United States Patent

Ikegami

[15] **3,706,912**

[45] **Dec. 19, 1972**

[54] **GASEOUS DISCHARGE DISPLAY DEVICE UTILIZING CYCLOTRON RESONANCE OF ELECTRON**

[72] Inventor: **Hideo Ikegami,** Nagoya, Japan

[73] Assignee: **Fujitsu Limited,** Kawashi, Japan

[22] Filed: **Aug. 9, 1971**

[21] Appl. No.: **170,084**

[30] **Foreign Application Priority Data**

Sept. 10, 1970 Japan 45/69890

[52] **U.S. Cl.** ....**315/169 TV,** 313/154, 313/155, 313/156, 313/161, 313/201, 313/210, 313/220

[51] **Int. Cl.**..........................**H01j 61/64,** H05b 41/02

[58] **Field of Search**......313/210, 156, 161, 162, 201, 313/220, 154, 155; 315/169 TV

[56] **References Cited**

OTHER PUBLICATIONS

"Gas Panel Display," by Pennebaker, IBM Technical Disclosure Bulletin, Vol. 12, No. 10, March 1970, pp. 1705, 1706.

Primary Examiner—Palmer C. Demeo
Attorney—Curt M. Avery et al.

[57] **ABSTRACT**

An addressable gaseous discharge device utilized for information display comprises a pair of spaced parallel oppositely positioned insulating walls forming between them a gas cell filled with ionizable gas. At least one of the insulating walls is transparent. The perimeters of the insulating walls are hermetically sealed. Field electrodes mounted on the insulating walls apply a microwave electric field to the gas cell and field electrodes mounted on the insulating walls partly and selectively apply a magnetic field in a direction crossing the microwave electric field. A glow discharge occurs in a selected part of the gas cell when the two applied fields meet the condition of cyclotron resonance of an electron.

