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Effect of Gas flow rate ratio on the structure and properties of a-C:H films deposited using Ar + H_2+ C_7H_8 Plasma CVD

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a-C:H films (Hydrogenated amorphous carbon films), which possess the properties of low friction coefficient, high hardness, chemical inertness, and gas barrier properties, have been widely used as protective coatings.[1,2) To obtain satisfactory protection performance of the a-C:H coatings and reduce the production cost in practical applications, high deposition rate is an important factor. In contrast to conventional methane as source materials for a-C:H films, toluene (C_7H_8), with many merits such as low ionization potential, thermal stability, and low hydrogen to carbon ratio, is expected to bring about a high deposition rate and an improvement of protection performances. Here, we introduce toluene as precursor gas of film deposition and investigate the effects of gas flow rate ratio R = H_2/ (H_2+Ar) on a-C: H films' structure and properties.

Experiments were performed using an H-assisted plasma CVD reactor, in which a capacitively-coupled main discharge and an inductively-coupled discharge of H atom source were sustained independently.[3)] Toluene was supplied at flow rate of 5 sccm, and the total flow rate of H_2 and Ar was 90 sccm. Gas flow rate ratio was set from 11% to 55%. The total pressure was 5 Torr To obtain a higher radical flux, a-C:H films were deposited to Si substrates set on a stainless steel step of 20 mm in height. The bias voltage was -60V. The substrate temperature was 100 °C. Optical emission intensity was measured with an optical spectrometerr. Hydrogen content of films were evaluated with an FT-IR spectrometer.

Ar emission intensity ratios of Ar $I_{425.9}$/Ar $I_{750.4}$ and Ar $I_{811.5}$/Ar $I_{750.4}$, which reflect changes in effective electron temperature and low-energy electron density respectively,[4,5)] are shown in Fig. 1. The ratio of Ar $I_{425.9}$/Ar $I_{750.4}$ is constant regardless of the gas flow rate ratio, whereas the ratio of Ar $I_{811.5}$/Ar $I_{750.4}$ decreases with increasing the gas flow rate ratio. These results indicate that the effective electron temperature is constant, Ar 1s5 metastable density and/or low-energy electron density decrease with increasing the gas flow rate ratio from 11 to 55%.

Figure 2 show gas flow rate ratio dependence of hydrogen content and mass density, respectively. The mass density of a-C:H films decreases from 1.83 to 1.52 g/cm^3 and the hydrogen content increases from 20% to 47% with increasing gas flow rate ratio from 11% to 55%. These results indicate that the mass density of a-C: H films depends on hydrogen content in the films and control of gas flow rate ratio is crucial to deposit carbon films of high deposition rate and high hardness.

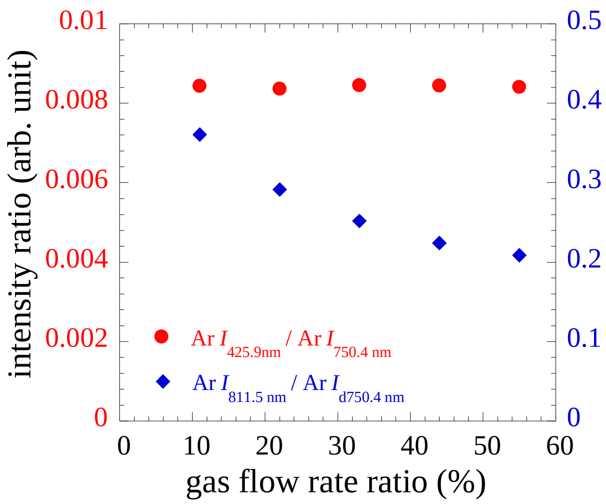

Figure 1. Dependence of Ar/ [Ar] emission intensity ratios on gas flow rate ratio.

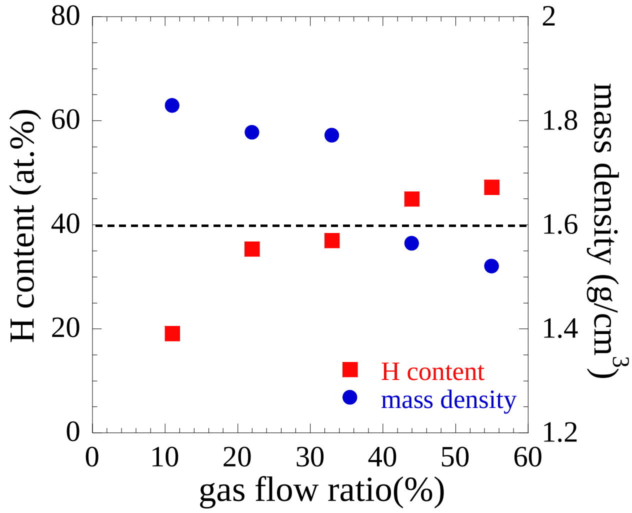

Figure 2. Gas flow rate ratio dependence of hydrogen content (by FTIR) and mass density of a-C: H films.

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