Discharge Dynamics of AC Plasma Display Panel

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Abstract

To investigate the discharge dynamics of alternating current plasma display panel (ACPDP), we measured the spatio-temporally resolved VUV and IR emission by an intensified charge coupled device (CCD). The breakdown begins around the anode inner edge and moves towards the cathode surface. As the ionization intensifies in front of the cathode surface, another emission region appears on the anode surface. While the anode side emission does not move but grows, the cathode side emission moves out and spreads over the entire cathode surface. The discharge dynamics emission by a 2 dimensional numerical simulation suggests that a cathode-directed streamer formation play an important role.

I. Introduction

PDP is a promising candidate for the large area wall-mounting HDTV (High definition television)[1]. Recently, PDP technologies have been improved tremendously in luminance, luminance efficiency and lifetime, but it still needs more improvement in especially the luminance and efficiency before it can be commercially successful. Those needed improvement can be made through the better design of cell and electrode structures, gas mixture and driving method which in turn can be obtained from the better understanding of fundamental discharge physics. However, the discharge volume of PDP is so small that it is very difficult to use conventional diagnostic methods.

Light emission image converter is an useful tool to understand the discharge dynamics. Recording of the spatio-temporally resolved light emission by a high-speed camera can lead to a precise understanding the discharge dynamics. Another useful tool is the computer simulation. Computer simulation makes possible a prediction of the time variation of the various species' density during the glow and afterglow period. Recently, a number of computational studies have been developed using 1 and 2 dimensional codes that provided very useful information.

In this work, we carried out detailed spatio-temporally resolved measurement of IR and VUV emission and a numerical simulation to understand the discharge physics of surface type AC PDP, and a new discharge model has been suggested.

II. Experimental Setup

An image intensified CCD camera for VUV detection with a MgF_2 lens system was used for obtaining the 147nm and 173nm emission images. Figure 1 shows a schematic diagram of the detection system and Figure 2 shows the sustain driving pulses. The rising time of these pulses is about 150nsec at 180V and we defined the elapsed time from the moment when the voltage pulse starts to rise. The test panel used in this experiment has only one pair of sustain electrodes with 460μm width and 80μm gap. The distance between the dielectric surface of the test panel and the MgF_2 window was set less than 200μm to simulate the discharge in the real AC PDP. We used optical filters, which have about 10nm FWHM for obtaining the selected wavelength emission images, and thus, we could not separate the 823nm and 828nm IR spectra. The discharge gas was Ne-Xe(1%) mixtures at 300Torr.

