Experimental Investigation of the Excited Xe Atoms Density in Ultra-high-resolution PDPs

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Abstract

We investigated experimentally the influence of the generation efficiency for excited Xe atoms on ultra-fine horizontal cell pitch AC PDPs. In the case of a 0.1 mm cell pitch, the sustain voltage increased; however, the generation efficiency was equal to or higher than for the conventional 0.22 mm cell pitch.

1. Introduction

Ultra-high definition TV broadcasting will convey a stronger sensation of reality than can be conveyed with Hi-Vision. With the aim of realizing such a broadcasting system, we proposed an "ultimate" broadcasting system with an extremely high-resolution video format, using 7,680 × 4,320 pixels and a 60 Hz frame rate progressive scanning scheme. We call this system Super Hi-Vision (SHV). The latest production technologies have enabled the creation of large screen TV monitors with diagonal sizes of 100 inches or more, such as PDPs. However, in order to reproduce an SHV image, it will be necessary to fabricate an ultra-fine discharge cell, even for a 100 inch diagonal screen size (an approximately 0.3 mm pixel pitch). In this case, the issue of particular concern is degradation of the luminance efficiency due to the small volume of the unit discharge cell.

The excited Xe atoms in the metastable Xe*(1s_5: Paschen notation) and resonance Xe*(1s_4) states play important roles for PDPs, because the line emission at 147 nm from exited Xe*(1s_4) atoms and the band emission at 173 nm from Xe_2* dimers are used to excite the red, green, and blue phosphors. Therefore, we investigated the spatio-temporal behavior of the excited Xe atoms in ultra-fine horizontal cell pitch PDPs [1, 2].

In this manuscript, we report the relationship between the generation efficiency of the excited Xe atoms and the horizontal cell pitch. Furthermore, this report presents the dependence of excited atom density on the discharge-gap length for a 0.1mm horizontal cell pitch.

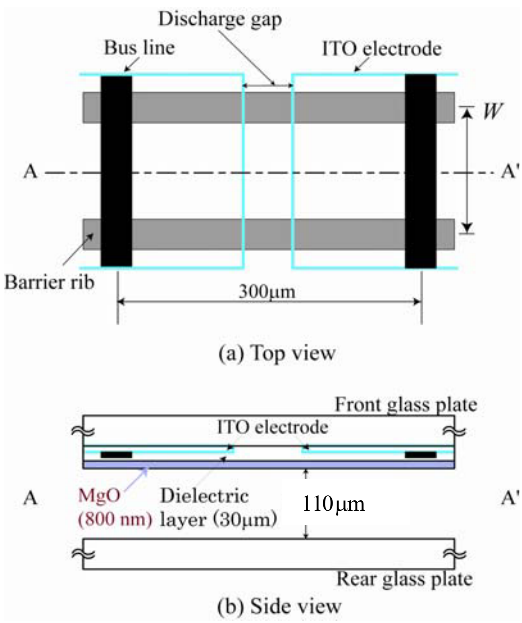

Figure 1. Unit-cell structure of the test panel, (a) front view and (b) cross-section along line A-A' of (a).

2. Experimental setup

In order to measure the spatio-temporal behavior of the excited Xe atoms, we fabricated test panels with different horizontal cell pitch values *W*. These panels, shown in Figure 1, had a coplanar structure, and were made without an addressing electrode or phosphor coating to allow access by probe laser beams. The coplanar electrodes made of indium tin oxide (ITO) films, covered with a dielectric layer and a magnesium oxide (MgO) protective layer, and set parallel to each other on the front glass plate at a

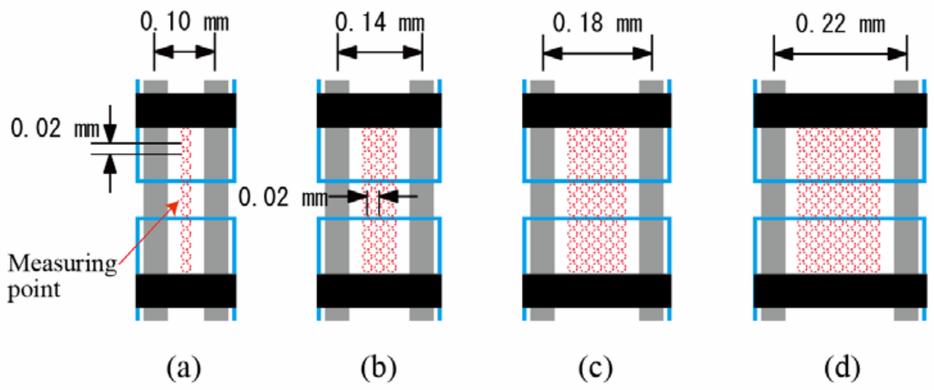

Figure 2. Measuring points for the various discharge cell pitches *W*. (a) *W*: 0.10 (1 × 11 points), (b) *W*: 0.14 (3 × 11 points), (c) *W*: 0.18 (5 × 11 points), (d) *W*: 0.22 mm (7 × 11 points).

constant discharge gap length. Each ITO electrode had bus lines, which were arranged parallel to it. The striped barrier ribs were formed with a 30 μm top width on the rear glass plate. The test panel specifications are shown in Table 1.

