Comparison of the fluid simulation with experimental data of excited Xe species density in PDP cell

***Sung Soo Yang**, Sang Woo Ko, Hyun Chul Kim, Sudeshna Mukherjee, and Jae Koo Lee*[*]
Department of Electronic and Electrical Engineering,
Pohang University of Science and Technology, Pohang, 790-784, S. Korea
Phone : +82-54-279-8086 , E-mail : nadia@postech.ac.kr

Abstract

We have compared 2-D and 3-D fluid simulation results of alternating current plasma display panel (AC-PDP) cell with experimentally measured two kinds of excited Xe species (Xe($^3P_1$) and Xe*($^3P_2$)) characteristics. Although direct experimental access and diagnostics of the discharge in a PDP cell is problematic due to the small cell size, some of experimental technologies have made it possible to diagnose the behavior of excited Xe species [1, 2]. The simulation shows the similar characteristics to the experimental results in the excited Xe species density distribution and the number of excited Xe atoms in anode and cathode region. In certain cases, we obtained the arch-shaped discharge path between two sustain electrodes due to the additional pulse applied to address electrode analogous to experiment. This long path discharge induced higher luminous and discharge efficiency compared to the standard case.*

1. Introduction

Recently, plasma display panels (PDPs) have shared the display consumer market with CRT, LCD, and projection TV. Several electronic companies in Korea and Japan have the mass production systems for large screen size PDP over 40 inches. However, low luminous efficiency of the order of 1~1.5 lm/W is still an important research issue for present PDP to compete other displays.

To improve the luminous efficiency and to reduce the consumed power, it is necessary to diagnose the plasma discharge phenomena in a PDP cell. However, the experimental access to plasma discharge has limitations due to the small cell size and short discharge time unlike other semiconductor process device using plasma. Therefore, numerical simulation is a good method to investigate discharge behavior in a PDP cell. We have developed 2-D and 3-D fluid simulation code for a PDP cell with radiation transport model [3, 4] and suggested many new PDP cell designs with high luminous efficiency [5, 6].

In experiment, K. Tachibana et al. observed the spatio-temporal behaviors of excited Xe atoms by using the laser absorption spectroscopy technique [1, 2] in a PDP system. To confirm the accuracy and reliance of our simulation codes, we compared our 2-D and 3-D simulation results with these experiments. We have focused our comparison on the spatio-temporal behavior of Xe atom density and total number of resonance level [Xe*($^3P_1$)] and metastable level [Xe*($^3P_2$)].

