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Mayer

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[54] **PLANAR PLASMA DISCHARGE DISPLAY PANEL**

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[22] Filed: **Feb. 22, 1974**

[21] Appl. No.: **444,634**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 292,598, Sept. 27, 1972, abandoned.

[52] **U.S. Cl.** **313/491,** 313/220
[51] **Int. Cl.** **H01j 61/30**
[58] **Field of Search** 313/109.5, 182, 188, 220; 315/169

[56] **References Cited**

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Primary Examiner—Archie R. Borchelt
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[57] **ABSTRACT**

A planar plasma discharge panel comprises a first group of electrical conductors secured to an electrically non-conducting substrate. A layer of electrically non-conducting dielectric material is secured to said substrate and to said conductors to form an electrically non-conductive surface thereover. A second group of electrical conductors is secured to said surface. The conductors of the second group cross the conductors of the first group at an angle so that the crossover areas of said conductors define discharge points of the plasma display panel. A second layer of electrically non-conductive dielectric material is secured to the first surface layer and to the second group of electrical conductors. An appropriate ionizable gas medium is confined above this second layer of dielectric material. The discharge pattern generated by the device is from point to point on the dielectric surface of the second layer of electrically non-conductive material with the desired electrical fields being generated by the underlying grid of conductors. The gaseous medium is selected for the desired discharge characteristics of the panel. Several embodiments are shown for controlling the discharge so as to improve panel resolution.

2 Claims, 10 Drawing Figures

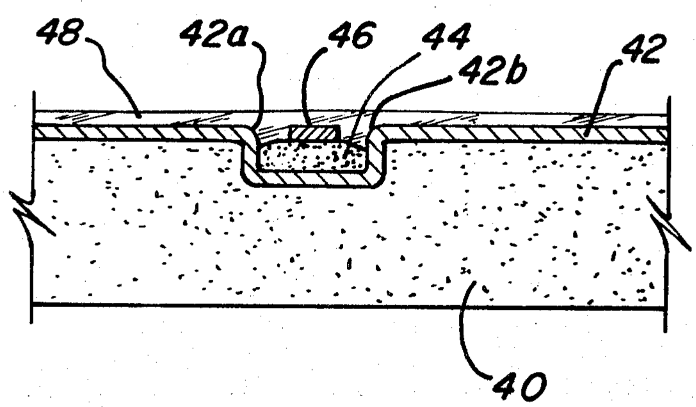


FIG. 1.

