United States Patent [19]

Hoehn et al.

[11] **3,852,607**

[45] **Dec. 3, 1974**

[54] **MULTIPLE GASEOUS DISCHARGE DISPLAY/MEMORY PANEL HAVING THIN FILM DIELECTRIC CHARGE STORAGE MEMBER**

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[73] Assignee: **Owens-Illinois, Inc.**, Toledo, Ohio

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[52] **U.S. Cl.** ..... **313/201**, 313/220, 313/221, 315/169 TV

[51] **Int. Cl.** **H01j 61/30**, H01j 65/04

[58] **Field of Search** ..... 313/201, 220, 221; 315/169 TV

[56] **References Cited**

UNITED STATES PATENTS

2,960,617	11/1960	Lodge et al.	313/65 X
3,189,781	6/1965	Lempert	313/68 R X
3,377,498	4/1968	Koury et al.	313/221
3,440,477	4/1969	Crowell et al.	313/66 X
3,614,509	10/1971	Willson	313/201
3,624,444	11/1971	Berthold et al.	313/221
3,634,719	1/1972	Ernsthausen	313/221 X

OTHER PUBLICATIONS

"Gas Display Panel," B. Welber, IBM Technical Disclosure Bulletin, Vol. 12, No. 10, March 1970, pp. 1552–1553.

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Assistant Examiner—Eugene R. LaRoche
Attorney, Agent, or Firm—Donald Keith Wedding

[57] **ABSTRACT**

There is disclosed a multiple gaseous discharge display/memory panel having an electrical memory and capable of producing a visual display, the panel being characterized by an ionizable gaseous medium in a gas chamber formed by a pair of opposed charge storage members which are respectively backed by a series of parallel-like conductor (electrode) members, the conductor members behind each charge storage member being transversely oriented with respect to the conductor members behind the opposing charge storage member so as to define a plurality of discrete discharge volumes constituting a discharge unit, each charge storage member being comprised of a continuous thin film of dielectric material having a thickness of 150,000 angstrom units or less.

