United States Patent

Ngo

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[54] **GASEOUS DISPLAY DEVICE**

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[52] **U.S. Cl.** ....**340/166 R,** 313/201, 315/169 R

[51] **Int. Cl.** **H05b 37/00,** H01j 17/00

[58] **Field of Search**............340/166, 174 TB; 315/169, 84.6, 315/169 R; 307/89; 313/201

[56] **References Cited**

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[57] **ABSTRACT**

An improved plasma display device in which the cellular or perforated middle layer of gas-filled holes is replaced with a substantially uniform continuous layer of gas, thereby simplifying manufacture and assembly of the device.

The display driving circuitry includes individual row and column pulse transformers having their secondary windings connected to a common alternating polarity sustaining signal source and having their primary windings connected to respective address signal input leads. An address signal on a selected row lead and column lead initiates discharge breakdown of the gas at the row-column intersection. The sustaining signal thereafter operates in conjunction with charge stored at the intersection by the initial breakdown to periodically break down the gas at the intersection. Initial breakdown is effected advantageously during a different interval than the interval in which periodic breakdown occurs at other intersections.

12 Claims, 6 Drawing Figures

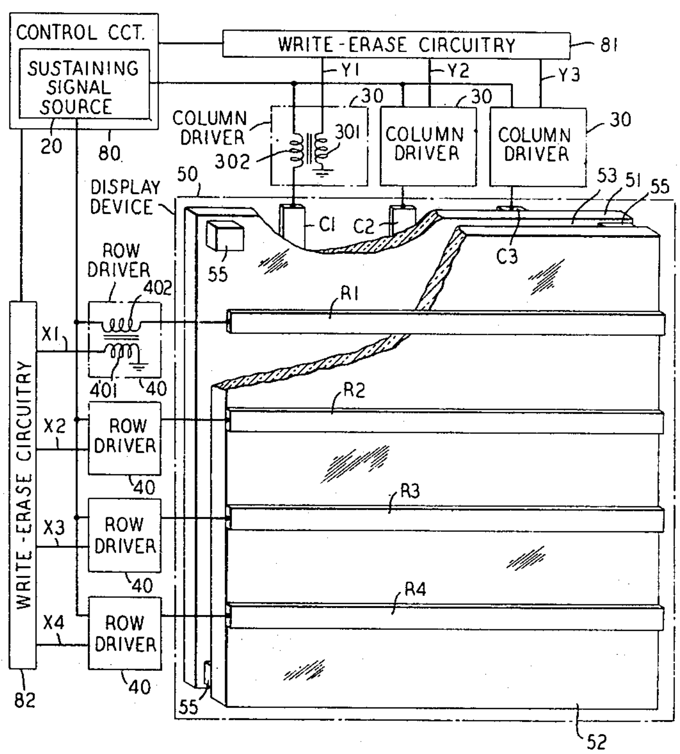


FIG. 1

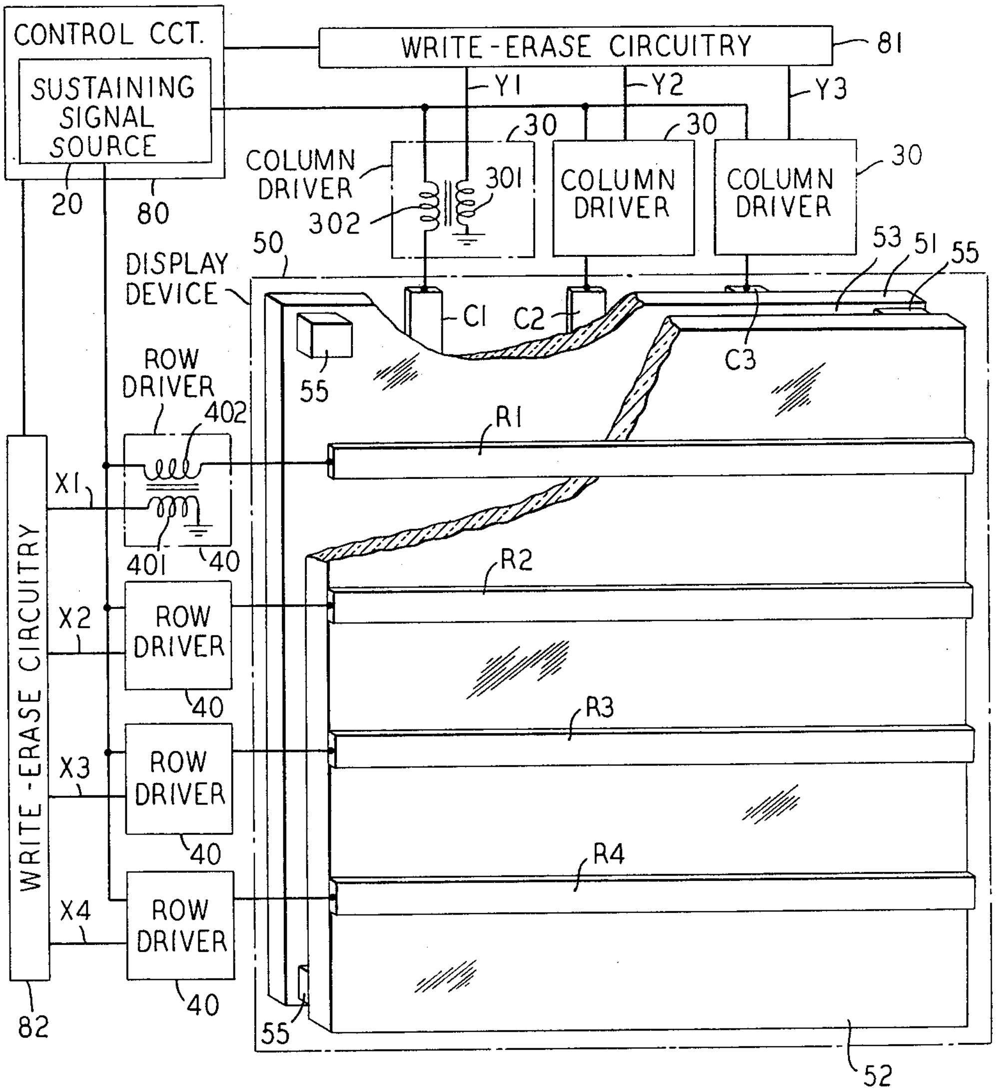


FIG. 3

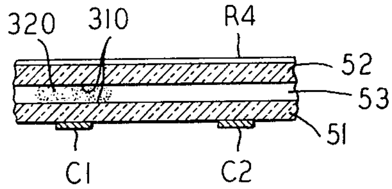
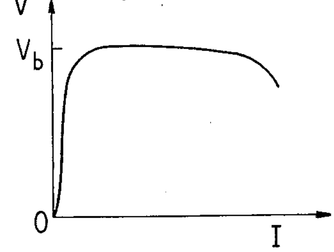


