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Osawa et al.

[11] **3,904,906**

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[54] **PLASMA DISPLAY PANEL INCLUDING AN OPAQUE, REINFORCING FILM**

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[30] **Foreign Application Priority Data**

Dec. 29, 1971 Japan 46-75752

[52] **U.S. Cl.** **313/188;** 313/220; 313/221; 313/518

[51] **Int. Cl.** **H01j 61/35**

[58] **Field of Search** 313/188, 201, 220, 221, 313/518

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Primary Examiner—Palmer C. Demeo
Attorney, Agent, or Firm—Allan Ratner; Nelson E. Kimmelman

[57] **ABSTRACT**

A plasma display panel of long life, more than several thousand hours, having a plurality of electrode pairs covered with dielectric layers facing to discharge gas space, and surface reinforcing film on one or both surface of the dielectric layers facing to discharge gas space. The surface reinforcing film is made from insulating materials, the chief component of which is an oxide of a rare-earth element.

1 Claim, 12 Drawing Figures

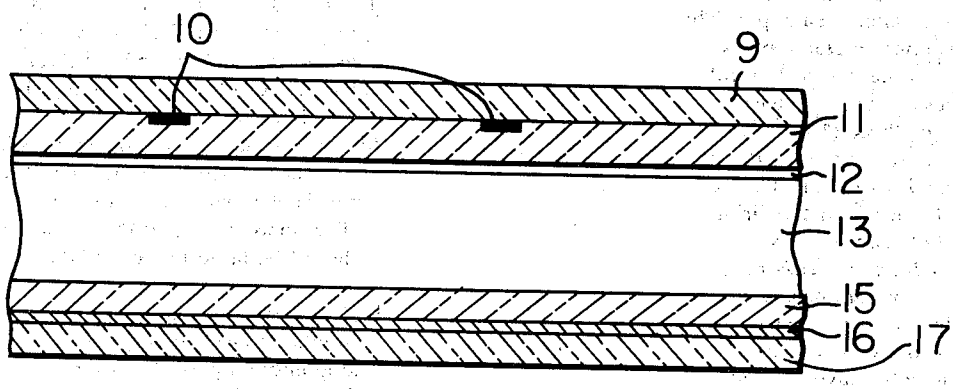


Fig. 1

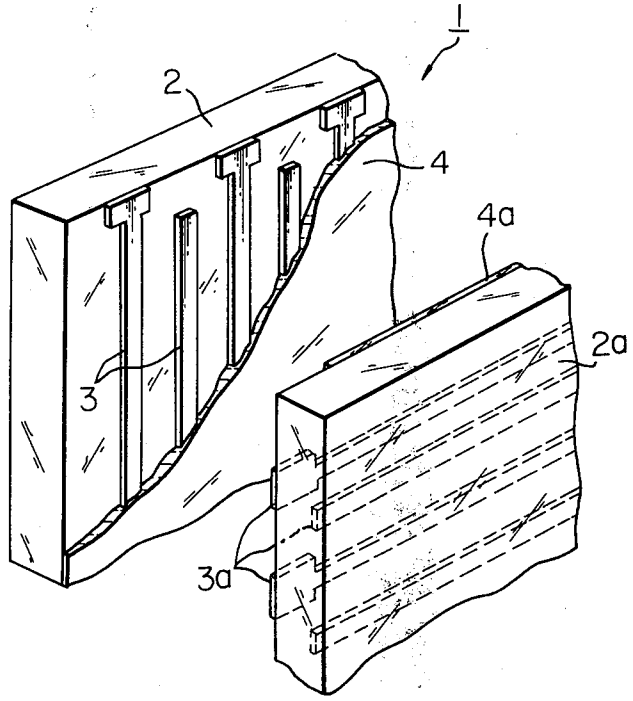


Fig. 2

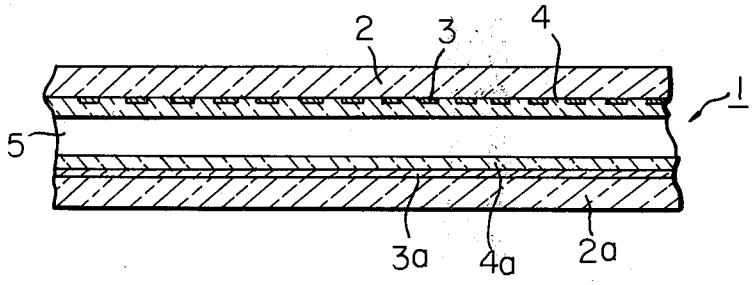


Fig. 3 (A)