3 Claims, 7 Drawing Figures

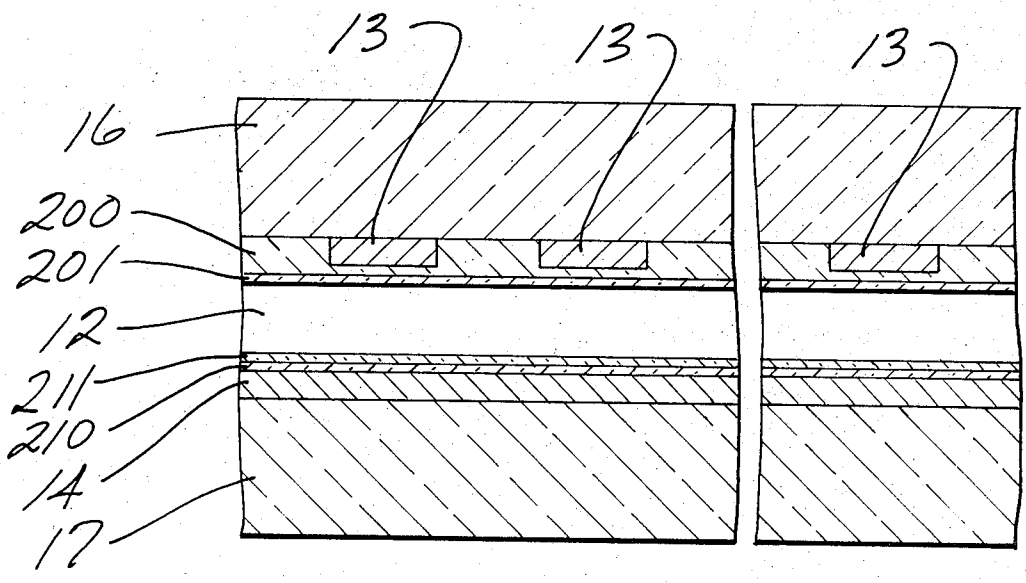


FIG. 2

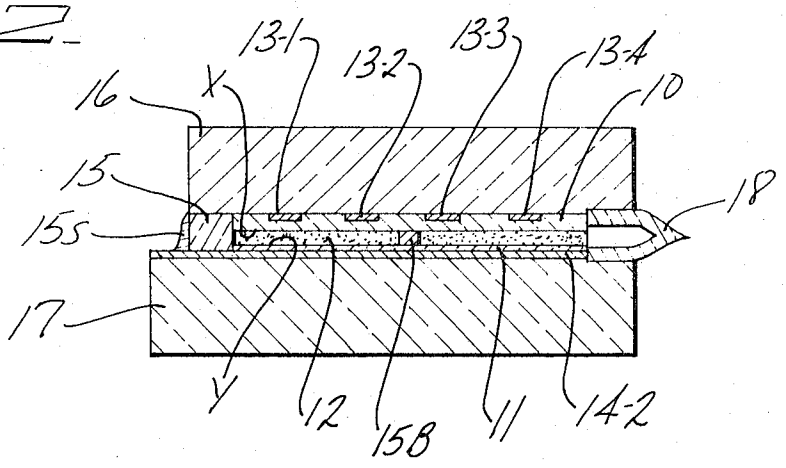

16
X
13-1
13-2
13-3
13-4
10
15
18
15S
17
Y
12
15B
11
14-2

FIG. 1

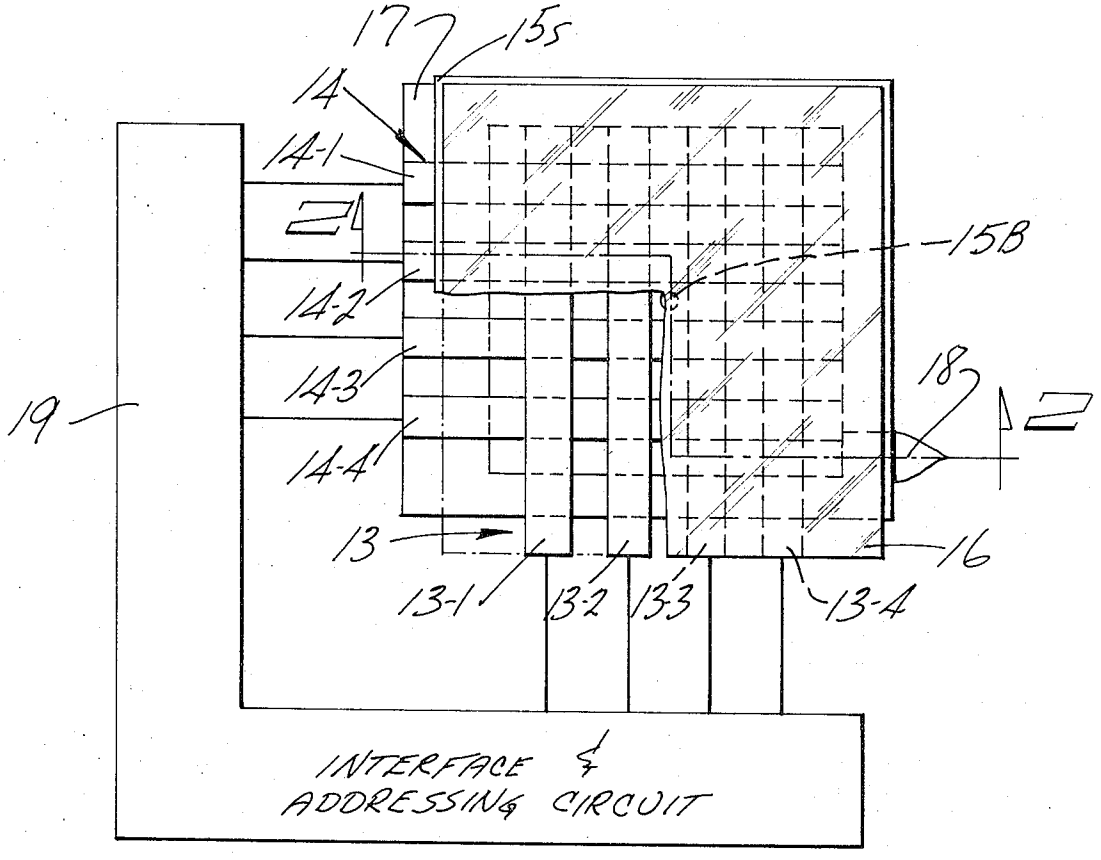

17
15S
14
14-1
2
15B
14-2
14-3
18
2
19
14-4
13
16
13-1
13-2
13-3
13-4
INTERFACE &
ADDRESSING CIRCUIT

FIG. 3

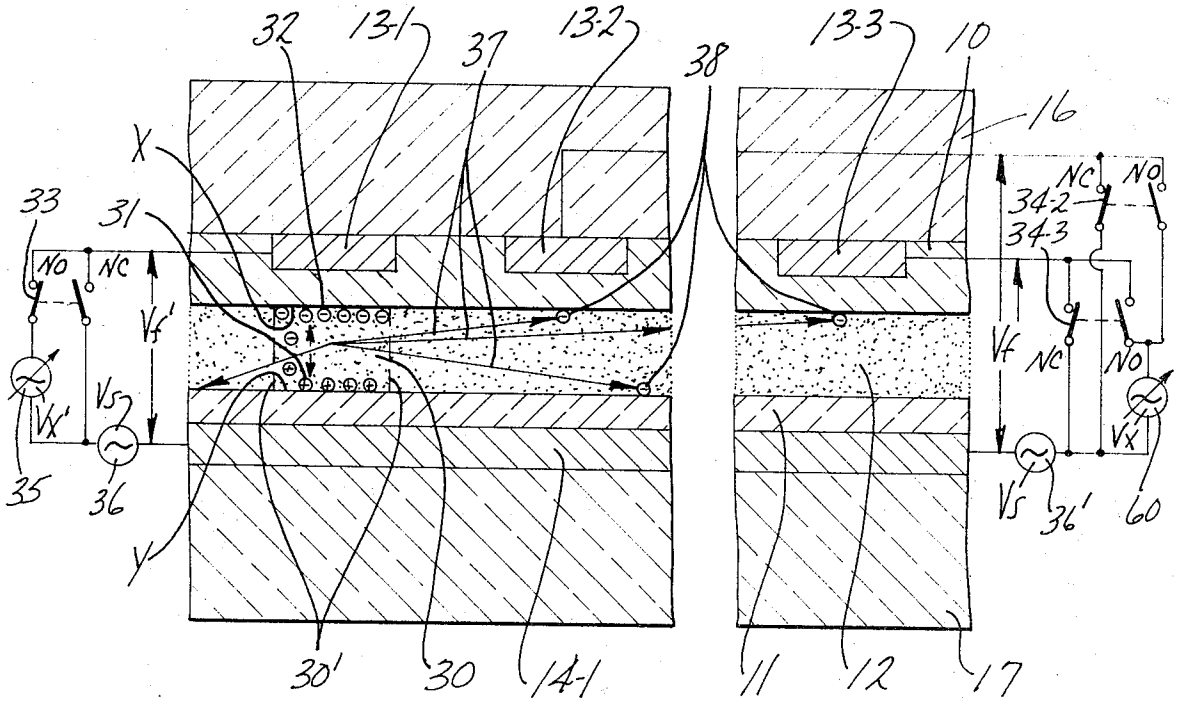

32
13-1
37
13-2
38
13-3
10
16
X
33
31
NO
NC
Vf'
Vx'
Vs'
35
36
Y
30'
30
14-1
11
12
17
NC
NO
34-2
34-3
Vf
NC
NO
Vx
Vs
36'
60