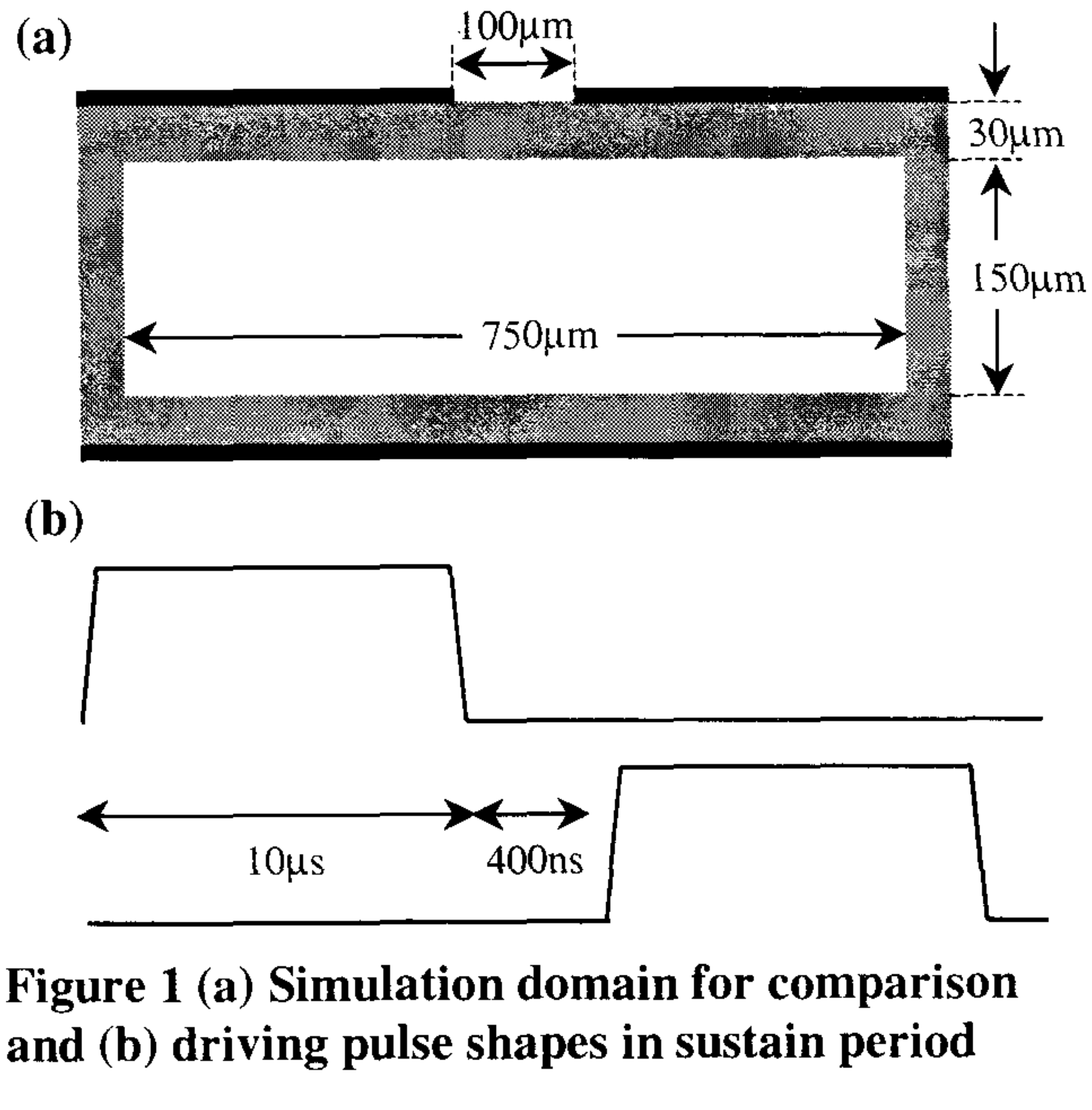

Figure 1 (a) Simulation domain for comparison and (b) driving pulse shapes in sustain period

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[*] jkl@postech.ac.kr

2. Simulation conditions

To do the comparison, we took into account the dimmer ion (Xe_2^+, Ne_2^+, and $NeXe^+$) effects and related chemical reaction data in our 2-D and 3-D fluid simulation codes. Figures 1(a) and (b) show the simulation domain and applied driving pulses on two sustain electrodes, respectively. 5% xenon and 95% neon gases are used at the gas pressure of 500Torr. Secondary electron emission coefficients of MgO layer for Ne ion and Xe ion are 0.5 and 0.05, respectively.

3. Simulation results

For the first comparison, we applied high voltage (250V) and low voltage (200V) on sustain electrodes with grounded address electrode as mentioned in Ref. 1. These simulations show the similar characteristics as in experiment. For low voltage case, the density distribution of excited Xe atoms is very similar to that of general PDP cases. When driving pulse is applied, initial discharge occurs at the inner edge region of the anode between two sustain electrodes. Although the distribution of excited Xe species density in the anode region is narrower than that in the cathode region, the local region with high density distribution appears in the anode region at side view of the panel.