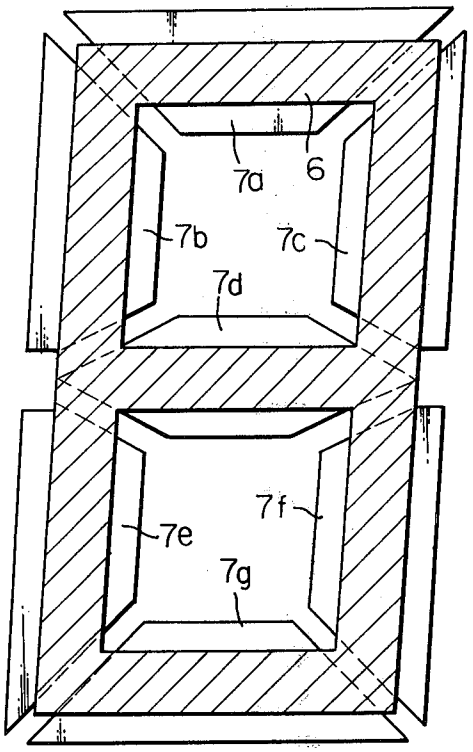


Fig. 3(B) Fig. 3(C) Fig. 3(D)

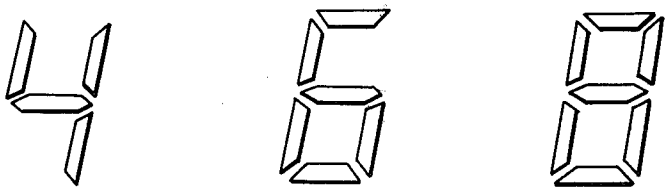


Fig. 4(A)

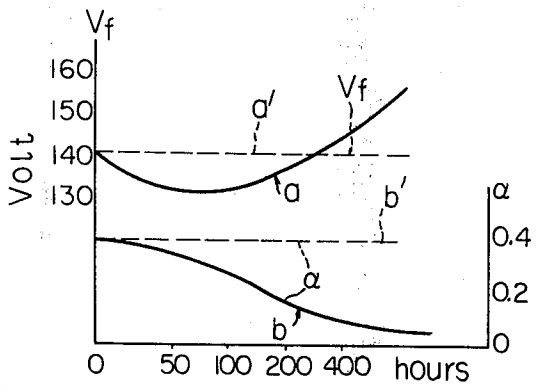


Fig. 4(B)

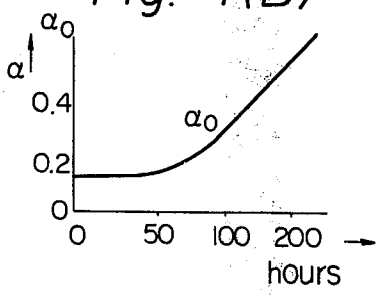


Fig. 5

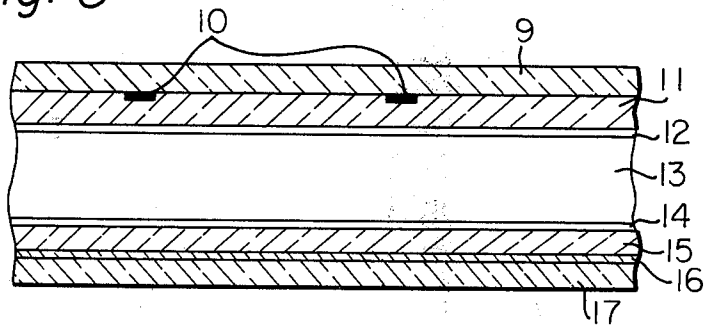


Fig. 6 (A)