We used microscopic laser absorption spectroscopy [3] (LAS) to measure the density of the excited Xe atoms. We used a diode laser in the LAS to measure the density of the excited Xe*(1s_4) and Xe*(1s_5) atoms by tuning its wavelength to the 828.0 nm (2p_5-1s_4) and 823.1 nm (2p_6-1s_5) transitions, respectively. In this method, a photoelectrically converted temporal absorption signal was detected by a digitizing oscilloscope with 8-bit signal resolution and 40 ns time resolution. The absolute excited Xe atom density was calculated by multiplying the measured absorption rate by a proportional coefficient. The diameter of the probe laser beam was estimated to be about 15 μm at the center of the gas gap in the discharge cell. Thus, as shown in Figure 2, the measurements were performed at 20 μm intervals in the discharge cell.

Table 1. Test panel specification.

Discharge gap length (*d* ;μm)	60
Barrier rib width (μm)	30/60 (top/bottom)
Bus line width (μm)	50
Gas contents	Ne (95%), Xe (5%)
Total gas pressure (kPa/Torr)	63/500
Cell pitch (*W* ;mm)	0.10, 0.14, 0.18, 0.22

When a different horizontal discharge cell pitch was used, the relationship between the sustain voltage and discharge current was not the same, even if the discharge gap length and inner gas condition were kept constant, because of the difference in the volume of the unit discharge cell. Consequently, in our investigations, the spatio-temporal behaviors and generation efficiencies for the excited Xe atoms were estimated under a constant discharge current density condition. Figure 3 shows the relationship between the sustain voltage and average discharge current as a function of the cell pitch when square wave pulses and a 2 μs duration were applied to one of the ITO electrodes with a period of 20 μs, and complementary pulses, delayed by 10 μs, were applied to the other electrode. Sustain voltages were operated as a controlled parameter, in order to proportionate the average discharge current for the increase in the horizontal discharge cell pitch. As a result, the sustain voltage increased 20 V at a cell pitch of 0.10 mm. Under the terms of these sustain voltage conditions, the estimated discharge current densities were approximately the same level, as shown in Table 2.

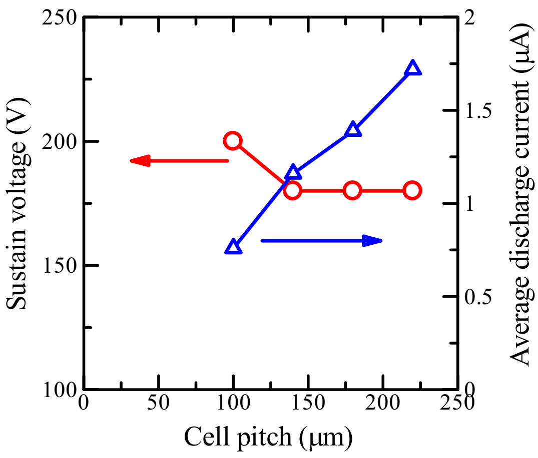

Figure 3. Sustain voltage and average discharge current as a function of cell pitch.

Table 2. Measurement conditions.

Cell pitch (*W* ;mm)	0.10	0.14	0.18	0.22
Sustain voltage (V)	200	180	180	180
Discharge current density (mA/cm^2)	4.56	4.71	4.95	4.85