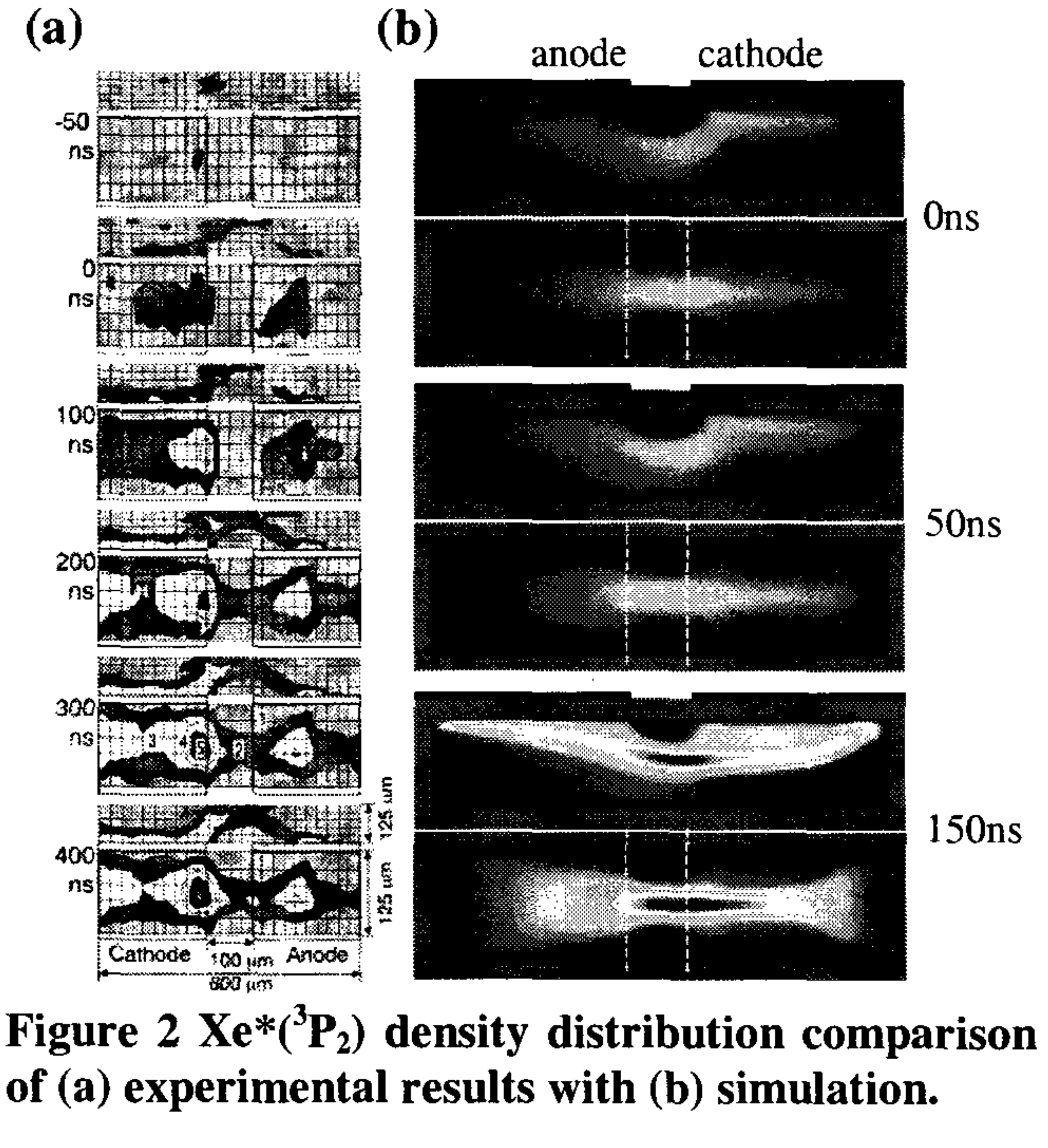

Figure 2 $Xe^*(^3P_2)$ density distribution comparison of (a) experimental results with (b) simulation.

However, in high voltage case, pre-discharge occurs between address electrode and a sustain electrode which is a cathode. Due to this pre-discharge, the discharge in cathode region is stronger than that in anode region and arch-shaped discharge is formed between sustain electrodes. Figures 2(a) and (b) show the time evolution of $Xe^*(^3P_2)$ density distributions in experiment and simulation, respectively.

