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REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,588,874

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : N/A

NASA Patent Case No. : ERC-10100

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☐ No ☒

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

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Enclosure
Copy of Patent cited above

FACILITY FORM 602

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United States Patent

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Hans B. Bullinger, Peabody, Mass.

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[22] Filed Oct. 11, 1968
[45] Patented June 28, 1971
[73] Assignee The United States of America as represented by the Administrator of the National Aeronautics and Space Administration

[54] **PLASMA-FLUIDIC HYBRID DISPLAY**
14 Claims, 6 Drawing Figs.

[52] U.S. Cl. 340/324, 313/109.5, 313/231, 315/108, 315/111, 340/336
[51] Int. Cl. H01j 17/22, H01j 61/28
[50] Field of Search .... 340/324, 334, 336, 343, (Inquired); 313/231, 109.5, 210, 175; 315/111, 108

[56] References Cited
UNITED STATES PATENTS

1,725,281	8/1929	Kingdon	313/175
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Primary Examiner—John W. Caldwell
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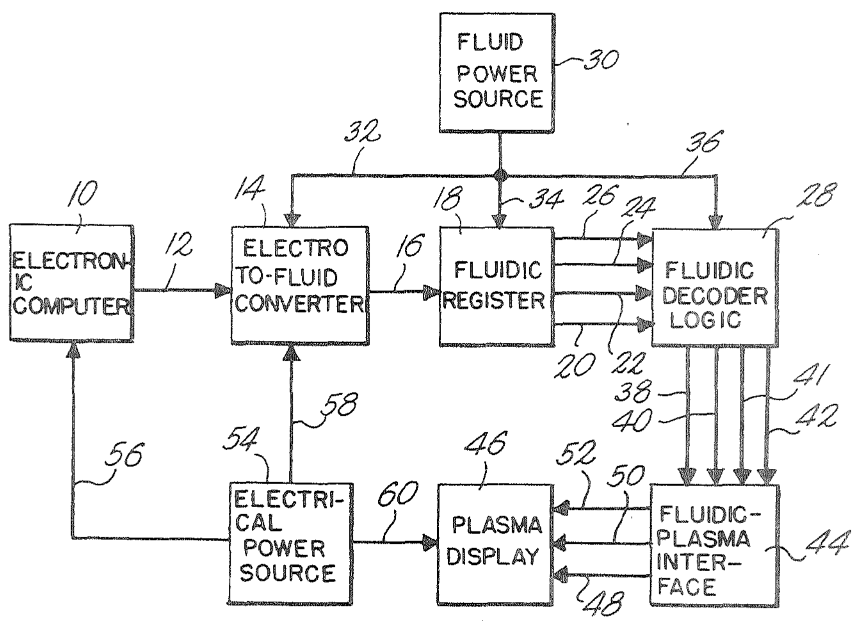
ABSTRACT: A plasma-fluidic hybrid display system combining the desirable high brightness and inherent memory characteristics of plasma display devices, such as neon tubes, with the equally desirable reliability and memory characteristics of fluidic logic devices, such as pure fluid amplifiers with no moving parts. System comprises an array of plasma cells, an electrical source for energizing the array, a fluid pressure source for pressurizing same and a fluidic logic circuit connected to each cell. Fluidic circuit changes the pressure within each cell and thus permits or suppresses ionization within selected cells.

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.



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SHEET 1 OF 2

Fig. 1.

