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Effects of Panel Temperature on the Discharge Characteristics of Micro Discharge Cells

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Abstract - The effects of ambient temperature on the discharge characteristics of Ne-Xe based micro discharge cells for ac-PDP (plasma display panel) have been studied. In ramp voltage driving, which is generally used as a reset method of PDP, two dissimilar modes of strong and weak discharge were found. As the interval between the former sustaining discharge and ramp voltage discharge becomes greater, the probability of a strong discharge increases. This suggests that a sufficient number of priming particles is necessary for initiating weak mode (Townsend discharge). It was discovered that under higher ambient temperatures, weak discharge occurs more frequently. The discharge time lag observed in square pulse driving of single cells becomes surprisingly smaller under higher ambient temperatures for the constant gas number density condition.

Keywords: discharge mode probability, panel temperature, PDP, time lag

1. Introduction

Understanding the characteristics of micro discharge is becoming increasingly important with the growth of the flat panel display industry, especially in the case of the plasma display panel (PDP). Luminous efficiency and discharge stabilities are the key issues in developing commercial PDPs. Misfiring or non-firing should never occur under a wide variety of graphic signal inputs and operating circumstances.

For the PDP driven with the ADS (Address-Display period Separated) scheme [1, 2], however, misfiring of a small number of cells is often observed during high and low temperature endurance testing. To improve the robustness of PDP operation, experimental and theoretical information concerning the effects of the ambient temperature is urgently required. However, there are very limited reports regarding the effects of panel temperature on the driving characteristics of PDP or micro discharge cells. With this background, we performed several experiments that can shed some light on the relationship between driving condition and discharge characteristics.

Discharge time lag analysis as a function of delay period and panel temperature using square probing pulse has been performed. Also investigated, with particular focus on the influence of panel temperature, was the effectiveness of the ramp-up voltage waveform on the controllability of weak and strong discharge modes.

2. Experimental

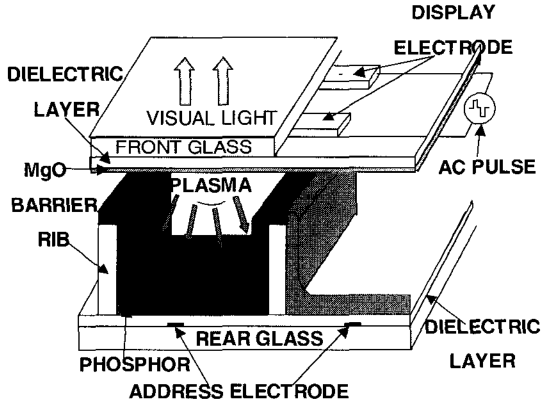

Fig. 1 The schematic diagram of an ac-PDP unit cell

Fig. 1 is an illustration of the structure of discharge cells used in our experiment. It is almost identical to the most general structure of the current three electrodes surface discharge type ac-PDP. Its characteristic features are that the sustaining and addressing electrodes are coated with dielectric layer, and the display is operated by the surface discharge mode. Table 1 shows the specifications of the panel. Our 7-inch test panel corresponds to the commercial 42-inch panel having XGA resolution. In the panel, the front glass bears two sets of parallel sustaining electrodes. Addressing electrodes are placed orthogonal to the sustaining electrodes, on the opposite rear glass. In the front glass, there is a protective film of MgO to prevent deterioration of the dielectric layer caused by ion bombardment. The rear glass has a phosphor layer for converting the VUV to visible light for color displays, and

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barrier ribs to control the discharge gap, which separates the cells.