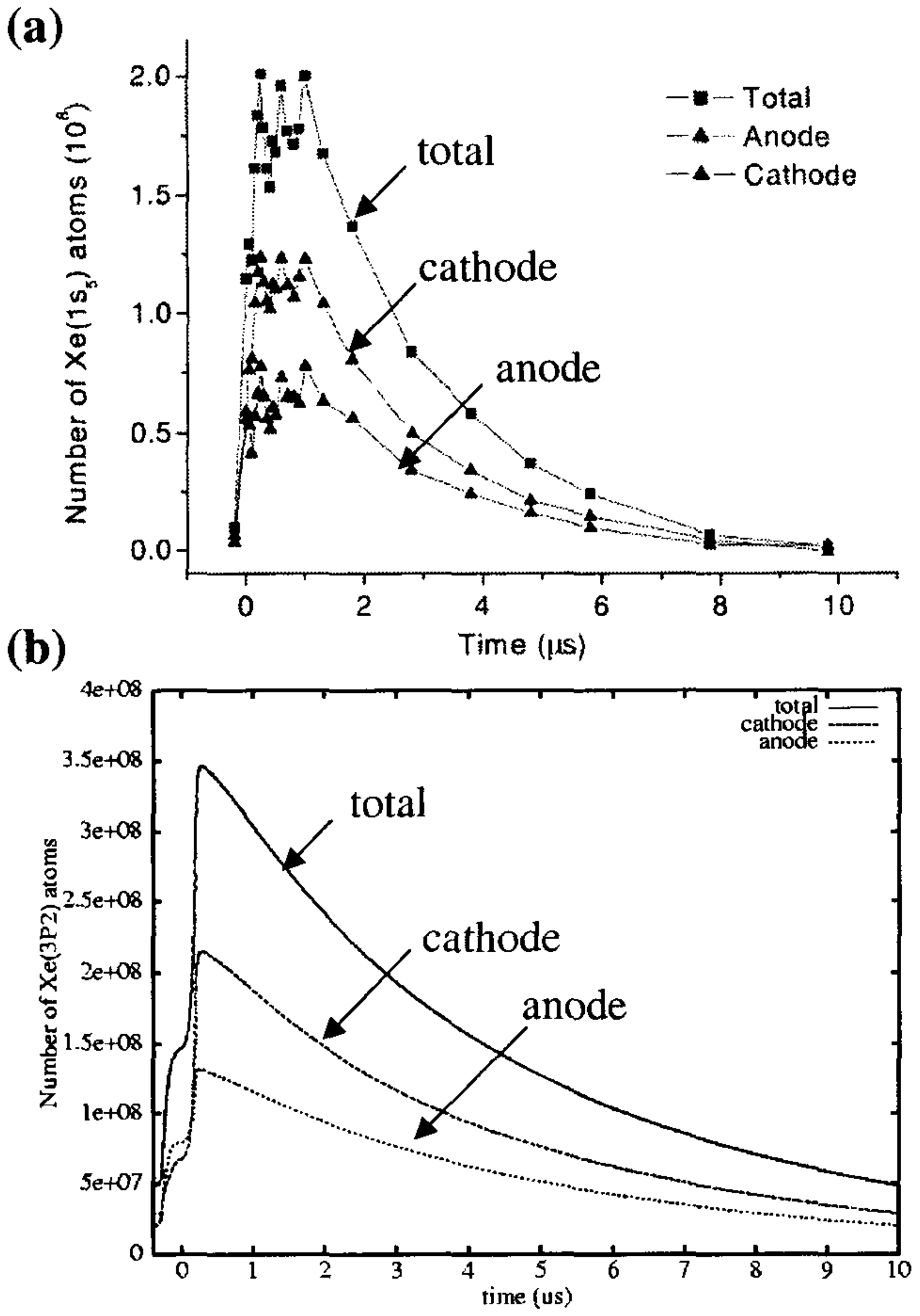

Figure 3 Total number of $Xe^*(^3P_2)$ comparison of (a) experimental results with (b) simulation results.

We have also compared the number of excited Xe atoms in anode and cathode regions as a function of time as shown in Fig. 3. In calculation of atom number, the regions within 25µm from the boundary are not included because these regions are not accessed by probing laser beam in experimental process [1]. Analogous to the experimental results, simulations show that the number of excited atoms in the cathode region is about 60% larger than that in the anode region. This is a very relevant value compared to the experimental results. The decay time from the peak number density to its half width is larger in our simulation (about 2.5µs) in comparison with experiment (about 2µs).

Recently, there are many experimental attempts to

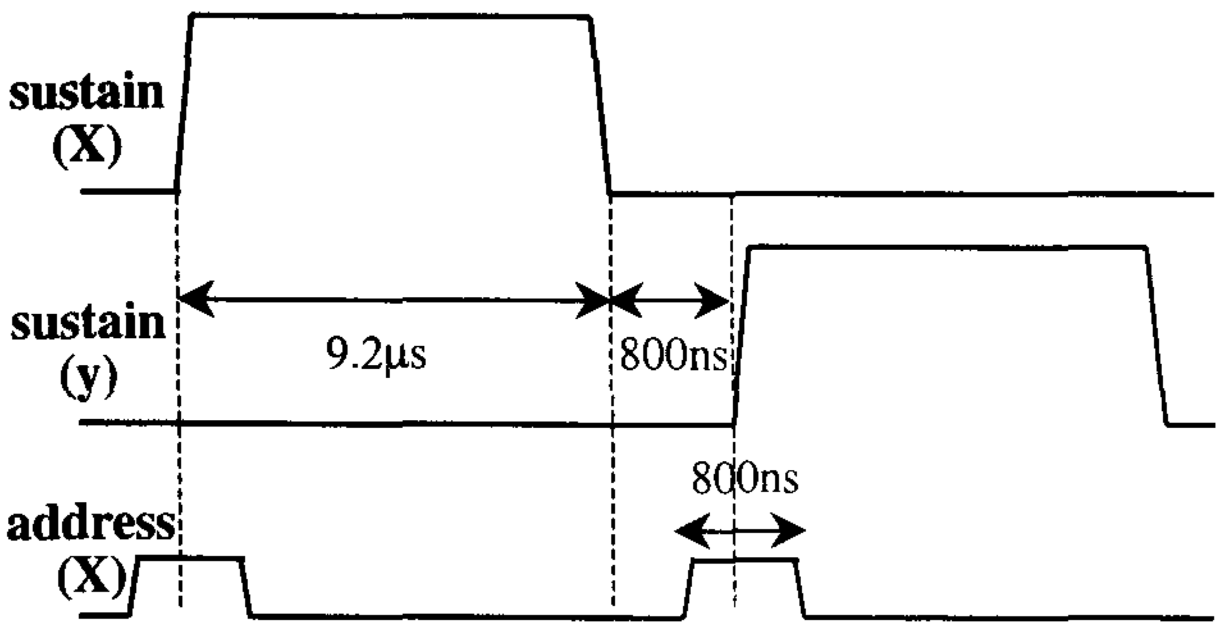

Figure 4 Driving pulse shapes for comparison with experiment.

