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# Electron field emission from various CVD diamond films

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## Abstract

Electron field emission properties from various CVD diamond films were studied. Diamond films were synthesized by microwave plasma CVD at 1173K and at 673K substrates temperature and pulse microwave plasma CVD at 1173K. B-doped diamond film was synthesized by microwave plasma CVD at 1173K also.

Estimation by SEM, both the non-doped diamond film and B-doped diamond film which were synthesized at 1173K substrate temperature were 2~3㎛ in diameter and nucleation densities were $10^8$ numbers/$cm^2$ order. The diamond film synthesized at 673K was 0.2㎛ in diameter and nucleation densities was 109 numbers/cm2 order. The diamond film synthesized by pulse microwave plasma CVD at 1173K was 0.2㎛ in diameter and nucleation density was $10^9$ numbers/$cm^2$ order either.

From the result of electron field emission measurement, electron field emission at 20V/㎛ from CVD diamond film synthesized by pulse microwave plasma CVD was 37.3 $\mu$A/$cm^2$ and the diamond film showed the best field emission property comparison with other CVD diamond.

*Key words* : *Diamond, NEA, CVD, Electric field emission, Pulse microwave*

## 1. INTRODUCTION

Diamond has fascinated chemical and physical properties. Diamond whose surface was terminated by hydrogen shows NEA (Negative Electron Affinity)[1]. Diamond film synthesized by CVD (Chemical Vapor Deposition) is terminated by hydrogen and it exhibits NEA[2]. When a low voltage applied to diamond, it can be expected to emit large electric current flows by tunneling effect and application for cold cathode of electron microscope and electric field emitter of display have been studied.

The investigation was carried out on electron filed emission from various CVD diamond films synthesized by microwave plasma CVD in various conditions.

## 2. EXPERIMENTAL PROCEDURE

Table 1 shows Diamond synthesis conditions. Sample 1 was synthesized by microwave plasma

Table 1. Diamnond synthesis conditions.

| Sample | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $CH_4$ floerate (SCCM) | 1 | 6 | 1 | 1 |
| $H_2$ flowrate (SCCM) | 199 | 194 | 199 | 198 |
| Microeave power (W) | 200 | 300 | 200 | 400 |
| Reaction pressure (kPa) | 1.3 | 1.3 | 1.3 | 5.2 |
| Substrate temperature (K) | 1173 | 673 | 1173 | 1123 |
| Reaction To-ime (h) | 3 | 7 | 3 | 3 |

CVD at 1173K substrate temperature. Sample 2 was synthesized by microwave plasma CVD using apparatus which has a substrate holder equipped cooling substrate holder. Substrate temperature was kept at 673K by controlling of microwave power and cooling water[3]. Sample 3 was synthesized using pulse microwave plasma CVD[4] at 1173K. Microwave is generated in a series of pulse.

Fig. 1 shows the shape of typical pulse microwave generation. The on time of microwave is 0.94s and off time is 3.67s, then duty cycle is 17.5%. Sample 4 is B-doped diamond synthesized by microwave plasma CVD at 1123K.

Deposits were observed by SEM (Scanning Electron Microscope /JSM-20/JEOL) and estimated by AES (Auger Electron Spectroscopy / JAMP-7100/JEOL).

Fig. 2 shows the schematic illustration of electric filed emission measurement apparatus. Electric field emission measurement was performed in a vacuum chamber evacuated to $10^{-5}$ Pa order. A platinum anode was placed in the position of 50 $\mu$m above from the cathode by glass fiber spacers and electric current was measured each applied voltage.

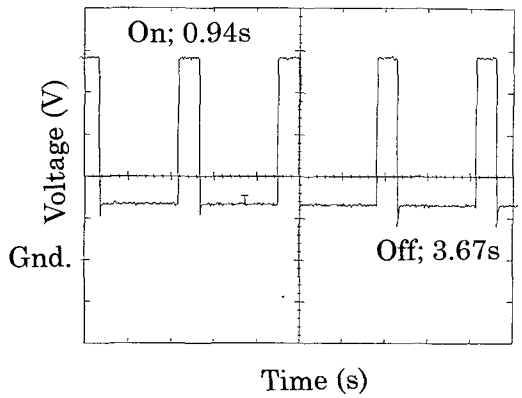


Fig. 1 The shape of typical pulse miclowave generation.

## 3. RESULT AND DISCUSSION

### 3. 1 Diamond synthesis

SEM images of the deposit on the scratched Si substrate synthesized in various growth conditions were shown in Fig. 3. Both sample 1 and 4 had 2~3$\mu$m in diameters and the nucleation densities were $10^8$ numbers/cm$^2$ order. Both sample 2 and sample 3 were 0.2$\mu$m in diameters and the nucleation densities were $10^9$ numbers/cm$^2$ order. From the AES spectra of the deposit synthesized by pulse microwave plasma CVD, deposits were identified to diamond.