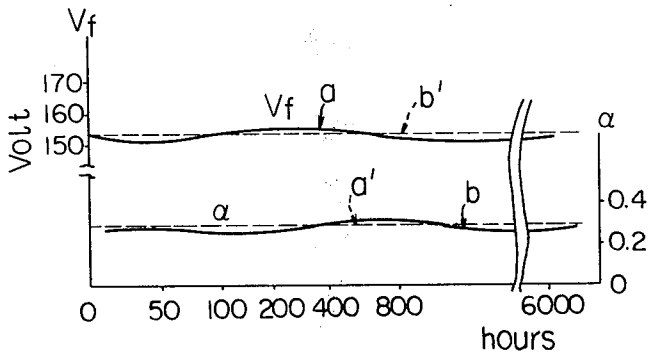


Fig. 6 (B)

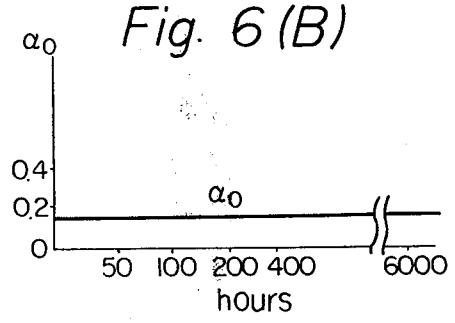
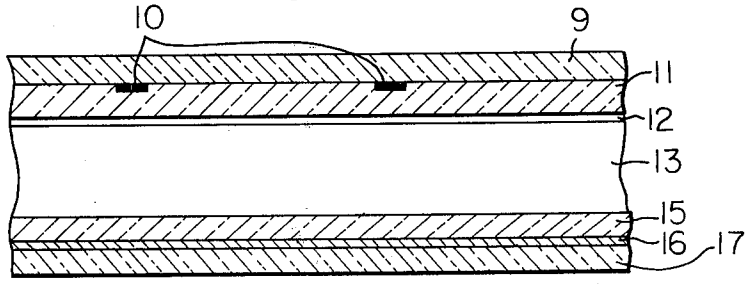


Fig. 7



PLASMA DISPLAY PANEL INCLUDING AN OPAQUE, REINFORCING FILM

This invention relates to a plasma display panel, particularly relates to a plasma display panel of long life and good durability.

Generally, in a display device utilizing gaseous discharge, a pair of electrodes covered with dielectric layers are positioned opposite each other. Between them is a gap filled with gas capable of ionization. An alternating sustaining signal is applied between the electrodes facing each other, and the firing spots are produced when write pulses larger than the firing voltage are added to the sustaining signal. Wall charges corresponding to the polarity of the applied voltage are then formed. When the potential difference between the wall charges and the following sustaining voltage becomes larger than the firing voltage, the firing spot is again produced, and the polarity of the wall voltage is reversed. Accordingly, once the firing is produced, a sustaining voltage lower than the firing voltage can continuously produce the firing spot. That is, the write information is memorized as the wall voltage and the display can be carried out. Such a gaseous discharge panel has become known in the art as a "plasma panel," and when utilized for display purposes is commonly referred to as "a plasma display panel."

Some structure and shape of said plasma display panel have been known in prior art. For instance, a pair of substrates each having a plurality of parallel linear conductors covered with dielectric means are positioned opposite each other so that said linear conductors of one substrate are perpendicular to said linear conductors of the other substrate and a suitable gas is placed between the two substrates. According to the other example of prior art, a pair of electrodes whose shape relates to the shape of some alphanumeric letters are positioned opposite each other and suitable discharge gas is filled between them.

The disadvantage of prior plasma display panel is short operation life.

