# United States Patent [19]

**Eukushima et al.**

[11] **3,886,395**

[45] **May 27, 1975**


[54] **FLAT, GASEOUS DISCHARGE, PHOSPHOR DISPLAY PANEL WITH OFFSET SUBSIDIARY ELECTRODES**


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[73] Assignee: **Hitachi, Ltd.,** Japan



[22] Filed: **July 29, 1974**

[21] Appl. No.: **492,730**

[30] **Foreign Application Priority Data**

July 27, 1973 Japan ..... 48-84136

[52] **U.S. Cl.** ..... **313/484;** 313/198; 313/220

[51] **Int. Cl.** ..... **H01j 61/42;** H01j 61/54

[58] **Field of Search** ..... 313/484, 485, 188, 220, 313/217, 198



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*Primary Examiner*—Palmer C. Demeo

*Attorney, Agent, or Firm*—Craig & Antonelli



[57] **ABSTRACT**

A flat display panel is disclosed which comprises an insulating substrate provided with a plurality of parallel slots, a plurality of anodes for subsidiary discharge each of which is disposed in each of the slots, a plurality of anode lines for main discharge disposed upon the insulating substrate, an insulating layer laid over the anode lines and provided with a plurality of openings so as to expose only the desired portions of the anode lines, a plurality of cathode plates disposed in contact with the insulating layer at right angles to the slots of the insulating substrate and provided with a plurality of through holes so as to expose said desired portions of the anode lines through the openings of the insulating layer, a transparent insulating substrate disposed in contact with the cathode plates, a gas hermetically sealed in the slots and through holes, a phosphor material disposed upon the insulating layer within the through holes of the cathode plates, and a plurality of communication passages hydraulically interconnecting between the slots and the through holes, the slots defining the subsidiary discharge spaces while the through holes, the main discharge spaces.