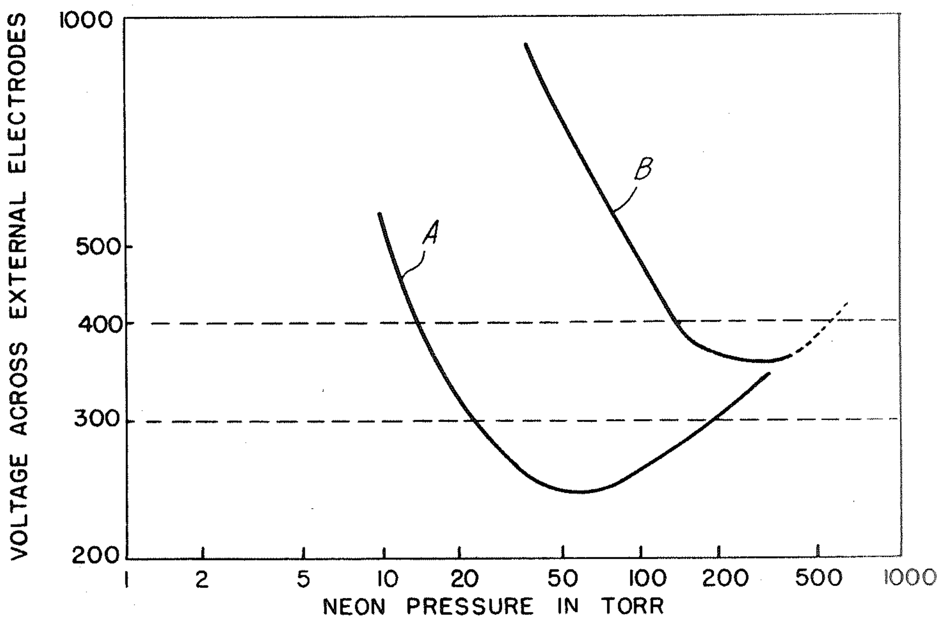

Fig. 2.

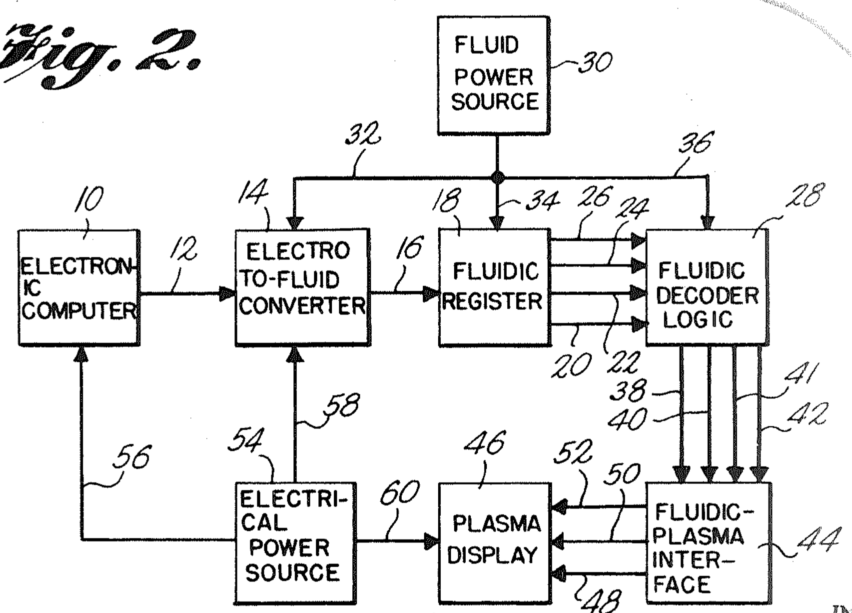

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Fig. 3.

