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Self-organized carbon mask formation on the top surface of fine trenches using a low temperature plasma anisotropic CVD for depositing fine organic structure

低温プラズマ異方性CVDを用いた微細トレンチ上面への自己組織カーボンマスク形成

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We have realized deposition of carbon masks on the top surface of trenched substrates using a hydrogen(H)-assisted plasma chemical vapor deposition (CVD). Deposition rate is determined by the balance between deposition rate of carbon containig radicals and etching rate by H atoms. Ion irradiation brings about the higher hardness of films and hence the lower etching rate. A high H atom flux is the key to deposition only on the top surfasse of trenched substrates.

1. Introduction

Diamond like carbon (DLC) and amorphous carbon films have widespread applications as protective coatings in several areas such as biomedical coatings and micro-electromechanical systems (MEMS) due to their biocompatibility, chemical inertness, high mechanical hardness, optical transparency, and wide band gap. Deposition profile of DLC and amorphous carbon films in trenches is one of the concerns to realize coatings on patterned substrates. Low temperature deposition below 100^{o}C is important to realize deposition on polymer substrates. We have succeeded in controlling deposition profile of plasma CVD carbon films in trenches and have realized sub-conformal, conformal and anisotropic deposition, for which carbon is filled preferentially from the bottom of trenches without sidewall deposition using a H-assisted plasma CVD method [1, 2]. In this study, we have examined effects of H atoms on deposition profiles and have realized a novel deposition profile, for which carbon films are deposited on the top of trenches without depositing on the bottom and sidewall, at a low substrate temperature of 100^{o}C. Here, we report these experimental results.

2. Experimental setup

Experiments were performed using the H-assisted plasma CVD reactor, in which a capacitively-coupled main discharge and an inductive-coupled discharge for an H atom source were sustained. This reactor provided independent control of generation rates of carbon-related radicals as deposition precursors and H atoms as etching precursors. An rf bias voltage of 400 kHz was applied to a substrate for controlling kinetic energy of ions impinging on it [1,2]. Toluene (C_7H_8) diluted with H_2+Ar gases were supplied to generate precursors for depositing carbon films.

3. Results and Discussion

To examine effects of H atoms on deposition profiles, we have studied dependence of deposition rate on the side wall and the bottom of trenches on the aspect ratio of trenches as a parameter of discharge power of the H atom source P_H as shown in Fig. 1. For P_H=0W, the deposition rate on the side and the bottom decreases with increasing the aspect ratio, while the deposition rate on the top surface is independent of the aspect ratio (not shown here). The decrease of deposition rate on the sidewall is larger than that on the bottom. The deposition rate for P_H=500W is smaller than that for P_H=0W. An emission intensity of H_α from the discharges increases with increasing P_H. These results indicate that the deposition profile is determined by the balance between carbon film deposition by carbon containing radicals and carbon film etching by H atoms. Moreover ion irradiation modifies film structure and hence changes deposition profile. For R= 33.3%, we have realized carbon deposition only on the top of the trenches above 1.6 in the aspect ratio at a low substrate temperature of 100°C. Figure 2 shows a typical SEM image of the novel deposition profile. This deposition profile is useful for selective deposition of carbon films on patterned substrates.

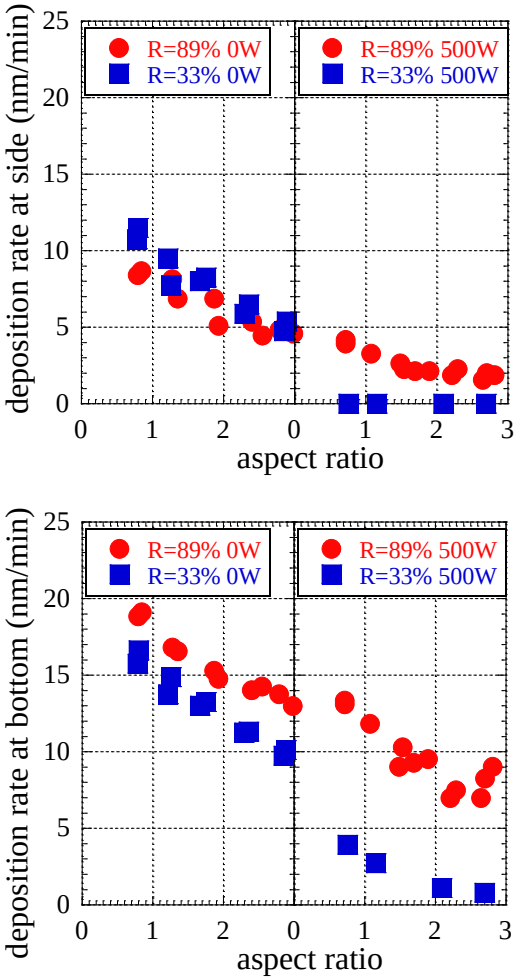

Fig. 1. Aspect ratio dependence of deposition rate at top, bottom, side of trenches. Conditions: substrate temperature 100°C, power of main discharge P_m = 45 W, ion energy = 45 eV, total gas flow rate 90 sccm, H_2 dilution ratio R=H_2 / (H_2+Ar) = 88.9% or 33.3%, C_7H_8 2.5 sccm, pressure 13 Pa, P_H = 0 W or 500 W.

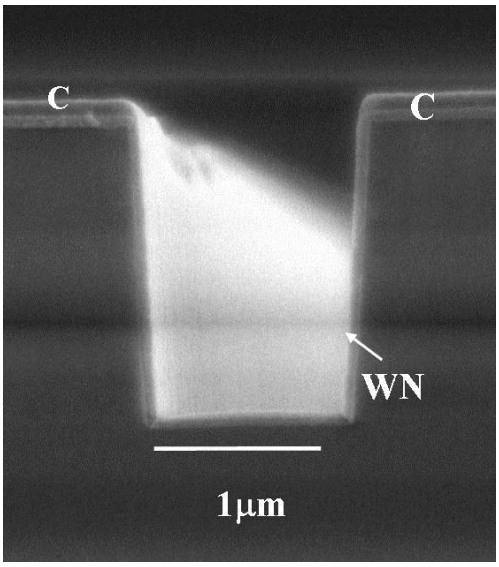

Fig.2. SEM image of deposition profile of carbon films. Carbon films are deposited only at the top of the trench. Conditions: R=11.1%, P_H=500W, Ts=100°C.

4. Conclusions

Low temperature deposition of carbon films only on the top surface of trenches was realized by using the H-assisted plasma CVD method. This self-organized deposition is determined by the balance between carbon film deposition by carbon containing radicals and carbon film etching by H atoms as well as modification of film structure by ion irradiation.

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