STUDY OF THE MICROWAVE DISCHARGE USED FOR NANOCRYSTALLINE DIAMOND FILMS DEPOSITION

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INTRODUCTION

Since its feasibility has been demonstrated (1), the deposition process of Nano-Crystalline Diamond (NCD) films has been subject of different investigations. Indeed, besides some physical properties similar to those of polycrystalline diamond (2), NCD films possess a very low surface roughness appropriate for some tribological and electronic applications. According to previous studies (3), NCD films can be achieved using MPACVD processes in $Ar/H_2/CH_4$ discharges characterized by low H_2 and CH_4 concentrations. The optimization of NCD deposition for specific applications requires then the understanding of the main phenomena that govern the MPACVD process. In this study, we investigated the effects of some experimental parameters, particularly the H_2-concentration in the feed gas (%H_2) and the input Micro-Wave Power (MWP), on the plasma characteristics.

MEANS

The plasma diagnostic was performed for experimental conditions related to NCD film synthesis, namely for a discharge ignited in a $Ar/H_2/CH_4$ gas mixture, in a MPACVD bell jar reactor extensively described elsewhere (4). For a given %H_2 in the feed gas, the input MWP is set at the maximum value allowing to maintain stable hemi-spherical plasma just above the substrate surface (5). The plasma was experimentally analyzed through Optical Emission Spectroscopy (OES) and Broadband Absorption Spectroscopy (BAS). These diagnostic techniques were mainly performed in order to determine the gas temperature that is one of the key parameters for the discharge chemistry and NCD deposition. A quasi-homogenous plasma model was developed for moderate pressure $Ar/H_2/CH_4$ discharges obtained in a microwave cavity system. This thermo-chemical model is used in the frame of a global plasma model to estimate species density, as well as gas and electron temperatures in the bulk of the plasma. The details of the global plasma model are extensively discussed in (6).

RESULTS

As an illustration, Fig. 1 shows the values of the gas temperature T_g calculated by the model, compared to those of the rotational temperature of the electronic ground states of $C_2(X^1\Sigma_g^+)$ and $CN(X^2\Sigma^+)$ estimated by BAS measurements (1% CH_4, 250 sccm total gas flow rate and 20000 Pa pressure). The CN radical is obtained in the discharge as a thermometer species by introducing N_2 impurities in the feed gas. A satisfactory agreement is observed between Trot[$C_2(X^1\Sigma_g^+)$] and Trot[$CN(X^2\Sigma^+)$], as well as between these measured rotational temperatures and the calculated gas temperature T_g. The values, that range from 3000 to 4000 K according to the discharge conditions, seem relatively high for the moderate MWP. This may be due to a low thermal conductivity and to a low dissipation of energy in the vibration of H_2. These results show that the investigation of the plasma composition by the model may be performed with a reasonable confidence concerning T_g values. For example, Fig. 2 shows that the calculated H-atom mole fraction is quite high in the investigated ranges of MWP and %H_2. Thus, the major part of molecular hydrogen is dissociated in the discharge due to the relatively high gas temperature insuring an enhanced thermal dissociation.

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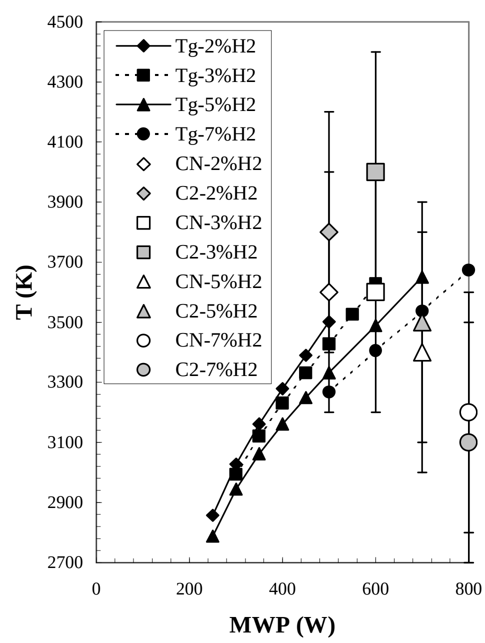

Fig. 1: Calculated T_g and measured Trot[$C_2(X^1\Sigma_g^+)$] and Trot[$CN(X^2\Sigma^+)$] as a function of MWP for several values of %H_2.

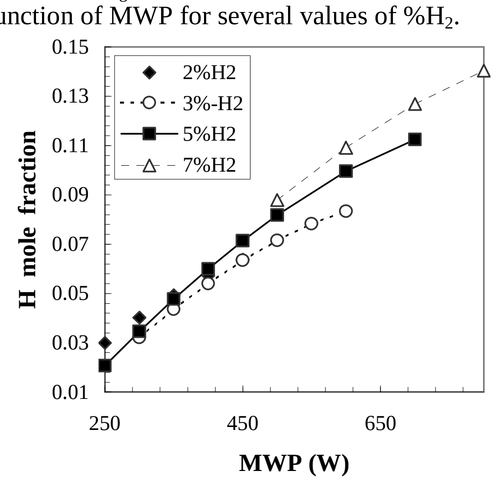

Fig. 2: Calculated H-atom mole fraction as a function of MWP for several values of %H_2.