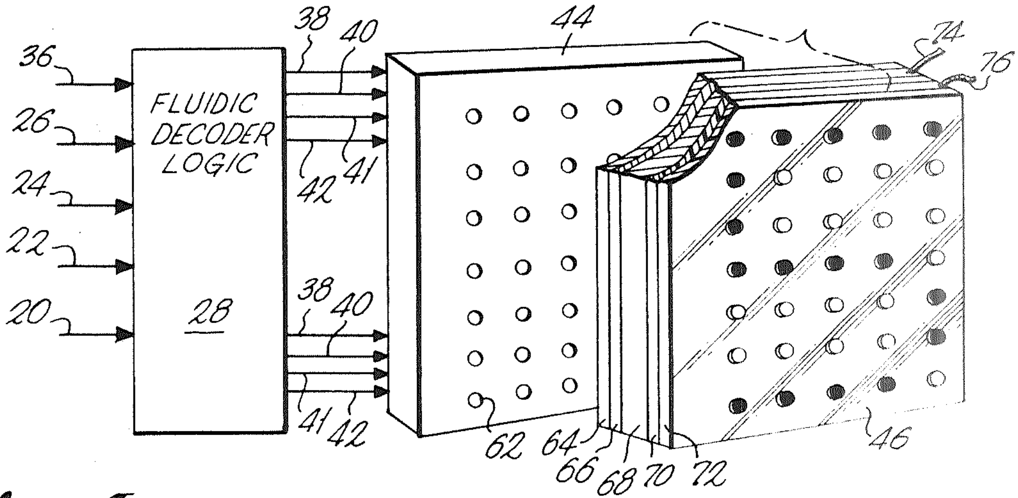


Fig. 4.

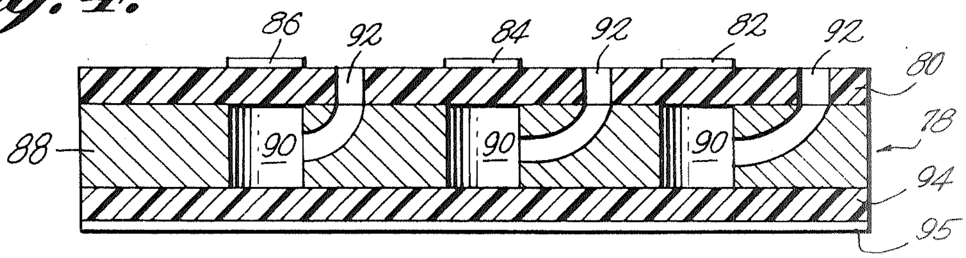


Fig. 5.

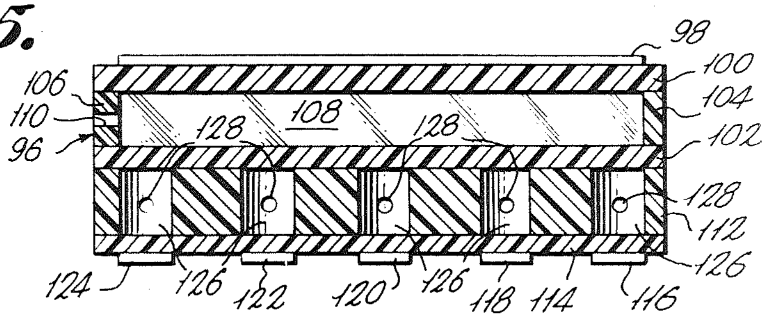
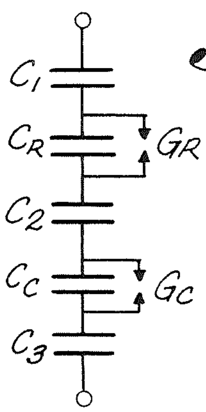


Fig. 6.



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PLASMA-FLUIDIC HYBRID DISPLAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to an information display matrix utilizing an array of gas filled cells, and more particularly to the interrelated electrical and fluidic circuitry for controlling the ignition of selected cells within the array.

2. Description of the Prior Art

The use of display devices employing therein electrical discharges between electrodes situated on opposite sides of the interior walls of gas filled tubes, also known as plasma display, has gained widespread acceptance, for such display devices provide an efficient and reliable manner of visually indicating information. The efficiency and reliability of the tubes is due to the high energy conversion as well as to the unique operational characteristic that such tubes are not susceptible to the catastrophic or sudden failure which occurs in conventional bulbs containing electrical filaments. Neon glow tubes are exemplary of this broad category of gas filled display devices, for neon tubes do not fail suddenly but exhibit a gradual diminution in light output as material from the internal electrodes is gradually sputtered off and accumulates within the interior of the glass tube or envelope.

The above noted shortcoming of conventional tubes with internal electrodes has been overcome, in large measure, by the deposition of electrodes on the outside of the glass envelope. However, the use of external electrodes has given rise to equally significant shortcomings, namely, greatly increased power consumption and more complex switching circuitry. Thus, while tubes with internal electrodes can be run efficiently on direct current or low frequency AC current, tubes with external electrodes require high frequency AC current, usually in the range of several hundred kilohertz. A representative display device using external electrodes is disclosed by U.S. Pat. No. 2,920,408, granted to T. B. McGuire.

