United States Patent

[11] 3,589,789

[72] Inventors **Carl R. Hubert**
Saugerties;
George M. Krembs, Hyde Park; Parviz Soltan, Poughkeepsie, all of, N.Y.

[21] Appl. No. **778,159**
[22] Filed **Nov. 22, 1968**
[45] Patented **June 29, 1971**
[73] Assignee **International Business Machines Corporation**
Armonk, N.Y.

[54] **METHOD OF PRODUCING AN OPEN CELL COLOR PLASMA DISPLAY DEVICE**
2 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **316/19,** 204/181, 313/108, 313/109, 316/20
[51] **Int. Cl.** **H01j 9/18,** H01j 9/38
[50] **Field of Search** 313/108, 109, 109.5; 117/33.5; 204/181; 315/169; 316/19, 20

[56] **References Cited**

UNITED STATES PATENTS

2,851,408	9/1958	Cerulli	204/181
2,965,801	12/1960	Archer et al.	315/169
3,013,182	12/1961	Russell	313/108 X
3,334,269	8/1967	L'Heureaux	313/204 X
3,360,450	12/1967	Hays	117/33.5 X

FOREIGN PATENTS

634,702	3/1950	Great Britain	204/181
1,022,474	3/1966	Great Britain	313/109.5

Primary Examiner—Roy Lake
Assistant Examiner—Palmer C. Demeo
Attorneys—Hanifin & Clark and A. Sidney Alpert

ABSTRACT: Color plasma display panels are produced by selectively applying, by cataphoretic deposition, predetermined phosphors to certain conductors carried on the inner faces of panel walls, and other phosphors to other conductors. The panel walls are positioned in spaced-apart relationship with the conductors in mutually orthogonal relationship, and a gas chamber formed that includes the inner faces of the panel walls. The cells of the resultant plasma display panel will exhibit either multiple or single color effects during operation.

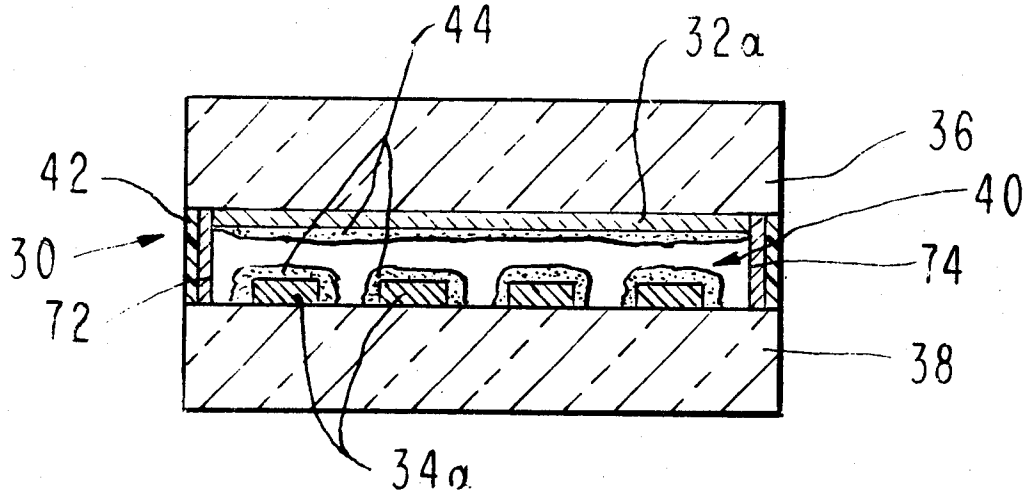
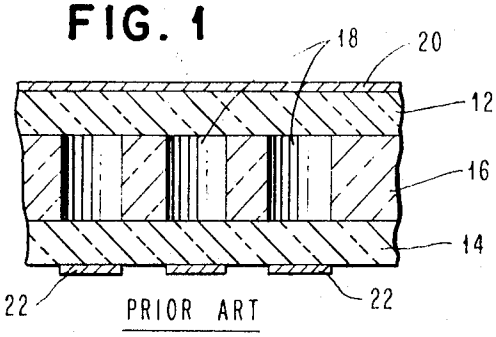


