United States Patent [19]

Hinson

[11] **3,904,915**

[45] **Sept. 9, 1975**

[54] **GAS MIXTURE FOR GAS DISCHARGE DEVICE**

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

[22] Filed: **Nov. 5, 1973**

[21] Appl. No.: **412,576**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 279,875, Aug. 11, 1972.

[52] **U.S. Cl.** ..... **313/484;** 313/226; 313/485; 313/510; 315/169 TV

[51] **Int. Cl.**[2] **H01J 63/04;** H05B 33/02

[58] **Field of Search** ..... 313/108, 109, 223–224, 313/226, 483, 484, 485, 491, 510, 512; 315/169 TV

[56] **References Cited**

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2,714,682 8/1955 Meister et al. 313/109

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Primary Examiner—James W. Lawrence
Assistant Examiner—Marvin Nussbaum
Attorney, Agent, or Firm—Donald Keith Wedding

[57] **ABSTRACT**

There is disclosed a gas discharge device gas mixture consisting essentially of about 15 to 45 percent atoms of argon and about 85 to 55 percent atoms of a xenon-based composition. The mixture is especially beneficial for use in a color phosphor gas discharge display/memory device because the mixture substantially lowers peak gas discharge currents while providing phosphor stimulation. The xenon-based composition consists essentially of about 95 to 100 percent atoms of xenon and about 5 to 0 percent atoms of another component, particularly one or more selected from neon, krypton, nitrogen, helium, and mercury.