Furthermore, both varieties of tubes have previously proven to be unsatisfactory for use in large arrays for the visual presentation of dynamic graphic or alphanumeric information. The unsatisfactory performance can be traced to the complexities of the electrical switching circuits for the tubes due to the high voltage required for operation thereof. To illustrate, conventional tubes with internal electrodes require 80 to 100 volts for their operation, whereas known tubes with external electrodes require several hundred volts for their operation. Therefore, known tubes, or arrays of tubes, are not directly compatible with the outputs of computers or most sensors, which generate an output voltage which is but a minute fraction of the voltage necessary to ignite a tube with internal electrodes. In order to effectuate the requisite voltage step-up to achieve compatibility, complex switching circuitry must be interconnected between the computer output and the array of tubes. The expenses and inconvenience in installing and maintaining such circuitry has sorely limited the acceptance, to date, of plasma display devices.

Let us now examine previous developments concerning the other aspect of the instant plasma-fluidic hybrid display, namely, fluidics. This rapidly developing technology, which is characterized by the utilization of no moving parts other than the fluid streams passing through the logic elements, has previously produced only visual readout and display devices compatible with fluidic signals. Little effort has been made to blend a fluidic output signal from a computing network or sensing system into a more comprehensive, integrated display system.

Accordingly, U.S. Pat. No. 3,001,698, granted to R.W. Warren, and U.S. Pat. No. 3,370,906, granted to P. Bauer, respectively disclose a pivotable tab and a rotatable mirror that are pivoted into indicating position when an output signal from a fluid amplifier, or a series of amplifiers, impinges thereupon. U.S. Pat. No. 3,057,375, granted to T. L. Etter, and U.S. Pat. No. 3,305,171, granted to E.R. Phillips et al., disclose a lightweight ball that is driven to an indicating position in response to a fluidic output signal. U.S. Pat. No. 3,200,525, granted to S.A. Francis, and U.S. Pat. No. 3,249,302, granted to R. E. Bowles, exhibit somewhat more sophisticated and effective fluidic controlled matrices with colored fluids passing therethrough for enhanced visual effectiveness. However, it is readily apparent that none of these fluidic display devices suggest a marriage to an alien technology, such as plasma display devices, to enhance and augment their limited operational capabilities in terms of speed, visual acuity, and compatibility to electronic computational equipment.

SUMMARY

Thus, with the deficiencies of known plasma display and fluidic display devices enumerated above in mind, the instant invention contemplates a plasma-fluidic hybrid display device that incorporates therein the desirable characteristics of both of these previously diverse technologies. This hybrid display device is predicated upon the proven principle that there exists an optimum pressure at which a gas filled cell or envelope can be ignited at a minimum voltage, for a plasma cell of given dimensions, particular electrode spacing, and a particular gas or gas mixture. Fluidic logic elements are connected to each cell for reliably controlling the firing of selected cells within a plasma matrix predicated upon such principle.

Furthermore, the inherent storage or memory characteristics of both the fluidic element and the plasma display minimize the requirements for the utilization of a computer memory to update the display at a flicker free rate and the switching speed of the fluidic logic elements provides updated information at rates which can be assimilated by a human operator.

Accordingly, a principal object of the instant invention is to provide a reliable, high brightness display which can produce brightness values ranging as high as 800 to 1,000 foot-lamberts, while obviating the use of high voltage switching circuits for individual display tubes or cells.

Another significant object is to provide a hybrid display which combines the desirable characteristics of two distinct technologies, namely, gas discharge and fluidics.

A further object is to provide a display having inherent storage characteristics so as to minimize requirements for the use of a computer memory.