Two of the items which effect the life of plasma display panel are: (a) the material on the surface of the dielectric layers has been dissolved and changed in quality, and; (b) the discharge gas includes some impurity or some components of the discharge gas have been absorbed into the surface of dielectric layers after a short time of operation.

The reason (a), above, is more important than the reason (b) with respect to effecting the operation life. The deterioration and change in quality of surface material of dielectric layers according to said reason (a) are caused by: ion-bombardment (impact by an ion) and electron-bombardment according to discharge, and; high temperature of dielectric layers according to said bombardments. The ion-bombardment effects the life of plasma display panel the most. Said ion-bombardment removes the surface gas film, and dissolves and spatters the surface material. As a result, the value of the coefficient $\gamma(=\gamma_a+\gamma_b+\gamma_m)$ of secondary electron emission from dielectric layers changes. Where γ_a, γ_b and γ_m are the coefficients of secondary-electron emission by ions, light beams and semi-stable atoms, respectively. The change of the value γ causes a change in the value of conductivity of the surface material of the dielectric layers. This results in the changing of the firing voltage V_f and memory coefficient α; further, the diameter of discharge spots changes and the transparency of the substrates is affected due to the blackening phenomenon of the surface of dielectric layers. These changes are larger for the discharge cells which have been fired more times. Accordingly a difference in the frequency of use of discharge cells in one plasma display panel destroys the uniformity of electric characteristics of the discharge cells, and this lack of uniformity limits the even life of the plasma display panel.

In above explanation, the value α is defined as:

$$\alpha = \frac{\Delta V_f - \Delta V_{sm}}{(V_f)/2}$$

where V_f is the firing voltage, and V_{sm} is the minimum limit of sustaining voltage. Further the value α_o is defined as:

$$\alpha_o = \frac{\Delta V_f + \Delta V_{sm}}{(V_f)/2}$$

where δV_f is the difference between maximum and minimum firing voltages of all cells on the whole panel, and δV_{sm} is the difference between maximum and minimum sustaining voltages of all cells on the whole panel. The value α_o is preferably as small as possible.

Generally speaking, the material for dielectric layers is low melting point glass which includes much lead that is to say, said glass includes 60 – 80% of oxide- lead (PbO). Said glass is superior in such electrical characteristics as firing voltage V_f and memory coefficient α, and is superior with respect to easy baking to a substrate and easy manufacturing of containers. Further said glass is superior with respect to small differences of expansion coefficients between glass and substrate, wettability, viscosity transparency and softening temperature. However, the disadvantage of said glass for dielectric layers of a plasma display panel is that the connection between lead and the oxygen of oxide- lead is not strong. Therefore, ion-bombardment due to discharge destroys said connection between lead and oxygen, which changes the quality of the surface and releases oxygen atoms into the rare discharge gas. The above is the reason why the life of plasma display panels of prior art is short.

The object of the present invention is to provide an improved plasma display panel which overcomes the above-mentioned drawbacks.

Another object of the present invention is to provide an improved plasma display panel of long life.

A further object of the present invention is to provide an improved plasma display panel whose V_f, α and α_o do not change over a period of long operation.

A plasma display panel according to the present invention to accomplish each of the above objects is provided with surface reinforcing or protection layer on at least one surface of the dielectric layers facing the discharge gas. Said surface protection layers are dielectric materials in which the main component is made from oxide of rare-earth elements.

Further features and advantages of the present invention will be apparent from the ensuing description with reference to the accompanying drawings; to which, however, the scope of the invention is in no way limited.

FIG. 1 is a perspective view illustrating the construction of a typical display panel utilizing a gas discharge;

FIG. 2 is a sectional view illustrating the construction of a typical display panel utilizing a gas discharge shown in FIG. 1;

FIGS. 3(A) through (D) show another embodiment of a typical display panel utilizing a gas discharge;

FIGS. 4(A) and (B) show life characteristic curves of prior plasma display panels;

FIG. 5 shows one embodiment of the present invention in an enlarged sectional view illustrating the construction of a typical display panel utilizing a gas discharge according to the present invention;

FIG. 6(A) and FIG. 6(B) show life characteristic curves of a plasma display panel according to the present invention;

FIG. 7 shows another embodiment of the present invention in an enlarged sectional view illustrating the construction of plasma display panel utilizing a gas discharge according to the present invention.

