表面波プラズマによるグラファイトライクカーボン膜の高速成膜

High-speed Deposition of Graphite-like Carbon Film by Microwave Surface-wave Plasma

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1. Introduction

Graphite-like carbon (GLC) film is attractive material because of its characteristics, such as high electrical conductivity, high thermal conductivity, protection of corrosion and so on. So far, various GLC deposition techniques have been reported such as physical vapor deposition (PVD), chemical vapor deposition (CVD) or plasma-enhanced chemical vapor deposition (PECVD). Among them, PECVD has achieved the highest deposition rate, but its value is less than 1 nm/s [1]. To enhance the deposition rate, high-density plasma source is required, and microwave surface-wave plasma (MWSWP) is strong candidate because MWSWP can easily produce wide plasma with high plasma density.

In this study, new PECVD method for GLC film deposition is explored using MWSWP with high bias voltage system.

2. Experimental setup

A vacuum chamber (50×26×16 cm^3) equipped with a slotted waveguide and a quartz plate is evacuated by a dry pump less than 0.1 Pa. Argon (65 sccm) and benzene (50 sccm) are introduced at a working pressure of 13 Pa. Surface-wave plasma is produced in front of the quartz plate by applying microwave power (2.45 GHz, 1.3 kW) to the waveguide. N-doped silicon (100) substrates (18×7 cm^2) those are cleaned by an ultrasonic cleaner with acetone are placed on a stage surface. Negative pulse bias voltage (0 ~ 2 kV) is applied to the stage. Deposition rate, electrical conductivity, and physical characteristics of deposited GLC film and their spatial uniformity are investigated by a step profiler, four-terminal sensing, and Raman spectrum, respectively.

3. Result and discussion

GLC film is deposited by different negative bias voltages (V_B) from 0 to 2 kV. The electrical conductivity increases with increasing bias voltage. At $V_B \geqq 1.5$ kV, GLC film conductivity was ~ 250 $\Omega^{-1}cm^{-1}$, which was much higher than that of silicon substrate (0.1 $\Omega^{-1}cm^{-1}$). The deposition rate of GLC film at $V_B \geqq 1.5$ kV was about 6 nm/s. Spatial uniformity of film characteristics were also confirmed.

Raman spectrum of carbon bond has two characteristic peaks, *i.e.*, *G* peak (1520 ~ 1600 cm^{-1}) and *D* peak (1340 ~ 1380 cm^{-1}). Fig 1 shows *G* peak wavenumber and peak intensity ratio of *D* and *G* peaks (I_D/I_G ratio) as a function of the bias voltage V_B. Both I_D/I_G ratio and *G* peak position monotonically increase with increasing the bias voltage. Ordered sp^2 state and sixfold ring cluster leads increase in *G* peak position ($\leqq$ 1600 cm^{-1}) and I_D/I_G ratio ($\leqq$ 2.0) from a-C to nc-graphite [2]. The experimental results qualitatively show existence of sp^2 state and ion bombardment enhances synthesis of graphite structure by increasing of bias voltage.

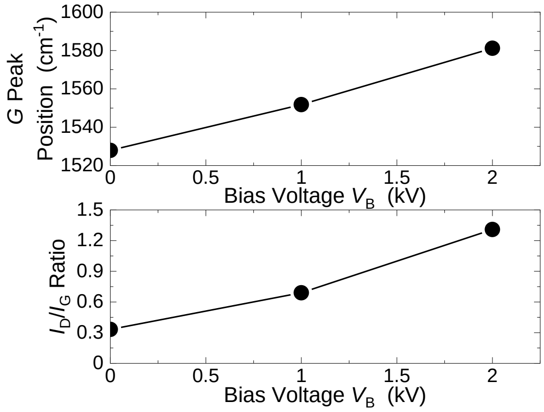

Fig.1. Bias voltage dependences of I_D/I_G ratio and *G* peak position

Reference

[1] Golap Kalita et al.: RSC Adv, **2**, 3225 (2012).

[2] A. C. Ferrari et al.: Phys. Rev. B, **61**, 14095 (2000).