

## Relationship between Field Emission Property and Composition of Carbon Nanotube Paste for Large Area Cold Cathode

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### Abstract

*CNT paste was fabricated by mixture of multi-walled carbon nanotubes (MWNT) powder, organic vehicles and inorganic binder. Then firing process was performed at different temperature under air and N<sub>2</sub> atmosphere. It was found that emission property of CNT paste was changed by firing temperature and time due to interaction between remained resins and CNT powder. We obtained good emission property from CNT paste treated at 350°C for 10 min.*

### 1. Introduction

CNTs have shown excellent field emission properties and would be potential candidate for use in cold cathode flat panel displays.[1-4] Many fabrication techniques such as chemical vapor deposition (CVD), arc discharge and laser ablation could produce an amount of CNTs with high aspect ratio.[5,6] But these method are difficulty to application in large area cold cathode of field emission display (FED) due to complicated fabrication process and high cost. Recently, screen-printing process using CNT paste was adopted to form the cathode layer due to low cost, simple process and mass production. [7,8] In case of screen-printing process, ration of organic vehicles,

inorganic binder and CNT powder determine that the fluidity of CNT paste. Especially, because CNT powder in paste was fixed by inorganic binder after firing process, content of inorganic binder in paste play an important role in property of CNT paste. Therefore, firing temperature, atmosphere and time acted as an important process parameter in controlling the electron emission of CNT paste. In this study, we investigated relationship among firing temperature, time, composition and emission property of CNT paste.

