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Effect of Deposition Temperature on the Surface Morphology of the Radio Frequency Plasma Enhanced Chemical Vapour Deposition Grown Diamond Like Carbon Films†

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The diamond like carbon (DLC) films have been grown by radio frequency plasma enhanced chemical vapour deposition (RF-PECVD) in methane-argon plasma. In plasma enhanced chemical vapour deposition, the plasma sheath potential drop arising due to argon plasma was utilized to grow the diamond like carbon film on silicon (100) substrates without using any external negative bias voltage. The morphological variations during the growth of the diamond like carbon film as function of deposition temperature have been studied. A set of experiments were carried out by varying the deposition temperatures (room temperature, 100, 200 and 400 ºC) and by keeping other parameters constant.

Key Words: Diamond like carbon, Film, Radio frequency plasma enhanced chemical vapour deposition.

INTRODUCTION

The properties of diamond like carbon (DLC) films deposited by radio frequency plasma enhanced chemical vapour deposition (RF-PECVD) strongly depends on deposition conditions such as deposition pressure, substrate temperature, deposition energy of the hydrocarbon or discharge power, application of bias voltage, reactive gases used and dilution of reactive gases[1,2]. Thus the growth parameters in PECVD play a critical role, since they all affect the average impact energy and greatly influence the hydrogen content incorporated into the diamond like carbon films during the deposition process and the way its atomic orbitals are hybridized when making chemical bonds.

The effects of the substrate temperature play an important role in the growth of diamond like carbon films. In fact, at low ion energy in RF-PECVD, surface reactions are temperature dependent and different species may have different residence time. The energetic ion bombardment on the growing surface and the substrate temperature of the films are two major parameters which controls the adatom mobility on the film surface and thereby influence the physical characteristics of the film, *e.g.*, microstructure, composition, mass density and optical indexes. The effect of substrate temperature for diamond like carbon films deposited from pure CH_4 plasma and also the CH_4 diluted in Ar plasma[3-6] was investigated before. In the present work, the morphological variations during the growth of the diamond like carbon film as function of deposition temperature have been studied.

EXPERIMENTAL

A silicon wafer (100) was taken and thoroughly cleaned by ultrasonicating in acetone for 0.5 h. The cleaned substrate was then placed in RF-PECVD chamber. The chamber was then pumped down to a vacuum of 1×10^{-6} mbar. Ar (30 sccm) was used as the precursor gas to generate capacitatively coupled plasma using RF power (13.56 MHz) at 200 W. After the creation of plasma, CH_4 (10 sccm) was introduced into the chamber. A set of experiments were carried out by varying the deposition temperatures (room temperature, 100, 200 and 400 ºC) and by keeping other parameters constant. The deposition time was fixed as 45 min for each run. The samples were then named as S_{RT}, S_{100}, S_{200} and S_{400}, respectively with their deposition temperature as suffix. The surface morphology of the films was characterized by AFM in contact mode. The bond nature and bond disorder in the films were studied using Raman spectroscopy.

RESULTS AND DISCUSSION

Morphological studies: Fig. 1 shows the surface of the sample S_{RT} and S_{100}. From the figure, it is clearly seen that when the deposition temperature increases from room temperature

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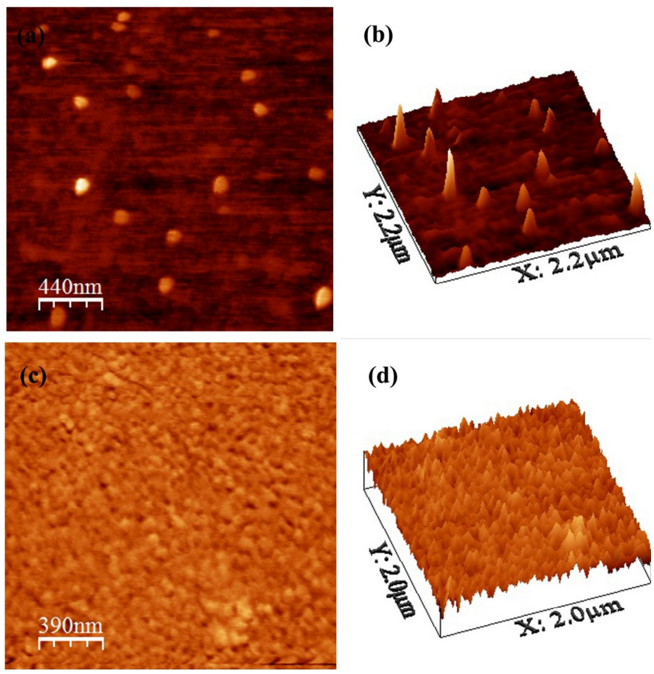

Fig. 1. Surface morphology of S_{RT} (a,b) and S_{100} (c,d)

