SYNTHESIS AND ELECTRON FIELD EMISSION STUDIES OF NANOCRYSTALLINE DIAMOND FILMS

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Introduction

In recent years, Nanocrystalline diamond (NCD) films have received considerable interest as electron emitting electrodes because of small grain size (< 100 nm) and sharp grain boundaries. Sharp grain boundaries contain non-diamond carbon in the film, which results in significant improvement in electron emission. The non-diamond contents and the crystal size of diamond grains in the films play a crucial role in electron field emission, solar cells, biomedical and biotechnological applications. We report here the growth of NCD films using microwave plasma enhanced chemical vapour deposition (µ-PECVD) technique and the field emission study of the films using AFM.

Experimental Setup

Deposition of the NCD films is carried out in a CYRANNUS® I ï 6ò µ-PECVD system (iplas GmbH, Germany) on silicon wafer (both side polished n-type <100>). Deposition is carried out at 200 mbar, 600°C and with 96.7 % Ar, 0.8 % CH_4 and 2.5 % H_2 (total flow of 800 sccm). The films are deposited with the variation of microwave power from 600 to 1600 Watt. The samples NCD 1, NCD 2, NCD 3, NCD 4, NCD 5 and NCD 6 correspond to 600, 800, 1000, 1200, 1400 and 1600 Watt microwave power, respectively. Prior to deposition, the substrates are pretreated with mechanical scratch seeding with diamond powder (0.1 µm size) followed by an ultrasonic bath cleaning with acetone and etched with H_2/Ar plasma for 30 min. The deposited films are characterized using Raman spectroscopy, XRD, FTIR spectroscopy and AFM. Field emission study of NCD films is carried out by using AFM with conducting tip.

Results and Discussion

Raman spectra of NCD films are shown in Fig. 1. All spectra of NCD films have two predominant peaks centered around 1335 cm^{-1} and 1560 cm^{-1} corresponding to vibrational state of D band and G band, respectively, and two humps around 1160 cm^{-1} and 1450 cm^{-1}, represent the formation of nano-crystalline phase [1-3].

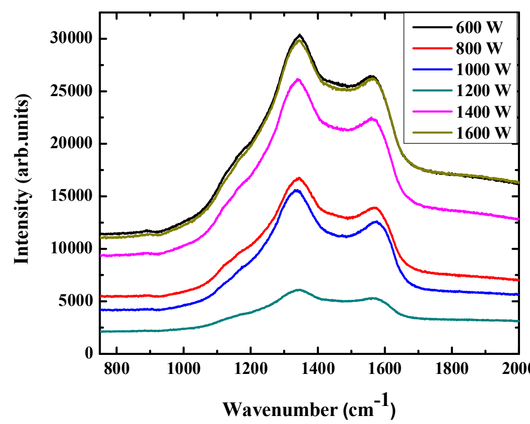

Fig. 1 Raman spectra of NCD films deposited at 600 W, 800 W, 1000 W, 1200 W, 1400 W and 1600 W microwave power

FTIR spectra (not shown here) of NCD films show peaks between 2800 ï 3300 cm^{-1} due to of CïH stretching mode and the peaks below 2000 cm^{-1} due to CïC and CïH bending mode. XRD spectra (not shown here) of films show a peak centered around 44° (2d) corresponding to (111) plane of diamond. These characterizations (Raman, FTIR and XRD) confirm the formation of NCD films during deposition. Surface morphology of NCD films, studied by AFM in lateral force mode on scan area 1μm × 1μm, is shown in Fig. 2.

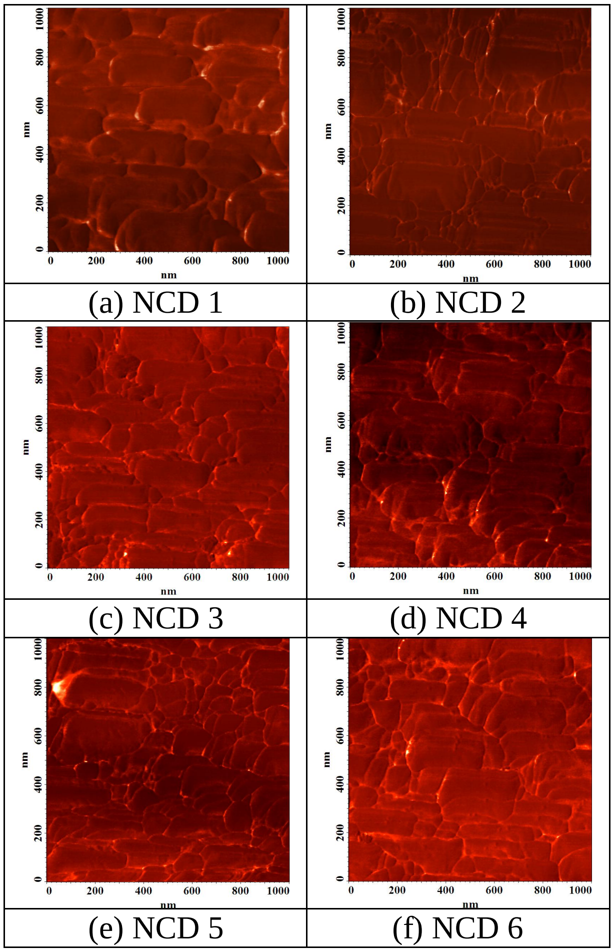

Fig. 2 AFM images of NCD films deposited at 600 W (a), 800 W (b), 1000 W (c), 1200 W (d), 1400 W (e) and 1600 W (f) microwave power

The AFM images depict the formation of nano grains elongated along one direction separated with sharp grain boundaries. It is clear that size of the grain and grain boundaries depend on process parameters and can be tailored by changing the gas ratio, pressure, temperature and microwave power. Plot between current and voltage of NCD 1 is shown in Fig. 3. Voltage is plotted on X axis (in Log_{10} scale) and current is on Y axis. Negative voltage (1 to 5 volt) is applied to the substrate and emission current is collected by conducting STM tip. A very low threshold voltage has been observed (< 2 volt).

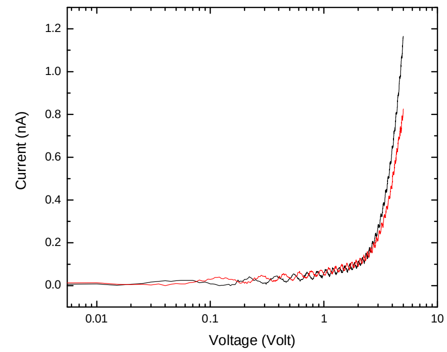

Fig. 3 Plot between current and voltage of NCD 1

Conclusion

AFM images show the formation of grains of nanometer dimension and separated with sharp grain boundaries. The grain boundaries, which contain sp^2 bonded carbon, are responsible for the electron emission. Diamond has been found to have no role in the field emission. When voltage is applied between the conducting tip and NCD film electron emission starts because of the movement of electrons across the grain boundaries. Different emission currents have been observed at different points of the same sample. This is because of different grain sizes.

References

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