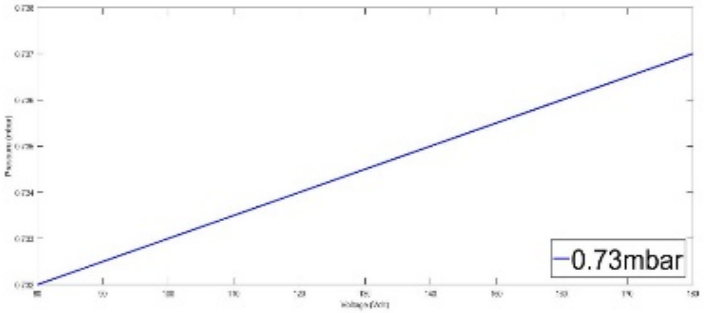
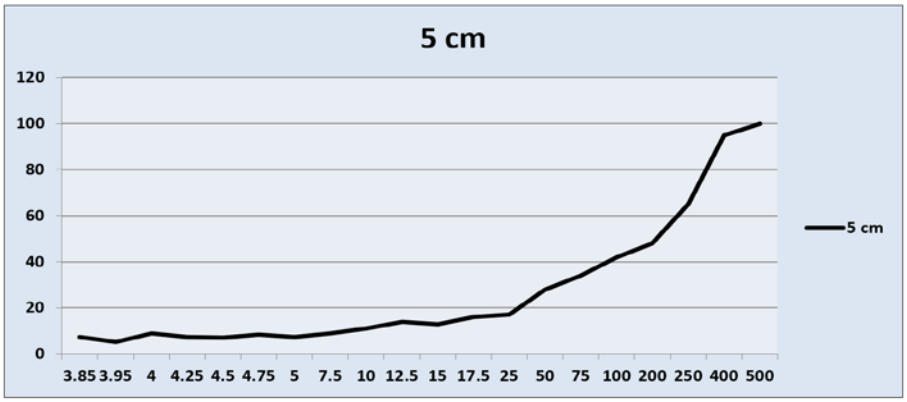


Figure 3. Anomalies in increase in Pressure after discharge



Y-axis: Volt / X-axis: atm*cm

Figure 4a. Experimental Paschen's Curve

Fig. 4a gives the Experimental Paschen's Curve. Fig. 4b is the ideal Paschen's Curve, where the highlighted segment of the same defines the range of the experimental parameters measured in the experiment.

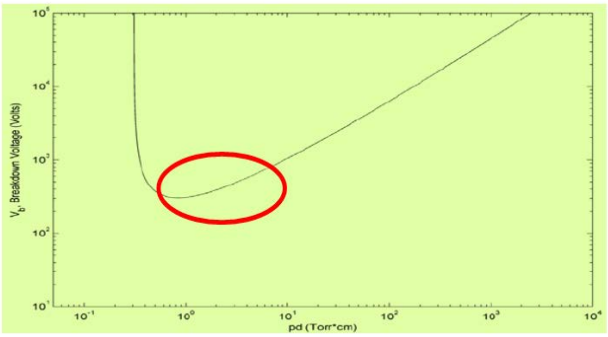
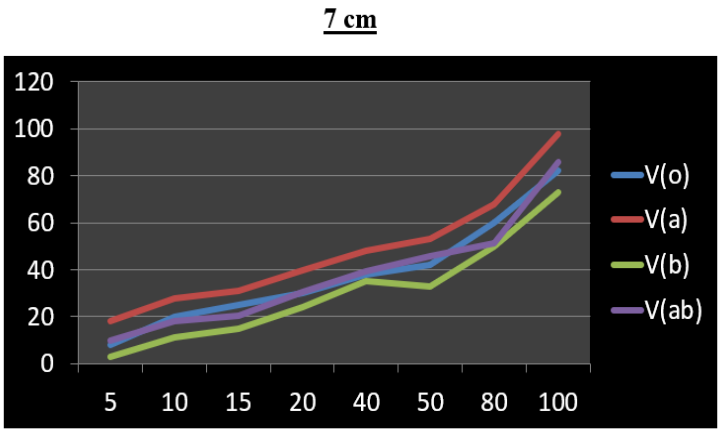


Figure 4b. Ideal Paschen's Curve

The results of the Objective-4 are represented in Fig. 5 which displays the effect of external magnetic field on the discharge voltage values. Here distance between the electrodes is 7 cm and letters 'a' and 'b' represent two distinct magnetic configurations.