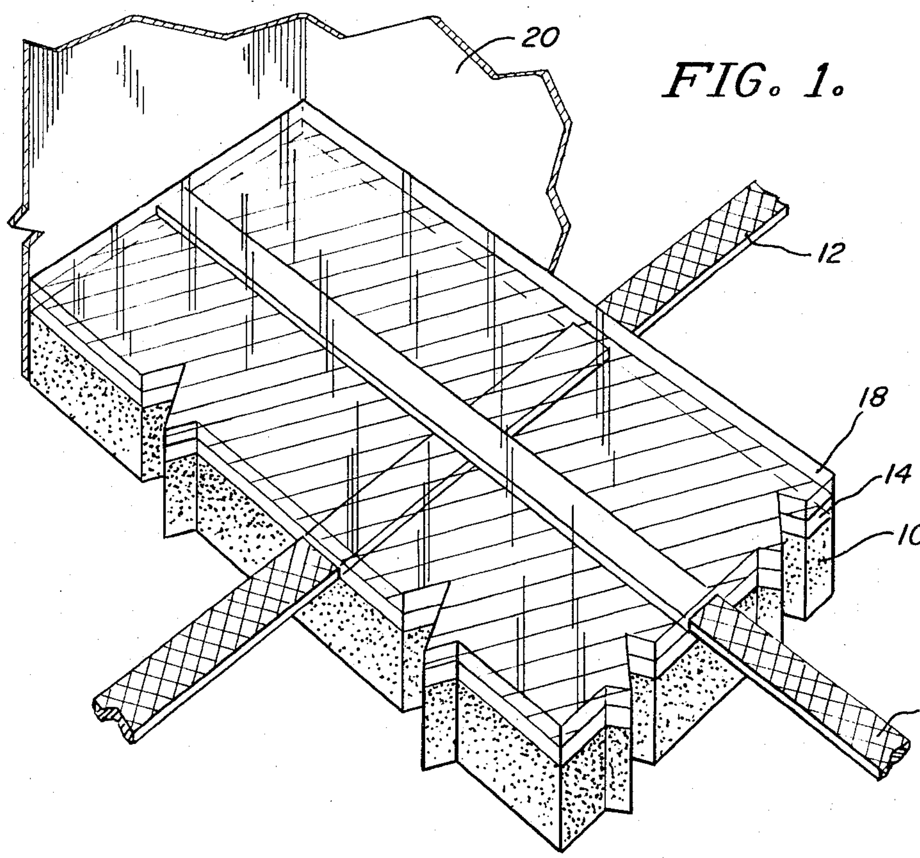


FIG. 2.

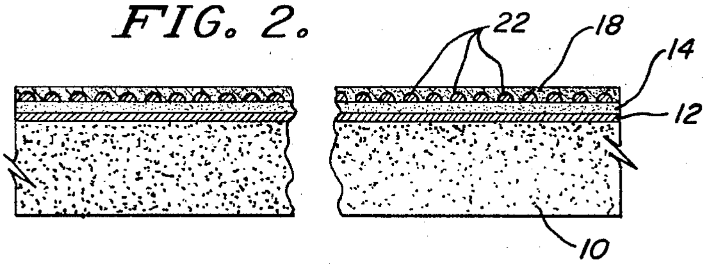


FIG. 3.

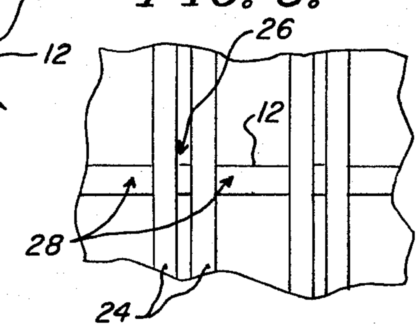


FIG. 5.

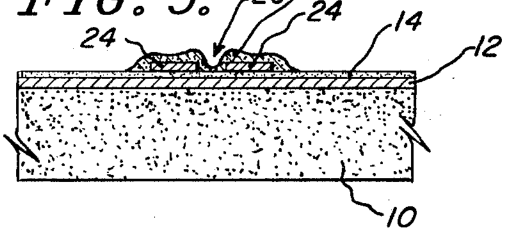


FIG. 4.

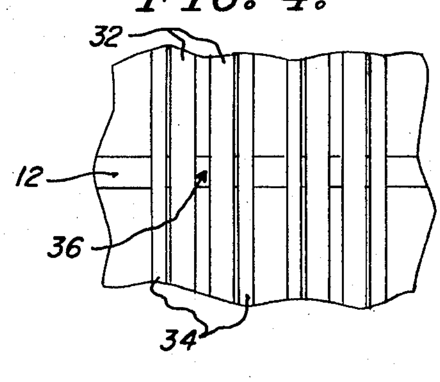


FIG. 6.

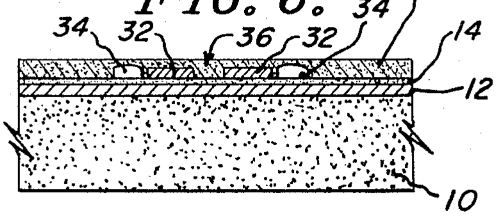


FIG. 7.

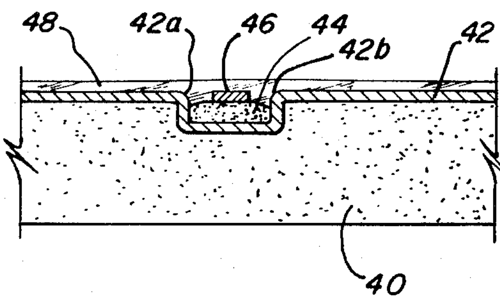


FIG. 8.

