GASEOUS DISCHARGE DISPLAY DEVICE

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ABSTRACT

The specification describes a flat panel gaseous discharge display device in which the display illumination is formed at least in part by luminescence resulting from excitation of an appropriate phosphor by low energy electrons drawn from a glow discharge. To provide scan, the discharge is either itself moving in stepwise fashion between discrete cells or is a secondary discharge primed by a scanning discharge and triggered by the display information signal. Varying the current through the phosphor produces gray scale. Illumination from the gaseous discharge may be mixed with the phosphor for color balance and increased brightness. The phosphor can be divided into color stripes with means for selective energization of the stripes to form a color display.

14 Claims, 6 Drawing Figures
GASEOUS DISCHARGE DISPLAY DEVICE

This specification describes a flat panel realtime display system based on the excitation of low voltage phosphors by low energy electrons drawn from a gaseous discharge. The discharge may be itself moving in stepwise fashion between discrete discharge cells or can be a secondary discharge selectively primed by a moving discharge. The chief advantages of the device are that it provides in a relatively straightforward manner full gray scale coupled with low voltage addressing and the option of full color display. Such a combination of features is not available in any flat panel display device known to date.

BACKGROUND OF THE INVENTION

To understand the operation of this device, it is useful to first describe some approaches to flat panel display reported in recent prior art.

A gas discharge device in which the discharge is localized and caused to scan through an array of discharge cells in a raster-like fashion is the object of extensive development for a variety of flat panel display applications. Various aspects of this device are described in "The Primed Gas Discharge Cell — A Cost and Capability Improvement for Gas Discharge Matrix Displays", 1970 IDEA Symposium, Digest of Papers, pp. 30–31, May 1970, by G. E. Holz. A similar idea is described by H. Horii, K. Kasahara and K. Inoue, "A New Gas-Discharge Display Device Using Through-Hole Enhancement", 1970 IEEE Conference on Display Devices, New York, December 1970. In this device, light is generated by the negative glow in a gas mixture, typically mostly neon, at about 100 Torr. The device comprises a set of cathodes and, running perpendicular to these, two sets of anodes. These anodes, typically fine wires, are disposed below and above the cathodes. The latter have small apertures (e.g., 3 mils) connecting the so-called display cell to the scan region to which the discharge is confined as long as the voltage is applied only to the cathodes and scan anodes. A line of discharges struck between a single cathode and m scan anodes may be moved by connecting to a common bus bar every pth cathode and driving the cathodes with a p-phase clock. Information is displayed along a line defined by a given cathode conductor by striking a discharge in the display cells using signals applied to the display anodes. Since the display cell is primed by diffusion of metastable ions from the scan region, the voltage required is somewhat less than the full striking voltage. This gas discharge scan system thus eliminates almost one-half of the leads and switches necessary for a conventional matrix-addressed system.

Multicolor displays have been produced by coating the walls of each display cell with a phosphor and exciting the phosphor with the uv emission of the discharge. The cell covers are made translucent rather than transparent to diffuse the color. The saturation property of the phosphor is exploited to produce a range of colors: at low current, the phosphor emission dominates; at high current levels, the red glow, characteristic of the neon discharge, is seen. This approach to flat panel color display is described in "Plasma Display Changes Color as Current Input Changes", Electronics, pp. 44, 66, July 1971, by R. A. Cola. One drawback to this device is the lack of independent control of color and intensity when more than one color is desired.

Another prior art gas discharge display device, reported by Kazan and Pennabaker in Proceedings of IEEE, Vol. 59, pp. 1130–1131, July 1971, consists of a cylindrical glass envelope, filled with about 5 torr of He, and containing a strip cathode and a strip anode spaced to form a gas discharge. Spaced beyond the anode is a third electrode, the display anode, coated with a zinc oxide phosphor and with means for varying its potential with respect to the anode. A glow discharge, maintained between the cathode and primary anode, creates above the display anode a plasma from which electrons may be withdrawn to excite the phosphor. Under DC excitation, a brightness of about 85 fL at a phosphor voltage of 10 volts with respect to the primary anode and current density of about 1.2 mA/cm² has been reported. A practical device can be made by breaking up the display anode into a number of individually addressed segments. The important feature of this device is the substitution of a "plasma" cathode for the thermionic cathode used in several commercial devices employing anodes coated with low voltage phosphors. The virtue of this approach is that it provides low voltage addressing and a "cathode" which may be used to uniformly excite an area several inches in each dimension. The chief drawbacks of the scheme, when applied to large area displays, are that it does not lend itself to matrix addressing and that the maintenance of an extended glow discharge to generate the plasma while exciting only localized segments (as in a time-shared application) is not efficient.