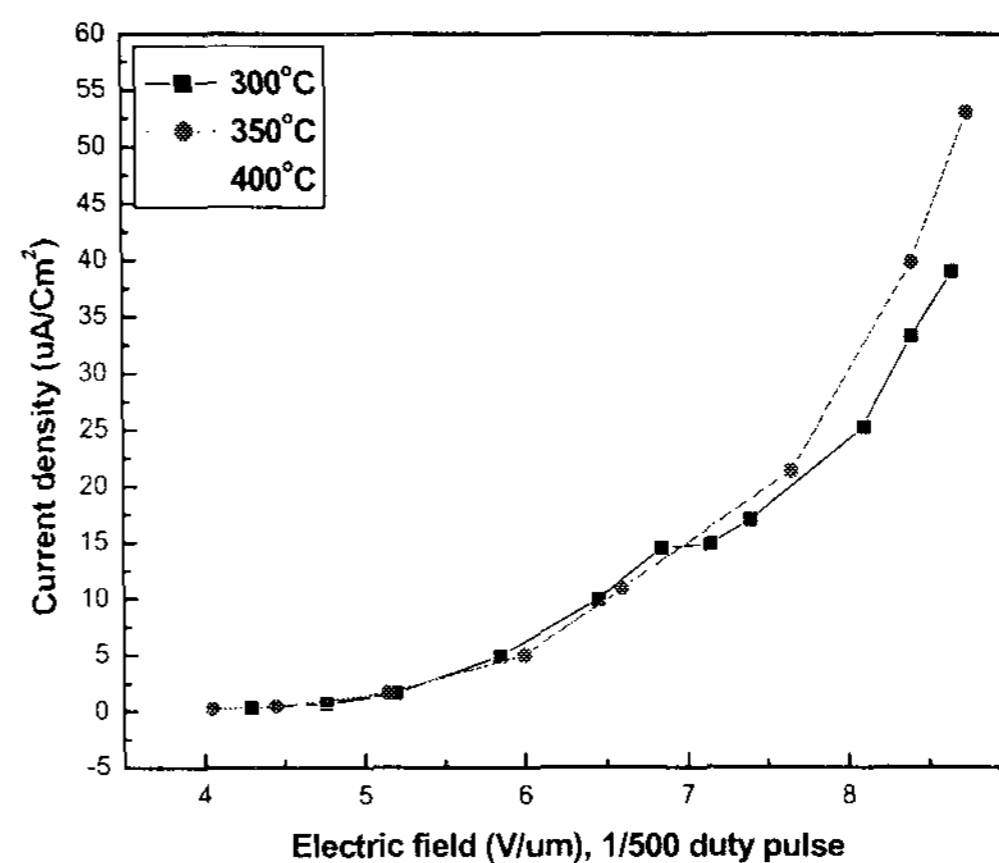
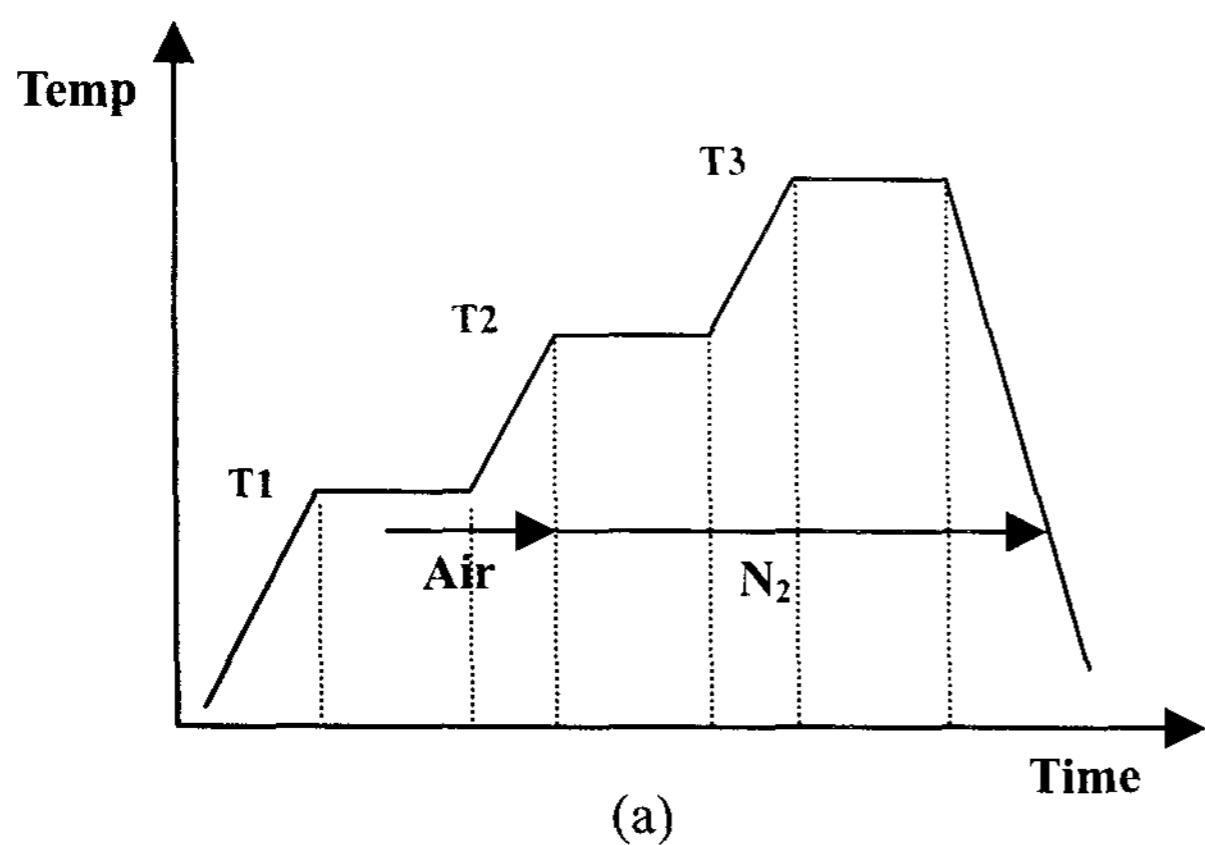
### 2. Experiment

