# Study and Measurement of Different Parameters of Spontaneous Gas Glow Discharge Plasma in Air

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**Abstract—** The glow discharges is a unique property for the understanding and measurements of the different parameters of glow formed in an evacuated glass tube, with circular plane disk electrodes at low pressure of air. Glow discharges are used in a large number of application fields. This paper attempts to give an overview of gas discharge plasmas in a broad perspective. In this work, a high dc voltage is passed through the discharge tube at different filling pressure of air. Initially the different pattern of glow formed inside the discharge tube is analyzed. Later on the different parameters i.e. number density "n" of the atoms, particle flux "Φ ", mean free path between two successive collision "λ " and the collision frequency "v " of the gas particles are measured at different pressure. It is observed that the calculated values of these parameters are much closer to the actual values.

**Index Terms—** Plasma; Gas discharge; Direct current; Radio-frequency; Pulsed; Dielectric barrier discharge; display panels;

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## 1 INTRODUCTION

The glow discharge is quasi-neutral plasma. Plasma is an ionized gas. It is consists of positive ions, electrons and neutral species. It is fourth state of matter and almost 99% of universe is consists of plasma. There two distinct categories of laboratory plasma i.e. high temperature or fusion plasma and low temperature plasma or gas discharges or glow discharges. There has been a growing interest in recent years in the generation of intense charged particle fluxes for applications such as space ion thrusters, plasma accelerators, and ion beam sources for surface treatment. Gas discharges or glow discharges and related plasmas are used in a large number of application fields. They are used in the microelectronics industry and in materials technology, for surface treatment, fabrication of integrated circuits, deposition of thin protective coatings, plasma polymerization, plasma modification of polymers and other surfaces. The discharge plasma is also used for several interesting applications, such as in the light industry, as gas lasers, and as flat plasma display panels for the flat, large area television screens. Furthermore, it is also used for the spectrochemical analysis of solids, liquids and gases. Because a lot of chemical reactions take place in the plasma. Atmospheric pressure plasmas has also a vast application in medical applications, i.e., plasma medicine, e.g., for the sterilisation of materials treatment of skin diseases, dental cavities, delicate surgeries, and cancer treatment.

Glow discharge is formed when some potential is passed through a gas filled in a tube at low pressure. The gas in the tube breaks-down into electrons and positive ions known as ionization [1]. In glow discharge positive and negative charges and neutral species are present in equal numbers leading to the formation of plasma inside the tube. It is formed when an electric current is passed through the gas at low pressure .When a potential difference is given to the electrodes of tube, the gas in the tube is ionized to produce free electrons and positively charged ions which is termed as gas breakdown .The ions are then accelerated to the cathode where they create secondary electrons emission. These electrons then collide with the molecules of gas to excite and ionize them. On de-excitation light photons emit and as a result glow discharge in the tube is formed [2]. The term ionization is used for the generation of charges by ionization of the gas between the electrodes and converting it from insulator into a conductor. Charges created in glow discharge plasma are by two methods i.e. due to head on collisions of gas molecules with each other and Secondly, due to impact of ions on cathode. These free electrons collide with the atoms of gas on applying a high power voltage across the electrodes. The electron give rise to new ionization collisions, creating new ions and electrons. This process of electron emission at the cathode and ionization in the tube make the glow discharge self-sustaining plasma. These collisions are actually chemical reactions which take place into seven different steps i.e. i. Conservation Reaction ii. Excitation Reaction iii. Ionization Reaction iv. Penning Reaction v. Electrons attachment Reaction vi. Associative ionization vii. X-Rays Ionization Reaction [3]. Another process in the glow discharge is the sputtering which takes place mainly at high voltage due to impinging of fast ions from the plasma on the cathode. This is the basis of the use of the glow discharges for the analytical analysis of the different elements. A d.c. glow discharges can be operated over a wide range of discharge conditions. The pressure can be varying from below 1 Pa to atmospheric pressure. The operating voltage is mostly between 300 V to 500 V. The discharges can operate in the

