Characterization of Ion Concentration in Arc Plasma Seeded with SiO2 at Atmospheric Pressure

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ABSTRACT

In this piece of study arc plasma was produced inside the vacuum chamber using dc power supply in order to measure the plasma parameter especially ion-concentration in arc plasma. Widely used moving Langmuir probes were successfully applied to measure the probe current at different values of the potential applied on the probe. The graph was plotted between the probe current and the probe potential, using the data obtained from the experimental set up of Double Probe Method (DPM) for the SiO_2 arc plasma at atmospheric pressure. The ion-concentration was estimated to be in the range of 1.65×10^{18} to 4.71×10^{18} ions m^{-3}, using the upper branch of the graph and range of 1.47×10^{18} to 4.27×10^{18} ions m^{-3}, using the lower branch of the graph.

KEYWORDS: Arc plasma, Plasma Parameter, Langmuir Probe, Double Probe Method, Ion-concentration.

I. INTRODUCTION

Plasma Parameters [1, 2] in the arc plasma can be measured by moving the probe through the plasma. They play important role in the background study of plasma processing. The use of the double probe method reveals a parametric structure in the arc plasma showing variation of ion densities between two extreme values. The movement prevents the Langmuir probe [3, 4, 5] from getting melted because the probe remains inside the high temperature for a fraction of second inside the low-cost vacuum chamber [6]. Double probe method (DPM) has an edge over the single probe method (SPM) as both the electrodes in the former are biased with respect to each other, and insulated from the ground. In SPM, one of the cathodes of the arc is taken to be the reference electrode. The entire system in the present case floats with the plasma and, therefore, follows the change of plasma potential [7-10].

II. MATERIALS AND METHODS

Table 1. Specifications of the arc and probes

Average Diameter of the Arc		0.461 cm
Time interval to cross arc-width		0.14 s
Average Velocity of probes		3.26 cm/s
Average Radius of probes	I	0.55 mm
	II	0.65 mm
Average Length of Probes	I	1.4 mm
	II	0.94 mm
Surface area of Probes	I	5.79 mm^2
	II	5.16 mm^2

1. Vacuum Chamber

2. Poly Carbonate Flange

3. Arc Plasma

4. Langmuir Probe

5. Pressure Gauge

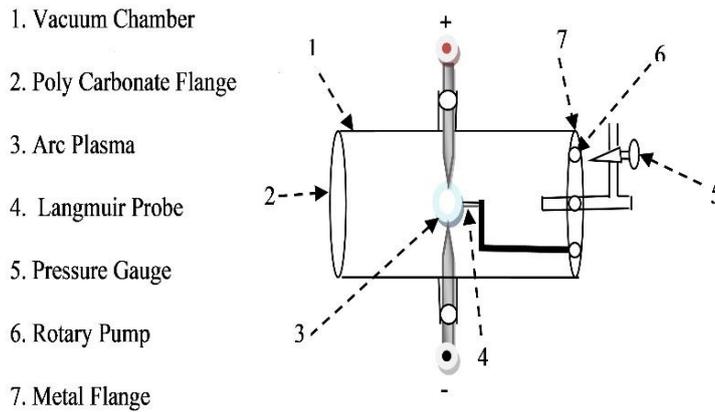6. Rotary Pump

7. Metal Flange

Figure 1: Schematic Diagram of Experimental Set up

Theory

The basic equation to determine the parameter, especially the ion-concentration of the arc plasma is [6]:

$$\left(\frac{di}{dV}\right)_0 = [(i_{+1} \times i_{+2}) / (i_{+1} + i_{+2})]\left(\frac{e}{kT}\right) \qquad \ldots(1)$$

where i_{+1} is the ion-saturation current flowing to one probe, i_{+2} the ion-saturation current flowing to the other probe, V the potential difference applied to the probes and, $\left(\frac{di}{dV}\right)_0$ the slope of the curve at $i = 0$.

