X-선 발생용 탄소나노튜브 전계 소자의 응용
Application of CNT Field Emitter for X-ray Generation

Hyun Suk Kim, Hae Young Choi, Won Suk Chang, Yang Ha Park and Jong Uk Kim*
Korea Electrotechnology Research Institute, Applied Imaging Research Group
*E-Mail: jukim@keri.re.kr

Recently, Carbon nanotube (CNT) field emitter has been explored for application to field-emission display. It is also useful as a vacuum device for high frequency and high power application. In this study, Carbon nanotube (CNT) field emitter has been applied for x-ray generation. CNT emitters were prepared on a stainless steel substrate (SUS304) by rapid thermal chemical vapor deposition (RTCVD). The characteristicsof the synthesized raw CNTs were examined by SEM and Raman spectroscopy. By optimizing morphology of the CNTs, a large and stable emission current couldbe obtained. The performance of the CNT field emitter was tested by simple triode geometry a triode by employing the CNTs - which were grown on the 4 × 4 mm^2 size of metal substrate and treated with high temperature - as a cathode. The grid is apart 0.5 *mm* from the cathode and the anode is apart 6.0 *mm* from the grid, respectively. The total anode tube current was measured by applying negative high voltage to the CNT emitter. When the triode was applied with positive 5.0 *kV* to the anode and negative 4.0 *kV* to the cathode the maximum anode tube current was found to be 2.0 *mA*. Stability of the anode tube current was also checkedand a typical phosphor image of the electron bombarding on the anode copper target was obtained.

Figure 1 show typical SEM images of CNTs grown on Ni-deposited TiN/SUS304 metal substrate by using RTCVD. Figure 1 present lateral side of the as-grown CNTs. As shown in the figure the lateral length of CNTs was approximately 30 ㎛. The synthesized raw CNTs were analyzed by Raman spectroscopy and the result is shown in Figure 2 As seen in the figure two sharp peaks were clearly observed at 1,355 cm^{-1} (D-band) and 1,580 cm^{-1} (G-band) representing typical characteristics of amorphous and graphite carbons, respectively [1]. The intensity ratio (I_D/I_G) of the D band over the G band for the synthesized CNT arrays is approximately 0.66. It means the as-grown CNTs have excellent graphitic structures with low amorphous carbon defect. Figure 3 shows a typical image of electron bombarding into the copper anode target painted with phosphor on the surface on it. The distance between the two electrodes is approximately 6 mm and the image was taken when the total anode tube current was approximately 1.5 mA. From the phosphor image, it was observed the electron beam size was little bit magnified than that of the original CNT emitter size. This is attributed to space charge effect of the electrons and it was proved by simulation result.

Multi-wall carbon nanotubes (CNTs) were directly grown in this study by using rapid thermal chemical vapor deposition (RTCVD) method and characteristics such as Raman Spectroscopy and total tube current vs cathode voltage were investigated. From the Raman spectroscopy it was measured the intensity ratio (I_D/I_G) of the D band over the G band for the synthesized CNT arrays was approximately 0.66 and from this result it was found the synthesized CNT samples were very nicely graphitic. Total anode tube current was also measured as increasing cathode voltage. No appreciable current was measured until the cathode voltage increased to - 2.2 *kV*. By increasing the cathode voltage more over the - 2.2 *kV*, the anode tube current was started to increase and finally reached to peak value of 1.8 *mA*. After the peak value current decrease was observed. In order to maintain the tube current with a constant (i.e., 1 *mA*) cathode voltage increase was required. Two stages in the voltage increase slope were observed; fast increase (first stage) and relatively slow increase (second stage). This behavior is not precisely well understood at this moment but this could be believed to be due to two different aging schemes existing in the CNT emitter. In additions, a typical phosphor image of the electron bombarding into the copper anode target was obtained. Although x-rays directly generated from the anode target was not measured at this time but it was anticipated the amount of x-rays could be high because of the bright phosphor image inthe central part of the target. In the near future, x-rays from the CNT triode manufactured in the present study will be measured and its energy distribution will also be precisely analyzed by using an x-ray spectrometer. And x-ray images of specific samples will be obtained and analyzed. Also, an optimum x-ray yielding condition will be studied by running a special code called "OPERA 3-D". In addition, by adding a focusing electrical lens into the CNT triode a micro-focus x-ray tube will be modeled.

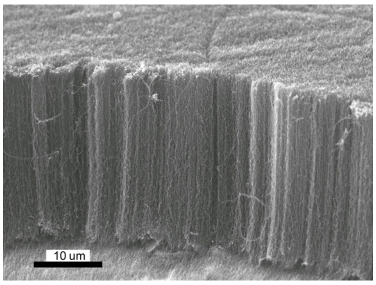

Figure 1. SEM image of the as-grown CNT

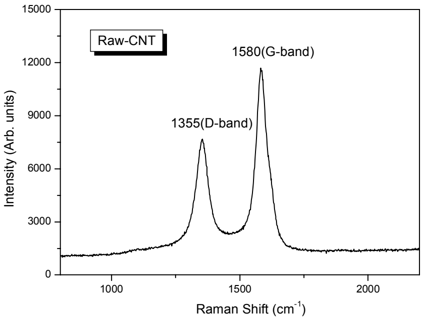

Figure 2. Raman Spectroscopy

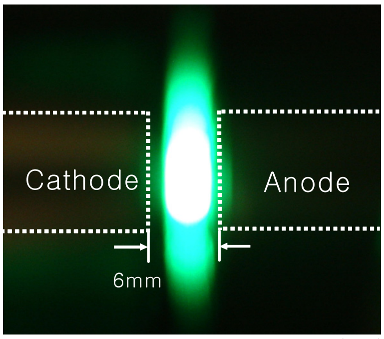

Figure 3. Image of the Electron Emission

Reference

[1] J. S. Kim, K. S. Ahn, C. O. Kim, J. P. Hong, Appl Phys Lett. 82, 1607 (2003).