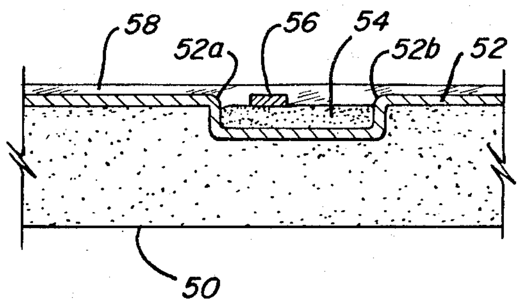


FIG. 9.

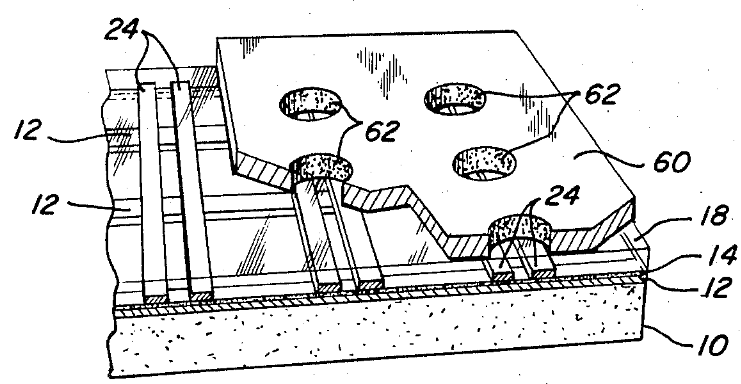
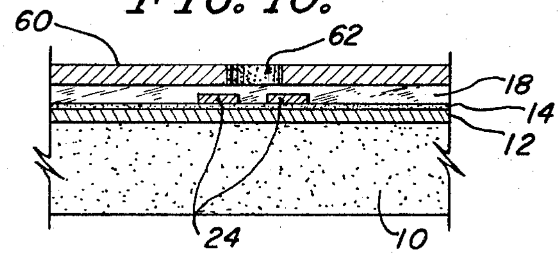


FIG. 10.



PLANAR PLASMA DISCHARGE DISPLAY PANEL

BACKGROUND OF THE INVENTION

This application is a continuation in part of application Ser. No. 292,598 filed Sept. 27, 1972 and entitled "Planar Plasma Discharge Display Panel, now abandoned."

This invention relates to the field of plasma discharge displays such as are used for the readout of alpha numeric information from digital signals. More particularly, this invention relates to the type of panel dependent upon a capacitive discharge memory. One form of such a display is shown in the patent to Bitzer, et al., U.S. Pat. No. 3,559,190.

Prior art plasma display panels operating on principles described in the Bitzer, et al., patent have shown a plasma discharge occurring between two opposed dielectric surfaces having the gaseous medium between them. Many efforts have been made to control variations in the spacing between these opposed surfaces so that each cell or discharge area of the display will have identical operating characteristics. It is well known that if the spacing between the cell end walls or the thickness of the dielectric separating the gaseous medium from the conductors should vary from cell to cell within a display panel, the cell characteristics such as the voltage level required for the lighting of an unlit cell, the maintenance of a lighted cell, and the erasing of the lighted cell may vary so as to cause an unworkable display. Efforts to increase the uniformity have, however, increased the complexity and cost of the display. Even though improvements have been made, the improved displays still may be sensitive to variations of temperature and atmospheric pressure as well as being sensitive to mechanical shock which would tend to preclude use of the panels in many applications. Consequently, it is desirable to provide a plasma discharge display panel having a relatively low cost while maintaining a high degree of uniformity from cell to cell in the display.

One effort in this direction is shown in the U.S. Pat. to Lay, No. 3,646,384, in which drive lines are shown on opposite surfaces of a thin sheet of glass or ceramic. However, this patent only recites the achievement of a drive line density of three lines per inch. In addition discharge occurs from both edges of the electrode closest to the gaseous discharge medium resulting in rather poor resolution.

