Characterization of the 2 inch CNT-FED Fabricated by using a Vacuum In-Line Sealing Technology

Sang Jik Kwon, Tae Ho Kim, Euo Sik Cho*, Byeong Kyoo Shon, Hyung Soo Uh, Jong Duk Lee,* Sung Hee Cho***, Chun Gyoo Lee*****

Dept. of Electronics Eng., Kyungwon University, San 65, Bokjung-dong, Soojung-gu, Seongnam City, Kyunggi-do 461-701, Korea

Inter-University Semiconductor Research Center(ISRC) and School of Electrical Engineering, Dept. of Electrical Engineering and Computer Science, Seoul National University, San 56-1, Shinlim-dong, Kwanak-gu, Seoul 151-742, Korea*

Dept. of Electronics Eng., Sejong University, San 98, Gunja-dong, Kwangjin-gu, Seoul 143-747, Korea**

Technology Development 3, Corporate R&D Center, Samsung SDI, 428-5 Gongse-Ri, Kiheung-Eup, Yongin-City 449-577, Korea***

Abstract

We have fabricated a carbon nanotube field emission display(CNT FED) panel with a 2 inch diagonal size by using screen printing method and vacuum in-line sealing technology. The sealing temperature of the panel was around 390 ℃ and the leak test was carried out for 72 hrs after sealing process. When field emission properties of fabricated and sealed CNT FED panel were characterized and compared with those of unsealed panel which was located in vacuum chamber of vacuum level similar with the sealed panel, the sealed panel showed more improved field emission properties.

1. Introduction

Field emission display(FED) has been generally described as a device to have CRT-like image qualities and low power consumption and has been expected to be a candidate for large-size flat panel display. Therefore it is important to find the most cost-effective way to produce FED panels with large screen size. High vacuum sealing is one of the most difficult technologies in commercializing FED. We have tried to apply vacuum in-line sealing technology to a CNT FEA on soda-lime glass substrate with 2 inch diagonal size fabricated by a screen printing method. In this paper, we are going to suggest the fabrication and sealing process of the diode type CNT FED.

2. Experimental Procedures

A. Fabrication of the CNT FED panel

Fig. 1 shows a schematic diagram of diode type CNT FED panel with 2 inch diagonal size. The panel is composed of two plates of soda-lime glass. The front glass plate has a size of 7 cm × 9 cm and a thickness of 1.8 mm. The rear glass plate has a size of 7 cm × 8 cm and a thickness of 1.8 mm. The active area in this experiment is 3.5 cm × 3.5 cm.

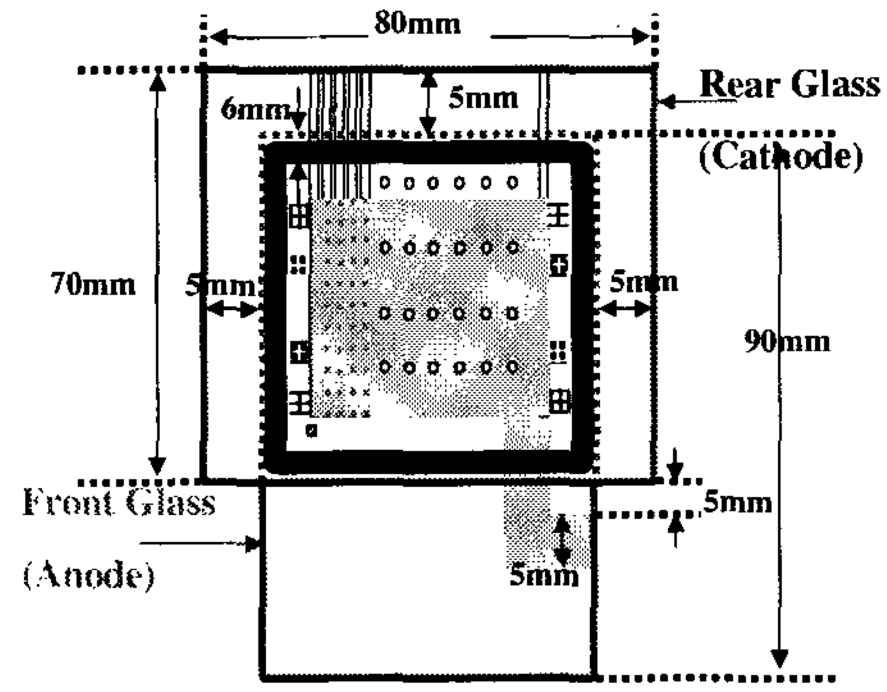


Fig. 1. Schematic diagram of a CNT FED panel.

Fig. 2 shows the fabrication sequences of the vacuum in-line sealed CNT FED in our experiment. First, the CNT FEA plate was fabricated by a screen printing method using CNT powder mixed paste. Then, the anode plate was prepared with a patterned ITO electrode. Finally, two plates were sealed by using a dispensed frit glass paste within the high vacuum chamber.

