PDP에서 방전전극상의 유전층의 절연내력과 투명도에 관한 연구

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A Study on the Dielectric Breakdown Strength and Transparency of Dielectric Layer on the Discharge Electrodes in PDP

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Abstract - The dielectric layers in AC plasma display panel(AC PDP) are essential to the discharge cell structure, because they protect metal electrodes from sputtering by positive ion and from a sheath of wall charges which are essential to memory function of AC PDP. Futhermore, this layer should be transparent because the visible light must pass through the layer.
In this paper, the dielectric breakdown strength and transparency of the dielectric layer on the discharge electrodes are studied. The variables in this test are the dielectric layer thickness, dielectric firing condition, gas pressure, species of gas and so on.

1. Introduction

The principle of a full-color AC PDP that utilizes ultraviolet(UV) radiation emitted from discharge to excite phosphors is similar to that of a fluorescent lamp. However, a full-color AC PDP utilizes secondary electron emission and negative glow, whereas a fluorescent lamp uses thermionic electron emission and positive column. In this AC PDP, the discharge electrodes are covered with dielectrics like as ozonizer and the discharge occurs on the surface of the dielectrics. Moreover, the dielectric layers protect metal electrodes from sputtering and pave the way for the memory function. Accordingly, they enable high image-quality without decreasing of luminance in large panel.

Therefore, the dielectric layers in AC PDP should have high dielectric breakdown strength over 10^5V/cm and transparency over 80% because the visible light must pass through this layers. But, the dielectric breakdown strength and transparency of the dielectric layers can be changed by the frequency of applied voltage, species of gas and gas pressure, etc. In this paper, we have studied electrical and optical characteristics of the dielectric layers under various experiment parameters.

2. Experimental procedure

Fig. 1 shows schematic diagram of surface-discharge type AC PDP and a capacitance equivalent circuit representation

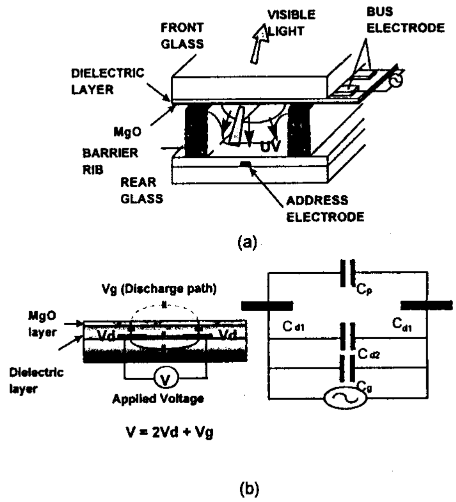

Fig 1. Schematic diagram of AC PDP and a C equivalent circuit representation of AC PDP

of AC PDP in absence of discharge. On the front glass, we arranged ten pairs of sustain electrodes, and then printed the dielectric layers. Sustain electrodes have a width of 300 μm, and a gap of 100μm between them. On the rear glass, barriers with a width of 150μm, a height of 200μm, and a gap of 350μm between them are prepared. Sustain electrodes were printed by the screen printing method with Ag paste (NORITAKE Co.), and then fired them. The dielectric under layers were printed several times with dielectric paste in order to make a given thickness. After drying them, dielectric paste for an upperlayer was printed once more, and then fired them. In this case, we changed the firing condition to study transparency and the dielectric breakdown strength of the dielectric layers.

Fig. 2 presents a small vacuum chamber of cylindrical type, which has a diameter of 200mm and a height of 80mm. The AC sinusoidal power source which has frequency of the range from 20Hz to 20kHz was applied in this equipment. And, the spectrometer (ARC SpectraPro -300i) was used for the measurement of transparency.

In this study, 20μm thickness of dielectric layer, 100torr

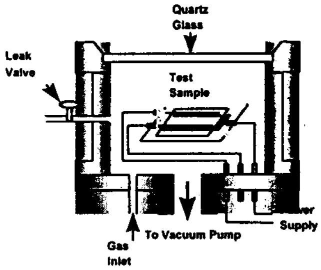

Fig 2. Schematic diagram of vacuum chamber for discharge

working pressure, 10kHz applied frequency, 570℃ firing temperature of dielectric material and 2000Å thickness of MgO layer were selected as standard parameters.

