

The Study of Fabricating the Field Emission Lamps with Carbon nano-Materials

K. J. Chung, C.C.Chiang, Y.M. Liu, N. W. Pu, M. D. Ger

Abstract—Fabrication and efficiency enhancement of non-mercury, high efficiency and green field emission lamps using carbon nano-materials such as carbon nanotubes as cathode field emitters was studied. Phosphor was coated on the ITO glass or metal substrates as the anode. The luminescence efficiency enhancement was carried out by upgrading the uniform of the emitters, improving electron and thermal conductivity of the phosphor and the optimization of the design of different cathode/anode configurations. After evaluation of the aforementioned parameters, the luminescence efficiency of the field emission lamps was raised.

Keywords—Field emission lamps, carbon nano-materials, luminescence efficiency

I. INTRODUCTION

THE development of nano materials is expected to bring about breakthroughs for industrial technologies. The nano particles with sizes ranging from 0.1~100 nm exhibit extraordinary properties such as the interface effects (surface effect), quantum size effects and macro-quantum tunnel effect, etc. The fantastic optical, electronic, magnetic, and chemical properties attracted great interest among scientists. In recent years, the nano carbon materials (carbon nanotubes, nano-graphite sheets, carbon nanofibers and carbon nanocoils, etc.) have been the most promising new material for many applications.

Carbon nanotubes (CNTs) have good potential for the application to field emitters because of their high aspect ratio in dimension, low threshold voltage, and good emission stability. The methods to fabricate CNT field emitters include paste screen-printing of CNT powders[1], direct growth of CNT arrays using chemical vapor deposition (CVD) methods[2], and electrophoretic depositing method[3].

Field emission technology has many applications such as field emission displays, field emission light sources[4-6], and microwave amplifiers[7]. Currently, energy-efficient lighting has become an important terrain of green technologies. The field emission lamp as a light source possess higher luminous efficiency than incandescent[8] and fluorescent lamps, and more importantly, it is mercury-free, in contrast with fluorescent lamps[9] filled with mercury vapor.

Here we report a method to fabricate non-toxic, high efficiency, and green field emission lamps (FELs) using carbon nano-materials, such as carbon nanotubes or carbon nano-coils, as field emitters. A new method utilizing Poly (Styrene-co-NipAAm)/Pd was developed to improve the carbon nano-materials deposition, and make the fabricating steps easier. The luminescence efficiency enhancement was carried out, by upgrading the uniform of the emitters, improving electron and thermal conductivity of the phosphor and the optimization of the design of different cathode/anode configurations. After evaluation of the aforementioned parameters, the luminescence efficiency of the field emission lamps was raised.

II. EXPERIMENTAL

A. Sample preparation

Figure 1 showed the schematic diagram of the processing steps. The substrates used are steel wires. The length is 10 cm and the diameter is 2mm. Firstly, the substrate is cleaned with acetone in the ultrasonic cleaner. Secondly, the substrate surface is roughened by sand blasting. Thirdly, we dispersed the multi-wall carbon nanotubes (MWNTs) purified by heat and acid treatments in the water, and then added Poly(Styrene-co-NipAAm)/Pd to form a nano-composite solution. The MWNTs and Poly(Styrene-co-NipAAm)/Pd were co-deposited by dipping the nano-composite solution on the surface of substrate. Finally, a Ni-P layer was electroless plated as a capping layer, and the MWNTs are uniformly embedded in the Ni-P film which offers better adhesion to the substrate and higher electrical conductance.

B. Field emission test

Figure 2 showed the schematic diagram of our field emission bulb. In the test, the anode plate and cathode plate was separated with 3cm pad isolators (spacer), and was clamp to fix with the tail clip. The field emission properties of our bulbs were test in a vacuum environment of 3×10^{-6} torr and the supply voltage from 0 ~ 10000V.