Table 1 The specification of PDP discharge cell used in this experiment

Bus width	85 ㎛
ITO width	270 ㎛
ITO gap	65 ㎛
Dielectric thickness	40 ㎛
MgO thickness	5000 A (E-beam evaporation)
Barrier rib width	75 ㎛
Barrier rib height	130 ㎛
Phosphor thickness	20 ㎛
Mixture gases	Ne+(6%)Xe

Fig. 2 displays the driving sequence. Following a sufficient number of pulses, ramp probing voltage and rectangular pulse were applied to measure the probability of discharge mode and discharge time lag as a function of delay period t_d, and ambient temperature. Exact temperature of the thermal bath was fixed at 358K for the high temperature condition. The room temperature was approximately 295K.

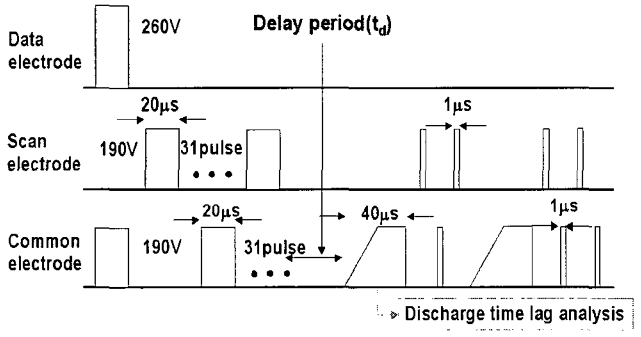


Fig. 2 Driving sequence for discharge mode and time lag

Fig. 3 presents the typical waveform for pulse voltage V, discharge current I. The charging or the displacement current flows first, and then the discharge current flows due to gas breakdown. The discharge current is shown as the current waveform with time delay in some extents after increase in the voltage pulse. This time delay is referred to as the discharge time lag. Total time lag T_d can be defined as the time needed to form 10% of peak discharge current after the voltage reaches 10% of its peak value.

As mentioned above, the delay time is defined as the discharge current. However, it is difficult to detect the discharge current of a single cell without significant errors because the current is too small. Therefore, in this paper, the delay time is measured by light waveform.

In order to detect the emitting light precisely, a high sensitive light detector has been used. The light detector consists of an avalanche photo-diode (APD), a temperature compensate bias circuit and a low noise I-V amplifier circuit[3]. This detector has an active area size of 1.5 mmΦ

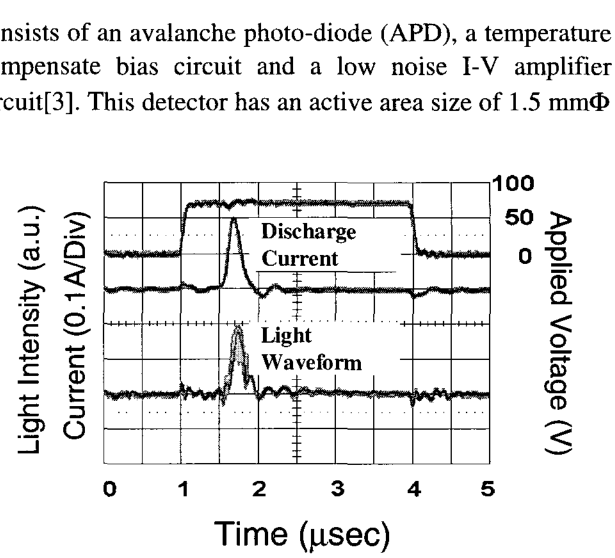


Fig. 3 Typical current waveform for pulse ac micro discharge

Fig. 4 shows the schematic diagram of the experimental system. It is composed of a signal generator, driving circuit heating system, and oscilloscope for measurement purposes. The measurements of voltage waveform, current and discharge time lag were carried out with the digital storage oscilloscope and current probe.

To measure the temperature dependency of discharge time lag a 7” test panel was located in the homemade heating system having an observation window.

