Low temperature synthesis of sulfur-doped nanocrystalline diamond films

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Nanocrystalline diamond growth has been extensively studied because its optical, mechanical, and electrical properties are expected to be attractive for both of future applications and scientific interests. In order to form diamond nanocrystallites, many studies have been performed to introduce defects into diamond structure. For introducing defects, high-energy ions are used to impact the growth surface by applying DC bias voltage to the surface in the plasma. Contrary to this, our growth method in this study focused to realize a damage-free growth process suitable for high-quality crystal growth.

We used a tubular flow-type MPCVD reactor for the growth experiments. In our system, the substrate position was apart from the plasma-ball during the growth in the MPCVD quartz reactor. The down stream position is expected to prevent the growth surface from being damaged by ion bombardments and electron irradiation from the plasma. The substrate temperature was controlled in the range of 350-400 °C with the level of microwave power. The substrate position was apart from the plasma, so that the temperature could be kept at such a low temperature. The gas pressure in the reactor during the growth was 5-40 Torr. The flow ratio of CH_4 to H_2 was 10%, and that of H_2S to H_2 was varied in the range of 0-5.0%. From the analogy of the effect of H_2S on the diamond CVD growth[1] and the carbon nanotube CVD growth[2], the added H_2S is expected to enhance the sp^3 formation and assist the diamond crystal growth.

Figure 1 shows a plane-view TEM image of the obtained film grown with 0.1% H_2S in the gas phase. The acceleration voltage was 200 kV. The film was consisted with nanocrystallites approximately 1-2 nm in size. Negligible amorphous phases and defects were observed in the grain boundaries. The crystal quality was high. Electron diffraction pattern of the film revealed that the nanostructure was diamond. The energy dispersive X-ray analysis indicated that the film mainly consisted of carbon and sulfur. These confirmed that the sulfur-doped nanocrystalline diamond film was grown in the growth system.

Figure 2 shows photoluminescence (PL) spectrum of the nanocrystalline diamond film excited with the 325 nm light from a He-Cd laser. A visible light was intensely observed from the film. The origin of the intensive PL will be discussed in terms of the optical band gap of the film.

In summary, Nanocrystalline diamond films were grown in the down stream of microwave plasma-assisted chemical vapor deposition (MPCVD) with using a gas mixture of H_2, CH_4 and H_2S. The size of nanocystallites was approximately 1-2 nm and obvious amorphous phases were not observed at the interface between these nanocrystallites.

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References

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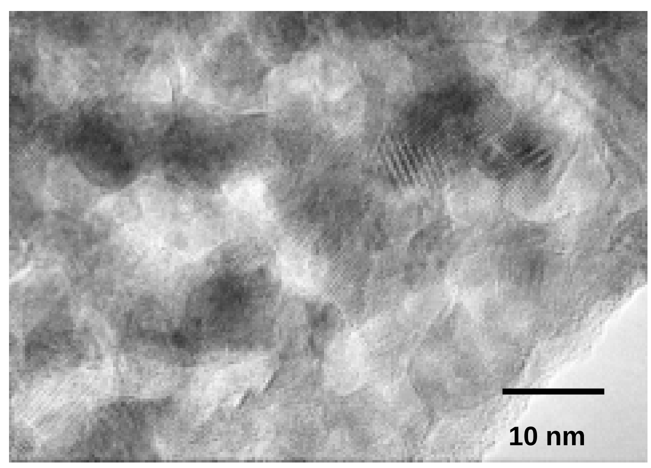

Fig. 1 TEM image of nanocrystalline diamond film.

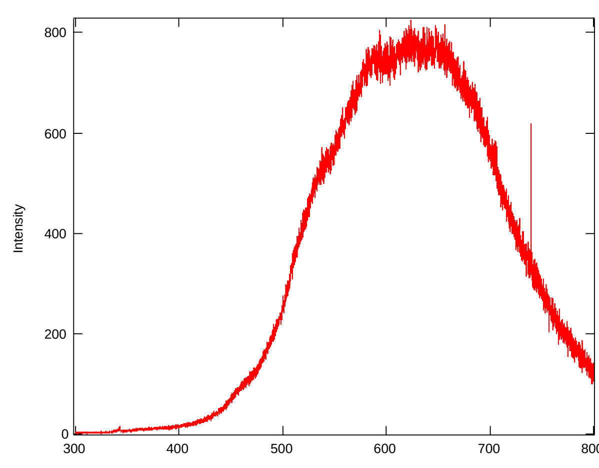

Fig. 2 PL spectrum of nanocrystalline diamond film.