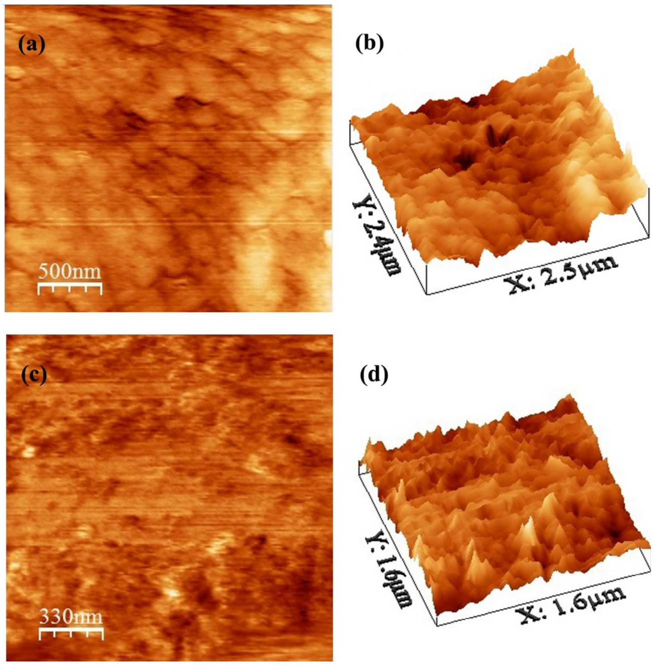

Fig. 2. Surface morphology of S_{200} (a,b) and S_{400} (c,d)

to 100 ºC the surface grain density increases and the surface grain size decreases. The surface roughness falls drastically (from 0.40185 to 0.15060 nm) in this range of temperature. The surface mobility of the adatoms from the vapour phase increases when deposition temperature increases[7], these species diffuse on the surface until either the re-evaporation occurs or a permanent site (dangling bond) is found[7]. Due to the plasma pretreatment more nucleation sites comes in the vicinity of these diffusing species to nucleate. Therefore the surface nucleation saturation will be attained faster than in the room temperature deposition, which increases the surface grain density and reduced grain size in the film. Thus the film is covered with uniform nano grains in the sample S_{100}, which reduces the surface roughness of the film.

As the deposition temperature increases above the transition temperature (around 200 ºC for a-C:H and depends on the deposition conditions[8] many factors plays a vital role in the growth of diamond like carbon film, like decrease in residence time and sticking coefficient, increased graphitization and effusion of hydrogen, *etc*. All these mechanisms severely affect the physical properties along with the surface topography of the diamond like carbon films. Below this temperature the variation in the surface morphology is only due to the surface reaction taking place between the adatom from the vapour phase and the surface atoms of the substrate.

Fig. 2 shows the surface of the samples S_{200} and S_{400}. Due to increase in deposition temperature (above 100 ºC), it was observed that the film was not uniformly coated and shows variation in the grain size, grain density and the surface roughness. Though, the surface diffusion increases at higher temperature the surface nucleation density decreases, due to decrease in the residence time and increased desorption rate. This affects the continuous growth of the film on the substrate. This favours the film to nucleate only in few regions and affects the surface grain density. Effusion of hydrogen and hydrocarbons from the nucleated region plays a vital role in the growth of the diamond like carbon film at higher deposition temperature, which increases the dangling bonds in the nucleated regions along with Ar ion bombardment. The grain size increases at high temperature due to the coalescence of the closely nucleated regions. Thus coalescence is also one of the reasons for the decreased grain density and variation in the grains height. The above said processes are mainly responsible for the variation in surface morphology and increase in the surface roughness of the film at higher deposition temperature.

Raman studies: Fig. 3 shows the Raman spectra of the samples S_{100}, S_{200} and S_{400}. The spectrum of all the films shows the formation of a distinct peaks around 1600 and 1350 cm^{-1}, indicates the formation of diamond like carbon films[9-12]. The G band shifts towards the higher wavenumber as the deposition temperature increases along with increase in I_D/I_G, which confirms that the film shows more graphitic nature at higher deposition temperature as discussed by many researchers[9-12].

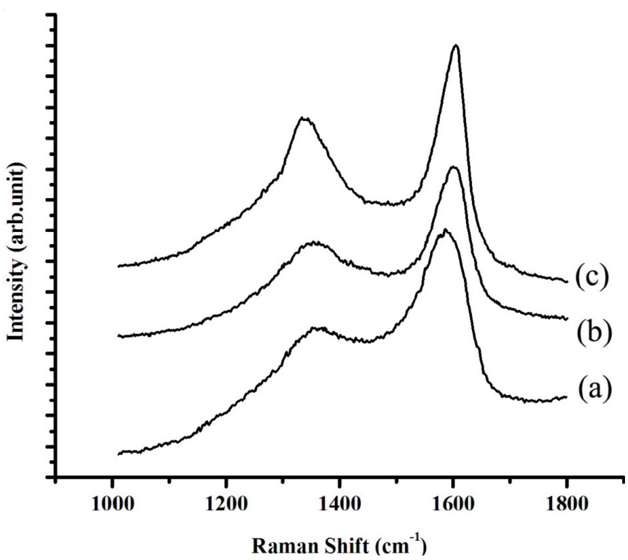

Fig. 3. Raman spectra, (a) S_{100}, (b) S_{200} and (c) S_{400}

Conclusion

The diamond like carbon films were coated on silicon at various temperatures starting from room temperature to 100 ºC. It was seen that when temperature raises from room temperature to 100 ºC the surface grain size and the roughness decreases and the grain density and uniformity of the film increases. Further increase in temperature leads to rougher surface with higher grain size and reduced nucleation density. The diamond like carbon films grown at higher temperature shows higher graphitization.

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