Field Emission Emitters Fabricated Using Carbon Nanotube Blasting

Ching-Ming Hsu, Wen-Tuan Wu, Ting-Shao Liu, Kun-Chi Wu, Jian-Shin Wu and Jiun-An Chen

Southern Taiwan University of Science and Technology, Department of Electro-Optical Engineering, 1 Nan-Tai St, Yung-Kang District, Tainan City, Taiwan 710, tedhsu@mail.stust.edu.tw

ABSTRACT

A traditional sand-blasting technique has been employed to implant carbon nano-tube (CNT) emitters onto a silver (Ag) electrode. This approach allows most of CNTs to stand on silver surfaces instead of being buried in Ag paste as the traditional screen-printing method does. Results from SEM images showed that the density of CNT-emitters on silver surfaces with this approach is much higher than the traditional screen-printing method. This leads to the current density ratio between blasted and screen printed CNT emitters measured to be as high as 500. The uniformity of phosphorous light-emitting induced by the blasted CNT electrons was also found improved. To our acknowledge, it is for the first time that CNT-emitters with this kind method are fabricated. The success of this technique is expected to open a new way for fabricating CNT-emitters at a lower cost and with higher emission performances.

Keywords: carbon nanotube, emitter, sand-blasting, screen-printing

1 INTRODUCTION

Carbon nano-tube (CNT) has been considered to apply for many optoelectronic devices since its discovery by Ijima in 1991 [1]. One of the superior potentials of CNTs is their high field emission characteristic, attributed to the extemely high aspect ratio of their physical appearances with a tube diameter generally less than 100 nm. Such an unique archetecture naturely brought CNT to be considered as an emitter candidate for electron suorces. The applications of CNT lectron emitters for field emission displays, x-ray sources, gas sensors, ionization vacuum gauges, etc. have been increasingly studied [2-5]. However, these devices need highly stable electron emission and high electron efficiency to bring these applications to a commercial stage. Hence, fabricating a field emission anode containing highly stable and efficient CNT-emitters is a topic of interest to study.

A field emission anode containing carbon nano-tube emitters are generally prepared by direct growth with chemical vapor deposition [6] or screen printing of conductive paste [7]. The direct growth is a complicate process and usually results in a high cost, although uniform and dense CNTs can be produced. On the contrary, the screen printing method is more cost effective but suffers from low current density and non-uniform electron emission. From the production point of view, the latter method is a prefered for its simplcity and low cost. Hence, overcoming the disadvantage of low current density for the traditional screen-printed CNT emitters is an important issue to work on.

In this work we proposed a novel approach, named CNT-blasting, aiming to fabricate CNT-field-emission anodes with high emission performances and cost effective. This approach implants CNTs directly onto a screen printed silver paste by traditional sand blasting method. The CNT-blasting allows CNTs to implant only on surfaces of Ag paste without being fully buried in th Ag paste. The blasted CNTs out of Ag area can be collected and reused. Hence, comparing with the conventional screen printing method, the CNT-blasting approach provides the advantages of producing CNT emitters with less CNT consumption and higher surface density.

2 EXPERIMENTALS

2.1 Preparation of CNT Emitters

The preparation of cathode plate consisting of CNT field emitters started with the screenting printing of silver, glass powder and solvent mixed paste on a pre-cleaned glass substrate. The glass consists of a commercially coated indium tin oxide (ITO) film of 7 ohm. The screen printed conductive paste was measured to have an area of 20 mm x 20 mm. CNTs were then blasted onto the silver paste at an air pressure of 3 kg/cm^2 using a tradional sand blasting tool, as schematically illustrated in Fig.1. This was followed by sintering the paste at a temperature of 400 ^{o}C for 10 min to ensure a better contact with CNTs and silver/glass substrate. After the sintering, the surface of the cathode was N_2 blown to remove CNTs which are not implanted firmly into silver plate.