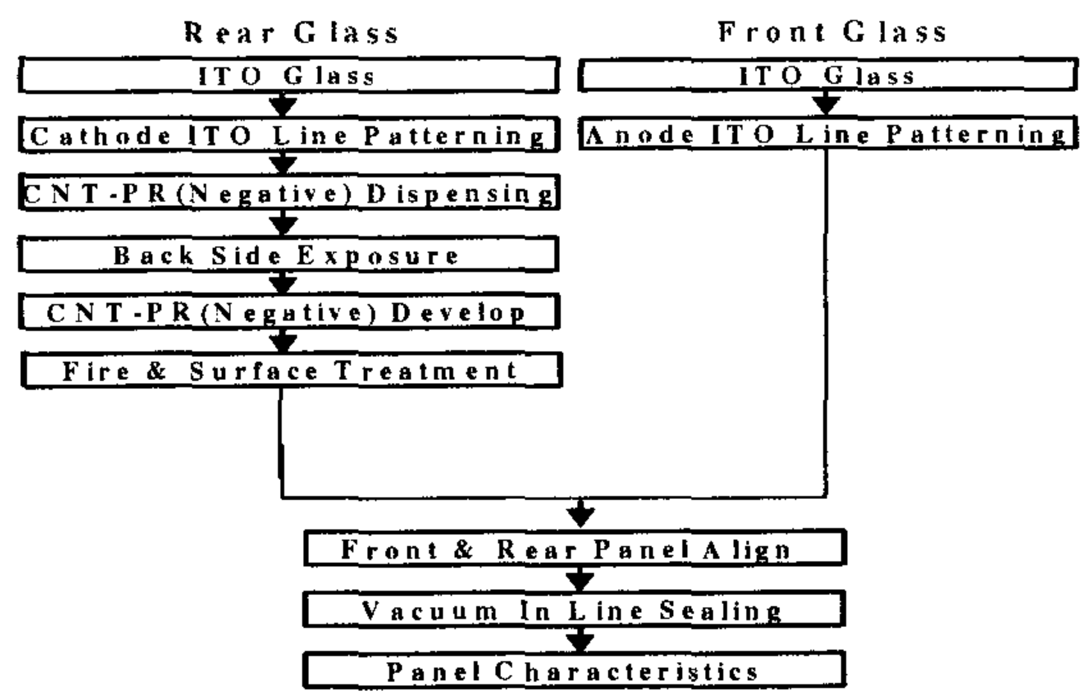
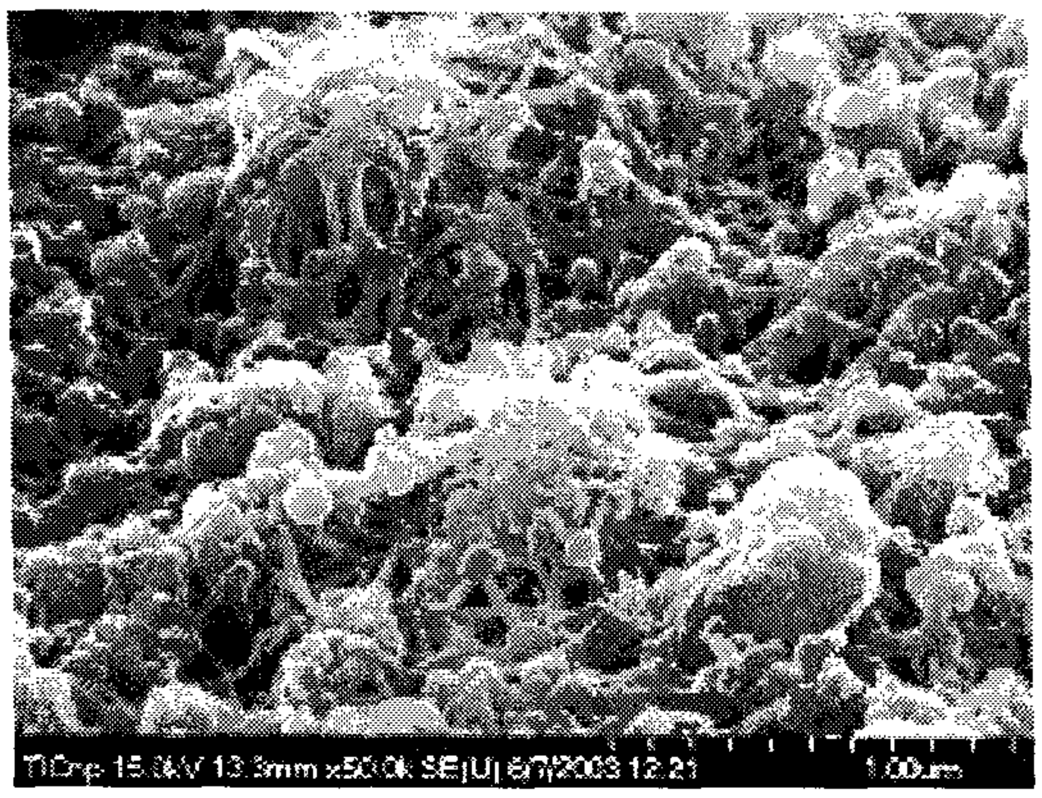
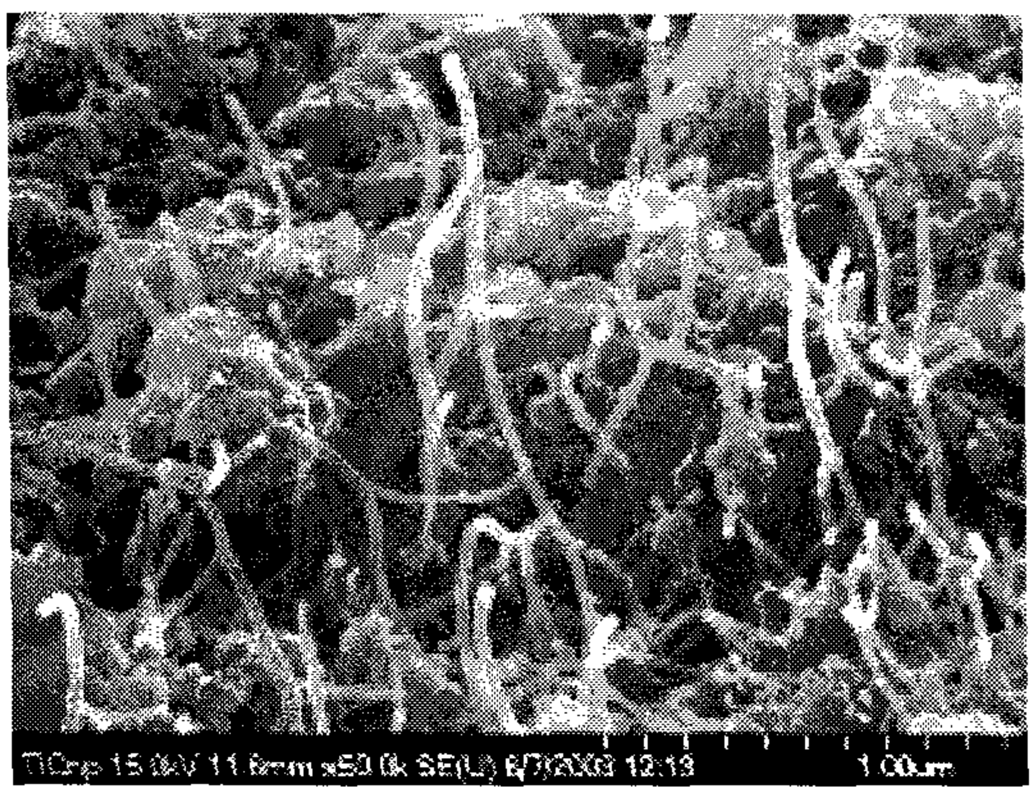


