Wall Voltage Characteristics Simulated Using an Equivalent Circuit Model for AC PDPs

Joon-Yub Kim, Jong-Sik Lim
Dept. of Electronics Engineering, Sejong University
98 Kunja-Dong, Kwangjin-Ku, Seoul, 143-747
Phone : +82-2-3408-3298 , E-mail : jkim@sejong.ac.kr

Abstract

As a convenient means for the characterization of the wall voltage and wall charge of AC PDPs during the sustain period, an equivalent circuit model for AC PDPs is presented. The equivalent circuit model for AC PDPs consists of capacitors and thyristors. The equivalent circuit model is based on the physical structure of the AC PDP and the I-V characteristic of the discharge space. This equivalent circuit model can be easily implemented in the standard simulators such as SPICE and can easily simulate the variation of the current, charge and voltage involved in AC PDPs as the supply voltage varies.

1. Introduction

There have been various efforts to investigate and improve the characteristics of AC PDPs, but we have had to mainly depend on experiments to test or understand the electrical behavior of PDPs. Because the wall charge is very difficult to measure directly, many researchers have been investigating many indirect methods for measuring the wall charge. Nevertheless, any effective means for measuring or simulating the wall charge has not been reported. Numerical models were developed to have effective means for simulating the nonlinear electrical characteristic of AC PDPs [1]. The simulation of the time-varying discharge characteristics of PDPs using the numerical models took too much time to be practical. Also, several macromodels were developed for PDPs, but the models were not accurate enough for the simulation of the time varying discharge characteristics of the PDPs.

In this paper, an equivalent circuit model for AC PDPs is presented. This equivalent circuit model can accurately simulate the variation of the wall charge as well as the I-V characteristics during sustain period. This equivalent circuit model can be easily implemented in the standard simulators such as SPICE.

2. Wall Voltage Input-Out (WVIO) Curve

Figure 1 shows the Wall Voltage Input-Output (WVIO) curve [2-3]. In Figure 1, *Vwin* is the initial voltage across the gas and *Vwout* is the consequent voltage across the gas.

When *Vwin* is below the weak discharge voltage, *Vwout* equals to *Vwin*. This represents that no discharge occurs in this case and that the wall charge in the cell does not change. For *Vwin* in the weak discharge region, weak discharge occurs. For *Vwin* above the weak discharge voltage, strong discharge occurs and the voltage across the gas in the cell is reduced to almost zero.

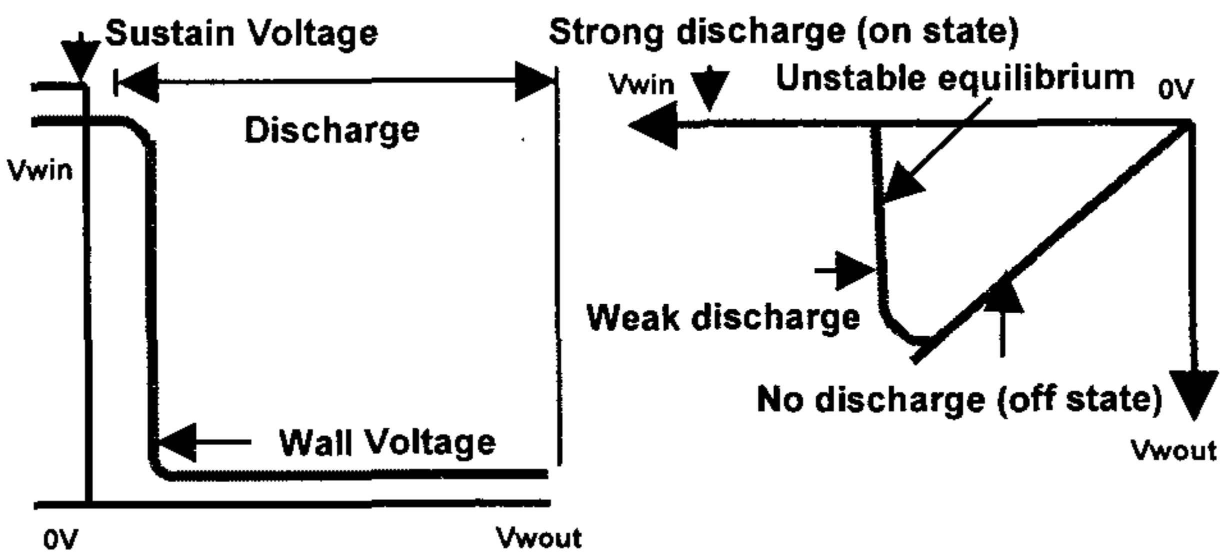


Figure 1. Wall Voltage Input-Output Curve

3. I-V Characteristics of Thyristor

Figure 2 shows the simulated I-V characteristic of thyristors [4]. The current doses not flow until the voltage is increased to the turn-on voltage. When the