FIG. 4



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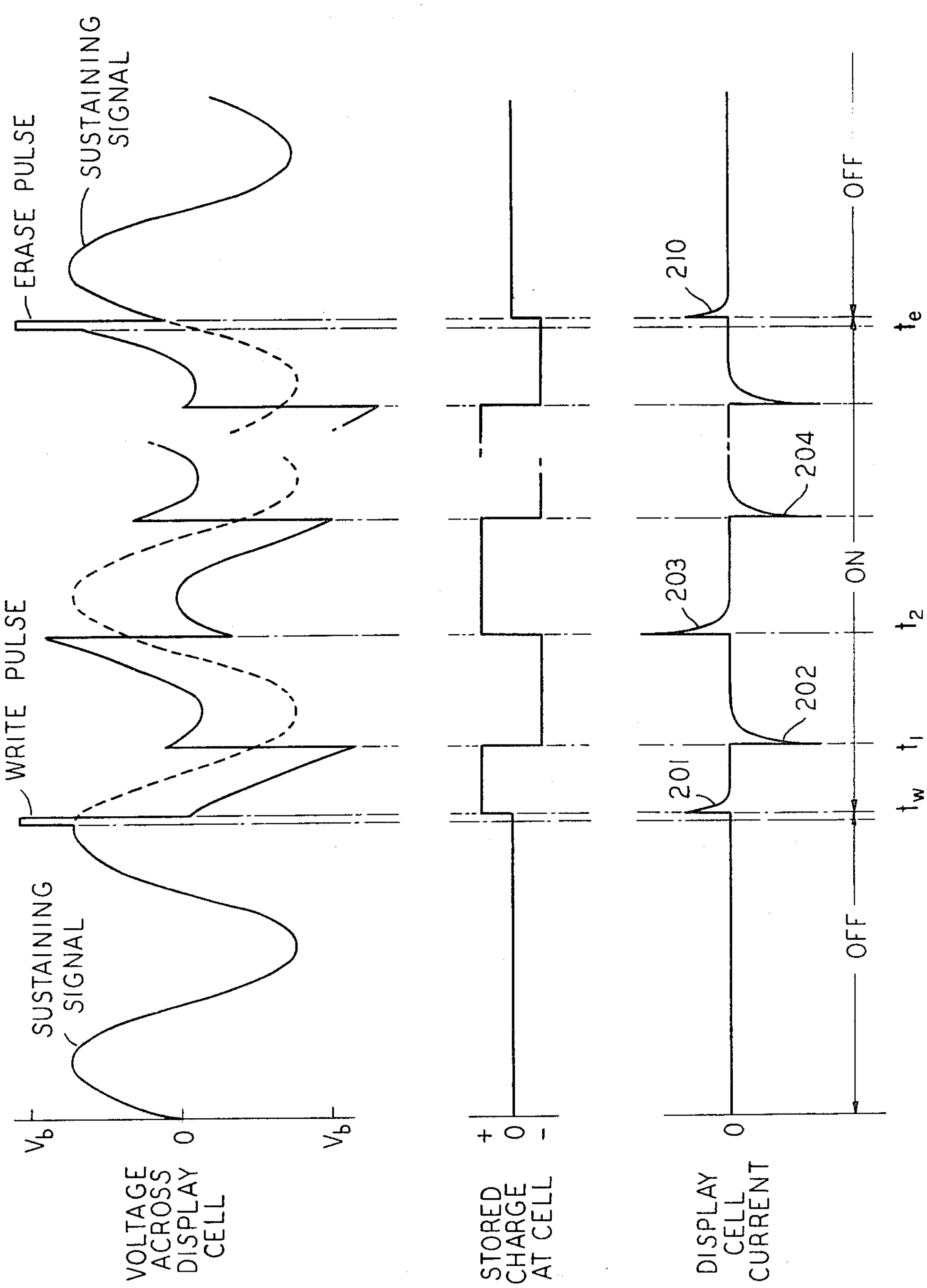

FIG. 2A

FIG. 2B

FIG. 2C

GASEOUS DISPLAY DEVICE

BACKGROUND OF THE INVENTION

This invention relates to display devices and, more particularly, to display devices upon which images are generated by the selective energization of individual display cells or elements.

Display devices are typically used for generating patterns of information or images in a two-dimensional raster for information display media, computer input/output terminals, telemetered data, instrumentation, high speed printing, and the like. The principal types of display devices currently available include matrix arrangements of light bulbs and various forms of cathode ray tube presentations, both of which suffer from well-known disadvantages related to size, cost, ruggedness and power requirements. The need for a display device which would overcome these disadvantages has been apparent for some time and considerable effort has been expended toward achieving such a display device.

Currently one of the areas of greatest promise appears to be gaseous displays of the type generating display images through the breakdown of a gas to light emitting plasma utilizing pulsed discharges, generally referred to as plasma displays. Plasma displays are digitally addressable and have inherent memory, the latter eliminating the need for external memory storage and associated circuitry to regenerate the display image. However, known plasma display devices suffer from disadvantages related to the cellular or perforated center layer which must be carefully fabricated and aligned in registration with the display conductor crosspoints, thereby increasing the manufacturing cost of the display.

SUMMARY OF THE INVENTION

It is accordingly an object of this invention to provide a new and improved plasma display arrangement which alleviates the disadvantages associated with the cellular or perforated center layer and the concomitant assembly problems of known arrangements.