Referring to FIG. 1, a display device 1 utilizing a gaseous discharge has a pair of supporting substrates of electrodes 2 and 2*a*. The supporting substrate of electrodes 2 provides a group of electrodes 3 arranged in columns, which is parallel to a vertical axis; dielectric layer 4 covers the group of electrodes 3. The supporting substrate of electrodes 2*a* provides a group of electrodes 3*a* arranged in rows, which is parallel to a horizontal axis; dielectric layer 4*a* covers the group of electrodes 3*a*. The supporting substrates of electrodes 2 and 2*a* are positioned in spaced parallel relation to the groups of electrodes 3 and 3*a* respectively. As shown in FIG. 2 these parallel rows and columns are separated from each other by a gap 5. This gap 5 is filled with a rare gas having suitable pressure and capable of ionization. When the device 1 is utilized for display purpose, it is necessary that, at least, one of the substrates 2, 2*a* and one of the dielectric layers 4, 4*a* are transparent.

In the above-mentioned display device utilizing gas discharge 1 shown in FIGS. 1 and 2, when an electric voltage higher than the firing voltage V_f is selectively applied between the groups of electrodes in columns 3 and rows 3*a*, each cross point of the electrodes in columns and row discharges into the gap 5 filled with an ionizable gas. At the time of this discharge, a wall charge is formed near the above-mentioned cross point in the dielectric layers 4 and 4*a*. With the effect of this wall charge, the discharge which is once generated is sustained with the pulsive sustaining voltage V_s smaller than the firing voltage V_f and is continued. That is, the information which inputs as the voltage exceeding the firing voltage V_f is kept in memory by the above-mentioned wall charge.

FIG. 3(A) shows the other embodiment of plasma display panel utilizing gas discharge of prior art. In FIG. 3(A), common electrode 6 and segment electrodes 7*a* – 7*g* divided into seven sections are positioned face to face and rare gas is filled between common electrode 6 and segment electrodes 7*a* – 7*g*. The surface of electrodes 6 and 7*a* – 7*g* are covered with dielectric layers (not shown) like the embodiment of FIG. 1 and FIG. 2. The display device which has the structure of FIG. 3(A) can be used to show numerical letters. That is to say, selective discharge between common electrode 6 and segment electrodes 7*a* – 7*g* provides the display of numerical letters like FIGS. 3(B) – (D), where FIG. 3(B) shows "4", FIG. 3(C) shows "6", and FIG. 3(D) shows "8." For instance, in FIG. 3(B), numerical letter "4" is displayed by discharge between common electrode 6 and segment electrodes 7*b*, 7*c* 7*d* and 7*f*.

A structure of the plasma display panel other than that shown in FIG. 1 – FIG. 3 is also possible. For instance a single plane discharge type or lateral discharge type plasma display panel which has a plurality of pairs of electrodes placed on the same side of the discharge gas is possible. (The plasma display panel of FIG. 1 and FIG. 2 is called cross point discharge type or vertical discharge type as plurality of electrodes are placed on both sides of discharge gas). Further, a self-shift type plasma display panel is possible which has a so-called chain reaction effect or fusing effect caused by ionized gas near discharged spots. In the self-shift type, firing voltage of spots near the discharged spot is lower than that of others because of presence of ionized gas. By utilizing said effect positively, in a self-shift plasma display panel, discharged spots move automatically towards a predetermined direction if a polyphase voltage is applied to the electrode.

FIGS. 4(A) and (B) show characteristic curves of firing voltage V_f, memory coefficient α, value α_0 against operation time of prior plasma display panels. In FIG. 4(A), curves *a* and *b* show the characteristics V_f and α of the spots discharged continuously, while curves *a'* and *b'* show the characteristics V_f and α of the undischarged spots. It should be understood from FIG. 4(A) and FIG. 4(B) that is prior plasma display panels the values of V_f, and α_0 for operation spots start to change after about 50 hours. Said change causes a shortening of the life of the plasma display panel itself.