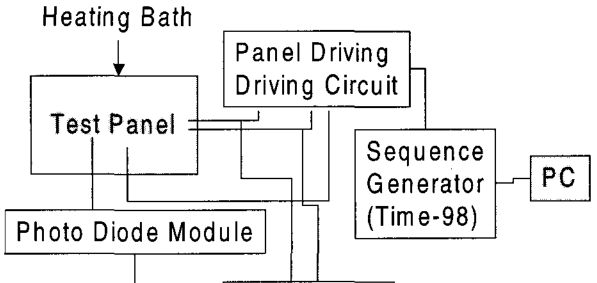


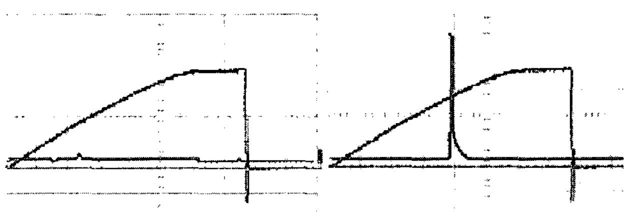
Fig. 4 Schematic diagram of the experimental system

3. Experimental Results

Two distinctive discharge light waveforms are observed when the voltage ramp is applied. For the condition of fixed ramp slope the discharge mode is reliant on the delay time. Fig. 5 shows such discharge light waveform. Case (a) is the weak discharge and Case (b) corresponds to the strong discharge. The weak discharge mode observed here is essentially Townsend discharge and effective gap voltage is close to breakdown voltage in dc-discharge analogy.

When the strong discharge occurs, breakdown voltage and its variation are much higher than the weak discharge mode.

Fig. 6 presents the probability of weak discharge and strong discharge as a function of delay period. This experiment is carried out at both room temperature and high temperature. The possibility of weak discharge mode decreases with increasing delay time. It is well known that ramp voltage with proper slope can provide Townsend discharge with positive resistance characteristics. However, the behavior of discharge mode probability with delay time suggests that the priming condition is also significant for the development of weak discharge mode. When the sufficient number of priming particles is provided, the discharge can be initiated at the low over-voltage condition, which leads to Townsend discharge. Alternatively, if the priming is insufficient, the strong discharge is induced in spite of ramp type driving voltage.



(a) Weak Mode **(b) Strong Mode**

Fig. 5 Two discharge modes observed for ramp voltage driving

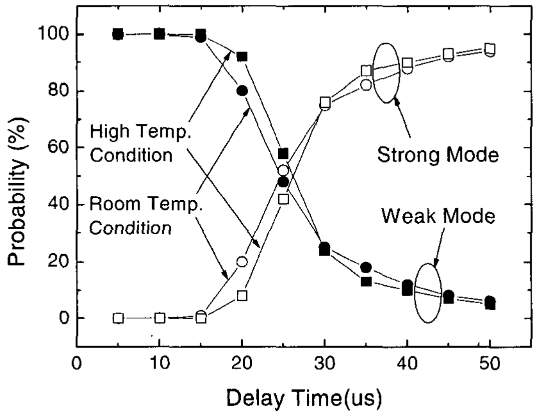


Fig. 6 The probability of weak and strong discharge as a function of delay period (Ramp rising time 20us, red 1 cell)

Fig. 7 displays further detailed results related to the effects of voltage ramp slope and panel temperature. As the slope of the voltage ramp decreases, the possibility of weak discharge increases. This behavior is more prominent in high temperature. Generally, the possibility of weak discharge in high temperature is higher than in room temperature condition, which can be correlated with higher priming particle level at higher temperature.

Fig. 8 shows the averaged discharge time lag (T_{lag}) as a function of delay period in both high and room temperature for the rectangular probing pulse voltage. It should be noted that variation of formative time lag is undetected within our experimental resolution (~ 0.05μsec), therefore average time lag presented is almost equivalent to statistical time lag.