6 Claims, 8 Drawing Figures

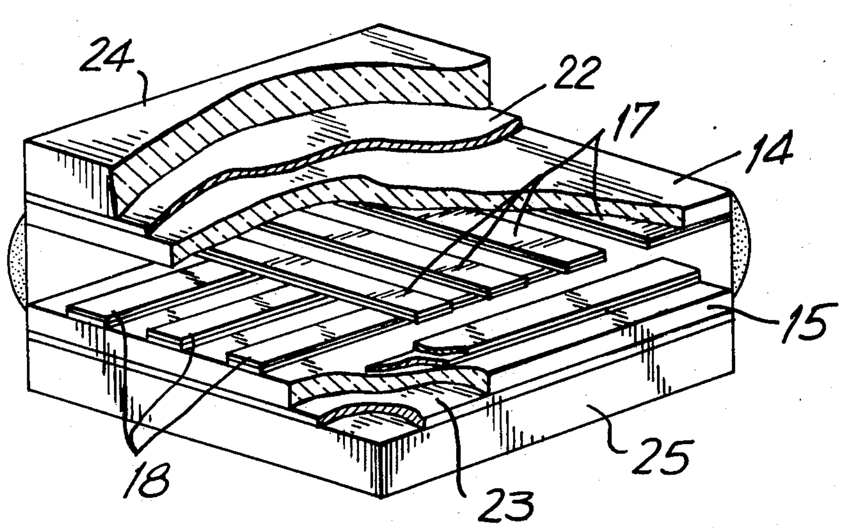


FIG. 1
PRIOR ART

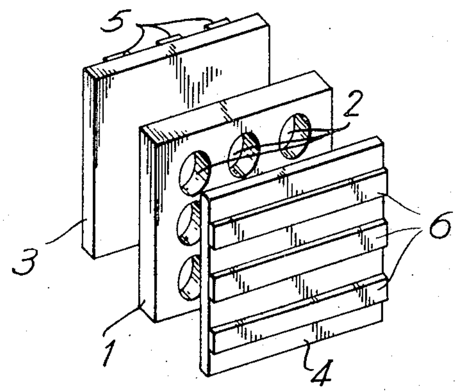


FIG. 2

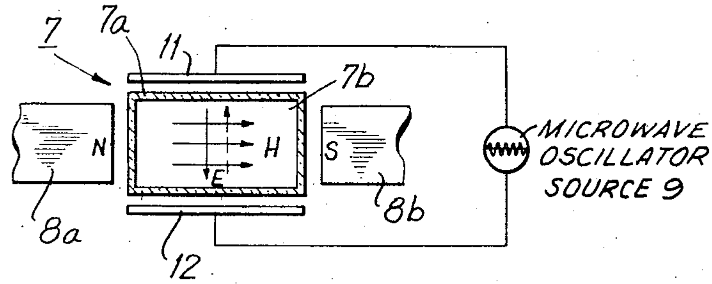


FIG. 3

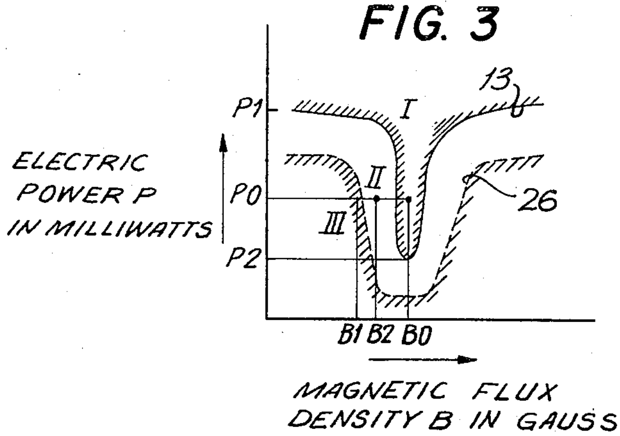


FIG. 4

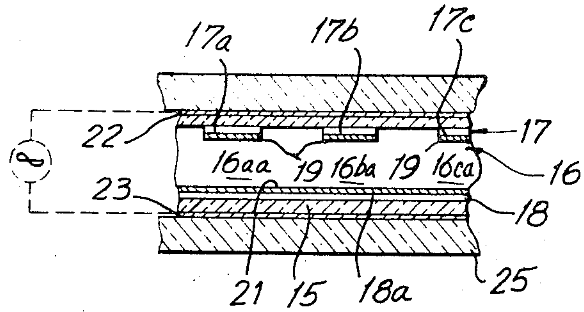

17a
17b
17c
22
17
16aa
19
16ba
19
16ca
16
23
18
21
15
18a
25

FIG. 5

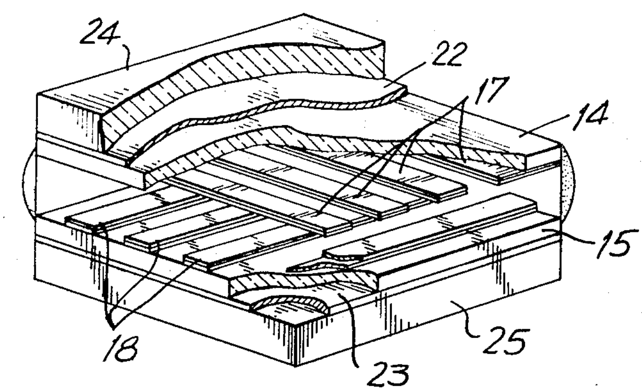

24
22
17
14
15
18
23
25

FIG. 6

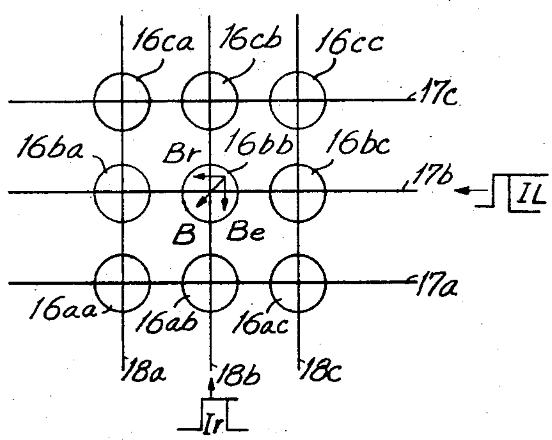


FIG. 7

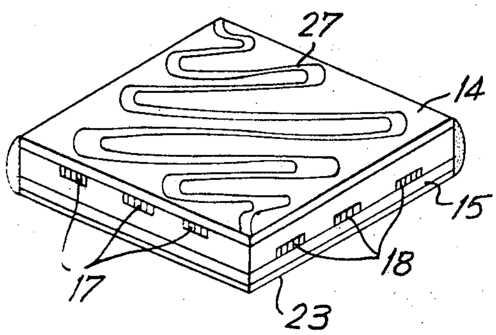
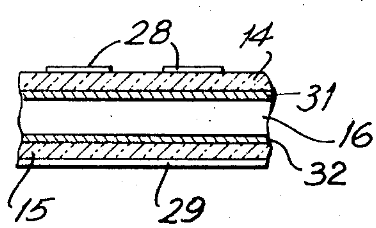


FIG. 8



GASEOUS DISCHARGE DISPLAY DEVICE UTILIZING CYCLOTRON RESONANCE OF ELECTRON

The invention relates to an information display device. More particularly, the invention relates to a gaseous discharge device utilizing cyclotron resonance of an electron.