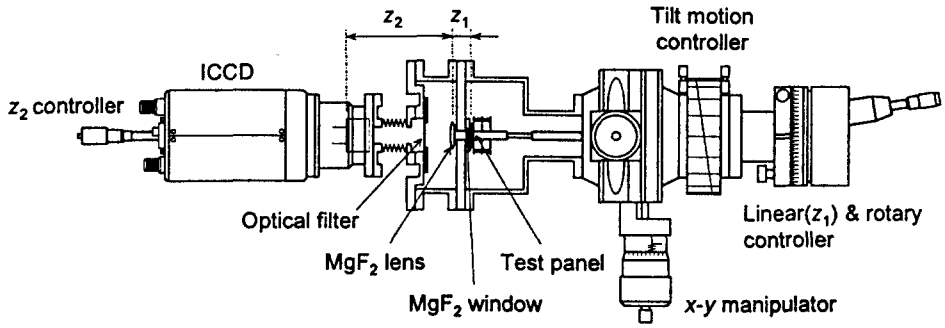


Figure 1. Schematic diagram of the surface discharge imaging system

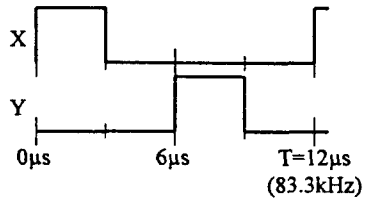


Figure 2. Driving pulses

III. Simulation model

To investigate the mechanism of discharge, we used a 2-dimensional multi-fluid simulation. The model equations consist of Poisson's equation, continuity and drift-diffusion equations. We assumed the local field approximation, therefore, the ionization and excitation rates are function of the local field. The reaction model used in this simulation consists of 8 level model for Xe and 6 level model for Ne. The Xe levels are the ground state Xe, Xe^* ($^3P_2$:metastable level), Xe^*($^3P_1$: resonance level), lumped higher excited states Xe^{**}(>=6p states), Xe^+, Xe_2^*($0u^+$, v>>0) (150nm radiation), Xe_2^*(1u, 0u-,v≈0) (173nm radiation), and dimer ion Xe_2^+. The Ne levels are ground state Ne, Ne^*, Ne^{**}, Ne_2^*, Ne^+ and dimer ion Ne_2^+.

III. Results and discussion

The dynamic pictures of time resolved emission images are shown in Figure 3 (a) and (b) for IR, 147nm, and 173nm of Ne-Xe mixture. All images have the anode, where sustain voltage is applied to when t=0, on the left-hand side and cathode on the right. The total time of the displayed pictures is 2μsec and it is composed of 9 sections, each has 5 elemental emission images with different time intervals for an effective display. The time interval between the elemental images is 20nsec from 0μsec to 0.5μsec, 50nsec from 0.5μsec to 1μsec, 100nsec from 1μsec to 2μsec, respectively. Among the several emission lines from Xe, the IR (823 & 828nm) spectra contains the direct information about the electron's density and temperature because they have very short radiation time and are immune to trapping. The breakdown begins around the anode inner edge and moves towards the cathode surface. As the ionization intensifies in front of the cathode surface, another emission region appears on the anode surface by electron injection onto anode. While the anode side emission does not move but grows, the cathode side emission moves out and spreads over the entire cathode surface.

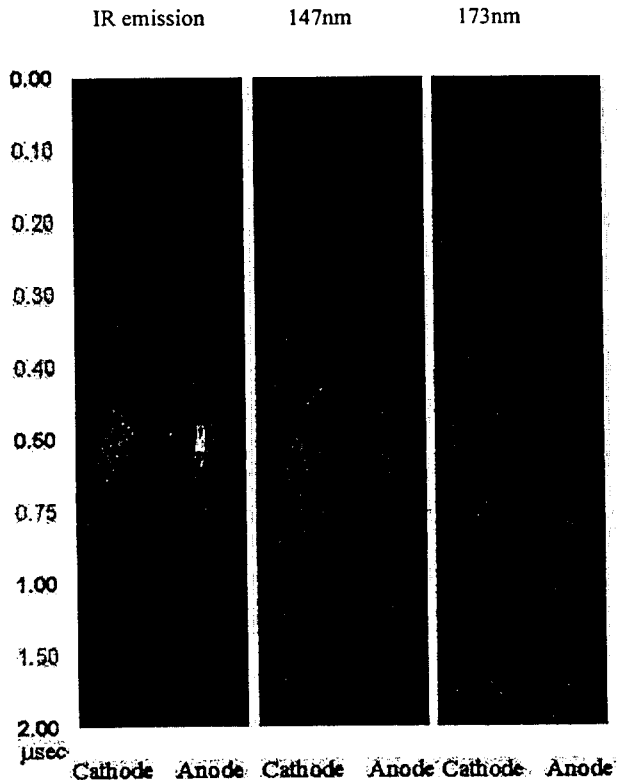
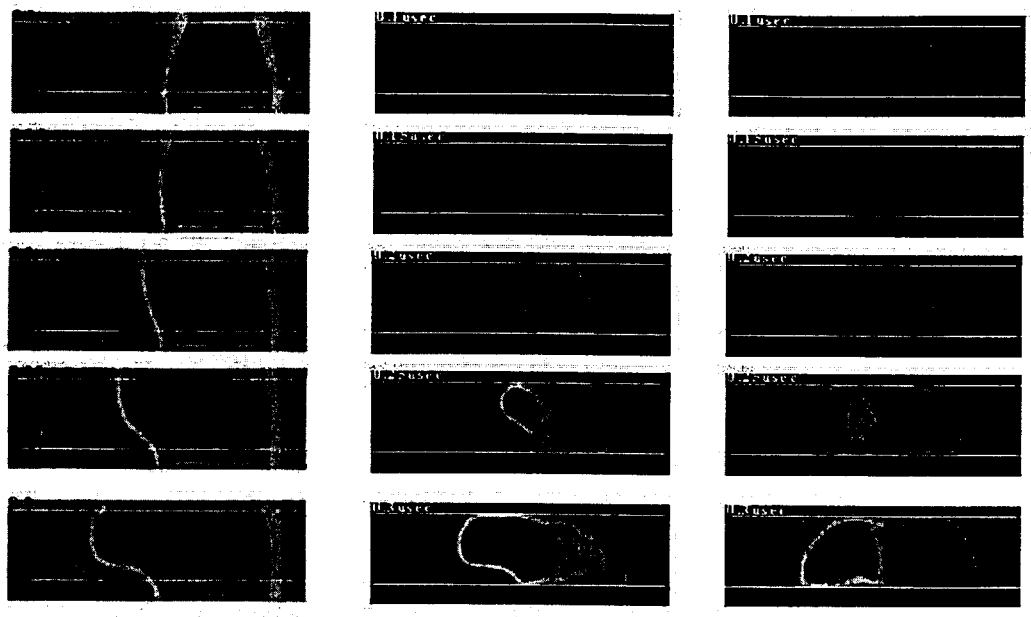


