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Development of an ECR Microwave Antenna for Hydrocarbon Radical Production

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Flux of hydrocarbon molecule suitable for functional carbon film deposition can be produced by chemical sputtering of graphite by hydrogen ion/neutral bombardment. The advantage of the system is the controllability of the molecular species depending upon plasma parameters and the radical source surface temperature. An ECR-PECVD device is used to generate hydrocarbon radicals by chemical sputtering using a microwave antenna at different configurations. The performance of the antenna in producing hydrocarbon was tested by mass spectrum and optical emission spectroscopies. The result indicated the influence of incident ion energy and hydrogen present near the surface on the production of hydrocarbon radicals.

1. Introduction

Generation of hydrocarbon radicals for carbon film deposition is possible through various chemical and physical vapour methods such as plasma enhanced chemical vapour deposition (PECVD), ion beam deposition, pulsed laser deposition, cathodic arc and sputtering. [1-3]

Sputtering technique has been widely used due to its controllability of deposition conditions by adjusting plasma power and gas pressure that are nearly independent of substrate properties. Compared to dc and rf sputtering, higher sputtering yield of graphite can be achieved by electron cyclotron resonance (ECR) condition that increases the electron mean free path, hence, the degree of ionization of the plasma. [4] Based on this principle, a device that produces ECR plasma with a spiral microwave antenna coupled to a ring-shaped graphite sputtering target in a dc magnetic field has been designed and being tested.

The microwave antenna excites plasma locally, and the distance between the antenna position and the graphite sputtering target should be an important parameter that decides system's overall film deposition efficiency. Therefore, the device has been operated with three antenna configurations to change the distance between the graphite target and the spiral antenna. This paper reports the performance of the device and the characteristics of hydrocarbon emission from the carbon target.

2. Methodology

Schematic diagram of the experimental system used in the study is shown in Fig. 1. It has a vacuum chamber of 340 mm in diameter and 230 mm in depth. A ring-shaped gas injection unit of 50 mm outer diameter and 38 mm inner diameter with 1 mm thick solid carbon disk placed on its nozzles serves as a carbon radical source. Through chemical sputtering process, the unit supplies hydrocarbon molecules homogeneously to the deposition substrate.

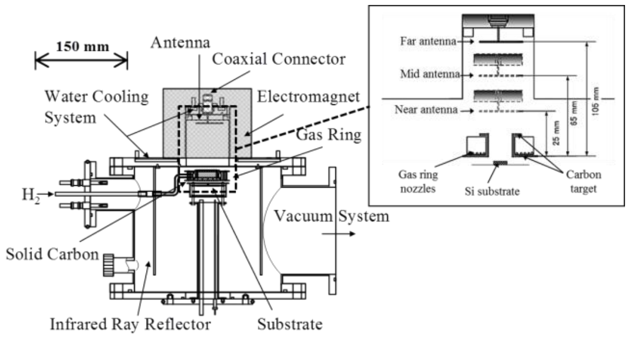

Fig.1. Schematic diagram of the ECR-PECVD device. The figure inset shows the position of microwave antenna with respect to the carbon target in each configuration.

The installed electromagnet generates a magnetic flux density of about 875 G at 50 mm above the carbon disk. The 2.45 GHz microwave supplied through a coaxial cable induces a high frequency electrical current to a spirally wound antenna made of nickel. Tested antenna configurations are: Far, Mid and Near, of distances 105 mm, 65 mm and 25 mm from the carbon sputtering target, respectively.

To monitor the particle flux near the surface of the carbon target, a quadrupole mass analyzer (SRS Co. Residual Gas Analyzer 200) is attached to the bottom of the chamber. The QMA ionizer located about 22 mm from the axis of observation toward the center of the gas injection unit delivers species for mass spectrum analysis in the direction perpendicular to the observation.

Light emission from the plasma was detected through a view port that observes the plasma region right beneath the gas injection unit. The light is transported by an imaging optical fiber attached to an Ocean Optics USB4000 spectrometer with 0.2 nm spectral resolution.

3. Results and Discussion

The effect of microwave antenna position on hydrocarbon production can be observed in Fig. 2 which displays the CH/H_α intensity ratio evaluated from the optical spectrum of the plasma at varying H_2 working pressure. More hydrocarbon radicals were produced when the antenna was positioned closer to the graphite target. The shorter distance between the graphite target and the antenna increases incident ion energy making higher bond breaking probability. [5]

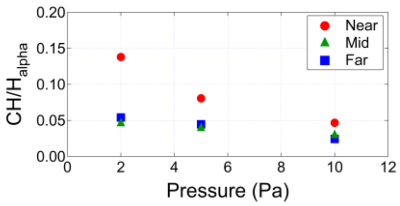

Fig.2. CH/H_α ratio from optical spectrograph of the plasma produced at different H_2 pressure

To further investigate the factors affecting the CH production, mass spectrum signal intensities of carbon and hydrocarbon radicals were measured as functions of the electrical bias induced onto the carbon target. In Fig. 3, the increasing trend of C^+ until saturation can be observed as the negative bias voltage was raised. At lower negative bias, CH_3^+ and $C_2H_3^+$ were formed together with almost equal amounts. As the sputtering target bias was increased, formation of $C_2H_3^+$ decreases.

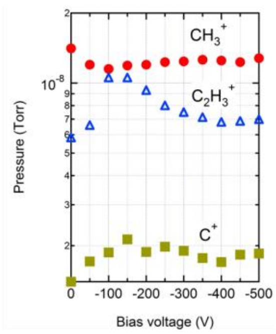

Fig.3. Partial pressure of carbon and hydrocarbon radicals as a function of the bias voltage induced on the graphite sputtering target. The plasma was excited using the far-antenna configuration.

Increased concentration of $C_2H_3^+$ at lower bias voltage can be attributed to the high hydrogen adsorption on the surface of the target enhancing chemical sputtering. During that phase, the graphite target can be exposed to thermal atomic hydrogen producing the radicals C_nH_m represented by $C_2H_3^+$. The higher bias voltage corresponds to the increased energy of bombarding hydrogen, and the sputtering yield should be higher at higher bias, provided the same amount of hydrogen atoms are adsorbed. The decrease in $C_2H_3^+$ partial pressure as the bias voltage was raised can be caused by depletion of hydrogen atoms near the surface of the carbon target leading to reduction of chemical sputtering.

5. Conclusion

The particle flux from the carbon target during plasma operation was monitored with a quadrupole mass analyzer, and the result has indicated the influence of the distance between the antenna and the carbon source on the production of hydrocarbon. The H-carbon-carbon bond collision was affected by the amount of adsorbed hydrogen on the carbon target and the energy of the incident ions produced around the antenna area.

The antenna configuration coupled to the target condition for optimizing the hydrocarbon emission can be further optimized based upon fundamental principles of chemical sputtering studied in plasma-wall interaction for fusion experiment devices.

References

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