BRIEF STATEMENT OF THE INVENTION

The device according to the invention avoids in large measure the drawbacks of the prior art devices while taking advantage of their virtues. It is characterized by a stepped gas discharge to provide the scanning function, and an array of display anodes which either selectively trigger a second discharge between the stepped discharge and the display anode, or extract electrons directly from the stepped discharge. Electrons extracted to the display anode excite a low voltage phosphor. For a flat panel, real-time display, this approach reduces the number of leads and switches required and offers a full gray scale, low voltage addressing, and the option of a full color display.

DETAILED DESCRIPTION OF THE INVENTION

In the drawing:

FIG. 1 is an exploded schematic view of one embodiment of a flat panel display device incorporating the advantageous features of the invention;

FIG. 2 is a sectional view of the panel of FIG. 1;

FIG. 3 is a view similar to that of FIG. 1, showing an alternative embodiment;

FIG. 4 is a schematic cross section of the device of FIG. 3, showing the selective generation of the second discharge as a source of electrons for the low voltage phosphor; and

FIGS. 5A and 5B are schematic representations of discharge cells illustrating an alternative form of display anode useful with either of the devices previously described.

The display device of FIG. 1 includes a front glass cover 10 which in this configuration functions as a support substrate for the display anodes 11. The display
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anodes are addressed through leads 12. The display anodes comprise a transparent electrode strip coated with a low voltage phosphor. Effective operation has been demonstrated with a display anode consisting of indium-tin oxide stripes photolithographically applied to the glass cover and coated with P 15 phosphor (3.5 mg/cm²). A phosphor with sufficient lateral conductivity can be used alone.

Referring again to FIG. 1, the display anodes are shown as stripes in trios 13, 14, 15, an exemplary arrangement for color display. Each stripe of a trio consists of a different color phosphor, known in the art of color video display, with electrical addressing means independent of the other stripes in the group. Color selection is made by electrically addressing common colored phosphor stripes via one or more groups of leads 16, 17, 18.

The glass cover 10, carrying the display anodes, is made part of the conventional gas discharge panel comprising an insulating spacer 19, with an array of cavities 20, and the scanning assembly, which basically includes crossed electrode grids 21 and 22 and insulating spacer 23. In this configuration, the electrode stripes of the scan anode grid 21 extend in the row direction and are addressed by row address leads 27. The electrodes of the cathode grid 22 extend in the column direction and are addressed by column address leads 28. The display anode stripes are arranged parallel to the row scan anodes, the direction of scan. The stepped discharge is controlled by stepping the cathode grid which therefore is orthogonal to the scan direction and to both anode grids.

The scanning assembly defines a matrix of gas discharge cells that create a reservoir plasma from which electrons can be selectively extracted to provide localized illumination for a given picture element. The electrons are extracted through apertures 24 in the scan anode grid 21 when the appropriate display anode lead 12 is energized.

The cathode scanning grid 22 is shown deposited on the rear panel cover 25. The anode grid 21 can be a self-standing conductive grid, or can comprise a conductor array deposited or formed on a support sheet.

The panel of FIG. 1 is shown assembled and in cross section in FIG. 2.


For example, an alternative embodiment in which at least a part of the visible display is produced by excitation of low voltage phosphors but in which the electrons are selectively extracted in a somewhat different way is shown in FIG. 3. The important structural distinction in this device is that the cathode and scan anode grids are interchanged. The front glass cover 30, rear glass cover 31, display anode grid 32, cathode grid 33 with openings 34, scan anode grid 35, and apertured insulating spacer 36, separating the display anodes from the upper scan electrode grid are substantially constructed as in the device of FIGS. 1 and 2. The insulating spacer means separating the scan discharge grids can be made integral with the rear glass cover 31, as shown.

Whereas this embodiment is similar structurally to the former embodiment, certain differences will be evident from the partly schematic sectional view of FIG. 4. The gas discharge steps along between the scan anode 35 and the cathode grid formed by electrode stripes 33. The openings 34 allow metastable ions to diffuse through the cathode grid into the secondary discharge charge cells formed in the spacer 36. These metastable ions prime each of the secondary cells in a manner known in the art to trigger the secondary discharge between the cathodes and display anodes 32. The secondary discharge is selective, shown here by activated electrode 32a and unibased electrode 32b. The improvement according to the invention is the provision of a low voltage phosphor 37 as, or in combination with, the display anode grid. Electrons produced by the secondary discharge are selectively attracted to the display anode and activate the phosphor.

