ELECTRON TEMPERATURE AND DENSITY OF A PLASMA JET FOR DIAMOND DEPOSITION

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Abstract

Preliminary measurements of the electron temperature and density of a plasma jet are presented. The plasma jet is produced by a low pressure DC arc discharge. The apparatus is intended to be used for synthesis of diamond films at high growth rate by the so called "Chemical Vapor Deposition" technique. Since the present apparatus was designed to be operated at low power the measurements were taken with a electrostatic double probe.

Introduction

Intensive research has been developed all around the world concerning the synthesis of diamond films from the vapor phase. Particularly, several schemes have been studied using the chemical vapor deposition technique (CVD) to grow diamond in a relatively low temperature substrate (600 − 1200)K and at low pressure environment.[1,2]

The use of a plasma jet, produced by a low pressure arc discharge, as the active medium for diamond synthesis was first reported by Kurihara et al in 1988.[3] The main advantage of this scheme over the others is the achievement of very high deposition rate. Deposition rate as high as $930\mu m/h$ has already been reported.[2]

A low power arc jet device has been developed at LAP/INPE in order to investigate the physics of the process. The results presented here refers to a preliminary set of measurements intended to estimate the electron temperature and density of the plasma jet.

Experiment

A schematic diagram of the plasma jet experiment is shown in figure (1). Basically, the system comprises a stainless steel vacuum vessel and an arc chamber. The arc chamber is composed of two axial electrodes. The inner one is the cathode, a copper rod with diameter of 12mm ended by a tungsten conical tip. The outer one is the anode, a cylindrical copper case with an orifice with diameter of 4mm (nozzle). The closest distance between anode and cathode is 0.5mm. Both electrodes are water cooled and electrically insulated by a nylon flange. A DC power supply (1500V $\times$ 20A) is connected to the electrodes. Gas can be fed by three independent accesses. Flow rates in the range of $4.7\ell/min$ of argon and $5.6\ell/min$ of hydrogen are normally used. The pressure in the vessel is kept constant at about 50mbar and the pressure at the admittance orifice of the arc chamber is 350mbar. At these conditions a voltage of about of 110V breaks down the gas insulation and the arc discharge is established. The ionized gas between the electrodes expands through the nozzle generating the plasma jet inside the vacuum vessel. The arc current is in the range of 0.5 − 3.5A and the voltage 140 − 230V.

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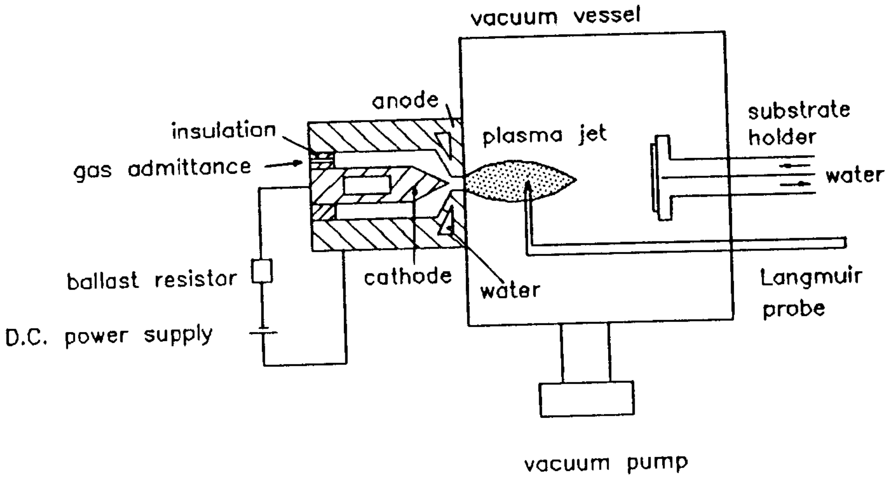

Figure 1: Schematic diagram of the plasma jet experiment.