FIG. 1



PRIOR ART

FIG. 2

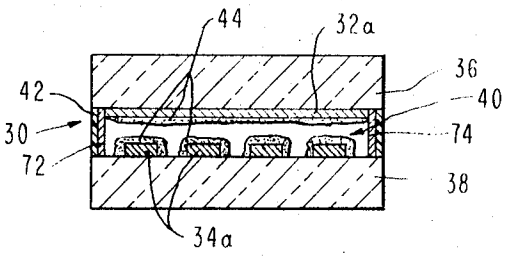


FIG. 3

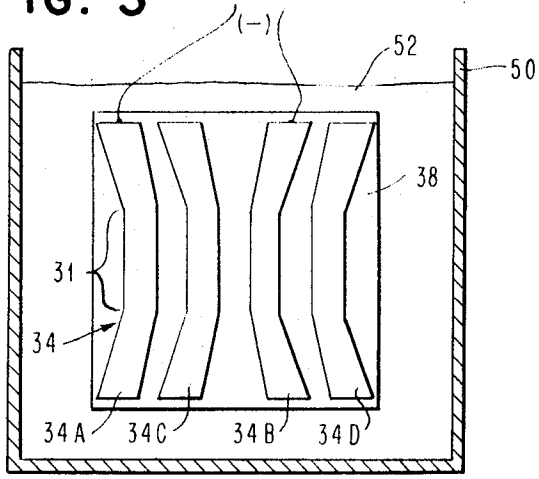


FIG. 4

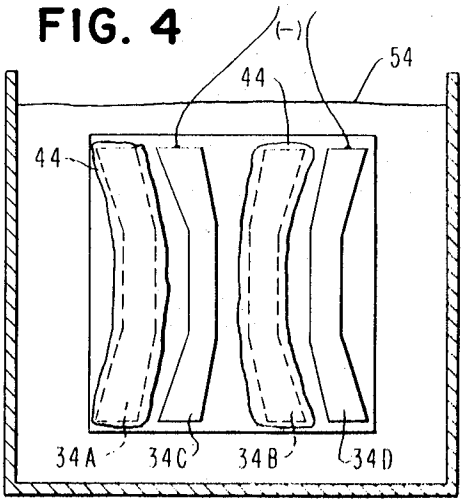


FIG. 5

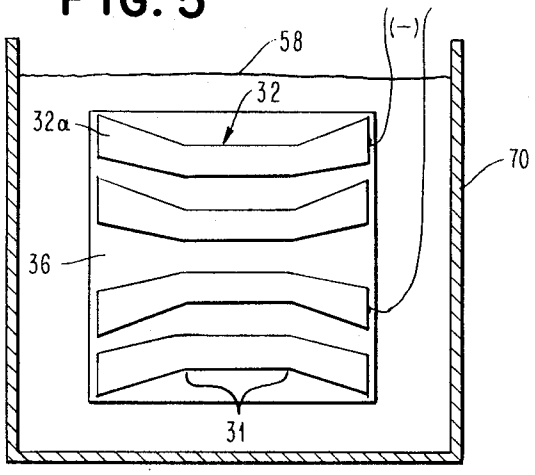
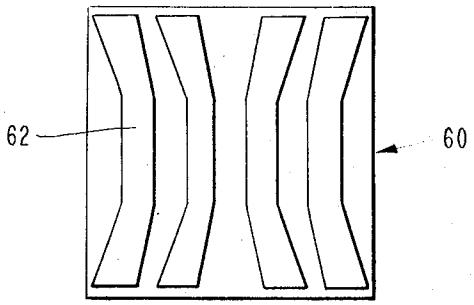


FIG. 6



INVENTORS
CARL R HUBERT
GEORGE M. KREMBS
PARVIZ SOLTAN

BY G. Sidney Cygan

ATTORNEY

METHOD OF PRODUCING AN OPEN CELL COLOR PLASMA DISPLAY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates generally to methods of fabricating gaseous or plasma display panels, and more particularly to improved methods of fabricating single or multicolor displays of the gaseous discharge or plasma type, and the panels produced thereby.

