Carbon Nanotube Cold Cathode Electron Beam (C-beam) for Various Ultraviolet (UV) Lighting

Sung Tae Yoo¹ and Kyu Chang Park¹

kyupark@khu.ac.kr
¹Department of Information Display, Kyung Hee University, Dongdaemun-gu, Seoul, 02447, Korea
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ABSTRACT

Ultraviolet (UV) light sources using carbon nanotube electron beam (C-beam) can generate various peak wavelengths. The peak wavelength depends on the structure of the anode materials and is affected by the electron emission characteristics of the C-beam. Here, we report on the performance of UV with anode materials and C-beam.

1 INTRODUCTION

Cold cathode electron beam with various electron emitters are being studied for next vacuum nano-electronics applications. Various electron emission sources have been developed and applied to vacuum nano-electronic devices. Among these electron sources, carbon nanotube (CNT) cold cathode is the most promising electron source candidate [1]. Some companies have started producing x-ray tubes with CNT electron beams, also have commercialized its system.

Ultraviolet (UV) ray is classified into UVA (315 ~ 400 nm), UVB (280~315 nm), UVC (200 ~ 280 nm), VUV (100~200 nm) and EUV (13.5 nm). UV lighting is required in huge industries, such as printing, medical, packaged food, agriculture, semiconductors, displays and more [2]. Specific peak wavelengths are required to be utilized in these applications. Currently, mainly mercury lamps and UV-LEDs are manufactured and applied as UV light sources. However, these UV light sources have some limitations to be applied as next-generation UV lighting [3]-[5].

We developed various UV light sources by irradiating CNT-based cold cathode electron beam (C-beam) on various anode materials such as SrB₂O₄:Eu phosphor, Zn₄SiO₄, sapphire, AlGaN multiple quantum wells [6]-[10]. UVC lights with various peak wavelengths from UVA to UVC emission were made with C-beam irradiation technology.

In this presentation, we report on the fabrication of UV lights in a wide wavelength range from 363 nm to 226 nm. Fabrication of anode layer, performance of UV lighting with C-beam irradiation conditions, C-beam structure and electron emission properties would be presented.

2 EXPERIMENT

C-beam is made of CNT emitters as a core component, and mesh gate and ceramic insulating part are used together. CNT emitters grown on a silicon wafer were prepared to be vertically aligned using dc-PECVD supplied with acetylene and ammonia gas. The SEM image of a CNT emitter with a fully vertically aligned structure is shown in Fig. 1.

Schematic of UV lighting was depicted in Fig. 2. The anode consists of a window, a wide bandgap material and an Al electrode. A quartz glass value was used to transmit UV light. A variety of wide bandgap materials have been used to generate UV light. For the anode electrode, an aluminum electrode was made using thermal evaporation technology.

3 RESULTS and DISCUSSION

Fig. 3 shows the electron emission characteristics of the C-beam. The anode current reaches 1.2 mA at a gate
bias of 950 V. For most UV generation, irradiation of 1.0 mA of anode current is sufficient.

![Fig. 3. Current-voltage characteristics of C-beam.](image)

The peak wavelength of UVC lighting depend on the anode materials, anode structure, and C-beam irradiation conditions. We developed various UV lighting. Fig. 4 shows various UV lighting images with C-beam. The UVA lighting with 363 nm peak wavelength was made with SrB$_4$O$_7$:Eu phosphor anode and annealed at 900 °C ambient atmosphere during 30 minutes [9]. After that, C-beam was irradiated on the anode by applying a bias of 12 kV and a current of 0.5 mA. UVC light generated by using sapphire as an anode has a peak wavelength of 226 nm and was generated by C-beam irradiation with anode bias of 10 kV and anode current of 1.3 mA [10].

![Fig. 4 Photo images of various UV lighting with C-beam Irradiation](image)

Visible light is produced by photoluminescence of the anode materials [10]. The color of light emission varies depending on the wavelength of the UV light [11]. As shown in Fig. 4, if an anode with a wider bandgap material is used, the color changes to pink. Details of the UV lighting for various anode, anode fabrication, and C-beam irradiation condition will be reported.

4 CONCLUSIONS

In this study, we used CNT cold cathode electron pumping technology to fabricate flat panel UV light with various wavelengths. The peak wavelength depends on the anode materials and C-beam driving conditions. Flat panel ultraviolet light source produced by C-beam irradiation is expected to be applied in many applications in optical cleaning, sterilization, deodorization, research, and medicine.

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