Relationship between Exo-electron Emission Currents and Glow Discharge Delay of ACPDP

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Keywords : PDP, Glow Discharge, Exo-Electron, Discharge Delay, Doping

Abstract

The effects of wall charge and bias voltage on exo-electron emission currents were examined. In addition, the effects of doping elements on the currents were investigated. These results indicated that the statistical delay is inversely proportional to the exo-electron emission currents measured.

1. Introduction

For the ignition of glow discharges during reset, addressing and sustaining period of ac-PDPs, priming species, especially the seed electrons over a critical concentration are required. The seed electrons became accelerated by an electric field applied, resulting in avalanche of electrons and ignition of the glow discharge. If the priming species do not exist in the discharge space with enough concentration, the ignition of glow discharge does not occur until the concentration of priming species reaches a critical value, resulting in statistical variation of discharge time lag.

Loeb [1] has proposed in his classical paper that the statistical delay (T_S) of glow discharge is inversely proportional to the concentration of priming species (n_0) and the probability that the electron induce the discharge (P_S):

$$T_S = \frac{1}{n_0 \; P_S} \qquad \text{eqn. 1)}$$

The formative delay, on the other hand, is mainly determined by the applied field.

In ac-PDPs, there are a few quantitative relationship between the exo-electron currents and the statistical delay reported since the exo-electron currents have not been measured in-situ during addressing periods. There are, however, many experimental data showing the effect of doping, temperature, applied field, on the statistical delay. In addition, Nagorny *et al* [2] estimated from his numerical simulation on ramp discharge of ac-PDP that we need an external supply of about 100 electrons per μs to each discharge cells in order to make-up for the charge losses to walls and recombination reaction. This supply should maintain the seed electron concentration constant within the discharge space and stabilize the ramp discharges. This corresponds to 10^2 pA/cm^2, which is approximately 5 orders of magnitude smaller than the glow discharge currents. Thus, we need a small fraction of exo-electron emission currents in order to initiate glow discharge.

Recently, Yan et al [3] has revealed a measuring scheme of exo-electron emission currents in-situ from a test panel. Using such apparatus, he measured the effects of temperature on exo-electron emission currents and statistical delay. Based on a similar measuring principle, the authors[4] have measured the current as a function of panel temperature, doping elements, sustaining frequency, and time. In those studies, the inverse relationship between the exo-electron current and statistical delay was demonstrated experimentally.

In those experimental measurements of exo-electron currents, however, it was implicitly assumed that the emission of electrons is coming solely from MgO layer. Negative bias was applied to sustaining electrodes on front plate while keeping the address electrodes on rear plate grounded in order to drive exo-electrons emitted from MgO layer toward address electrodes. In actual, there are some substantial experimental evidences that the emission may come not only from MgO layer but also from other sources like phosphor layer in the discharge cells. Whang [ ] et al, has shown that the statistical delay is affected by the type of phosphor layer used in the discharge cells.

In the context of such experimental observation, it may be presumed that the phosphor layer is emitting exo-electrons into the discharge space of ac-PDPs.

The emission of exo-electrons is a phenomenon of relaxation of energy stored during glow discharge of ac-PDPs. Thus, any materials within the discharge cell capable of storing the glow discharge energy should be able to emit the exo-electrons. Within the discharge cells of ac-PDPs, MgO and phosphor layers are in direct contact with glow discharge and the both have a potential of emitting exo-electrons. In this study, we attempted to determine the contribution of phosphor layer to the concentration of exo-electrons ejected into the discharge cells. In addition, the effect of wall charge on the emission of exo-electrons was examined since the wall charge is an integral part of energy stored within the dielectric layer such as MgO. Based on such information, the relationship between exo-electron emission current and the delays of glow discharges AC-PDPs was examined.

2. Experimental

Using MgO pellets containing several doping elements including Be and Al, thin films were formed on dielectric surfaces of front plates by e-beam evaporation process. Base pressure of the coating chamber was $8.5x10^{-7}$ ~ $1.0x10^{-6}$ torr and the glass plate was heated to 300°C prior to coating. For hydrogen doping, the chamber was suppiked with hydrogen gas and its partial pressure was $5x10^{-4}$ torr. The film was deposited approximately at a rate of 5 nm/sec and its thickness was ~ 5000Å. Using the front glass plate, the test panel was produced by sealing with a rear plate. The rear plate was formed with rectangular type barrier ribs of XGA grade of 42 inch diagonal size. Zn_2SiO_4:Mn green phosphor was coated within the discharge cells on the rear plate. The discharge gas was Ne-10%Xe and the pressure was 400 torr.

