22P050-P

Measurement of Plasma and Electron Beam of a Pseudo-spark Discharge Plasma Jet by Hydrogen-diluted Methane

水素希釈メタンを用いた擬火花放電プラズマジェットのプラズマおよび電子ビーム計測

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A pseudo-spark discharge (PSD) is a high current glow-like discharge, which is formed on the left side of the minimum of the Paschen curve. Even if the discharge current exceeds several tens of kiloamperes, discharge craters are less than the arc discharge on electrodes. And the PSD can generate high density plasma. For the reasons mentioned above, it is expected the plasma chemical vapor deposition method with high deposition rate and quality by using the PSD to plasma source of the DLC. In this study, the PSD plasma is generated with hydrogen dilution methane, and plasma parameters are investigated by triple probe and faraday cup to check whether there is any electron beam.

1. Introduction

In the semiconductor manufacturing process, the material process technology using plasma is gaining importance. It's a diamond-like carbon (DLC) [1] thin film to one of material processes. This is a metastable form of amorphous carbon containing a significant fraction of sp^3 bonds. It can have a high infrared transparency, hardness, chemical inertness, insulation and low dielectric constant. The DLC thin films have electron emission devices for plasma display panels, insulator film for LSIs and coatings treatments for forming dies for industrial applications. In generally, the DLC thin films are deposited under low pressure. A microwave plasma chemical vapor deposition (CVD) method is mentioned to a typical technique of deposition. This method can make a film with very stable growth and sufficient reproducibility. But this have a problem with low deposition rate because of low pressure discharge.

In this study, a pseudo-spark discharge (PSD) [2, 3] is applied to the plasma source of DLC film. The PSD is a large current discharge at low-pressure, but discharge craters are less than the arc discharge on electrodes. Consequently, the plasma density increase and it is less that impurities are ejected from the melted electrode to the plasma. If the PSD with these features is applied to plasma source of the DLC, high deposition rate will be obtained in a low pressure.

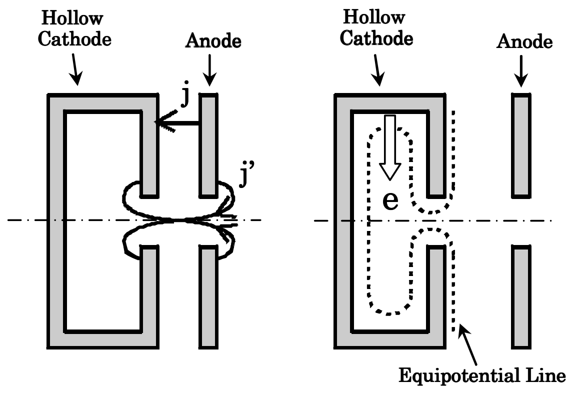

Fig.1 Schematic diagrams of the PSD electrodes. (a) Discharge path j' in the case of the PSD. (b) Activation of ionization in the hollow cathode by the γ-effect.

PSD is a large current discharge with an especially geometrical shape of a pair of parallel disk electrodes at low pressure region on the left hand side of the minimum point of the Paschen curve. The PSD's electrodes consist of a small circular hole on the axis are adopted instead of a pair of single plane and the cathode has a cylindrical cavity behind the circular hole as shown in Fig.1. In the case of the PSD, the discharge path can be formed into or through circular holes so that its length becomes long compared with the distance between the electrodes by using at low pressure region. Because pulse voltage is applied, electric field changes in time between electrodes. Furthermore, electric field is formed into the cathode cavity and the ionization is enhanced by the gamma effect [3]. Many electrons are supplied from the cathode cavity to the bulk of the discharge. As a result, the discharge retains the glow mode and the discharge current density can be small. Our studies revealed that high density plasma (~ 10^{-20} m^{-3}) was spouted out from the anode hole in experiment with hydrogen gas [4]. However, the applied voltage is approximately 2.3 kV between electrodes when it is generated the PSD discharge. Therefore it is possible that high density plasma is generated by high energy electron beam. In this study, the PSD plasma is generated with hydrogen dilution methane, and plasma parameters are investigated by triple probe and faraday cup to check whether there is any electron beam. It's described the experimental equipment in this paper.

