Characteristics of a Wall Voltage During Sustain Period in AC Plasma Display Panels

Bhum Jae Shin, *Member, IEEE*, Kyung Cheol Choi, *Member, IEEE*, and Ki-Woong Whang

Abstract—**According to the viewpoint of a driving scheme, the luminance and luminous efficiency is mainly determined during the sustain period. Therefore, it is very important to understand the characteristics of the wall voltage during the sustain period, which is essential to design the driving pulse scheme. In this study, the quantitative analysis of the wall voltage has been carried by the wall voltage measurement method during the sustain period. The initial difference of the wall voltage is sharply stabilized due to the sustain discharges and it is mainly determined by the sustain voltage. The wall voltage between the sustain electrodes is changed symmetrically for the reference voltage level, while the wall voltage between the address and sustain electrode is positively sustained which is roughly mean value of the total effective voltage.**

Index Terms—**Priming effects, sustain period, wall voltage, wall voltage measurement method.**

I. Introduction

PLASMA display panels (PDPs) have been rapidly commercialized for high-definition television due to their large size, slim structure, and self-emissive color image quality. However, several critical issues remain regarding their low-luminous efficiency and poor image quality [1], [2]. Among them, the luminous efficiency is most critical issue; therefore, many studies have been intensively carried out such as the optimization of gas mixtures, new cell structures, and new discharge modes [3]–[5].

According to the viewpoint of the driving scheme, the luminance and luminous efficiency is mainly determined during the sustain period. Therefore, it is very important to understand the characteristics of the wall voltage during the sustain period, which is essential to design the driving pulse scheme. Therefore, in this study, it has been investigated the characteristics of the wall voltage by the wall voltage measurement method during the sustain period.

II. Experimental Conditions

The cell structure of the test panel is a conventional reflective three-electrode surface discharge type of alternating current (ac) PDP. This study uses two major measurement variables: the light emission which is measured using a photosensor amplifier (Hamamatsu C6386) and the current which is measured using a current probe amplifier (Tektronix AM503B) [6], [7].

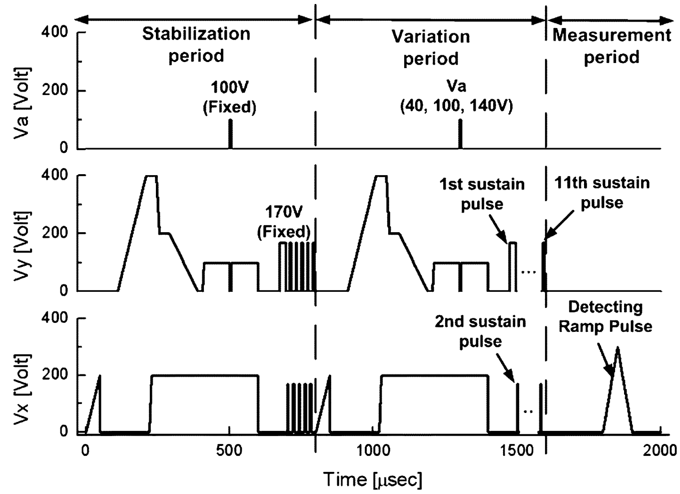


Fig. 1. Wall voltage measurement driving scheme during the sustain period.

The wall voltage measurement method was briefly described in previous study [7]. Since the discharge driven by a ramp pulse with sufficiently low ramp slop is occurred when an internal wall voltage plus externally applied voltage is equal to a firing voltage, the ramp pulse can be used as a detecting pulse for the wall voltage [8]–[10]. In this study, since the object is investigating the characteristics of the wall voltage during the sustain period, the measurement driving scheme was designed, as shown in Fig. 1. The wall voltage is stabilized during the first stabilization period and it is varied during the second variation period where the driving pulse scheme is necessary to adjusted to the objective of the measurement. Therefore, the number of sustain pulses are sequentially increased in this study, as shown in Fig. 1. And finally it was measured by the detecting ramp pulse in the measurement period.

