Measurement of Electron Temperature and Plasma Density in Coplanar AC Plasma Display Panels.

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Abstract

The electron temperature and plasma density in coplanar alternating-current plasma display panels (AC-PDPs) have been experimentally investigated by a micro Langmuir probe and the high speed discharge images in this experiment.

1. Introduction

The present AC-PDP has several technical problems, including low brightness and low efficiency. In order to overcome these difficulties, it is necessary to find the fundamental properties of the plasmas generated from the electrical discharge in PDP cells. For the investigation of the basic parameters in AC-PDP plasma, the micro Langmuir probe and ICCD (Intensified Charge Coupled Device) camera have been used to diagnose electron temperature and plasma density in AC-PDP cells. The electron temperature can be obtained from the expansion of the discharge plasma area in time. The value of the plasma density can be obtained from the saturated ion current flowing into the micro Langmuir probe. The actual size of the AC-PDP cells is several hundred of micrometers. To measure electron temperature and plasma density, the diameter of a micro Langmuir probe must be considerably smaller than the sustaining electrode gap. We, therefore, fabricate a micro probe with a diameter of 20 ㎛. The electron temperature and plasma density can be measured by sweeping the probe voltage from negative to positive bias-voltage. Inserting a micro Langmuir probe into the discharge plasma in the AC-PDP cells, the current flows into the external circuit connected to the Langmuir probe. Whenever the negative to positive probe-bias-voltage is applied to an inserted micro Langmuir probe, the probe current from the discharge plasma changes accordingly, due to the mobility of ions and electrons collected on the surface of the probe. Using the current-voltage (I-V) characteristic curve obtained by sweeping the probe-bias-voltage, the basic plasma parameters such as electron temperature and plasma density can be determined. We measure experimentally the ion and electron saturation current and obtain the high-speed discharge images, from which the electron temperature and plasma density of the discharge plasma in the AC-PDP cells are obtained. Some of the important observed results suggest a few clues to the origin of the plasma propagation on the sustaining electrodes in the PDP cells. With the previous results of electron temperature measured by micro Langmuir probe method [1] and with careful examination of the propagation distance of the surface discharged plasma in AC-PDP [2], it is concluded that the plasma propagation speed on the cathode is closely related to the ion acoustic waves [3,4]. The main purpose of the study is to investigate the electron temperature from the propagation speed of the cathode plasma, which is a new diagnostic tool for measurement of electron temperature in micro discharge plasma, as well as the plasma density from the ion saturation current of the micro Langmuir probe.

2. Experimental

The size of the actual AC-PDP cells is several hundred of micrometers. To measure the electron temperature and plasma density in the micro dimensions of AC-PDP, the diameter of the probe must be smaller than the gap distance between the sustaining electrodes. The micro Langmuir probe tip with a diameter of 20㎛ is manufactured by electro-chemical etching. The micro probe's end-edge of 100㎛ is not covered with an insulator

Figure1 shows the micro Langmuir probe is installed at the lateral distance of 125 μm from the center of the electrode gap.