After MWNT powder synthesized by thermal CVD (TCVD) was crushed with ball milling process, it was mixed with organic vehicles to form the paste. And then mixed CNT paste passed through 3-roll mill. CNT paste was printed onto ITO coated glass substrate by paste squeeze. In order to remove the organic binder in CNT paste, heat treatment was performed in a vacuum furnace at different temperatures and time under air and N<sub>2</sub> gas as shown in Fig 1(a). And morphology of CNT paste was also investigated through scanning electron microscopy (SEM). The emission characteristics were measured in a vacuum chamber with a parallel

diode-type configuration at  $3 \times 10^{-6}$  Torr. Cathode area was  $2 \times 2$  cm.

### 3. Results and Discussion

Fig 1 (a) shows temperature profile and ambient gas. CNT paste was placed in the furnace at T1 for 10 min in order to evaporate the solvent under air atmosphere. And then temperature was increased to T2 ( An increase rate was  $10^\circ\text{C}$  per minute ). At T2, furnace atmosphere was changed to  $\text{N}_2$  gas instead of air to atmospheric pressure. CNT powders in paste were fixed by inorganic binder after firing process. Because inorganic and organic binder melt in between T2 and T3, T2 temperature and time play an important role in field emission characteristics of CNT paste such as uniformity, stability and cathode life. Finally, after it was maintained at T3 for 10 min, temperature decreased from T3 to room temperature. Emission measurement was performed with CNT paste treated at different T2 ( 300, 350 and  $400^\circ\text{C}$  ) for 10 min. We observed through Fig 1(b) that the best result was obtained from CNT paste treated at  $350^\circ\text{C}$ . We suggested that because CNT was oxidized by  $\text{O}_2$  gas at high temperature ( $400^\circ\text{C}$ ) and inorganic and organic binder insufficiently melted at low temperature ( $300^\circ\text{C}$ ), emission property was poorer than CNT paste treated at  $350^\circ\text{C}$ .



(b)

Fig 1. (a) Heat treatment temperature profile and ambient gas, (b) emission characteristics of CNT paste treated at different firing temperature.

Fig 2 shows the morphology of CNT paste after firing process for different time.