III. Results and Discussions

A. Priming Effects

Fig. 2 shows the light emissions of the sustain discharges during the sustain period driven by the stabilization period of the driving scheme, as shown in Fig. 1, where the variation and measurement period were not used. The first sustain discharge is relatively weak and it is slightly increased before it is stabilized. The reason is as follows. In this test driving conditions, since the wall voltage between the Y and X electrode (hereafter

Manuscript received November 5, 2004; revised December 23, 2004. This work was supported by the Basic Research Program of the Korea Science and Engineering Foundation under Grant R08-2003-000-10376-1.

B. J. Shin is with the Department of Electronics Engineering, Sejong University, Seoul 143-747, Korea (e-mail: hahusbj@sejong.ac.kr).

K. C. Choi is with the Department of Electrical Engineering and Computer Science, Korea Advanced Institute of Science and Technology (KAIST), Daejeon 305-701, Korea.

K.-W. Whang is with the Plasma Laboratory, School of Electrical Engineering, Seoul National University, Seoul 151-742, Korea.

Digital Object Identifier 10.1109/TPS.2005.845092

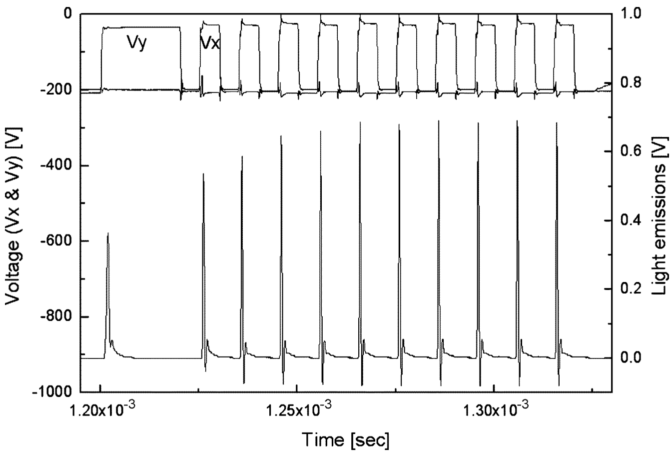


Fig. 2. Light emissions of the sustain discharges during the sustain period driven by the stabilization period of the driving scheme, as shown in Fig. 1.

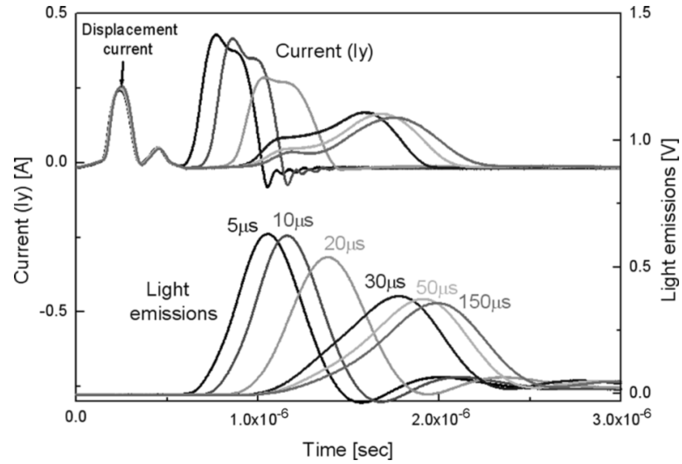


Fig. 4. Light emissions and currents of the Y electrode (Iy) on the dependence of the time interval between the address discharge and the first sustain discharge.