The device of the invention is utilized to partly and selectively control the glow discharge of a panel-shaped gas cell by utilizing the cyclotron resonance phenomenon of an electron in the presence of a microwave electric field and a magnetic field extending in a direction which crosses the microwave electric field.

Various types of display devices have been utilized to convert electrical output information from computers into visible information. One such device is a recently developed display device utilizing gaseous discharge, and is known as a plasma display panel. The plasma display panel is hereinafter referred to as the PDP. The PDP is described in detail in, for example, U.S. Pat. No. 3,559,190 for "Gaseous Display and Memory Apparatus."

In accordance with U.S. Pat. No. 3,559,190, the PDP comprises the device shown in FIG. 1. The PDP is generally driven by a sustaining voltage of a designated frequency and a control voltage for writing and erasing. The sustaining voltage and the control voltage are determined by the composition of the ionizable gas, the gas pressure and the gap length of the cells corresponding to the firing voltage obtained from the well known Paschen's curve and the wall voltage produced by the wall charge. Therefore, considerably high sustaining voltage and control voltage are required for actually driving the PDP. The best utilized reported voltages are a sustaining voltage of 150 volts and a control voltage of 50 volts. Such high required driving voltages greatly hinder the utilization of miniaturized and integrated circuits as peripheral circuits and also entail considerable expense.

An object of the invention is to provide an addressable gaseous discharge device of panel shape for visual display or memory which overcomes the disadvantages of known devices of similar type.

Another object of my invention is to provide a gaseous discharge device of panel shape which may be driven at relatively low electrical power.

Still another object of the invention is to provide a gaseous discharge device of panel shape which may utilize integrated circuits as peripheral circuits with facility.

A further object of my invention is to provide a gaseous discharge device of panel shape which is free from non-uniformity of characteristics due to partial errors in dimensions.

Still another object of my invention is to provide a gaseous discharge device of panel shape which is of simple structure, inexpensive in operation and manufacture and capable of writing and erasing with precision and rapidity.

Another object of my invention is to provide a gaseous discharge device of panel shape which functions with efficiency, effectiveness and reliability.

The gaseous discharge device of the invention is based upon the cyclotron resonance phenomenon of an electron in the presence of a microwave electric field and a magnetic field which crosses the microwave electric field. In the gaseous discharge device of the invention, the glow discharge of a hermetically sealed gas cell may be partly and selectively controlled. The gas cell comprises a pair of spaced parallel oppositely positioned insulating walls which are hermetically sealed in their perimeters. The insulating walls are provided with electrodes for applying a microwave electric field and for partly and selectively producing a magnetic field in a direction which crosses the microwave electric field. When the crossed fields satisfy the condition for cyclotron resonance of an electron, a glow discharge is produced, which is not related to Paxchen'Paschen' curve, in the selected part of the gas cell.

In accordance with the invention, an addressable gaseous discharge device utilizing the cyclotron resonance of an electron comprises a pair of spaced parallel oppositely positioned insulating walls forming between them a gas cell filled with ionizable gas. At least one of the insulating walls is transparent. Sealing means hermetically seals the perimeters of the insulating walls. Field means in operative proximity with the gas cell applies a microwave electric field to the gas cell. Field means in operative proximity with the gas cell partly and selectively applies a magnetic field in a direction crossing the microwave electric field whereby a glow discharge occurs in a selected part of the gas cell when the two applied fields meet the condition of cyclotron resonance of an electron.

Each of the insulating walls has an inside surface and an outside surface. The field means for applying a microwave electric field comprises electrode means mounted on a corresponding surface of each of the insulating walls. The field means for partly and selectively applying a magnetic field comprises electrode means mounted on the other surface of each of the insulating walls. Reinforcing material on the outside surface of at least one of the insulating walls protects the insulating walls from breakage due to pressure difference.

The field means for applying a microwave electric field may comprise a plate-shaped electrode mounted on the outside surface of each of the insulating walls.

The field means for applying a microwave electric field may comprise an electrode mounted on the outside surface of each of the insulating walls, at least one of the electrodes comprising a zigzag strip.

The field means for partly and selectively applying a magnetic field comprises a first group of spaced parallel electrodes mounted in rows on a surface of one of the insulating walls and a second group of spaced parallel electrodes mounted in columns on a surface of the other of the electrodes. The first and second groups of electrodes are in mutually perpendicular relation to each other. Means supplies signal currents to selected electrodes of the first and second groups of electrodes whereby when signal currents are supplied to a selected one of the first group of electrodes and to a selected one of the second group of electrodes a required magnetic field is produced in the part of the gas cell located between the two selected electrodes at their crossover area.