Recent events in the field of displays have led to the development of so-called gaseous or plasma display panels. One such display panel is shown, for example, in *Electronics* Vol. 41, No. 15, dated July 22, 1968 at page 39. That display panel is a three-layer glass sandwich, with a center layer having rows of holes filled with ionizable gas. The outer layers are transparent, and electrodes or conductors are arrayed in orthogonal relationship in overlapping registry at each of the holes. As noted in the above article, a current applied between the conductors to the gas changes it to plasma and causes it to light up. A "wall voltage" effect provides each cell with an inherent memory that enables the panel to be used either in a display or a memory system, or both.

It is well known that phosphor color presentations are useful in enhancing the efficiency of displays by providing more effective information coding and generally giving more contrast for human discrimination. There are certain known ways of providing the aforementioned plasma display panels with color capability. For example, it is known that phosphor can be placed by conventional techniques such as gravity settling inside each hole in the center layer of the panel or upon the exterior thereof. The gravity settling technique in depositing phosphor is generally satisfactory for such applications as cathode-ray tube screens where there is an aluminum backing that prevents pin holes or unevenness in the phosphor from presenting a problem, and where the precise thickness of the phosphor layers is not a major consideration. However, the gravity settling technique is grossly inefficient and costly when applied to plasma display panels due to the complexity of the deposition, the inefficiency since the phosphor thickness cannot be precisely controlled, and the general inability to provide an easy means of selectively applying different phosphors to different electrodes.

Accordingly, it is an object of the present invention to provide an improved method of producing color plasma display panels.

It is another object of the present invention to provide a simple, yet efficient method of producing a single or multicolor plasma display panel and the panels produced thereby.

SUMMARY OF THE INVENTION

In accordance with the preferred embodiment of the invention, a colored gaseous or plasma display panel is produced by initially selectively applying a preferred phosphor by cataphoretic deposition on preselected conductors carried on the inner faces of first and second panel members. Thereafter, other preferred phosphors are, if desired, selectively applied by cataphoretic deposition on other conductors of the first and second panel members. Preferably, the anode used during the cataphoretic deposition step closely physically resembles the cathode; i.e., the conductors carried on the panel members. The panel members are then positioned with their inner faces in close proximity, and with the electrodes in mutually orthogonal relationship. A chamber is then produced that includes these inner faces. A suitable ionizable gas is then introduced into that chamber to complete the panel.

This method is quite advantageous, since it permits the application of selected phosphors to different conductors in a simple yet effective manner. To achieve this would otherwise be a costly and time-consuming matter. Further, if desired, one selected color phosphor may be applied by this method to all the conductors of the panel in one application. It is believed that this technique will make the production of color plasma displays relatively inexpensive, and probably competitive with those panels that do not presently have color capability.

In accordance with another aspect of the present invention, an open cell color plasma display panel is produced. That plasma display panel has first and second substantially transparent platelike members defining the major walls of the discharge chamber. Carried on the inner surfaces of the plates, and laying at least substantially within the chamber, are conductors that are positioned in orthogonal relationship. Each of the conductors on at least one of the plates has an extremely thin coating of cataphoretically deposited phosphor thereon. The phosphor acts to insulate the conductors from the gas within the chamber and also to produce a color when activated, thereby providing the display panel with color capability.

BRIEF DESCRIPTION OF TH E DRAWINGS

FIG. 1 is a cross-sectional view through a plasma display panel of the type known to the prior art;

FIG. 2 is a view similar to that of FIG. 1 showing the plasma display panel of the present invention;

FIGS. 3, 4 and 5 show, in schematic form the preferred method of this invention for producing plasma display panels by cataphoretic deposition of phosphors onto the conductors of the display panel wall members; and