Up to about 40μsec of delay time, T_{lag} for both high and low temperature cases are identical. After this point T_{lag} increases rather rapidly due to decay of the priming particle

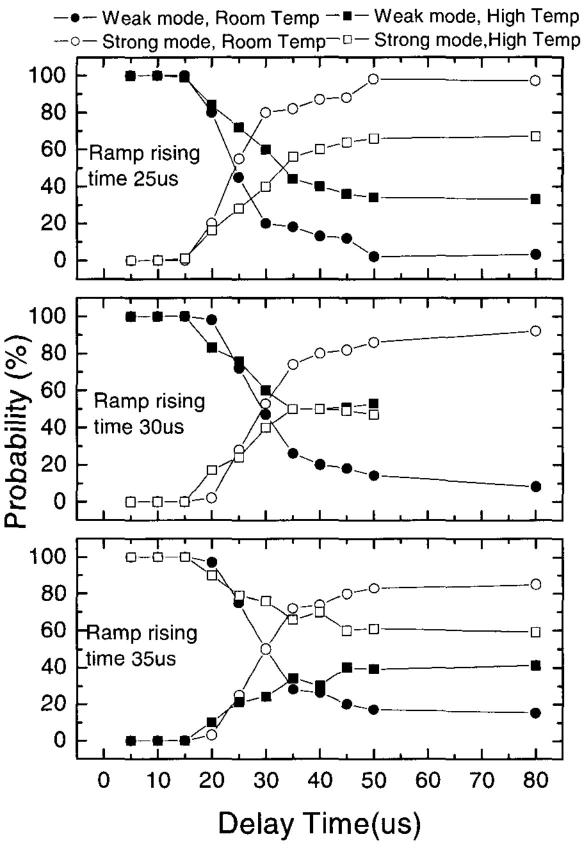


Fig. 7 Discharge mode probability for the various ramp rising times (from top 25, 30, 35μs)

After approximately 60-100μsec, T_{lag} increases slowly with delay time. The general trend of time lag as a function of delay period is similar to pervious results[4, 5]. Time lag in high temperature is slight compared with that in room temperature. This result is consistent with earlier results for ramp discharge experiments. An interesting point is that the T_{lag} in high temperature remained at low value for a long delay time of msec range. Fig. 9 illustrates discharge time lag when the priming particles are supplied by neighboring cells. The effects of priming particles from nearby cells are less conspicuous for the high temperature condition.