Other objects and advantages of the instant invention will become apparent in light of the following description of the invention when construed in connection with the accompanying sheets of drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph illustrating the relationship between pressure and firing voltage for conventional plasma cells containing neon gas;

FIG. 2 is a block diagram of the hybrid plasma fluidic display system embodying the principles of the instant invention;

FIG. 3 is an exploded perspective view of a portion of the display system;

FIG. 4 is a cross-sectional view of a single level plasma display module;

FIG. 5 is a cross-sectional view of a dual level plasma display module; and

FIG. 6 is a schematic representation of the electrical circuit equivalent to the dual level plasma display module of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in greater detail to the drawings in which similar reference numerals refer to similar components, FIG. 1 illustrates the minimum firing voltage for two different sized plasma cells A, B as a function of gas pressure. In this instance, the cells are filled with neon gas, although other inert gases are equally suitable, and the cells have external electrodes. Operational curves for cells with internal electrodes can be developed with equal facility.

Cell A has a depth of 0.10 cm. and a radius of 0.066 cm., while cell B has a depth of 0.025 cm. and a radius of 0.017 cm. These operational curves were computed on page 41 of Report R-303 published in June 1966 by the University of Illinois Coordinated Science Laboratory. The voltage applied across the external electrodes is plotted along the ordinate in volts, and the gas pressure in each cell is plotted along the abscissa in Torrs.

Thus, FIG. 1 shows that when an array of cells A, having the above noted dimensions, is supplied with 300 volts, only those cells having internal gas pressures ranging between 20 and 200 Torr will fire or ignite across their external electrodes. Such pressure range is indicated by the dishlike portion of the operational curve below the dotted line extending horizontally across the graph at 300 volts. Similarly, with respect to an array of cells B, FIG. 1 shows that, when supplied with 400 volts, only those cells having internal gas pressures ranging between 150 and 500 Torr will fire or ignite across their external electrodes. Such pressure range for cells B is indicated by the dishlike portion of the operational curve below the dotted line extending horizontally across the graph at 400 volts.

FIG. 2 depicts a block diagram of a hybrid plasma-fluidic system utilizing the principle depicted in FIG. 1 that there exists an optimum pressure at which a gas filled tube can be fired at a minimum voltage. The sequence of operation of the hybrid circuit, as well as the connections between the diverse components of the circuit, is shown in FIG. 2 by appropriate directional arrows.

Thus, the output from conventional electronic computer 10 is fed via line 12 to an electro-to-fluid converter or transducer 14, wherein the electrical signal is converted into a fluidic pulse. Representative transducers are disclosed in U.S. Pat. No. 3,266,511, granted to J. M. Turick and U.S. Pat. No. 3,269,419, granted to E.M. Dexter.

The fluidic pulse is then transmitted from transducer 14 via conduit 16 to a fluidic shift register 18, stored temporarily therein, and then introduced in parallel over conduits 20, 22, 24 and 26 to fluidic decoder logic module 28. A fluidic power source 30 simultaneously pressurizes the converter 14, the fluidic shift register 18, and the fluidic decoder logic module 28 via conduits 32, 34 and 36, respectively.

The fluidic outputs from the decoder logic module 28 are introduced via lines 38, 40, 41 and 42, respectively, to a plasma-fluidic interfacing block 44. As will become apparent from the ensuing disclosure when construed in conjunction with FIG. 3, block 44 has a series of apertures in registry with a like series of cavities in plasma display device 46. Communication between the apertures in block 44 and the cavities in plasma display device 46 is established via conduits 48, 50 and 52. The block diagram of FIG. 2 is completed by the provision of an electrical power source 54 which simultaneously supplies power of the requisite voltage and frequencies to electronic computer 10, converter or transducer 14 and plasma display device 46 via leads 56, 58 and 60 respectively. It is noted that the number of electrical leads and fluid conduits illustrated is selected for clarity and is merely representative of the far greater number to be employed within the actual hybrid display system.

FIG. 3 shows a combined schematic and perspective view of a portion of the block diagram of FIG. 2. More specifically, FIG. 3 illustrates, in detail, the structural and functional relationships between fluidic decoder logic module 28, fluidic plasma interface block 44, and plasma display device 46.

Logic module 28 is pressurized from fluid power source 30 over conduit 36, and receives fluidic binary signals, in parallel, over conduits 20, 22, 24 and 26 from fluidic shift register 18. Alternatively, conduits 20, 22, 24 and 26 can convey fluidic binary signals from a bank of electro-to-fluid converters or transducers (not shown).