FIG. 6 is a simplified perspective view of the preferred anode used during cataphoretic deposition.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Prior to discussing the preferred embodiment, reference should be made to FIG. 1 which shows the plasma display panel 10 of the type known to the prior art. It will be noted that the plasma display panel 10 comprises a glass sandwich including outer transparent glass insulators or plates 12 and 14 and an inner glass member 16 having a plurality of cells 18 provided therein. The cells or holes 18 in member 16 are terminated at their ends by the inner surfaces of the plates 12 and 14 and contain a suitable ionizable or discharge responsive gas. Conductors or electrodes 20 and 22 are arranged along mutually orthogonal reference axes and secured to respective outer surfaces of plates 12 and 14 so that they are exterior to the volume defined by the cells when the panel is dissembled. In operation, an AC voltage is applied between a pair of these external conductors, and the particular cell at the intersection of the corresponding conductors is discharged. The gas used in the cell may be a 95 percent neon and 5 percent nitrogen mixture or the like, and a sinusoidal voltage of approximately 700 volts peak-to-peak at a repetition time of approximately 100—200 microseconds is applied to fire the display.

As known in the prior art, and explained in greater detail in an article entitled "The Plasma Display Panel—A Digitally Addressable Display With Inherent Memory" by Bitzer and Slottow, published in the proceedings of the 1966 Full Joint Computer Conference, Volume 29, pages 591—547, and the references thereto, the theory of operation of the plasma cell 10 is based upon so-called "wall charges." These wall charges have a "memory" that permits sustaining signals that are lower than initial firing signals to discharge a cell when a wall charge is built up. The wall charge is a phenomenon whereby electrons and positive ions collect on the walls of the cell when the gas discharges, thereby providing the cell with an inherent memory. It is known that the external conductors or electrodes 20 and 22 will cause such charges to appear on the walls of the cell 18 in the prior art apparatus of FIG. 1.

In accordance with the present invention, there is provided a so-called "open cell" plasma display panel 30 in which the wall charges collect on nonconductive walls adjacent selected conductors or electrodes, for example, conductor groups 32 and 34 shown in FIG. 2. In the plasma panel 30 of FIG. 2, there are outer platelike panel walls or members 36 and 38 comprising the major walls of a gas cell 40. The gas cell is

completed by an insulating wall 42 that extends between the panel walls 36 and 38 about their periphery. In the preferred embodiment, there are a plurality of the conductors or strip 34*a* of group 34 arranged in generally parallel relationship on the inner face of panel member 38 within the gas cell 40. Another plurality of conductors or strips 32*a* of group 32 are arranged in generally parallel relationship on the inner face of panel 36 and are also within the gas cell or chamber 40.

As will be seen in FIG. 2, the conductors of groups 32 and 34 are in mutually orthogonal relationship. As will also be seen in that figure, each of the conductors is covered with a thin coating, which in the preferred embodiment is a cataphoretically deposited phosphor layer or coating 44. The coating 44 on each of the conductors serves several functions; e.g., to provide insulation between the conductors and gas within cell 40, to enable the collection of wall charges in accordance with the operation of such devices, and to provide the display panel 30 with color capability.

Regarding the first function of the coatings 44, i.e., to provide insulation between the conductors and the gas, it is known that internal conductors in the open-cell-type plasma panel construction must be insulated from the gas within the cell. This is because in the absence of such insulation, one of the sets of conductors would deposit onto the other set, much as in the manner as the well-known sputter deposition technique. Regarding the color giving function of the phosphor, it is important that the coatings 44 be uniform and even in order to give uniform illumination when excited. In this regard, it is believed that excitation of the phosphor coating 44 in the present embodiment occurs by photoexcitation. The gas mixture in chamber 40 is preferably a neon-nitrogen mixture in a 90–10 percent proportion at 150 Torr pressure. When the gas breaks down during operation of the plasma cell 30, ultraviolet light is given off, causing the phosphor coatings 44 to luminesce. It is also possible, however, that a heavier gas than the above mixture may excite the phosphor by molecular bombardment. In addition, a very thin phosphor coating (e.g., in the order of 5 microns thick in the exemplified embodiment) is most desirable since it was found that a thinner coating has less resistance and will age slower than a thicker coating. Further, as mentioned above, the coatings 44 must be free from pinholes to prevent sputter deposition of the conductors 32*a* or 34*a* during operation of the panel 30. The cataphoretically deposited coatings 44 meet all these requirements. Thus, a cataphoretically deposited coating of phosphor may be precisely controlled as to thickness, is uniform and even, and is substantially free from pinholes or discontinuities.