SUMMARY OF THE INVENTION

This invention provides a plasma discharge display panel in which the ionized gas discharge path occurs from one point to another point on a surface in a confined ionizable gaseous medium. In one form of the invention the discharge may occur from a point on the surface which is a dielectric to another point on the same surface which is a conductor. In another embodiment of the invention, the discharge may occur from one point on a dielectric surface to another point on a dielectric surface where an electrical potential exists between the two points because of a voltage applied between conductors in the dielectric. Generally, it is anticipated that panels according to this invention may be planar, but it can readily be anticipated that certain desired optical effects may be created by a slight concave or convex curvature of a panel according to the present invention or that an entirely different shape of display may be provided (e.g., cylindrical, spherical).

One form of the panel according to the present invention comprises an insulating substrate upon which the display elements are constructed. The substrate, which, for example, may be ceramic or glass, provides mechanical support for the display elements. A group of generally parallel electrical conductors is deposited upon or otherwise conventionally secured to the substrate. Next, an insulating dielectric layer is secured to the substrate and the first electrical conductor group to provide a dielectric surface. A second group of electrical conductors is secured to the dielectric surface in a direction which may be generally orthogonal to the first conductor group to thereby define discharge cells associated with the cross-over points of the conductors. The discharge display will work in this fashion with the discharge occurring from the exposed conductors of the second group to the dielectric surface deposited or secured over the first conductor group. However, it is preferred to secure an additional non-conductive dielectric layer of material over the second electrical conductor group so that the discharge points will occur from point to point on a dielectric surface. This will eliminate sputtering or other deterioration of the electrodes as well as improving the uniformity of interelectrode characteristics.

Several embodiments of the invention are disclosed, some of which control and confine the discharge region so as to improve the resolution of the panel. One such embodiment has the conductors of the second group split longitudinally so that the discharge occurs in the area between portions of the conductor. Various means are used to arrest the occurrence of a discharge on the outside edges of the top conductors. One such means comprises a pair of guard conductors one on each side of the split top conductor. The additional conductor pair is connected to a voltage potential such that insufficient potential exists between either the first or second conductor group to initiate or maintain a discharge. The guard conductors may be grounded for example. Alternatively, the topmost dielectric layer may be formed and shaped on the outside edges of the top conductor to increase the thickness of the layer thereby decreasing the capacitance between undesired discharge areas so that the discharge occurs only in the center region over the split conductor. In the figures:

FIG. **1** is a detailed perspective view of a portion of a planar display panel according to one embodiment of the present invention.

FIG. **2** is a cross-sectional view through a panel according to another embodiment of the present invention.

FIG. **3** is a schematic top plan view of a portion of a panel according to another embodiment of the present invention.

FIG. **4** is a top plan schematic view of a portion of a panel of yet another embodiment of the present invention.

FIG. **5** is a cross-sectional view through a modified form of the embodiment shown in FIG. **3.**

FIG. **6** is a cross-sectional view through a form of the invention shown in FIG. **4.**

FIG. **7** is a cross-sectional view of yet another form of the invention.

FIG. **8** is a cross-sectional view of still another form of the invention.

FIG. **9** is a perspective view of a form of the invention having an aperture plate.

FIG. 10 is a cross-sectional view through a portion of the form of the invention shown in FIG. 9.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, illustrative of one form of the present invention, an insulating substrate 10, such as ceramic or glass, having sufficient rigidity to support a panel structure of the type described acts as a foundation upon which the structure of the invention is formed. A first group of substantially parallel conductors 12, one of which is shown in FIG. 1 are secured to the substrate 10. Appropriate terminations to conductors 12 are provided so that appropriate driving circuity, such as that shown in U.S. Pat. No. 3,573,542 for example, may be provided to drive the panel. Conductors 12 may be secured to the substrate 10 in any conventional way such as by standard deposition techniques. In fact, it would be possible to construct the panel according to the present invention if conductors 12 were held in place by the subsequently applied layers of the panel rather than rigidly secured to the substrate. Conductors 12 may be of any suitable cross-sectional shape, such as rectangular as shown in FIG. 1, or such as circular to better define the discharge area by providing a smaller section of the conductor near the surface of the dielectric material of the panel. It would also be possible to use conductors which are semi-circular in cross-section with the flat surface secured to substrate 10 and the rounded surface providing a focal point for concentration of the discharge.