Magnetic films on the electrodes of the first and second groups of electrodes of the field means for applying a magnetic field concentrate the magnetic field.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawings, wherein:

FIG. 1 is an exploded perspective illustration of the plasma display panel of the prior art as described in U.S. Pat. No. 3,559,190;

FIG. 2 is a schematic circuit diagram illustrating the principle of operation of the gaseous discharge device of the invention;

FIG. 3 is a graphical presentation illustrating the firing and erasing characteristics of the gaseous discharge device of the invention based on the cyclotron resonance of an electron;

FIG. 4 is a schematic cross-sectional diagram of an embodiment of the gaseous discharge device of the invention;

FIG. 5 is a partially broken perspective view of the embodiment of FIG. 4 of the gaseous discharge device of the invention;

FIG. 6 is a schematic diagram for explaining the operation of the gaseous display device of FIGS. 4 and 5;

FIG. 7 is a perspective view of another embodiment of the gaseous discharge device of the invention; and

FIG. 8 is a cross-sectional view of part of still another embodiment of the gaseous discharge device of the invention.

In the FIGS., the same components are identified by the same reference numerals.

FIG. 1 illustrates a PDP as disclosed in U.S. Pat. No. 3,559,190. In FIG. 1, a thin glass plate 1 has a plurality of small holes 2 formed therethrough in rows and columns and is positioned between two thin plates of glass 3 and 4. The glass plates 3 and 4 hold the glass plate 1 from both sides. The three glass sheets 1, 3 and 4 are hermetically sealed to form an integral unit with ionizable gases sealed in the small holes 2 of the glass plate 1. A first group 5 of transparent electrodes corresponds to the longitudinal lines along which the small holes 2 are arranged and is mounted in matrix configuration on the outside surface of the thin glass plate 3. A second group 6 of transparent electrodes corresponding to the lateral lines along which the small holes 2 of the glass plate 1 are arranged is mounted in matrix configuration on the outside surface of the thin glass plate 4. The first and second groups of electrodes 5 and 6 thus extend in directions which are mutually perpendicular to each other.

The device of FIG. 1 may produce a number of gaseous discharge minicells which are formed by the small holes 2 and the glass plates 3 and 4 on both sides of each of such small holes. The minicells are positioned at the points of intersection of the electrodes of the first and second groups of electrodes 5 and 6 and are controllable independently from each other. The PDP thus provides a plurality of gaseous discharge minicells which are insulated from the electrodes. The PDP has two useful functions. The first useful function is the display function which utilizes the pulse glow discharge. The second useful function is the memory function which is provided by wall charges formed on the inner walls of the minicells.

In FIG. 2, which illustrates the principle of operation of the gaseous discharge device of the invention, a gas cell 7 is described in a manner which describes the cyclotron resonance phenomenon of an electron on which my invention is based. The gas cell 7 comprises a vessel 7*a* in which ionizable gas 7*b* is sealed. When a magnetic field H is applied in the horizontal direction of the plane of illustration, between a pair of magnetic poles 8*a* and 8*b*, provided on both sides of the gas cell 7, electrons present within the ionizable gas 7*b* will rotate at an angular frequency ωc. The angular frequency ωc may be expressed as

$$\omega c = eB/m = 1.759 \text{ times } 10^7 B \qquad (1)$$

wherein m is the mass of an electron, e is the charge of an electron and B is the magnetic flux density in Gauss.

The rotating frequency fc at such time is usually known as the cyclotron frequency and is defined from Equation (1) as

$$fc = 2.8 \text{ times } 10^6 B \qquad (2)$$

wherein fc is in Hertz.

When microwaves having a frequency f are supplied from a microwave oscillator source 9 to a pair of electrodes 11 and 12, spaced on opposite sides of the vessel 7*a*, a microwave electric field E is produced in the gas cell 7. The microwave electric field E crosses the magnetic field H. When the microwave frequency f is selected as equal to the cyclotron frequency fc, the condition

$$f = fc = 2.8 \text{ times } 10^6 B \qquad (3)$$

is satisfied. The frequency f is in Hertz. The resonance phenomenon known as the cyclotron resonance of an electron then occurs and the electrons within the gas cell 7 absorb the energy of the microwave electric field E, increase the radius of rotation of the electrons, and also increase the energy of the electrons themselves.

On the other hand, it is known that discharge plasma accompanied by luminescence is usually produced by microwaves in the gas cell of FIG. 2 when the following equation is satisfied;

$$V = K \frac{\omega^2}{(\omega - \omega c)^2 + v^2} Eo \qquad (4)$$

wherein V is the firing voltage determined by the composition of the ionizable gas, K is a constant, ω is the angular frequency of the microwaves, ωc is the angular cyclotron frequency of Equation (1), v is the collision frequency of an electron and a neutral atom, and Eo is the intensity of strength of the microwave electric field.