The structure of the display anode can be modified to advantage by aperturing the anode, insulating the underside and causing the electrons to activate the upper surface of the phosphor layer as shown in FIGS. 5A and 5B. FIG. 5A is a schematic representation of the discharge cell of the device of FIGS. 1 and 2, while FIG. 5B schematically illustrates a similar phosphor activation scheme for the discharge device of FIG. 4. The device with this inverted display anode configuration is constructed and operated essentially as before. The important structural modifications are the provisions of apertures 50 in the scan anodes and an insulating layer 51 so that the electrons impinge on the far side of the anode. The insulating layer may be any of a variety of known materials. Glass or alumina is appropriate.

The virtue of this arrangement is that the electrons drawn from the discharge will strike the surface of the phosphor facing the viewer as shown, rather than the inner surface, and the light generated (mostly at the surface of the phosphor layer) will not suffer attenuation due to transmission through the phosphor layer.

To demonstrate the efficacy of the novel form of display anode that forms the basis for the invention, a matrix of gas discharge cells driven by 7 anodes and 110 cathodes was assembled in the form shown in FIG. 3. The display anodes consisted of the glass cover coated with transparent electrode stripes, with a phosphor layer over the electrode stripes. The electrode stripes were made by sputtering indium-tin oxide over the glass cover, defining the stripe pattern with a photolithographic mask and etching with 50% HCl at 50° C for 5 minutes. The phosphor was P 15, settled onto the electrode cover plate from a distilled water suspension. The faceplate was sealed into a panel with the scanning assembly shown, pumped out to about 4 × 10⁻⁴ torr and filled with neon at 95 torr (pd = 9.5 torr-cm) in one instance and with neon at 95 torr and argon at 0.5 torr (Penning mixture) in another.

To establish the scan function, 160 V were applied to the scan anodes through 160 K ohm resistors and the cathodes were switched between -180 V and -80 V, representing respectively the on and the off states. The cathode array was energized with a three-phase drive, with a clock frequency held at 8 KHz, and the reset pulse for the reset cathode was maintained at 200 microseconds in length, with a period of 12.5 milliseconds. Thus, each row was active for 125 microseconds.
at a time, with a duty cycle of 1/100. The display anodes were directly connected to the collector of a 2N5282 PNP transistor in the grounded emitter configuration. The intensity of the glow of the cells was controlled by changing the base current.

The light output from the secondary gas discharge of the device is red-orange in color with a brightness of the order of 7,500 fl. The objective of this device was to provide luminescence by low voltage excitation from the P 15 phosphor, balance this with the illumination from the glow discharge, and obtain a black and white display. To do this requires the phosphor to cover the glow discharge region. Other utilizations of the low energy electron excitation mechanism require blanking of the glow to give a pure luminescent output. For example, blanking the glow is desirable for color display. Blankling the glow to the exterior of the device can be achieved in a variety of ways. The cathode can be geometrically shaped with respect to the aperture so no glow is visible, or an electrically inert spacer can be provided over the otherwise visible region of the glow. The latter expedient is illustrated in FIG. 5A, wherein a glass or ceramic spacer 55 is shown blanking the glow that would otherwise be visible from the front panel. This invention is directed to both types of embodiments. Alternatively, a gas with low luminosity, e.g., xenon, can be used, making a blanking structure unnecessary, or the apertures can be offset to achieve the same result.

The performance of the device just described established that an appealing black and white display can be obtained with the display operated in a line-at-a-time video mode having a line time of 125 microseconds and frame time of 1/30 seconds to give an average cell brightness of 20 FL at 0.5 A/cm². Color display devices, using phosphors incorporated into gas discharge panels, like that of FIG. 1, are reasonably straightforward extensions in principle and performance.

The phosphors useful in the devices described are those capable of excitation by low voltage electrons. Phosphors that are excited by direct injection of free electrons from space are normally termed cathodoluminescent phosphors. However, because of the origin of this term, there is a tendency to construe its meaning in connection with electrons produced in a conventional cathode ray tube. Typically, these electrons are high voltage electrons. For the purposes of defining this invention, the appropriate phosphors will be termed low voltage cathodoluminescent phosphors. In turn, low voltage is intended to mean voltages not exceeding 100 volts.

Various additional modifications and extensions of this invention will become apparent to those skilled in the art. All such variations and deviations which basically rely on the teachings through which this invention has advanced the art are properly considered to be within the spirit and scope of this invention.