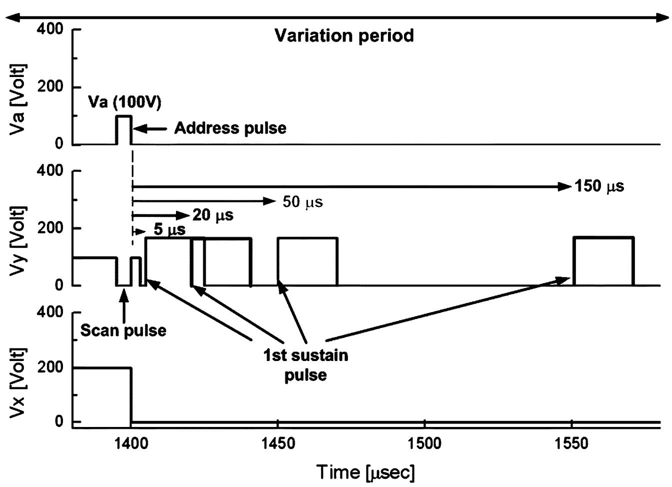


Fig. 3. Wall voltage measurement driving scheme for the priming effects.

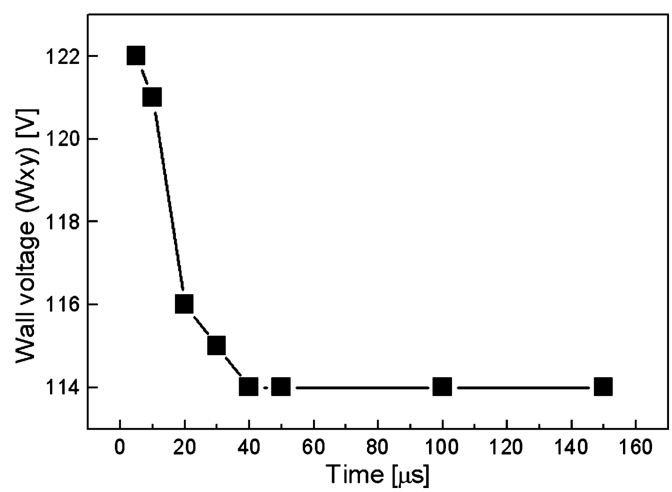


Fig. 5. Wall voltage (Wxy) on the dependence of the time interval between the address discharge and the first sustain discharge.

Wyx) due to the address discharge is lager than Wyx due to the sustain discharge [7], the increased intensity of the light emissions is mainly related to the priming effects. The time interval between the address discharge and the first sustain discharge is 275 μs, while the time interval between the first discharge and the second discharge is 25 μs, and the time interval between the second discharge and third discharge is 5 μs, as shown in Fig. 2.

In order to analyze the priming effects on the sustain discharges; the test driving scheme was modified based on the driving scheme, as shown in Fig. 1. The stabilization and measurement period are same, as shown in Fig. 1. The differences can be founded in Fig. 3. The variation is the time interval between the address discharge and the first sustain discharge where it is changed from 5 to 150 μs.

Fig. 4 shows the light emissions and currents of the Y electrode (Iy) on the dependence of the time interval between the address discharge and the first sustain discharge. The priming effects of the strong address discharge show the large influences on the intensity of light emissions, however, it is hardly some effects after 50 μs, and eventually its effect is negligible after 200 μs. The resultant wall voltage due to the priming effects is also changed, as shown in Fig. 5. However, it is almost constant after 40 μs in spite of the changed intensity of the discharge. Consequently, since the wall voltage is related to the intensity of the discharge which is also related to the priming effects, therefore, it is difficult to separate the priming effects from the factors of the wall voltage generation. Therefore, the measured wall voltage is included the priming effects as the following results, however, it is more practical because the sustain discharges are always including the priming effects in the practical situations.