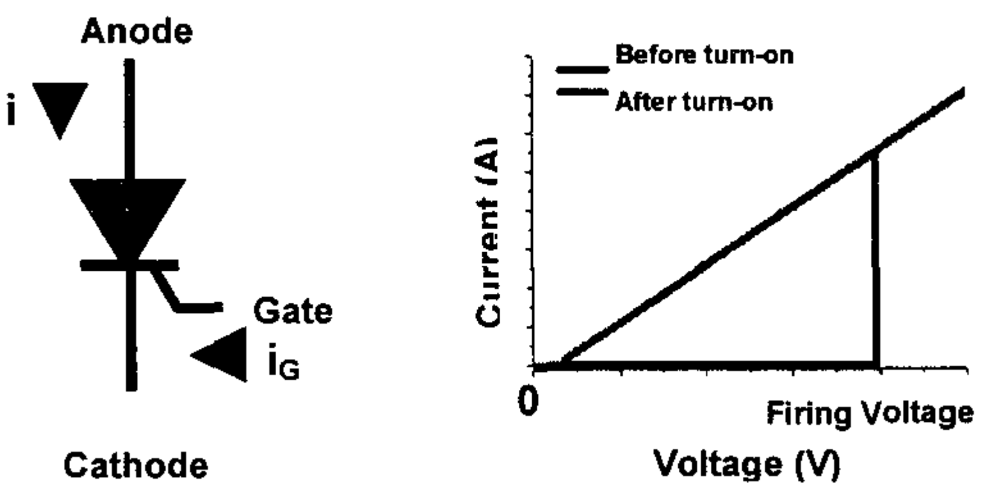


Figure 2. I–V Characteristic of Thyristor

voltage across the thyristor reaches the firing voltage, the thyristor is turned on and large current flows through the thyristor. Once the thyristor is turned on, current flows continuously until the voltage across the thyristor is reduced to almost zero. This characteristic is very similar to the I-V characteristic of the discharge cell of the AC PDP.

4. Equivalent Circuit Model for AC PDP

The front panel of the AC PDP is composed of an MgO layer, a dielectric layer, X- and Y-sustaining electrodes, and a front glass layer. The capacitance existing between the X- and Y-sustain electrodes can be modeled as the combination of three capacitors connected in series and one capacitor connected in parallel with the three capacitors [5]. The middle capacitor, C_1, in the three capacitors connected in series represents the capacitance of the discharging space. The discharging space has I-V characteristic very similar to the I-V characteristic of the thyristor. Thus, we can propose an equivalent circuit model shown in Figure 3 which can be conveniently used to simulate the electrical characteristics between the two sustain electrodes. The behavior of the equivalent circuit model is very similar to that of the actual AC PDP.

Until the voltage between the sustain electrodes reaches the firing voltage, small current flows to charge C_4 and the series capacitance of C_1, C_2 and C_3. Once the supply voltage reaches the firing voltage, one of the thyristor (depending on the polarity of the voltage) is turned-on. The discharge of the charge (equivalent to the wall charge) on C_1 continues until the current through the thyristor is turned off. The thyristor is turned off when the voltage across it becomes almost zero. To keep the voltage between the sustain electrodes constant while the charge on C_1 discharges through the thyristor, large current (discharge current) should flow into C_2 and C_3 because the series capacitance of C_2, C_3 and C_1 abruptly increases as C_1 is shorted by the thyristor.