improve the luminous efficiency or image quality using the address electrode. For the second comparison, we have applied small additional pulse to address electrode as shown in Fig. 4 to compare with the experimental results in Ref. 2. In this case, the small pulses applied to address electrode are not synchronized with sustain driving pulses in rising time. When applied voltage to address electrode is fixed to 0V during the sustaining period, only surface discharge occurs along the upper dielectric layer as shown in Figs. 5(a) and (b). In simulation, small self-discharge can be observed in the cathode region before sustain pulse is applied. However, it is very weak and does not influence the main discharge. Considering some regions apart from MgO surface, which is not accessed by laser beam in experiment, the distribution of excited Xe atoms in simulation [(Fig. 5(b)] is very similar to that in experiment as shown in Fig. 5(a).

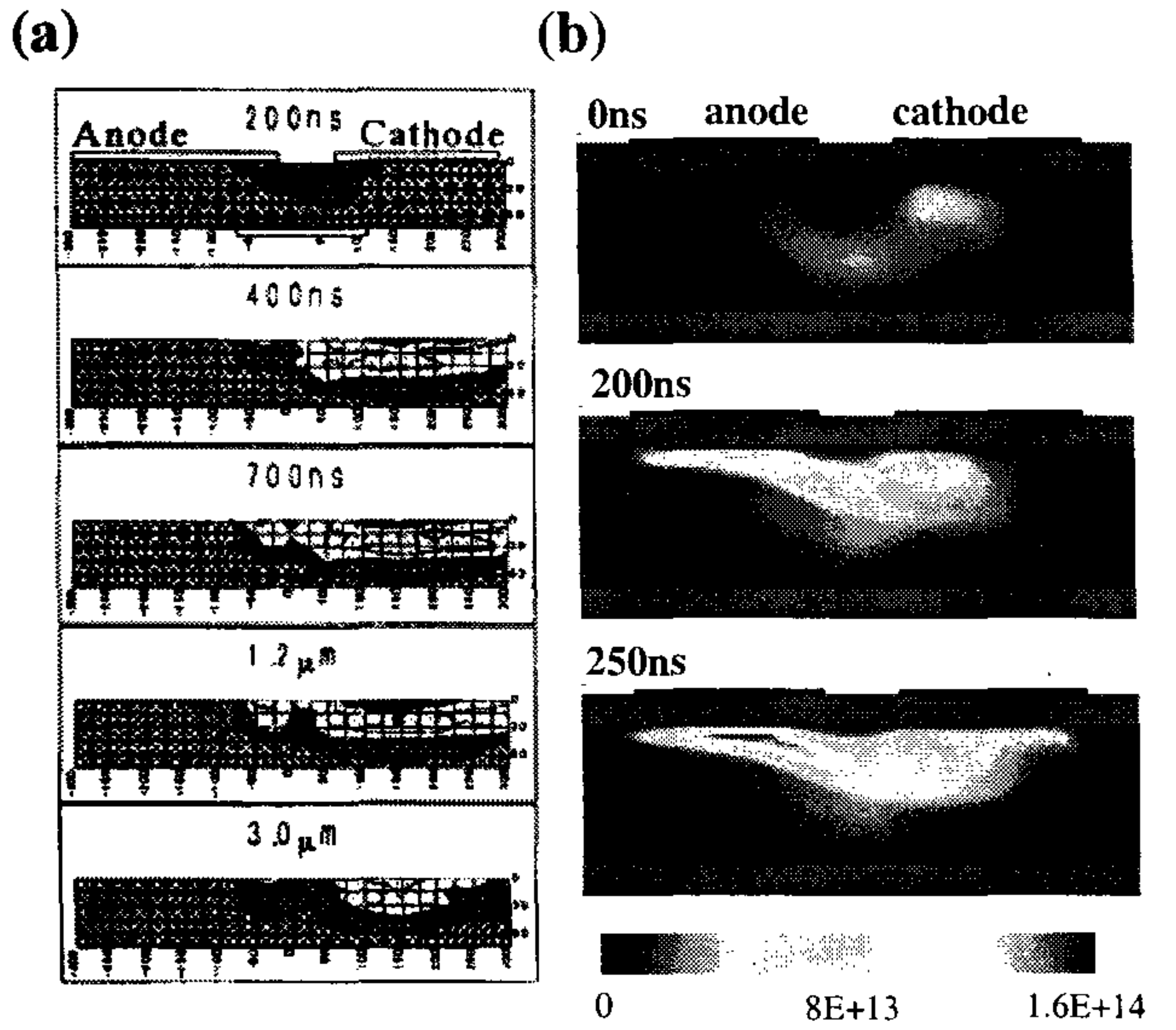

Figure 5 Xe*($^3P_2$) density distribution in case of 0V applied on address electrode. Comparison of (a) experimental results with (b) simulation results.