Fig. 2. Process sequences for the fabrication and sealing of the CNT FED panel.

Fig. 3(a) and 3(b) show the scanning electron micrographs (SEM) of screen printed CNT paste before and after surface treatment, respectively. The diameter of CNT was about 20 nm after surface treatment as shown in Fig. 3(b).



(a)

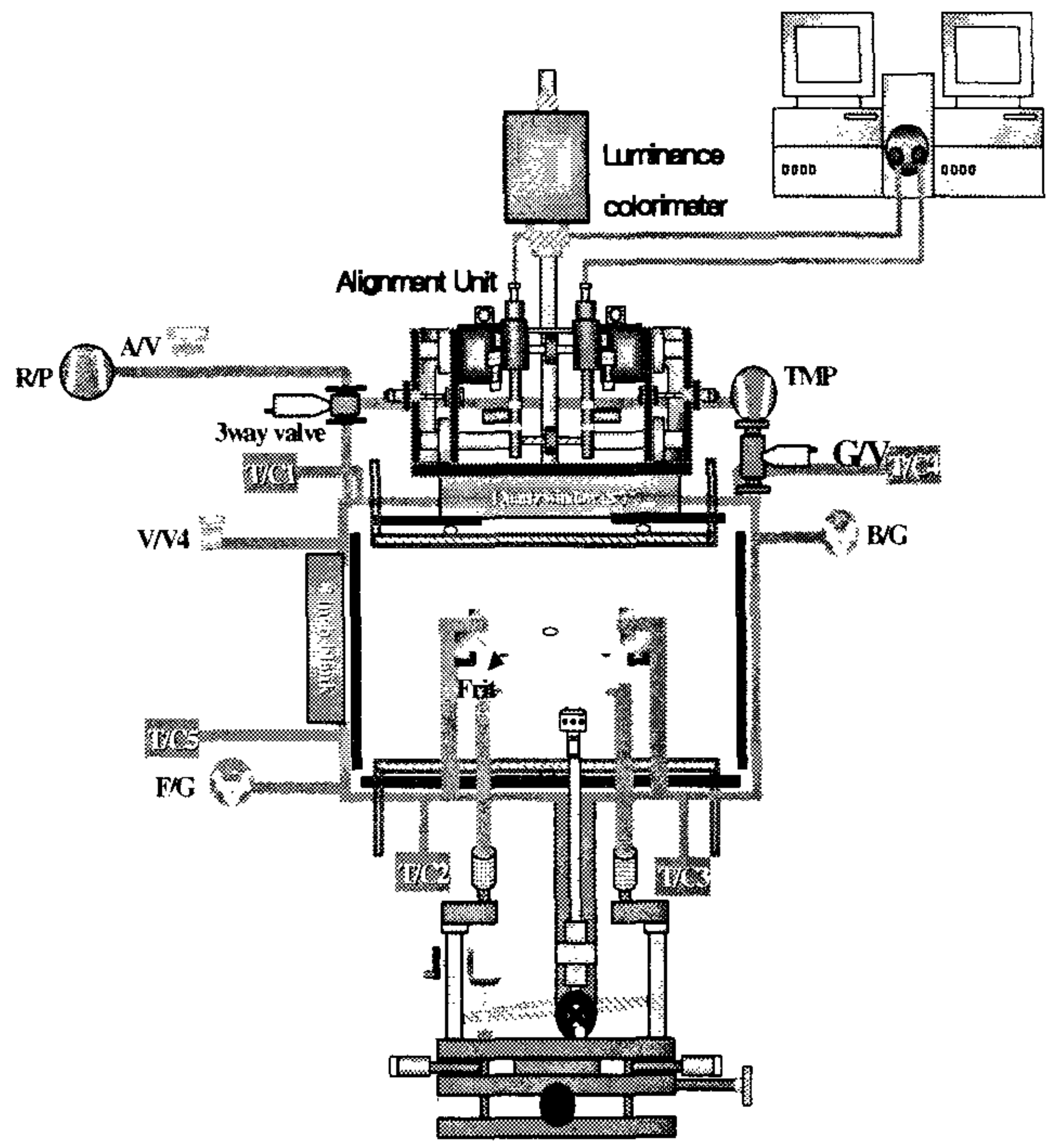


(b)