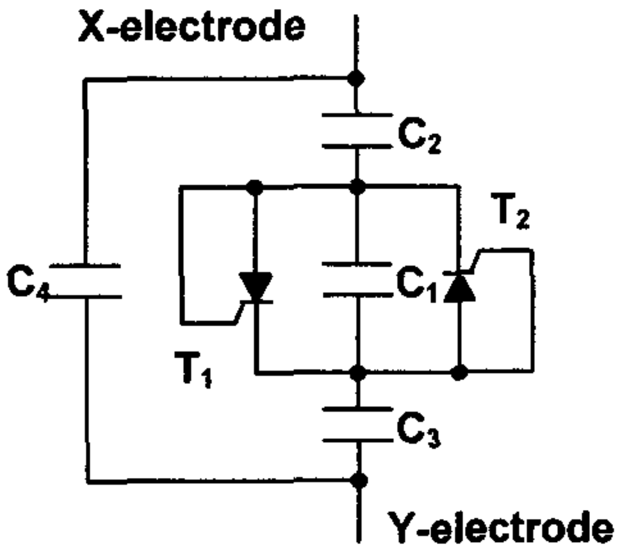
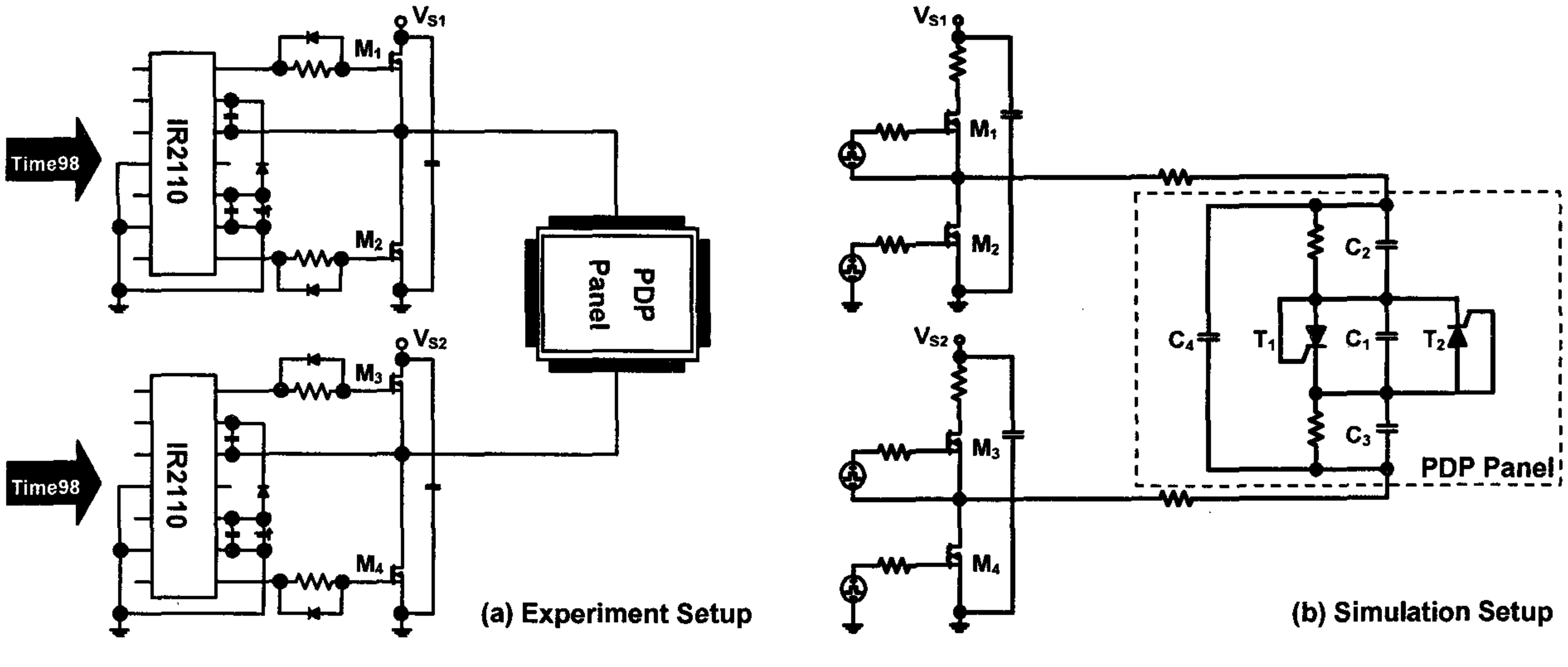


Figure 3. Equivalent Circuit Model for AC PDP

5. Experimental Results vs. Simulated Results

Figure 4 shows the experimental setup which was used to measure the electrical characteristics of the AC PDP during the sustain period. Also shown in Figure 4 is the simulation setup employing the equivalent circuit model shown in Figure 3. A 4-inch