Results and Discussions

An electrostatic double probe[4,5] was used to measure the electron temperature (T_e) and density (n_e) of the plasma jet. At present, the power of the arc discharge is low (< 1kW), allowing the insertion of the probe inside the plasma. A double probe was chosen because the disturbance on the discharge is smaller than a single probe, since the drained current is small. The tip of the probe is a tungsten wire (diameter: 0.5mm and length: 3.5mm). Figure (2a) shows the circuit used to polarize and measure the signals of the double probe. Figure(2b) shows two typical probe characteristic curves, measured at two different axial positions with respect to the nozzle (x = 24mm and x = 36mm). The curves are in agreement with other experiments,[4,6] and the small deviation from the origin should be caused by a slightly difference in the floating potential measured by the two wires of the double probe.

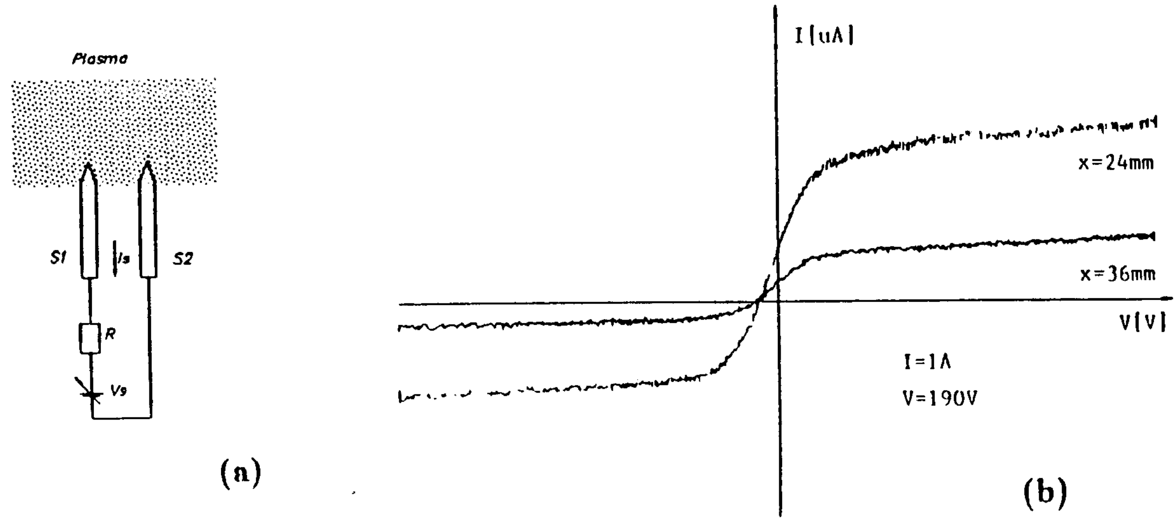

Figure 2: (a) Schematic diagram of the double probe circuit, (b) characteristic curve for axial positions at x = 24mm and x = 36mm.

Figure (3) shows the electron temperature (triangles) and density (dark circles) of the