11 Claims, 7 Drawing Figures

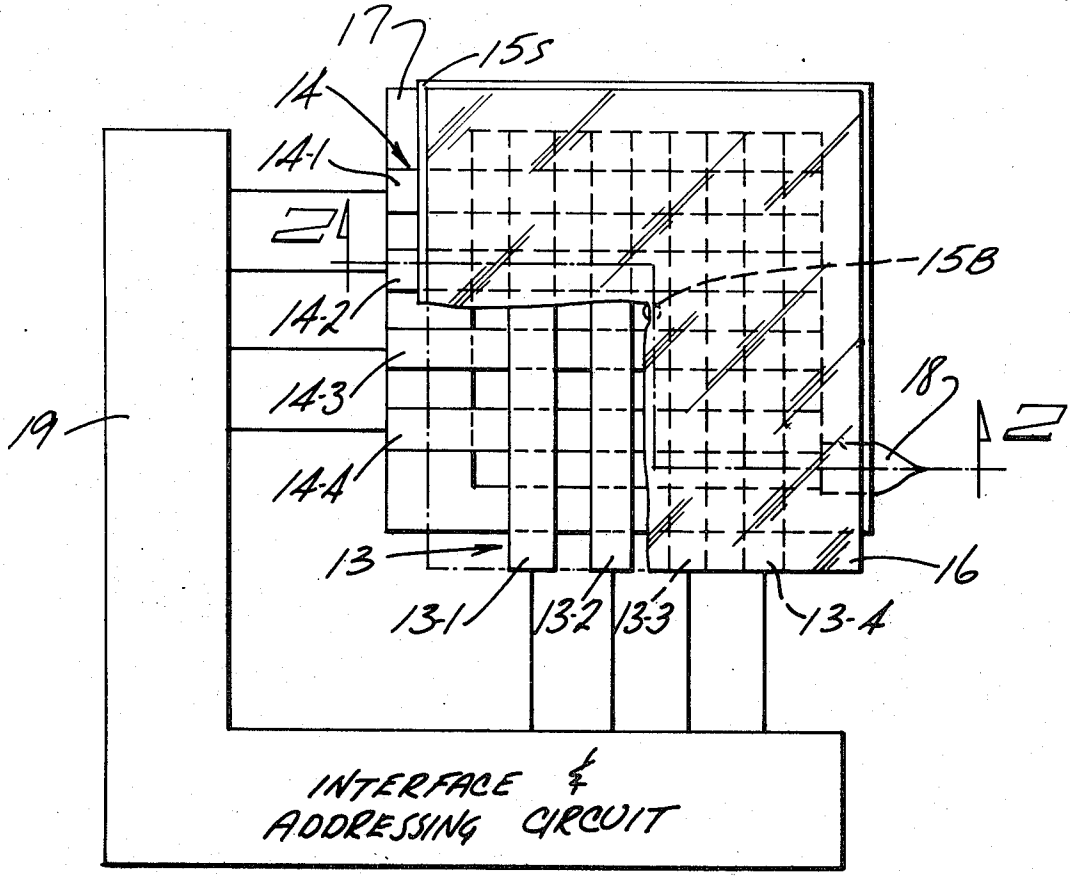


FIG. 2

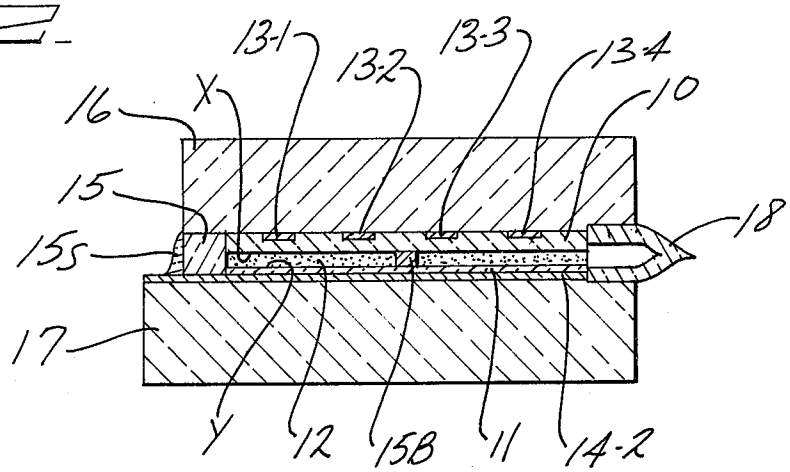

13-1
13-2
13-3
13-4
X
16
10
15
18
15S
17
Y
12
15B
11
14-2

FIG. 1

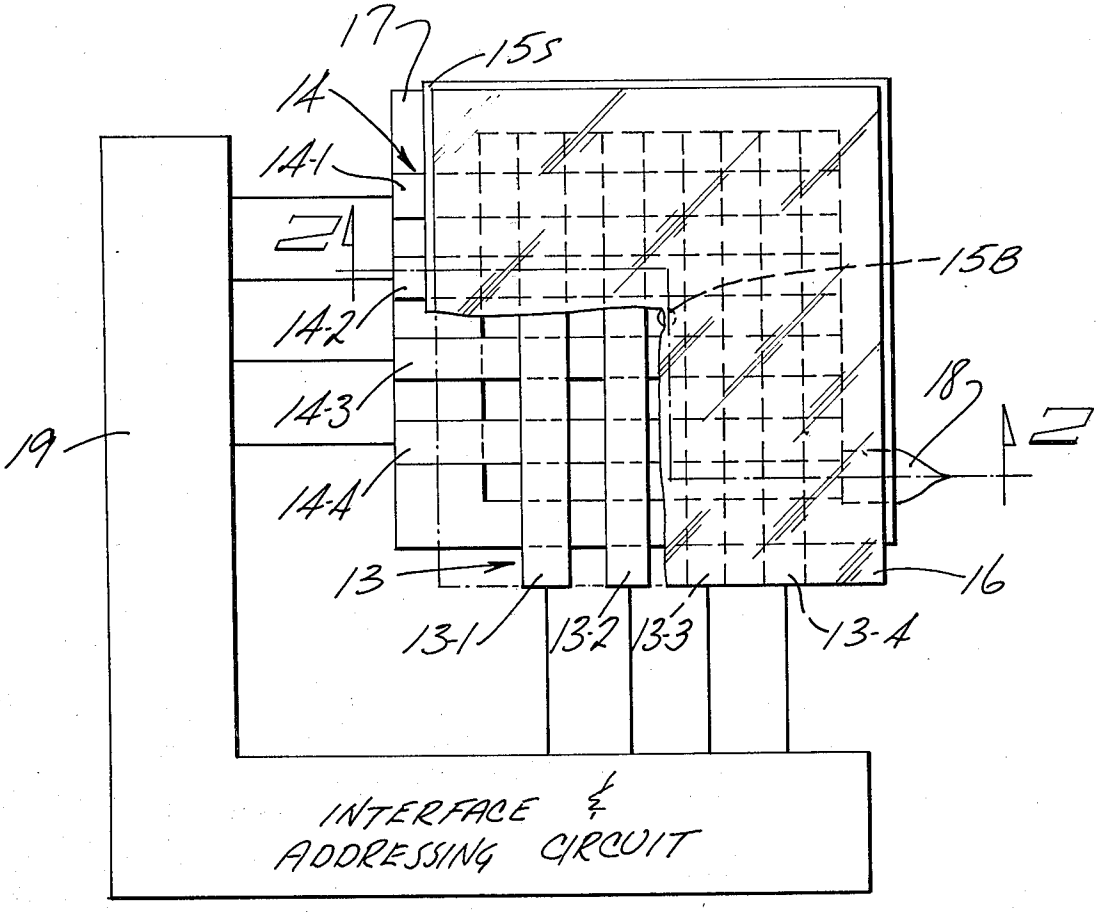

17
15S
14