(a) Experiment Setup

(b) Simulation Setup

Figure 4. Experiment Setup and Simulation Setup

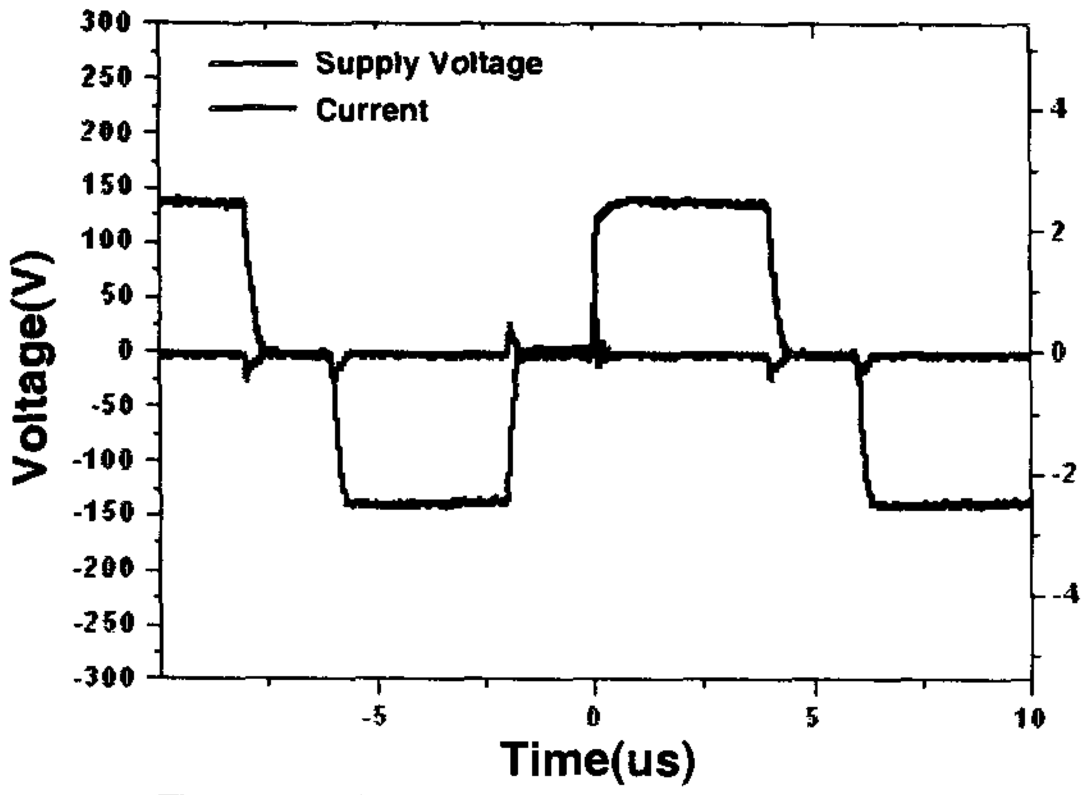


Figure 5. (a) Measured I-V Characteristic

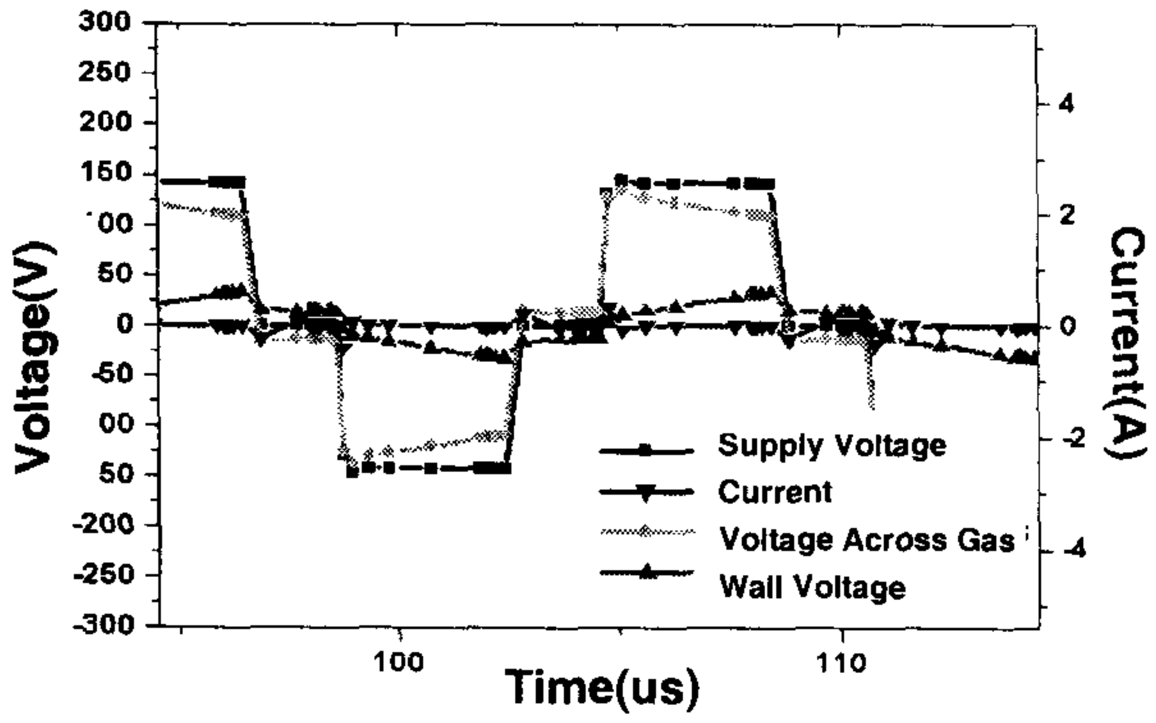


Figure 5. (b) Simulated I-V Characteristic

panel consisting of 42 scan lines and 108 addressing lines was used in the experiments.

Figure 5 (a) shows the experimentally measured voltage between the X- and Y-sustain electrodes and the current flowing into the panel as a function of time for off-state. In this case the applied voltage between the sustain electrodes is not high enough to ignite strong discharge. Figure 5 (b) shows the simulated voltage between the X- and Y-sustain electrodes, voltage across gas, wall voltage and current flowing into the panel as a function of time for off-state.