The reason the life of a prior plasma display panel is as short as shown in FIG. 4(A) and FIG. 4(B), is the change in the quality of the dielectric material on the surface of dielectric layers facing the discharge gas as explained above.

In general, the condition required in the material of the dielectric layers facing the discharge gas of a plasma display panel is as follows.

a. The coefficient γ of the second electron emission should be large in view of the lower firing voltage V_f.

b. The surface resistance and volume resistance should be large enough to hold a wall charge for a long enough period of time.

c. The equivalent capacitance of the dielectric layers should be small enough to restrict the value of discharge current, that is to say, the dielectric layers should have the property that it is possible to manufacture thick layers in order to obtain small capacitance.

d. The material should have enough dielectric strength.

e. The material should have enough strength against ion-bombardment.

f. Wettability and the difference of expansion coefficient between substrates and dielectric layers should be reasonable, and further chemical property, softening temperature and transparency should be reasonable.

Among the above conditions, (a) and (e) relate to the property of the surface of dielectric layers only, and these two conditions have a large effect on the life of the plasma display panel. For conditions (b), (c), (d) and (f) dielectric material which has been successfully

employed many times previously can be preferably used.

Accordingly, the plasma display panel of the present invention has the structure that at least one surface of dielectric layers facing the discharge gas is covered with thin surface reinforcing film having properties which satisfy said conditions (a) and (e).

The desired properties of a surface reinforcing film are strong connection with oxygen, small sputtering coefficient, good insulation, transparency and easy manufacture. One material for surface reinforce film which satisfies said desired properties is oxide-cerium (CeO_2), which has strong connection with oxygen, strong oxidation property and small sputtering coefficient. Oxide-cerium is also a good dielectric material and is chemically stable.

1000 – 5000 A thick of oxide-cerium is attached to the surface of dielectric layers of about 10 – 20 μ thick by evaporation technique heated by resistance heating.

FIG. 5 shows one embodiment of the present invention in an enlarged sectional view of a plasma display panel having a surface reinforcing film according to the present invention. In FIG. 5, 9 is a first substrate on which a plurality of parallel spaced conductors are positioned as a first group of electrodes **10.** Said group of electrodes **10** are covered with a first dielectric layer **11,** whose surface facing the discharge gas space **13** is further covered with a first surface reinforcing film **12.** 17 is a second substrate on which a plurality of parallel spaced conductors are positioned as a second group of electrodes **16.** This second group of electrodes **16** are covered with a second dielectric layer **15,** whose surface facing the discharge gas space **13** is further covered with a second surface reinforcing film **14.** Two substrates **9** and **17** are placed so as to face each other across the discharge gas space **13** so that the two groups of electrodes **10** and **16** are perpendicular to each other.

FIGS. 6(A) and (B) show characteristic curves of firing voltage V_f, memory coefficient α and value α_o versus operation time of the plasma display panel of FIG. 5. In FIGS. 6(A) and (B) time axis (lateral axis) is marked with logarithm degree. In FIG. 6(A), curves a and b show the characteristics V_f and α of the spots discharged continuously, while curves a' and b' show characteristics V_f and α of the undischarged spots.

It should be understood from FIG. 6(A) and FIG. 6(B) that the value of V_f, α and α_o of the plasma display panel according to the present invention hardly change for a long time for discharged and undischarged spots. Therefore, life of the plasma display panel is considerably improved by the present invention, said life being more than several thousand hours.