FIG. 4

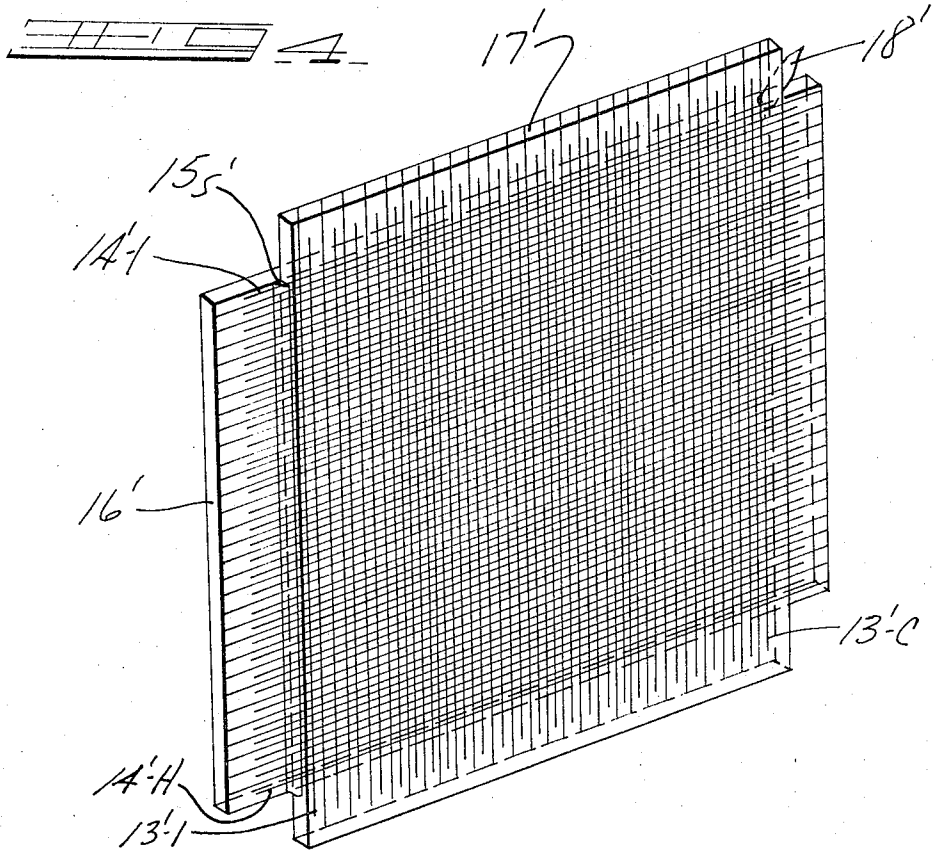

17'
18'
15'
14'-1
16'
13'-C
14'-H
13'-1

FIG. 5

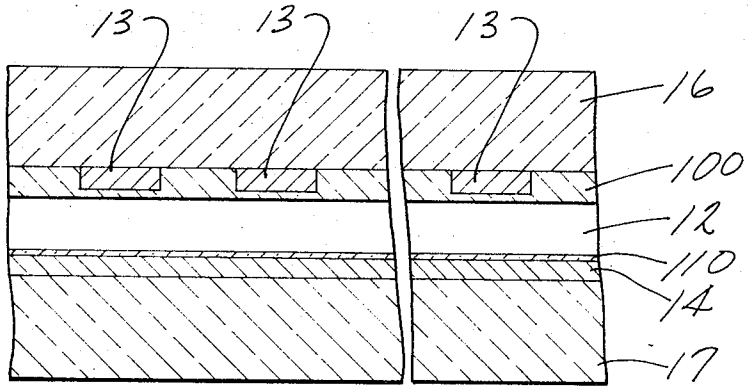


FIG. 6

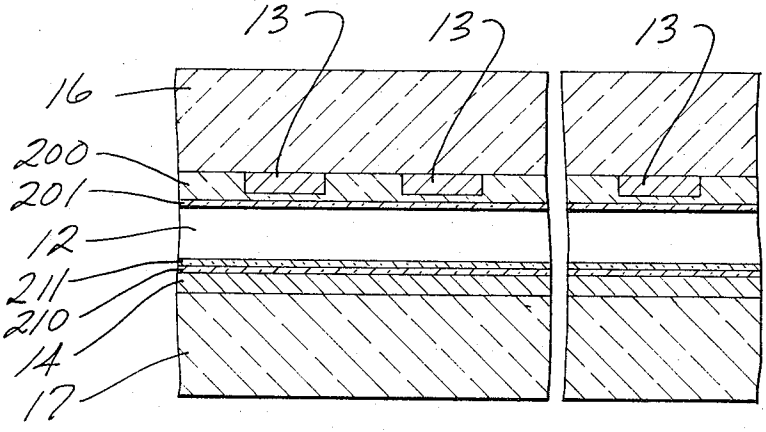
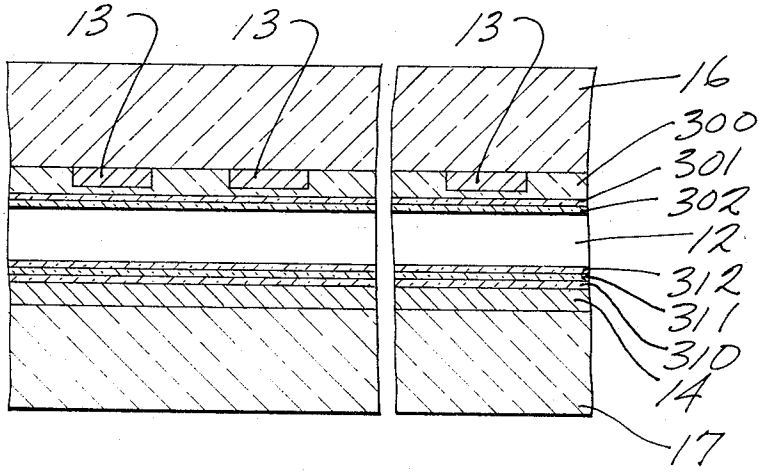


FIG. 7



MULTIPLE GASEOUS DISCHARGE DISPLAY/MEMORY PANEL HAVING THIN FILM DIELECTRIC CHARGE STORAGE MEMBER

RELATED APPLICATION

This is a continuation-in-part of copending U.S. Pat. Application Ser. No. 146,796, filed May 25, 1971, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to novel multiple gas discharge display/memory panels which have an electrical memory and which are capable of producing a visual display or representation of data such as numerals, letters, television display, radar displays, binary words, etc.

Multiple gas discharge display and/or memory panels of one particular type with which the present invention is concerned are characterized by an ionizable gaseous medium, usually a mixture of at least two gases at an appropriate gas pressure, in a thin gas chamber or space between a pair of opposed dielectric charge storage members which are backed by conductor (electrode) members, the conductor members backing each dielectric member typically being appropriately oriented so as to define a plurality of discrete gas discharge units or cells.

