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A periodic magnetic field assisted chemical vapor deposition technique to fabricate diamond film with preferred orientation

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ABSTRACT

Microcrystalline diamond films with an orientation evolution were initially deposited through periodic magnetic field assisted hot filament chemical vapor deposition system (PMF-HFCVD). The results indicated that lower angular frequency (ω_f) favored the (110) orientation while higher ω_f facilitated the (100) orientation. We attributed this evolution to the effect of increasing collision possibility with increasing angular frequency of the magnetic field. In addition, the films with (110) orientation exhibited better electron field emission properties than that with (100) orientation.

1. Introduction

Highly oriented diamond films have unique performance based on their orientation [1,2,3]. The common orientations of diamond are: the (111) orientation with triangular surface, the (110) orientation with roof-shaped surface and the (100) orientation with square surface [4,5]. (100) oriented diamond films are promising candidate for heat conducting application, due to their higher thermal boundary conductance than that of (111) surfaces [1]. While, the (111) surfaces have the lowest friction coefficients in comparison with (110) and (100) surfaces, making them more suitable for tribological applications [2]. It has been reported that surface morphology of diamond films is an important aspect related to the field emission properties. The smooth (100) facets have negligible electron emission [6], while (110) and (111) oriented diamond films have higher electron emission current [3]. Therefore, it is necessary to fabricate the oriented diamond film. Oriented diamond films could be prepared by various chemical vapor deposition conditions. Generally, low methane concentration facilitated the formation of (111) surfaces [7]. Diamond films with (110) preferred orientation could be obtained at low gas pressure [8]. The (100) oriented film could be deposited through acetylene [9] or with bias assistance [10]. Little et al. [11] reported the preparation of single crystalline diamonds under strong static magnetic field. To our knowledge, the fabrication of oriented diamond films under low-intensity periodic magnetic field (PMF) has not been reported.

In this paper, PMF-HFCVD system with a maximum intensity of 127 G was initially applied to prepare diamond films with preferred orientation. An orientation evolution occurred with the increase of angular frequency. Besides, the electron field emission properties of the corresponding diamond films were revealed subsequently.

2. Experimental details

Diamond films were deposited by the PMF-HFCVD system which was shown schematically in Fig. 1. The PMF-HFCVD system consists of a quartz chamber, a three-phase stator winding and an AC transducer. The PMF, with $B = B_0 \sin \omega_f \cdot t$, was generated by the stator winding of a three-phase electric motor. The direction of magnetic line rotated in clockwise with the angular frequency of ω_f. Prior to deposition, single crystalline p-type Si (100) substrates (5 mm × 5 mm × 1 mm) were ultrasonically pretreated in acetone for 20 min, in nano-diamond colloid for 30 min and in ethanol for 2 min successively. A gas mixture with a total flow of 50 sccm consisting of methane and hydrogen (1/99 vol%) was introduced with a total pressure of 3 kPa. The substrate temperature was maintained at around 700 °C. The deposition time was 4 h. The angular frequencies (ω_f) of 0, 1 Hz, 50 Hz, 100 Hz, 1000 Hz, were applied to the deposition process. For convenience, these samples were denoted as B0, B1, B50, B100 and B1000, respectively.

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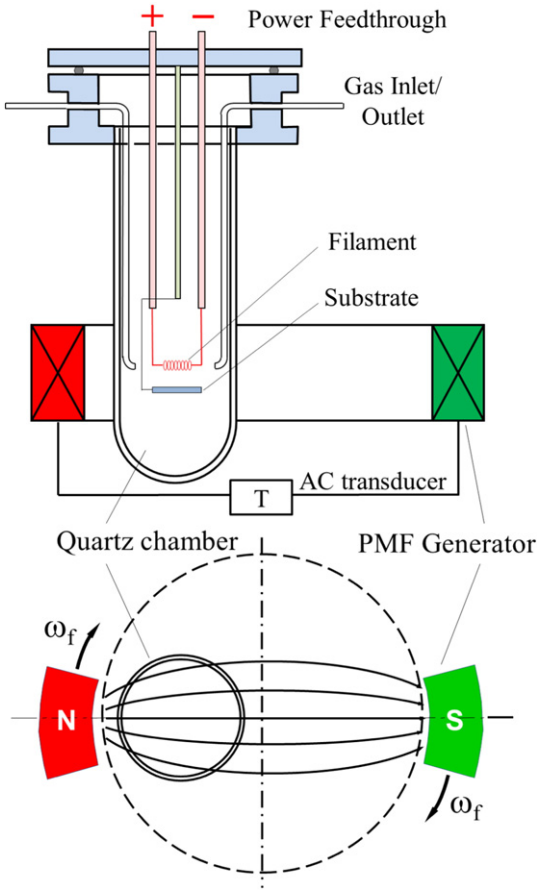

Fig. 1. Schematic diagram of the PMF-HFCVD system.