B. Wall Voltage Variations During Sustain Period

Fig. 6 shows the wall voltage variation of Fig. 2 by the wall voltage measurement method, as shown in Fig. 1. In this figure, six sustain discharges are presented for clear presentation and the wall voltage is actually stabilized after fifth sustain discharges, as shown in Fig. 2 and Fig. 6. The Vyx is introduced which is the voltage difference between the Y and X electrode and the value of wall voltage is provided for clear understanding. As shown in Fig. 6, the Wyx is stabilized at -122 and 122 V, while the Way (the wall voltage between

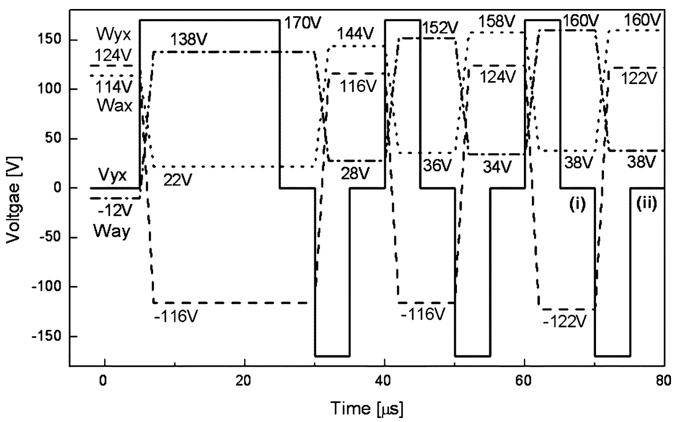
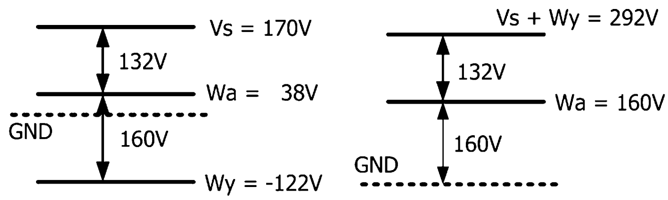


Fig. 6. Wall voltage variation of Fig. 2.



(a) (b)

Fig. 7. Voltage difference relative to the X electrode is calculated in Fig. 7. [(a) and (b) show the time instant of (i) and (ii) labeled in Fig. 6, respectively.].

the A and Y electrode) and Wax (the wall voltage between the A and X electrode) are stabilized at 38 and 160 V. Therefore, it can be inferred that the wall voltage of the A electrode is always positively sustained relative to the ground.

For better understanding, the voltage difference relative to the X electrode is calculated in Fig. 7. Fig. 7(a) and (b) shows the time instant of (i) and (ii) labeled in Fig. 6. As shown in Fig. 7, the wall voltage of the A electrode is roughly stabilized at the mean voltage of the total effective voltage (sustain voltage + wall voltage), more specifically, it is somewhat positive than the mean voltage of the total effective voltage. More quantitative analysis needs further studies.

C. Wall Voltage Variations on the Dependence of the Address Voltage

In this experiment, the address voltage (Va) was changed as 60, 100, and 140 V to investigate the variations of the wall voltage on the dependence of the address voltage. In the conventional driving scheme, the Wyx is roughly independent on the address voltage, while the Way is sharply decreased with increasing the address voltage [7]. Therefore, as shown in Fig. (8a) and (b), the initial Wyx is roughly independent on the address voltage, while the initial Way is strongly dependent on the address voltage. Therefore, the variations of the Wyx are almost same for the three different address voltages, while the Way shows the large variations during the first few sustain discharges. As such, the amount of changed wall voltage is strongly dependent on the initial wall voltage. Considering the first sustain discharge, the Way is changed from 36 to 152 V (116 V), −10 to