### 3. 2 Electric field emission properties

Fig. 4 shows the result of electric field emission measurement from CVD diamond films synthesized in various growth conditions. The

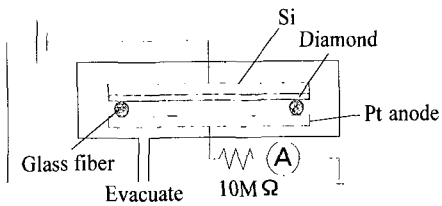


Fig. 2 Schematic illustration of electric field emission measurement apparatus,

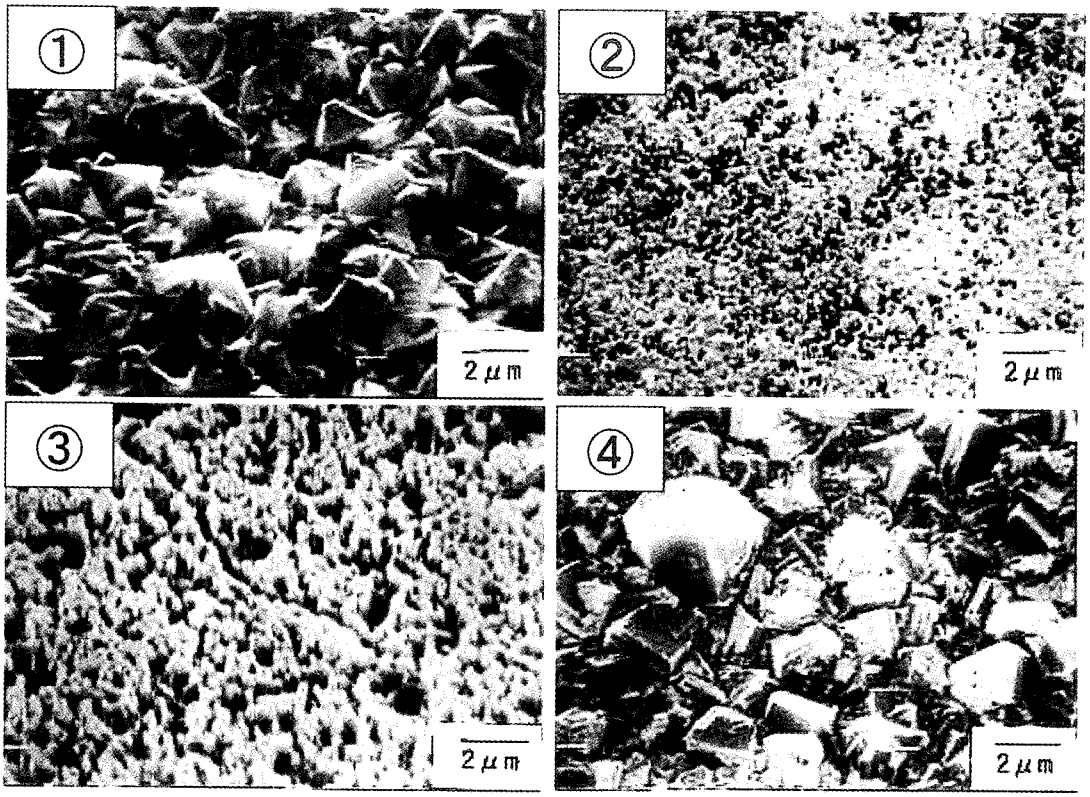


Fig. 3 SEM images of the deposit on the Si substrates.
① 1173K ② 673K, ③ Pulse microwave, ④ B-doped

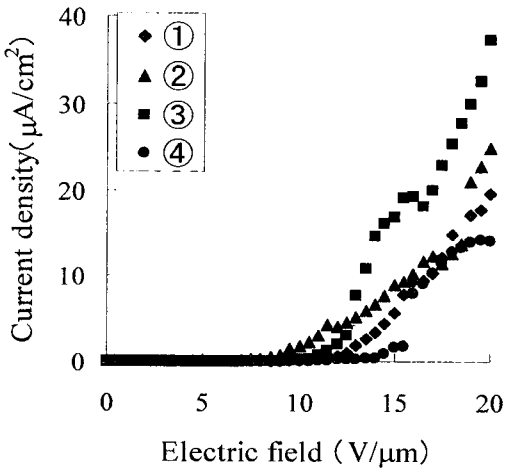


Fig. 4 Electric field emission properties.

electric field emission were recognized at about 8.5V/㎛ from each samples and the electric field emission at 20V/㎛ from sample 1 shows 19.6 $\mu$A/㎠ and sample 2 shows 24.7 $\mu$A/㎠. Sample 3 shows 37.3 $\mu$A/㎠ and sample 4 shows 14.0 $\mu$A/㎠ at 20V/㎛. The diamond film synthesized by pulse microwave plasma CVD showed the best field emission property comparison with other CVD diamond films.

It was seemed that the diamond grain sizes of sample 2 and sample 3 are smaller than sample 1 and sample 4. And the result, there are a lot of emission sites. Also from AES spectrum, as sample 3 was identified to the diamond which includes graphite, it is seemed there are a lot of conduction channel in this sample

## 4. CONCLUSIONS

Investigation results of electric field emission from various diamond films synthesized by microwave plasma CVD at various conditions are follows,

1) The electric field emission was recognized at about 8.5V/?m from each diamond films synthesized by microwave plasma CVD at various conditions.

2) The electric field emission from CVD diamond films synthesized by pulse microwave plasma CVD showed the best property comparison with other CVD diamond films.

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