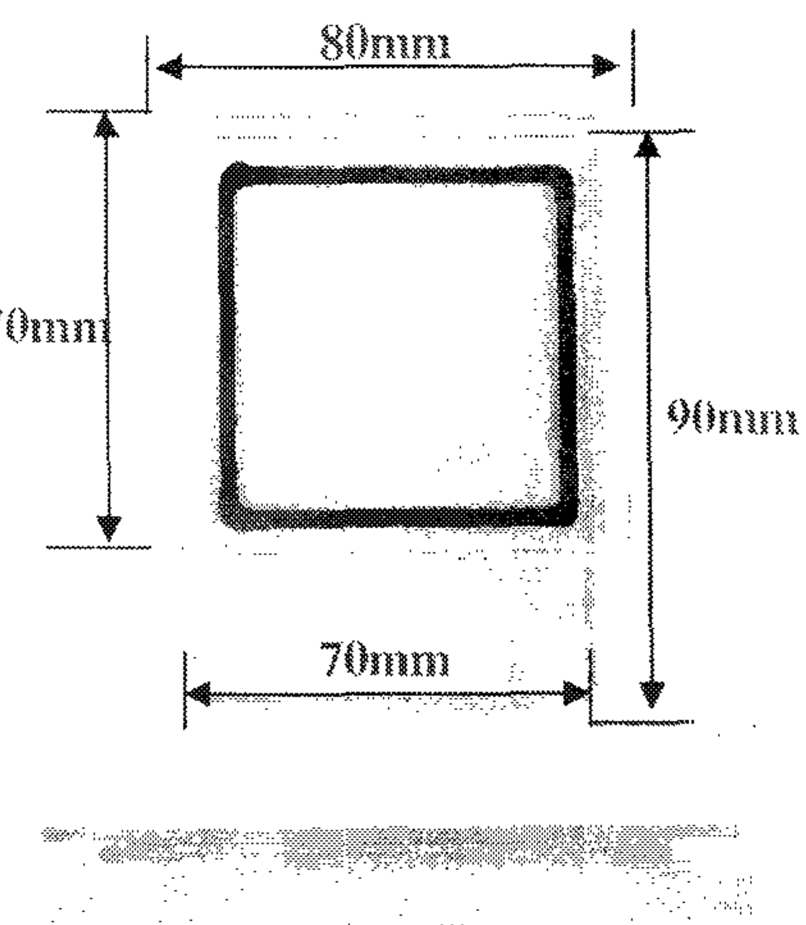
Fig. 3. Scanning electron micrographs of CNT paste (a) without surface treatment and (b) with surface treatment.

B. Vacuum in- line sealing of the fabricated CNT FED plates.

Fig. 4(a) shows the system for the vacuum in-line sealing including the heating stages and in-line alignment system. The heating of the two glass plates is done by using an infrared light source from a tubular heater. After arriving at the critical temperature, the two panels put into contact by using positional controls. That is, the lower glass plate is moved up via a x-y-z-Θ manipulator until it touches the upper glass plate. The manipulator gives a large enough press to seal the two plates. Fig. 4(b) shows the pictures of the top and side view of the sealed unit panel by using this method. The sealing area was defined as 6 cm × 5.5 cm by frit dispensing. The panel was sealed when frit glass was fired and melted at the chamber temperature of 390 ℃. The chamber temperature was uniformly increased with a rate of 3 ℃/min. Clean frit surface was obtained without cracks or pores as shown in Fig. 4(b). The gap between two glass plates was 0.2mm sustained by glass spacers.