The slope $\left(\frac{di}{dV}\right)_0$ and the ion- saturation currents, i_{+1} and i_{+2} ,can be calculated by drawing a graph between i and V. Using equation (1), electron temperature can be calculated. Ion temperature cannot be calculated since it is about one tenth of the electron temperature. The plasma density can be calculated from either of the two branches of the graph using the equation [4]

$$i_+ = \frac{1}{2} n_+ A \left(\frac{kT}{M}\right)^{1/2} \qquad \ldots(2)$$

or, $$n_+ = \frac{2i_+}{A} \left(\frac{M}{kT}\right)^{1/2} \qquad \ldots(3)$$

where, M is mass of the ion and A is the area of the probe.

The probe method is used for the study of moderate-density plasma. The schematic diagram of the experimental set-up is shown in Fig.1, at atmospheric pressure. Figure 2 shows the basic circuit for the Double Probe Method. The two cylindrical probes of tungsten material were separately fixed on the ebonite base which can move to and fro. The major portion except a small part at the front of the probes were covered with insulating material of high thermal resistance. The probes were made to move through the arc using oscillating (Ebonite base) system, and experimental data were noted.

After the experimental set-up, both the tips of the electrodes were brought in contact with each other with a conductor having wooden handle. As soon as the conductor was removed, the arcing between the electrodes got started because the dc supply to the electrodes was already switched on. The desired potential difference was applied on the probes with the help of a dc power supply. Velocity of the probes, once adjusted, was maintained constant and the distance between the electrodes was also maintained fixed throughout the experiment.
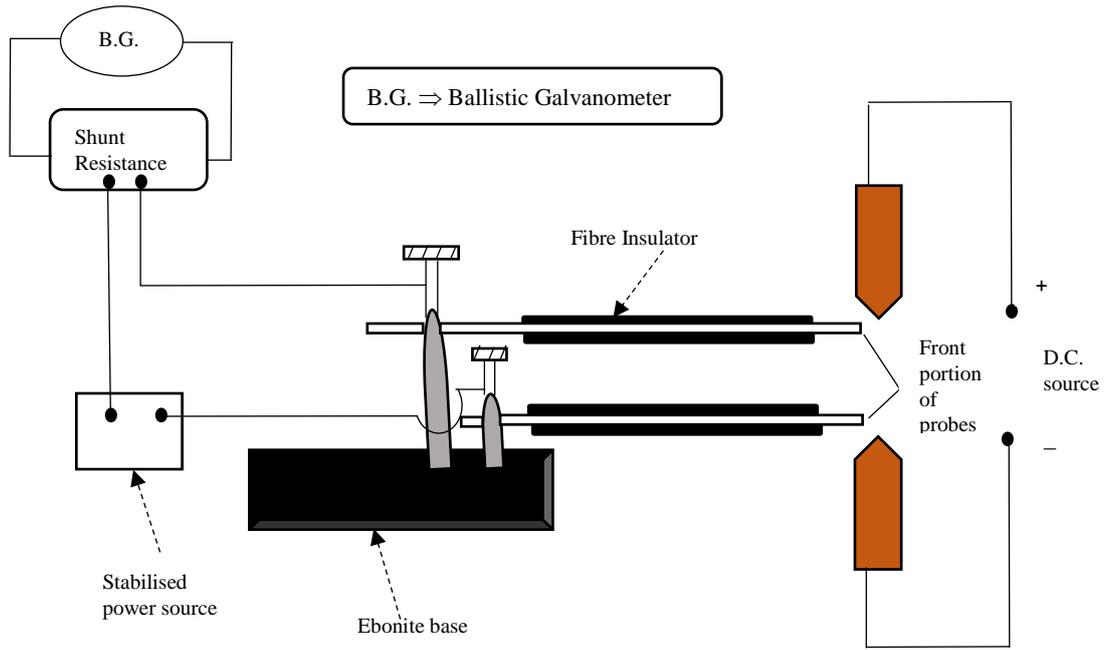
Figure 2: Basic Circuit for Double Probe Method

III.   RESULTS AND DISCUSSION

The ion-concentrations (**Table 2**) were calculated from the three values of current each from the upper branch and the lower branch of the I-V curve (**Fig. 3**).

