Characteristics of Subnormal Glow Discharge in Longitudinal Magnetic Field in Air

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ABSTRACT
The current-voltage characteristic of subnormal glow discharge has a negative slope [1]. The voltage decreases exponentially with the discharge current. This property has been studied and an analytical expression has been introduced to represent the subnormal glow region [2]. This expression contains a dimensional constant $m_p$. In transverse magnetic field the same work has been studied and the subnormal glow discharge has been explained satisfactorily using the same analytical expression [3]. The aim of the present work is to study the current-voltage characteristic in longitudinal magnetic field and to explain the subnormal glow discharge with the introduced dimensional constant $m_p$. It is observed that the subnormal glow discharge is explained satisfactorily in longitudinal magnetic field as well using the analytical expression containing dimensional constant $m_p$.

Keywords: Subnormal glow, analytical expression, dimensional constant.

1. Introduction
With an appreciable potential difference maintained between two electrodes of the discharge tube containing air at atmospheric pressure, no discharge occurs. As the pressure is decreased, at first a spark is found. This spark becomes broader as the tube pressure decreases more. In this procedure the gas breaks down. The aim of the present investigation is to study the variation of discharge current with tube voltage in subnormal glow region in presence of longitudinal magnetic field in air at different fixed pressures to specify this region by an analytical expression. The discharge with positive space charge between Townsend discharge and normal glow discharge is known as subnormal glow which is found to be striated in few inert gases and Hg-vapour [4]. Few other authors [5,6] have reported that the current fluctuations are found in subnormal glow region due to the motion of space charges. The experimental set-up for the study of the present work is shown in Fig. 1.

2. Experimental arrangement
The experimental set-up for the study of the present work is shown in Figure 1. The discharge tube used is made of pyrex glass and it is of length 6 cm, inner diameter 4.8 cm, fitted with two plane parallel circular copper electrodes of diameter 4 cm separated by a distance 1.8 cm. The tube is thoroughly cleaned and dried. The discharge tube was
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exited by a dc voltage from the high voltage unit which could supply up to 1.5 KV with insignificant ripples.

![Figure 1. Experimental Set-up](image)

The ballast resistor of 1.0 MΩ limits the discharge current and keeps the high voltage unit within its current capacity. A current meter was connected in series with discharge tube to record the discharge current. A high input impedance VTVM is connected across the discharge tube to record potential difference. A micro-leak needle valve is connected with the discharge tube to control the gas pressure within the tube. The magnetic field was produced by an electromagnet. The tube was excited at different pressures and longitudinal magnetic field and the current-voltage readings were recorded in the Subnormal glow region.

3. Results and discussion

The variation of potential difference (V) across two electrodes with discharge current (I) is represented by an analytical expression,

\[ V = V_0 \exp (-m_p I), \]

where, \( m_p \) = dimensional constant

and \( V_0 \) = potential difference at zero discharge current.

The value \( m_p \) has been calculated by the following statistical method:

\[ V = V_0 \exp (-m_p I) \]
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Or, \( \ln V = \ln V_0 - m_p I \)

and \( S = \sum (\ln V - \ln V_0 + m_p I)^2 \)

Therefore for the minimum value of \( S \),

\[
\frac{\partial S}{\partial m_p} = 2 \sum [\ln V - \ln V_0 + m_p I] = 0
\]

Or, \( \sum I \ln V = \ln V_0 \sum I - m_p \sum I^2 \)

Or, \( m_p = [ \ln V_0 \sum I - \sum I \ln V ] / \sum I^2 \)

The values of \( V \), potential difference across the electrodes after breakdown and their corresponding discharge currents\( (I) \) have been recorded for different pressures\( (P) \), namely, 0.4, 0.45, 0.5, 0.6 Torr for without and with different longitudinal magnetic fields\( (H) \) 0 Gauss, 375 Gauss, 750 Gauss, and 1125 Gauss and these are plotted in Fig.2, Fig.3, Fig4 & Fig.5 respectively.

Figure 2. Current-Voltage Characteristics, \( H = 0 \) Gauss, Pressures: I: 0.4 torr, II: 0.45 torr, III: 0.5 torr, IV: 0.6 torr
Figure 3. Current - Voltage Characteristics. H=375 Gauss, Pressures: I:0.4 torr, II:0.45 torr, III:0.5torr, IV:0.6 torr

Figure 4. Current - Voltage Characteristics . H=750 Gauss, Pressures: I:0.4 torr, II:0.45 torr, III:0.5torr, IV:0.6 torr
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Figure 5. Current-Voltage Characteristics. H=1125 Gauss, Pressures: I:0.4 torr, II:0.45 torr, III:0.5torr, IV:0.6 torr

The values of $m_p$ are calculated from Figure-2, Figure-3, Figure-4 and Figure-5 and entered in Table 1.

Table 1. Variation of $m_p$-values with magnetic field and pressure

<table>
<thead>
<tr>
<th>Magnetic field(H) in Gauss</th>
<th>Value of $m_p$ for Pressure: 0.4torr</th>
<th>Value of $m_p$ for Pressure: 0.45torr</th>
<th>Value of $m_p$ for Pressure: 0.5torr</th>
<th>Value of $m_p$ for Pressure: 0.6torr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0G</td>
<td>965.283</td>
<td>1062.386</td>
<td>1117.78</td>
<td>1291.096</td>
</tr>
<tr>
<td>375G</td>
<td>862.465</td>
<td>906.449</td>
<td>1015.013</td>
<td>1164.353</td>
</tr>
<tr>
<td>750 G</td>
<td>695.889</td>
<td>838.217</td>
<td>924.953</td>
<td>1155.349</td>
</tr>
<tr>
<td>1125 G</td>
<td>678.836</td>
<td>762.640</td>
<td>884.745</td>
<td>1053.624</td>
</tr>
</tbody>
</table>
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4. Conclusion
The current–voltage characteristics are studied and an analytical expression is introduced to describe the subnormal glow region. This is extended in presence of the longitudinal magnetic field. The value of the dimensional constant \(m_p\) is determined and it is found that \(m_p\) decreases with the increase in magnetic field. From this investigation it is found that there is a future scope of study of the same work for molecular and inert gases with the variation of magnetic field and pressure.

REFERENCES