It is very difficult to experimentally measure the gas voltage or the wall voltage. Figure 5 (b) illustrates that it is quite simple to simulate the gas voltage or the wall voltage as well as the voltage between the sustain electrodes or the current into the panel using the equivalent circuit model.

Figure 6 (a) and (b) are the measured and simulated results for on-state. In this case the voltage applied between the sustain electrodes is high enough to ignite strong discharge. Thus, in Figure 6 (a) and (b), not only the displacement current but also the larger discharge current flows into the panel. From the simulated results, we can see the behaviors of the voltage across gas and the wall voltage as a function

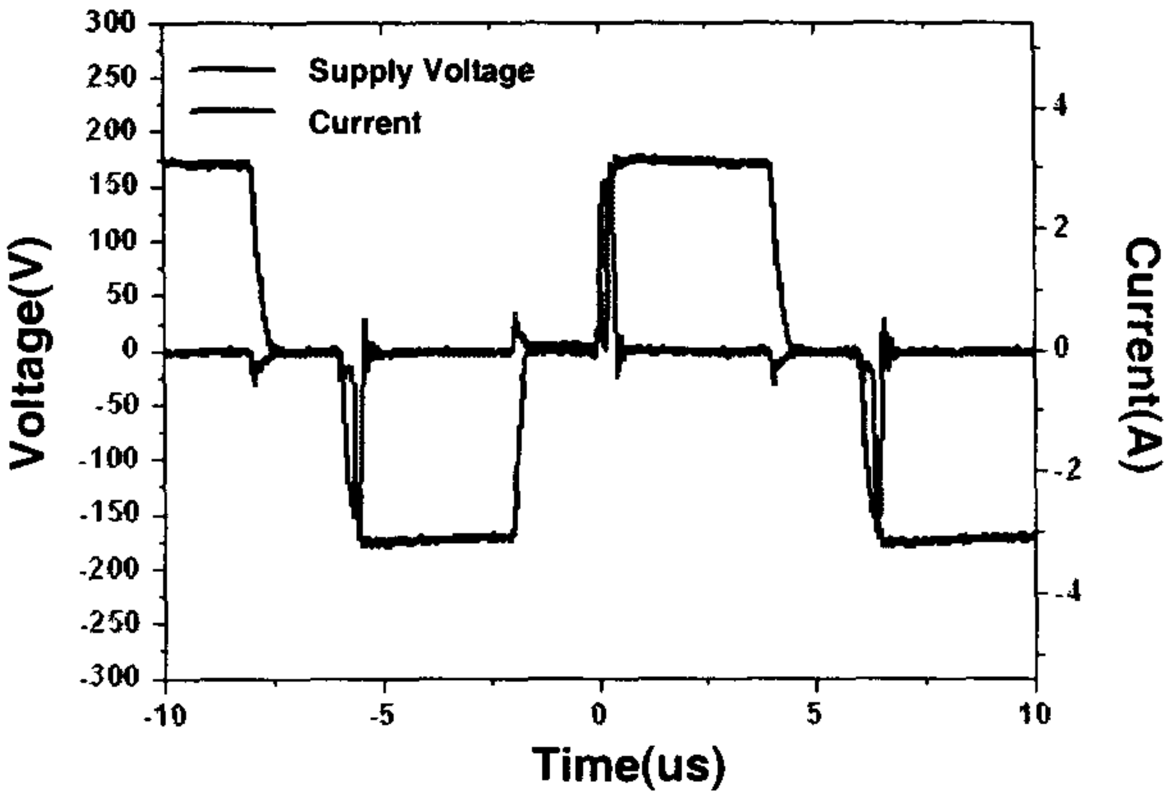


Figure 6. (a) Measured I-V Characteristic

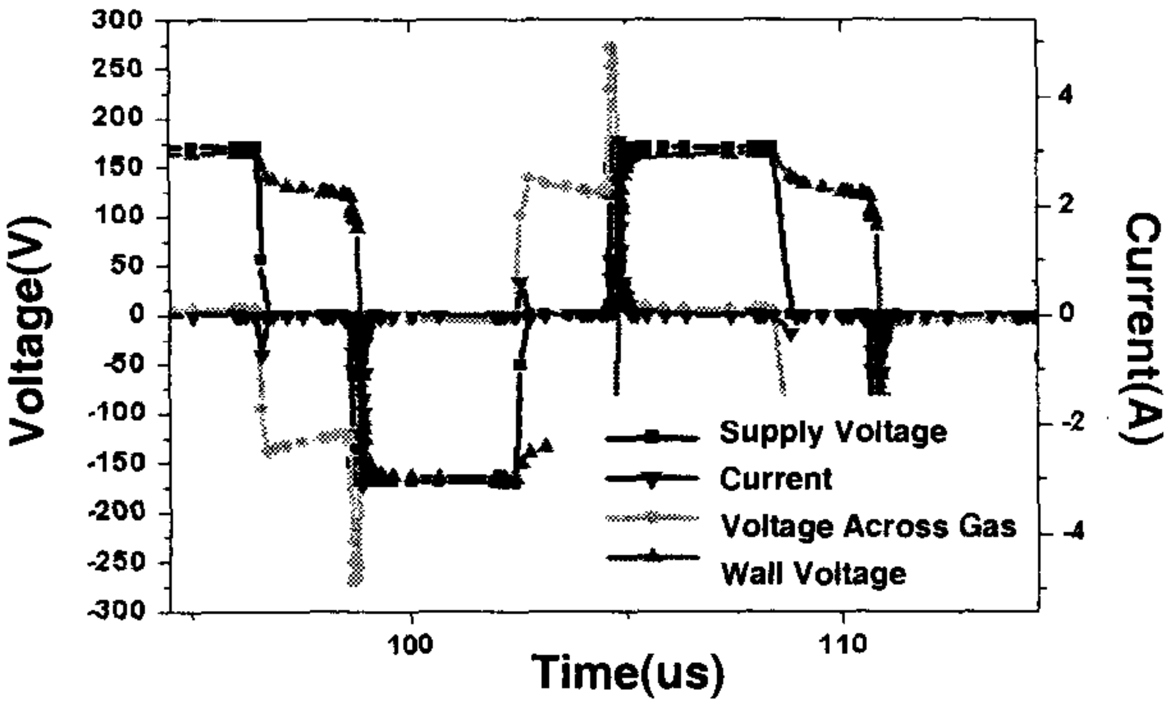


Figure 6. (b) Simulated I-V Characteristic

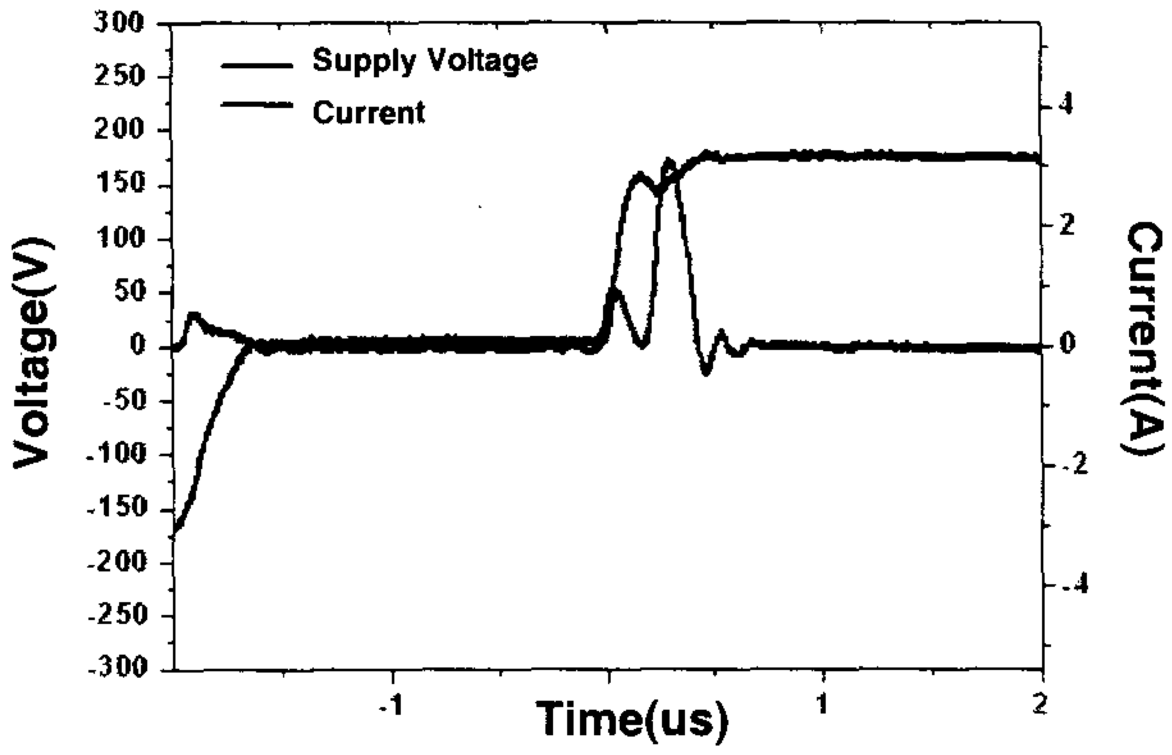


Figure 7. (a) Measured I-V Characteristic

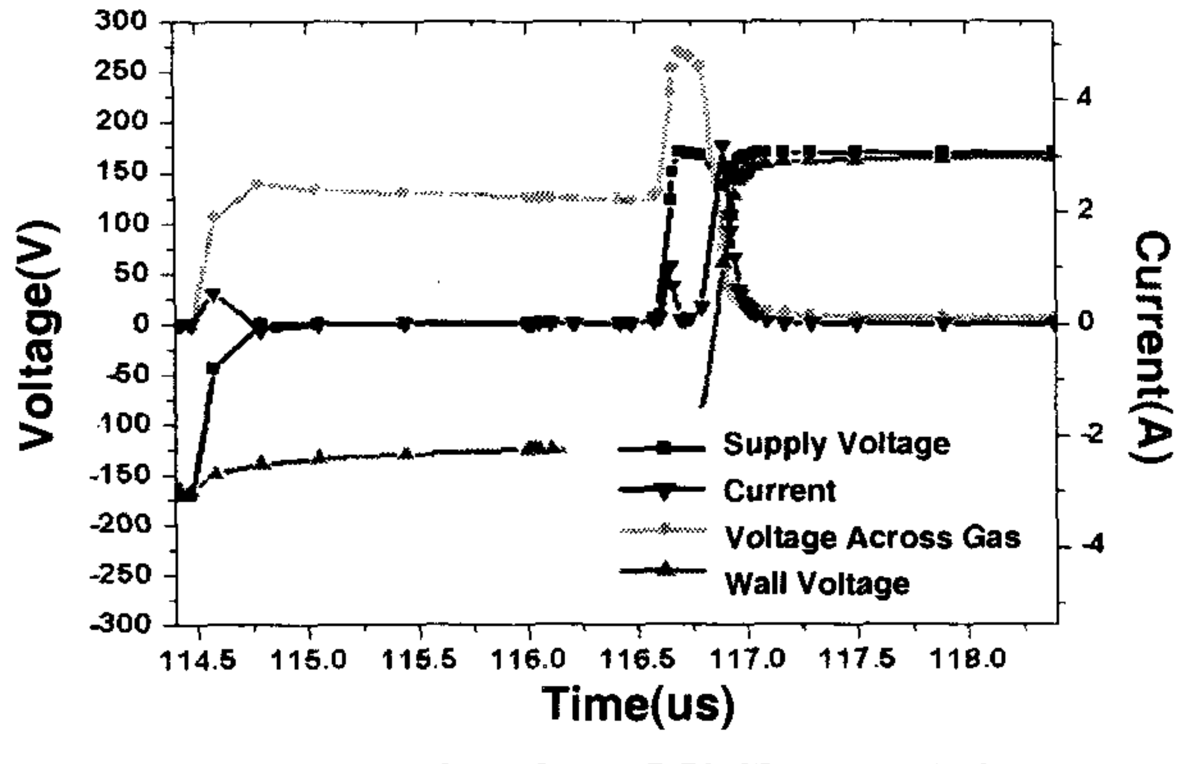


Figure 7. (b) Simulated I-V Characteristic

of time. The voltage across gas is the voltage that actually appears in the discharge cells and this voltage is the direct cause of the discharge in the cells.