In some prior art panels the discharge cells are additionally defined by surrounding or confining physical structure such as apertures in perforated glass plates and the like so as to be physically isolated relative to other cells. In either case, with or without the confining physical structure, charges (electrons, ions) produced upon ionization of the elemental gas volume of a selected discharge cell, when proper alternating operating potentials are applied to selected conductors thereof, are collected upon the surfaces of the dielectric at specifically defined locations and constitute an electrical field opposing the electrical field which created them so as to terminate the discharge for the remainder of the half cycle and aid in the initiation of a discharge on a succeeding opposite half cycle of applied voltage, such charges as are stored consituting an electrical memory.

Thus, the dielectric layers prevent the passage of substantial conductive current from the conductor members to the gaseous medium and also serve as collecting surfaces for ionized gaseous medium charges (electrons, ions) during the alternate half cycles of the A.C., operating potentials, such charges collecting first on one elemental or discrete dielectric surface area and then on an opposing elemental or discrete dielectric surface area on alternate half cycles to consitute an electrical memory.

An example of a panel structure containing non-physically isolated or open discharge cells is disclosed in U.S. Pat. No. 3,499,167 issued to Theodore C. Baker, et al.

An example of a panel containing physically isolated cells is disclosed in the article by D. L. Bitzer and H. G. Slottow entitled "The Plasma Display Panel — A Digitally Addressable Display With Inherent Memory," Proceeding of the Fall Joint Computer Conference IEEE, San Francisco, Calif., Nov. 1966, pages 541–547. Also reference is made to U.S. Pat. No. 3,559,190.

In the construction of the panel, a continuous volume of ionizable gas is confined between a pair of dielectric surfaces backed by conductor arrays typically forming matrix elements. The cross conductor arrays may be orthogonally related (but any other configuration of conductor arrays may be used) to define a plurality of opposed pairs of charge storage areas on the surfaces of the dielectric boudning or confining the gas. Thus, for a conductor matrix having H rows and C columns the number of elemental or discrete areas will be twice the number of such elemental discharge cells.

In addition, the panel may comprise a so-called monolithic structure in which the conductor arrays are created on a single substrate and wherein two or more arrays are separated from each other and from the gaseous medium by at least one insulating member. In such a device the gas discharge takes place not between two opposing electrodes, but between two contiguous or adjacent electrodes on the same substrate; the gas being confined between the substrate and an outer retaining wall.

It is also feasible to have a gas discharge device wherein some of the conductive or electrode members are in direct contact with the gaseous medium and the remaining electrode members are appropriately insulated from such gas, i.e., at least one insulated electrode.

In addition to the matrix configuration, the conductor arrays may be shaped otherwise. Accordingly, while the preferred conductor arrangement is of the crossed grid type as discussed herein, it is likewise apparent that where a maximal variety of two dimensional display patterns is not necessary, as where specific standardized visual shapes (e.g., numerals, letters, words, etc.) are to be formed and image resolution is not critical, the conductors may be shaped accordingly, i.e., a segmented display.

The gas is one which produces visible light or invisible radiation which stimulates a phosphor (if visual display is an objective) and a copious supply of charges (ions and electrons) during discharge.

In the prior art, a wide variety of gases and gas mixtures have been utilized as the gaseous medium in a number of different gas discharge devices: Typical of such gases include pure gases and mixtures of Co; CO_2; halogens; nitrogen; NH_3; oxygen, water vapor; hydrogen; hydrocarbons; P_2O_5; boron fluoride, acid fumes; $TiCl_4$; air; H_2O_2; vapors of sodium, mercury, thallium, cadmium, rubidium, and cesium; carbon disulfide, laughing gas; H_2S; deoxygenated air; phosphorous vapors; C_2H_2; CH_4; naphthalene vapor; anthracene; freon, ethyl alcohol; methylene bromide; heavy hydrogen; electron attaching gases; sulfur hexafluoride; tritium; radioactive gases; and the so-called rare or inert Group VIII gases.

In an open cell Baker, et al., type panel, the gas pressure and the electric field are sufficient to laterally confine charges generated on discharge within elemental or discrete dielectric areas within the perimeter of such areas, especially in a panel containing non-isolated discharge cells. As described in the Baker, et al., patent, the space between the dielectric surfaces occupied by the gas is such as to permit photons generated on discharge in a selected discrete or elemental volume of gas to pass freely through the gas space and strike surface areas of dielectric remote from the selected discrete volumes, such remote, photon struck dielectric surface

areas thereby emitting electrons so as to condition at least one elemental volume other than the elemental volume in which the photons originated.

With respect to the memory function of a given discharge panel, the allowable distance or spacing between the dielectric surfaces depends, inter alia, on the frequency of the alternating current supply, the distance typically being greater for lower frequencies.

While the prior art does disclosed gaseous discharge devices having externally positioned electrodes for initiating a gaseous discharge, sometimes called "electrodeless discharge," such prior art devices utilized frequencies and spacing or discharge volumes and operating pressures such that although discharges are initiated in the gaseous medium, such discharges are ineffective or not utilized for charge generation and storage at higher frequencies; although charge storage may be realized at lower frequencies, such charge storage has not been utilized in a display/memory device in the manner of the Bitzer-Slottow or Baker, et al., invention. The term "memory margin" is defined herein as

$$M.\ M. = (V_f - V_E)/(V_f/2)$$

where V_f is the half amplitude of the smallest sustaining voltage signal which results in a discharge every half cycle, but at which the cell is not bi-stable and V_E is the half amplitude of the minimum applied voltage sufficient to sustain discharges once initiated.

It will be understood that the basic electrical phenomenon utilized in this invention is the generation of charges (ions and electrons) alternately storable at pairs of opposed or facing discrete points or areas on a pair of dielectric surfaces backed by conductors connected to a source of operating potential. Such stored charges result in an electrical field opposing the field produced by the applied potential that created them and hence operate to terminate ionization in the elemental gas volume between opposed or facing discrete points or areas of dielectric surface. The term "sustain a discharge" means producing a sequence of momentary discharges, at least one discharge for each half cycle of applied alternating sustaining voltage, once the elemental gas volume has been fired, to maintain alternate storing of charges at pairs of opposed discrete areas on the dielectric surfaces.

As used herein, a cell is in the "on state" when a quantity of charge is stored in the cell such that on each half cycle of the sustaining voltage, a gaseous discharge is produced.

In addition to the sustaining voltage, other voltages may be utilized to operate the panel, such as firing, addressing, and writing voltages.

A "firing voltage" is any voltage, regardless of source, required to discharge a cell. Such voltage may be completely external in origin or may be comprised of internal cell wall voltage in combination with externally originated voltages.