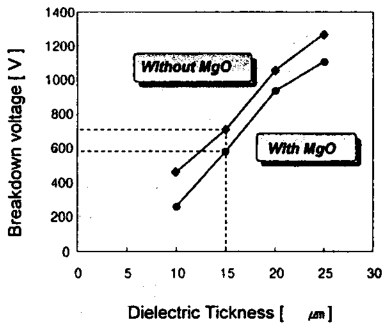

Fig 3. Breakdown voltage versus thickness of dielectric layer

Fig. 3 shows breakdown voltage of dielectric layer as a parameter of dielectric thickness. During the discharge, discharge space is almost short state until the discharge is extinguished by the sheath of wall charge which is made up on the dielectric layers. Consequently, most of applied voltage is assigned to the dielectric layers during the discharge period because the capacitance(C_p) of discharge space can be ignored from the serial capacitance equivalent circuit, as shown in Fig. 1(b), which consists of capacitance (C_p) of discharge space and capacitance(C_{dl}) of dielectric layers.

Therefore, it is natural that the dielectric breakdown voltage increases with an increase in thickness of the dielectric layer. In general, the dielectric breakdown voltage of solid dielectrics has the following relationship.

$$V=Ad^{n} \quad (1)$$

where, A,n are constant, d is thickness of dielectrics.

From Fig. 3, the dielectric breakdown voltage is decreased as much as difference of firing voltage by the existence of a MgO layer. The reason may be due to that the secondary electron emission coefficient of MgO is higher than dielectrics, so that the MgO make the discharge start and sustain voltage decrease. As a result, The voltage applied to the dielectrics with MgO is always higher than the one without MgO, so that the breakdown voltage of dielectrics with MgO is lower. The peak value of working voltage in present PDP is about 240V, so that about 15㎛ of dielectrics with MgO may become the desirable thickness. Because the dielectric layer of 15㎛ thickness withstands about 600V.

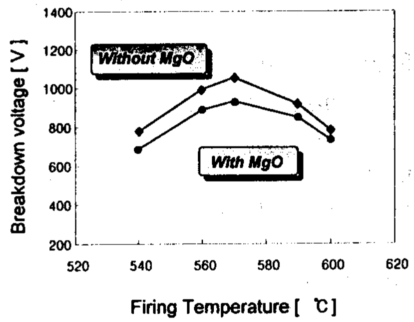

Fig 4. Breakdown voltage versus firing temperature of dielectric

Fig. 4 shows dielectric breakdown voltage as a parameter of firing temperature of the dielectric layer. At present, the front and rear glass of PDP are used as soda-glass whose thickness is 3mm. By the way, the viscosity of glass decreases with an increase in temperature, and at $10^{14.5}$, 10^{13} and $10^{7.6}$ poise, each temperature are called distortion point, annealing point and softening point, respectively.

In case of soda-glass, their temperatures were known as 511℃, 554℃, 735℃. Glass can be distorted by external force when the temperature of glass reaches between the distortion point and the annealing point. Glass also can be distorted by it's weight at the temperature of over the annealing point. Therefore, dielectric material, barrier rib and phosphor etc. must be firing below 600℃[1].

In this study, the firing temperature of the electrode was 590℃ and the firing temperature of the dielectric was 570℃ as a standard firing temperature.

From Fig. 4, the highest breakdown voltage is obtained for the sample fired near 570℃ and if the firing temperature is higher or lower than 570℃, the breakdown voltage decreases. It is considered that a void formation and non-uniform thickness of dielectric layer at low firing temperature lead to rapid breakdown near the cavity and relatively thin point of dielectric layer[2].

Moreover, when the firing temperature is higher than optimum value, the characteristic of dielectric layer decreases because of diffusion of the electrode material, formation of cavity and reduction of the thickness of dielectric layer by excessive melt.