Figure 3. Spatio-temporal variation of 147nm ,173nm and IR emission in Ne-Xe(1%)

The peaking time of 147nm emission is slightly delayed by about 0.1 μsec compare to IR. But the duration of the intense 147nm radiation is much longer. Finally, 173nm emission shows the same tendency, namely, very much delayed peaking time and very long decay time compared to those of IR and 147nm emissions.

Figure 4 shows the time variation of potential, electron and ion density distribution. At the beginning of discharge, electrons are accelerated toward anode and then ionize and excite neutral particles. The peak density of electron and excited Xe appears in the front of anode surface. As time goes on, the ion space charge resulted from the electron avalanche distorts the potential distribution and cathode sheath begins to be formed at about 0.2μsec after the application of pulse. Thereafter, the dominant ionization and excitation occur at the cathode sheath. As wall charge builds up on the inner edge of the dielectric surface, ions move to outer edge of the cathode and the cathode side emission moves out and spreads over the entire cathode surface. The generated electrons in the cathode sheath move to anode side and result in anode glow and then the discharge extinguishes with the decrease of gap voltage. Figure 5 shows the spatio-temporal distribution of Xe^{**}, $Xe^{*}(^3P_1)$ and Xe_2^{*} which are related to IR, 147nm and 173nm emission, respectively.



(a) Potential distribution (b) Electron density (c) Ion density

Figure 4. Spatio-temporal variation of potential, electron and ion density.