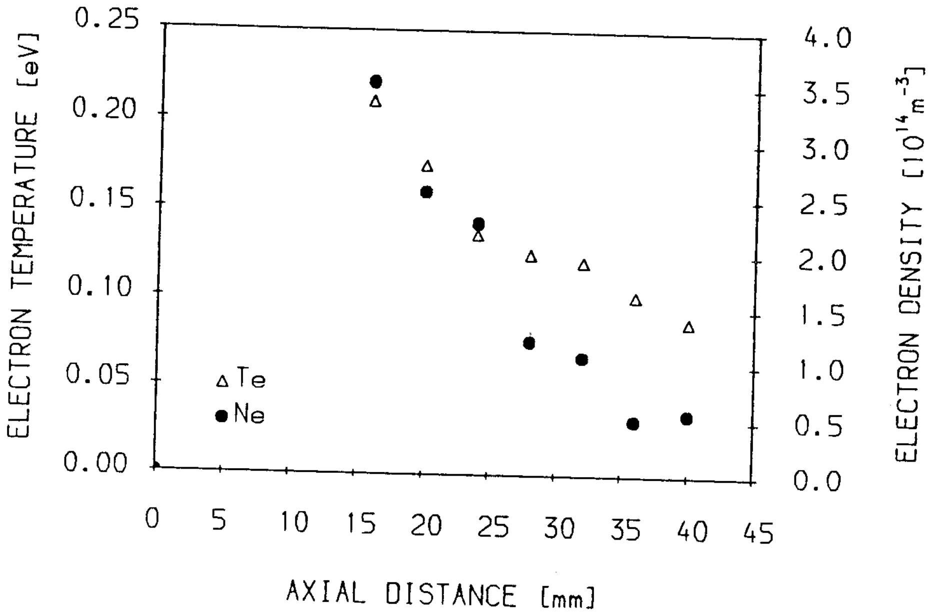

Figure 3: Dependence of the electron temperature and density on the axial distance from the nozzle for I = 1A.

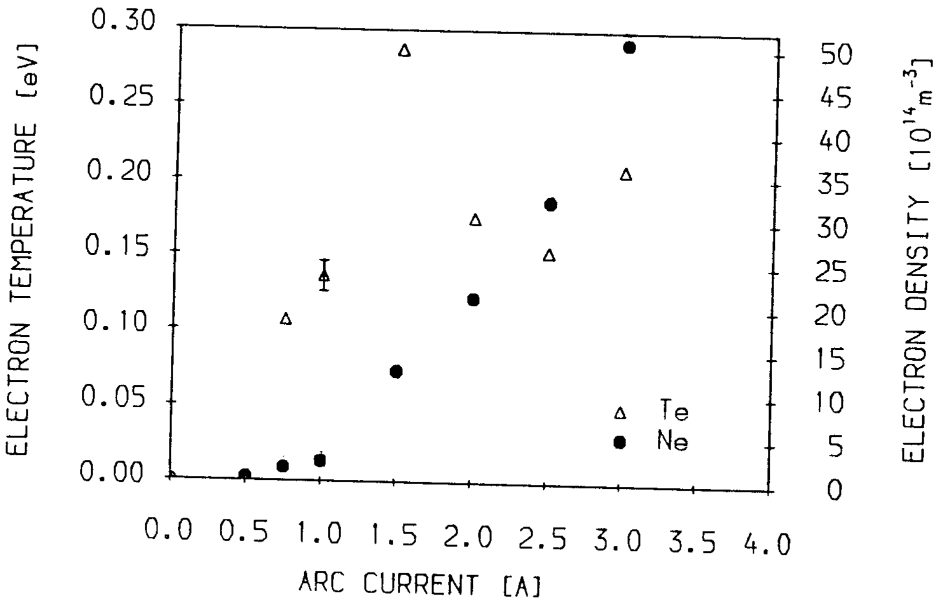

Figure 4: Dependence of the electron temperature and density on the arc current, measured at x = 24mm

plasma jet as a function of the distance from the nozzle. The measurements were taken at the axis (r = 0), for an arc current of I = 1A with H_2 (5.6ℓ/min) and Ar (4.7ℓ/min) as working gas mixture. It can be observed that both T_e and n_e, decrease as the distance from the nozzle increases. The values of T_e in the range $0.09eV < T_e < 0.21eV$ and the values of n_e in the range $10^{13} - 10^{14}m^{-3}$ are quite reasonable for this kind of plasma and are in close agreement with other measurements.[7]

The electron temperature and density of the plasma jet as a function of arc current are shown in figure (4). The measurements were taken at 24mm from the nozzle. As expected, T_e and n_e increase for higher arc currents. A typical error bar is shown for I = 1A.

Conclusions

Preliminary results concerning the electron temperature and density in a low power plasma jet are presented. The axial profiles of T_e and n_e are as expected, as well as, the dependence of T_e and n_e on the arc current. The values of T_e and n_e are in agreement with other measurements. Further measurements are in progress in order to confirm and extend the results.

Acknowledgment

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