14-1
2
15B
14-2
14-3
18
2
19
14-4
13
16
13-1
13-2
13-3
13-4
INTERFACE & ADDRESSING CIRCUIT

FIG. 3

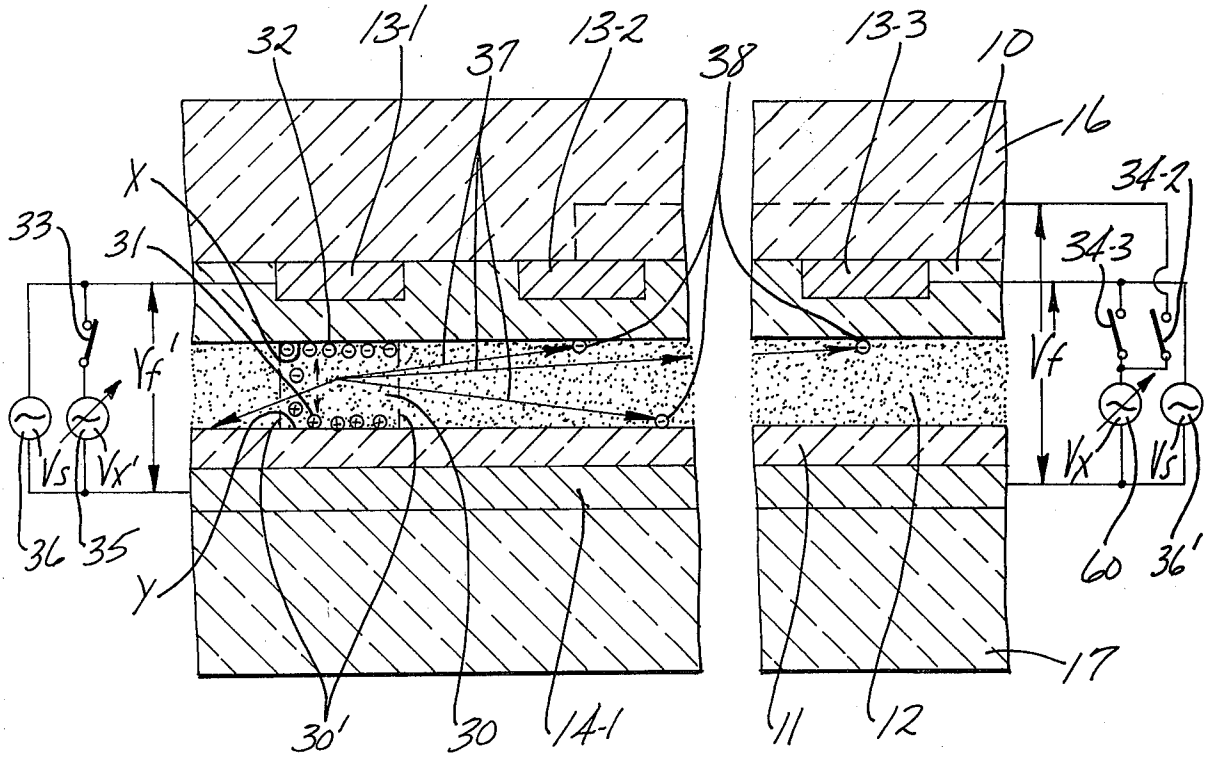

32
13-1
37
13-2
38
13-3
10
16
34-2
X
33
31
34-3
Vf'
Vf
Vs
Vx'
Vx
Vs
36
35
60
36'
Y
17
30'
30
14-1
11
12

