The Plasma Experiment

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Abstract

The aim of this experiment was to investigate some of the effects of plasma. There were two parts;

- The ratio of the electron charge to electron mass and the ionisation potential of argon were measured. These were found to be $\frac{e}{m} = 4.5 \times 10^1 1$C m and 15.3V respectively.
- The plasma electron density and electron temperature were measured using a Langmuir probe. These were found to be $0.81eV$ and 45.

Introduction and Basic Theory

Experiment 1

To derive the Child-Langmuir equation, we consider the case of a 1-D problem

- Take the anode and cathode as two infinitely large parallel plates at some arbitrary distance from each other along the x axis.
- Assume a potential of V(x) across the plates
- Assume V(0)=0, electrons start with no energy and gain it as a function of distance.
- This gives us the velocity of an electron at a time t as: $v = \sqrt{\frac{2eV}{m}}$ where e is the charge and m is the mass of an electron.
- Poisson's equation is given by: $\frac{d^2V}{dx^2} = -\frac{\rho_f}{\epsilon_0}$ where ρ_f is the charge density and ϵ_0 is the permittivity of free space.
- Current density is related to charge density by: $\rho_f = \frac{J}{v}$
- Combining all this together gives:

$$\frac{d^2V}{dx^2} = -\frac{J}{\epsilon_0}\sqrt{\frac{m}{2eV}} \tag{1}$$

This ODE is easily solved, giving:

$$J = -\frac{4\epsilon_0}{9x^2}\sqrt{\frac{2e}{m}}V^{3/2} \tag{2}$$

The negative sign just signifies the direction of the flow of current. For a cylinder in the 3-D case, the derivation is more complicated and the result is given as:

$$I = 2\pi\epsilon_0\frac{4L}{9R}\sqrt{\frac{2e}{m}}V^{3/2} \tag{3}$$

Where L is the anode length and R and the anode radius. The dependence on $V^{3/2}$ is the same in both scenarios however. By measuring the characteristc I-V curve the value of $\frac{e}{m}$ can be found. When the applied potential is enough for electrons to ionise the argon, this relationship will no longer apply. The difference between this breakdown voltage and the voltage at $I = 0$ is the ionisation potential of argon.

Experiment 2

Experimental Setup

Results

Conclusion

Appendix

Sources

Space-Charge Effects in Field Emission,
Barbour, J. P. and Dolan, W. W. and Trolan, J. K. and Martin, E. E. and Dyke, W. P