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rare gases (Argon or helium) or in reactive gases i.e. N2, O2, H2, as well as in the mixtures of these gases. The glow column is divided into two main blocks, (1) Cathode block which contains cathode glow, negative glow, crooks dark space and Faradays dark space. Cathode block is strongly affected by the pressure and do not depend upon the length of the tube. When the pressure in the tube is reduced, the crooks dark space becomes longer and longer and covers the entire tube. The faradays dark space is too narrow to be seen as it depends on the diameter of tube. (2) Anode Block which contains anode dark space, anode glow and positive column. Positive column depends on the length of the tube and elongates by increasing the length of the tube. Later on positive column becomes divided into stripes as the electrons are absorbed in ionization process and give energy to the molecules of gas and this energy is utilized by the newly produced secondary electrons to cause the ionization process. The gaps between the strips of glow column depend on the pressure. Figure 1.1 shows different column developed in discharge tube [4].

The glow discharge was first studied by Paschen for atomic spectrometer. Before 1960 the glow discharge suggested as spectrometric radiation sources. Caroli used hollow discharge cathode as an ion source. Meanwhile Marcus published a book on glow discharge atomic spectrometry [5]. Stephane Baude et al. used glow discharge in optical atomic spectrometry as radiation sources. They preferred planar cathods in glow discharge for environmental analysis of airborne dust, plants and soil [6]. Bogart and Gibels [7] explained the fundamentals of glow discharge processes in his review.specially they reviewed energy distribution of plasma species and sputtering. T Cserfalvi and p Mezei [8] produced a type of glow discharge in which the cathode was an electrolyte solution, and the anode was placed at a distance above it. They produced discharge between electrodes and studied oxidation in solution. The internal energy of glow discharge at atmospheric pressure was measured by David stack [9]. He measured both the vibrational and rotational temperatures of particles as a whole.

Satiko Okazaki et al. [10] investigated and established the operating principles in air for establishment of uniform glow discharge. It was an unoffortunate that their operating principles were failed due to two main reasons, first the low frequency were almost of the same range as of low value of dV/dt as the optimum glow discharge is possible at higher values of dV/dt. This scaling for dV/dt originates from there being a finite time that the discharge will transition into conducting plasma, a time called the formative time-lag. Laroussi et al [11] replaced the impedance in the system used by Okazaki et al. They used a resistivity but finite electrode conductivity instead of mesh-dielectric electrode. They obtained the uniform glow discharge at atmospheric pressure, energized by DC and radio frequency (RF) voltage both. This discharge was then used to sterilization of surfaces. A similar concept using graphite electrodes was also used to stabilize early pulsed CO2 laser discharges [12]. For material processing, chemical synthesis, environmental cleanup and now days biotechnology applications, the glow discharge has attracted the attentions of the research community for the production of uniform glow discharge according to their desires and needs [13]. In low temperature plasma, if the ionization is only from the ground state, then according to the scaling in low temperature, the density of the gas N is constant, the ratio of electric field E and density N is constant, the product $N\tau$ is constant where $\tau$ is the characteristic time where the plasma comes into a steady state [14]. M. Moissan et al., reviewed and analyzed the work on gas discharge plasma sterilization which takes not only short time than any other sterilization method but also works at low temperature [15]. Similarly an experiment for sterilization using glow discharge plasma in hydrogen peroxide vapor was performed by [16] I A.Soloshenko et.al. They used active particles for sterilization in such a system rather than ultraviolet (UV). They determined that it was more convenient for sterilization using discharge plasma in hydrogen peroxide vapor than in gases. Sterilization time in open surfaces was greater and in packed articles time was very short. This was due to some biologically active particles, such as oxygen molecules and atomic oxygen excited to lower metastable states [17]. (I A.Soloshenko et.al. 2012). Bogaerts [18] worked on glow discharge plasma in analytical chemistry. His work deals with sputtering. The analyzed material is placed as cathode when positive ions are bombarded at the cathode which liberates atoms of the cathode material in the plasma that is called 'sputtering'. These atoms are then entered the discharge plasma where they collide with electrons. The characteristics name of the 'glow' discharge are responsible by the excitation collisions that normally followed by de-excitation which can cause emission of radiation. The process of ionization can create new electrons and ions. The latter can cause secondary electrons emission at the cathode and give rise to new ionization collisions. Therefore, the glow discharge in the plasma is self-sustaining plasma due to the process of electrons emission at the cathode and ionization in the plasma. David stack [19] calculated the different parameters of glow discharge at low pressure in his experiment. He determined that the temperature of gas was due to the energy. This mechanism was stated as strong electric field between the electrodes imparts high energy to electrons .the electrons give their energy to the gas molecules. Gas molecules then transfer their energy to the electrodes or tube walls to cool the temperature down. Though the cooling rates at atmospheric pressure are high but heating overcome this cooling. That is why it is difficult to obtain cold plasma at atmospheric pressure. Seo and chunkn [20] worked to determine the different parameters using low-pressure inductively coupled oxygen plasmas. They obtained spectral lines intensities for this purpose using a mixture of molecular oxygen ions and oxygen atoms. They combined their calculated parameters with Langmuir probe data, to investigate neutral and charged species and found a significant change between neutral and charged species densities.