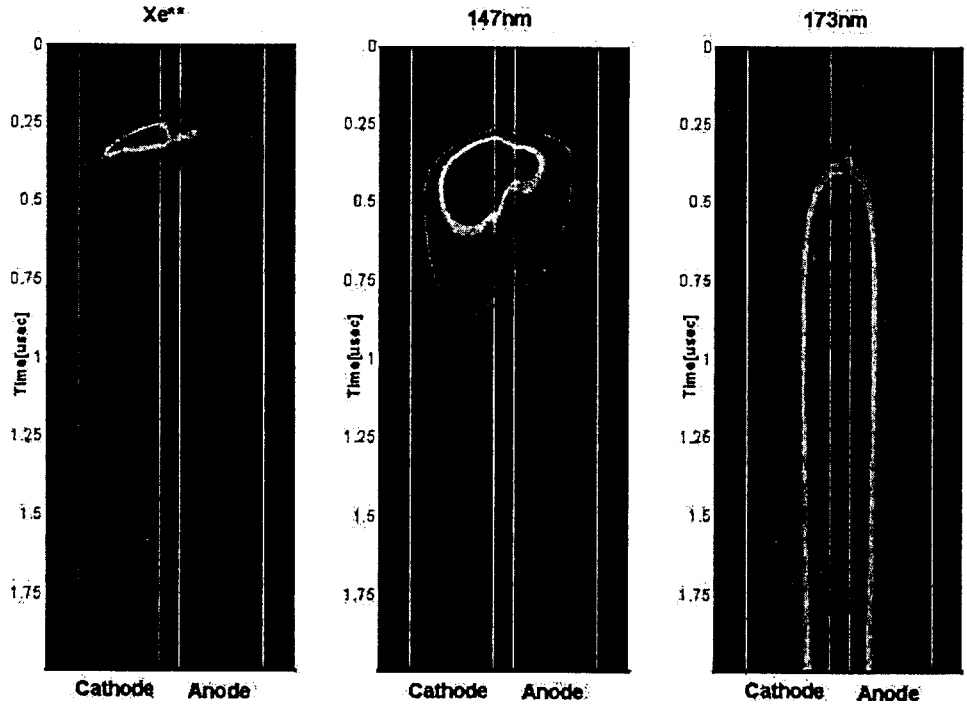


Figure 5. Spatio-temporal variation of IR,147nm and 173nm emission (simulation).

Figure 6 shows the energy level diagram of Xe gas. Xe^{**} state is generated by the electron impact excitation and decays through the radiative and collisional radiation. Since the decay time of this state is a few tens of nanosecond[3], IR emission shows a fast rise and fast decay. 147nm is radiated from the decay of $Xe^*(^3P_1$:resonance state). However, 147nm VUV is trapped severely during the propagation through high-pressure Xe gas. Thus, its decay time becomes longer than that of IR emission. 173nm is radiated from Xe_2^*. This species is generated from the three-body collision process of $Xe^*(^3P_2$: metastable state). The radiation frequency of Xe_2^* is 10^7/s and the generation rate from $Xe^*(^3P_2)$ is $\sim 10^5$/s.[3] Therefore, the decay of 173nm is determined by the slow process, generation rate. This makes 173nm decay much slower than other two.

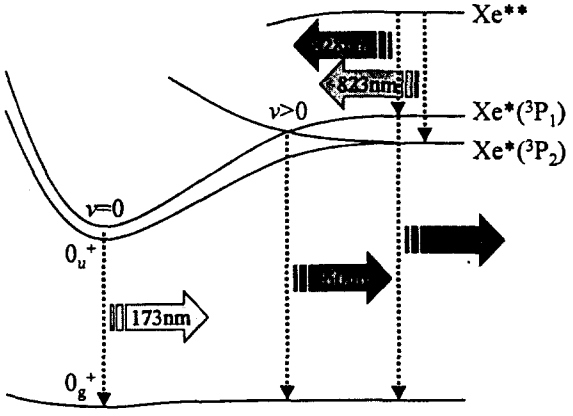


Figure 6. Energy states of Xenon

IV. *Conclusion*

The spatio-temporally resolved emission images of 147nm, 173nm, and IR spectra were obtained from a surface discharge type of PDP cell with Ne-Xe mixture. The breakdown begins around the anode inner edge and moves towards the cathode surface. As the ionization intensifies in front of the cathode surface, another emission region appears on the anode surface. While the anode side emission does not move but grows, the cathode side emission moves out and spreads over the entire cathode surface. 2 dimensional numerical simulation suggests that the discharge in an AC PDP cell is generated by a cathode-directed streamer formation.

Reference

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[3] P.Moutard, P.Laporte, J.-L.Subtil, N.Damany, and H.Damany, "Pressure effects on kinetics and decay processes in xenon after selective photoexcitation", J.Chem.Phys., vol **68(12)**,pp7485,1988