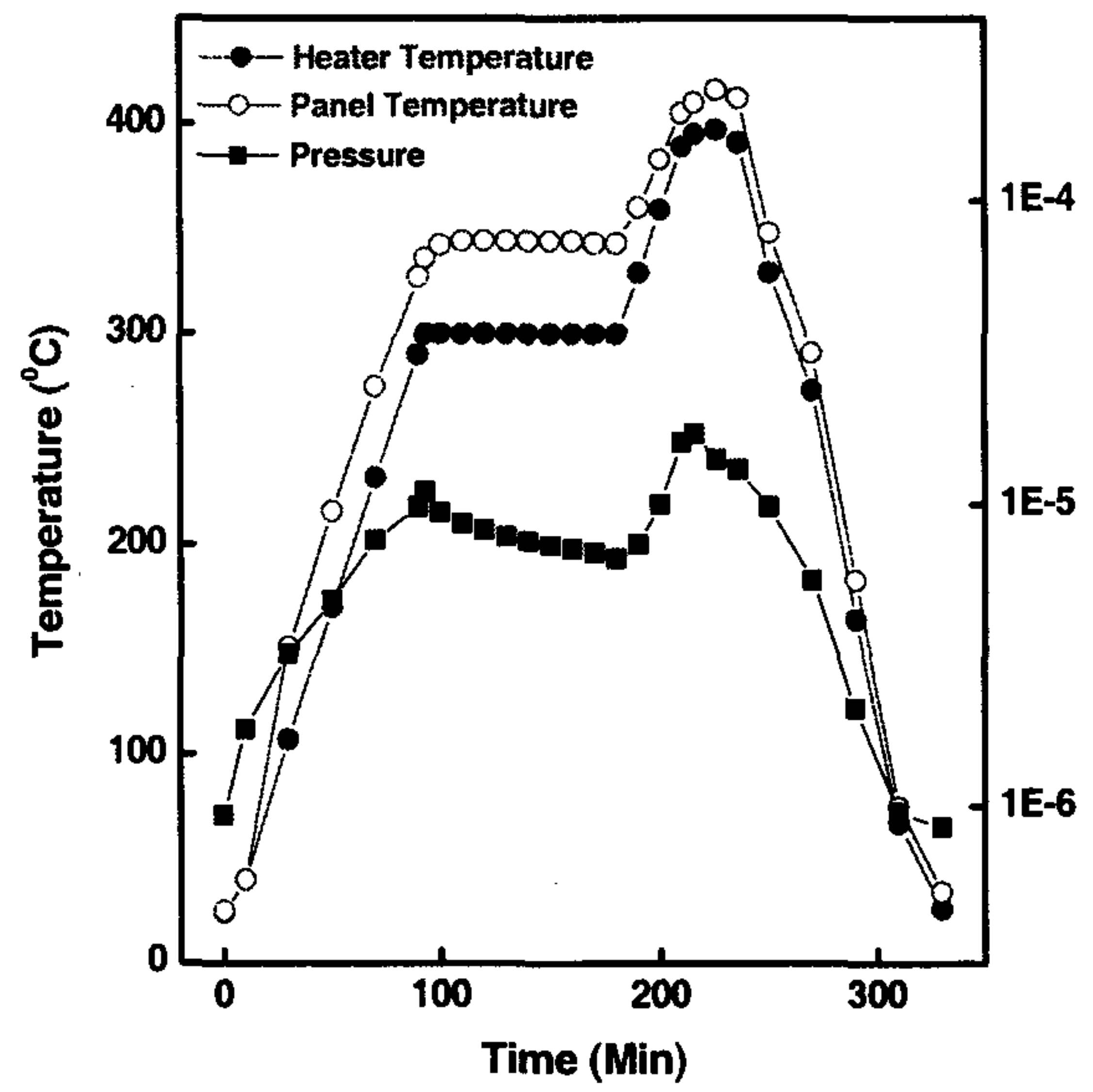
(a)



(b)

Fig. 4. (a) Schematic diagram of the equipment for vacuum in-line sealing technology (b) Front view and side view of a vacuum in-line sealed test panel.

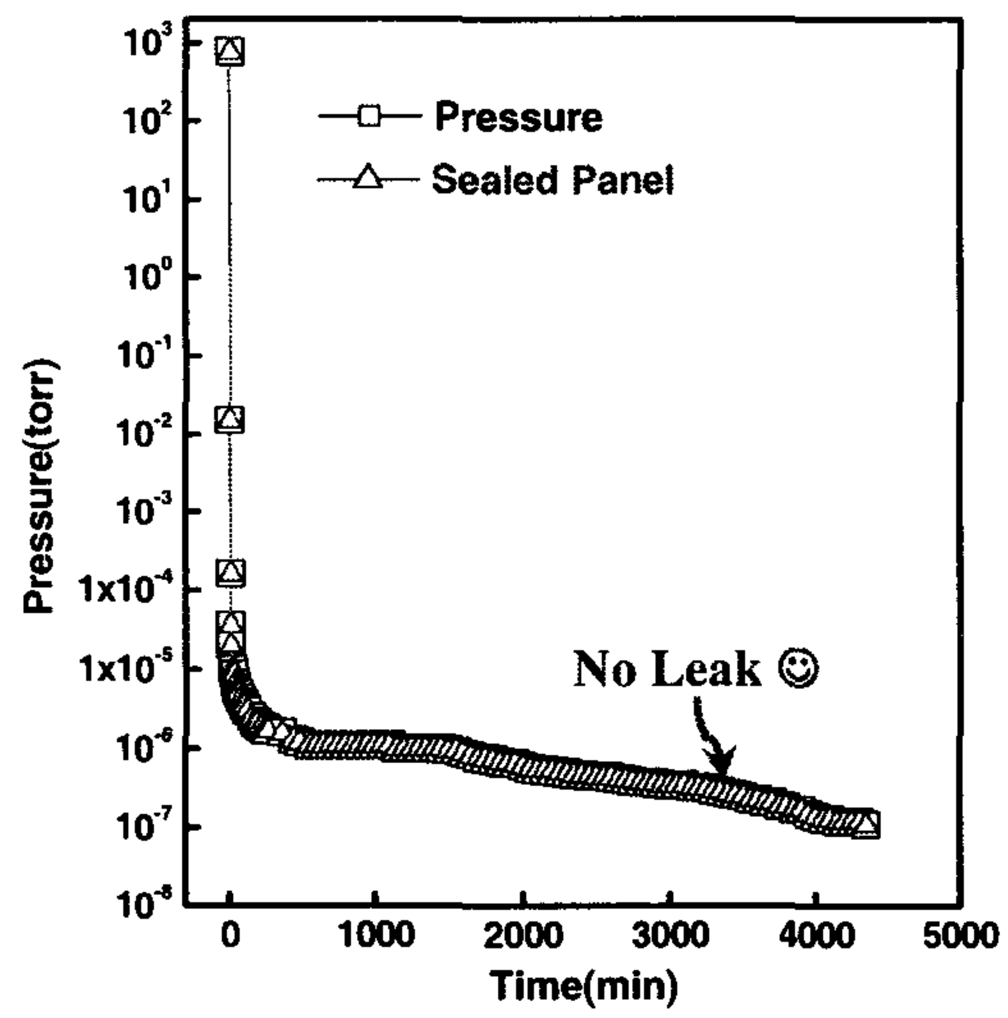
Fig. 5 shows the temperature profiles of the panel and chamber during sealing process.



(c)

Fig. 5. Temperature profiles of the test panel for the vacuum in-line sealing technology.