Our main focus in this experiment is on, to produce glow discharge in a tube at low pressure, to study the different parts and structures of glowing column in glow discharge tube, to determine the number density "n" of O2 atoms at different pressures, to determine the particles flux "Φ ", at different pressures, to draw a relation between mean free path "λ "and collision frequency "ν "and to compare the mean free path with pressure. In the present experimental work, the following apparatus were used to perform the experiment i.e. Discharge Tube, Rotary-Vane vacuum pump, small flanges, centering rings, clamping rings of different sizes, variable leak valve, ball value valve with two flanges, thermovac vacuum meter, gauge tubes, gauge head cables, high-vacuum grease, high voltage power supply, and high voltage cables. The set-up to perform the experiment is described in the section Experimental set-up. The aim of this study is to investigate and analyze the different structures of glow discharge plasma in a tube at low pressure.

## 2. Experimental

Glow discharges have a wide scope of life from home to industry. It has brought revolution not only for analytical chemistry but also in microelectronics industry and materials technology. Glow discharge plasma is the oldest and easiest source for different applications. Its simplicity has made it advantageous in all the fields of science. If it is compared with other plasma sources, GD operates at very low voltage due to its small volume [4]. Glow discharge is plasma which is generated at low pressure but the main problem is the maintenance of it at low pressure for a long time as it is costly. Many scientists worked to find out new techniques for the generation of glow discharge plasma at atmospheric pressure to get rid of its conventional method. The generation of ideal glow discharge at atmospheric pressure mainly depends upon the pressure, nature and humidity of gas used in a tube, structure of electrodes, distance between electrodes and applied voltage. In this work we explore the dynamical behavior of the plasma tube in the region of glow discharge. We have investigated and analyzed the different parameters of glow discharge i.e. variation of number density with pressure, flux, means free path and collisions frequency with pressure at room temperature. This experiment is carried out in a gas discharge tube. The following experimental apparatus are used, Discharge Tube, vacuum chamber made of glass, Rotary-Vane vacuum pump for vacuum purpose, high voltage power supply, high voltage cables, small flanges, centering rings, clamping rings, variable leak valve, ball valve with two flanges and thermovac vacuum meter, gauge , gauge head cables . In the experimental set-up, First of all, the ball valve is attached with two flanges to the inlet manifold of the rotatory vane vacuum pump and then connected to the left side of the T-shaped socket. The variable leak valve and the gauge tube are mounted on the right sides of the cross of the T-shaped socket. The ground socket of the discharge tube is lubricated with a thin layer of high vacuum grease to create high vacuum purpose. The discharge tube is then pressed on the male ground joint of the T-shaped socket or joint smoothly and gently to avoid the damage. The male ground joint of T-shaped socket or joint is connected to the cross and closed the clamping rings carefully. Then the thermovac vacuum meter is connected to the gauge tube for measurement of pressure inside the discharge tube. The electrodes of the discharge tube are then connected with high voltage source through high voltage cables. The schematic diagram of experimental set-up is shown in figures 1.2.