Fluidic decoder logic module 28, in turn, transforms the plurality of binary signals received therein into an output signal using a different numerical base. The base most frequently selected is ten so as to be compatible with the decimal system of computation. The decimal output from module 28 provides selectively controlled gas pressure or gas flow via conduits 38, 40, 41 and 42 to fluidic-plasma interface block 44. The block is fabricated from rigid plastic or metal, and is characterized by a regular pattern of spaced apertures 62 extending through the block. Apertures 62 open outwardly at the rear face of block 44 to accommodate therein the output conduits, such as 38, 40, 41 and 42, from logic module 28. These apertures are unobstructed at the front face of block 44, so that the decoded output signals from module 28 can pass freely through selected apertures 62 in the block.

Plasma display device 46 is juxtaposed to block 44 and in alignment therewith, so as to be responsive to the fluid signals passing through apertures 62 in block 44. As seen in the broken away portion in the upper left hand corner of device 46, the device is laminar in nature and comprises a rear cover sheet 64, a rear layer 66 of conductive material, a central thicker insulating layer 68, a transparent forward layer of conductive material 70, and a transparent front cover sheet 72. Rear cover sheet 64 and rear layer 66 contain a regular pattern of spaced apertures (not shown) aligned with apertures 62 of block 44, and conductive layer 66 contains slightly smaller apertures (not shown) aligned with both sets of apertures.

Layer 30 has a series of cavities formed therein, which cavities communicate with apertures 62 through the apertures in layers 64 and 66. One electrode (not shown) is positioned on the innermost face of layer 66 at one end of the cavity, and a second electrode is positioned on the innermost face of forward layer 70. The electrodes are placed on opposite sides of the cavities in layer 68 so as to fire or ionize the neon gas contained therein. Electrical leads 74 and 76 are connected to conductive layers 66 and 70 and sufficient voltage is supplied from a power source (not shown) to create a discharge within the cavities of layer 68. The gas filled cavities that are ignited are visible to the human eye through transparent layers 68 and 70. Thus, by a proper selection of cavities in layer 68 to be pressurized from logic module 28 via apertures 62 in block 44, the numeral "5" has been formed on the front layer 72 of plasma display device 46.

The useful life of conventional gas filled tubes or cells with internal electrodes ranges from 1,000 to 2,000 hours, at which point the material sputtered from the electrodes has settled on the cell walls and the brightness falls below useful levels. However, the instant plasma display provides a much greater surface area for such deposition, thereby increasing the useful lifetime of the system by one to several orders of magnitude.

Furthermore, it is noted that two distinct information storage mechanisms or memory characteristics, i.e., fluidic memory and electrical memory, are correlated within the hybrid display system to increase its responsiveness and efficiency. The ability of fluidic amplifiers to maintain constant fluid flow and pressure in a deflected path after the termination of the fluidic control signal that impinged upon the power stream and deflected same; this memory characteristic is attributable to the well-known Coanda effect. Additionally, since plasma elements with internal electrodes usually exhibit a 20 to 30 volt differential between firing and extinction voltages, the optimum operational voltage for the display system of FIGS. 2 and 3 is approximately midway between the firing and the extinction voltage. Consequently, a slight reduction in gas pressure causes a cell to fire, whereas a slight increase in gas pressure extinguishes a cell. The magnitude of the reduction, or increase, in pressure is well within the switching capabilities of known fluidic amplifiers; similarly, although known fluidic amplifiers are much slower than their electrical counterparts, they are fast enough in operation to update the display device at a flicker free rate.

FIG. 4 depicts a horizontal cross-sectional view of a plasma display device 78, employing external electrodes, such view passing midway through a row of spaced electrodes and cavities. Device 78 is designed to be readily connected into the block diagram circuit of FIG. 2 and actuated thereby; alternatively, device 78 is designed to replace device 46 and to be positioned in alignment with apertures 62 of block 44 in FIG. 3.