An "addressing voltage" is a voltage produced on the panel X – Y electrode coordinates such that at the selected cell or cells, the total voltage applied across the cell is equal to or greater than the firing voltage whereby the cell is discharged.

A "writing voltage" is an addressing voltage of sufficient magnitude to make it probable that on subsequent sustaining voltage half cycles, the cell will be in the "on state."

In the operation of a multiple gaseous discharge device, of the type described hereinbefore, it is necessary to condition the discrete elemental gas volume of each discharge cell by supplying at least one free electron thereto such that a gaseous discharge can be initiated when the cell is addressed with an appropriate voltage signal.

The prior art has disclosed and practiced various means for conditioning gaseous discharge cells.

One such means of panel conditioning comprises a socalled electronic process whereby an electronic conditioning signal or pulse is periodically applied to all of the panel discharge cells, as disclosed for example in British patent specification No. 1,161,832, page 8, lines 56 to 76. Reference is also made to U.S. Pat. No. 3,559,190 and "The Device Characteristics of the Plasma Display Element" by Johnson, et al., IEEE Transactions On Electron Devices, September, 1971. However, electronic conditioning is self-conditioning and is only effective after a discharge cell has been previously conditioned; that is, electronic conditioning involves periodically discharging a cell and is therefore a way of maintaining the presence of free electrons. Accordingly, one cannot wait too long between the periodically applied conditioning pulses since there must be at least one free electron present in order to discharge and condition a cell.

Another conditioning method comprises the use of external radiation, such as flooding part or all of the gaseous medium of the panel with ultraviolet radiation. This external conditioning method has the obvious disadvantage that it is not always convenient or possible to provide external radiation to a panel, especially if the panel is in a remote position. Likewise, an external UV source requires auxiliary equipment. Accordingly, the use of internal conditioning is generally preferred.

One internal conditioning means comprises using internal radiation, such as by the inclusion of a radioactive material.

Another means of internal conditioning, which we call photon conditioning, comprises using one or more so-called pilot discharge cells in the on-state for the generation of photons. This is particularly effective in a so-called open cell construction (as described in the Baker, et al., patent) wherein the space between the dielectric surfaces occupied by the gas is such as to permit photons generated on discharge in a selected discrete or elemental volume of gas (discharge cell) to pass freely through the panel gas space so as to condition other and more remote elemental volumes of other discharge units. In addition to or in lieu of the pilot cells, one may use other sources of photons internal to the panel.

Internal photon conditioning may be unreliable when a given discharge unit to be addressed is remote in distance relative to the conditioning source, e.g., the pilot cell. Accordingly, a multiplicity of pilot cells may be required for the conditioning of a panel having a large geometric area. In one highly convenient arrangement, the panel matrix border (perimeter) is comprised of a plurality of such pilot cells.

DRAWINGS ILLUSTRATING GAS DISCHARGE DISPLAY/MEMORY PANEL

Reference is made to the accompanying drawings and the hereinafter discussed FIGS. 1 to 4 shown

thereon illustrating a gas discharge display/memory panel of the Baker, et al. type.

FIG. 1 is a partially cut-away plan view of a gaseous discharge display/memory panel as connected to a diagrammatically illustrated source of operating potentials.

FIG. 2 is a cross-sectional view (enlarged, but not to proportional scale since the thickness of the gas volume, dielectric members and conductor arrays have been enlarged for purposes of illustration) taken on lines 2 — 2 of FIG. 1.

FIG. 3 is an explanatory partial cross-sectional view similar to FIG. 2 (enlarged, but not to proportional scale).

FIG. 4 is an isometric view of a gaseous discharge display/memory panel.

FIGS. 5, 6, and 7 are partial cross-sectional views illustrating three different embodiments of this invention.

The invention utilizes a pair of dielectric films **10** and **11** separated by a thin layer or volume of a gaseous discharge medium **12**, the medium **12** producing a copious supply of charges (ions and electrons) which are alternately collectable on the surfaces of the dielectric members at opposed or facing elemental or discrete areas X and Y defined by the conductor matrix on non-gas-contacting sides of the dielectric members, each dielectric member presenting large open surface areas and a plurality of pairs of elemental X and Y areas. While the electrically operative structural members such as the dielectric members **10** and **11** and conductor matrixes **13** and **14** are all relatively thin (being exaggerated in thickness in the drawings) they are formed on and supported by rigid nonconductive support members **16** and **17** respectively.

Preferably one or both of nonconductive support members **16** and **17** pass light produced by discharge in the elemental gas volumes. Preferably, they are transparent glass members and these members essentially define the overall thickness and strength of the panel. For example, the thickness of gas layer **12** as determined by spacer **15** is usually under 10 mils and preferably about 4 to 8 mils, dielectric layers **10** and **11** (over the conductors at the elemental or discrete X and Y areas) are usually between 1 and 2 mils thick, and conductors **13** and **14** about 8,000 angstroms thick. However, support members **16** and **17** are much thicker (particularly in larger panels) so as to provide as much ruggedness as may be desired to compensate for stresses in the panel. Support members **16** and **17** also serve as heat sinks for heat generated by discharges and thus minimize the effect of temperature on operation of the device. If it is desired that only the memory function be utilized, then none of the members need by transparent to light.

Except for being nonconductive or good insulators the electrical properties of support members **16** and **17** are not critical. The main function of support members **16** and **17** is to provide mechanical support and strength for the entire panel, particularly with respect to pressure differential acting on the panel and thermal shock. As noted earlier, they should have thermal expansion characteristics substantially matching the thermal expansion characteristics of dielectric layers **10** and **11**. Ordinary 1/4 inch commercial grade soda lime plate glasses have been used for this purpose. Other glasses such as low expansion glasses or transparent devitrified glasses can be used provided they can withstand processing and have expansion characteristics substantially matching expansion characteristics of the dielectric coatings **10** and **11**. For given pressure differentials and thickness of plates, the stress and deflection of plates may be determined by following standard stress and strain formulas (see R. J. Roark, *Formulas for Stress and Strain*, McGraw-Hill, 1954).