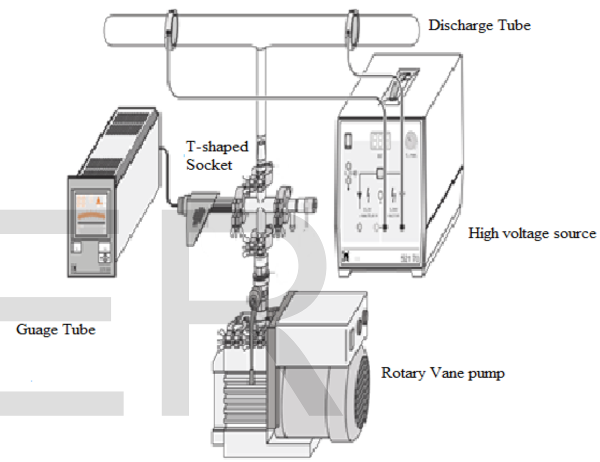


**Figure1.1 Different column developed in discharge tube [4].**

In this experiment, the gas used for glow and plasma generation is air. First of all, the discharge tube is evacuated slowly and gradually by the rotary-vane pump for one hour. A high voltage is applied to the tube by high voltage source. At high pressure, there was no luminescing. On reducing the pressure inside the discharge tube a current begins to flow accompanied by glow discharge. On further decreasing the pressure, several phase of the glow discharges are appeared as will discuss in results and discussion section. The layers of the luminous zones becomes appear because of the electrons which excites the atoms by collisions have to cover an accelerating gap after each collisions excitations in order to acquire the energy needed for another excitation.

## 3. Results and Discussion

This article is intended to discuss and to elaborate more in detail the formation of stable d.c glow discharges plasma inside a discharge tube at low pressure. The gas phase ions are very unique in the universe as almost 99% of the universe is made of it, known as plasma state. In this state, the matter is consists of ions, electrons and neutral particles. However in every y life, the plasma state is not so common as well as understands by the common public. At earth, the plasma is produced by the gas discharges and other techniques. The plasma and its closely related cousin i.e. gas discharges are instrumental in modern life, getting revolution in everyday life, affecting the daily life from everyday lighting and transportation. In plasma processing i.e. sputter metal deposition and reactive ion etching is very important for the development of the computer chip. The gas discharges has also applications in the automobile industries for ignition process in the igniting flux. The fluorescent lighting and energy efficient compact fluorescent light bulbs are gas discharges lamps. The other applications of such technology is such as atmospheric pressure plasma jets for killing tumors and healing wounds, micro plasma array for high efficiency light and plasma thruster for more efficient space travel.

**Table 1. 1 Different results of glow column at different filing pressure.**

| S. No | Applied voltage U (kV) | Pressure P (pa) | Results (In the glow column) |
|---|---|---|---|
| 1 | 5.0 kV | 4000 | No discharge was seen |
| 2 | 5.0 kV | 2500 | No discharge was seen |
| 3 | 5.0 kV | 1500 | Blue-red streamer arose from the cathode to the anode |
| 4 | 5.0 kV | 700 | The positive column became thicker. A small luminous spot and a dark space in front of the cathode was studied |
| 5 | 5.0 kV | 80 | The whole cathode covered with a luminous layer, a dark space spreaded between cathode and the positive column. |
| 6 | 5.0 kV | 35 | Positive column lost the color. Some bright and dark zones emerged. |
| 7 | 5.0 kV | 10 | Distance between the layers increased |
| 8 | 5.0 kV | 6 | Dark space widened. layers in the positive column adopted mushroom shaped. The Glow light disappeared in front of the cathode after some time. |
| 9 | 5.0 kV | 4000 | No discharge was seen |

The glow discharge is considered to stable only at low pressure gas discharges. It is because that the gas discharges concentrates on one point at a pressure of about 100 Torr. On rising the pressure, the discharges converts into sparks and arc on atmospheric pressure and make it impossible to process an object uniformly.

But the glow discharges become stabilizes if the applied voltage is minimum. A stable and homogeneous glow discharge at atmospheric pressure in a gas discharge tube is due to its low breakdown stress and thus, makes it easy to produce small avalanches which are required. In a gas discharge or plasma, the electrical current is flowing through the gap of the gases. In this case, the gas becomes a conductor. In the gas discharges, the ions generation is characterized by the applied potential or electric field. Glow discharge is a special form of gas discharge. It happens spontaneously at low pressure with relatively small current density which is accompanied by conspicuous luminous effects. The aim of the present experiment is to analyze the formation of a glow discharge and its structure along with other parameters measurements and their mutual relations in a gas discharge tube. In the present experiment, a stable glow is achieved and different parameters of the glow discharge i.e. number density "n", particle flux "Φ", mean free path "λ" and collision frequency "ν" with pressure p at a constant fixed voltage of 5 kV. A stable glow was achieved at 6 Pa. Some results of the glow column are studied. These results are given in the table 1.1.