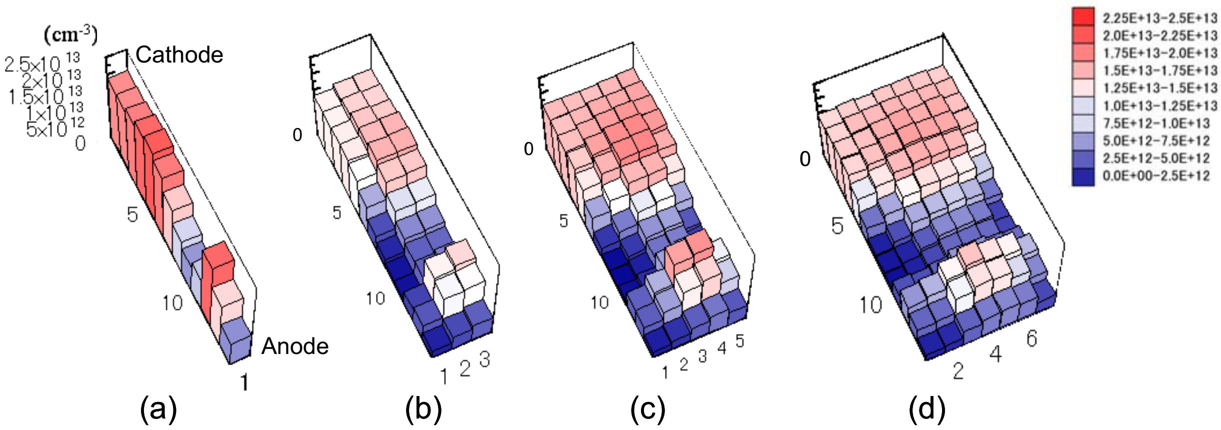

Figure 4. Spatial distribution of the Xe*(1s_5) density as a function of the discharge cell pitch *W* at the time of peak atom density. (a) *W*: 0.10, (b) *W*: 0.14, (c) *W*: 0.18, (d) *W*: 0.22 mm.

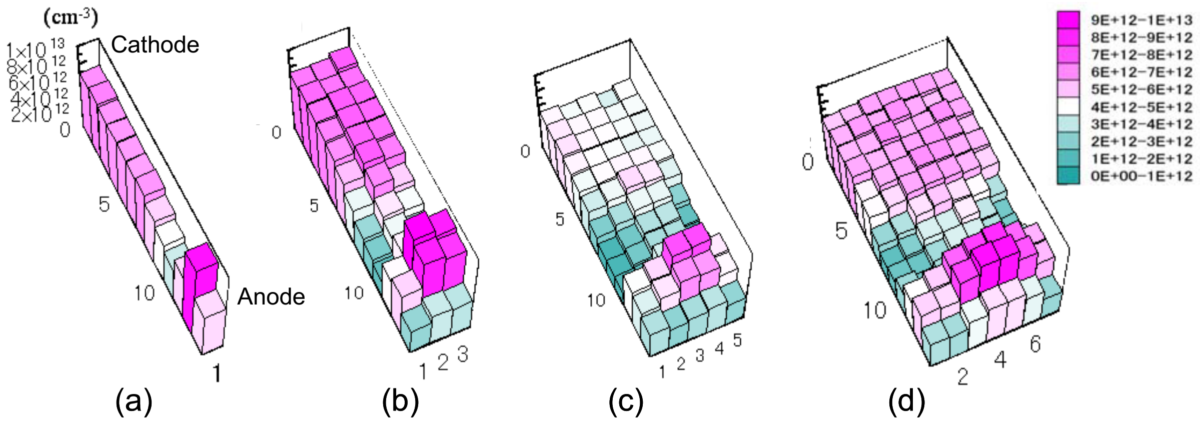

Figure 5. Spatial distribution of the Xe*(1s_4) density as a function of the discharge cell pitch *W* at the time of peak atom density. (a) *W*: 0.10, (b) *W*: 0.14, (c) *W*: 0.18, (d) *W*: 0.22 mm.

3. Results and discussion

In order to investigate the effects on the generation efficiency of the excited Xe atoms for the narrowed horizontal cell pitch, the spatio-temporal distribution of the excited Xe atoms were measured by the LAS with the same discharge current density. Additionally, we had some studies for the other discharge parameters at a cell pitch of 0.10 mm [2]. As an example, we introduce the estimation result of the discharge-gap length dependence in this chapter.

3.1 Cell pitch dependence

Figures 4 and 5 show the spatial distribution of the Xe*(1s_5) and Xe*(1s_4) densities as a function of the discharge cell pitch *W* at the time of peak atom density. In the case of a wide cell pitch, the generated excited atom density gradually decreased from the centerline of the horizontal cell width toward the barrier rib side. This phenomenon appeared prominently on the anode side.

In contrast, high-density excited atom generation was observed at a cell pitch of 0.10 mm. It appears certain that the higher applied-voltage must be one of the effective factors to generate the excited atoms. However, on several measuring points, the increment of the excited atom density exceeded the increment of applied-voltage. In particularly, the generation efficiency of the metastable Xe*(1s_5) was equal to or higher than for a conventional 0.22 mm cell pitch.

3.2 Gap length dependence

Figure 6 shows the measured results for the discharge gap dependence of the sustaining voltage (Vs) margin at a cell pitch of 0.10 mm. The minimum and maximum sustaining voltage values (Vsmin and Vsmax) were defined as the self-erasing and extinguishing voltages, respectively. These measured voltages increased based on an increase in *d*, as expected. In particular, Vsmin increased significantly; the sustaining voltage increased to 0.5 V per micro-meter for gap length *d*.