For the vacuum in-line sealed panel, a leak test was performed using an apparatus for leak test and the result was compared with the reference pumping rate without the panel connection. The results are shown in Fig. 6 From the measurement, no leak was confirmed in the panel sealed by using the vacuum in-line sealing technology.

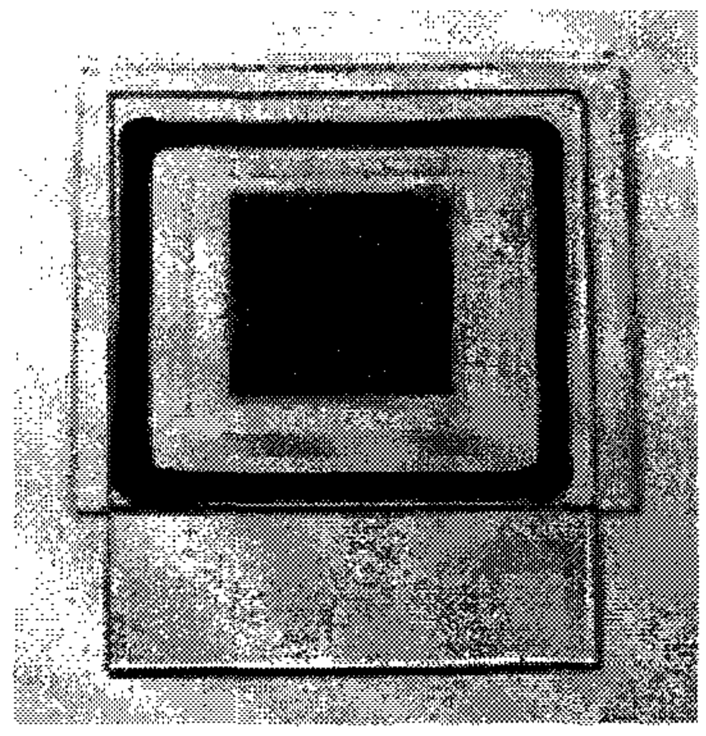


(a)

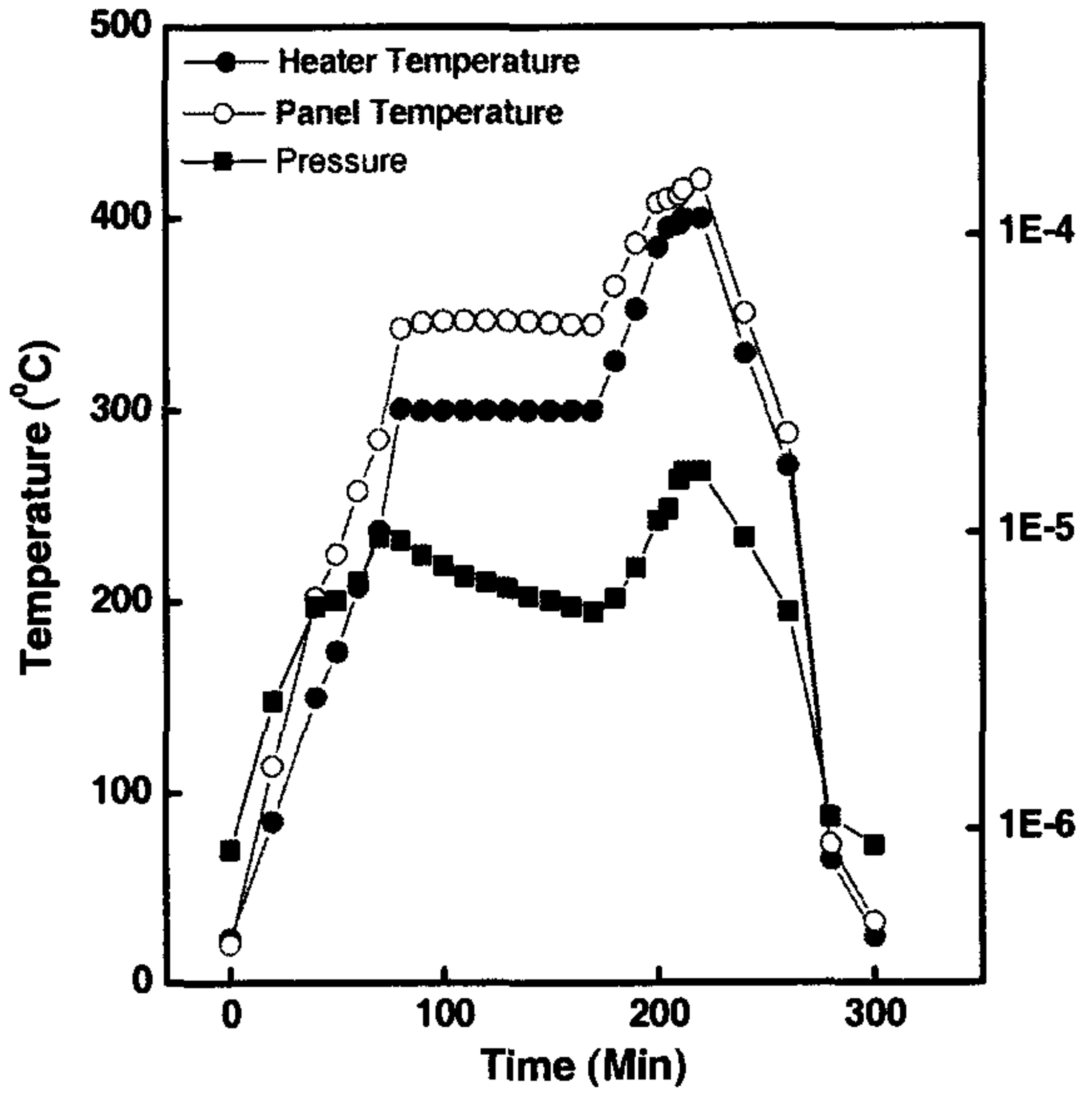
Fig. 6. Vacuum profile of the test panel during a leak test for the pumping time of 72 hrs.

