High quality tubular field emission lamp using a wire type carbon-nano-structure emitter (CNX)

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Abstract

The tubular field emission lamp (FEL) was developed using a wire type carbon-nano-structure emitter called CNX. The luminous efficiency of the tubular FEL (diode type, diameter: φ15.5mm, length: 200mm) has already achieved around 45lm/W and we expect to achieve over 60lm/W within the year.

1. Introduction

Liquid crystal displays (LCD) are currently the dominant technology of FPD. To keep this position, a lot of work has been done to improve LCD properties. The late trends of LCD seem to be large size, high qualities, good design and low costs. Backlight unit (BLU) is a key technology for achieving these requirements.

In general, cold cathode fluorescent lamps (CCFL) are used as light sources in BLU. Although CCFL is an excellent light source, it is not a little entirely satisfactory for further quality LCD. And in terms of ecology, mercury is a disadvantage.

Now LED-BLU is expected to be a candidate for the next generation BLU. Since LED is a mercury-free spot light source, it is easy to apply LEDs to thin and large size LCD. As for high quality, it is reported that the local dimming backlight technologies can enhanced the quality of LCD.

But, cost of LED is still so high that it is a real bottleneck for the spread.

Under the present situation, it appears that marketing of LCD will be divided into two directions, that is high-end marketing with high quality and the mainstream marketing with low cost.

As field emission lamp (FEL)-BLU is able to apply to both high-end marketing and the mainstream marketing. FEL-BLU has the potential to be a strong candidate for the next generation BLU. As for high-end marketing, the research group of ETRI in Korea reported at IDW'07 that FEL for dynamic BLU was developed by using the printed carbon nanotube emitters. [1] Our group and Professor Nakamoto's group in Shizuoka university also reported at SID'08 that flat FEL for local dimming LCD BLU was fabricated.[2]

As for the mainstream marketing, it is tried to reduce the number of lamps by using U shape CCFLs for cost reduction. But it is difficult to apply U shape CCFL to over 37''LCD-BLU, so it seems to be effective for reducing the number of lamps by using tubular FELs of 15.5 mm in diameter. From our cost estimation, we judge FEL has a chance of winning, and in this paper, we report the recent progress of our tubular FEL.

In addition, as one of other applications of FEL, we will suggest the bulb type FEL as a substitute for an incandescent lamp at the day of presentation.

2.Structure of our tubular field emission lamp

Although FELs are widely developed by many companies and research institutes in many countries including Japan and Korea, most of research activities focus on flat FELs and there are few reports about tubular FELs. A tubular FEL emits light in all directions like a fluorescent lamp. In order to emit light in all directions, electron-emitting material films have to be developed by some methods on a wire type metal substrate all around. But these are very difficult. We think this is one reason why there are few reports about tubular FELs.

As shown in Fig.1, we have already developed the emitter growth technology on metal wire substrate (diameter from 0.1 to 2mm, the length from 10 to

1000mm) by using a specially designed CVD.

Fig.1. Wire-type Emitters with different lengths.

Fig.2 shows the schematic of our tubular FEL in cross section. We adopt diode structure for cost reduction, so it is very simple structure, which consists of only anode and cathode. Nano-carbon electron emitter called CNX, which is developed on a wire type metal substrate by a specially designed CVD, is used as a cathode. The anode is composed of ITO layer, phosphor layer inside the glass tube. A new green phosphor ($SrGa_2S_4$:Eu), whose luminance is 1.4 times as high as that of ordinary P22-G at an acceleration voltage of 6kV, is mixed with P22-B and P-22 R phosphors to form the phosphor layer.

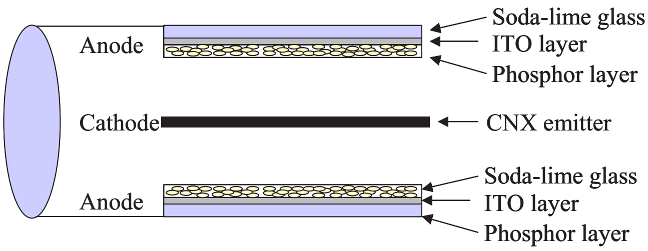

Fig.2. Schematic of our tubular FEL in cross section.