In operation, the panel 30 permits individual cell or location selectively by application of approximately 800 volts AC (peak-to-peak) across orthogonally arranged conductor groups 32 and 34. The gas molecules break down at the intersection of a selected conductor or conductors from each of groups 32 and 34. Adjacent locations are not fired or energized at such time, however, due to insufficient voltage to achieve breakdown. Reference should be made to the aforementioned Bitzer and Slottow article and reference for additional details relative to theory of operation. In practice, the walls 36 and 38 are spaced so that there is approximately 8 to 10 mils between the groups of conductors 32 and 34. Thus, the field strength for the exemplified embodiment is approximately 10^4 volts/cm. Further, the conductors 32 and 34 themselves are approximately 10 mils in width in the working area, designated 31, of the display panel, with approximately 10 mils spacings therebetween to effect relatively high resolution. A working area ranging from a single character (or 0.025 square inch) to multiple characters is possible.

Reference should now be made to FIGS. 3 through 6 for the preferred method of fabrication of the panel 30. Initially, suitable transparent conductive material that will withstand a phosphor suspension, such as tin oxide, is deposited on one face of the glass walls 36 and 38 to form the conductive groups 32 and 34. Preferably, the front wall of the display 30, in the exemplification wall 36, has a highly polished or mirror quality inner face or surface at the working area. The conductor group 32 is deposited onto this inner face.

A solution of tin chloride and methanol, doped with antimony-trichloride, is prepared. The solution is chemically deposited onto the glass wall members 36 and 38 by initially heating the members to approximately 425° C., and spraying the above solution through a mask in the presence of a water vapor atmosphere. The chemical deposition of tin oxide is achieved by a chemical interaction of the vapor as explained, for example, in U.S. Pat. No. 2,732,313. The conductor groups 32 and 34 are formed in this fashion. The preferred thickness of the conductors is approximately 3,000 A., and the preferred width and spacing are respectively 10 mils by 10 mils.

Referring now specifically to FIG. 3, one of the wall members, for example, wall member 38 having the conductors 34*a* thereon is placed in a suitable container 50. In the container is a phosphor suspension 52, which may, for example, be a *zinc cadmium* sulfide silver activated phosphor commonly known as "P-20." The suspension is prepared by adding elutriated fine particles of phosphor, approximately 1 to 2 microns in diameter, to an ethyl alcohol vehicle that contains 5 percent water (by volume) and 10^{14} mols per liter of thorium nitrate. The suspension is formed by addition of the ingredients and agitation for approximately 30 minutes by milling, stirring or vibration. With the wall member 38 in the suspension 52, the anode member 60 (FIG. 6) is introduced therein also. The anode member 60 has conductors 62 thereon that closely physically resemble the conductors 34*a* forming group 34 in shape, size and spacing. This will permit a uniform field across the conductors (anode and cathode) during cataphoretic deposition, without field scattering, resulting in direct migration of phosphor particles from the suspension to the conductors 34*a* and hence, a uniform even coating, free from pin holes.

Selected conductors from group 34 such as 34A and 34B are connected to the negative terminal of a suitable DC source, and the anode member 60 is connected to the positive side of the DC source. The phosphor coatings 44 are cataphoretically deposited in this manner over the electrodes 34A and 34B to a desired thickness. For example, with the above noted suspension being used, at a field strength of approximately 50 volts per centimeter, a 4 micron thick phosphor coating 44 may be coated onto the conductors 34A and 34B in approximately 1.5 minutes. It will be noted that the conductors 34C and 34D of group 34 that are not connected to the DC source do not receive a coating at this time.