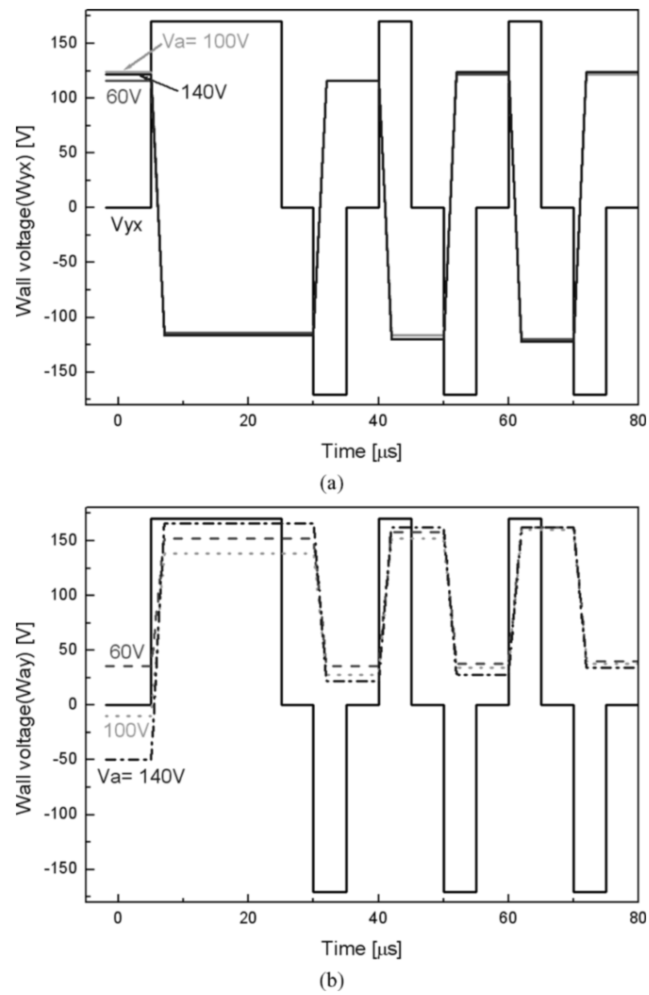


Fig. 8. Wall voltage variations on the dependence of the address voltage (a) Wyx (b) Way.

138 V (148 V), and −50 to 166 V (216 V), where the voltage in parenthesis represents variation, corresponding to the address voltage of 60, 100, and 140 V, respectively. However, it is also sharply stabilized after few sustain discharges. Consequently, the Wyx is roughly independent on the address voltage while the Way shows the large variations during the first few sustain discharges, which is caused by the different initial Way due to the address voltage.

D. Wall Voltage Variations on the Dependence of the Sustain Voltage

Fig. 9 shows the final wall voltage variations as a function of the sustain voltage. Since the conventional driving scheme is finished by the positive voltage of the Y electrode, the Wxy is used in this figure. The Wxy is linearly increased as increasing the sustain voltage, however, the slope of the Wxy is slightly decreased when the sustain voltage is above 190 V. The Wxy is also increased when the sustain voltage is below 180 V, but it is decreased when the sustain voltage is above 190 V.

It might be related to the characteristics of the wall charge generation on the dependence of the sustain voltage. Yet, the main reason might be as follows. Since the Way is close to the

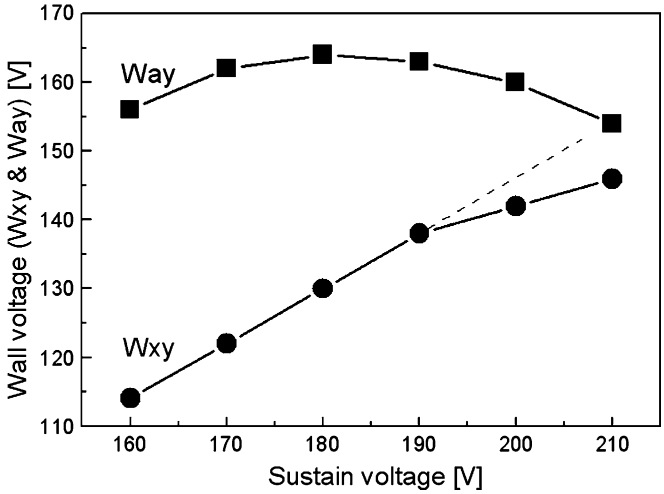


Fig. 9. Final wall voltage variations as a function of the sustain voltage.