Spacer **15** may be made of the same glass material as dielectric films **10** and **11** and may be an integral rib formed on one of the dielectric members and fused to the other members to form a bakeable hermetic seal enclosing and confining the ionizable gas volume **12**. However, a separate final hermetic seal may be effected by a high strength devitrified glass sealant **15S**. Tubulation **18** is provided for exhausting the space between dielectric members **10** and **11** and filling that space with the volume of ionizable gas. For large panels small beadlike solder glass spacers such as shown at **15B** may be located between conductor intersections and fused to dielectric members **10** and **11** to aid in withstanding stress on the panel and maintain uniformity of thickness of gas volume **12**.

Conductor arrays **13** and **14** may be formed on support members **16** and **17** by a number of well-known processes, such as photoetching, vacuum deposition, stencil screening, etc. In the panel shown in FIG. **4**, the center-to-center spacing of conductors in the respective arrays is about 17 mils. Transparent or semi-transparent conductive material such as tin oxide, gold, or aluminum can be used to form the conductor arrays and should have a resistance less than 3,000 ohms per line. Narrow opaque electrodes may alternately be used so that discharge light passes around the edges of the electrodes to the viewer. It is important to select a conductor material that is not attacked during processing by the dielectric material.

It will be appreciated that conductor arrays **13** and **14** may be wires or filaments of copper, gold, silver or aluminum or any other conductive metal or material. For example 1 mil wire filaments are commercially available and may be used in the invention. However, formed in situ conductor arrays are preferred since they may be more easily and uniformly placed on and adhered to the support plates **16** and **17**.

Dielectric layer members **10** and **11** are formed of an inorganic material and are preferably formed in situ as an adherent film or coating which is not chemically or physically affected during bake-out of the panel. One such material is a solder glass such as Kimble SG-68 manufactured by and commercially available from the assignee of the present invention.

This glass has thermal expansion characteristics substantially matching the thermal expansion characteristics of certain soda-lime glasses, and can be used as the dielectric layer when the support members **16** and **17** are soda-lime glass plates. Dielectric layers **10** and **11** must be smooth and have a dielectric breakdown voltage of about 1,000 v. and be electrically homogeneous on a microscopic scale (e.g., no cracks, bubbles, crystals, dirt, surface films, etc.). In addition, the surfaces of dielectric layers **10** and **11** should be good photoemitters of electrons in a baked out condition. Alternately, dielectric layers **10** and **11** may be overcoated with materials designed to produce good electron emission, as in U.S. Pat. No. 3,634,719, issued to Roger E. Ernsthausen. Of course, for an optical display at least

one of dielectric layers **10** and **11** should pass light generated on discharge and be transparent or translucent and, preferably, both layers are optically transparent.

The preferred spacing between surfaces of the dielectric films is about 4 to 8 mils with conductor arrays **13** and **14** having center-to-center spacing of about 17 mils.

The ends of conductors **14–1 . . . 14–4** and support member **17** extend beyond the enclosed gas volume **12** and are exposed for the purpose of making electrical connection to interface and addressing circuitry **19.** Likewise, the ends of conductors **13–1 . . . 13–4** on support member **16** extend beyond the enclosed gas volume **12** and are exposed for the purpose of making electrical connection to interface and addressing circuitry **19.**

As in known display systems, the interface and addressing circuitry or system **19** may be relatively inexpensive line scan systems or the somewhat more expensive high speed random access systems. In either case, it is to be noted that a lower amplitude of operating potentials helps to reduce problems associated with the interface circuitry between the addressing system and the display/memory panel, per se. Thus, by providing a panel having greater uniformity in the discharge characteristics throughout the panel, tolerances and operating characteristics of the panel with which the interfacing circuitry cooperate, are made less rigid.

One mode of initiating operation of the panel will be described with reference to FIG. **3,** which illustrates the condition of one elemental gas volume **30** having an elemental cross-sectional area and volume which is quite small relative to the entire volume and cross-sectional area of gas **12.** The cross-sectional area of volume **30** is defined by the overlapping common elemental areas of the conductor arrays and the volume is equal to the product of the distance between the dielectric surfaces and the elemental area. It is apparent that if the conductor arrays are uniform and linear and are orthogonally (at right angles to each other) related each of elemental areas X and Y will be squares and if conductors of one conductor array are wider than conductors of the other conductor arrays, said areas will be rectangles. If the conductor arrays are at transverse angles relative to each other, other than 90°, the areas will be diamond shaped so that the cross-sectional shape of each volume is determined solely in the first instance by the shape of the common area of overlap between conductors in the conductor arrays **13** and **14.** The dotted lines **30'** are imaginary lines to show a boundary of one elemental volume about the center of which each elemental discharge takes place. As described earlier herein, it is known that the cross-sectional area of the discharge in a gas is affected by, inter alia, the pressure of the gas, such that, if desired, the discharge may even be constricted to within an area smaller than the area of conductor overlap. By utilization of this phenomena, the light production may be confined or resolved substantially to the area of the elemental cross-sectional area defined by conductor overlap. Moreover, by operating at such pressure charges (ions and electrons) produced on discharge are laterally confined so as to not materially affect operation of adjacent elemental discharge volumes.

In the instant shown in FIG. **3,** a conditioning discharge about the center of elemental volume **30** has been initiated by application to conductor **13–1** and conductor **14–1** firing potential V_x' as derived from a source **35** of variable phase, for example, and source **36** of sustaining potential V_s (which may be a sine wave, for example). The potential V_x' is added to the sustaining potential V_s as sustaining potential V_s increases in magnitude to initiate the conditioning discharge about the center of elemental volume **30** shown in FIG. **3.** There, the phase of the source **35** of potential V_x' has been adjusted into adding relation to the alternating voltage from the source **36** of sustaining voltage V_s to provide a voltage V_f', when switch **33** has been closed, to conductors **13–1** and **14–1** defining elementary gas volume **30** sufficient (in time and/or magnitude) to produce a light generating discharge centered about discrete elemental gas volume **30.** At the instant shown, since conductor **13–1** is positive, electrons **32** have collected on and are moving to an elemental area of dielectric member **10** substantially corresponding to the area of elemental gas volume **30** and the less mobile positive ions **31** are beginning to collect on the opposed elemental area of dielectric member **11** since it is negative. As these charges build up, they constitute a back voltage opposed to the voltage applied to conductors **13–1** and **14–1** and serve to terminate the discharge in elemental gas volume **30** for the remainder of a half cycle.

