

Analysis of hydrocarbon dissociation processes in C_xH_y+Ar plasma by quadrupole mass spectrometry

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Hydrogenated amorphous carbon (a-C:H) films have a wide range of applications because of their valuable properties such as high mechanical hardness and chemical stability. For protective coating, processes with high deposition rate of high density film are required together with low stress [1]. However, film density is positively correlated with the stress. Plasma chemical vapor deposition (CVD) is a promising method to realize large area deposition with high uniformity. For the method, the selection of the ingredient gas is one of the important factors to improve the film deposition characteristics. It is preferable to employ ingredient gas molecule with a high number of carbon atoms and a low number of hydrogen atoms to realize high-rate deposition of a-C:H film with high density [2]. We currently consider cumene (C_9H_{12}) as a new candidate material for hard masks. To understand how gas-phase reactions influence film deposition behavior, a quantitative assessment of the species generated in the gas phase is necessary. Quadrupole mass analyzer (QMA) has become a critical technique for analyzing the radicals in plasma, which governs deposition reaction. In this study, to analyze the correlation between the plasma and the film deposition results, we acquired fragmentation patterns using QMA and researched the chemical species contributing to film formation.

The film deposition experiments and the residual gas analysis (RGA) using QMA were carried out with a capacitively coupled plasma CVD method [3]. Acetylene (C_2H_2) and cumene (C_9H_{12}) were used as material gases. The total gas flow rate was set at 100 sccm (Ar: 80 sccm, material gas: 20 sccm), and the chamber pressure was varied from 0.02 Torr to 0.3 Torr. A 10 mm × 10 mm Si (100) substrate was placed on the lower electrode, and plasma was generated by applying a 13.56 MHz RF voltage (280 Vpp to 600 Vpp). Optical emission spectroscopy (OES) was used for plasma emission analysis.

Fig. 1 shows (a) the dependence of deposition rate on CH^* emission intensity, and the mass spectra obtained by the RGA for (b) acetylene and (c) cumene. As shown in Fig. 1(a), both when using cumene and when using acetylene, the deposition rate linearly increases with CH^* emission intensity, and the slope is steeper where the chamber pressure is 0.15 Torr or more. These results suggest that secondary reactions become dominant in the gas phase, leading to the increased production of larger chemical species in the high-pressure regime.

In cumene plasma, CH^* emission intensity is lower than in acetylene plasma at the same deposition rate. As shown in Fig. 1(b) and (c), it is observed that the RGA mass spectrum of acetylene plasma is dominated by C_2H_2 , C_2H , and C_2 species. On the other hand, the RGA mass spectrum of cumene plasma is dominated by a wide variety of fragmented species in addition to the parent C_9H_{12} molecule. These results suggest that cumene plasma generates diverse chemical species, including those contributing to enhanced film deposition rates.

References

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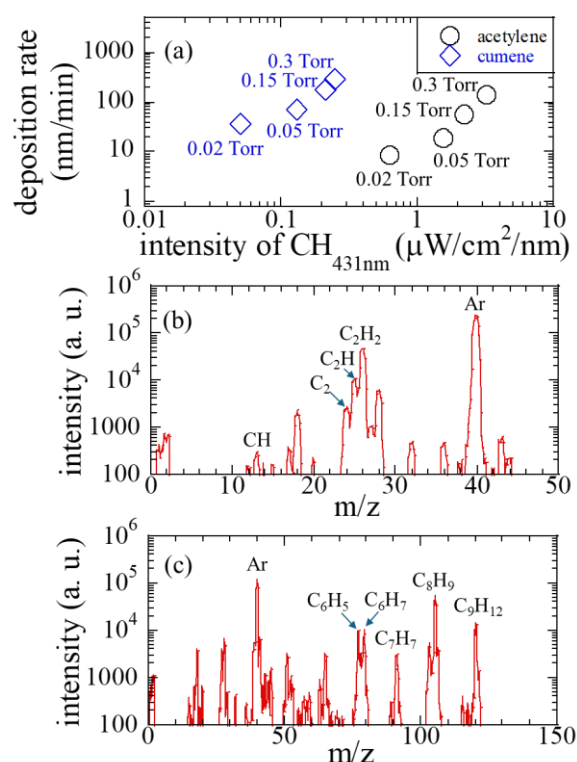


Fig. 1. (a) Deposition rate vs. intensity of CH_{431nm}^* emission measured by OES and Mass spectrum of residual gas analysis using QMA (b) acetylene, (c) cumene.