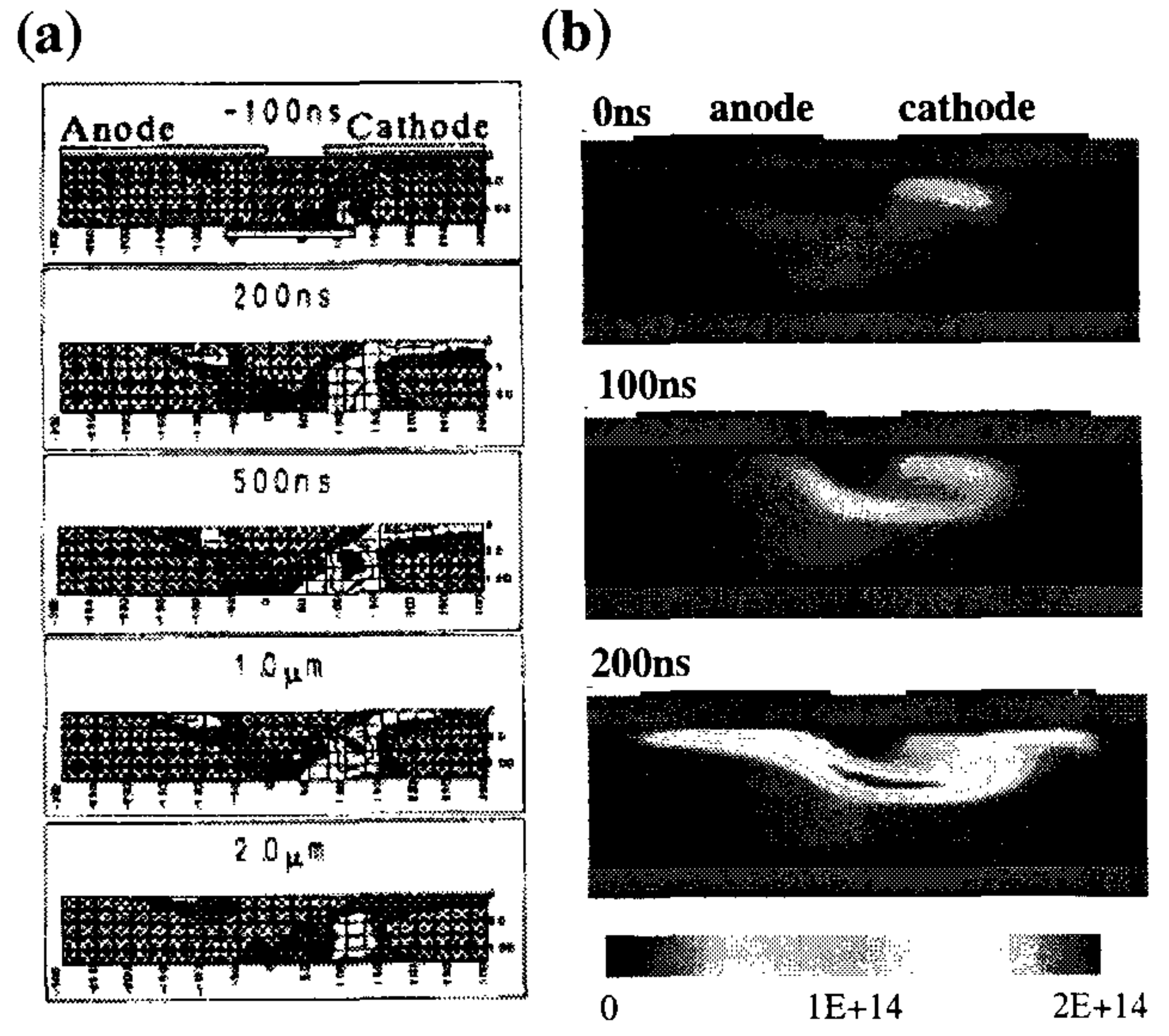

Figure 6 Xe*($^3P_2$) density distribution in case of small width pulses applied to address electrode. Comparison of (a) experimental results with (b) simulation results.

