Density Dependent Emitter Array Design of Electron Beam X-ray Module for High Resolution X-ray Imaging Applications

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ABSTRACT

The relationship between the density of electron emitters and x-ray image quality has been investigated. Under diode mode, x-ray images have been successfully acquired even under 30kV of bias. Vertically aligned CNT emitters were grown as electron emitters. With respect to the inter-emitter pitch, even at the same electrical energy, different emitter patterns showed different image qualities. By optimizing the CNT emitter design, we expect that we can develop a high-resolution x-ray source without using additional focusing components.

1 INTRODUCTION

Carbon Nanotubes (CNTs) have received much attention for its outstanding electrical properties since their discovery.[1] Attributed to their outstanding properties, various applications are viable. Especially, electron emission properties based on quantum mechanics allow them to become electron sources of diverse devices including field emission displays and field effect transistors.[2,3]

CNT emitters have also been applied in x-ray sources.[4] Cold cathode x-ray sources show various extraordinary properties compared to conventional thermionic x-ray sources. First, they operate instantaneously, which able to reduce the radiation dose of the patients. This is a big advantage compared to thermionic emitters since thermionic emitters require time for heating before electron emission. Second, they have smaller beam divergence angle so images with better resolution can be acquired.

In this report, we investigated the relationship of the image quality and the emitter's density. The aim of this research was to verify the feasibility to develop a high-resolution x-ray source with simple manipulation and without complex optical components.

We fabricated diode type x-ray modules with different CNT densities. I-V characteristics and x-ray images from the modules were investigated.

2 EXPERIMENT

2.1 Growth of vertically aligned CNTs in arrays

We prepared vertically aligned CNTs as electron emitters. Samples with different emitter densities were fabricated. Bundled vertically aligned CNTs were grown on silicon wafer by photolithography and DC Plasma Enhanced Chemical Vapor Deposition (DC-PECVD) process.[5]

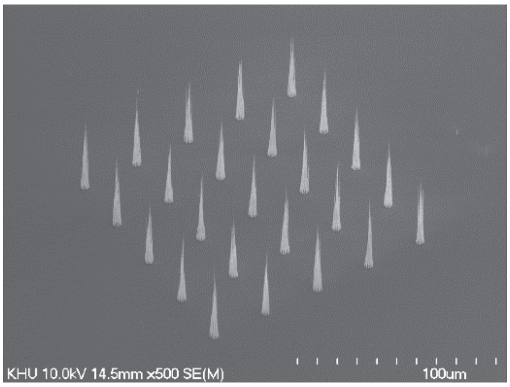

Fig. 1 One island of5 by 5 CNT emitter array

The array of the CNTs were selectively positioned by patterning nickel, the catalyst used in the growth process, on silicon wafer by conventional photolithography. DC-PECVD. By using the home-made recipe, the CNT emitters showed the diameter of 5μm and 40μm in length in average. Fig. 1 shows a one island array with 5 by 5 emitters for the high resolution x-ray imaging.

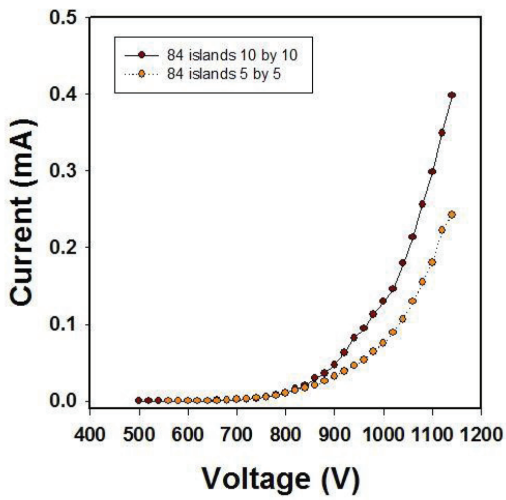

Fig. 2 Comparison of IV characteristics of emitters of 84 islands comprised of 100 emitters and 25 emitters each

2.2 Evaluation of X-ray Image Quality acquired by different density emitters

Fabricated samples were evaluated inside a vacuum chamber in a diode mode.

Before the acquisition of x-ray images, I-V characteristics of different densities of emitters have been investigated. Fig.2 shows the IV characteristics of two samples with 84 islands. However, one sample contained 10 by 10 emitters in one island and the other contained 5 by 5. For the evaluation of electrical properties, the cathode and the anode was kept 250 μm.