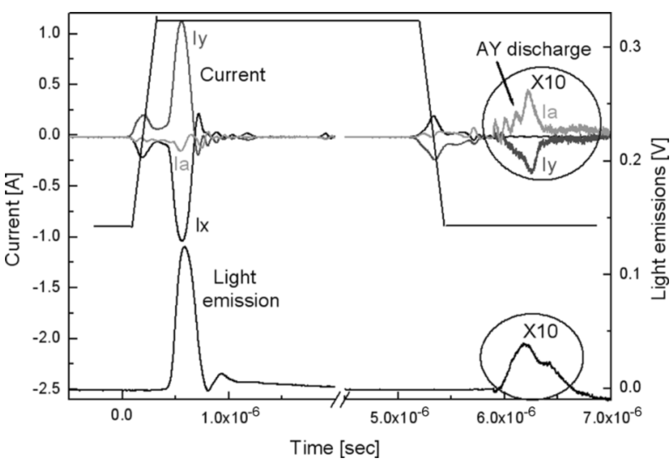


Fig. 10. Light emissions and the discharge currents when the sustain pulse is applied to the Y electrode. $(\mathrm{Vy} = 210\ \mathrm{V})$.

firing voltage between the A and Y electrode, the discharge is occurred between the A and Y electrode when the voltage of the Y electrode is falling to the ground. Fig. 10 shows the light emissions and the discharge currents when the sustain pulse is applied to the Y electrode which voltage is 210 V. As shown in Fig. 10, the weak discharge is occurred between the A and Y electrode where the light emissions of AY discharge are magnified 10 times (X10) for clear presentation. In this situation, the Y electrode is acted as a cathode while the A electrode is acted as an anode. Therefore, the wall voltage of the Y electrode is slightly changed positively and that of the A electrode is slightly changed negatively, which are resulted in decreasing the Wxy and Way.

IV. Conclusion

In this study, the quantitative analysis of the wall voltage has been carried by the wall voltage measurement method during the sustain period. The initial difference of the wall voltage is sharply stabilized due to the sustain discharges and it is mainly determined by the sustain voltage. The wall voltage between the sustain electrodes is changed symmetrically for the reference voltage level, while the wall voltage between the address and sustain electrode is positively sustained which is roughly mean value of the total effective voltage. Though exact quantitative analysis needs further study, these results might be helpful to optimize the driving scheme during the sustain period.

References

[1] M. Uchidoi, "14.1: Fourth-generation PDPs: high image quality and low power consumption," in *Proc. SID Dig.*, 2004, pp. 202–205.
[2] K.-Y. Choi, J.-P. Choi, M.-S. Chang, E.-H. Yoo, W.-T. Kim, J.-Y. Kim, E.-C. Park, S.-T. Park, and J.-H. Ryu, "30.1: Recent research and development on 71-in.-diagonal color PDPs," in *Proc. SID Dig.*, 2004, pp. 1022–1025.
[3] L. F. Weber, "Positive column AC plasma display," in *Proc. IDRC Dig.*, 2003, pp. 119–124.
[4] G. Oversluizen, T. Dekker, M. F. Gillies, and S. T. Dezwart, "High-Xe-content high efficacy PDP's," *J. SID*, vol. 12/1, pp. 51–55, 2004.
[5] K. D. Kang, J. I. Kwon, W. T. Kim, H. S. Yoo, S. G. Woo, E. Y. Jung, J. C. Ahn, S. J. Kim, E. G. Heo, and W. J. Yi, "30.3: Discharge characteristics of high efficiency rib and its optimizes electrodes (HERO) using Xe gas mixture," in *Proc. SID Dig.*, 2004, pp. 1030–1033.
[6] B. J. Shin, K. C. Choi, H.-S. Tae, J.-H. Seo, J. Y. Kim, and J.-W. Han, "Case studies on the temperature dependent characteristics in AC PDPS," *IEEE Trans. Plasma Sci.*, vol. 33, no. 1, pp. 162–169, Feb. 2005.
[7] B. J. Shin, K. C. Choi, and H.-S. Tae, "Characteristics of an address discharge in AC plasma display panels," IEEE Trans. Plasma Sci., submitted for publication.
[8] H. Kim, J. Jeong, K. Kang, J. Seo, I. Son, K. Whang, and C. Park, "Voltage domain analysis and wall voltage measurement for surface-discharge type ac-PDP," in *Proc. SID Dig.*, 2001, pp. 1026–1029.
[9] K. Sakita, K. Takayama, K. Awamoto, and Y. Hashimoto, "Analysis of cell operation at address period using wall voltage transfer function in three-electrode surface-discharge AC-PDPs," in *Asia Display/IDW* , 2001, pp. 841–844.
[10] S. T. de Zwart and B. Salters, "Wall voltage fingerprint method in a three-electrode PDP cell," in *Asia Display/IDW* , 2001, pp. 845–848.