In addition to long life, some of the advantages of the plasma display panel having surface reinforcing film of oxide-cerium according to the present invention are: easy evaporation property; firing voltage V_f memory coefficient α and property of discharged spots being about equal to prior display panels; desirable transparency, and; easy treatment. Other than oxide-cerium said surface reinforcing film can be made from some oxides of rare-earth elements such as Yttrium (Y), Europium (Eu), Gadolinium (Gd), Teribium (Tb) or Dysprosium (Dy); Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb) or Lanthanium (La); Scandium (Sc) or Thorium (Th). For the method of attaching said surface reinforcing film on the surface of dielectric layers it is possible to use, for instance, some evaporation technique like resistance heating evaporation, electron beam heating evaporation, high-frequency sputtering evaporation, melt and spray method, sedimentation method or spray method. In said method of attaching the film on the surface of the dielectric layers is also possible to obtain oxide by an anode-oxidize method after attachment of the metal element to said surface, or to obtain oxide film by activated sputtering of metal in a rare gas atmosphere including oxygen. Further, the evaporation of mixtures like Y_2O_3 - TiO_2, and thin film made from mixture Dy_2O_3 - B_2O_3 - SiO_2 of the weight ratio **80** : **10** : **10,** are possible. If oxide-lanthanium (La_2O_3) is used for the surface reinforcing film, the operation should be done in dry atmosphere as it is hygroscopic.

FIG. 7 shows another embodiment of the present invention in an enlarged sectional view of a plasma display panel according to the present invention. One point in which the embodiment of FIG. 7 differs from that of FIG. 5 is that the second surface reinforcing film **14** is removed and only the first surface reinforcing film **12** is provided in the embodiment of FIG. 7. Though the plasma display panel of FIG. 7 has surface reinforcing film on only one dielectric layer, the life property of it is almost the same as that of FIG. 5.

The reason the plasma display panel of FIG. 7, which has surface reinforcing film on only one dielectric layer, can obtain almost the same long life as that of FIG. 5, which has surface reinforcing films on both dielectric layers, is as follows.

The surface reinforcing film provided on one dielectric layer protects not only the layer which has reinforcing film, but also the layer which does not have reinforcing film, because said reinforcing film is sputtered by electron and/or ion during discharge. Consequently, the sputtered materials cover and protect little by little the dielectric layer which has no surface reinforcing film, and thus something like sputtered protection film is provided on the dielectric layer. Said sputtered protection film may be composed of a mixture of the material of the protection film and that of the prior dielectric layers, as the prior dielectric layer may also be sputtered. Further, the sputtered protection film may also cover the protected surface.

The other advantage of the embodiment of FIG. 7 is that an opaque film on the one dielectric layer may be used as a reinforcing film. In addition the manufacturing cost of the plasma display panel of FIG. 7 may be lower than that of FIG. 5, as only one surface reinforcing film is needed.

Further, in the case where a change in quality of discharge gas disturbs the characteristics of the plasma display panel due to the decomposition of oxygen gas from oxide by the sputtering and/or ion attack from the surface reinforcing film and/or dielectric layer in FIG. 5 or FIG. 7, getter which observes oxygen gas gently may provide longer life of the plasma display panel.

From the foregoing it will now be apparent that an improved plasma display panel with long life has been provided. It should be understood of course that the eembodiments disclosed here are merely illustrative and are not intended to limit the scope of the invention. Some modification within the spirit of the invention may be possible. For instance, the whole dielectric layer may be made of the same material as that of the surface reinforcing film, instead of said layer being cov-

ered with reinforcing film. Further, the surface reinforcing film may be applicable not only to cross point discharge type or vertical discharge type plasma display panels but also to all kinds of plasma display panels including single plane discharge type or lateral discharge type, and that of FIG. 3.

What we claim is:

1. A plasma display panel comprising;

a. a first and a second dielectric substrate, said first and second substrates being spaced from each other and sealed, a discharge gas contained within said sealed substrates forming a discharge gas space, at least one of said substrates being transparent;

b. first and second electrodes mounted on said first and second substrates, respectively;

c. a first and a second dielectric film covering said first and said second electrodes, respectively, said films facing said discharge gas space.

d. a surface reinforcing film only on the non-viewing side of one of said dielectric films, said reinforcing film being opaque and having a major component made from an oxide of a rare earth element selected from the group consisting of CeO_2 and La_2O_3.

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