FIG. 4

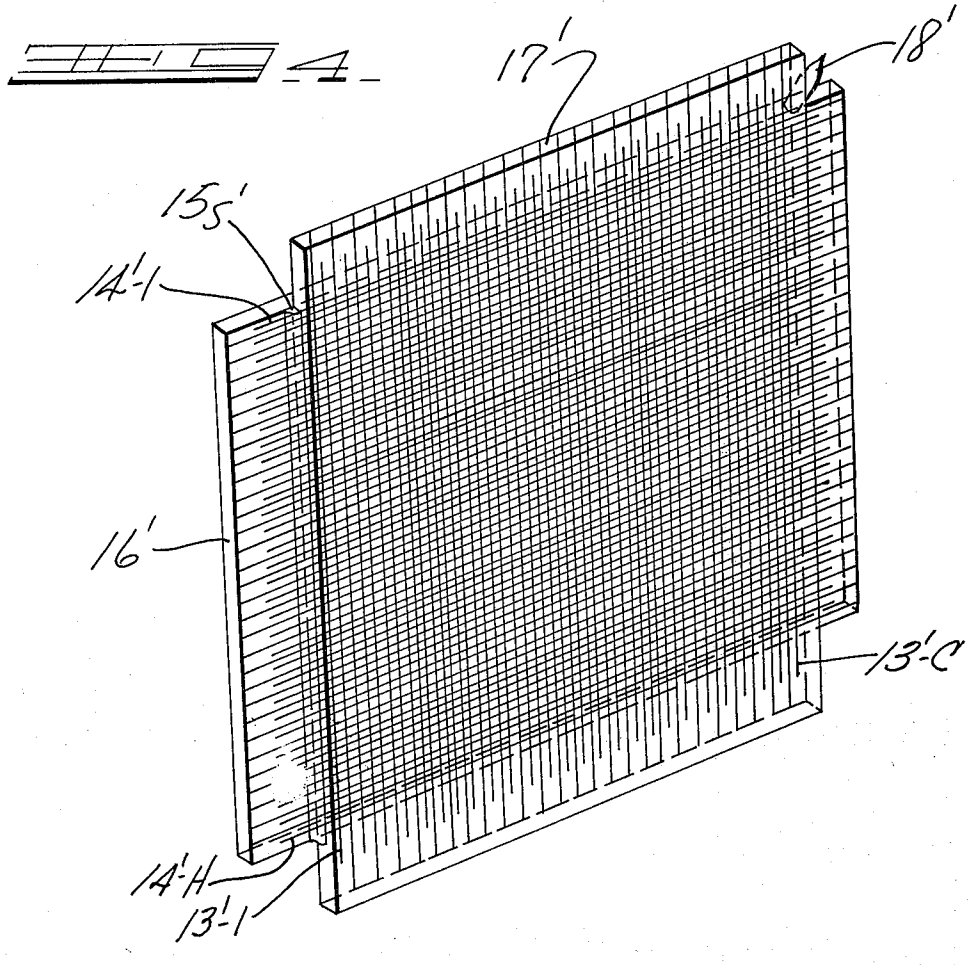

17'
18'
15'
14'-1
16'
13'-C
14'-H
13'-1