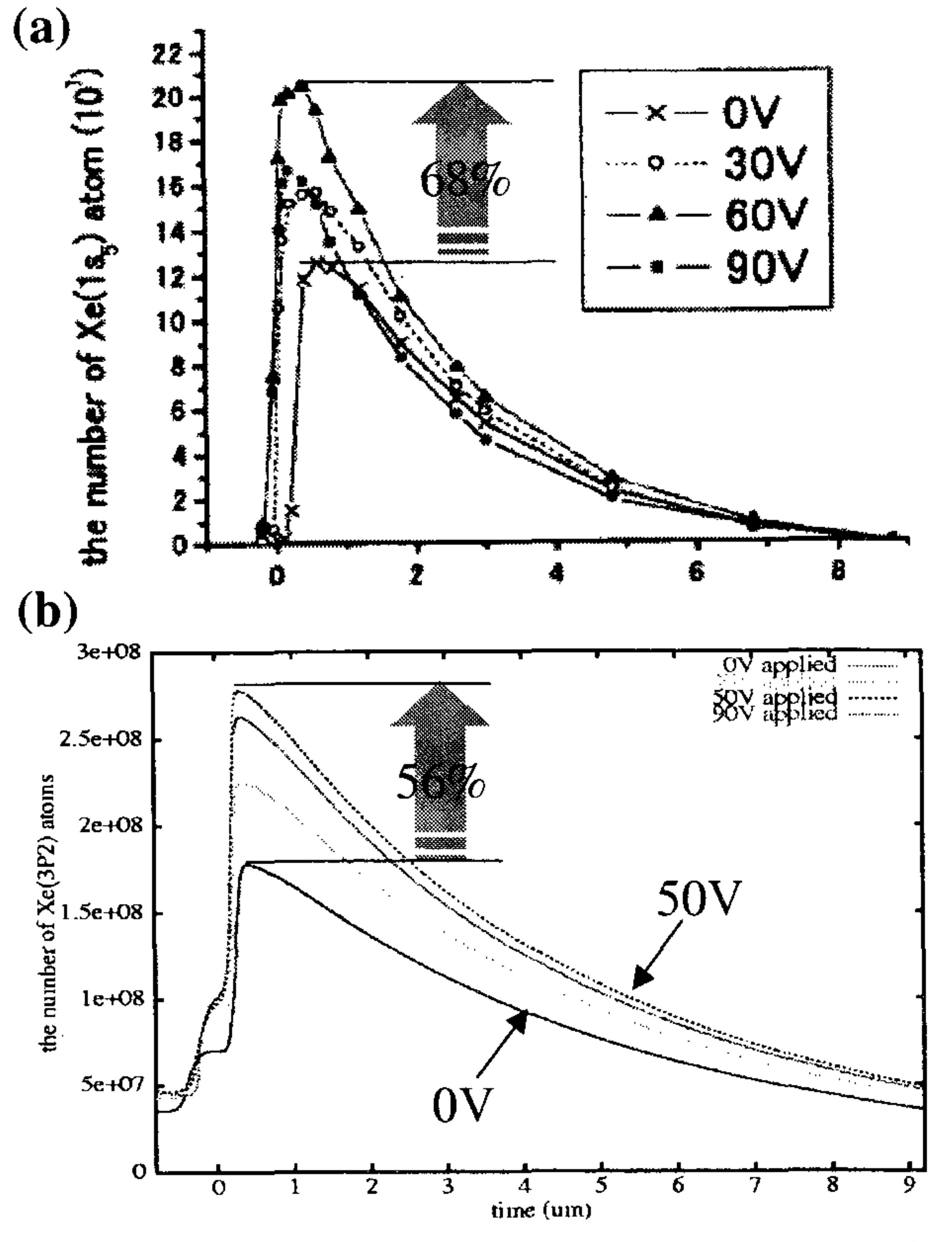

Figure 7 Comparison of the number of Xe*($^3P_2$) atoms as the applied voltages on address electrode are varied. (a) Experimental results (b) Simulation results

However, when additional pulses with short pulse width are applied to address electrode, we have observed arch-shaped long discharge path as shown in Fig. 6. The additional pulse to address electrode creates the pre-discharge between address electrode and cathode. This pre-discharge generates priming particles in the cell space and these priming particles influence the main discharge. For the same sustain voltage, the case with additional pulses to address electrode has faster main discharge ignition than the case without additional pulses. Therefore, it is possible to generate excited Xe atoms during voltage rising time. We have also changed the applied voltage of additional pulse to address electrode. Figure 7 shows the comparison of experimental results with simulations for total number of $Xe^*(^3P_2)$ as a function of time. In both of experiment and simulation, the total number of $Xe^*(^3P_2)$ and discharge efficiency are higher for the cases of 50~60V than those for other cases.

