Abstract
The discharge condition of Plasma display panel (PDP) changes as the display time increases. Imaginary part of permittivity of dielectric material which is related to dielectric loss has been often neglected because of relatively small value compare to that of the real part. The thermal characteristics of PDPs with two different dielectrics has been studied and compared.

1. Introduction
Quality of plasma display panel (PDP) has reached in high level recently through unflagging skill development in spite of tough competition between various kind of display, but still needs improvements. It is conjectured that progressive deterioration caused by long term discharge is due to panel temperature rise which leads to change in material characteristics. For example the image sticking is one of the common problems which all the self-emissive display have. Among the possible candidates which cause the image sticking problem, the research for the phosphor layer whose emission characteristics is affected by the panel’s temperature change[1] [2] and that for MgO layer what is continuously eroded and re-deposited[3] [4] have been studied much, but not on the dielectric layer itself. The capacitance variation of panel by the change in the permittivity may have influence upon the discharges. The dielectric permittivity is composed of the real and imaginary parts, but only the former one has been concerned so far since it has a large value compared to that of the imaginary part. In this paper, we measure the variation of tangent δ and the thermal characteristics of PDPs with the continuous discharge and tried to correlate them with the panels’ display characteristics.

2. Simulation result for discharge cell components
First we examined the effects of the variation of the dielectric permittivity of the dielectric material in PDP by the computer simulation. Since the simulation results of VUV efficacy and VUV output of 50inch HD resolution cell with various rear dielectric permittivity and barrier rib permittivity were not much different from each other, we can consider the rear dielectric and barrier rib permittivity are not important. However, in the case of front dielectric layer, the VUV efficacy varies with the dielectric permittivity as shown in Fig.1. VUV efficacy becomes low with the decrease in permittivity when the sustain voltage is over 180V, but if the discharge occurs with sustain voltages lower than 180V, the VUV efficacy increases as the permittivity decreases. Therefore, it may be possible to decrease the panel temperature and improve the luminous efficacy by applying low permittivity front dielectric if discharges can be maintained in the low voltage region. The purpose of
this study is to investigate the effect of aging process and long term display operation with two different front dielectric materials on the display characteristics of PDP.

3. Measurement for dielectric loss

The permittivity of dielectric material is a complex number, but usually the imaginary part has been ignored because it is small compared to real part relatively. However, the imaginary part is related with the power loss and temperature rise of the panel. Tangent $\delta$ is defined of the ratio of the loss energy to stored energy on the ratio of the imaginary to real part of permittivity.

$$\tan \delta = \frac{\text{Energy loss per cycle}}{\text{Energy stored per cycle}} = \frac{\varepsilon''}{\varepsilon'}$$ (1)

To measure the tangent $\delta$, the following methods have been suggested
i) Measuring by impedance analyzer
ii) Measuring to phase difference in a RC circuit as shown in Fig.2 with function generator

$$\frac{v(t)}{V_{in}} = \frac{1}{\sqrt{\frac{R}{L}}} \cdot \frac{\sin \omega t}{\omega} + j\omega L$$ (2)

Fig. 2. RC circuit array for measurement phase difference.

4. Experiment results

4-1. Sample experiment

Since the discharges in the real PDP cell is determined by many parameters, we made simple dot capacitor samples as shown in Table1 and measured the tangent $\delta$ variation with discharge time. The Joule heat generation in the real PDP can be calculated by using volume current density $j = \sigma E$ and the equivalent conductivity $\sigma = \omega \varepsilon''$ for volume $V$.

$$P = \int_{V} \frac{1}{\sigma} \cdot E \cdot j \, dv$$ (3)

Consequently we can find equations for Joule heat generated during the reset and sustain period as follows.

$$\frac{1}{2} \varepsilon' E^2 \times V \times \text{reset time} \times 60 \text{[Frame]}$$ (4)
$$\frac{1}{2} \varepsilon'' E^2 \times V \times \text{sustain num.} \times \text{Pulse width} \times 60 \text{[Frame]}$$ (5)

$E$: Voltage, $V$: Dielectric volume

Fig.3 shows the Joule heat variation in the PDP with the dielectric material studied with the dot sample. The amount of Joule heat generation increases with discharge time and bigger during sustain period. To confirm the results obtained from the dielectric sample, we made 2inch test panels with 50inch HD resolution with two different kinds of permittivity. Panel specification used in experiment is arranged shown Table.2. Fig.4 shows the tangent $\delta$ variation with aging time in 2 inch test panels. As the time goes by, tangent $\delta$ value increases for both cases. Even though the tangent $\delta$ of low permittivity dielectric is small in early stage, its increment becomes higher with aging time. After 1000hr aging, an increment in tangent $\delta$ is about 20% with $\varepsilon'=12$ and 36% with $\varepsilon'=7$ from initial state. Especially the increment is higher during the first 600hr.