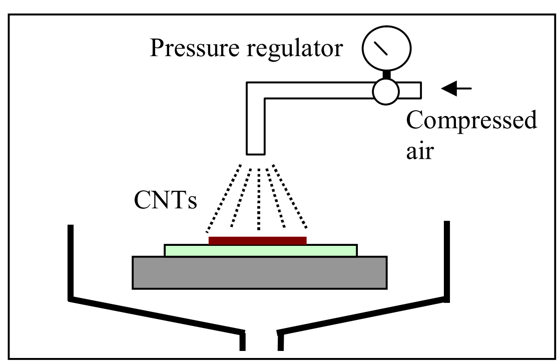
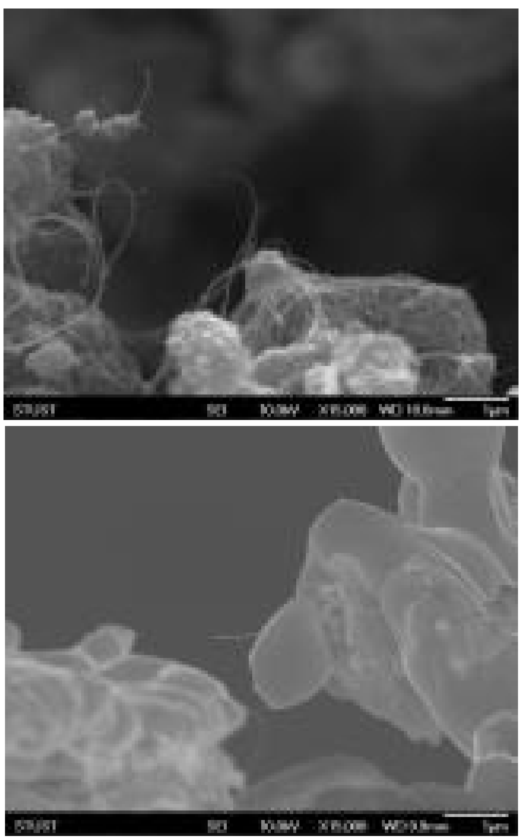


Fig. 1 Scehmatic of the CNT-blasting tool

NSTI-Nanotech 2013, www.nsti.org, ISBN 978-1-4822-0581-7 Vol. 1, 2013

2.2 Charaterization of CNT Emitters

To characterize the currnt-volatge (I-V) relationship of the CNT emitters, another ITO glass was employed to act as a counterpart anode. To perform the luminance-volatge (L-V) characteristics of the CNT emitters, phosphoroscence based phosphers were additionally screen printed on the ITO glass. The cathode and anode plates were then combined to a piece with a cell gap of aound 200 um between the two plates. The two glass substrates were separated by quartz pads. The measurement of field emission characteristics of CNT emitters was conducted by applying voltages ranging from 0 to 1000 volt using a keithley-237 I-V meter. The corresponding luminance of the emitted light from the phosphers was measured using a PhotoSearch PR650 photospectrometer.



(a)

(b)

Fig. 2 SEM images of CNTs on silver prepared by (a) CNT-blasting and (b) screen printing.

3 RESULTS AND DISCUSSIONS

3.1 Topograpgy of CNT Emitters

The blasted-CNT emitters appearing on surfaces of silver are revealed by scanning electron microscope (SEM) imaging (Fig. 2a). The SEM image of CNT emitters fabricated by screen printing is also shown for comparison, as can be seen in figure 2b. Both silver surfaces were not treated with taping to yield CNT-emitters normal to the surface. Apparently from the images, on can see that the blasted CNTs are much more abundant on Ag surfaces than those screen-printed, indicating higher CNT density can be obtained by the CNT-blasting method. The blasted CNT-emiters were also proved to be able to naturally stand upward without the taping process. However, it is not clear how firmly these blasted CNTs stay on the silver surfaces and how well these CNTs in contact with the silver. We would measure this by observing I-V characteristics of the blasted CNT-emitters.

3.2 I-V Charateristics of CNT Emitters

Fig. 3 shows the I-V characteristics for both blasted and screen printed CNT-emitters. It is clear that the I-V characteristic of the CNT-emitters prepared by CNT-blasting method was significantly improved. The current density of blasted CNT-emitters is at least 3.7 times higher than that of screen printed emitters. At voltages higher than 600 V, the current density ratio between blasted and screen printed CNT emitters can be as high as 500. The electric current of blasted CNT-emitters, however, shows overshoot at volatges less than 400 V. This could be resulted from over current flow through some CNT-emitters which protrude too much on silver surface. These CNTs could have been burn due to the local high joule effect, and left the rest of CNTs to performance their nornal I-V characteristics. Assuming current density is directly proportional to the density of CNT-emitters, one can then estimate that the density of CNT-emitters by blasting method could be 500 times that by tradional screen printing method. And from this aspect, we could confirm that the blasted CNTs were firmly implanted into silver surface and in good contact with the silver. The next question would be "could these blasted CNT-emitters be able to ignite light-emitting of the phosphors on the counter-electrode.

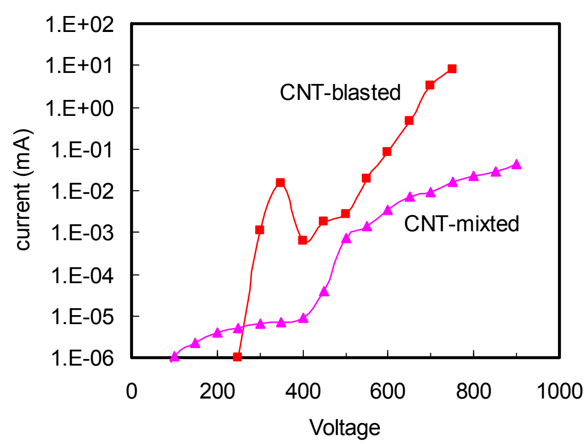


Fig. 3 I-V characteristics of CNT-emitters on CNT-blasted and CNT-screen printed Ag paste.