C. Electron conductivity of the phosphor test

In this study, the graphene was added to the fluorescent powders to improve the anode's conductivity properties. The electrical properties and the improvement of the phosphor efficiency were evaluated.

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III. RESULTS AND DISCUSSION

A. Surface morphology of the samples

Figure 3(a) shows the TEM photograph of the Poly(Styrene-co-NipAAm)/Pd. Fig.3(b) shows the nano composite of 0.2 wt.% MWNTs and 300 ppm Poly(Styrene-co-NipAAm)/Pd. It reveals that the MWNTs and the Poly(Styrene-co-NipAAm)/pd form a uniform nano-composite solutions.

Figure 4 showed the SEM of CNTs/Ni-P nano-compositing plating layer where we can observe that MWNTs are uniformly embedded in the Ni-P film and the exposed MWNTs are well revealed. It shows the MWNTs having good adhesion with the substrates. The concentration of MWNTs and Poly(Styrene-co-NipAAm)/pd are 0.2wt % and 300ppm, respectively. We mixed them in the solution and then dipped the substrates 1-2 times into it for 5min. The substrate was then heated to dry in 90°C oven. Electroless plating of Ni-P film was conducted for 3min to embed the MWNTs on the Ni-P layer. The pH value of the bath was 5.0 ± 0.1 , and the plating temperature was controlled in the range of $50 \pm 1^\circ\text{C}$.

B. Field emission test

There are some literatures indicated that doping part of the fluorescent powders with carbon nanotubes or other conductive particles can increase the thermal conductivity and enhance the phosphor's efficiency. In recent years, nano-graphite flakes or graphene have attracted a considerable attention as a new nano-materials. Their electrical and thermal conductivity properties are subject to expectations. Our research group has plentiful experience on the preparation of nano-graphene sheets and related researches. Our graphene was shown in Figure 5. We mixed the fluorescent compound with our nano-graphene sheets, as shown in Fig. 6. The result reveals that the conductivity of the originally non-conductive phosphor surface can be increased to $10^4 \Omega / \square$, which significantly improved the life of the phosphor in the field emission test without apparent loss of the lighting efficiency.

In Fig. 7, we combined the previous best parameters of the filament and the phosphor in the anode to prepare the field emission bulbs. And the result shows the voltage is about 7 KV in 2 mA (the work is about 14 W), the brightness is about 15000 cd/m^2 .