Bhum Jae Shin (M'03) received the B.S. degree from the Department of Electrical Engineering, Seoul National University, Seoul, Korea, in 1990 and the M.S. and Ph.D. degrees in plasma engineering from Seoul National University in 1992 and 1997, respectively.

He worked on the development of PDPs as a Senior Researcher in the PDP team of Samsung SDI, Korea, from 1997 to 2000. From 2000 to 2001, he worked on the capillary discharges as a Visiting Researcher in the Physics Department, Stevens Institute of Technology, Hoboken, NJ. In 2002, he returned to Korea, and following on one-year postdoctoral at Seoul National University, he is currently working as a Research Professor in the Electronics Engineering Department, Sejong University, Seoul, Koera. His research interests include high efficiency PDP cell structure and driving scheme.

Dr. Shin is a Member of the Society for Information Display.

Kyung Cheol Choi (M'04) received the B.S. degree from the Department of Electrical Engineering, Seoul National University, Seoul Korea, in 1986, and the M.S. degree and Ph.D. degree in plasma engineering from Seoul National University in 1988 and 1993, respectively.

From 1993 to 1995, he was with the Institute for Advanced Engineering, Seoul, Korea, where his work focused on the design of field emission display devices. He was a Research Scientist in the Microbridge Plasma Display panel of Spectron Corporation of America, Summit, NJ, from 1995 to 1996. He was a Senior Research Scientist at Hyundai Plasma Display, Hawthorne, NY, from 1996 to 1998, where his work was to continue on developing plasma display technology. From 1998 to 1999, he was involved in the development of an ac 40-in plasma display panel at Advanced Display Research and Development Center of Hyundai Electronics Industries, Kyoungki-do, South Korea as a Senior Research Scientist. From 2000 to 2004, he had been an Associate Professor in the Department of Electronics Engineering, Sejong University, Seoul, Korea. He also was in charge of the Information Display Research Center supported by Korean Ministry of Information and Communication. Since February 1, 2005, he has been an Associate Professor in the Department of Electrical Engineering and Computer Science, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea. His research interests include plasma display panel, field emission display, and micro-plasma applications for laser and bio-electronics.

Dr. Choi is a Member the Society for Information Display and the Korean Information Display Society.

Ki-Woong Whang graduated from Seoul National University (SNU), Seoul, Korea, in 1972. He received the M.S. and Ph.D. degrees in physics from the University of California, Los Angeles (UCLA), in 1976 and 1981, respectively.

He worked as a Research Engineer in the Plasma Laboratory at UCLA from 1981 to 1982. He worked at the Plasma Laboratory at the University of Maryland, College Park, from 1982 to 1983. In 1983, he returned to Korea, and since then, has been a Professor in the School of Electrical Engineering, Seoul National University, Seoul, Korea.

Dr. Whang is a Member of the American Physics Society, Electrochemical Society, and the Society for Information Display.