The possible mechanism for getting a stable glow may be that the electric field between the electrodes in a gas is equal to the applied potential difference and the separation between electrodes. Electrons inside the gas scatter in all the probable direction in the absence of applied electric field. When the applied voltage is strong enough, an electron is accelerated in the gas already produced by external agent i.e. cosmic rays which produces a large number of electrons, ions and negative ions in equal number. The strength of glow near electrodes is greater than that in positive column. The speed of electrons to reach the wall of the tube is faster than that of positive ions in positive column. Electrons get energy from the applied electric field intensity to collide with neutral molecules to produce ionization and electron ion pairs. Inside plasma the ionization rate is equal to the loss rate of ions in recombination due to the energy gotten from the longitudinal field. On this stage velocities gained by the ions inside the tube is so high that positive ions knocked out the electrons from the cathode. These electrons migrated to the anode and on the way they ionized neutral molecules. When we decreased down the pressure further, we noticed a bluish red "stream" like thread for a short period. This luminous thread like structure later on, converted into a luminescent cloud filling the whole tube. On decreasing the pressure further more we noticed that this luminescent stream disintegrated into layers adopting the shape of discs or mushrooms respectively. The distance between these discs or layers increased and the luminescent cloud inside the tube became weaker and weaker till demolished on further decreasing the pressure.

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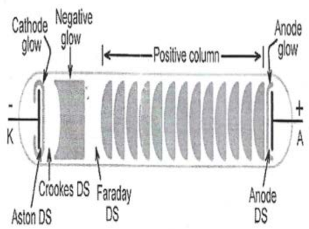


**Figure1.2 Experimental set-up for glow discharge plasma.**

Number density can be thought of as the number of particles that are present in a particular volume at a specific pressure. The number density is calculated according to ideal gas law,

$$n = \frac{P}{KT}$$

Where "n" is the number density of the O2 molecules in the gas at a specific pressure and temperature, "R" is the universal gas constant i.e. 8.3145 J/mole K, k is the Boltzmann constant i.e. 1.38066 x 10-23 J/K = 8.617385 x 10-5 eV/K . The number density is calculated at the average speed of oxygen molecule O2, at 304 K which is v = 486.8 m/s. The table 1.2 shows the calculated values of number density "n" at different pressures which is graphically illustrated in figure 1.1.

**Table 1.2 Measured values of number density "n" at different filling pressure of the discharge tube.**

| S.no | Pressure (p) (Pascal) | V ($m\ s^{-1}$) | Number density (n) ($Cm^{-3}$) |
|---|---|---|---|
| 1 | 6 | $4.868x10^2$ m/s | $1.44x10^{21}$ |
| 2 | 10 | $4.868x10^2$ m/s | $2.4x10^{21}$ |
| 3 | 35 | $4.868x10^2$ m/s | $8.45x10^{21}$ |
| 4 | 80 | $4.868x10^2$ m/s | $19.32x10^{21}$ |
| 5 | 200 | $4.868x10^2$ m/s | $48x10^{21}$ |
| 6 | 700 | $4.868x10^2$ m/s | $1.6x10^{23}$ |
| 7 | 1500 | $4.868x10^2$ m/s | $3.62x10^{23}$ |
| 8 | 2500 | $4.868x10^2$ m/s | $6.03x10^{23}$ |
| 9 | 4000 | $4.868x10^2$ m/s | $9.66x10^{23}$ |

It is revealed by figure 1.1 that the number density increases with increase in the internal pressure of the discharge tube. The increase in density with pressure is that the particles in the gas i.e. electrons, ions and neutral atoms, are in incessant thermal motion because their motions are perfectly elastics. At low pressure, the electron temperature is very different from the temperature of ions and neutral atoms due to mass difference. At low temperature the electron receives more energy from the applied electric field and can exchange energy very difficulty with neutral atoms and ions leading it to a reservoir of kinetic energy which is a very weak contact with the neutrals atoms.

