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Si-V luminescent center formation in nanocrystal diamond by atomic Si induced diamond nucleation

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Abstract

Diamond has excellent electrical and mechanical characteristics. From these characteristics, its application to several fields is expected. Color centers in diamond are very promising as single photon emitters. By introducing atomic Si during the early nucleation, nano-crystal diamond (NCD) with high ratio of sp^3 bonds has been successfully fabricated. Micro PL results indicate that Si-V luminescent centers are formed in NCD.

1. Introduction

Diamond has excellent characteristics such as high hardness, high thermal conductivity and wide band gap. Recently color centers in nanocrystal diamond (NCD), such as nitrogen-vacancy (N-V) centers, are attracting much attention to apply to luminescent biomarkers and single photon emitters [1]. In particular, silicon-vacancy defects (Si-V centers) in diamond are expected because of their high emission rate and stability at room temperature [2].

Bias-enhanced nucleation (BEN) is a good way to generate diamond nuclei on heterogeneous substrates. Recently we have proposed the nucleation enhancement by atomic silicon micro addition and high microwave power removing a-C during BEN. The SERS spectrum shows quite similar to the typical spectrum of NCD [3]. In this paper, we discuss the formation of Si-V luminescent centers in high quality NCD by atomic silicon induced diamond nucleation.

2. Experimental

Microwave plasma enhanced chemical vapor deposition (MP-CVD) was used for NCD formation. The nucleation processes were performed on silicon substrates using CH_4, H_2 as source gases. Mono-methyl silane (MMS: $Si(CH_3)H_3$) was used as an atomic silicon source. Bias condition of the nucleation is shown in Fig.1. Then microwave power is 500W, and the atomic Si induced nucleation is dominant under this condition.

Diamond nucleation was observed by SEM. In order to characterize NCD, surface enhanced Raman scattering spectroscopy (SERS) was performed by using second harmonic generation (SHG) of Nd-YAG laser (532nm) as an excitation light. At the same time, we attempted to obtain photoluminescence from NCD by micro Raman system.

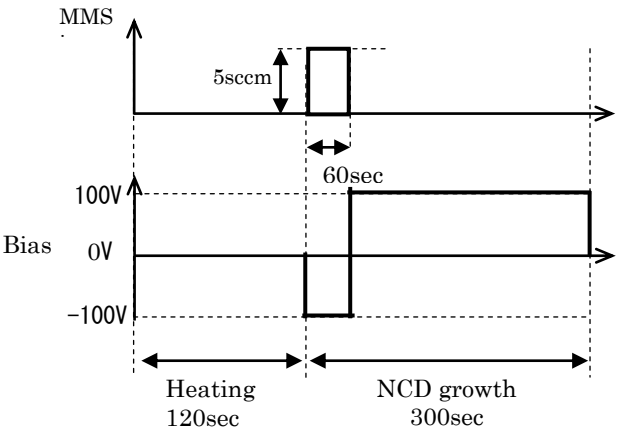

Fig. 1 Time sequence of bias supply during NCD formation

3. Results and discussions

Fig.2 shows a SEM photograph of the NCD grown surface. The density is low but the grain size becomes large about 100 nm, because positive bias after the MMS addition enhances entirely the growth of NCD.

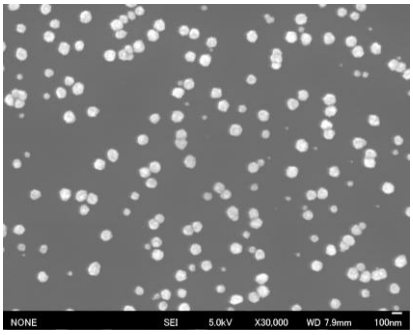

Fig.2 SEM image of NCD

Fig.3 shows the SERS spectrum of NCD formed under the bias condition as shown in Fig.1. Since spot size of an excitation laser light for SERS is about 3μm, about 30 NCD exist in the spot. The diamond fine peak at 1332 cm^{-1} can be observed from NCD. This result indicates the good crystallinity of NCD induced by atomic Si. The SERS spectrum is typical for NCD, because the two peaks (t-PA) at 1150 cm^{-1} and 1500 cm^{-1}, which are frequently observed in NCD films, can be seen [4].

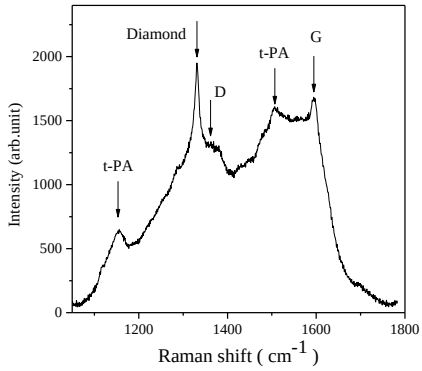

Fig. 3 SERS spectrum of NCD

We also attempted photoluminescence (PL) measurements to observe the luminescence from Si-V center at the same time as the micro Raman measurements. The NCD PL is observed as well as Raman scattering. Fig.4 shows PL spectrum of NCD. Peak at 738 nm indicate the zero-phonon line from Si-V center in diamond [2].

NCD show the good crystallinity and luminescence from Si-V luminescent centers. On the other hand, diamond nuclei and Si (100) substrate show the similar polarization dependence. Under the severe condition such as microwave power atomic is 500 W, atomic Si that was decomposed from MMS in the plasma is supplied to the vapor phase and is coupled with Si surface as the diamond nucleation center. Si is a substance with sp^3 structure only. Then the nucleation center due to Si, which has more sp^3 bonds and less sp^2 bonds, is formed preferentially. Then NCD is grown surround a Si nucleation center by methyl radical preferential supply due to the high energy plasma condition. Thus, it is considered to have Si-V luminescent centers with high probability.

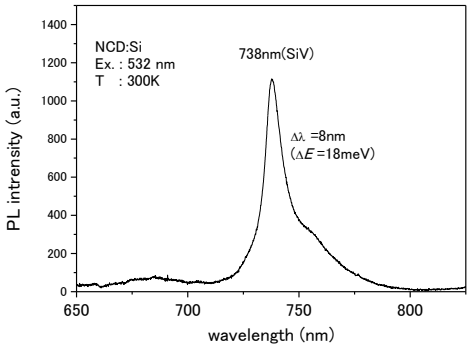

Fig. 4 Room temperature micro-PL of SiV center in NCD

4. Conclusion

Formation of Si-V luminescent centers by atomic silicon in the enhanced diamond nucleation was investigated. From observation of the diamond fine peak at 1332 cm^{-1} and the luminescence from Si-V center, we consider that atomic Si is a valid nucleation site helping to form the sp^3 structure of diamond and Si-V luminescent centers in NCD with high probability, at the same time.

References

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