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Synthesis of White Diamond Thin Film by Microwave Plasma Enhanced Chemical Vapor Deposition Method

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Abstract

White diamond thin film, which should be composed of almost pure diamond, could be successfully obtained under high pressure conditions(above 150 Torr) by means of MPECVD(microwave plasma enhanced chemical vapor deposition, ASTeX 1.5 kW). Characteristics of the films with varing experimental parameters have been examined. From the experimental results, we will discuss the surface morphology and the growth mechanism of the films.

Introduction

Recently, the excellent physical and electrical properties of diamond are noted for the application to optics, electronics, and semiconductor devices as well as to hard coatings[1]. To use the diamond thin films for optics and electronics, the enhancement of the film quality is required. Particularly for optics, the diamond thin films should be transparent, which has been conventionally called as white diamond. Carbon and hydrocarbon would be frequently incorporated into the films during the deposition. Therefore they eventually deteriorate the film quality and transparency. Although many efforts, such as various deposition methods[2] and different source gas conditions[3], have been made since the first successful synthesis of diamond thin film by Eversole in 1958[4], the enhancement of the film quality is necessary for the practical application.

In this work, we report the successful method for the formation of the high quality white diamond thin film at high growth rate by MPECVD technique.

Experimental

Plasma would be generated by using HPMM(ASTeX, 1.5kW) system and produced onto the substrate surface by adjusting the height of the substrate position. N-type(100) Si wafer(1.5 × 1.5 cm^2) was used as the

substrate, that was pretreated with 30μm-diamond powder/acetone solution in a ultrasonic cleaner for 5 hours. Before the plasma on, the reaction chamber was evacuated to 10^{-2} Torr by mechanical pump and then CH_4, premixed with H_2, was introduced into the reactor with increasing the substrate temperature up to 850°C. The total pressure was set initially at 40 Torr and increased up to 200 Torr. The microwave(2.45 GHz) plasma power was fixed at 1450W.

Results and Discussion

Fig.1 shows the Raman spectra of the thin films after 2 hours deposition with changing CH_4 concentration. The ratio of peak intensity(I_d) of diamond(1332 cm^{-1}) to that(I_a) of amorphous carbon(1500 cm^{-1}) increases, passes through maximum(at 150 Torr), and slightly decreases with increasing CH_4 concentration as shown in Fig.2. At 150 Torr, we could obtain the white diamond thin film by dissolving the Si substrate in HF and HNO_3 mixture. Fig.3 shows the transparency of white diamond thin film.

Characteristics of the films with the experimental parameters have been examined by SEM, XRD, and Raman spectrometer. As the total pressure and the microwave power increase, the film quality has been enhanced. Substrate temperature is the main factor in changing the surface morphology of the film. The microstructure of white diamond thin film was investigated by TEM. It was found that the diamond thin film was grown by island growth and secondary nucleation of {111} plane. Crystal defects and impurities were usually found at boundaries of the islands.

Conclusions

We could succesfully obtain white diamond thin film by MPECVD technique. The film quality and morphology is strongly dependent upon total pressure, microwave power, and substrate temperature.