It may be seen from Equation (4) that when the magnetic field is zero, the angular cyclotron frequency ωc is also zero, so that in order to produce a discharge plasma at such time, it is necessary to apply a microwave electric field $Eo1$. The microwave electric field $Eo1$ may be expressed as

$$Eo1 = \frac{1}{K} \frac{\omega^2 + v^2}{\omega^2} V \approx \frac{V}{K} \qquad (5)$$

When the cyclotron resonance condition of an electron, as indicated in Equation (3) is satisfied, however, ω becomes equal to ωc. The discharge plasma may therefore be produced only by the application of a microwave electric field $Eo2$ which may be expressed as

$$Eo2 = \frac{1}{K} \frac{v^2}{\omega c^2} V \qquad (6)$$

It is therefore evident that the intensity or strength of the microwave electric field required for the production of the discharge plasma is a minimum when the aforedescribed cyclotron resonance condition of an electron is satisfied, and the minimum value $Eo2$ is equal to about ν^2/ω^2 the value available when the magnetic field is zero.

It is assumed that the magnetic flux density B is gradually increased from zero in the gas cell 7 of FIG. 2 under the condition that microwaves having a frequency fr are supplied to the electrode 11. The electric power P of the microwaves required for the production of the discharge plasma is then varied as shown in FIG. 3. In FIG. 3, the abscissa represents the magnetic flux density B in Gauss and the ordinate represents the electric power P in milliwatts. FIG. 3 illustrates the firing characteristic curve 13 which may be obtained. The firing characteristic curve 13 has a critical region I. In the curve 13, a magnetic field BO at which firing occurs with the minimum microwave electric power P2 is the magnetic field which satisfies the resonance condition of Equation (3).

At such time, the microwave electric power P2, similarly to the ratio of Eo2 and Eol hereinbefore described, may be expressed as ν^2/ω^2 of the microwave electric power P1 required for firing at the time when there is no resonance. P2 is thus equal to approximately 1/100 of P1. The firing characteristic is slightly varied by the gas pressure of the ionizable gas and the frequency of the microwaves. However, when the gas pressure is several Torr and the microwave frequency is several thousand megahertz, discharge plasma may be produced by a microwave electric power of several milliwatts at the instance of resonance, and the half-width of the firing region I of the magnetic field (FIG. 3) may be limited to less than several Gauss.

As is obvious from the foregoing disclosure, a discharge plasma accompanied by luminescence may be produced by an extremely low microwave electric power of the order of milliwatts in the ionizable gas space to which a microwave electric field and a magnetic field which crosses the microwave electric field are applied, when the cyclotron resonance condition of an electron is satisfied. It is also obvious that the production of the discharge plasma may be critically controlled by the electric field or the microwave frequency.

The gaseous discharge device of my invention, as hereinbefore described, provides high speed writing and high speed erasure by utilization of the discharge phenomenon caused by microwaves in the cyclotron resonance phenomenon of an electron. Furthermore, the gaseous discharge device of my invention has a memory function.

FIG. 4 illustrates an embodiment of the gaseous discharge device of the invention. In FIG. 4, a pair of spaced parallel transparent insulating plates 14 and 15 may be hermetically sealed to form a plate-shaped ionizable gas space 16 between them. A first group of electrodes 17 comprises a plurality of spaced parallel electrode strips 17*a*, 17*b*, 17*c*, . . . 17*n* arranged in rows. The first group of electrodes 17 are mounted on the inside surface of the insulating wall or plate 14 and face the inside surface of the insulating plate or wall 15. A second group of electrodes 18 comprises a plurality of spaced parallel electrode strips 18*a*, 18*b*, . . . 18*n*. The second group of electrodes 18 are mounted on the inside surface of the insulating plate or wall 15.

The first and second groups of electrodes 17 and 18 are mutually perpendicular to each other and extend in directions which cross each other. Each of the electrodes of the first and second groups of electrodes 17 and 18 crosses the electrodes of the other of said groups of electrodes. The first and second groups of electrodes 17 and 18 are thus arranged in matrix configuration. Each of the electrodes is led out from the device separately, so that pulse currents for producing a magnetic field may be separately supplied to said electrodes. A magnetic film 19 is formed on the surfaces of the electrodes of the first group of electrodes 17 to concentrate the magnetic field. A magnetic film 21 is formed on the surfaces of the electrodes of the second group of electrodes 18 to concentrate the magnetic field.