FIG. 5

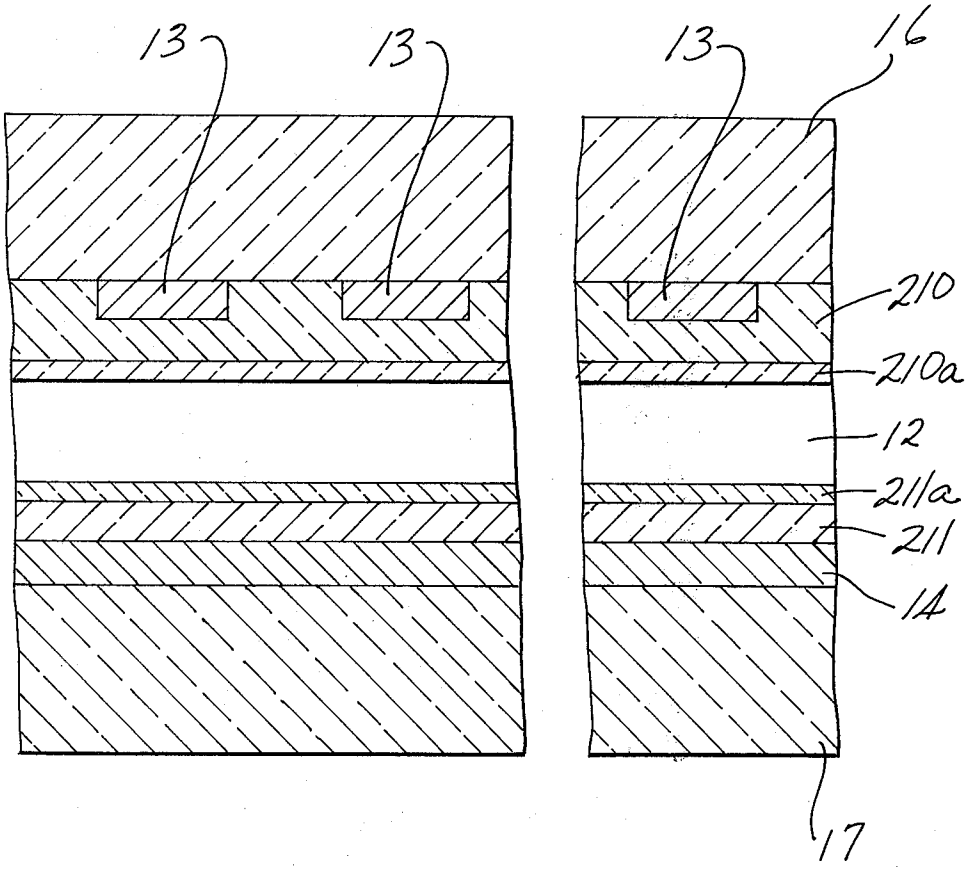
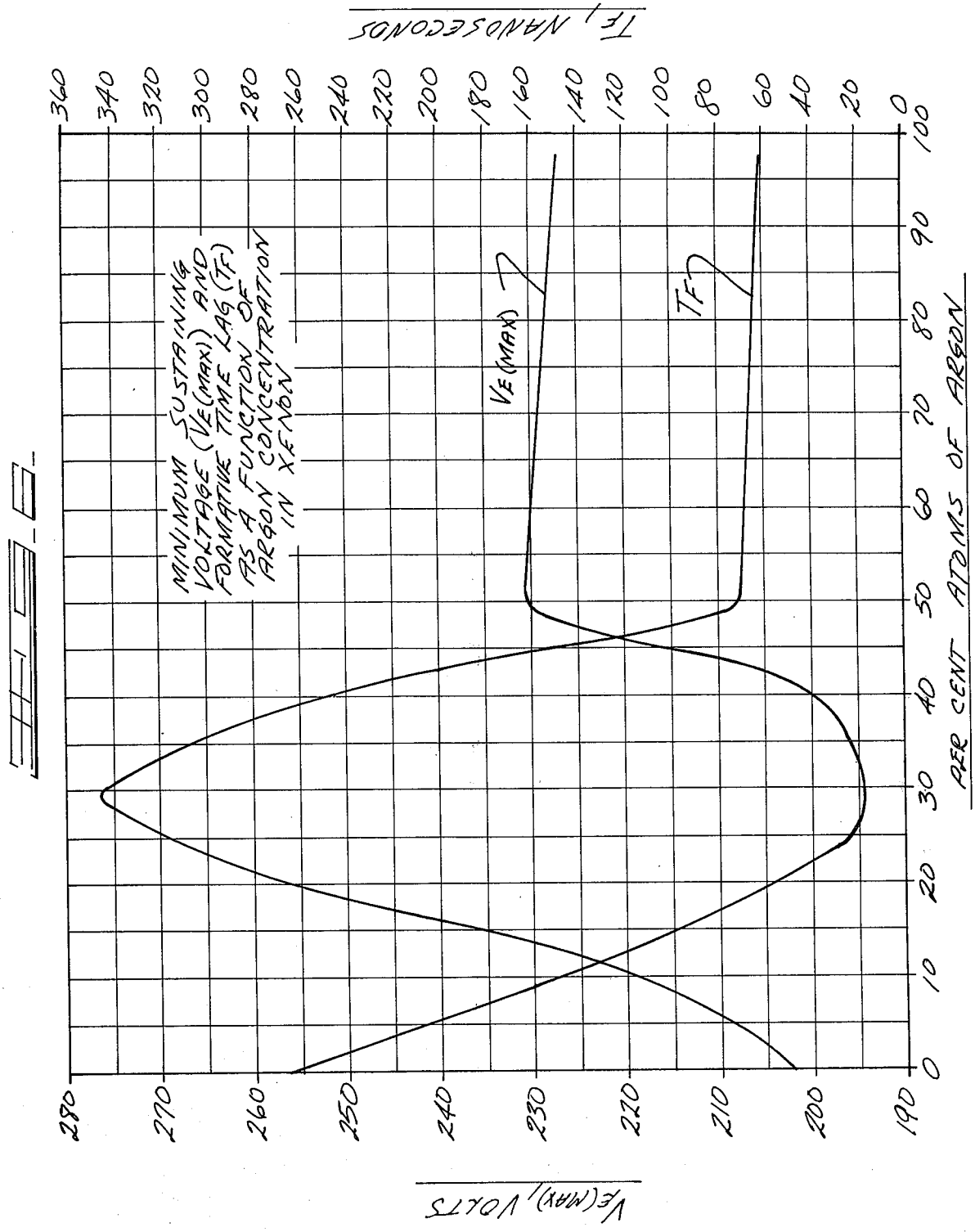