Figure 7 (a) and (b) shows the expanded waveforms of the voltages and current in Figure 6 (a) and (b). The current of the relatively lower peak at the beginning of the rise of the applied voltage is the displacement current, which charges the capacitances of the AC PDP. The current of the higher peak following the lower peak is the discharge current, which flows into the panel when the voltage across the panel reaches the firing voltage.

Before the voltage across the panel reaches the firing voltage, the displacement current charges C_2, C_3 and C_1 that are connected in series. Because C_1 corresponding to the capacitance of the discharge space is much smaller than C_2 and C_3, the applied voltage between the electrodes mostly appears across C_1. When the voltage across the panel reaches the firing voltage, discharge occurs and C_1 is shorted by the discharge. In the equivalent circuit model, this is modeled by the thyristor T_1 or T_2 turned-on at this moment. The voltage across C_1 quickly drops to zero, and thus C_2 and C_3 should be charged to the half of the voltage between the electrodes respectively. Because C_2 and C_3 are much larger than C_1, the discharge current flowing into C_2 and C_3 connected in series at this moment is much larger than the displacement current. The thyristor turned-on accumulates the wall charge across C_1 and this charge induces the wall voltage. The thrystor turns itself off when the voltage across it reduces to zero. When the voltage across the electrodes is reversed, the wall voltage serves as a part of the voltage across the gas. Thus, the voltage across gas reaches the firing condition with lower voltage applied between the electrodes.

Figure 8 shows the simulated I-V characteristics of the case of self-erasing discharge. In this case, a very high voltage is applied between the sustain electrodes. Thus a large amount of wall charge is accumulated, and the voltage across gas becomes high enough to cause a self-erasing discharge when the voltage between the electrodes drops to zero. This behavior of the AC PDP is well presented in Figure 8. As the voltage across the panel falls to the ground, the voltage across gas is high enough to cause a discharge by itself. Therefore a high peak of discharge current appears when the voltage between the electrodes drops to zero and the wall charge is erased.