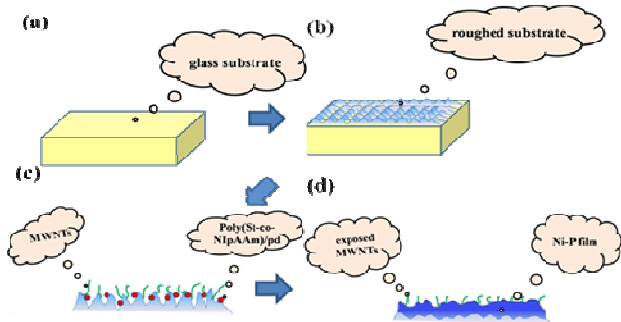


Fig. 1 The schematic diagram of our field emitter production steps

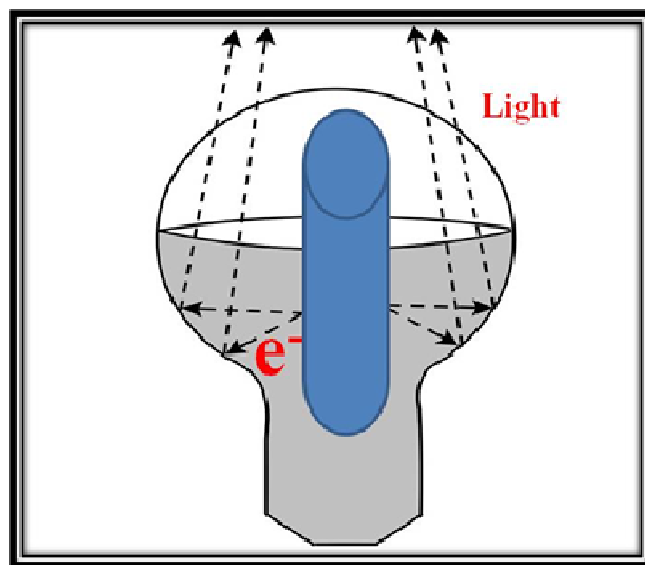


Fig. 2 Schematic diagram of our field emission bulb

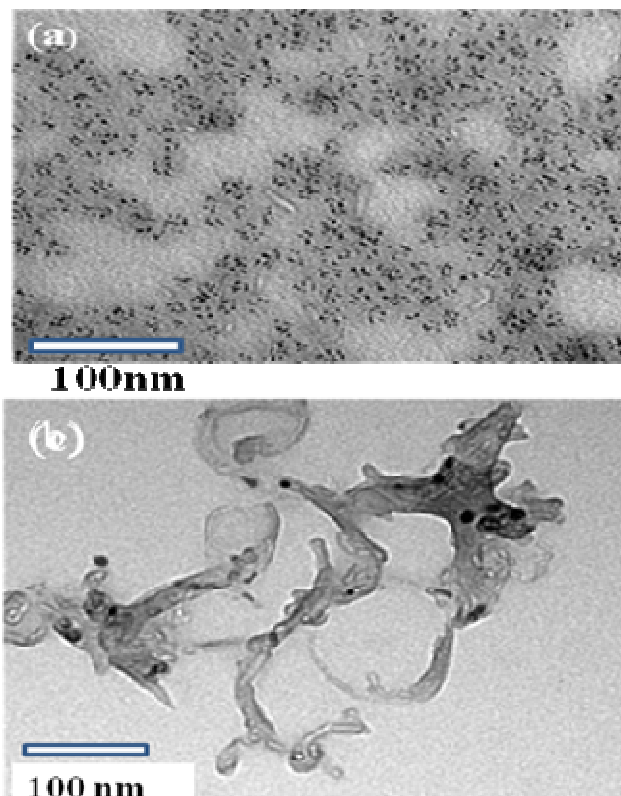


Fig. 3 TEM images of (a) Poly(Styrene-co-NipAAm)/pd. (b) Nano-composite of the Poly(Styrene-co-NipAAm)/pd/MWNTs. The MWNTs and Poly(Styrene-co-NipAAm)/pd are 0.2 wt.% and 300 ppm, respectively