FIG. 6


MINIMUM SUSTAINING VOLTAGE ($V_{E(MAX)}$) AND FORMATIVE TIME LAG (T_F) AS A FUNCTION OF ARGON CONCENTRATION IN XENON
$V_{E(MAX)}$
T_F
$V_{E(MAX)}$, VOLTS
T_F, NANOSECONDS
PER CENT ATOMS OF ARGON
280
270
260
250
240
230
220
210
200
190
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100

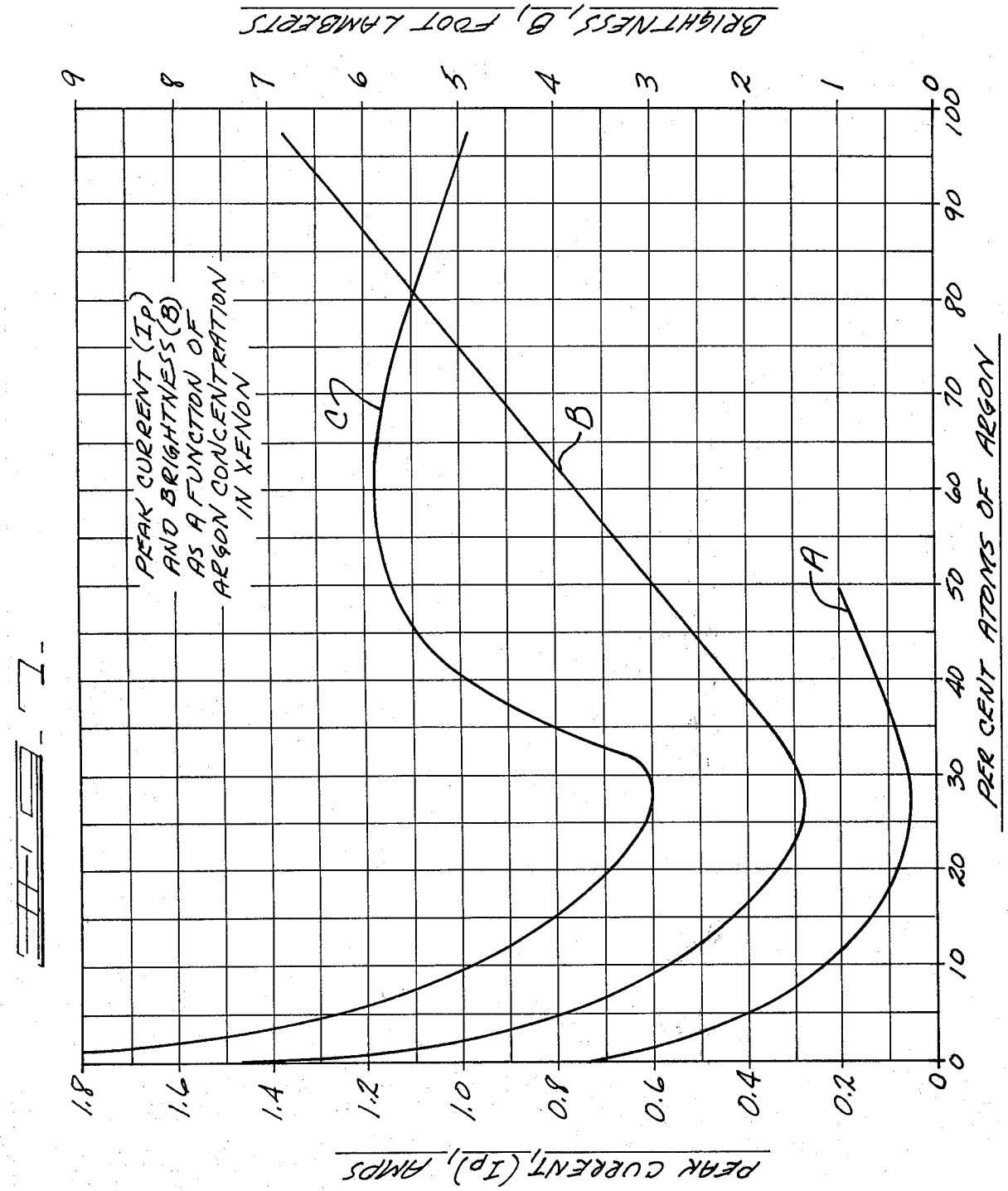

PEAK CURRENT (Ip), AMPS
BRIGHTNESS, B, FOOT LAMBERTS
PER CENT ATOMS OF ARGON
PEAK CURRENT (Ip) AND BRIGHTNESS (B) AS A FUNCTION OF ARGON CONCENTRATION IN XENON
A
B
C

FIG. 7

GAS MIXTURE FOR GAS DISCHARGE DEVICE

RELATED APPLICATION

This is a continuation-in-part of copending U.S. Pat. Application Ser. No. 279,875 filed Aug. 11, 1972.

BACKGROUND OF THE INVENTION

This invention relates to gas discharge devices, especially multiple gas discharge display/memory devices which have an electrical memory and which are capable of producing a visual display or representation of data such as numerals, letters, radar displays, aircraft displays, binary words, educational displays, 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 constituting 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 constitute an electrical memory.

An example of a panel structure containing non-physically isolated or open discharge cells is disclosed in U.S. Letters Patent 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, California, November 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 two conductor arrays may be orthogonally related sets of parallel lines (but any other configuration of conductor arrays may be used). The two arrays define at their intersections a plurality of opposed pairs of charge storage areas on the surfaces of the dielectric bounding 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 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 elemental areas on two different substrates, but between two contiguous or adjacent elemental areas 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 (e.g., a segmented digit display).

The gas is selected to produce visible light and invisible radiation which may be used to stimulate 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; H_2S; deoxygenated air; phosphorus 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 disclose 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

$$M.\,M. = \frac{V_f - V_E}{V_f/2}$$

where V_f is the half-of-peak-to-peak amplitude of the smallest sustaining voltage signal which results in a discharge every half cycle, but at which the cell is not bistable 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 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.

FIG. **5** is a further cross-sectional view similar to FIG. **3** showing specific location of the phosphor.

FIG. **6** is a plot of minimum sustaining voltage and formative time lag as a function of argon concentration in an argon-xenon gas mixture.

FIG. **7** is a plot of peak current as a function of argon concentration and a plot of brightness as a function of argon concentration.

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 the nonconductive support members **16** and **17** pass light produced by discharge in the elemental gas volumes. Preferably, they are transparent glass members. 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 3 to 8 mils, dielectric layers **10** and **11** (over the conductors at the elemental or discrete X and Y areas) are usually between 0.1 and 2 mils thick, and conductors **13** and **14** at least about 1,000 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 be transparent to light.

The electrical properties of support members **16** and **17** are not critical so long as the electrodes are appropriately insulated from one another. 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. Ordinary ¼ inch commercial grade soda lime plate glasses have been used for this purpose. Other glasses such as low expansion glasses or devitrified glass can be used provided they can withstand processing.

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, vaccum 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 for one typical commercial configuration. 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 3000 ohms per line. Alternately, narrow opaque electrodes may be used so that discharge light passes the edges of the electrodes to reach 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** should have a dielectric breakdown voltage of about 1000 v. and be electrically homogeneous on a microscopic scale (e.g., no cracks, bubbles, 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 the facing surfaces of the two dielectric films is about 3 to 8 mils if the conductor arrays **13** and **14** have center-to-center spacing of about 17 mils.

The ends of conductors **14-1 . . . 14-4** and support members **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. In addition, by providing a panel having greater uniformity in discharge characteristics throughout the panel, manufacturing tolerances of the interfacing circuitry can be 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. 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 instance 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 created in every other discrete elemental gas volumes, and condition these volumes for operation at a firing potential V_f which is lower in magnitude than the firing potential V_f' for the initial discharge.

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 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 substanially 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 "fixed" 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 irradiating the panel with ultraviolet radiation or by including 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 typically in the submicrosecond 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 at the opposed elemental areas X and Y, the elemental gas volume **30** will discharge again at or near the peak of the following half cycle of V_s (which is of opposite polarity) 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_r from source **60** is selectively added by one or both or 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 by photons from 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 discharges 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 that 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, so that the gap between plates remains substantially uniform over their entire surfaces. 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 Patent 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. 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.

