Numerical Simulation on Fundamental Properties in Low-Pressure Radio-Frequency CH_4 Plasmas for Diamond-Like Carbon Films

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Diamond-like carbon (DLC) films have excellent material properties in high wear resistance, high hardness, low friction, and chemical stability. For further optimisation of the DLC films deposition, the fundamental properties in low-pressure radio-frequency CH_4 plasmas have been analysed using a one-dimensional fluid model, which is composed of the mass balance equations for charged particles, radical neutrals, and non-radical neutrals, the electron energy balance equation, coupled with the Poisson equation. Influence of external parameters on the amount of incident carbon atoms by hydrocarbon radicals and ions to substrate/electrode has been also discussed.

Diamond-like carbon (DLC) films are the hydrogenated amorphous carbon films, which is composed of a mixture of sp^2- and sp^3-bonded carbon. Since this films have excellent material properties in high wear resistance, high hardness, low friction, and chemical stability, the films have been widely used for many technological applications, such as automotive, semiconductors, medical devices, and so on [1-3]. Until now, plasma assisted chemical vapor deposition has been frequenly utilised as a technique for deposition of DLC films. For further optimazation of deposition of DLC films, the clarification between the external parameters (gas-pressure, input-power, etc.) and fundamental properties in hydrocarbon plasmas is strongly desired.

In this paper, the fundamental propeties in a low-pressure radio-frequency CH_4 plasmas have been analysed using a one-dimensional fluid model. In addiiton, influence of extrenal parameters on the plasma propeties is examined.

Fig. 1 shows a schematic diagram of low-pressure radio-frequency discharge plasmas in the present paper. The CH_4 gas with a total pressure of 0.1-1.0 Torr and a gas temperature of 300 K is filled between two parallel-plate metallic electrodes. The flow rate of CH_4 gas varies from 10 to 100 sccm. The discharge plasmas are sustained by applying AC voltage with a driving frequency of 13.56 MHz. The discharge-gap spacing and diameter of the elecrodes are set to be 3.0 cm and 6.0 cm, respectively.

Simulation model, adopted in this paper is a one-dimensional fluid model. Governing equations are composed of the mass balance equations for charged particles, radical neutrals and non-radical neutrals, the electron energy balance equation, coupled with the Poisson's equation. The particle-

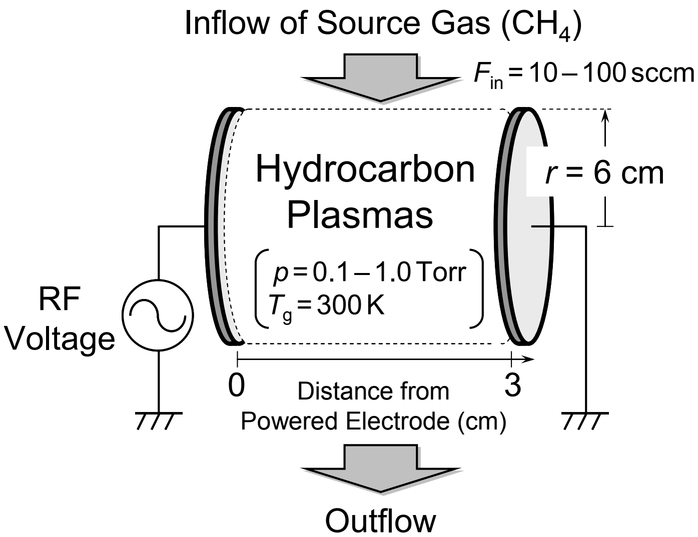
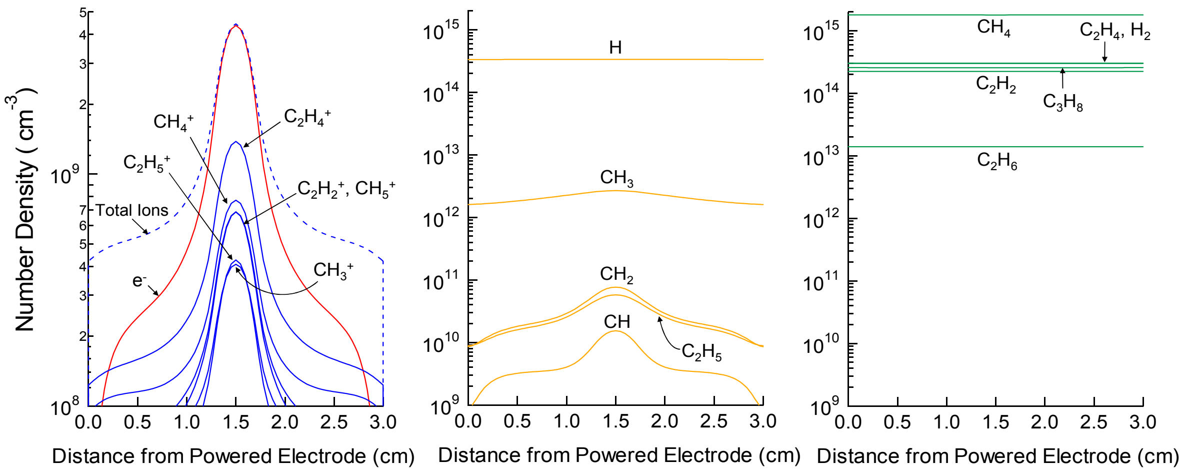


Fig. 1: Schematic diagram of low-pressure radio-frequency CH_4 plasmas

species are considered as eleven charged particles (e^-, H^+, H_2^+, H_3^+, CH_3^+, CH_4^+, CH_5^+, $C_2H_2^+$, $C_2H_4^+$, $C_2H_5^+$, $C_2H_6^+$), five radical neutrals (H, CH, CH_2, CH_3, C_2H_5) and six non-radical neutrals (H_2, CH_4, C_2H_2, C_2H_4, C_2H_6, C_3H_8) in this model. The spatio-temporal evolutions of the concentration of the charged particles, the radical neutrals and the non-radical neutrals, the electric field strength and mean electron energy can be obtained by solving the above equations until reaching periodic steady state. The transport coefficients and the other data, which are needed solving the goverining equations, are taken from the previous papers [4-6].

Fig. 2 shows the cyclic-averaged spatial distributions of the number density of (a) the charged particles, (b) the radical neutrals and (c) the non-radical neutrals in low-pressure radio-frequency CH_4 plasmas. The simulation conditions are set to be a gas pressure of 0.1 Torr, an input power density of 1 Wcm^{-2} and a gas flow rate of 10 sccm. In Fig. 2(a), despite of a low-pressure CH_4 gas condition, not a few positive ion species, such as $C_2H_4^+$, CH_4^+, $C_2H_2^+$, CH_5^+, appeared in the plasmas. The non-radical neutrals, such as C_2H_4, C_3H_8, C_2H_2 and C_2H_6, have also found with higher densities comparable to the source gas (CH_4) concentration, as shown in Figs. 2(b) and 2(c). This result indicates that this complexity of background gas in CH_4 plasmas is strongly affected to the electron energy distribution function, which is important for the determination of plasmas properties. Influence of the extrenal parameters (gas-pressure, gas-flow rate, etc.) on the amount of incident carbon atoms by hydrocarbon radicals and ions to substrate/electrode will be presented in the conference.



(a) charged-species (b) radical neutrals (c) non-radical neutrals

Fig. 2: Cyclic-averaged spatial distributions of number density in low-pressure radio-frequency plasmas in CH_4 at a gas pressure of 0.1 Torr, an input power density of 1 Wcm^{-2} and a gas flow rate of 10 sccm.

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