A plate-shaped electrode 22 for applying a microwave field is provided on the outside surface of the transparent insulating plate or wall 14. A plate-shaped electrode 23 for applying a microwave field is provided on the outside surface of the transparent insulating plate or wall 15. At least one of the electrodes 22 and 23 is transparent. Each of the electrodes 22 and 23 preferably covers the entire outside surface of the insulating plate on which it is mounted. Furthermore, reinforcing transparent base plates 24 and 25 are provided at the outside surfaces of the insulating walls 14 and 15, respectively, to prevent modification and breakage of the device due to pressure differences between the internal pressure of the gas space 16 and the atmospheric pressure. The perimeters of the insulating walls or plates 14 and 15 may be hermetically sealed by any suitable means such as, for example, solder or the like.

FIG. 5 clearly discloses the internal structure of the embodiment of FIG. 4. The embodiment of FIGS. 4 and 5 may be provided without difficulty by utilizing the conventional method of manufacture adopted for the manufacture of PDPs and the like. A plurality of discharge unit regions, areas, zones, or the like, 16*aa*, 16*ba*, 16*ca*, . . . 16*na*; 16*an*, 16*bn*, 16*cn*, . . . 16*nn* are formed in the ionizable gas space 16 between the first and second groups of electrodes 17 and 18 at the points of intersection or crossover of the electrodes of each of said groups. The discharge unit regions 16*an* to 16*nn* are controllable independently from each other by the aforedescribed method.

FIG. 6 is a schematic diagram for further explaining the operation of the embodiment of FIGS. 4 and 5. The transparent electrodes 22 and 23 for applying a microwave field are not shown in FIG. 6. It is assumed, for the sake of illustration, that a writing current I is selectively applied to the electrode 17*b* of the first group of electrodes 17. A magnetic flux Be is produced by a writing current IL around the electrode 17*b*. The magnetic flux density B of the magnetic flux be may be expressed as

$$B = \mu H$$

wherein μ is the magnetic permeability of the magnetic film 21 and H is the magnetic field intensity concentrated by the magnetic film 21.

It is further assumed that a writing current Ir is supplied to an electrode **18***b* of the second group of electrodes **18**. The writing current Ir produces a magnetic flux B*r* around the electrode **18***b*. The magnetic flux B*r* is concentrated by the magnetic film **21**. If the writing currents IL and I*r* are supplied simultaneously to the electrodes **17***b* and **18***b*, a magnetic flux B is produced in a direction horizontal to the plane of illustration in the discharge unit region **16***bb*, located between the electrodes **17***b* and **18***b* at the point of intersection or crossover of said electrodes. The magnetic flux B is equivalent to the vector sum of the magnetic fields for magnetic fluxes B*e* and B*r*.

Thus, if the magnitudes of the writing currents IL and I*r* are selected so that the resultant magnetic flux density of the discharge unit region **16***bb* may become B0, that is, so that the microwave frequency f and the magnetic flux density B may satisfy the condition of cyclotron resonance of an electron in Equation (3), under the condition that microwaves at the designated frequency *f* are supplied between the electrodes **22** and **23**, applying a microwave field, and the electric power of the microwave is set to a magnitude of, for example, P0 from the firing characteristics of FIG. **3**, the discharge unit region **16***bb* is fired and produces discharge plasma accompanied by luminescence. The discharge luminescence or light may be seen through one or both insulating plates **14** and **15** and both reinforcing plates **24** and **25** and through the electrodes. When electrode strips are utilized as the first and second groups of electrodes **17** and **18** on the display surfaces of the insulating walls **14** and **15**, and when such electrode strips are opaque, the discharge luminescence or light may be seen from outside the gaseous discharge device.

The other discharge unit regions may be fired in the same manner. Therefore, by the selective application of writing currents for producing magnetic fields in the first and second groups of electrodes **17** and **18**, arbitrarily selected discharge unit regions may be fired to provide a desired display. In the foregoing example, other discharge unit regions than the selected discharge unit regions **16***bb*, particularly the unit regions **16***ba*, **16***bc*, **16***cb*, and **16***ab*, adjacent to the discharge unit region **16***bb*, are not fired by the resultant magnetic field produced by the supply of the writing current. This is due to the fact that in such other discharge unit regions the magnetic field strength is outside the firing region I (FIG. **3**) and the condition for cyclotron resonance is not satisfied. The fired discharge unit region is not spread, because the charged particles produced by ionization do not move in a direction horizontal to the magnetic field.