In gas discharge devices of the aforementioned types, phosphors may be appropriately positioned within the device so as to be excited by radiation from the gas discharge of the device. For example, in a memory charge storage device of the Baker, et al. type, phosphors can be positioned on or be embedded in one or more charge storage dielectric surfaces, such as disclosed in copending U.S. Pat. Application Ser. No. 101,433, filed Dec. 24, 1970 by Robert N. Clark, and assigned to the same assignee as the instant application.

The presence of the phosphors within the device can be utilized to provide color display, the color being the result of radiation emitted by an excited phosphor alone or in combination with radiation emitted by the gas discharge, such as disclosed in copending U.S. Pat. Application Ser. No. 199,802, filed Nov. 17, 1971 by Felix H. Brown and Maclin S. Hall and assigned to the same assignee as the instant application.

In the prior art, phosphor panels of the gas discharge display/memory type have been operated with various gas mixtures, especially rare gas mixtures such as pure xenon or Penning mixtures of xenon in neon, having extremely high peak discharge currents such that a driver circuit is necessary for each electrode line of a proposed large area color display terminal. For example, a **1,000,000** cell display (1024 discharge cells by 1024 discharge cells) with a peak discharge current of one milliamp per cell has a possible total peak discharge current of 1000 amps when all of the panel cells are in the on-state. Present multiplexing electronic circuitry cannot handle this much peak current.

THE INVENTION

In accordance with this invention, there has been discovered a gas mixture having peak discharge currents per cell lower by an order of magnitude (factor of 10) relative to pure xenon or heavy xenon Penning mixtures in the same panel.

More particularly, in accordance with this invention, the peak gas discharge currents of a multiple gas discharge display/memory phosphor device are substantially decreased by utilizing an ionizable, phosphor stimulating, gaseous mixture consisting essentially of about 15 to 45 percent atoms of argon and about **85** to **55** percent atoms of a xenon-based composition.

As used herein, the xenon-based composition is defined as consisting essentially of about 95 to 100 percent atoms of xenon and **5** to **0** percent atoms of another gaseous component, such as already mentioned hereinbefore, particularly one or more members selected from neon, krypton, nitrogen, helium, and mercury.

In a preferred embodiment of this invention, the gaseous mixture consists essentially of about 25 to about 40, most preferably 25 to 35, percent atoms of argon incorporated with a majority gas of xenon-based composition.

In addition to the benefit of decreased peak gas discharge currents, the gas mixture also provides lower operating voltages than Xe, similar to Penning mix-

tures, and slower discharge speed (formative time lag). Therefore, there are inherent resultant advantages in electronic circuitry design and operation. Also the static operating voltage range and the mean memory margins are much higher with the gas mixture of this invention relative to pure xenon or Penning mixtures (40 volts compared to 10 volts) thereby indicating improved dynamic operation.

The 15 to 45 atoms percent argon mixture of this invention provides optimum panel operation at a pressure dependent on panel spacing, but generally similar to the Paschen minimum for pure xenon, i.e., about 250 Torr or lower.

This invention was arrived at from an investigation of binary rare gas mixture for use in color phosphor DIGIVUE display/memory panels with the intent purpose of lowering the very high peak discharge currents experienced in phosphor panels using either pure Xe or heavy xenon Penning mixtures. The high xenon concentration is necessary for phosphor stimulation because of its known high ultraviolet light output. Previous work has shown that peak current increases with minority gas concentration in a Penning mixture. It was thought that if the voltage of a predominately xenon mixture could be lowered, without having to make a fast high Xe concentration Penning mixture, the peak current would decrease also. It is known that He-Ne mixtures, although not Penning mixtures, exhibit slight voltage lowering from either of the individual gases, and a search was made for similar mixtures with xenon. Mixtures of argon in xenon were found to exhibit this effect, which is probably associated with the highly efficient excitation exchange from excited Ar_2 molecules to Xe atoms, forming excited Xe atoms from which the characteristic xenon radiation is emitted. The excited Xe atoms can also combine to form excited Xe molecules, which can collide to produce Xe+z ions, leading to efficient gas breakdown and the observed lowered voltages.

In the practice of this invention, it is contemplated using any suitable luminescent phosphor. In the preferred embodiment, the phosphor is photoluminescent. The term "photo-luminescent phosphor" includes quite generally all solid and liquid, inorganic and organic materials capable of converting an input of absorbed photons into an output of photons of different energy, the output comprising visible light of a brightness and intensity sufficient for visual display.

Typical photoluminescent phosphors contemplated include, not by way of limitation, both activated and non-activated compounds, e.g., the sulfides such as zinc sulfides, zinc-cadmium sulfides, zinc-sulfo-selenides; the silicates such as zinc silicates, zinc beryllo-silicate, Mg silicates; the tungstates such as calcium tungstates, magnesium tungstates; the phosphates, borates, and arsenates such as calcium phosphates, cadmium borates, zinc borates, magnesium arsenates; and the oxides and the halides such as self-activated zinc oxide, magnesium fluorides, magnesium fluorogermanate. Typical activators include, not by way of limitation, Mn, Eu, Ce, Pb, etc.

In one highly preferred embodiment, there is utilized a phosphor P1 as defined by JEDEC Electrode Tube Council, Publication No. 16A of January 1966, revised February 1969.