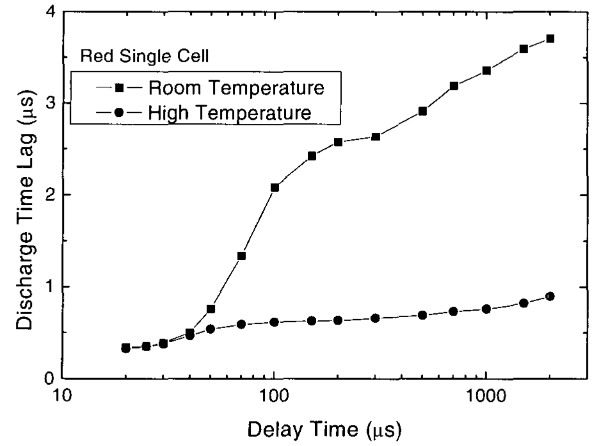


Fig. 8 Averaged discharge time lag as a function of delay time

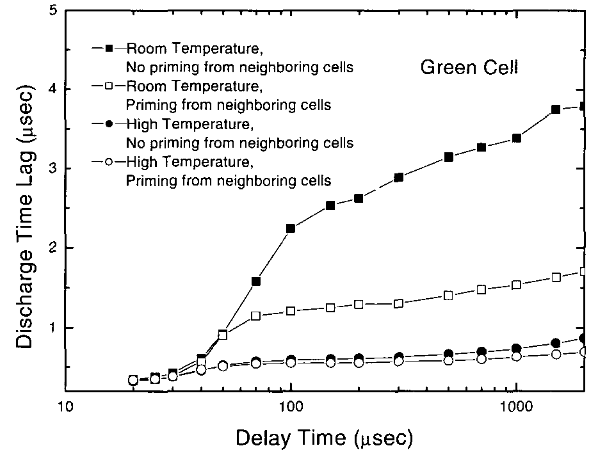


Fig. 9 Discharge time lag with and without priming from neighboring cells

4. Discussion

The most significant finding of our work is that after delay time of several tens of μsec, very short T_{lag} is shown for the high temperature condition. In this region of afterglow, T_{lag} is probably determined by priming particles having long lifetime and time-independent terms such as surface condition of MgO and natural priming level. There can be two major paths for ambient temperature to affect the discharge characteristics. One is direct alteration of particle reaction in the glow or afterglow processes. The other is indirect influence via modification of surface or material properties.

For the glow process, it can be thought that neutral gas temperature hardly affects electron impact process under the fixed gas number density since the electron temperature is far greater than the gas temperature during the glow process. Only a very small fraction of low energy electrons in the distribution function can feel the variation of neutrals kinetic energy. Therefore, the generation of active species is almost independent on the gas temperature in our experimental range. During the afterglow space electrons are lost as wall charge through drift, recombination and diffusion. The estimated characteristic decay time of electrons from the simulation results of Meunier[6] is about 0.5μsec. Therefore T_{lag} differences are in the 1msec range, which is three orders of magnitude longer than the decay time of electrons, and can hardly be correlated with the afterglow decay of electrons.

Neutral reactions can be directly influenced by gas temperature. In particular, metastable species such as $Ne(^3P_2)$ may have an important role for the reduction of statistical time lag time under the high temperature condition because they can provide charged priming particles via penning ionization during afterglow.

$$Ne^* + Xe \text{ -> } Xe^+ + e$$

$$Ne^* + Xe \text{ -> } NeXe^+ + e$$

The rate coefficients for these reactions are dependent on the cross-section and relative velocity of colliding particles The total cross-section of the above reactions is nearly independent[7] or slightly increasing[8] with particle energy in our experimental range. Reaction rate in the high temperature can be enhanced about 10%, $(T_{high}/T_{room})^{1/2}$. The effective lifetime τ of Ne* due to reactions (1) and (2) can be estimated from

$$\tau^{-1}=k_1 n_{Xe} + k_2 n_{Xe}$$

where k_1 and k_2 correspond to the rate coefficients of reaction (1) and (2). The estimated lifetime using the value of $k_1(7.5\times10^{-11}cm^3s^{-1})$ and k_2 $(2.5\times10^{-11}cm^3s^{-1})$ is order of nsec. Therefore penning ionization from Ne* the neutrals also do not explain the reduction of T_{lag} at the delay time of the 1 - 2 msec region.

Although detailed investigation of the effect of temperature on the surface and panel material is beyond the scope of this paper, our experimental results imply that there are some possibilities of surface modification or enhancement of electron detachment from negatively charged dielectric surfaces at high temperatures since the time scale of slowly increasing part of T_{lag} is very lengthy compared with the lifetime of the priming particles.

5. Conclusion

Two different discharge modes, weak and strong discharge, are observed in ac micro discharge cells driven with ramp voltage. It has been shown that a sufficient number of priming particles is necessary for developing weak discharge, which corresponds to the Townsend discharge region. The probability of weak discharge is enhanced with ambient temperature. Discharge time lag in single cell pulse sustain mode has been measured. An important finding is that T_{lag} in high temperatures is dramatically reduced at the high panel temperature condition. The reduction of T_{lag} lasted more than the 1msec of afterglow period. Considering the time scale of these effects we concluded that the results are not originated from the temperature-dependent decay of priming particles. Although the exact reason of this result is not known at this time, we speculated that reduction of T_{lag} is related to the enhancement of electron detachment from negatively charged dielectric surfaces at high temperature or modification of material properties including MgO surfaces.

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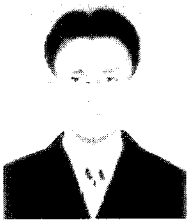

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