3. Results and Discussion

Fig. 7(a) shows an operational CNT FED panel fabricated by the vacuum in-line sealing technology. The sealing process was carried out in the same way applied for the test panel and vacuum level was maintained at 1.4×10^{-5} torr at the sealing time.



(a)



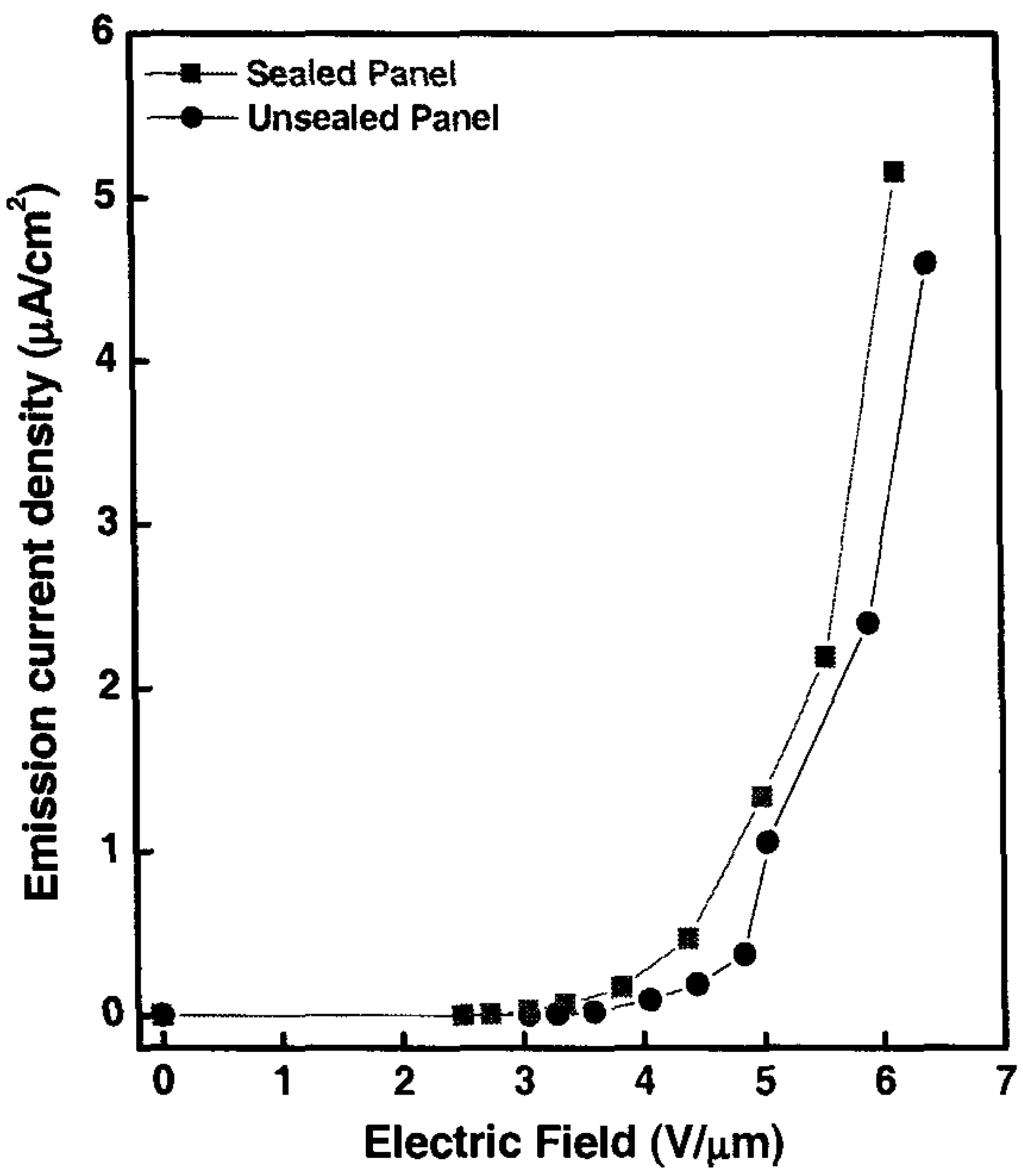
(b)

Fig. 7. (a) An operational CNT FED with a 2 inch diagonal size panel fabricated by the vacuum in-line sealing technology and (b) temperature profile including the vacuum level during the sealing process.