According to a feature of my invention the above and other objects are attained in a simple and economical manner in an illustrative embodiment of a plasma display arrangement comprising a coordinate array of crosspoint display cells defined by row and column conductors which are spaced apart by first and second layers of dielectric material having a continuous uniform layer of gaseous display material disposed therebetween. The capacitance provided by the dielectric material between the conductors provides each crosspoint display cell with inherent memory which operates, in conjunction with an alternating signal sustaining voltage, to maintain a selected cell "lighted" upon application of a write pulse thereto.

In operation the alternative signal sustaining voltage is continually applied, via the row and column conductors, across each crosspoint display cell of the array. A particular cell is turned ON, i.e., is lighted by a write pulse applied to the particular cell row and column conductors, the write pulse being sufficient to break down the gas in the region adjacent the cell crosspoint to a plasma state, providing a discrete area or spot of emitted light. The resulting current flow stores charge on the dielectric material surface adjacent the cell crosspoint. During succeeding half cycles of the sustaining voltage the stored charge, in combination with the sustaining voltage maintains the crosspoint cell lighted via successive pulsed discharges. The cell is turned OFF by an erase pulse applied to the cell row and column conductors such that the charge is removed from the cell.

A display device in accordance with my invention is compact, rugged, and reliable and is significantly less expensive to manufacture than known arrangements since the usual perforated center layer is eliminated along with its associated assembly problems.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects and features of the invention may be fully apprehended from the following detailed description and the accompanying drawing in which:

FIG. 1 is a diagram of an illustrative embodiment of a display device arrangement in accordance with the principles of my invention;

FIG. 2 is a time chart useful in describing the operation of the illustrative embodiment of FIG. 1;

FIG. 3 shows a portion of the display device embodiment of FIG. 1 in cross section; and

FIG. 4 is a graphical representation of a typical voltage-current characteristic for electric discharge across a display cell.

DETAILED DESCRIPTION

In FIG. 1 of the drawing an illustrative embodiment of the invention comprising an $n \times m$ display device **50** is shown for generating images by the selective energization of individual ones of the nm crosspoint display cells. For example, as shown in FIG. 1, display device **50** may comprise a 3×4 coordinate array of 12 crosspoint display cells. However, it will be apparent from the description herein that the crosspoint display cells may be employed individually or in combination in any form of array desired for particular display device applications.

The crosspoint display cells of display device **50** in FIG. 1 are defined by row conductors R1 through R4 and column conductors C1 through C3 which are spaced apart by dielectric material layers **51** and **52**. Dielectric material layers **51** and **52** are in turn spaced apart, such as by spacers **55**, and a substantially uniform continuous layer of gaseous display material **53** is disposed between dielectric layers **51** and **52**. Suitable gaseous display materials are well known in the art and may comprise, for example, one or more of the inert gases or mixtures of these gases with other gases. Different gases, of course, have different light, speed and power characteristics and the particular gaseous display material chosen will depend generally upon the application of the display device.

As is well known in the art, dielectric material layers **51** and **52** may advantageously comprise glass sheets or plates, each illustratively on the order of 5 mils or so in thickness and spaced apart a like distance by spacers **55**. The row and column conductors R1 through R4 and C1 through C3 may comprise transparent gold conducting strips vapor deposited on the respective dielectric material layers **51** and **52**. Illustratively, row conductors R1 through R4, and similarly column conductors C1 through C3, may be on the order of 15 mils wide and spaced apart on the order of **90** mils on the respective dielectric material layers.

A cross section of a portion of display device **50** is depicted in FIG. 3 showing the crosspoint display cells defined by row conductor R4 and column conductor C1 and by row conductor R4 and column conductor C2.

Display device **50**, as mentioned above, utilizes the mechanism of electrical discharge breakdown of the gaseous display material to plasma at selected crosspoint display cells for generating images. When an electric field is applied across a crosspoint display cell, such as the cell defined by row conductor R4 and column conductor C1 in FIG. 3, of a breakdown magnitude V_b determined by the pressure-distance characteristic of the particular gaseous display material employed, the gas in the crosspoint region **320** breaks down and provides a light-emitting discharge of low current density. A typical voltage-current characteristic for such breakdown of a gas is shown in FIG. 4. As may be appreciated from FIG. 4, when voltage of increasing magnitude is applied across the display cell very little current flows until the breakdown voltage V_b is reached. At this point the cell breaks down in a so-called Townsend discharge characterized electrically by a substantially constant low current density.