(a) 540℃ firing (b) 570℃ firing (c) 600℃ firing

Fig 5 Cross section of sample as a firing temperature

The cross sccion SEM photography of sample as a firing temperature is shown in Fig 5.

Fig. 6 shows breakdown voltage as a parameter of gas pressure. As shown in Fig. 6, the curves are similar to Paschen Curve. According to the Paschen theory, the breakdown voltage decreases near the Paschen minimum as like 200torr in this experiment.

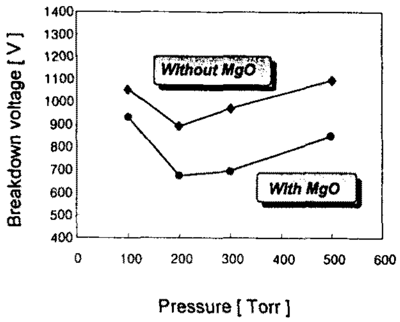

Fig. 6. Breakdown voltage versus working gas pressure

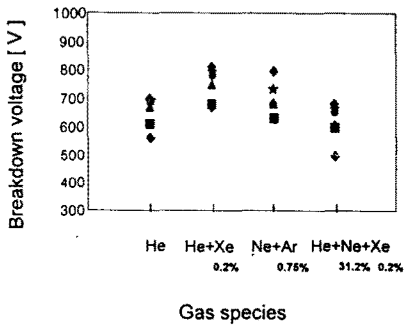

Fig. 7 Breakdown voltage versus working gas species

Fig. 7 shows breakdown voltage as a parameter of working gas species. This experiment was done under the condition of 300torr which is near the actual working pressure of general PDP. The lowest breakdown voltage is obtained when the mixtures of He-Ne-Xe gases are used. The discharge start voltage also decreased when the mixtures of He-Ne- Xe gases are used.

It is well known that the color purity and luminance increase with an increase in amount of He or Xe of the mixtures of He-Ne-Xe gases and Ne plays an important role in decrement of the breakdown voltage.

Average energy of electron which is obtained by gas discharge under electric field E can be expressed (2).

$$eV=\frac{3}{2}kT_e=\frac{e^2E^2}{\delta m \nu_m^2} \quad (2)$$

(where, Te is electron temperature, e is electron charge, m is electron mass, E is external electric field intensity, ν_m is collision frequency and δ (=m/2M) is the fraction of energy loss by elastic collision between electron and atom having mass M[3].)

When the electron energy is within a few eV ranges as a PDP, collision frequency increases as order of Ne<He<Ar<Xe[4]. Therefore, Ne plays an important role in increment of electron average energy by eq. (2), and generation of excitation and ionization.

Consequently, it can be considered that the discharge start voltage decreases by the such an effect of Ne.

Fig. 8 shows transparency of dielectric layer as a parameter of firing temperature of dielectrics. It is shown that the transparency increases with an increase in dielectric firing temperature.

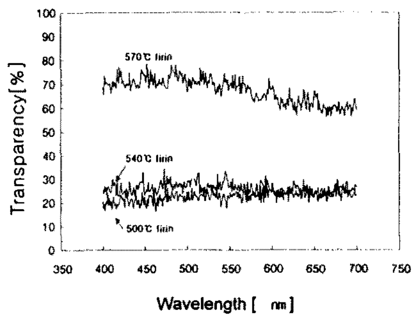

Fig 8. Transparency versus wavelength as a parameter of firing temperature

3. Conclusion

In this study, the dielectric breakdown strength and transparency of dielectric layer are investigated under various conditions. The result may be summarized as a follows.

(1) The optimum thickness of dielectric layer may be about 15㎛ in view point of dielectric strength.

(2) The optimum firing temperature of dielectric is about 570℃, but it may be changed as a characteristics of dielectric material and furnace which are used.

(3) The dielectric breakdown strength is the lowest near 200 or 300torr that is working pressure of PDP. For it is considered that the discharge is the most vigorous near the Paschen minimum.

(4) The dielectric breakdown strength is the lowest when the mixture of He-Ne-Xe gases was used.

(5) The transparency increases with an increase in firing temperature.

4. References

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