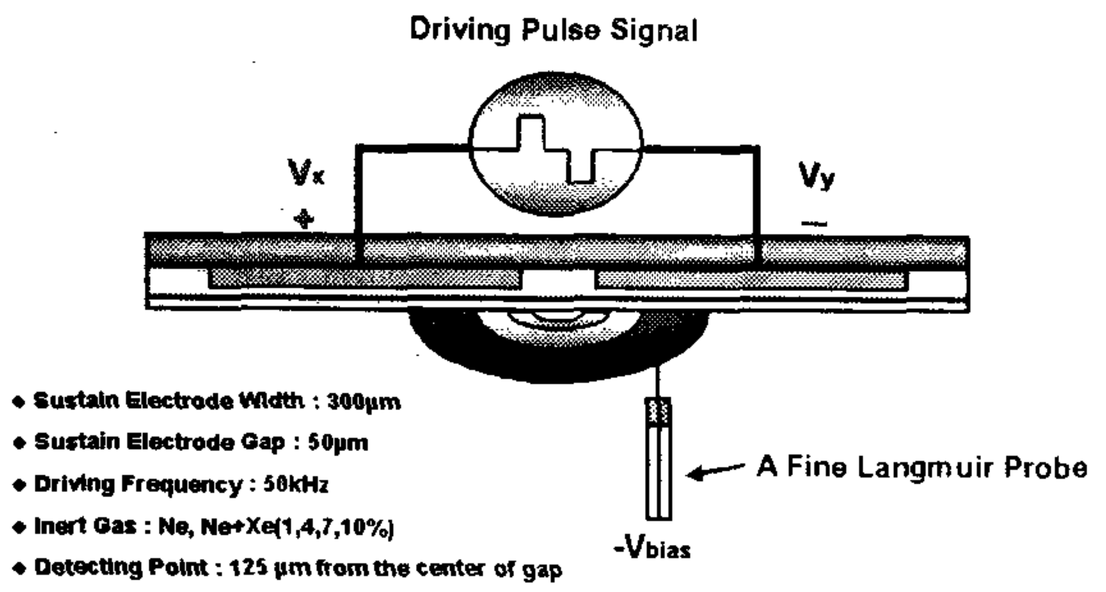

Fig 1. Experimental setup

The probe-bias-voltage of -30V has been fed to the micro probe tip for the collection of ion saturation current. The plasma current flowing into the micro probe is read by a digital oscilloscope with1 MΩ impedance. The AC-PDP panel, which has a sustaining electrode width of 300• and a gap of 50•, is operated by the square pulse with a duty ratio of 40% and a driving frequency of 50 kHz. The filling gas in AC-PDP has been used Ne and Ne+Xe mixture gas and it's pressure is varied to be from 150 Torr to 350 Torr. After breakdown, the sustaining voltage is maintained at 270V. The electron temperature and plasma density can be measured by

$$\frac{\Delta \ln|I|}{\Delta V} = \frac{e}{kT_e}$$

$$I_{is} = n_i e A \sqrt{\frac{kT_e}{M}}$$

, where I and V are probe current and bias voltage, respectively, T_e is the electron temperature, n_i is the ion (electron) density. The A is a surface area of micro Langmuir probe being taken into account the plasma sheath, M is the filling gas mass of ion, k is the Boltzman constants, e is the charge of electron and I_{is} is the ion saturation current[2, 3]. It is recently observed that the propagation speed of cathode plasma in AC-PDP is strongly close to the ion acoustic wave[1-4] v_i which is given by

$$v_i = \sqrt{\frac{kT_e}{M}}$$

The saturation plasma ion current flowed into micro Langmuir probe can be obtained by differentiating the probe voltage difference ΔV_{probe} with respect to time, which is given by

$$I_{is} = C\frac{d\Delta V_{probe}}{dt}$$

The plasma ion density can be obtained by

$$n_i = \frac{I_{is}}{eA\sqrt{\frac{kT_e}{M}}}$$

Figure 2 shows the discharge images by ICCD (Intensified Charge Coupled Device) camera[2] at elapsed time from t = 100 ns to t = 500 ns with respect to the beginning of voltage pulse applied to the cathode and anode electrodes. It is noted from Fig. 2 that the largest discharge area and brightest light emission have been occurred for the largest current at t=300 ns. The light emission patterns of the anode and cathode are different from each other. It is shown in Figs. 2 (a) – 2 (d) that the emission intensity from cathode is strong and the emission expands outward by ion mobility in time duration between t=100 ns and t=300 ns. On the other hand, emission intensity is weak and the area shrinks inward by temporal decrease of applied voltage pulse during the time between t=300 ns and t=500 ns.

The plasma electron temperature can be obtained by micro Langmuir probe[1] as well as by high speed ICCD (Intensified Charge Coupled Device) camera[2].