The morphology of samples was characterized by field emission scanning electron microscopy (SEM: FEI Sirion200). The quality of diamond films was investigated by a micro-Raman spectrometer (Lab Raman HR800), at an excitation wavelength of 488 nm (argon ion laser) with a power of 10 mW. The preferential orientation of films was analyzed by X-ray diffraction (XRD: Rigaku TTR III) in the 2θ range of 30°–125° with a step size of 0.02°. The spectra in the 2θ range of 66°–72° were excluded due to the strong Si diffraction peak. The electron field emission measurement of diamond films was carried out at room temperature in a high vacuum chamber of 10^{-5} Pa with an anode-cathode spacing of 200 μm and the effective area of anode was 19.63 mm^2.

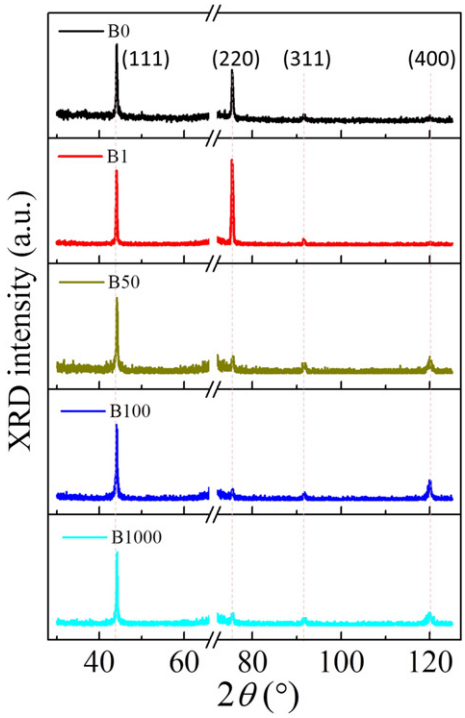

Fig. 3. XRD patterns of diamond films deposited with different angular frequencies.

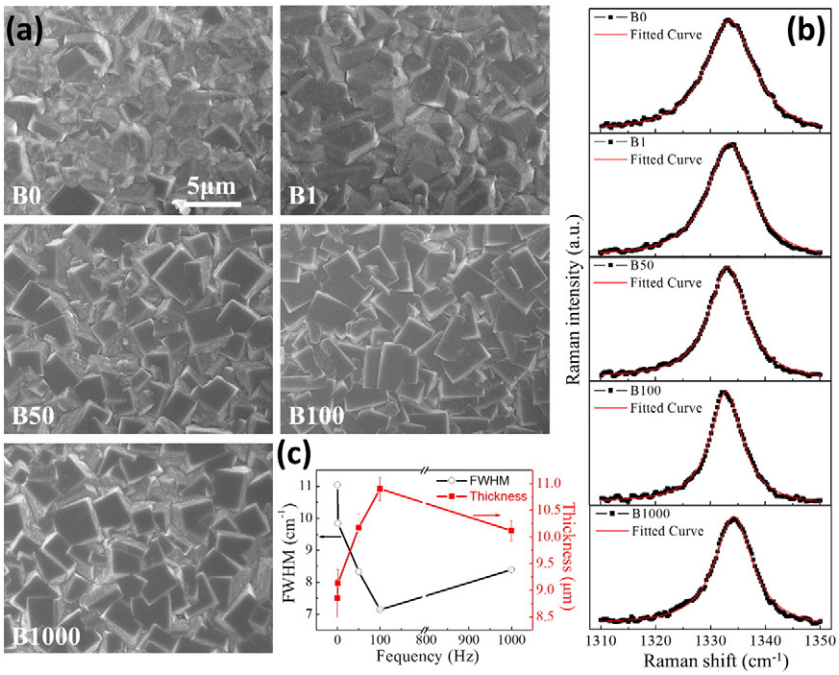

Fig. 2. (a) SEM images, (b) Raman spectra, (c) The FWHM and the thickness of diamond films deposited with different angular frequencies.