Fig. 1 shows a driving waveform used to measure the exo-electron currents with different wall charges. Firstly, X and Y electrodes are supplied with pulsed voltages to initiate discharges between them. After the short pulses of glow discharges, in this case, four pulses of discharges, a small ramp pulse was applied between the sustaining electrodes to modify the wall charges on MgO surface. The wall charge after the ramp was determined by the VTC measurement.

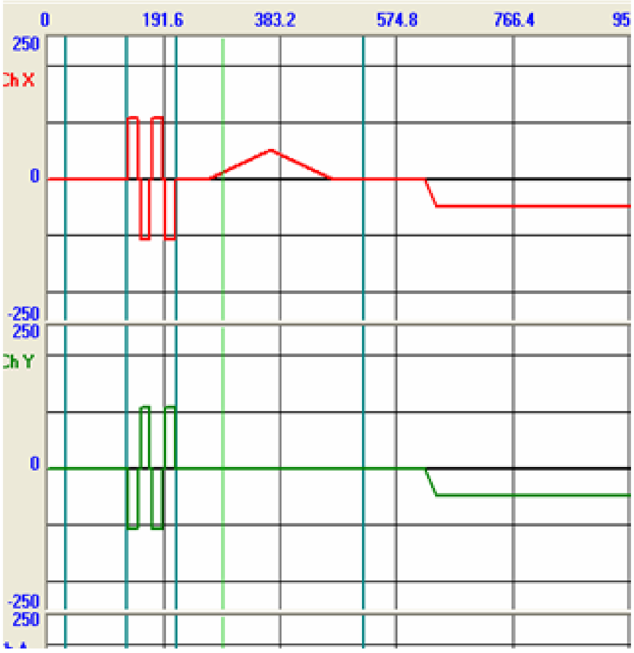


Fig. 1. Waveform of wall charge modification and exo-electron currents measurement.

After 400 μsec of the glow discharge, a negative bias voltage was applied to sustaining electrodes while the address electrodes were grounded. This bias voltage drives the electrons emitted from MgO layer towards the address electrodes, to which the current sensor is attached. The address discharge time lags were measured by a photo multiplier tube(PMT) which detected infrared emission signals from Xe excited atoms. The address light of test panel was driven by ADS driving wave as shown in Fig.2.

3. Results and discussion

Figure 2 shows the effect of bias voltage on the exo-electron currents of a test panel with Be-Al doped MgO film. Peak voltage of the ramp was 150V and almost all the wall charges were erased due to the ramp pulse. Under this condition, the exo-electron currents increase linearly with the increase in bias voltage. This phenomenon is probably due to gas amplification commonly observed in Townsend discharge regime[ ] rather than the increased emission of electrons by the applied bias electric field. The applied field is too weak to induce the field emission. Thus, the exo-electron currents measured should be specified with the bias voltage applied, more precisely with the effective cell voltage applied between the measuring electrodes.

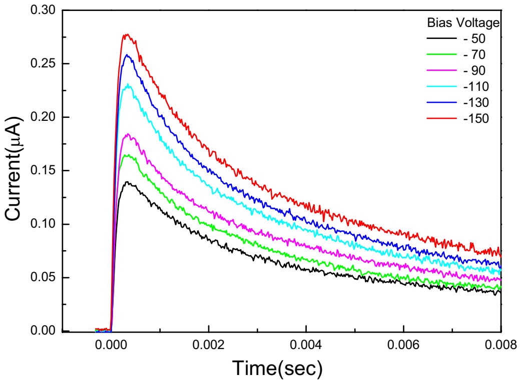


Fig. 3. Effect of bias voltage on the exo-electron currents measured. In this case, the peak ramp voltage was 150V.