As the breakdown discharge and the resultant current flow are established initially at a crosspoint display cell, charge is stored on the surfaces of dielectric material layers **51** and **52** in the immediate vicinity of the cell crosspoint, such as on surfaces **310** for the display cell defined by row conductor R4 and column conductor C1 in FIG. 3. The stored charge opposes the voltage drop across the display cell and quickly reaches a level where the voltage across the cell becomes too low to maintain the discharge, thereby quenching the discharge at the crosspoint.

In operation, an alternating current sustaining signal voltage provided by source **20**, which may be either sinusoidal or pulsed, is extended by control circuit **80** across each display cell via row conductors R1 through R4 and column conductors C1 through C3. The sustaining signal voltage extended by source **20** across each display cell is of a magnitude less than the breakdown voltage level V_b; for example, the sustaining signal voltage may be on the order of one-half the breakdown voltage level.

Addressing of a selected display cell is effected under control of control circuit **80** by application of coincident signals to the particular row and column conductors defining the selected display cell. The voltage thus extended across the selected display cell by the coincident row and column signals, by itself or preferably in conjunction with the sustaining signal voltage applied to the row and column conductor, is sufficient to effect breakdown of the gaseous display material at the selected cell. At the same time, however, the voltage extended across the other display cells connected to the addressed row and column conductors is insufficient to effect breakdown of the gas at these other cells.

The addressing signals, as well as the sustaining signal voltage in the embodiment of FIG. 1, are applied to the row and column conductors of display device **50** through respective row drivers **40** and column drivers **30**, illustratively shown in FIG. 1 as pulse transformers. Thus source **20** is connected to each column conductor C1 through C3 via the secondary winding **302** of a respective column driver **30** and to each row conductor R1 through R4 via the secondary winding **402** of a respective row driver **40**. Column conductors C1 through C3 are addressed selectively by signals from write-erase circuitry **81** on leads Y1 through Y3, respectively connected to the primary windings **301** of respective column drivers **30**. Similarly, row conductors R1 through R4 are addressed selectively by signals from write-erase circuitry **82** on leads X1 through X4, respectively connected to primary windings **401** of respective row drivers **40**.

With the above description in mind and with reference to FIGS. 2A, 2B and 2C, consider now the operation of the illustrative embodiment of FIG. 1. Assume initially that the display cell defined by the intersection of row conductor R4 and column conductor C1 is OFF, i.e., that no charge appears on the adjacent surfaces of dielectric material layers **51** and **52** and that the display cell is not lighted. The sustaining signal voltage from source **20** extended through the respective row and column drivers to row conductor R4 and column conductor C1 appears across the display cell as shown in FIG. 2A. Since the sustaining signal voltage is less than the breakdown voltage for the particular gaseous display material employed, no significant current flow through the display cell occurs.

Assume now that it is desired to turn ON the display cell defined by row conductor R4 and column conductor C1. This is accomplished by addressing row conductor R4 and column conductor C1 with coincident signals in the form of a write pulse which, advantageously in conjunction with the sustaining signal voltage applied across the display cell, is sufficient to effect breakdown of the gaseous display material at the addressed cell. In the manner mentioned above, in the illustrative embodiment of FIG. 1 the write pulse is extended over row conductor R4 and column conductor C1 to the selected display cell via coincident signals applied on leads X4 and Y1 from write-erase circuitry **82** and **81**, respectively, which signals are reflected through the corresponding row and column drivers. Advantageously, to minimize the magnitude of the write pulse required, the write pulse is applied to the selected display cell under control of control circuitry **80** near a peak of the sustaining signal voltage as shown at time t_w, by way of example, in FIG. 2A.