A layer 14 of electrically insulating, dielectric material is applies to the substrate 10 covering conductors 12 in such a way that a uniform, non-conducting surface is available for the next group of electrical conductors. Any material which has suitable breakdown strength as an insulating property may be used for the material 14. The distance separating crossing conductors in the layered relationship may be as small as a few ten thousandths of an inch or several one thousandths of an inch and the voltages applied to such conductors may have peak values of a few hundred volts. Glass or ceramic are suitable materials for layer 14. One suitable way of forming layer 14 would be to apply a frit of glass uniformly over the substrate 10 and the conductor grid 12 and then apply sufficient heat to fuse the frit into a solid surface secured to the substrate 10. Glass frits are known in the art and a frit is generally powder-like and consisting of very small particles of the material forming the frit.

A conductor grid formed of conductors 16, one of which is shown in the fragment of FIG. 1, is next secured to the surface 14 by any well known means, one of which would be a deposition technique. Conductors 16 generally run orthogonally to conductors 12 and parallel to one another. The discharge points for the display are defined at the intersections where conductors 16 pass over conductors 12.

It is desirable, but not absolutely necessary, to apply a final layer of material 18 over the surface 14 and the conductors 16 in order to form the uniform, electrically non-conducting dielectric surface on which the discharge display occurs from point to point on the surface. It would be possible to have a panel without this final surface 18, however, it would be necessary to deal with the problem of the sputtering of the electrode 16 in the case where the discharge was directly from the electrode 16 to the dielectric surface 14. Also, with the dielectric surface 18 the memory characteristics of the panel will be more desirable because the dielectric will encompass both conductors 12 and 16.

The layered structure is surrounded by an enclosure 20 shown in broken segment in FIG. 1, which has characteristics appropriate to confining a gaseous environment for the complete display panel, means for evacuating the chamber so created by the enclosure and reinjecting the appropriate gaseous environment, and generally, a viewing area for the display so created or other appropriate means for detecting the state of the panel. Other such appropriate means might be photodetecting transistors placed in a matrix conforming to the matrix formed by the plurality of conductors 12 arranged with the plurality of conductors 16 to form a matrix optical isolating device similar to the unitary optical isolating devices now prepared using light emitting diodes in combination with photo-detecting transistors.

An appropriate gas atmosphere for enclosure 20 would consist of approximately 99 percent neon and 1 percent trace gases, primarily argon and nitrogen to produce an acceptable display. Variation in the composition of the atmosphere can occur without losing display capability. The display atmosphere may be confined at various pressures. It has been found that pressures in the range from ½ atmosphere to 1 atmosphere (350 to 760 Torr) are suitable, without being necessarily limited to this range. A conventional pump may be used to evacuate enclosure 20 and a conventional low pressure valve system used to inject the desired gas. Several cycles of purging and filling may be required to ensure that the gas is pure and not contaminated.

Typically the dielectric layers 14 and 18 will be on the order of a few thousandths of an inch thick. It is desirable to have the dielectric layers comparatively thin so that the capacitive coupling to the ionizable gas will be comparatively large. With the dielectric layers in this thickness range, operating voltages can be on the order of approximately 350 volts for write pulses, 250 volts for sustain pulses and 150 volts for erase pulses. A drive system such as that shown in U.S. Pat. No. 3,573,542 entitled "Gaseous Display Control" may be used to provide the interelectrode voltages to operate a panel according to the present invention. From FIG. 1 and this specification it is clear that a number of conductors in the array will protrude beyond the walls of enclosure 20, as is conductor 12 in FIG. 1, to provide electrical attachment points for a drive system such as is shown in the above referenced patent. Of course, the drive system referenced is only one way of driving a panel according to the present invention and is not to be taken as an exclusive way.