Table 2. Ion-Concentration in Arc Plasma

I-V graph	Probe current (micro-ampere)	Ion-concentration (ions/m^3)
Upper branch of the curve	2100	1.65×10^{18}
	5300	4.16×10^{18}
	6000	4.71×10^{18}
Lower branch of the curve	2100	1.47×10^{18}
	4400	3.08×10^{18}
	6100	4.27×10^{18}
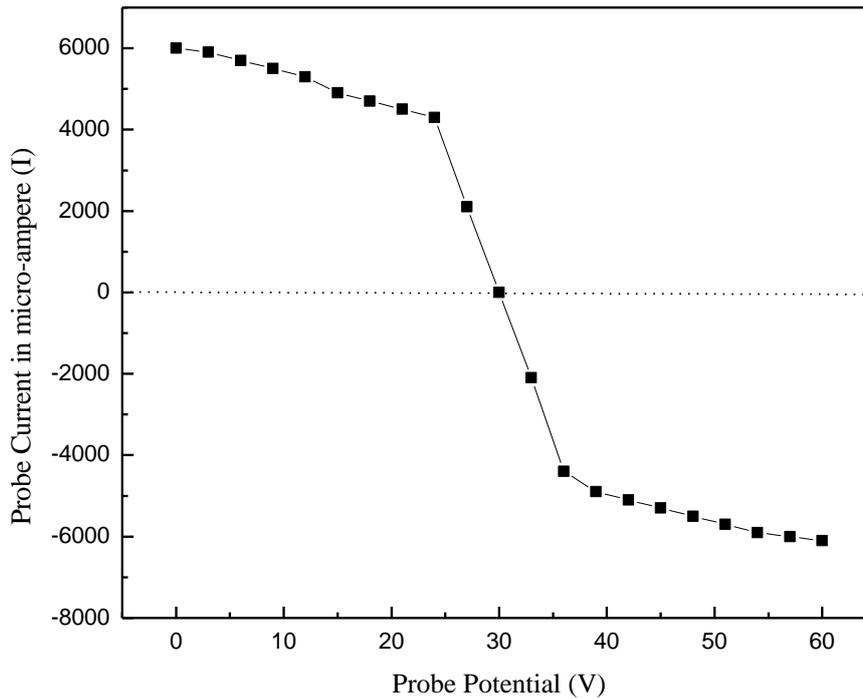
Figure 3: I-V graph for Double Probe Method

As the magnitude of current is proportional to the area of the probe [8] the lesser one of the two surface areas $(5.16 \times 10^{-6} \text{ m}^2)$ of the two probes has been used in order to calculate ion densities from the upper branch of the graph. It is clear from Fig. 3 and Table 2 that ion-concentration shows variations from 1.65×10^{18} ions/m^3 to 4.71×10^{18} ions/m^3 and from 1.47×10^{18} ions/m^3 to 4.27×10^{18} ions/m^3 obtained from the upper branch and lower branch of the I-V curve respectively. It is worthwhile to note that the different values of ion-concentrations are due to the different values of the saturation current. Because of the difference in areas of the two probes, the double probe characteristic is not symmetrical. As the curve in Fig. 3 intersects the voltage axis at a potential positive with respect to the origin, it is clear that a potential difference exists between the two probes even if no current is measured in the external circuit [5].

IV. CONCLUSION

Langmuir probes can be successfully used to estimate ion-concentration in a seeded arc plasma using DPM. It is revealed that there is variation in ion-concentration obtained from the upper branch and the lower branch of I-V curve due to impurities present in electrodes of commercial copper. The present study can be extended with modifications for measuring useful plasma parameters to improve various plasma processing and other industrial applications of plasma.

V. ACKNOWLEDGEMENTS

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