The electrons get the speed over the thermal speed due to the applied field, its produces secondary electrons by ionization collisions. Then these two produces more electrons through elastic collisions and so on. On increasing the pressure the number of collisions will also increase leading to an avalanche of free electrons, ions and neutral particle in the tube.

The other reasons for increasing of the number density of the atoms inside the tube with pressure is that the inter-molecular distances decrease with increase in pressure leading to the large number occupation in the a small volume.

The relation between the particles flux and the pressure is given by the relation,

$$\Phi = \frac{P}{\sqrt{2\pi mKT}}$$

Where P is the pressure inside the tube, m is the mass of the particle, T is the room temperature. In table 4.3 we have measured the random flux of O2 atoms at different pressures. Figure 4.3 gives the variation in flux density with pressure.
Figure 1.4 gives the variation in flux density with pressure.

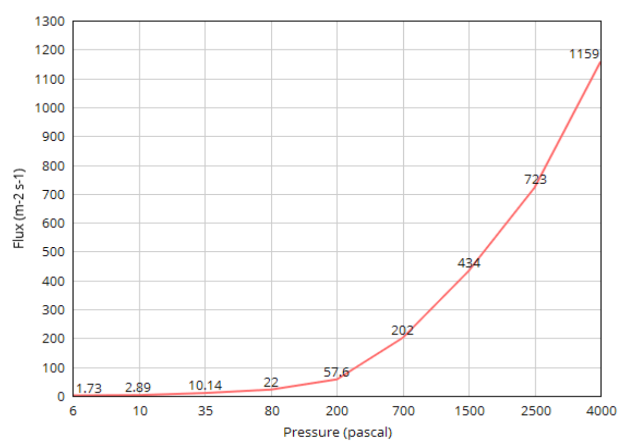


**Figure 1.4 Variation in flux density "Φ "with pressure "P" at a constant voltage of 5 kV.**

The flux density of the oxygen molecules in the discharge tube has a direct relation with inside pressure of the discharge tubes. Which shows that number density increases with increasing pressure. The random flux of ions and electrons depends upon the number density. When number density is going to increase, the particles flux will also increase. The reason is that when the pressure of system increases, the distance between particles decreases which increase the particles thermal velocity as a result more and more electrons flow per unit time. Figure 1.2 also satisfies the result.

The distance between the two successive collisions is known as mean free path. The mean free path in a gas discharge tube is given by,

$$\lambda = \frac{KT}{\sqrt{2}\pi\ pd2}$$

Where $\lambda$= Mean free path between the two successive collisions, k= Boltzmann's constant, P= Gas pressure of the tube and d= molecular diameter of the O2 Molecules = 3.6 x10-21m

The mean free path is inversely proportional to the pressure. Table 1.4 shows the calculated vales of mean free path at different gas pressure in the tube. Figure 1.5 shows the graphical relation between the mean free path and filling pressure of the gas discharge tube.

**Table 1. 4 Variation of Mean free path "λ" with pressure "P".**

| S.no | Pressure (p) pascal | Number density (n) $Cm^{-3}$ | Mean free path (λ) m |
|---|---|---|---|
| 1 | 6 | $1.44x10^{21}$ | $2.76x10^{-1}$ |
| 2 | 10 | $2.4x10^{21}$ | $1.65x10^{-1}$ |
| 3 | 35 | $8.45x10^{21}$ | $4.73x10^{-2}$ |
| 4 | 80 | $19.32x10^{21}$ | $6.02x10^{-2}$ |
| 5 | 200 | $48x10^{21}$ | $8.28x10^{-3}$ |
| 6 | 700 | $1.6x10^{23}$ | $2.34x10^{-3}$ |
| 7 | 1500 | $3.62x10^{23}$ | $1.21x10^{-3}$ |
| 8 | 2500 | $6.03x10^{23}$ | $6.24x10^{-4}$ |
| 9 | 4000 | $9.66x10^{23}$ | $4.14x10^{-4}$ |