2. Experimental setup

The experimental device is shown in Fig. 2. The vacuum chamber is made of stainless steel, it is 26.7 cm in diameter and 51.8 cm in height. The chamber was evacuated to about 10^{-4} Pa using an oil diffusion pump. After the evacuation, the vacuum valve to the oil diffusion pump was closed and the chamber was flushed with material gas (CH_4+H_2) up to a desired pressure using needle and stop valves. A gas flow can be added, maintaining the pressure by slight pumping. The 24 μ F condenser bank is slowly charged up to negative high voltage. When the potential of the cathode reaches the breakdown voltage, the discharge is generated spontaneously. The discharge current is measured with a Rogowskii coil and the breakdown voltage is measured with a high-voltage meter. The ion density of the plasma is determined with a triple probe, time evolutions of the electron beam is measured by a faraday cup. Most of the cathode is made stainless, the central part of cathode is made tungsten, and anode is made of molybdam. The diameter of the cathode hole is 5mm and that of the anode hole is a 10mm. The distance between the anode and cathode is 5 mm. Initially the discharge path of the PSD is formed into or through the circular holes. Then, it moves between the anode and cathode with time. To prevent this motion of the discharge path between the anode and cathode, an intermediate insulator was inserted between them. The intermediate insulator is made of alumina and has a hole diameter of 10 mm. The capacitance (C in Fig.2) is 24 μ F, and the breakdown voltage for the discharge current of 10 kA is approximately 2 kV.

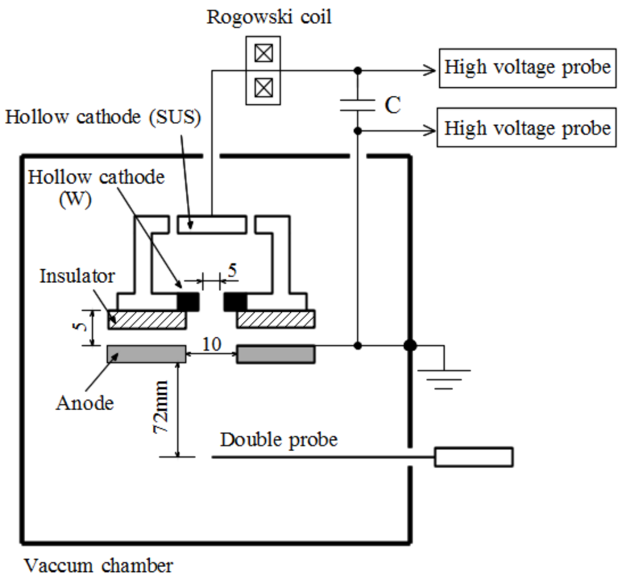

Fig.2 Schematic diagrams of experimental setup.

References

[1] J.Rovertson : "Diamond-like amorphous carbon", Mater. Sci. Eng. R, Vol.37, pp.129-281 (2002)

[2] J.Christiansen and C.Schultheiss : "Production of high current particle beams by low pressure spark discharge", Z. Phys., Vol.A290, pp.35-41 (1979)

[3] M.Stetter, P.Felsner, J.Christiansen, K.Frank, A.Gortler, G.Hintz, T.Mehr, R.Stark and R.Tkotz : "Investigation of the different discharge mechanisms in pseudospark discharges", IEEE Trans. Plasma Sci., Vol.23, No3, pp.283-293 (1995)

[4] T.Kamada, T.Fujiwara, M.Itagaki, T.Ishikawa and M.Watanabe : "Production of plasma jet based on high-current pseudo-spark discharge", Jpn. J. Appl. Phys., Vol.44, No.9A, p.6747-6751 (2005)