During the discharge about the center of elemental gas volume **30,** photons are produced which are free to move or pass through gas medium **12,** as indicated by arrows **37,** to strike or impact remote surface areas of photoemissive dielectric members **10** and **11,** causing such remote areas to release electrons **38.** Electrons **38** are, in effect, free electrons in gas medium **12** and condition each other discrete elemental gas volume for operation at a lower firing potential V_f which is lower in magnitude than the firing potential V_f' for the initial discharge about the center of elemental volume **30** and this voltage is substantially uniform for each other elemental gas volume.

Thus, elimination of physical obstructions or barriers between discrete elemental volumes, permits photons to travel via the space occupied by the gas medium **12** to impact remote surface areas of dielectric members **10** and **11** and provides a mechanism for supplying free electrons to all elemental gas volumes, thereby conditioning all discrete elemental gas volumes for subsequent discharges, respectively, at a uniform lower applied potential. While in FIG. **3** a single elemental volume **30** is shown, it will be appreciated that an entire row (or column) of elemental gas volumes may be maintained in a "fired" condition during normal operation of the device with the light produced thereby being masked or blocked off from the normal viewing area and not used for display purposes. It can be expected that in some applications there will always be at least one elemental volume in a "fired" condition and producing light in a panel, and in such applications it is not necessary to provide separate discharge or generation of photons for purposes described earlier.

However, as described earlier, the entire gas volume can be conditioned for operation at uniform firing potentials by use of external or internal radiation so that there will be no need for a separate source of higher potential for initiating an initial discharge. Thus, by radiating the panel with ultraviolet radiation or by inclusion of a radioactive material within the glass materials or

gas space, all discharge volumes can be operated at uniform potentials from addressing and interface circuit **19.**

Since each discharge is terminated upon a build up or storage of charges at opposed pairs of elemental areas, the light produced is likewise terminated. In fact, light production lasts for only a small fraction of a half cycle of applied alternating potential and depending on design parameters, is in the nanosecond range.

After the initial firing or discharge of discrete elemental gas volume **30** by a firing potential V_f', switch **33** may be opened so that only the sustaining voltage V_s from source **36** is applied to conductors **13–1** and **14–1.** Due to the storage of charges (e.g., the memory) at the opposed elemental areas X and Y, the elemental gas volume **30** will discharge again at or near the peak of negative half cycles of sustaining voltage V_s to again produce a momentary pulse of light. At this time, due to reversal of field direction, electrons **32** will collect on and be stored on elemental surface area Y of dielectric member **11** and positive ions **31** will collect and be stored on elemental surface area X of dielectric member **10.** After a few cycles of sustaining voltage V_s, the times of discharges become symmetrically located with respect to the wave form of sustaining voltage V_s. At remote elemental volumes, as for example, the elemental volumes defined by conductor **14–1** with conductors **13–2** and **13–3,** a uniform magnitude or potential V_x from source **60** is selectively added by one or both of switches **34–2** or **34–3** to the sustaining voltage V_s, shown as **36'**, to fire one or both of these elemental discharge volumes. Due to the presence of free electrons produced as a result of the discharge centered about elemental volume **30,** each of these remote discrete elemental volumes have been conditioned for operation at uniform firing potential V_f.

In order to turn "off" an elemental gas volume (i.e., terminate a sequence of discharge representing the "on" state), the sustaining voltage may be removed. However, since this would also turn "off" other elemental volumes along a row or column, it is preferred that the volumes be selectively turned "off" by application to selected "on" elemental volumes a voltage which can neutralize the charges stored at the pairs of opposed elemental areas. This can be accomplished in a number of ways, as for example, varying the phase or time position of the potential from source **60** to where the voltage combined with the potential from source **36'** falls substantially below the sustaining voltage.

It is apparent that the plates **16–17** need not be flat but may be curved, curvature of facing surfaces of each plate being complementary to each other. While the preferred conductor arrangement is of the crossed grid type as shown herein, it is likewise apparent that where an infinite variety of two dimensional display patterns are not necessary, as where specific standardized visual shapes (e.g., numerals, letters, words, etc.) are to be formed and image resolution is not critical, the conductors may be shaped accordingly. Reference is made to British Pat. Specification 1,302,148 and U.S. Pat. No. 3,711,733 wherein non-grid electrode arrangements are illustrated.

The device shown in FIG. **4** is a panel having a large number of elemental volumes similar to elemental volume **30** (FIG. **3**). In this case more room is provided to make electrical connection to the conductor arrays **13'** and **14'**, respectively, by extending the surfaces of support members **16'** and **17'** beyond seal **15S'**, alternate conductors being extended on alternate sides Conductor arrays **13'** and **14'** as well as support members **16'** and **17'** are transparent. The dielectric coatings are not shown in FIG. **4** but are likewise transparent so that the panel may be viewed from either side.

THE INVENTION

In accordance with the practice of this invention, there is provided a gaseous discharge display/memory device having charge storage members, each of which comprises at least one thin continuous dielectric film having a minimum thickness sufficient to store charges without breaking down or otherwise deteriorating upon gas discharge due to thermal, physical, electrical, or other operation originated stresses and having a maximum thickness less than that thickness where the film becomes discontinuous due to breakdown caused by deposition originated stresses.

In the practice hereof, it is contemplated that the dielectric thickness may typically range from about 250 angstrom units up to about 150,000 angstrom units, preferably about 10,000 angstrom units up to about 100,000 angstrom units.

The thin dielectric film may comprise a single layer or a combination of two or more layers, each layer being of the same or different composition.

In the broad practice hereof, it is contemplated using a thin dielectric film comprised of one or more layers selected from any suitable metal or metalloid compound, particularly oxides.

It is especially contemplated using oxides of Al, Ti, Zr, Hf, Si, Pb, or Groupa IIA (Be, Mg, Ca, Sr, Ba, or Ra).

One specific combination contemplated herein comprises a first layer of silicon oxide having a thickness of about 10,000 angstrom units to about 70,000 angstrom units, a second layer of aluminum oxide having a thickness of about 100 angstrom units to about 2,000 angstrom units, and a third (or top) layer of lead oxide having a thickness of about 100 angstrom units to about 2,000 angstrom units.

Another specific combination includes a first layer of about 10,000 angstrom units to about 70,000 angstrom units of silicon oxide and a second layer of about 100 angstrom units to about 2,000 angstrom units of lead oxide.