Device 78 is laminar in nature and comprises a rear layer of insulating material 80 with a series of spaced rear electrodes 82, 84 and 86 positioned thereon, and a thicker, central layer 88 having a plurality of cylindrical cavities 90 formed therein. Each cavity 90 is pressurized, or exhausted, via an individual passageway 92 which opens rearwardly through layer 80. A transparent front insulating layer 94 with a transparent front electrode 95 affixed thereto complete the sandwichlike structure of device 78.

Each cavity 90 is aligned with apertures 62 in block 44 for fluid communication therewith over passageways 92. When electrical power of the proper voltage and frequency, e.g. 300 volts, 400 kilohertz, is constantly supplied to electrodes 82, 84, 86 and electrode layer 95 by way of suitable leads (not shown) then variations in gas pressure within each cavity 90 will determine which ones of the cells will ignite and define a visible informational pattern.

For simple displays, such as the generation of a single alphanumeric character, the utilization of a separate fluidic element to control the gas pressure and/or flow within an individual cell has been satisfactory. For larger matrices, such as those displaying a plurality of alphanumeric characters, the electrical and fluidic power requirements are such that it is expedient to address individual rows and columns within the matrices. Thus, the number of fluidic control elements or amplifiers required is reduced to 2N rather than N^2 in number, where N represents the number of columns or rows in the matrix. FIG. 5 shows a two level display device, indicated generally by reference character 96, implementing this principle, and FIG. 6 shows the equivalent electrical circuit.

FIG. 5 is a cross-sectional view of a two level display device 96. Device 96 comprises a transparent conductive layer 98, a transparent insulating layer 100, and a second transparent insulating layer 102. Walls 104 and 106 separate layers 98 and 102 and maintain the layers in spaced, parallel relationship. The walls and the separate layers define the outline of a chamber 108, which chamber is pressurized or exhausted, via passageway 110, in strut 106. Alternatively, chamber 108 could be integrally formed within layer 100.

The lower level of device 96 includes a thick insulating layer 112 and a rear cover or insulating layer 114 with a series of electrodes 116, 118, 120, 122 and 124 positioned thereon. Layers 112 and 114 have a plurality of cavities 126 defined therebetween, which cavities are pressurized or exhausted by means of apertures or posts 128 located therein. If so desired, either layers 98 and 100 are transparent or electrodes 116, 118, 120, etc. and layer 114 are transparent, so that the orientation of the display device with respect to a human operator is a matter of design choice.

Gas from the fluidic control elements is admitted to selected cavities 126 via ports 128, each cavity being representative of an individual column within the matrix. Gas from the fluidic control elements is also admitted to chamber 108 via aperture 110 in strut 106, such chamber being representative of a row within the matrix. A cell is formed by the intersection of a column and a row. To ignite the cell, both the column and the row must be addressed, by fluidic control elements, such as decoder logic module 28 and block 44, and the conductive layers 98 and 116, 118, 120, 122 and 124 must be energized over suitable leads from an electrical power source.

Turning now to FIG. 6, which is the electrical circuit equivalent to the display device 96 of FIG. 5, capacitors C_1, C_2 and C_3 represent the capacities of those portions of the insulating layers 100, 102, and 114 respectively, which are an integral part of the individual gas discharge cell. Similarly, capacitor C_R and C_C represent the capacities of those portions of the row and column that are part of the individual gas discharge cell. Their respective spark gaps G_R and G_C represent the actual discharge between the conductive layers or electrodes.

Since numerous additional modifications of the hybrid plasma-fluidic display device may be made without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative in nature and not in a limiting sense.

We claim:

1. A plasma-fluidic hybrid display device of laminar construction comprising:

a. a first insulating layer;

b. a second insulating layer secured to said first insulating layer;

c. a third insulating layer secured to said first insulating layer;

d. first electrode means secured to one surface of said first insulating layer;

e. second electrode means secured to one surface of said third insulating layer;

f. said second insulating layer having a plurality of cavities formed therein;

g. a plurality of passages extending through said first and second insulating layers and terminating within said plurality of cavities;

h. electrical supply means connected to said electrode means for supplying a voltage differential between said first and second electrode means;

i. fluid supply means connected to said plurality of passages to pressurize said cavities, with an ionizable gas; and

j. fluidic control means connected to said passages for altering the gas pressure level within selected cavities, to permit or suppress ionization when a substantially constant voltage differential is applied to said electrodes.