Y-axis: Discharge Volt / X-axis: atm

Figure 5. Discharge characteristics under external magnetic field

2.3 Ion-Propulsion

Ion thrusters are being designed for a wide variety of missions—from keeping communications satellites in the proper position to propelling spacecraft throughout our solar system. These thrusters have high specific impulses—ratio of thrust to the rate of propellant consumption, so they require significantly less propellant for a given mission than would be needed with chemical propulsion. Ion propulsion is even considered to be mission enabling for some cases where sufficient chemical propellant cannot be carried on the spacecraft to accomplish the desired mission.

An innovative and experimental model of an ion-propulsion engine has been developed for simple diagnostics and demonstration purposes which is shown in Fig. 6.

The model is consisting an electrode in the form of a nail which ionizes the atoms surrounding its tip through the phenomenon of Corona discharge, when it is biased. The ions created are thus accelerated towards the hollow cylinder, which functions as the cathode. After passing through the hollow cylinder, the ions hit the graphite slab which works as a Faraday's cup and it is connected to an output circuit to display the result on the screen of the oscilloscope.

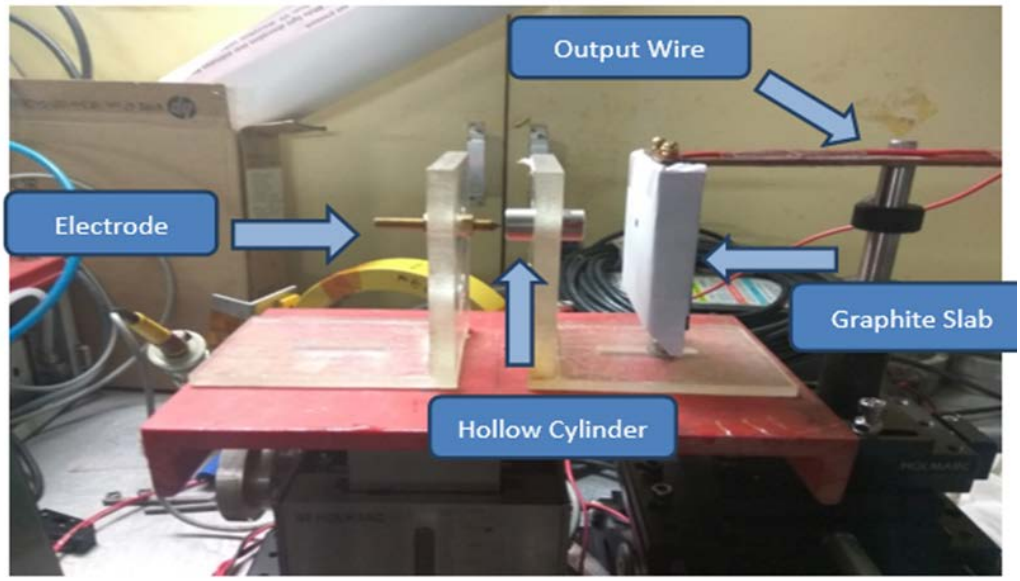


Figure 6. Ion-Propulsion engine model

2.4 Future study

1) Future studies involving discharge voltages and pressure could be done by varying the distance between the electrodes. Also, certain basic changes in the experimental system which allows measurement of plasma density and temperature using different diagnostic systems. Magnetic mirror confinement and its diagnostics are also possible.

2) Further scope in ion propulsion includes trying out various combinations of magnetic configurations, permanent or electromagnetic, to efficiently channelize the ion beam and to vary the distance of the graphite slab as well as to alter the open area of the slab to optimize the output of ions in terms of distance and thrust.

3. ACKNOWLEDGEMENT

This project would not have been possible without the invaluable guidance and mentorship of Mr. K.K. Mohandas and also Dr. Tushar Pandya who helped me finalize the report. Also, I would like to thank Institute for Plasma Research for the opportunity to utilize its facilities and infrastructure for the tenure of the project.

References

[1] F. F. Chen, Introduction to Plasma Physics and Controlled Fusion, vol. 1: Plasma Physics. Plenum Press, 1984.

[2] Michel A. Lieberman, Principles of Plasma Discharges and Material Processing, Second Edition, Wiley Publications, 2005.

[3] The physics of plasmas by Richard Fitzpatrick in association with R.D. Hazeltine and F.L. Waelbroeck (PDF version).

[4] Fundamentals of Plasma Physics by J.A. Bittencourt (PDF version).