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<td>Ahn, JC; Shintani, Y; Tachibana, K; Sakai, T; Kosugi, N</td>
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Kyoto University
Effects of pulsed potential on address electrode in a surface-discharge alternating-current plasma display panel

Jeong Chull Ahn, a) Youichi Shintani, Kunihide Tachibana, b) Tetsuo Sakai, c) and Naoki Kosugi d)

Department of Electronic Science and Engineering, Kyoto University, Kyoto 606-8501, Japan

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The influence of pulsed potential application onto the address electrode of an ac-type plasma display panel was investigated from the observation of front and side views of Xe atom densities in the metastable (1s5) and excited (2p) states in a unit discharge cell by using microscopic laser absorption spectroscopy and optical emission spectroscopy. It was seen that a predischarge occurs between the address electrode and one of the sustain electrode worked as a preceding anode, which is a similar effect found previously by applying a higher sustain voltage. The predischarge partially erases the surface charge accumulated in the preceding pulse, but it induces a faster main sustain discharge, bowing towards the address electrode, and enhances the production efficiency of Xe(1s5) atoms, if the applied potential is within an optimal range. © 2003 American Institute of Physics. [DOI: 10.1063/1.1580638]

One of the most important issues of the present alternating-current plasma display panels (ac-PDPs) is to improve luminous efficiency, which is dependent on the composition of rare gases, total pressure, cell structure, and driving wave forms. Various driving techniques using address pulses in sustain periods have been suggested to improve the luminous efficiency. 1–5 However, real phenomena occurring in the discharge by applying address pulses have not been experimentally investigated as yet. In this work, we examine the behavior of metastable Xe atoms in the 1s5 state, Xe∗(1s5), under this condition by using the microscopic laser absorption spectroscopy (LAS) technique, which we have developed previously. 6–9 The near-infrared emission from excited Xe atoms in the 2p state, Xe∗(2p), is also examined, which is composed mostly of the 823- and 828-nm lines and correlates with the vacuum ultraviolet emission at 173 and 147 nm through the cascade transitions to the metastable (1s5) and resonance (1s4) states. 10,11 As the total gas pressure or the Xe concentration increases, the emission intensity at 173 nm from Xe∗(1s5) and excited (2p) states increases through the enhanced production efficiency via three-body collisions of Xe∗(1s5) atoms with Ne and Xe atoms in the ground states. 12,13 It is, therefore, of great importance to investigate the total number of Xe∗(1s5) atoms for the estimation of the luminous efficiency in ac-PDPs.

The structure of an ac-PDP unit cell shown in Fig. 1(a) was specially designed for the three dimensional (3D) observation of spatiotemporal behaviors. 8,9 The sustain electrodes of 200 μm width made of indium tin oxide (ITO) film were successively covered with a dielectric layer and a MgO protective layer, and set in parallel to each other on the front glass plate with a gap of 75 μm. By using transparent glass prisms of 150-μm thickness as barrier ribs, we could observe the front and side views of the discharge at the same time. On the rear glass plate, the address electrode also made of ITO was located perpendicularly to the sustain electrodes. A mixture of Ne and Xe (5%) was filled at a pressure of 500 Torr. The width, frequency, and voltage of the sustain voltage pulses (Vx and Vy) employed in this experiment were 9.2 μs, 50 kHz, and 200 V, respectively. The width of the address voltage pulses (Va) was fixed at 800 ns. The timing of Va at the center was adjusted to the rising edge of Vx, as shown in Fig. 1(b). Hereafter, the time origin (t = 0) is defined at the rising edge of Vx. The values of Va was varied from 0 to 90 V. The LAS measurement of the Xe∗(1s5) atom density was performed by tuning the laser wavelength to the 823.1 nm (2p 6–1s5) transition. The IR emission from Xe∗(2p) atoms...
The discharge current at the sustain electrode \( I_x \) and address electrode \( I_a \) were measured by a differential probe through a small resistor of 680 \( \Omega \). Figures 4(a) and 4(b) show the current wave forms of \( I_x \) and \( I_a \), respectively, which were measured at \( V_a = 0, 30, 60, \) and 90 V. Here, we define the response (or delay) time \( \tau \) as the time difference between the rising edge of the sustain pulse (\( t=0 \)) and the peak of the sustain current. At a given sustain voltage of 200 V, \( \tau \) was measured to be 360, 135, 100, and 95 ns at \( V_a = 0, 30, 60, \) and 90 V, respectively, showing a tendency of shortening with the increase of \( V_a \). The occurrence of pre-discharge is also seen in the wave forms of \( I_a \) at \( V_a = 60 \) and 90 V, where the address electrode is working as the anode. However, it is noticed that in each wave form of \( I_a \), a smaller negative peak follows the positive peak just after the start of the main sustain current. It suggests that the address stronger discharge causes a similar pre-discharge after the falling edge of the preceding sustain pulse.\(^9\)

FIG. 3. Temporal sequence of contour diagram of Xe\(^*\)(1\( s_\perp \)) atom density (in units of cm\(^{-3}\)) at an address pulse voltage of \( V_a = 60 \) V viewed from front (left column) and side (right column).
electrode turns the role from anode to cathode in the period of sustaining discharge, since the surface of the address electrode has been charged negatively within the predischarge period. Therefore, the polarity of the address electrode charge changes to positive after the sustain period, which is favorable for the next predischarge phase.

Figure 5 shows the total number of Xe*(1s) atoms, which is spatially integrated in the whole cell volume, as a function of time. The peak number of Xe*(1s) atoms increases from $1.3 \times 10^8$ to $2.1 \times 10^8$ as $V_a$ increases from 0 to 60 V, but it decreases as $V_a$ increases further to 90 V. At $V_a=90$ V, it is suggested that too much surface charge is lost from the sustain electrode in the predischarge, and as the result the main discharge is weakened. At the optimal condition with $V_a=60$ V, the total input power estimated from the current wave form and the applied voltage increases by about 50% as compared to the case without $V_a$. However, the density of Xe*(1s) atoms increases by about 70% and, then, the production efficiency increases by about 25% with the power expense at the address electrode of only 6% of the sustain discharge power consumption.

In conclusion, by the application of address pulse potential with a moderate amplitude, say 60 V in our case, the spatiotemporal distribution of the electric field caused by both the surface charges and the external applied voltages becomes optimal across the whole electrode area, leading to an expanded discharge scheme with higher luminance and luminous efficiency. At higher values of $V_a$, however, the predischarge becomes too strong to disturb the optimum balance of the electric field.

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