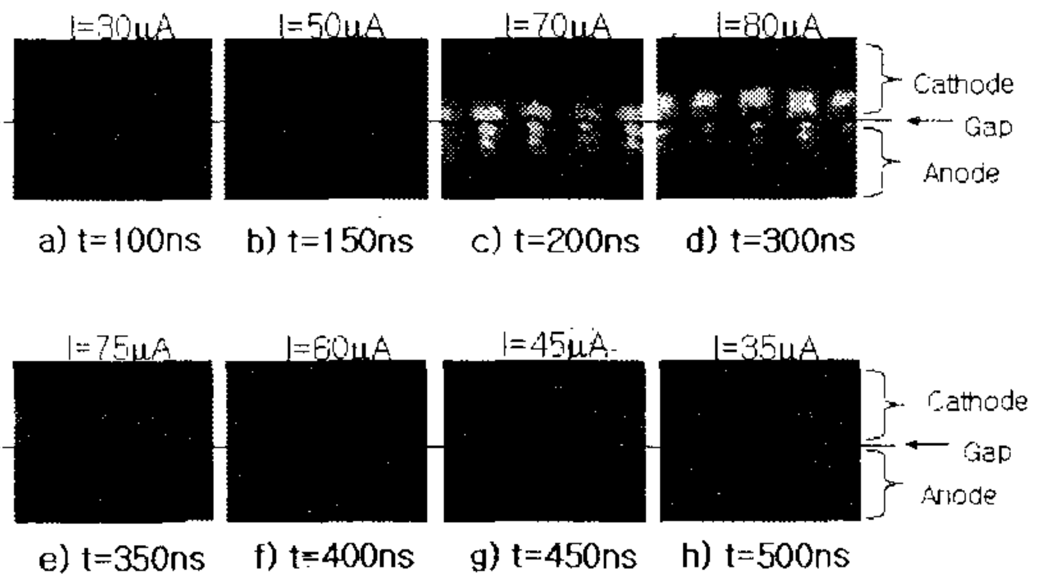

Fig 2. High speed discharge images by ICCD camera

It is noted that these electron temperatures from micro Langmuir probe and ICCD (Intensified Charge Coupled Device) camera are measured to be about 1.6 eV under the gas pressure of 350 Torr and Ne-Xe (7%), which all in good agreement with each other within 5% error limit.

3. Results and discussion

The cathode propagation speed decreases as the Ne gas and Ne+Xe mixture gas pressure increases. The plasma propagation speed on the cathode electrode obtained from the $\Delta x/\Delta t$, where Δx is the change in propagation distance of cathode plasma between the elapsed time interval Δt. The propagation speed of cathode plasma has been measured to be in the range of 3.0 and 2.0 mm/μs.

Figure 3 shows the electron temperature as a function of the Ne and Ne+Xe gas pressure. It is noted that the electron temperature, in this experiment, decreases from 2.5 eV to 1.2 eV, as the Ne gas and Ne+Xe mixture gas pressure increases from 150 Torr to 350Torr.

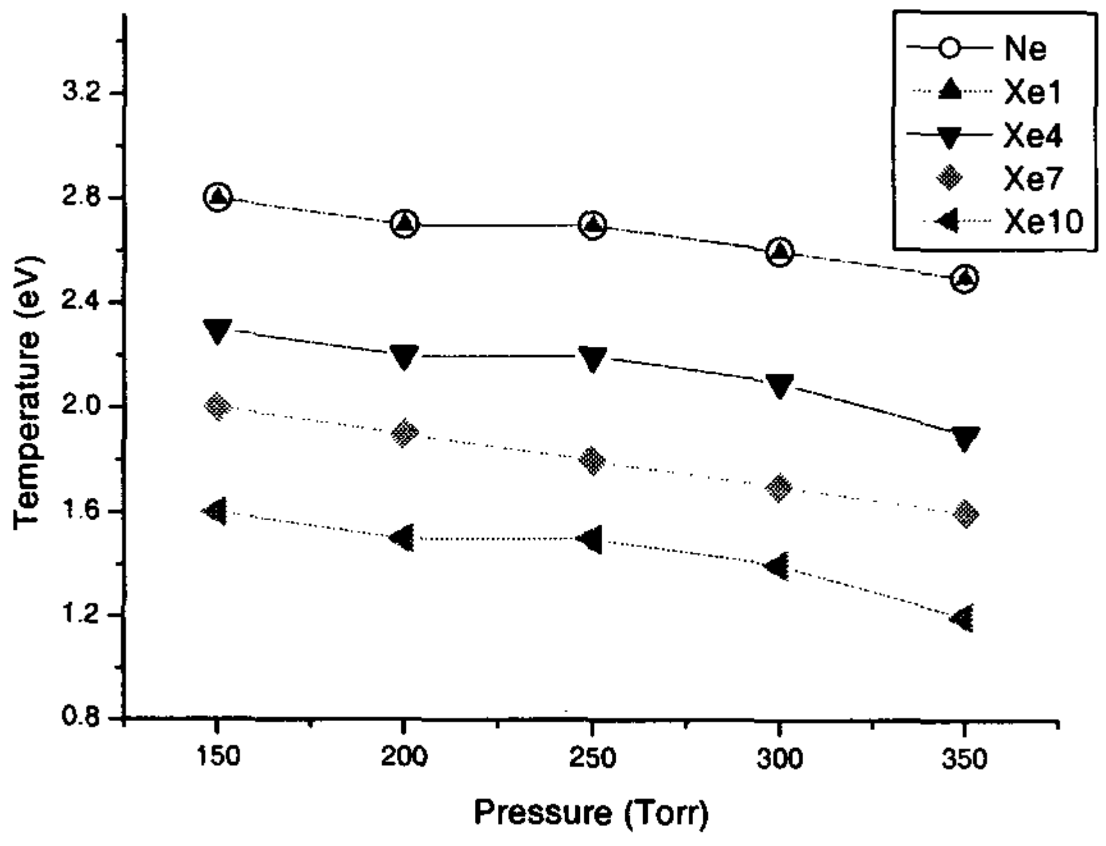

Figure 3. Plasma temperature versus pressure

Figure 4 shows plasma density at the various pressures ranged from 150 Torr to 350 Torr. The plasma density at the Ne gas and various Ne+Xe mixture gas have been measured to be 2.3×10^{11}cm^{-3} ~ 8.9×10^{11}cm^{-3}. As rate of Xe mixture increase, the density of plasma is saturated.