As the ramp voltage was reduced to 100V, the exo-electron current responded quite differently to the bias voltage applied(Fig. 3). In this condition, as the bias voltage is increased, the currents start to decrease as the bias voltage increase until the bias voltage reaches -90V. This decreasing trend of exo-electron currents with increasing bias voltage is in contrast with those observed in Fig. 3. When the bias voltage reached -90V, the currents at the initial stage of measurements became negative. This suggests that electrons moving toward the sustaining electrodes instead of address electrodes. This can only be achieved when the electrons are emitted from phosphor layer coated on address electrodes and attracted to MgO layer coated on sustaining electrodes. Further increase in bias voltage over -110V, however, resulted in increasing currents with the bias voltage. As the ramp voltage is further reduced to 50V, the negative current became more prominent as shown in Fig. 4.

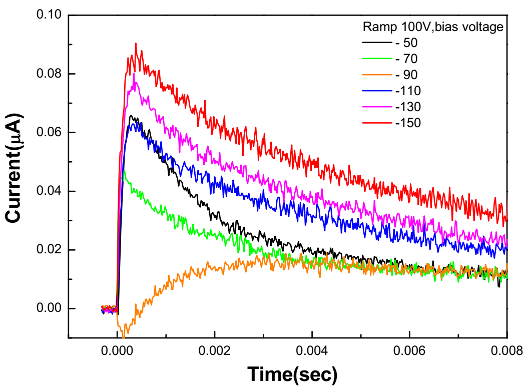


Fig. 4. Effect of bias voltage on the exo-electron currents measured. In this case, the peak ramp voltage was 100V.

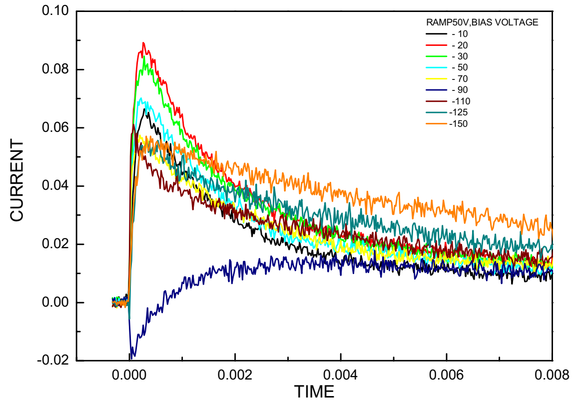


Fig. 4. Effect of bias voltage on the exo-electron currents measured. In this case, the peak ramp voltage was 50V.

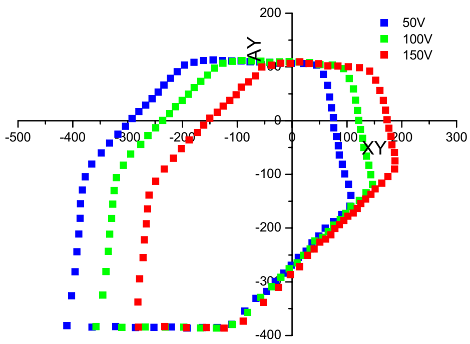
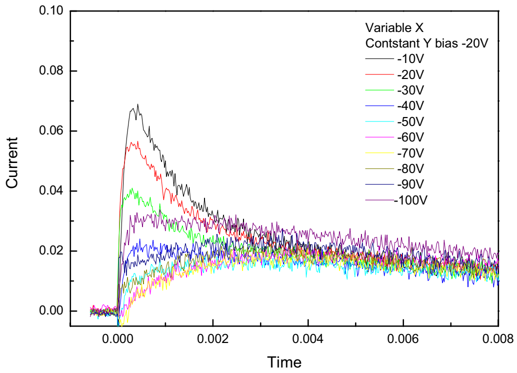


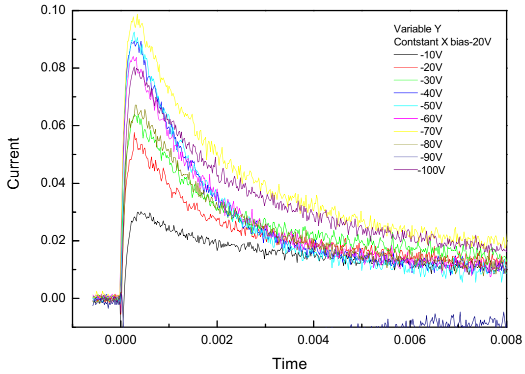
Fig. 5. VTC curves of test panels with different ramp voltage of Fig. 2.