Referring now to FIG. 2, a panel formed according to the structure of FIG. 1 is shown with a substrate 10, a cross-sectional view of a single lower conductor 12, a layer of electrically non-conducting dielectric material 14. However, the orthogonal conductor array is composed, for purposes of illustration, of conductors having a semi-circular cross section, each conductor being flat on the surface secured to dielectric 14 and generally rounded upwardly. The dielectric surface 18 is formed in a generally flat, planar fashion over the conductor array formed by conductors 22. As may be appreciated from FIG. 1, the discharge occurring on the surface 18 at the intersections of conductors 12 and 16 can occur from a point on the surface 18 to another point on the surface 18 at a region on either side of conductor 16 but yet over a line conductor 12. The upwardly rounded surface of conductors 22 produces a comparatively thin dielectric surface in a concentrated region over the center of the individual conductors 22, thereby producing a comparatively high capacitance in that concentrated region and tends to concentrate the region of discharge more closely around the center of the conductor than in the case shown in FIG. 1 with flat top conductors 16. If the conductors or portions of the conductors are located too far beneath the surface of the topmost layer of dielectric, those conductors or portions thereof will not create or maintain a display because an electric field sufficient to breakdown and ionize the gas will not be generated.

Referring now to FIG. 3, which is a schematic showing of yet another embodiment of the invention, bottom conductors 12 are associated with divided and separated top conductors 24 to define discharge regions in a space 26 overlying the bottom conductor 12 and in the region between the portions of the divided top conductor 24. In addition, it will be appreciated that there may be regions of discharge at either side of the top conductor 24 in the area designated generally 28. With three discharge regions, the display will have greater brightness than the display of FIG. 1. Alternatively, various methods may be employed to diminish the brightness of the lateral discharge regions 28 or to prevent their formation altogether in order to produce increased resolution of the panel by having a single, more uniformly controlled discharge region 26.

Referring now to FIG. 5 which is a modification of the embodiment of the invention shown in FIG. 3, a substrate 10 has bottom conductors 12 over which the dielectric layer 14 is prepared. The divided top conductor 24 defines a region of discharge 26 in the area between the portions thereof. A top dielectric layer 30 is formed in such a fashion as to be comparatively thick at the outside edges of the top conductor 24, thereby lowering the capacitance between the lower electrode 12 and the upper electrode 24 in these side regions to a point where discharge will not occur within the normal operating voltage range of the display device. The thickness of the dielectric material in the desired discharge region 26 is such that the capacitance is great enough in this region so that discharge ignition and sustain will occur in the normal operating parameters of the display device.

Referring now to FIG. 4, another embodiment of the invention is shown having bottom conductors 12 and a divided and separated top conductor 32. Guard conductors 34, located in spaced apart relationship to the outside edges of top conductor 32, are provided to prevent discharge in the lateral regions of the top conductors. The single normal discharge region is designated by reference 36. The guard conductors will have connections extending outside enclosure 20 so that electrical connections may be made. Guard conductors 34 may be connected to ground potential, for example, to prevent side discharges by lowering the potential of the electric field in their vicinity in the ionizable gas below that required to initiate and maintain a discharge.

Referring now to FIG. 7, another form of the invention is shown with a shaped substrate 40 which has been formed to have a contoured surface or which may be built up in a contoured fashion by appropriate deposition techniques. A bottom electrode 42 similar to electrode 12 in other forms of the invention conforms to the surface or substrate 40 by having steeply rising sides and by presenting shoulder areas 42*a* and 42*b* in the vicinity of the area in which the discharge is to take place. The channel formed by the contoured electrode 42 is filled with an insulating dielectric material 44 and an orthogonally directed electrode 46 is secured to this dielectric material 44. A final layer of dielectric material 48 is then applied over the entire surface of what is generally a flat planar plasma display panel having a plurality of intersections between electroces 46 and electrodes 42 which are display elements of the panel. The discharge occurs very generally on the surface of the panel in the vicinity of the shoulders 42*a* and 42*b* of electrode 42 at the intersection with electrode 46 because the electric field in the ionizable gas is sufficient to initiate and maintain a discharge. This form of a plasma display panel is constructed in this way so that both electrodes 42 and 46 are generally covered by approximately the same thickness of dielectric material 48 to ensure a more uniform characteristic of the plasma display panel which will not tend to favor one electrode over the other on opposite half cycles of the driving voltage. In addition, the interelectrode capacitance and dissipation of energy in the dielectric can be minimized in this form of the invention while developing maximum electrical potential in the discharge region.