The write pulse is shown in FIG. 2A as applied to the right side of the peak of the sustaining signal voltage to minimize loading of the write pulse circuitry which is particularly important in the case of integrated write pulse circuitry. Although the write pulse can be applied at the peak or to the left of the peak of the sustaining signal voltage, as will be apparent from the description below, other cells of display device **50** which are ON will be operating during this interval to break down the gaseous display material thereat. Any such ON cells connected to row conductor R4 or column conductor C1, therefore, will tend to provide low impedance shunt paths for the write pulse during the interval to the left of the sustaining signal voltage peak. However, during the interval to the right of the sustaining signal voltage peak the other cells of display device **50** will present a high impedance state to the write pulse and thus will minimize loading of the write pulse circuitry.

The write pulse applied to row conductor R4 and column conductor C1 causes momentary breakdown of the gaseous display material at the selected display cell permitting current flow thereacross to store charge on the adjacent surfaces **310** of dielectric material layers **51** and **52**, as depicted in FIG. 2B. The resulting current flow across the display cell during breakdown is in the form of a current pulse, shown as pulse **201** in FIG. 2C, which may illustratively have a duration on the order of 50 to 75 nanoseconds.

The level of charge stored on adjacent surfaces **310** of dielectric layers **51** and **52** is determined principally by the net voltage across the cell during breakdown. During the following negative half-cycle of sustaining signal voltage applied across the display cell, the stored charge adds to the sustaining signal voltage as shown in FIG. 2A. A time t_1 the combined voltage exceeds the breakdown voltage V_b causing a momentary breakdown discharge at the display cell. The resulting negative current pulse **202** between row conductor R4 and column conductor C1 removes the stored charge from surfaces **310** and charges surfaces **310** in a reverse direction as indicated in FIG. 2B.

During the following positive half-cycle of the sustaining signal voltage, therefore, the reverse charge on surfaces **310** of the display cell adds to the sustaining signal voltage, as shown in FIG. 2A, reaching a level sufficient to break down the gas at the display cell again at time t_2. The positive current pulse **203** resulting therefrom through the display cell reverses the cell charge. During succeeding half-cycles of the sustaining signal voltage the charge stored on surfaces **310** of the display cell, in combination with the sustaining signal voltage, causes periodic breakdown of the gas at the display cell to emit light in the form of pulsed discharges at a frequency twice that of the sustaining signal source **20**.

Additional one of the display cells in display device **50** are turned ON in a similar manner by application of a write pulse to the particular row and column conductors which define the additional cells. Conversely, a selected display cell is turned OFF by applying an erase pulse to the row and column conductor defining the selected cell such that the erase pulse removes or erases the charge stored at the cell. This is effected advantageously by applying an erase pulse to the particular row and column conductors of sufficient magnitude to break down the gas at the cell at a point when the instantaneous magnitude of the sustaining signal voltage applied to the row and column conductors is at or near zero. During the resulting pulsed discharge of the cell, therefore, no significant charge is stored. Accordingly, when the pulsed discharge ceases, the net voltage across the display cell is approximately equal to the sustaining signal voltage and is thus insufficient to cause further breakdown of the gas at the cell.

For example, assume that the display cell defined by row conductor R4 and column conductor C1 is ON and that it is desired to turn it OFF. Row conductor R4 and column conductor C1 are addressed via coincident signals applied on leads X4 and Y1 in the form of an erase pulse at a time when the instantaneous value of the sustaining signal voltage is near zero, as shown at time t_e by way of example in FIG. 2A.

The erase pulse is assumed to be sufficient in magnitude to cause momentary breakdown of the gas at the selected display cell. The resulting current flow depicted in FIG. 2C by current pulse **210** removes the charge stored on surfaces **310** of the cell as shown in FIG. 2B. As mentioned above, since the instantaneous value of the sustaining signal voltage across the cell at time t_e is approximately zero, no significant charge builds up on surfaces **310** during the momentary breakdown of the cell. Thus no further discharge occurs at the cell until another write pulse is applied to the particular display cell.