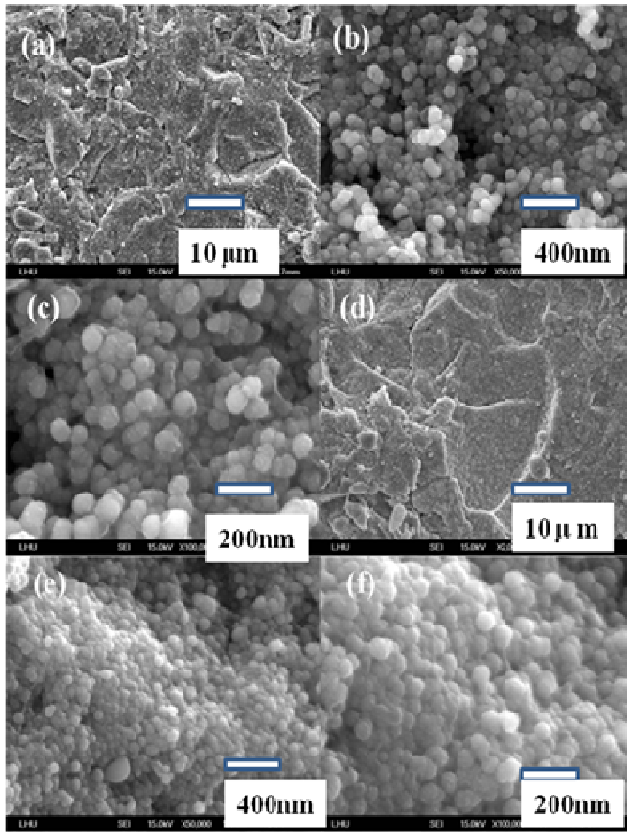


Fig. 4 The SEM surface morphology images of the rough substrate by dipping with the same concentration of 400ppm CNT composite Pd catalyst solution one time(a) (b) (c) and two times (d) (e) (f) and then electroless plating with Ni-P for 3 min

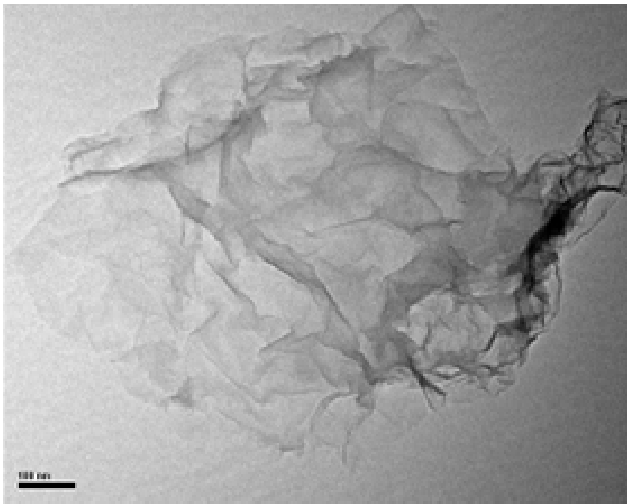


Fig. 5 The research team prepared the TEM image of nano-graphene sheets

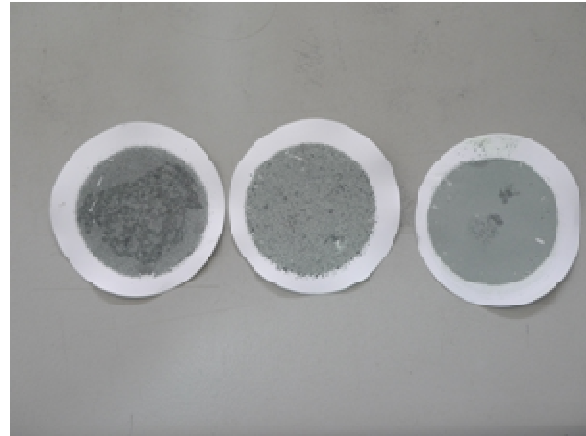


Fig.6 The fluorescent powders added with different concentration graphene nano-sheets.

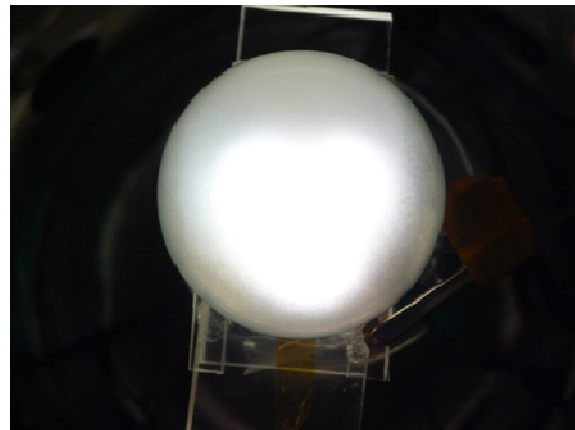


Fig.7 The FEL light bulb diagram

IV. CONCLUSION

We can fabricate a non-mercury, high efficiency and green field emission lamps using carbon nano-materials such as carbon nanotubes as cathode field emitters. Now the brightness is about 15000 cd/m^2 , but as the time it decline because of the phosphor aging. In the future, we will improve the heat and conducted problem of the phosphor continuously.

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