From these experimental and simulation results, new PDP cells with high efficiency can be designed using address electrodes. Figure 8(a) shows one of the new PDP cell designs. If additional pulses are applied to address electrode like in Fig. 4, it is possible to make wide distance between two sustain electrodes with stable voltage margins and high luminous efficiency as shown in Fig. 8(b).

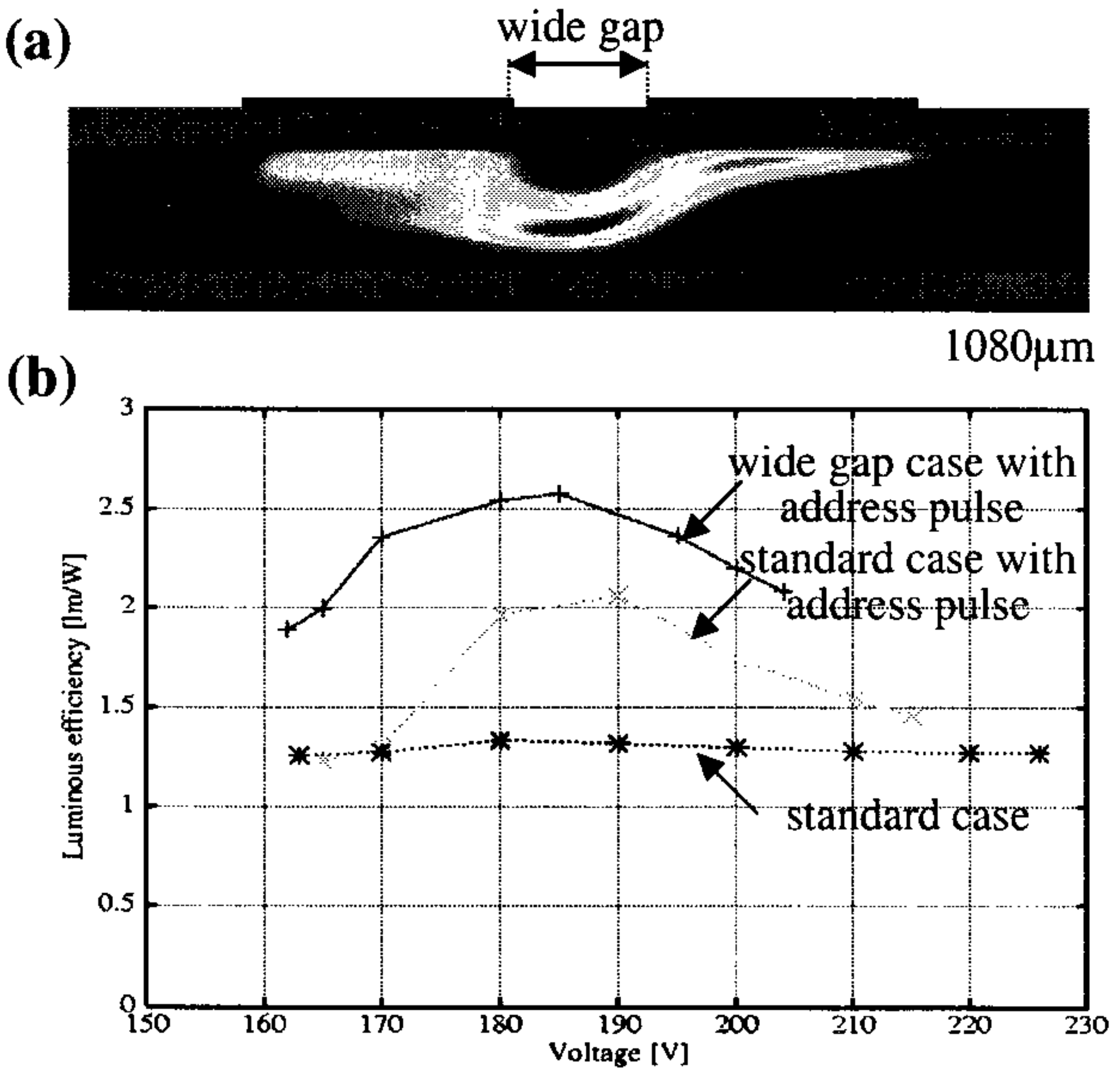

Figure 8 (a) New PDP cell design using additional pulses on address electrode with $Xe^*(^3P_1)$ density distribution and (b) luminous efficiency.

4. Summary

Using the fluid simulation codes, we compared the results of simulation with experimentally measured excited Xe species characteristics to confirm the accuracy and reliance of simulation codes. For the density distribution and the time trace of total number of $Xe^*(^3P_2)$ on the anode and the cathode region, simulation showed the similar characteristics as in experiments. Based on the comparison of address electrode case with additional pulses, it is possible to suggest new cell designs with high luminous efficiency.

5. Acknowledgement

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6. References

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