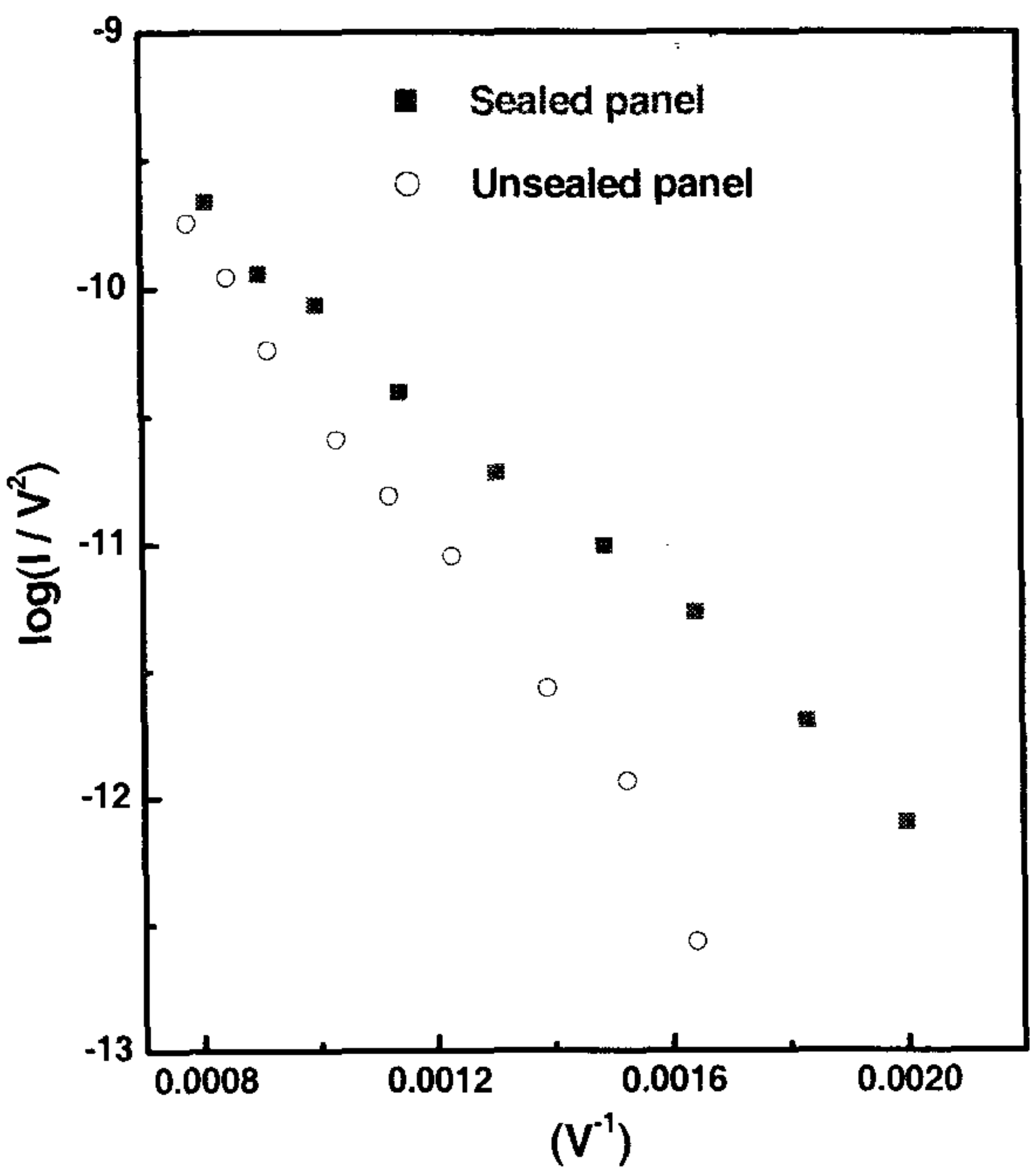
Field emission properties of the sealed CNT FED with a diode configuration were characterized and compared with those the unsealed CNT FED panel. For the comparison, the unsealed CNT FED plates were loaded into electrical test chamber and measured with the same configuration as the sealed panel. The vacuum level of the test chamber was maintained at 6.8×10^{-5} torr. Which is a higher value than that inside the sealed panel. Fig. 9 shows current density-electric field characteristics and Fowler-Nordheim plot from the emission properties for sealed panel and unsealed panel respectively. From the results, the sealed panel shows a little better field emission properties than that of the unsealed panel. It can be concluded that the real vacuum level inside the sealed CNT FED is corresponding to 1.5×10^{-5} torr obtained from the vacuum gauge attached to the vacuum in-line sealing chamber and the CNT FEA is not contaminated or affected by the sealing process.

4. Conclusions

A 2 inch diagonal size diode type CNT FED panel was fabricated by using a screen printing method and the vacuum in-line sealing technology. For the reliability of the vacuum level inside the CNT FED panel which was sealed by the vacuum in-line technology, the field emission properties of fabricated panel were characterized and compared with those of unsealed panel which was located in similar vacuum level. The vacuum level of the sealed panel was expected to be maintained without any leak inside the panel as the results of the field emission characteristics. From our results, it is expected to obtain a better sealing process for more reliable and smart CNT FED than that fabricated by a conventional tube evacuation method.



(a)



(b)

Fig. 9. Electrical characteristics of the sealed and unsealed panel : (a) current density-electric vs field characteristics (b) the Fowler-Nordheim plot.

5. Acknowledgment

This research was supported by a grant(M1-02-KR-01-0001-02-K18-01-016-1-0#) from Information Display R&D Center, one of the 21st Century Frontier R&D Program funded by the Ministry of Science and Technology of Korean government.

6. References

[1] J. A. Castellano, Solid State Technology 41, 67(1998).

[2] B. R. Chalamala, Y. Wei, and B. E. Gnade, IEEE Spectrum 35, 42(1998).

[3] A. Roth, Vacuum technology(Publisher, city, year), Chap. 7, p.329

[4] C. Boffito and E. Sartorio, *Vacum Technik* 35, 212 (1986).

[5] S. J. Kwon, K. S. Ryu, T. H. Cho, and J. D. Lee, J. Korean Phys. Soc. 33, S440 (1998).

[6] S. J. Kwon, K. J. Hong, J. D. Lee, C. W. Oh, J. S. Yoo and Y. B. Kwon, J. Vacuum and Science Technology(B), 18(3), 1227(2000).