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Density Measurement of Metastable Excited Ar Atoms in RF Magnetron Sputtering Plasma Using Carbon Target

RF マグネトロンカーボンスパッタリングプラズマ中の準安定励起 Ar 原子密度の計測

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RF magnetron carbon sputtering has been used for the formation of DLC films having high hardness and low coefficient friction. Metastable excited Ar atoms affect the gas phase or the film quality. We measured the number density and translational temperature of metastable excited Ar atom with a tunable diode-laser absorption spectroscopy. The translational temperature was measured to be from 560 to 820 K and number density was from 0.3 x 10^{10} to 3.5 x 10^{10}cm^{-3} at RF power from 10 to 100 W and pressure from 3 to 70 Pa.

1. Introduction

DLC (Diamond-Like Carbon) film has many features such as the excellent surface smoothness, low coefficient of friction, high hardness, and chemical stability, and has been used to antifriction protective coating of the sliding machine components. The friction coefficient of the DLC decreases as the hydrogen content is low [1]. Sputtering method is available to from DLC films containing no hydrogen.

High energy sputtered species are decelerated by colliding with Ar atoms. The transport process of the sputtered species changes with density distribution and the temperature of Ar atom. Moreover, the crystalline structure of the DLC thin films strongly depends on the sputtering conditions such as input power and pressure and so on. It is essential to diagnose the behavior of the species in the gas phase, in order to form a high quality DLC thin film. Metastable excited Ar atom is one of important species to characterize the gas phase. In this study, we measured the absorption spectral profile of metastable Ar atoms with a tunable diode-laser absorption spectroscopy, and evaluated the number density and translational temperature.

2. Experimental

Figure 1 shows a schematic diagram of the experimental setup. ϕ2-inch pure carbon was used as the target, and Ar was used as the discharge gas. RF power was varied from 10 to 100 W, and the pressure was varied from 3 to 70 Pa. The distance between the target and the substrate was 74 mm.

Absorption wavelength for metastable Ar atoms is 811.531 nm which is a transition of the $4p\ ^2[^3/_2]$ - $4s\ ^2[^3/_2]°$. Scan width of the tunable diode-laser was 0.011 nm. The laser beam was passed at 16 mm above the carbon target.

Translational temperature and number density are derived from equation (1) and (2), respectively.

$$T=M\frac{c^2}{(8R\ ln\ 2)^2}\frac{\Delta v_D^2}{v_0^2} \quad (1)$$

$$N=\frac{4\pi v_0^2}{c^2}\frac{g_1}{g_2}\frac{1}{A}\sqrt{\frac{\pi}{ln\ 2}}k_0\Delta v_D \quad (2)$$

where Δv_D is full width at half maximum, M is atomic weight, R is gas constant, g_1 and g_2 are statistical weight, A is Einsteins A coefficient, c is speed of light, and v_0 is center frequency of absorption profile.

3. Results and discussion

Figure 2 shows absorption profile of metastable Ar atom. RF power was 20 W, and the pressure was 3 Pa. Absorption profile was well fitted Gaussian profile and number density and translational temperature were calculated to be 0.6 x 10^{10}cm^{-3} and 510 K, respectively. Figure 3 shows the pressure dependence of the number density and translational temperature of metastable Ar atoms. The RF power was 40 W. Translational temperature increased up to 820 K at 12 Pa with increasing the pressure and saturated. Number density has the maximum value of 3.5 x 10^{10}cm^{-3} at 12 Pa, and slightly decreased with increasing the pressure. Figure 4 shows the power dependence of the number density and translational temperature of metastable Ar atoms. The pressure was 3 Pa. Number density increased with increasing the pressure and the translational temperature was almost constant between 490 to 540 K.

4. Conclusion

The absorption spectral profile of metastable Ar atoms in RF magnetron carbon sputtering was measured with a tunable diode-laser absorption spectroscopy. The absorption profile was well fitted to Gaussian profile. The number density and translational temperature were calculated to be from 0.3 x 10^{10}cm^{-3} to 3.5 x 10^{10}cm^{-3}, from 490 K to 820 K.

References

[1] L. Joly-Pottuz, C. Matta, M. I. de Barros Bouchet, B. Vacher, J. M. Martin, T. Sagawa: J. Appl. Phys. **102** (2007) 064912.

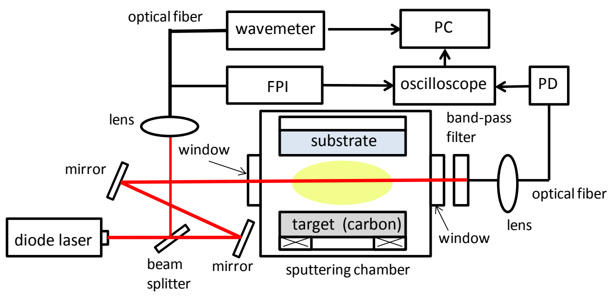

Fig.1. Experimental setup. (FPI: Fabry-perot interferometer, PD: Photodetector)

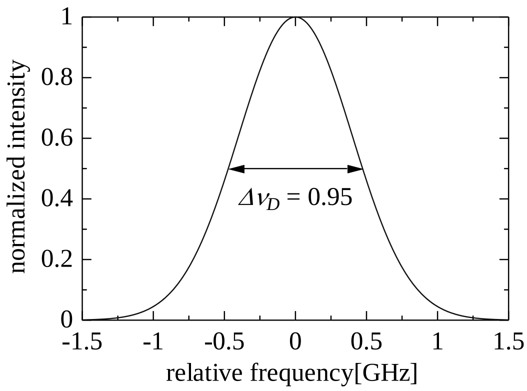

Fig.2. Absorption profile of metastable Ar atom.

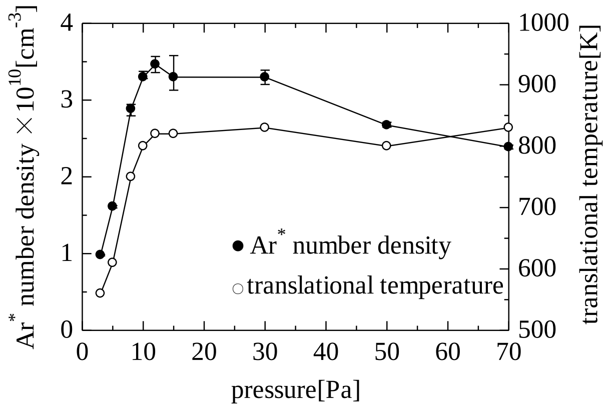

Fig.3. Pressure dependence on Ar*number density and translational temperature.

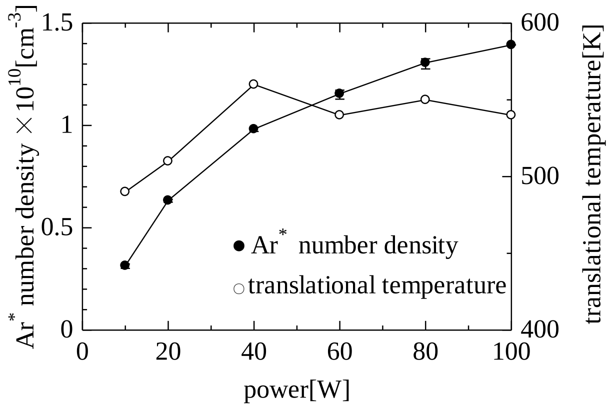

Fig.4. Power dependence on Ar*number density and translational temperature.