References

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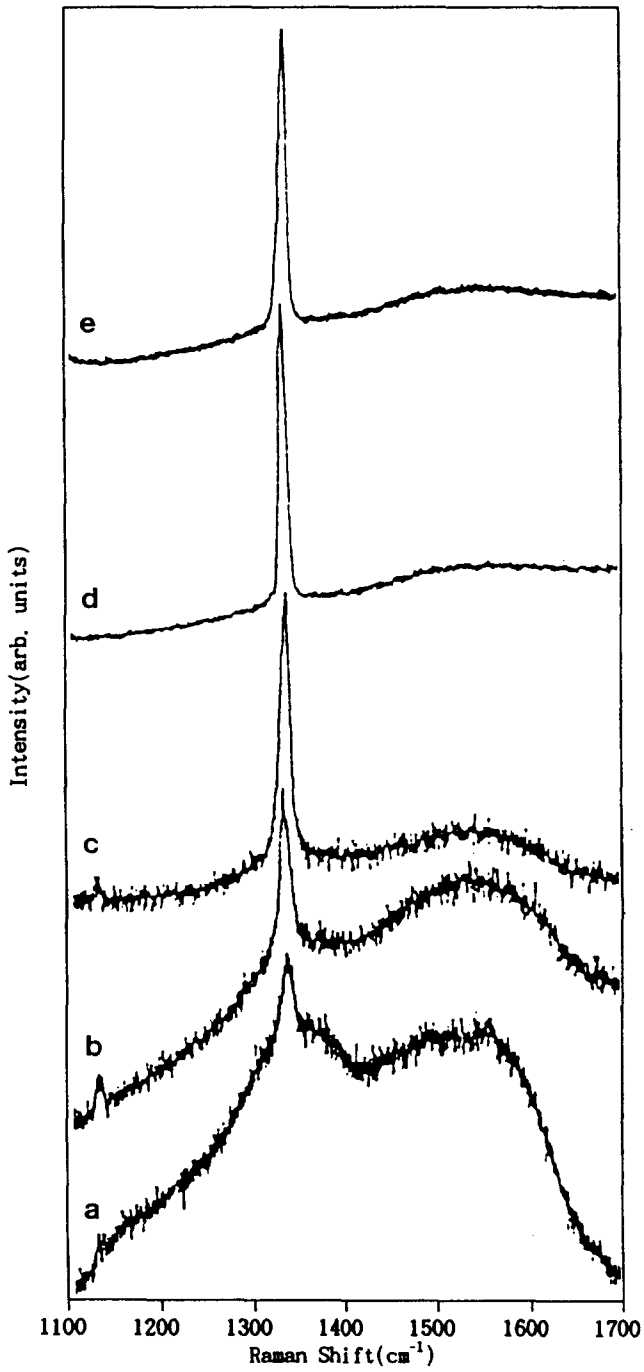

Fig.1 Raman spectra of thin films with total pressures:
(a) 27.5 Torr, (b) 40 Torr, (c) 60 Torr, (d) 150 Torr, and (e) 250 Torr.

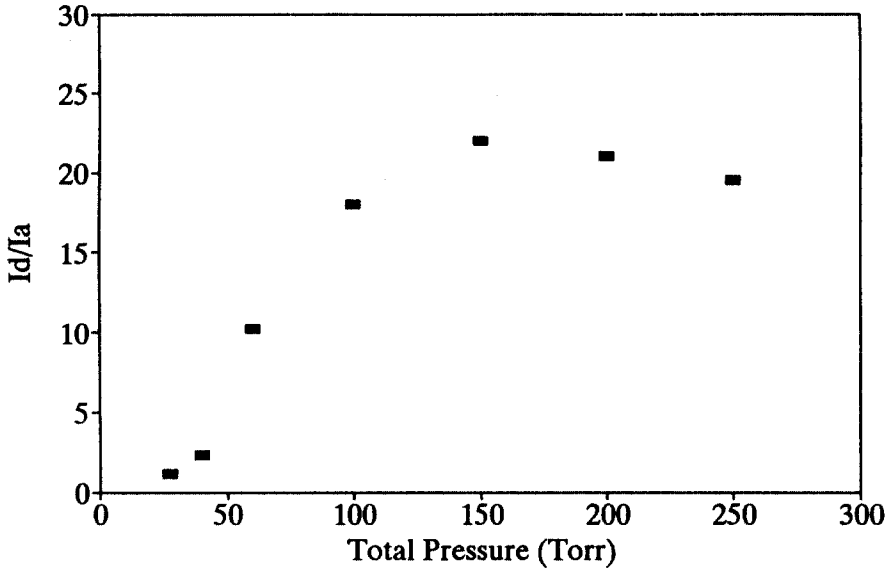

Fig.2 The ratio of peak intensity of diamond(I_d) to that of amorphous carbon(I_a) with total pressures.

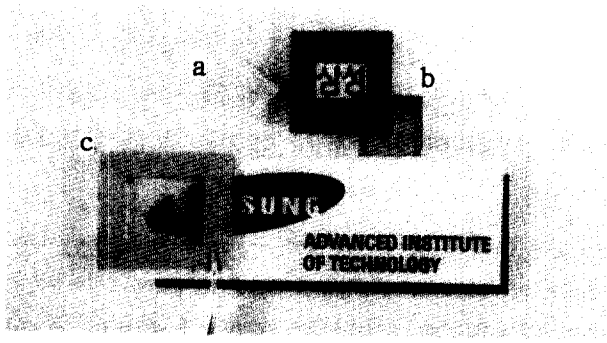

Fig.3 Photographs of white diamond thin films:
(a) white diamond thin film,
(b) diamond thin film which was incorporated by small quantities of carbon impurities,
(c) the transparency of white diamond thin film.