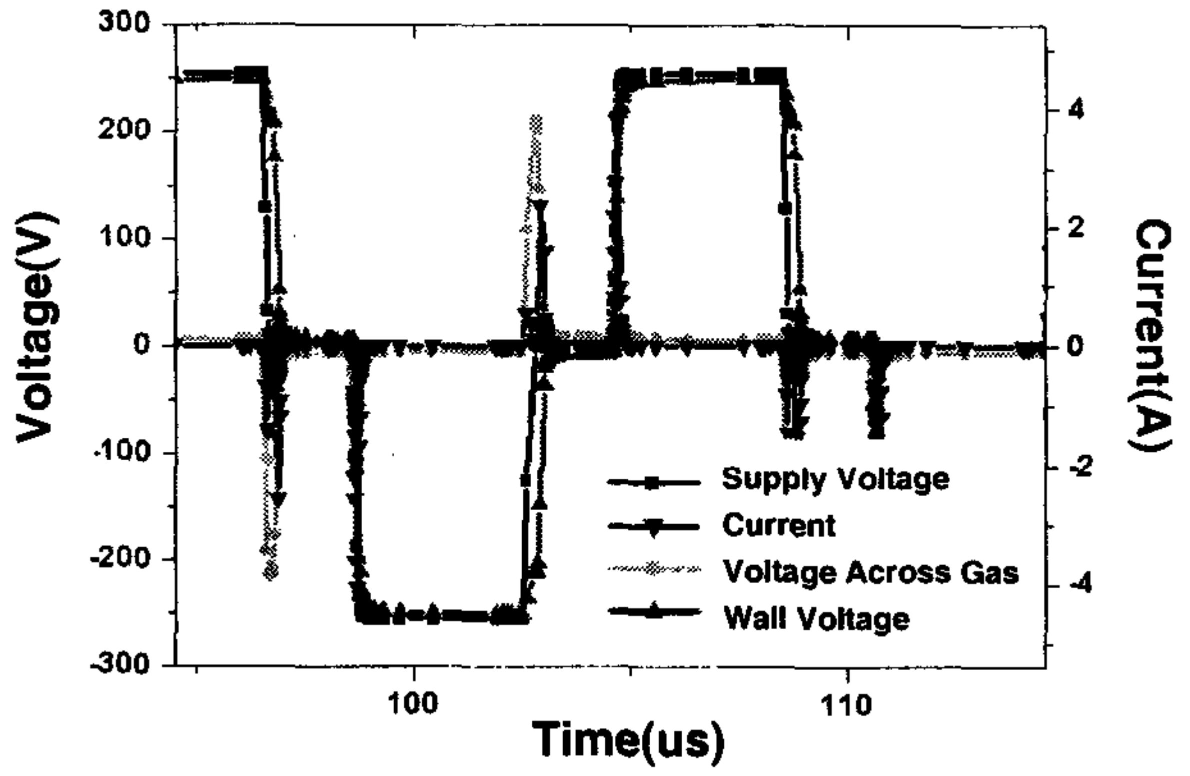


Figure 8. Simulated I-V Characteristic

6. Conclusion

An equivalent circuit model for AC PDPs was presented and the I-V characteristics of an AC PDP were simulated and compared with the experimentally measured results. It is very difficult to measure the wall charge, the wall voltage or the voltage across gas, but it is quite simple to accurately simulate them using the equivalent circuit model proposed in this paper. Even the variation of the voltages and currents can be easily simulated as a function of the applied voltage or time. This equivalent circuit model can be easily implemented in standard circuit simulators such as SPICE.

Accurate qualitative and quantitative analysis and understanding of the behaviors of the voltages, currents and charges involved in the operation of AC PDPs are very essential for the further development of AC PDPs. The equivalent circuit model will also serve as a useful tool for the development of efficient driving methods for AC PDPs

7. References

[1] J.-P Boeuf, C. Punset, L.C. Pitchford, "Two-Dimensional Model of ac Plasma Display Panels in Complex Geometries," SID'96, pp. 1~5, 1996.

[2] H.G. Slottow and W.D. Petty, "Stability of Discharge Series in the Plasma Display Panel," IEEE Trans. Electron Devices, vol. ED-18, pp.650~654, 1971

[3] L.F.Weber, "Plasma Display Device Challenges," ASIA DISPLAY 98, pp15~27, 1998.

[4] B.G. Streeman, S. Banerjee, "Solid State Electronic Device," 5th Ed, Prentice Hall, pp.504~518, 2000.

[5] Joon-Yub Kim, "An Equivalent Circuit Model for AC PDP," IDW' 01, pp.1001~1004, 2001.