The selective firing operation in the gaseous discharge device of the invention has been hereinbefore described. The display memorizing or storage operation and the selective erasing operation are now described. As hereinbefore described with reference to curve **13** of FIG. **3**, a discharge unit region may be selectively fired by utilizing the critical firing region I formed by the cyclotron resonance phenomenon of an electron. The discharge unit region has a discharge sustaining region, zone, area, or the like, having a specific range, once it is fired. In the gaseous discharge device of the invention, electrons produced in the first discharge remain in the unit discharge region and continuously contribute to the discharge while the microwave electric field is present. Therefore, even if the operating point determined by the magnetic field and microwave electric power is shifted away from the firing region I afterward, the same discharge continues and the written information may be stored or memorized.

The mechanism for providing the storage or memory function is different from the mechanism of the aforedescribed PDP which utilizes a wall charge. A curve **26** in FiG. **3** illustrates the minimum sustaining characteristic of the device of the invention. The region II between the curve **26** and the firing characteristic curve **13** is the discharge sustaining region and the region III under the curve **26** is the discharge erasing region. Therefore, in the discharge unit region fired at the point of microwave electric power PO and magnetic flux density B0, shown in FIG. **3**, the discharge is sustained between B0 and B1 and is erased under B1.

Thus, by supplying microwave electric power P0 to the electrodes **22** and **23** which produces the microwave electric field and supplying DC sustaining current to all the electrodes of the first and second groups of electrodes **17** and **18**, so that the resultant magnetic flux density produced may have a magnitude B2 at approximately the center of the sustaining region II and then shifting the magnitude of the resultant magnetic flux density left and right from the central magnitude B2, it is possible to arbitrarily fire the discharge unit regions and sustain and erase the discharge of the discharge unit regions. That is, by first supplying DC sustaining current to the first and second groups of electrodes **17** and **18** so that the resultant magnetic flux density of the discharge unit regions **16***ab*, **16***ac*, . . . **16***an*, . . . **16***nn* (FIG. **6**) may become B2, and then selectively adding a positive writing current so that the resultant magnetic flux density of the selected discharge unit region may become B0, the selected unit region may be fired instantaneously.

The discharge may be sustained and the display may be stored or memorized after the writing pulse current is removed, since the operating point remains in the range of the sustaining region II, which is P0, B2. The discharge of the discharge unit region which has been fired may be selectively erased by selectively overlapping the negative erasing current pulse on the DC sustaining current and making the magnetic flux density of the resultant magnetic field in the discharge unit region lower than B1. During these operations, the microwaves may be applied without modification. The writing and erasing operations may be undertaken with great facility and rapidity, because it is not necessary in the device of the invention to consider the phase relation with the sustaining voltage, as in the aforedescribed PDP.

Although the structure and operation of the aforedescribed embodiment of the invention is the basis for the gaseous discharge device of my invention, various modifications may be made without departing from the scope of the invention. Thus, for example, a zigzag-shaped line may be utilized as one of the two plate-shaped electrodes **22** and **23** (FIGS. **4** and **5**) for applying the microwave field. FIG. **7** discloses an embodiment of the gaseous discharge device utilizing a zigzag-shaped strip as the electrode **27**, replacing the plate-shaped electrode **22** of the embodiment of FIGS. **4** and **5**.

FIG. **8** illustrates still another embodiment of the gaseous discharge device of the invention. In the embodiment of FIG. **8**, the first group of electrodes **28** is provided on the outside surface of the insulating plate or wall **14** and the second group of electrodes **29** is mounted on the outside surface of the insulating plate or wall **15**. The first and second groups of electrodes **28** and **29** have current supplied to them for producing the magnetic field. An electrode **31** is mounted on the inside surface of the insulating wall or plate **14** and an electrode **32** is mounted on the inside surface of the insulating plate or wall **15**. The electrodes **31** and **32** produce the microwave electric field. In the embodiment of FIG. **8**, magnetic fields produced around the electrodes of the first and second groups of electrodes **28** and **29** are applied to the discharge unit regions via the electrodes **31** and **32** for producing the microwave electric field.

In the embodiments of FIGS. **7** and **8**, reinforcing plates, of the type shown as the plates **24** and **25** in FIGS. **4** and **5**, are not shown, in order to maintain the clarity of illustration, although such reinforcing plates are preferably utilized. The shapes and positions of the electrodes may thus be varied arbitrarily. It is also possible to utilize in common the electrodes of the first and second groups of electrodes to produce the microwave electric field and to produce the magnetic field as far as such fields which cross each other may be applied to the discharge unit regions. The electrodes may either be exposed to the ionizable gas space or insulated therefrom, as in the PDP, with completely the same operation being available.