Figure 4 shows plasma density at the various pressures ranged from 150 Torr to 350 Torr. The plasma density at the Ne gas and various Ne+Xe mixture gas have been measured to be 2.3×10^{11}cm^{-3} ~ 8.9×10^{11}cm^{-3}. As rate of Xe mixture increase, the density of plasma is saturated.

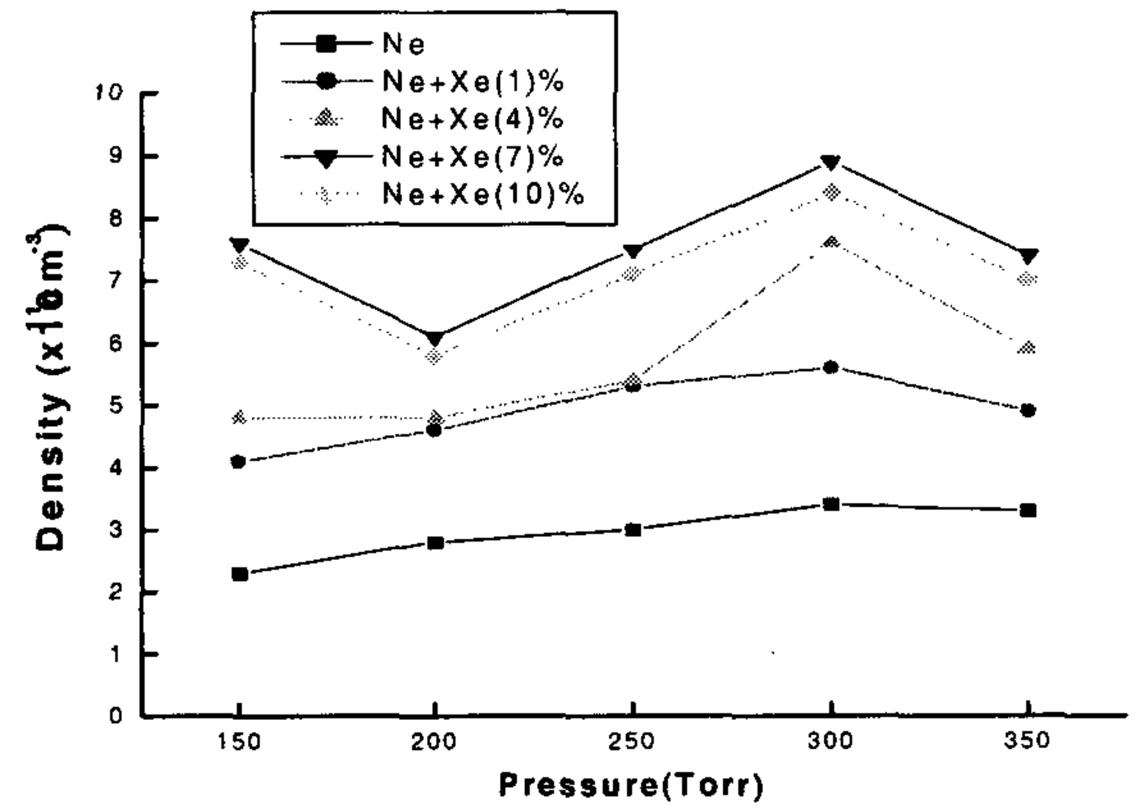

Fig 4. Plasma density at various Ne and Ne+Xe gas pressure

4. Conclusion

The plasma temperature and density of coplanar AC-PDP at the various Ne and Ne+Xe pressures of 150, 200, 250, 300 and 350 Torr have been experimentally investigated by using the micro Langmuir probe and high speed discharge images, in this experiment. It is noted in this experiment that the electron temperature obtained from both the micro Langmuir probe and high speed ICCD (Intensified Charge Coupled Device) camera decreases from 2.5 eV to 1.2 eV as the filling Ne gas and Ne+Xe mixture gas pressure increases from 150 Torr to 350Torr. The plasma density of coplanar AC-PDP at the Ne gas and various Ne+Xe mixture gas have been measured to be 0.73×10^{11}cm^{-3} ~ 7.54×10^{11}cm^{-3} . As the Xe mixture ratio to Ne increases, the density of plasma is saturated.

5. References

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