Table 2. Test panel specification and aging condition for tangent $\delta$ variation with aging time.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>50inch HD discharge cell size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas condition</td>
<td>Xe10%, 400Torr</td>
</tr>
<tr>
<td>Phosphor</td>
<td>Full green</td>
</tr>
<tr>
<td>Dielectric layer</td>
<td>$\varepsilon'=7, \varepsilon''=12$</td>
</tr>
<tr>
<td>Aging condition</td>
<td>Square pulse, 50kHz, 50%duty, 300V</td>
</tr>
</tbody>
</table>
4-2. Experiment for dielectric material

In order to know the fact that tangent $\delta$ variation is caused by the charge of permittivity rather than dielectric material composition, new experiment is carried in compliance with the material ingredient change. The specifications of test panels are the same as shown Table 2. Dielectric materials for two kinds of materials, paste type and sheet type, and two different permittivity of $\varepsilon'=12$ and $\varepsilon'=7$ are applied. Fig. 5 shows the variation of luminance and surface temperature of test panels for each permittivity.

Luminance decreases continuously according to aging time and the level of luminance drop with $\varepsilon'=12$ panels is larger than that with $\varepsilon'=7$, but after 500hr it becomes similar for all panels. The surface temperature of panels which is measured with the infrared thermometer rises continuously with the aging time and $\varepsilon'=12$ panels maintain higher temperature compared to $\varepsilon'=7$ panels. Fig. 6 shows tangent $\delta$ variations in four panels. For all panels, tangent $\delta$ increases according to aging time and the augmentation of tangent $\delta$ of $\varepsilon'=7$ panels which have low initial value is relatively higher than that of the other panels. Especially, the augmentation of $\varepsilon'=7$ panels increases rapidly during the early aging period. All of these tendencies agree well with the previous experiment and therefore the luminance loss which is changed with aging time is mainly affected by permittivity rather than material ingredients.

4-3. Loss variation with full size panel

We also measured the tangent $\delta$ variation with 42inch size panels which have high definition resolution and different dielectric permittivity $\varepsilon=7$ & $\varepsilon=12$ and thickness 20µm & 28µm. Table 3 lists the specification of 42inch panel and aging condition for panel deterioration. Applying the same voltage to discharge and non-discharge area as shown in Fig. 7, tangent $\delta$ is measured with aging time for each area and the variation of loss with different permittivity is examined in large size panels. Since the tangent $\delta$ variation of dielectric deposited on non-discharge area is little, only the tangent $\delta$ variation of dielectric deposited on discharge area is shown in Fig. 8. Panel with $\varepsilon'=7$ has a lower tangent $\delta$ but the increment becomes higher with aging time, which is similar to results of 2inch test panel. The temperature and luminance variation of 42inch panel with two different dielectric permittivity values and thicknesses were
measured as shown in Fig.9. The temperature of $\varepsilon'=7$ panels is lower than that of $\varepsilon'=12$ panels, but it increases more rapidly with aging time. For the panels with the dielectric thickness of 20$\mu m$, both the initial and final temperatures were higher than those of panels with the dielectric thickness of 28$\mu m$.

5. Summary

In this paper, we show that the panel temperature and the level of tangent $\delta$ variation increased with aging time due to the change in imaginary part of dielectric permittivity. Especially, the tangent $\delta$ of panels of low permittivity dielectric is low in early time, but the increment becomes bigger with aging time. Thus the panel of low permittivity dielectric which has large tangent $\delta$ variation with aging time may not maintain their initial quality after long term operation. Also, in case of thinner dielectric layer, panel characteristics may become different with aging time. This study shows that both the tangent $\delta$ and thickness of dielectrics must be considered simultaneously to reduce the panel temperature and improve the display quality variation of panels with time.

6. References

[4] Yong-gyu Han, IDW/AD '05, PDP, pp1-13