Another specific combination includes a first layer of about 10,000 angstrom units to about 70,000 angstrom units of silicon oxide and about 100 angstrom units to about 2,000 angstrom units of magnesium oxide.

Another specific combination includes a first layer of about 10,000 angstrom units to about 70,000 angstrom units of silicon oxide, about 100 angstrom units to about 2,000 angstrom units of aluminum oxide, and about 100 angstrom units to about 2,000 angstrom units of magnesium oxide.

Another specific combination includes a first layer of about 10,000 angstrom units to about 125,000 angstrom units of aluminum oxide and a second layer of about 100 angstrom units to about 2,000 angstrom units of lead oxide.

Another specific combination includes a first layer of about 10,000 angstrom units to about 125,000 angstrom units of aluminum oxide and a second layer of about 100 angstrom units to about 2,000 angstrom units of magnesium oxide.

Another specific combination includes a first layer of about 10,000 angstrom units to about 40,000 angstrom units of magnesium oxide, about 40,000 angstrom units to about 90,000 angstrom units of aluminum oxide, and about 100 angstrom units to about 2,000 angstrom units of lead oxide.

In addition, one or more dielectric layers may be of an electron emissive substance, as discussed in copending U.S. Pat. Application Ser. No. 67,604, filed Aug. 27, 1970, and owned by the same assignee of the instant application.

It may be especially useful to use an electron emissive substance as the top layer in the dielectric, e.g., with a thickness of about 100 angstrom units to about 2,000 angstrom units. Typical electron emissive materials include not by way of limitation Group IA elements, Group IA oxides, GaAs, GaP, InAs, InSb, InP, NiO, CsF, CsI, AgOCs, and AuOCs. Use of CsI has resulted in substantially lower operating voltages in a gas discharge device.

As used herein the terms "film" or "layer" are intended to be all inclusive of other similar terms such as deposit, coating, finish, spread, covering, etc.

It is contemplated that each dielectric oxide layer may be applied directly to the supporting substrate or formed in situ thereon.

Typical means of applying a dielectric layer directly to a supporting substrate include not by way of limitation vapor deposition; vacuum deposition; chemical vapor deposition; wet spraying upon the surface a mixture or solution of the dielectric composition suspended or dissolved in a liquid followed by evaporation of the liquid; dry spraying of the dielectric composition; electron beam evaporation; plasma flame and/or arc spraying and/or deposition; ion plating; and sputtering target techniques. Likewise, combinations of such techniques may be used.

In situ processes include applying a metal or metaloid (or source thereof) to the supporting substrate and then oxidizing the applied material. The applying of the metal, metalloid, or source thereof may be by any convenient means, such as discussed hereinbefore — vapor deposition; vacuum deposition, etc.

One specific in situ process comprises applying metal or metalloid melt followed by oxidation of the melt during the cooling thereof so as to form the oxide layer. Another in situ process comprises an oxidizable source of the elemental metal or metalloid to the surface. Typical of such oxidizable sources include minerals and/or compounds containing the metal or metalloid, especially those organometals or organometalloids which are readily heat decomposed or pyrolyzed.

One of the advantages of this invention is that the thin dielectric layer or multi-layer is applied directly over the electrode array, thus substantially reducing the relatively high economic cost inherent in a so-called thick-film process. Likewise, the practice of this invention is essentially a cold process, relative to a thick-film process, since thin films may typically be applied at lower temperatures. The use of lower temperatures has the further advantage of reducing the number of electrode breaks and substrate warping.

Although this invention has been primarily described hereinbefore with reference to thin dielectric oxide compositions, other metal or metalloid compounds may be utilized, especially the halides such as MgF_2, BeF_2, CaF_2, NaCl, etc. Likewise, glass or ceramic compositions may be utilized, especially the dolomitic aluminosilicates, borosilicates, lead silicates, and lead borosilicates.

In FIG. **5**, there is shown substrates **16, 17,** gaseous medium **12,** electrodes **13, 14,** and thin dielectric layers **100, 110.**

In FIG. **6,** there is shown substrates **16, 17,** gaseous medium **12,** electrodes **13, 14,** thin dielectric layers **200, 210,** and dielectric overcoats **201, 211.**

In FIG. **7,** there is shown substrates **16, 17,** gaseous medium **12,** electrodes **13, 14,** thin dielectric layers **300, 310,** first overcoats **301, 311,** and second overcoats **302, 312.**

We claim:

1. In a gaseous discharge display/memory device comprising an ionizable gaseous medium in a sealed gas chamber formed by a pair of opposed charge storage members backed by electrode members, the improvement wherein at least one charge storage member, consisting of at least two thin continuous dielectric layers, has an effective thickness ranging between about 250 angstrom units and about 150,000 angstrom units, the minimum thickness being sufficient to store charges without deteriorating upon gas discharge and the maximum thickness being less than that thickness at which said charge storage member becomes discontinuous due to breakdown caused by deposition originated stresses, said charge storage member having a first layer of silicon oxide and at least one additional layer selected from the oxides of Al, Ti, Zr, Hf, Pb, and Group IIA.

2. In a gaseous discharge display/memory device comprising an ionizable gaseous medium in a sealed gas chamber formed by a pair of opposed charge storage members backed by electrode members, the improvement wherein at least one charge storage member, comprising a plurality of layers, has an effective thickness ranging between about 250 angstrom units and about 150,000 angstrom units, the minimum thickness being sufficient to store charges without deteriorating upon gas discharge and the maximum thickness being less than that thickness at which said charge storage member becomes discontinuous due to breakdown caused by deposition originated stresses, the top layer of said charge storage member comprising an electron emissive material selected from Group IA elements, Group IA oxides, GaAs, GaP, InAs, InSb, InP, NiO, CsF, CsI, AgOCs and AuOCS.

3. In a gaseous discharge display/memory device comprising an ionizable gaseous medium in a sealed gas chamber formed by a pair of opposed charge storage members backed by electrode members, the improvement wherein at least one charge storage member, consisting of at least one thin continuous dielectric film, has an effective thickness ranging between about 250 angstrom units and about 150,000 angstrom units, the minimum thickness being sufficient to store charges without deteriorating upon gas discharge and the maximum thickness being less than that thickness at which the film becomes discontinuous due to breakdown caused by deposition originated stresses, said thin dielectric film comprising a compound selected from MgF_2, BeF_2, CaF_2 and NaCl.

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