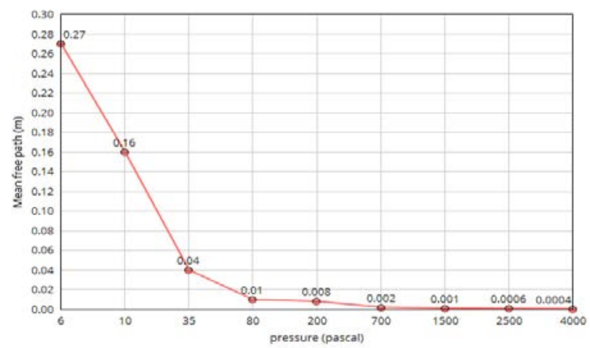


**Figure 1.5 Variation in pressure mean free path "λ" with pressure "P".**

From table 1.4 and figure 1.3 shows the relation between the mean free paths of atoms before taking part in a collision with pressure. The data shows that the mean free path of the atoms is inversely proportional to the pressure of the gas inside the gas discharge tube which is in good agreement with other results (David B.Go, 2012). The main reason is that by increasing the pressure, the distance between electrons squeezes leading to a small free path. The other main reason might be that the mean free path is inversely proportional to the molecular diameter of the gas. By increasing the pressure of the gas inside the discharge tube leads to a large number of collisions as the distance between the molecules becomes smaller. Figure 1.3 also satisfies this result.

**Table 1. 2 Variation in flux density "Φ "with pressure "P" at a constant voltage of 5 kV.**

| S. No | Pressure (p) Pascal | Number density (n) $Cm^{-3}$ | Flux (Φ) $m^{-2}s^{-1}$ |
|---|---|---|---|
| 1 | 6 | $1.44x10^{21}$ | $01.73x10^{23}$ |
| 2 | 10 | $2.4x10^{21}$ | $2.89x10^{23}$ |
| 3 | 35 | $8.45x10^{21}$ | $10.14x10^{23}$ |
| 4 | 80 | $19.32x10^{21}$ | $22x10^{23}$ |
| 5 | 200 | $48x10^{21}$ | $57.6x10^{23}$ |
| 6 | 700 | $1.6x10^{23}$ | $202x10^{23}$ |
| 7 | 1500 | $3.62x10^{23}$ | $434x10^{23}$ |
| 8 | 2500 | $6.03x10^{23}$ | $723x10^{23}$ |
| 9 | 4000 | $9.66x10^{23}$ | $1159x10^{23}$ |

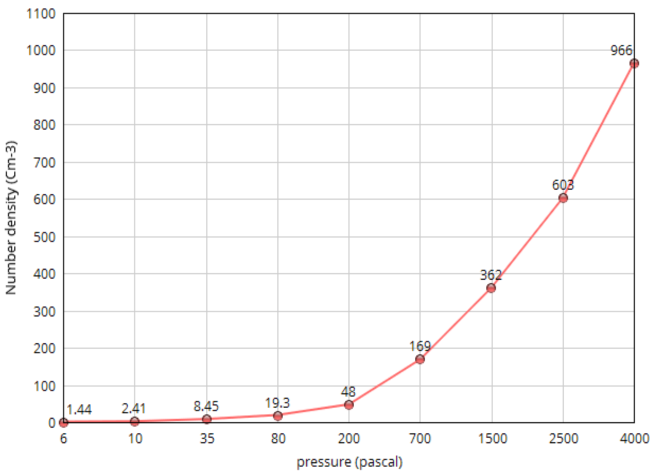


**Figure 1.3 Variation in number density "n" with pressure "P" at a constant voltage of 5 kV**

The collisions frequency is defined as the number of collisions by an atom or electron per unit time. It depends on the probability that the electron hits a neutral atom or molecules, which depends upon the collision cross-section.

The collision frequency is given by,

$$\nu = v/\lambda$$

Where V is the drift velocity of the molecule at room temperature. The drift velocity of the molecule is given by,

V= (2kT/M)1/2

Where K is the Boltzmann constant, T is absolute room temperature and M is molecular weight of the O2 molecule. The calculated value of the drift velocity of molecule is 4.86 x102 m/s.

Table 1.5 shows the calculated values of the collision frequency at different pressure and mean free path.