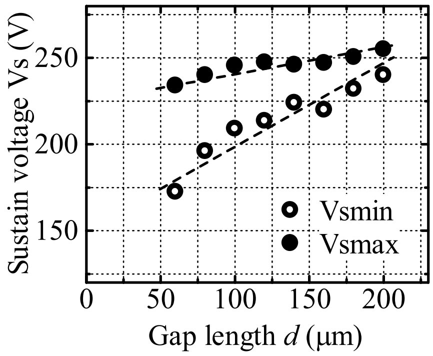

Figure 6. Variation in the sustain voltage for the discharge-gap length *d*.

Figure 7 shows temporal streak images of the measured spatial distribution of the Xe*(1s_5) atom density as a function of the discharge gap length *d* at the median point of the sustaining voltage margin. The horizontal axis shows the elapsed time after applying a pulse voltage between the coplanar electrodes. When the discharge gap increases, an additional area where the excited atoms are generated is formed in the discharge gap region. Such an area is particularly observed for the case shown in Fig. 7(d). It is predicted that this formation area corresponds to the positive column region observed in PDPs with a conventional pixel size [4].

4. Conclusion

We investigated the generation efficiency for excited Xe atoms in the world's finest horizontal cell pitch PDP. The results showed that, in the case of a 0.1 mm cell pitch, the sustain voltage increased; however, the generation efficiency of the metastable Xe*(1s_5) was equal to or higher than for a conventional 0.22 mm cell pitch.

Then we measured the spatial-temporal behaviors of the Xe*(1s_5) atom densities for various discharge-gap lengths. In conclusion, even in the case of a fine cell pitch, it was clarified that excited atom generating points can be caused in the gap region as the discharge-gap increased. This work will contribute to an improvement in the luminous efficiency of ultra-high-resolution PDPs.

5. References

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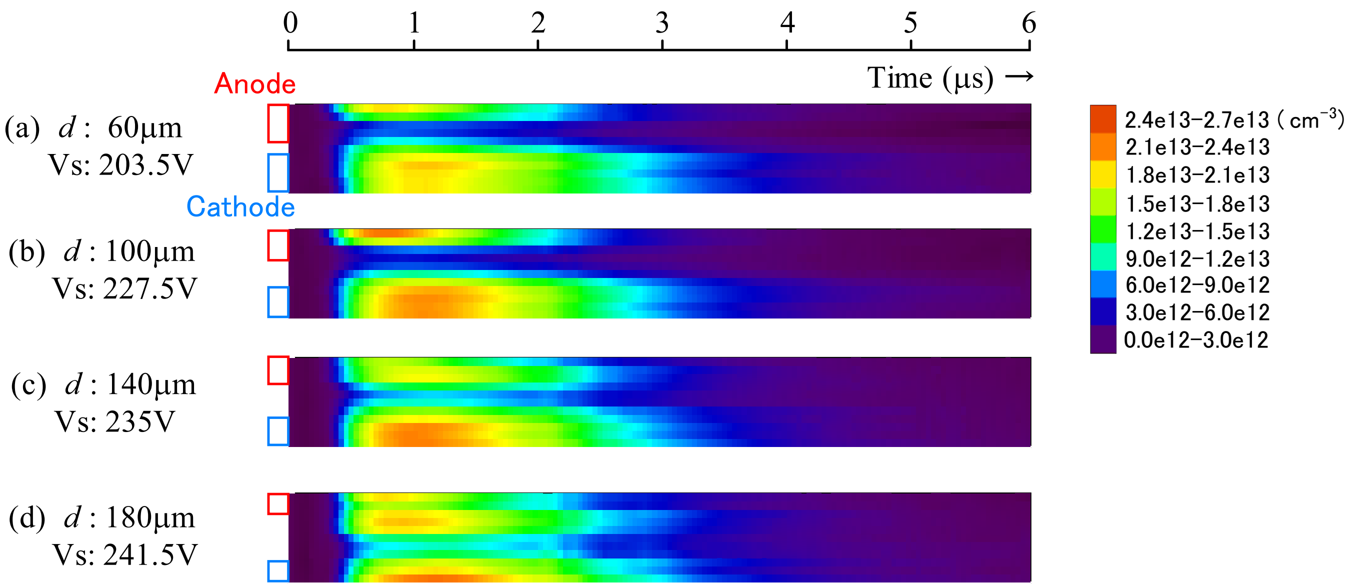

Figure 7. Spatial-temporal distributions of the Xe*(1s_5) atom density measured per unit cell as a function of the discharge-gap length *d* for Ne (95%) and Xe (5%) gases at a total gas pressure of 67 kPa.