Referring now to FIG. 8, a somewhat different plasma display panel structure is shown having a shaped substrate 50 formed with a plurality of channels across which electrodes 52, one of which is shown in cross section, are secured. Wider channels are formed on the surface of dielectric 50 than in the form of the invention shown in FIG. 7. The channels are filled with an insulating dielectric material 54. On the dielectrid material 54 are secured a plurality of electrodes 56 but each of which is displaced from the center of that material to a significant degree. The electrodes 56 are displaced in such a fashion that the discharge will occur in only one direction with respect to the electrode 56. That is, the discharge will tend to occur on the surface of the top layer 58 of dielectric material between a single shoulder 52*a* of electrode 52 and electrode 56, thereby tending to limit the discharge to a single rather than a double spot and tending, thereby, to improve the resolution of the display panel. No discharge will normally occur on the surface between shoulder 52*b* and electrode 56.

Referring now to FIG. 9, a planar plasma display panel similar to that shown in FIG. 3 and showing a plurality of discharge cells formed at the intersections of conductors 12 and divided and separated conductors 24 is provided with an overlaying aperture plate 60 formed with a plurality of holes, each of which is centered over a discharge cell. An inside surface of each hole in the aperture plate 60 is coated with a phosphorescent material 62 having desired characteristics for the application intended. Thus, the planar panel may be useful for providing a display having various colors or greater brightness than that obtainable with only a gas discharge. FIG. 10 is a cross-sectional view of one such cell shown in FIG. 9 showing the proximity of the phosphorescent material to the discharge area. Another way of making this type of panel would be to make the final dielectric layer 18 substantially thicker than necessary and causing holes to be formed therein for coating with desired materials for creating additional display effects.

In addition it will be appreciated that certain features of the invention in one embodiment may be combined in another embodiment of the invention. For example, guard conductors, as shown in FIGS. **4** and **6**, may be utilized with the form of the invention shown in FIGS. **7** and **8** to further control and define the discharge area improving panel resolution. In FIG. **8**, for example, a single guard conductor might run parallel to conductor **56** in the region of shoulder area **52*a*** but spaced further away from electrode **56** than is shoulder area **52** to define the discharge area more exactly. The guard conductor may be connected to ground potential or to some other potential preventing discharge. Similarly, conductor **56** may be formed with a rounded upper surface to better control the discharge area.

What is claimed is:

1. A plasma discharge display panel comprising:

an electrically non-conducting substrate, said substrate being contoured to have a plurality of parallel channels therein;

a first group of electrical conductors secured to said substrate in orthogonal relationship to said channels and conformed to the contour thereof and in generally parallel relation to one another and, further, said conductors being adapted to be connected with a source of drive voltage for the panel;

a first layer of electrically non-conducting dielectric material secured to said substrate in overlying relation to said electrical conductors to form an electrically non-conducting generally planar surface;

a second group of electrical conductors secured to said surface, each of said conductors in generally overlying relation to one of said channels, so that the conductors of said second group are in crossing relation to the conductors of said first group, said substrate having at least one shoulder for each conductor of said first group in relation to each of said channels to define discharge areas on said panel between said shoulders of said conductors of the first group and related conductors of said second group, the conductors of said second group being adapted to be connected with a source of drive voltage for the panel;

a second layer of electrically non-conducting dielectric material secured to said first layer in overlying relation to said second group of electrical conductors forming an electrically non-conducting surface; and,

means for confining an ionizable gaseous atmosphere over said second layer of dielectric material.

2. The structure of claim **1** wherein each of said second conductors is displaced in overlaying longitudinal relationship to said channels, the displacement being sufficiently to one side of each of said channels so that the discharge area on the surface of said panel only occurs between one shoulder of each of said first conductors and associated ones of said second conductors.

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