2. A plasma-fluidic hybrid display device as defined in claim 1 wherein said first electrode means comprises a series of spaced electrodes and said second electrode means comprises a layer of electrically conductive material.

3. A plasma-fluidic hybrid display device as defined in claim 1 wherein said first electrode means is secured to the exterior surface of said first insulating layer and said second electrode means is secured to the exterior surface of said third insulating layer.

4. A plasma-fluidic hybrid display device as defined in claim 1 wherein said first electrode means is secured to the interior surface of said first insulating layer and said second electrode means is secured to the interior surface of said third insulating layer.

5. A plasma-fluidic hybrid display device as defined in claim 1 wherein said fluidic control means comprises a block with a pattern of spaced apertures extending therethrough, said apertures being in number to the plurality of cavities formed within said second insulating layer.

6. A plasma-fluidic hybrid display device as defined in claim 5 wherein said fluidic control means further comprises a fluidic decoder logic module, said module having input conduit means and output conduit means, said input conduit means connected to said supply means for pressurization therefrom, and said output conduit means connected to said block to supply fluid signals to selected apertures within said block.

7. A plasma-fluidic hybrid display device as defined in claim 1 wherein said first insulating layer and said first electrode means are transparent so that the gas ionized within the selected cavities is visible therethrough.

8. A multilevel plasma-fluidic hybrid display matrix of laminar construction comprising:

a. a first insulating layer;

b. first electrode means secured to one surface of said first insulating layer;

c. vertical wall means secured to said first insulating layer and depending therefrom;

d. a second insulating layer secured to said wall means so as to be positioned parallel to said first insulating layer and spaced therefrom;

e. said first and second layers and said vertical wall means defining a chamber therebetween;

f. a slot extending through said wall means and terminating within said chamber;

g. a third insulating layer secured to one surface of said second insulating layer;

h. said third insulating layer having a plurality of cavities formed therein;

i. a plurality of passages extending through said third insulating layer and terminating within said plurality of cavities;

j. a fourth insulating layer secured to one surface of said third insulating layer;

k. second electrode means secured to said fourth insulating layer;

l. electrical supply means connected to said electrode means for supplying a voltage differential between said first and second electrode means;

m. fluid supply means connected to said slot and said plurality of passages to pressurize said chambers and said cavities with an ionizable gas; and

n. fluidic control means connected to said passages for altering the gas pressure level within selected cavities, to permit or suppress ionization when a substantially constant voltage differential is applied to said electrodes.

9. A plasma-fluidic hybrid display matrix as defined in claim 8 wherein said first electrode means comprises a series of spaced electrodes and said second electrode means comprises a layer of electrically conductive material.

10. A plasma-fluidic hybrid display matrix as defined in claim 8 wherein said first electrode means is secured to the exterior surface of said first insulating layer and said second electrode means is secured to the exterior surface of said fourth insulating layer.

11. A plasma-fluidic hybrid display matrix as defined in claim 8 wherein said first electrode means is secured to the interior surface of said first insulating layer and said second electrode means is secured to the interior surface of said fourth insulating layer.

12. A plasma-fluidic hybrid display matrix as defined in claim 8 wherein said fluidic control means comprises a block with a pattern of spaced apertures extending therethrough, said apertures being equal in number to the plurality of cavities formed within said third insulating layer.

13. A plasma-fluidic hybrid display matrix as defined in claim 12 wherein said fluidic control means further comprises a fluidic decoder logic module, said module having input conduit means and output conduit means, said input conduit means connected to said supply means for pressurization therefrom, and said output conduit means connected to said block to supply fluid signals to selected apertures within said block.

14. A plasma-fluidic hybrid display matrix as defined in claim 8 wherein said fourth insulating layer and said second electrode means are transparent so that the gas ionized at the intersection of the selected cavities and the chamber is visible therethrough.