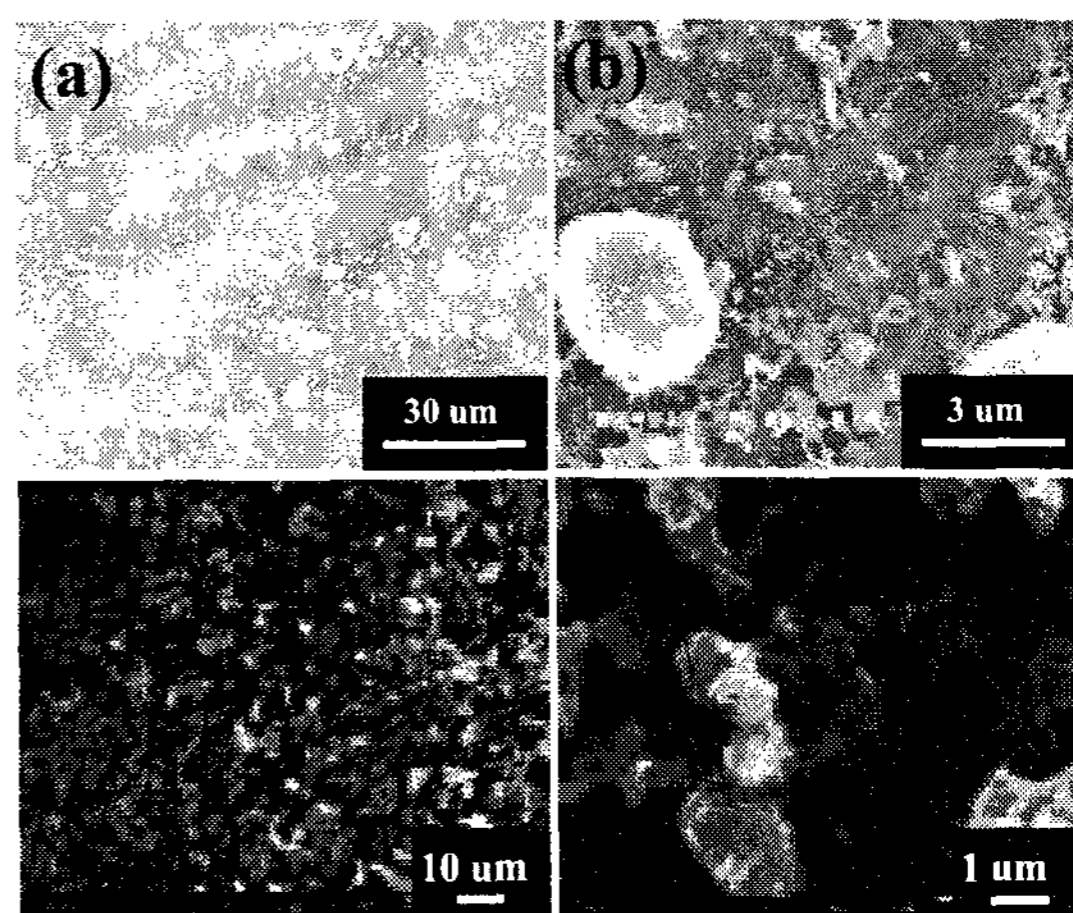


Fig 2. FESEM images of CNT paste after firing process for different time ; (a) and (b) for 10 min, (c) and (d) for 30 min. (b) and (d) were high magnification of (a) and (c), respectively.

We can clearly observe the remained resin and CNT powder after firing through fig 2. Current density of

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30  $\mu\text{A}/\text{cm}^2$  was obtained at 8.1 V/ $\mu\text{A}$  from CNT paste treated for 10 min (Fig 2 (a) and (b)). However, in case of CNT paste treated for 30 min, field emission was not accomplished at high electric field. Increase in firing time, inorganic binder mostly melted in paste. CNT powders were covered with melted inorganic binder as shown in fig 2 (c) and (d). Therefore, we can confirm that because melted inorganic binder covered up CNT powder, field emission was not accomplished.

#### 4. Conclusion

Emission characteristics of CNT paste were measured at various firing temperatures. We obtained good emission property from CNT paste treated at 350 °C. In case of CNT paste treated for 30 min, field emission was not accomplished due to melted inorganic binder.

#### 5. Acknowledgement

This research was supported by a grant ( M1-02-KR-01-0001-02-K18-01-016-1-2 ) from Information display R&D Center, one of the 21st Century Frontier R&D program funded by the

Ministry of Science and Technology of Korea government.

#### 6. Reference

1. 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, *Appl. Phys. Lett.* **75**, 3129 (1999).
2. S. J. Tan, A. R. M. Verschueren, and C. Dekker, *Nature (London)* **393**, 49 (1998).
3. Y. Saito, K. Hamaguchi, T. Nishino, K. Uchida, Y. Tasaka, F. Ikazaki, M. Yumura, A. Kasuya, Y. Nishina, *Nature (London)* **389** (1997) 554.
4. B. R. Chalamala, Y. Wei, and B. E. Gnade, *IEEE Spectrum* **43** (1998).
5. Suk Jae Chung, Sung Hoon Lim, Choong Hun Lee, et al., *Diamond Relat. Mater.* **10** (2001) 248.
6. Young-Rae Cho, Jin Ho Lee, Yoon-Ho Song, et al., *Mater. Sci. Eng. B* **79** (2001) 128.
7. Jong Min Kim, Won Bong Choi, Nae Sung Lee, Jae Eun Jung, *Diamond Relat. Mater.* **9**, 1184 (2000).
8. L. Yukui, Z. Changchun and L. Xinghui, *Diamond Relat. Mater.* **11**, 1845 (2002)