What is claimed is:

1. A gaseous discharge flat panel display device comprising:
   - a gas-tight, panel-shaped gas-filled envelope having an insulating bottom plate and an insulating top plate, and disposed therebetween a first parallel grid of electrode elements;
   - a second parallel grid of electrode elements extending orthogonal to said first grid;
   - a grid of electrode elements extending orthogonal to the discharge region, each element being connected to a scan anode electrode element, the display anodes being disposed between the first and second grids, said spacing means being apertured, leaving cavities extending between portions of said first and second grids with one aperture for each line of one of the parallel grids to form an array of discharge cells, each cell corresponding to the area of the vertical intersection of the electrode elements of the first and second array;
   - insulating spacing means overlying said second grid, having apertures therethrough corresponding to each discharge cell and defining a multiplicity of display cavities, each communicating with a discharge cell through at least one opening;
   - an array of display anodes disposed between the display cavities and the top plate and extending parallel to one of said first and second grids;
   - the invention characterized in that the display anodes comprise conductive low voltage cathodoluminescent phosphor elements.
2. The device of claim 1 in which the conductive phosphor elements comprise conductive stripes coated with low voltage cathodoluminescent phosphor.
3. The device of claim 2 in which some conductive stripes are coated with one color phosphor and others with another color phosphor.
4. The device of claim 2 in which every third conductive stripe is coated with one color phosphor and every group of third stripes is coated with a different color phosphor.
5. The device of claim 2 in which the conductive stripes are indium-tin oxide and the low voltage cathodoluminescent phosphor is P 15 phosphor.
6. The display device of claim 1 having additionally an insulating blank covering one or more of the openings in the electrode grid elements to prevent illumination from the glow discharge from striking the top plate.
7. A gas-discharge flat panel display device comprising:
   - a gas-tight, panel-shaped gas-filled envelope having an insulating bottom plate and an insulating top plate,
   - a cathode grid of parallel electrode elements supported by the bottom plate,
   - an insulating slotted spacer overlying the cathode grid, with the slots extending orthogonal to the cathode grid electrode elements,
   - a scan anode grid of parallel electrode elements overlying the insulating spacer with the electrode elements aligned with and substantially covering the slots in the spacer, the electrode elements further having openings through their thickness with at least one opening approximately vertically aligned with an electrode element of the cathode grid below,
   - an apertured spacer overlying the scan anode grid having a row array of apertures each aligned with the vertical intersection of one of the cathode and scan anode electrode elements and communicating with the slotted portions of the insulating slotted spacer through at least one opening in the scan anode grid,
   - a display anode grid overlying the apertured spacer, the display anode grid having parallel display anode elements with each element aligned with a row of apertures in the apertured spacer and with a scan anode electrode element, the display
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anode elements further comprising a low voltage cathodoluminescent phosphor.

8. The display device of claim 7 in which the display anode elements are supported by the insulating top plate.

9. The display device of claim 7 in which the display anode grid elements are coated on the side facing the aperture array with an insulating material and further have at least one opening through the region of their thickness corresponding with each aperture to allow electrons drawn from the aperture to strike the side of the display anode elements that faces the insulating top plate.

10. A gaseous discharge flat panel display device comprising:
   a gas-tight, panel-shaped, gas-filled envelope having an insulating bottom plate and an insulating top plate,
   a scan anode grid of parallel electrode elements supported by the bottom plate,
   insulating spacing means extending between the elements of the scan anode grid,
   a cathode grid of parallel electrode elements overlaying the spacing means with the electrode elements extending orthogonal to the elements of the scan anode grid, and having openings through their thickness with at least one opening approximately vertically aligned with an electrode element of the anode grid below,

an apertured spacer overlying the cathode grid having a row array of apertures each aligned with the vertical intersection of one of the scan anode and cathode elements and communicating with the cathode grid electrode elements through at least one of the openings in the cathode grid,

and a display anode grid overlying the apertured spacer, the display anode grid having parallel display anode elements with each element aligned with a row of apertures in the apertured spacer and with a scan anode electrode element, the display anodes further comprising a low voltage cathodoluminescent phosphor.

11. The display device of claim 10 in which the low voltage cathodoluminescent phosphor is P15 phosphor and the gas comprises neon.

12. The display device of claim 10 in which the display anode grid elements are coated on the side facing the aperture array with an insulating material and further have at least one opening through the region of their thickness corresponding with each aperture to allow electrons drawn from the aperture to strike the side of the display anode elements that faces the insulating top plate.

13. The display device of claim 10 in which the gas comprises neon.

14. The display device of claim 10 in which the gas comprises xenon.

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