Although in the description above it is tacitly assumed that only a single display cell is addressed by a write or erase pulse during each cycle of the sustaining signal voltage, it will be apparent that more than one cell can be addressed during each sustaining signal voltage cycle by consecutively or concurrently addressing a number of cells in each cycle. Further, the entire display can be erased if desired by terminating the sustaining signal voltage from source **20** for a period sufficiently to permit the stored charges at the display cells to dissipate. It is to be understood, therefore, that the above described arrangements are but illustrative of the application of the principles of my invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A display device comprising first and second pluralities of conductors, an array of display cells individually defined by the intersection of one of said first plurality of conductors and one of said second plurality of conductors, and means disposed between said first and second pluralities of conductors including first and second dielectric means separated by a substantially uniform continuous layer of gaseous display material.

2. A display device arrangement comprising first and second pluralities of conductors arranged so as to define a matrix of crosspoint display cells, and first and second layers of dielectric material disposed between said first and second pluralities of conductors, characterized by a substantially uniform continuous layer of gaseous display material disposed between said first and second layers of dielectric material.

3. An arrangement in accordance with claim **2** further comprising means for selectively addressing individual ones of said display cells to initiate a discharge breakdown thereat, and sustaining means connected to each of said display cells and operative upon the initial discharge breakdown of individual ones of said cells for thereafter periodically breaking down said individual ones of said cells.

4. An arrangement in accordance with claim **3** wherein said addressing means comprises respective pulse transformers having secondary windings connected to individual ones of said first and second pluralities of conductors, each said transformer having a primary winding connected to a respective address signal input lead, and wherein said sustaining means comprises an alternating signal source connected to the secondary windings of each of said pulse transformers.

5. An arrangement in accordance with claim **3** further comprising means for selectively addressing said display cells to initiate a discharge breakdown at said addressed cells, said initial breakdown at a display cell storing a charge on the adjacent surfaces of said first and second layers of dielectric material at said addressed cells, and alternating signal means connected to each of said cells, said alternating signal means operative in conjunction with said stored charge at respective ones of said display cells for periodically breaking down said respective cells.

6. In combination, a first layer of dielectric material, a plurality of first conductors disposed on one side of said first dielectric material layer, a second layer of dielectric material, a second conductor disposed on one side of said second dielectric material layer, said first and second dielectric material layers being disposed with the other sides of said first and second dielectric material layers in facing, spaced apart relationship such that said second conductor defines an individual display cell with each of said plurality of first conductors, and a substantially uniform continuous layer of gaseous display material disposed between said other sides of said first and second dielectric material layers.

7. The combination in accordance with claim **6** further comprising means for addressing a selected one of said display cells to initiate a discharge breakdown through the portion of said gaseous display material between said first and second conductors defining said selected display cell, and sustaining means connected to each of said display cells and operative upon the initial discharge breakdown of individual ones of said cells for thereafter periodically breaking down said individual ones of said cells.

8. The combination in accordance with claim **7** wherein said sustaining means comprises an alternating signal source connected to each of said display cells and of a magnitude insufficient to initially break down said cells.

9. The combination in accordance with claim **8** wherein said addressing means comprises respective pulse transformers having secondary windings connected to individual ones of said first and second conductors, each said transformer having a primary winding connected to a respective address signal input lead, and wherein said alternating signal source is connected to the secondary windings of each of said pulse transformers.

10. The combination in accordance with claim **8** wherein said addressing means includes means for applying a predetermined signal to said selected display cell of sufficient magnitude in conjunction with said alternating signal source to initially break down said selected display cell.

10. The combination in accordance with claim **10** wherein said applying means applies said predetermined signal to said selected display cell during a predetermined interval other than during said periodic breaking down of said individual ones of said cells by said sustaining means.

12. The combination in accordance with claim **7** wherein said addressing means includes means for applying a write pulse to said selected display cell during a predetermined interval, said predetermined interval being different than any interval during which said sustaining means is operative for periodically breaking down said individual ones of said cells.

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Disclaimer

3,671,938.—*Dinh-Tuan Ngo*, Colts Neck, N.J. GASEOUS DISPLAY DEVICE. Patent dated June 20, 1972. Disclaimer filed Oct. 29, 1976, by the assignee, *Bell Telephone Laboratories, Incorporated.*

Hereby enters this disclaimer to claims 1–10 of said patent.

[*Official Gazette December 14, 1976.*]