3.Results and discussion

Figure 3 shows scanning electron microscopy (SEM) image taken from the CNX film. A straight carbon needle stands upward, around which there are many pieces of carbon nano-walls. The carbon nano-walls at the bottom of needle are large, and those at the upside are small, which indicates that the carbon needle was firstly grown, then, the nucleation of carbon nano-walls were formed along the needle from bottom to upside, and the carbon nano-walls were appeared and gradually become large with growth time lasting. As our group has already reported, the CNX emitter has the excellent emission property whose emission current density was 109mA/cm^2 at 2.5V/μm. Due to the special structure, the CNX emitter is easy to obtain high-filed concentration, and can also avoid screening effect. [2,3]

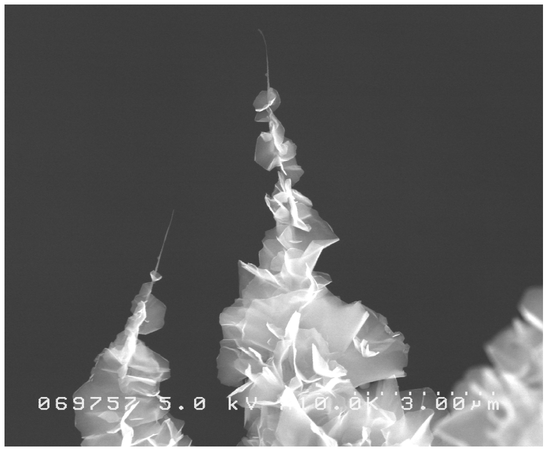

Fig.3. SEM image of CNX film.

On the other hand, the luminous efficiency of the anode using P-22 phosphors should be considered. As Kumho Electric, Samsung SDI (Korea) pointed out, we have to apply high voltages and low current densities to get high efficiency. [4]

Since a triode type FEL can control the current density by using the gate electrode, it is better to adopt the CNX emitter, which has the excellent emission property. But in the case of a diode type FEL, the current density is not controllable, so we have to change the emission property of the CNX emitter to low current density at high voltages.

Generally, if we use an emitter whose emission property is low current density at high voltages, the luminous condition is not good due to a lack of emission sites densities.

So we had studied growth conditions of CVD and finally we have succeeded in developing modified CNX emitter whose emission property is low current densities at high voltages with high emission sites densities, as shown in Fig.4, 5.

We fabricated the tubular FEL (diameter: ϕ 15.5mm length:200mm) by using modified CNX emitter and measured the luminous properties with DC drive by a integrated sphere. The luminance was over 10,000cd/m^2 with an efficiency of 42 lm/W at an acceleration voltage of 8.5kV(current:0. 5mA).

The luminous efficiency of our FEL is a little lower than that of CCFL at present, but by completing the technology of Al film evaporation on the phosphor layers (under developing), we expect to achieve over 60lm/W within the year.

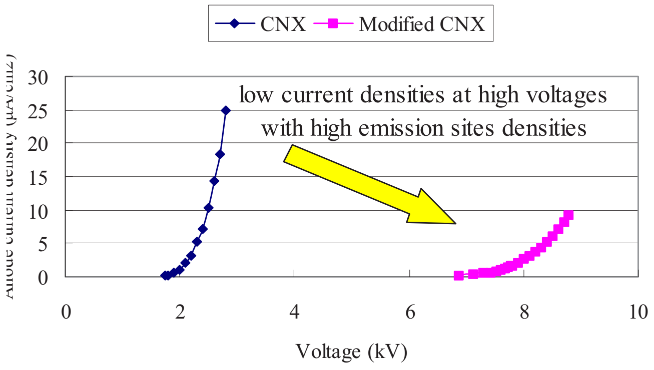

Fig.4. Filed emission property of modified CNX film.

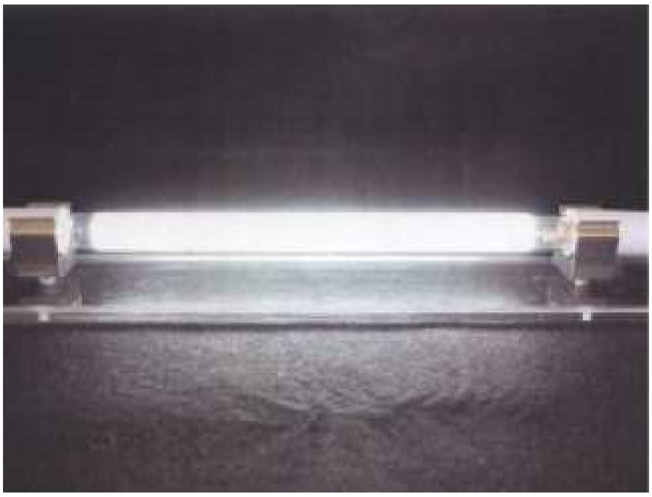

Fig.5. The tubular FEL
(diameter: Φ 15.5mm , length:200mm)

4.Conclusion

A tubular field emission lamp using a wire type modified CNX emitter has been developed. The efficiency has already achieved around 45lm/W and we expect to achieve over 60lm/W within the year.

In addition, as one of other applications of FEL, we will suggest the bulb type FEL as a substitute for an incandescent lamp.

5.References

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