**Table 1. 5 Relation between mean free path "λ" and collision frequency "ν"**

| S.no | Pressure(p) Pascal | Velocity (m/s) V= 4.86 $x10^2$ m/s | Mean free path (λ) m | Collision frequency ν $s^{-1}$ |
|---|---|---|---|---|
| 1 | 6 | V= 4.86 $x10^2$ m/s | $2.76x10^{-1}$ | $1.76\ x10^3$ |
| 2 | 10 | V= 4.86 $x10^2$ m/s | $1.65x10^{-1}$ | $2.94\ x10^3$ |
| 3 | 35 | V= 4.86 $x10^2$ m/s | $4.73x10^{-2}$ | $1.01\ x10^4$ |
| 4 | 80 | V= 4.86 $x10^2$ m/s | $6.02x10^{-2}$ | $2.37\ x10^4$ |
| 5 | 200 | V= 4.86 $x10^2$ m/s | $8.28x10^{-3}$ | $5.79\ x10^4$ |
| 6 | 700 | V= 4.86 $x10^2$ m/s | $2.34x10^{-3}$ | $2.4\ x10^4$ |
| 7 | 1500 | V= 4.86 $x10^2$ m/s | $1.21x10^{-3}$ | $3.6\ x10^5$ |
| 8 | 2500 | V= 4.86 $x10^2$ m/s | $6.24x10^{-4}$ | $7.6\ x10^5$ |
| 9 | 4000 | V= 4.86 $x10^2$ m/s | $4.14x10^{-4}$ | $1.15x10^6$ |

Figure 1.6 shows the graphical representation of mean free path and collisions at different pressures.

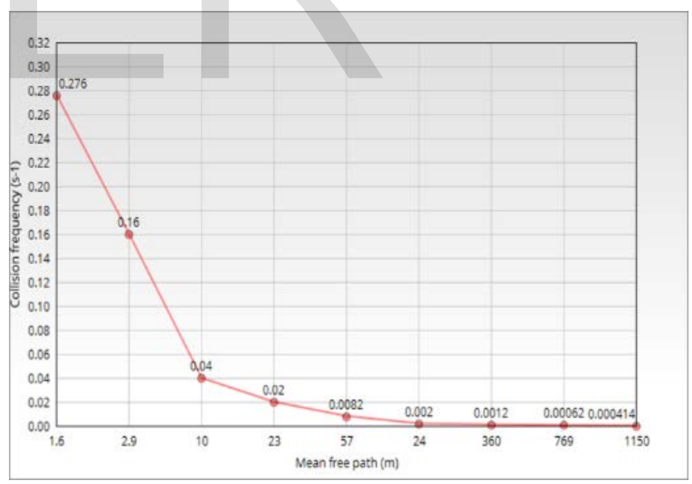


**Figure 1.6 Graphical Representation relation between collision frequency "ν" and mean free path "λ"**

The number density "n" of the oxygen molecules in the discharge tube has an inverse relation with mean free path λ of the particles in tube. The main reason of this inverse relation is clear from that λ∞1/p which states that mean free path decreases when pressure is increased. This decrease in the distance between molecules increases the number of molecules per unit volume, so each molecule travels shorter distance before collision. That is why the collision rate increases when the mean free path is decreased.

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## 4. CONCLUSION

In conclusion an experiment is performed to analyze the glow discharge in a gas discharge tube at different pressure. Different glows were formed at different pressure and was analyzed. Further parameters like number density "n", particle flux "Φ ", mean free path "λ "of collisions of the particles at different pressure and collisions frequency "ν " of the atoms inside a discharge tube is studied at different pressure while keeping the applied potential to the discharge tube constant. The maximum number density "n" of the atoms of the order of 9.66x1023 (Cm-3) are find at a pressure of 4000 pa. The maximum value of flux density "Φ" (m-2s-1) "of 1159x1023 are found at a pressure of 4000 pa. The maximum value of mean free path "λ " of the order of 2.76x10-1(m) at 6 pa and collision frequency "ν " of the order of 1.15x106 (s-1 ) at a pressure of 4000 pa respectively. Our results are in good agreement with the results already reported by different groups around the world.

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