In another preferred embodiment hereof, there is utilized a gas discharge display/memory device containing at least one dielectric charge storage surface, the phosphor being appropriately applied to such dielectric.

In such embodiment, the phosphor may be applied to the dielectric by way of any convenient method including, not by way of limitation, vapor deposition; vacuum deposition; chemical vapor deposition, wet spraying or settling upon the dielectric a mixture or solution of the phosphor suspended or dissolved in a liquid, followed by evaporation of the liquid; silk screening; dry spraying of the phosphor upon the dielectric; electron beam evaporation; plasma flame and/or arc spraying and/or deposition; thermal evaporation; laser evaporation; Rf or induction heating evaporation; sputtering target techniques; and/or attachment of the phosphor to the dielectric as disclosed in the copending U.S. Pat. application Ser. No. 101,433, filed Dec. 24, 1970 by Robert N. Clark, and assigned to the assignee of the instant patent application.

In accordance with the broad practice of this invention, it is contemplated applying the phosphor to the dielectric (surface or sub-surface) in any suitable geometric shape, pattern, or configuration, symmetrical or asymmetrical as disclosed for example in the copending U.S. Pat. Application Ser. No. 98,846, filed Dec. 16, 1970 by Felix H. Brown and Robert F. Schaufele, and assigned to the assignee of the instant patent application.

FIG. 5 is a cross-sectional view similar to FIG. 4.

In FIG. 5, there is shown substrates 16 and 17, electrodes 13 and 14, dielectric members 10 and 11, gaseous medium 12, and phosphor 20 selectively applied to the gas contact surfaces of dielectric members 10 and 11.

In FIG. 6, there is shown a plot of minimum sustaining voltage and formative time lag as a function of argon concentration in an argon-xenon gas mixture in a 33 lpi (electrode lines per inch) tri-color panel.

In FIG. 7, there is shown a plot of peak current as a function of argon concentration in an argon-xenon gas mixture in a 33 lpi (curve B) and 60 lpi (curve A) tri-color panel and a plot of brightness as a function of argon concentration for both a 33 lpi and 60 lpi tri-color panel (curve C). For the 60 lpi panel (curve A), the peak current is plotted in milliamps per cell. Both the 33 and 60 lpi panels are represented by the same brightness curve B.

Formative time lag is the different between the time at which the sustaining voltage reaches its maximum value and the time at which the discharge current pulse reaches its peak value.

Peak discharge current is defined as the maximum instantaneous value the current reaches across a given portion of the panel while the panel is in the "on" state.

Sustaining voltage is as already defined hereinbefore.

A tri-color panel is one containing at least three different colors of phosphor, each phosphor being located in the vicinity of a different cell site. Three cell sites, each of a different phosphor color output, and a fourth cell having no phosphor make up a four cell arrangement.

As shown by the FIGS. 6 and 7, there is some decrease in relative brightness over the range of this invention. However, this trade-off is more than compensated by the decrease in peak current.

I claim:

1. In a process for operating a multiple gas discharge device comprising a multiplicity of gas discharge cells,

electrodes locating the cells, an ionizable gaseous medium at the cells, and at least one phosphor, with radiation from the gas discharge exciting the phosphor, the improvement which comprises decreasing the peak gas discharge currents by utilizing an ionizable gaseous medium consisting essentially of about 15 to 45 percent atoms of argon and about 85 to 55 percent atoms of a xenon-based composition, said xenon-based composition consisting essentially of about 95 to 100 percent atoms of xenon and about 5 to 0 percent atoms of another selected component.

2. The invention of claim **1** wherein the other component is a member selected from neon, krypton, nitrogen, helium, and mercury.

3. The invention of claim **1** wherein the device is of the display/memory type and includes at least one dielectric insulation charge storage member on one electrode thereof, and said phosphor is applied to said dielectric member.

4. The invention of claim **1** wherein the gaseous medium consists essentially of 25 to 40 percent atoms of argon and 75 to 60 percent atoms of a xenon-based composition.

5. The invention of claim **1** wherein said at least one phosphor is a **P1** phosphor.

6. In an article of manufacture comprising a multiple gas discharge phosphor display device containing an ionizable gaseous medium, the improvement wherein the gaseous medium consists essentially of 15 to 45 percent atoms of argon and 85 to 55 percent atoms of a xenon-based composition, said xenon-based composition consisting essentially of about 95 to 100 percent atoms of xenon and about 5 to 0 percent atoms of another selected component.

7. The invention of claim **6** wherein the phosphor in said phosphor display device is a **P1** phosphor and said gas discharge phosphor display device includes a dielectric having charge storage surface and the **P1** phosphor is applied to said dielectric.

8. The invention of claim **6** wherein the other component is a member selected from neon, krypton, nitrogen, helium, and mercury.

9. The invention of claim **8** wherein the device is of the display/memory type and contains at least one dielectrically insulated electrode.

10. The invention of claim **6** wherein the gaseous medium is at a pressure of 250 Torr or less.

11. The invention of claim **6** wherein the gaseous medium consists essentially of 25 to 40 percent atoms of argon and 75 to 60 percent atoms of a xenon-based composition.

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