In order to investigate the effect of ramp discharge on the wall charge, VTC curves of test panels with different peak voltages of the ramp were obtained (Fig. 6). When the ramp voltage is 50V and 100V, a large positive wall voltage remained on the surface of X-electrodes and negative wall voltage on Y-electrode, making the curves non-symmetric. In this case, the wall voltage on X-electrode should be large enough to overcome the bias voltage applied between the X- and address-electrodes. This effect can easily be examined by measuring the exo-electron currents coming from each sustaining electrode.

As the bias voltage applied to X-electrodes is increased, the exo-electron currents decreased. On the other hand, the currents measured by applying bias voltage to Y-electrode increased with the increase in bias voltage. These results clearly show the effect of wall charge on the exo-electron currents measured.



(a)



(b)

Fig. 7. Exo-electron emission currents measured by bias voltage to each electrode: (a) bias voltage applied to X-electrodes and (b) to Y-electrodes.

As the peak voltage of the ramp is increased to 150V, the VTC curve became almost symmetrical, indicating most of the wall voltage formed from previous pulse discharges is erased. Under this condition, the wall charge may not affect the exo-electron currents, revealing the materials properties only. Thus, in this study, the measurement of exo-electron currents were measured after setting the wall charge in MgO erased almost completely.

Fig. 7 shows the effect of doping various elements on exo-electron emission currents. The test panels with Be-Al and Be-H_2 co-doped panels showed larger exo-electron currents. Fig. 8 shows the Laue plot of the test panels showing the effects.

4. Summary

The exo-electron currents was dependant on the wall charge formed and bias voltage applied between the electrodes. Thus, the currents should be measured under specified wall charge as well as bias voltage. The results showed that the exo-electron currents are affected very sensitively by the doping elements.

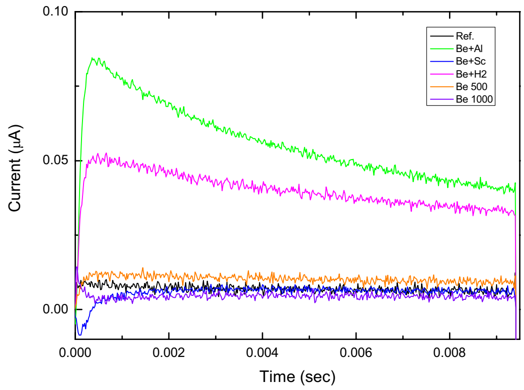


Fig. 7. Effect of doping on exo-electron currents.

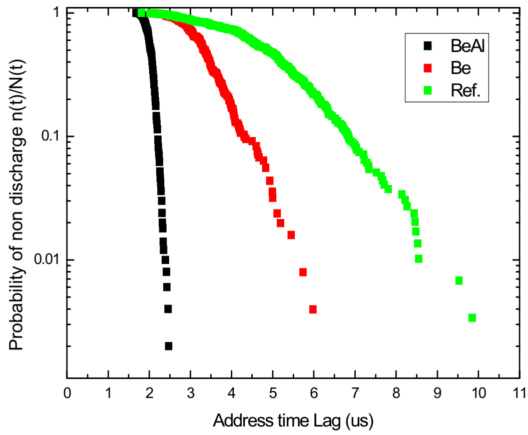


Fig 8. Effect of doping elements on address delay time.

5. Acknowledgements

This work has been financially supported by 21C Frontier Research Program through Advanced Display Research Center. Authors would like to express their appreciation for the support.

6. References

[1] 1. L. B. Loeb, *Rev.Mod. Phys.*, vol. 20, no. 1, pp. 151–160(1948).

[2] V. P. Nagorny, et al, *IEEE Transaction on Plasma Science* **34**, p343 (2006).

[3] Q. Yan, et al, IDW'06 Technical Digest, pp359-362(2006)

[4] S.-H. Yoon, et al, SID'08 DIGEST, pp287-290(2008).