3.3 Phosphorous Illumination by CNT Emitters

To demonstrate the balsted-CNTblasted emitters can properly operate for phosphorous light-emitting, CNTs were blasted onto Ag pastes in forms of a 2cm x 2cm square and CNTFED letters, as shown in Fig. 4a-b. Phosphorous light-emitting can be clearly seen at a starting voltage of 400 V and it went very bright at 600 V. Fig. 4 (c) and (d) shows the images of the light-emitting from the 2cm x 2cm square and CNTFED letters operated at a volatge of 800 and 500 V, respectively. Comparatively for screen-printed CNT-emitters, the luminance of the excited phosphors was hardly measured. And from our experiences, the light-emitting from phospors for screen-printed CNT-emitters are usually non-uniform. This reflects the poor distribution of CNTs in the silver paste, attributed to the difficulty on dispersion process of CNTs. However, we observed that the lumination from CNTFED letters does not look like very uniform as well. This is believed not due to the non-uniform distribution of the blased CNTs. The non-uniformity of the screen-printed silver is reckoned to be responsible for such an observation. The even but discontinuous light-emitting along the line of a letter is the evidence revealing the non-uniformity of the screen-printed silver.

From the results shown above, we could conclude that an electron emitter fabricated by blasting CNTs on silver surface could perform better I-V and L-V characteristics than those by screen printing method. The main breakthrough point is that the CNT-blasting method coule easily generate CNT-emitters of high density on a surface. Nevertheless, it is noticed that the surface uniformity of blasted CNT-emitters is still not promising due to the screen-printed silver base, and has to be improved as compared to direct growth methods.

4 CONCLUSIONS

This study has demonstarted that a silver electrode containing CNT emitters can be fabricated by directly blasting CNTs onto silver surfaces. SEM images revealed that the density of blasted CNT-emitters on silver surfaces is much higher than that by the traditional screen-printing method. Results from I-V and L-V characteristics confirmed that the blasted CNTs exhibit superior emission ability to the screen-printed ones. The current density ratio between blasted CNT emitters and screen printed CNT emitters is calculated be as high as 500, attributed to the difference on surface density of CNTs. To our acknowledge, it is for the first time CNTs are implanted onto a silver anode using a traditional sand-blasting method. The success of this technique is expected to provide a new choice for fabricating CNT-emitters at a lower cost and with higher emission performances.

(a) (b) (c) (d)

Fig. 4 CNTs were blasted on Ag pastes in forms of a 2cm x 2cm square and CNTFED letters. Phosphorous light-emitting can be observed with the CNT-blasted emitters.

REFERENCES

[1] S. Iijima, "Helical microtubules of graphitic carbon ", Nature, 354, 56-58, 1991.

[2] W. B. Choi, D. S. Chung, J. H. Kang, H. Y. Kim, Y. W. Jin, I. T. Han, Y. H. Lee, J. E. Jung, N. S. Lee, G. S. Park and J. M. Kim, "Fully sealed, high-brightness carbon-nanotube field-emission display", Appl. Phys. Lett., 75, 3129-3131, 1999.

[3] G. Z. Yue, Q. Qiu, Bo Gao, Y. Cheng, J. Zhang, H. Shimoda, S. Chang, J. P. Lu and O. Zhou, "Generation of continuous and pulsed diagnostic imaging x-ray radiation using a carbon-nanotube-based field-emission cathode", Appl. Phys. Lett., 81, 355-357, 2002.

[4] S. Chopra, K. McGuire, N. Gothard, A. M. Rao and A. Pham, "Selective gas detection using a carbon nanotube sensor", Appl. Phys. Lett., 83, 2280-2282, 2003.

[5] A. B. Kaul, "Carbon Nanotube Vacuum Gauges With Wide Dynamic Range", IEEE Trans. Nanotech., 8, 252-257, 2009.

[6] G. Patil, C. Sarode, R. Patil, S. Gokhale, " CVD Synthesis of Highly Graphitized Single-walled Carbon Nanotubes Using Nitrogen-pretreated Fe-Mo/MgO Catalyst", Chem. Lett., 41(9), 871-873, 2012.

[7] H.C. Wu, M.J. Youh, W.H. Lin, C.L. Tseng, Y.M. Juan, M.H. Chuang, Y.Y. Li, A. Sakoda, "Fabrication of double-sided field-emission light source using a mixture of carbon nanotubes and phosphor sandwiched between two electrode layers", CARBON, 50**(**13), 4781-4786**,** 2012