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

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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 nanoelectronics applications. Various electron emission sources have been developed and applied to vacuum nanoelectronic 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 SrB_4O_7:Eu phosphor, Zn_2SiO_4, 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.

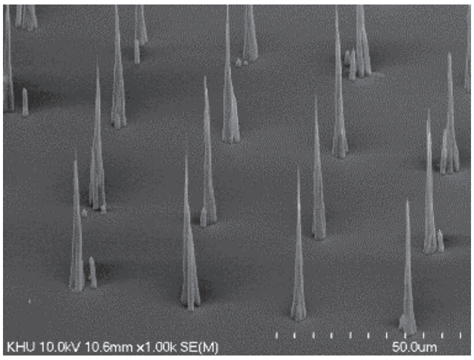

Fig. 1. CNT emitters for UV excitation.

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.

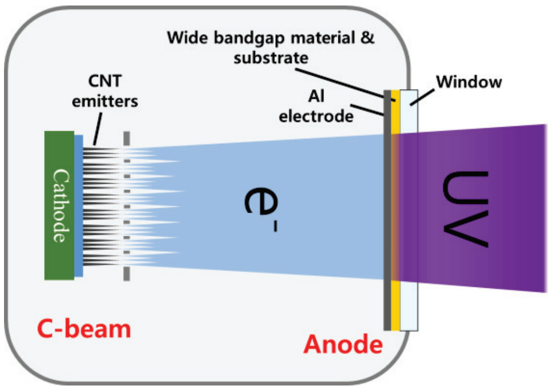

Fig. 2. Schematic of UV lighting.

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.

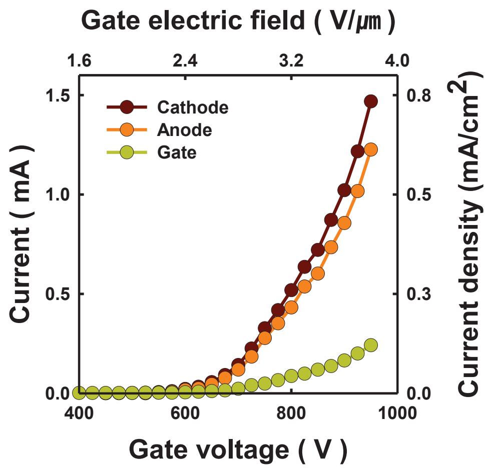

Fig. 3. Current-voltage characteristics of C-beam.

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_4O_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].

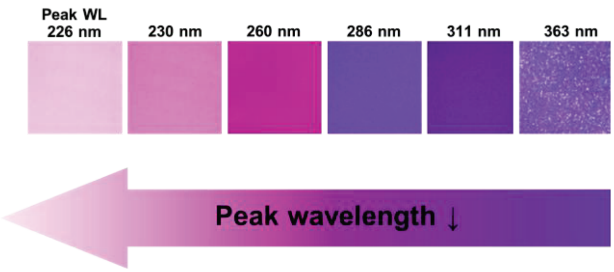

Fig. 4 Photo images of various UV lighting with C-beam Irradiation

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.

5 ACKNOWLEDGMENTS

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