The magnetic films **19** and **21** in the embodiment of FIG. **4** may effectively concentrate the magnetic fields to be applied to the discharge unit regions and increase the magnetic field producing efficiency. The magnetic films **19** and **21** are, however, not absolutely necessary in the gaseous discharge device of the invention. In other words, magnetic fields satisfying the cyclotron resonance condition may be applied to the discharge unit regions simply by supplying currents to the electrodes of the first and second groups of electrodes in the matrix configuration. When the magnetic films **19** and **21** are utilized, however, care must be taken that the discharge luminescence or light is not shielded by said films. In this case, it is not absolutely necessary to utilize transparent magnetic films. It is merely required that all or part of the discharge light or luminescence in the discharge unit region may be seen from the outside. In order to accomplish this, it is possible to utilize a glassy transparent magnetic material recently developed, to reduce the thickness of the magnetic films. It is also possible to provide small holes for transmitting the light through the magnetic films.

As is obvious from the foregoing description, the panel-shaped gaseous discharge device of the invention may be utilized not only as a display device but also as an information memory or storage device. In this case, the informations may be written in the storage device in the same manner as the writing in the display device hereinbefore described. the informations may be read out by coupling a suitable photoelectric transducing device to the storage device and detecting the discharge luminescence or light of the discharge unit regions in which the informations are stored. The panel-shaped gaseous discharge apparatus of the invention may be utilized as a display device or as a memory or storage device without special modification of the structure of the device.

As hereinbefore described, the panel-shaped gaseous discharge device of my invention involves a microwave electric field and a magnetic field crossing the microwave electric field, which fields are applied to a hermetically sealed ionizable gas space. The glow discharge of the gas space is selectively controllable due to the utilization of the cyclotron resonance phenomenon of an electron. Due to this feature of the invention, the device of the invention may be driven without relation to Paschen's curve determined by the gap length of the cell and the pressure. This results in the elimination of the partial nonuniformity of performance characteristics due to errors in dimensions caused by the manufacturing process.

The microwave electric power required for driving the device of the invention is of the order of several milliwatts, so that the size of perimeter circuits may be readily decreased by the utilization of a semiconductor element such as a Gunn diode as the source of oscillations. Furthermore, the glow discharge may be fired and erased surely, since firing and erasing are performed by the critical characteristic based upon the cyclotron resonance of an electron. The firing and erasing may be performed rapidly, since it is not necessary to consider the phase relation between the signal for firing or erasing and the microwave field.

While the invention has been described by means of specific examples and in specific embodiments, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. An addressable gaseous discharge device utilizing the cyclotron resonance of an electron, said discharge device comprising a pair of spaced parallel oppositely positioned insulating walls forming between them a gas cell filled with ionizable gas, at least one of the insulating walls being transparent; sealing means hermetically sealing the perimeters of the insulating walls; field means in operative proximity with the gas cell for applying a microwave electric field to the gas cell; and field means in operative proximity with the gas cell for partly and selectively applying a magnetic field in a direction crossing the microwave electric field whereby a glow discharge occurs in a selected part of the gas cell when the two applied fields meet the condition of cyclotron resonance of an electron.

2. A gaseous discharge device as claimed in claim **1**, wherein each of the insulating walls has an inside surface and an outside surface, the field means for applying a microwave electric field comprises electrode means mounted on a corresponding surface of each of the insulating walls, the field means for partly and selectively applying a magnetic field comprises electrode means mounted on the other surface of each of the insulating walls, and further comprising reinforcing material on the outside surface of at least one of the insulating walls for protecting said insulating walls from breakage due to pressure difference.

3. A gaseous discharge device as claimed in claim **1**, wherein each of the insulating walls has an inside surface and an outside surface and the field means for applying a microwave electric field comprises a plate-shaped electrode mounted on the outside surface of each of the insulating walls.

4. A gaseous discharge device as claimed in claim **1**, wherein each of the insulating walls has an inside surface and an outside surface and the field means for applying a microwave electric field comprises an electrode mounted on the outside surface of each of the insulating walls, at least one of the electrodes comprising a zigzag strip.

5. A gaseous discharge device as claimed in claim **1**, wherein each of the insulating walls has an inside surface and an outside surface and the field means for partly and selectively applying a magnetic field comprises a first group of spaced parallel electrodes mounted in rows on a surface of one of the insulating walls and a second group of spaced parallel electrodes mounted in columns on a surface of the other of the electrodes, the first and second groups of electrodes being in mutually perpendicular relation to each other, and means for supplying signal currents to selected electrodes of the first and second groups of electrodes whereby when signal currents are supplied to a selected one of the first group of electrodes and to a selected one of the second group of electrodes a required magnetic field is produced in the part of the gas cell located between the two selected electrodes at their crossover area.

6. A gaseous discharge device as claimed in claim **5**, further comprising magnetic films on the electrodes of the first and second groups of electrodes of the field means for applying a magnetic field for concentrating the magnetic field.

* * * * *