Referring now to FIG. 4, it will be seen that the wall member 38 is now placed in a suspension 54, that may be a phosphor of another color, prepared in the same manner as related above. For example, the suspension 54 may be a zinc sulfide silver activated phosphor, commonly known as "P-11." It will be again noted that the conductors 34C and 34D, that were not connected to the DC source when in suspension 52, did not receive a coating. Thus, when placed in the suspension 54, these conductors 34C and 34D are connected to the source and cataphoretically coated with phosphor of another color. Of course, it will be realized that in actual practice, the panel wall members 36 and 38 will have many more conductors than the four conductors shown in FIGS. 2, 3 and 4. It will be appreciated that the problem of applying different colored phosphors to many small conductors would be exceedingly difficult by known methods, whereas it is rather simple by the present invention. It will be realized, of course, that if all the conductors 34*a* on panel 38 were to be coated with the same color phosphor, this could be accomplished merely by connecting all the conductors to the DC source when in suspension 52. Further, it should be noted that a third or more different phosphor coatings may be applied to the conductors in the same fashion as indicated in FIGS. 3 and 4. In this regard, a wall member 38 has been fabricated with many conductors 34*a*, alternately coated with green, blue and red phosphor coatings 44.

Referring now to FIG. 5 the wall member 36 is shown in a suspension 58 in a container 70. The conductors comprising group 32 on this wall member receive cataphoretically deposited phosphor coatings in the same manner as described above, using an anode member similar to member 60 (not illustrated) that closely physically resembles the conductor group 32.

When the conductor groups 32 and 34 have received their cataphoretically applied phosphor coatings 44, the wall members 36 and 38 are positioned with their inner faces in close proximity, and the chamber or gas cell formed by positioning spacers 72 and 74 therebetween. As mentioned above, preferably the conductor groups 32 and 34 are located approximately 10 mils apart at this time. The spacers are retained and the wall 42 formed to complete and seal the chamber in a known manner, as by using an epoxy resin sealer or the like. The chamber 40 is then evacuated, for example, by drilling a hole through either panel wall member 36 or 38 and drawing a vacuum. After evacuation, a suitable gas such as a mixture comprising 90 percent neon and 10 percent nitrogen is introduced into the chamber to complete the fabrication of the panel 30.

While the preferred embodiment of the invention was described above, it will be apparent to those skilled in the art that certain alternatives may be introduced in the practice thereof. For example, the conductor groups 32 and 34 may alternately be indium oxide sprayed upon the panel walls 36 and 38 in accordance with the above-described method. It will be appreciated also that other thin transparent conductors may be used, such as titanium oxide or the like. In addition, while the conductors of group 34 (i.e., the conductors on front panel wall 36) should preferably be transparent since the panel 30 is viewed from the front, it is not essential for the conductors of group 34 to be transparent. It may also not be necessary for the conductors of both of the groups to have phosphor coatings 44 thereon, and other suitable insulators such as glass may be applied thereto, since the color imparted by the phosphor coatings on the other group may be sufficient.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the true spirit and scope of the invention.

We claim:

1. A method of producing an open cell color plasma display panel, comprising:

applying a plurality of conductive strips in predetermined patterns on first and second generally transparent panel walls;

providing a first suspension containing phosphor particles of a first color and a second suspension containing phosphor particles of a second color;

placing in the first suspension at least one of the first and second panel walls and at least one electrode member having a plurality of conductive strips arranged in a pattern that closely physically resembles the predetermined pattern of conductive strips on the at least one panel wall;

cataphoretically depositing phosphor coatings on selected ones of the plurality of conductive strips on the at least one panel wall;

placing said one of the panel walls in said second suspension and cataphoretically depositing phosphor coatings on other of said conductive strips;

forming a chamber including the panel walls as the major sides thereof, with the coated portions of the conductive strips lying within the chamber; and

introducing within the chamber a suitable discharge responsive gas.

2. The method set forth in claim 1 including:

placing in the suspension the other of the panel walls and another electrode member having a plurality of conductive strips arranged in a pattern that closely physically resembles the predetermined pattern on the other of the panel walls; and

cataphoretically depositing phosphor coatings on at least portions of the plurality of conductive strips on the other panel wall.