Fig.3 shows the schematic of the x-ray generation system. Vacuum was kept in 7×10^{-7} Torr. For the anode, a copper rod with 5 mm tungsten inserted at the surface was used. CNTs were used as the cathode. Maximum voltage of 30 kV was applied on the anode. The distance between cathode and the anode was kept as 10 mm. While checking the current level, x-ray images has been acquired by using a-Se direct type x-ray imaging detector, FDXD-810 (DR-TECH). Various SOD was used to optimize the image resolution. Image qualities of the samples with different densities were evaluated under various electron irradiation conditions.

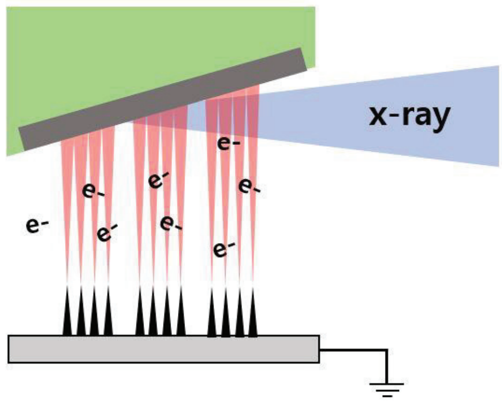

Fig. 3 Schematic of x-ray generation system

3 RESULTS AND DISCUSSION

Fig. 4 shows x-ray image with different exposure conditions. Fig. 5(a) show exposure condition in which PCB image starts to become observable. We could obtain x-ray image at 19kV, however, the image was not clear. Fig. 4(b) is a representative image acquired from this research. X-ray image of a PCB board was taken ay 23 kV. The image was acquired with 84 islands of 10 by 10 emitters in each. Anode voltage was 23kV and the current was 1.4 mA. Even under low current level, an x-ray image in which the lines and IC chips are precisely differentiated has been achieved.

X-ray images were successfully acquired under 30 kV. Image quality was different according to the pattern of the CNT emitters even in the same energy level. We expect that the characteristics are attributed to the quantum mechanical properties of our electron emitters. Further investigation needs to be held by increasing the anode voltage as it is expected to provide better image quality.

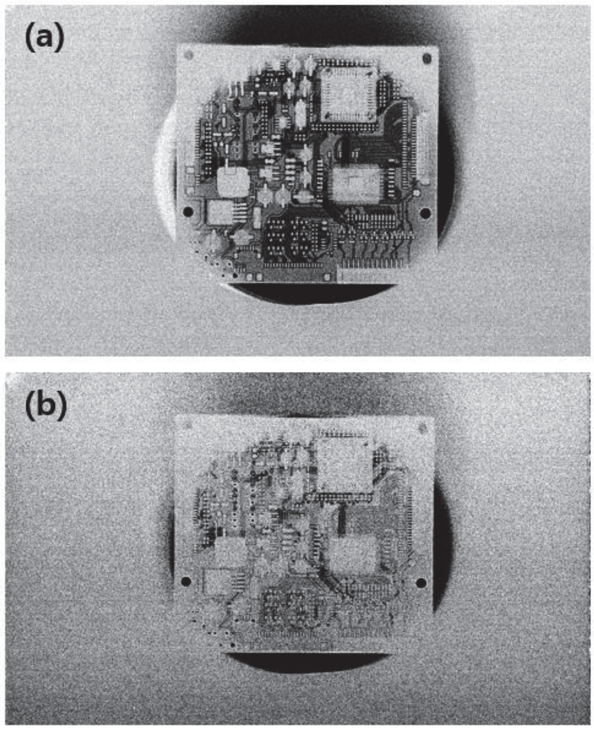

Fig. 4 PCB board x-ray image with 10 by 10 CNT emitter array (a) exposure at 1.4A 23kVp (b) exposure at 1A 19kVp

4 CONCLUSION

Diode type x-ray modules carrying different emitter densities have been fabricated. Vertically aligned CNTs in bundled in a cone shape was used as an electron emitter. X-ray images were acquired under 30kV. Different image quality was obtained according to the different emitter densities. We expect that this research would contribute to the development of high-resolution x-ray source without complicated optical components in the tube structure.

CNT emitters even in the same energy level. Further investigation needs to be held by increasing the anode voltage as it is expected to provide better image.

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