**7 Claims, 11 Drawing Figures**

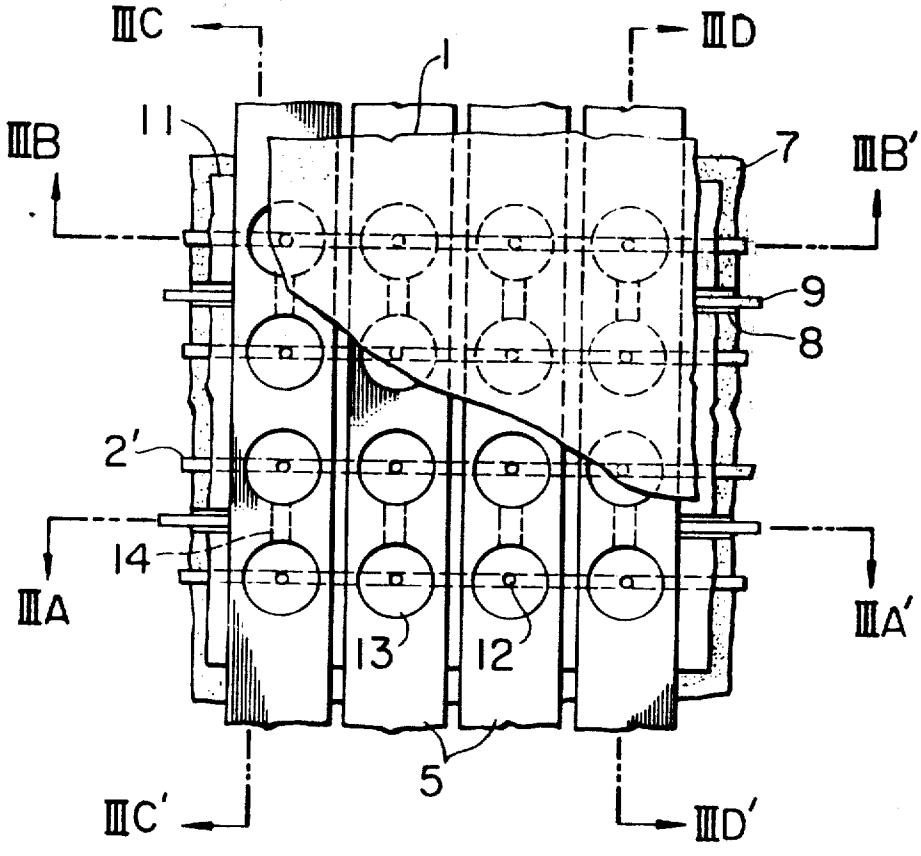


FIG. 1 PRIOR ART

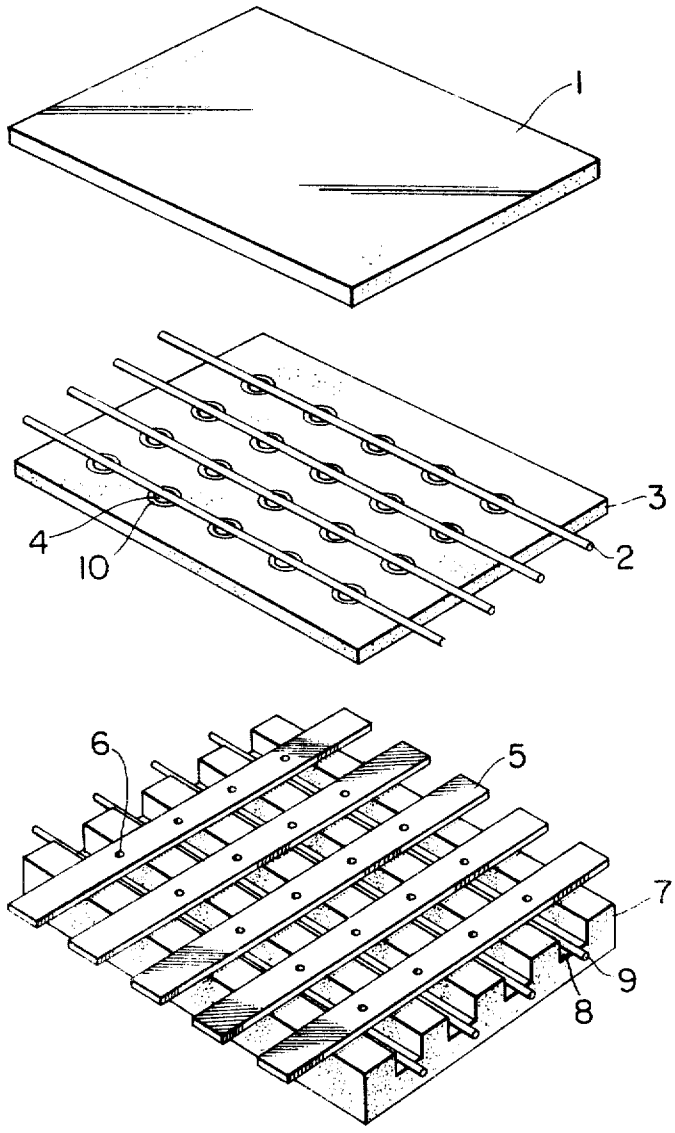


FIG. 2

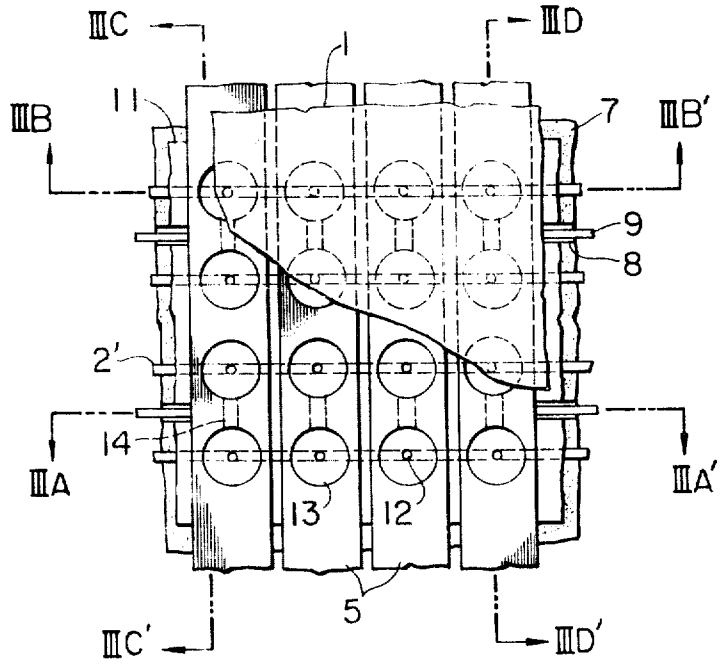



FIG. 3C

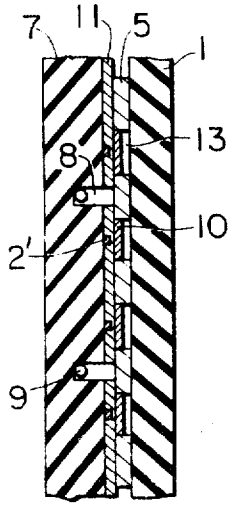



FIG. 3A

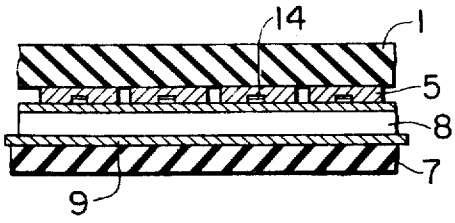



FIG. 3B

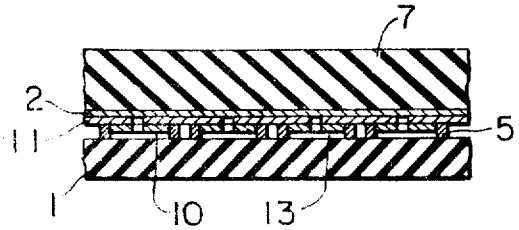



FIG. 3D

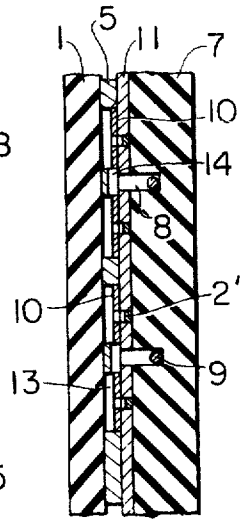


FIG. 4

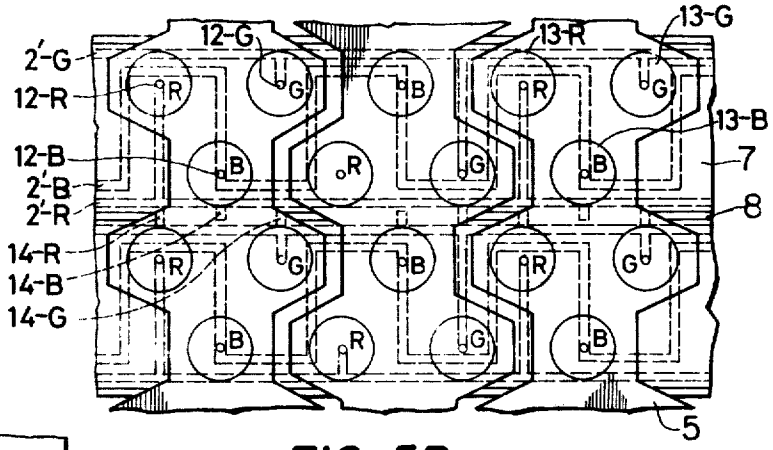



FIG. 5A

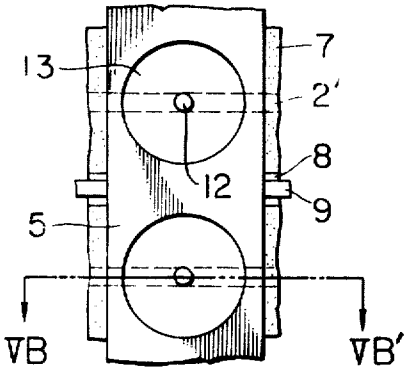



FIG. 5B

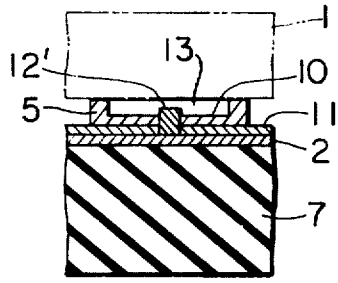



FIG. 6A

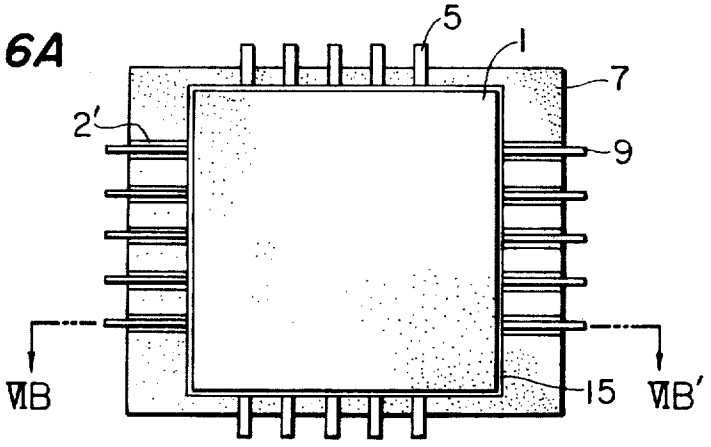
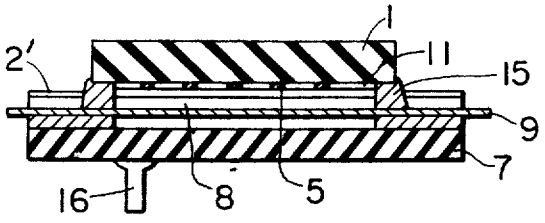



FIG. 6B



# FLAT, GASEOUS DISCHARGE, PHOSPHOR DISPLAY PANEL WITH OFFSET SUBSIDIARY ELECTRODES

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to, generally, a flat display panel of the type utilizing DC discharge in a gas; and, more particularly, a flat display panel of the type utilizing subsidiary discharges so as to facilitate the initiation of main discharges.

2. Description of the Prior Art

FIG. **1** shows a conventional flat display panel of the type utilizing subsidiary discharges to facilitate th initiation of main discharges. In FIG. **1** illustrating an exploded perspective view of the conventional flat display panel, reference numeral **1** denotes a transparent insulating substrate; **2**, anode lines for main discharge; **3**, an insulating plate; **4**, through holes formed through the insulating plate **3** so as to define main discharge spaces; **5**, cathode plates each provided with a row of through holes **6**; **7**, an insulating substrate provided with a plurality of slots **8** which define subsidiary discharge spaces and in which are disposed anode lines **9** for subsidiary discharge; and **10**, a phosphor material coated on the inner wall of each through hole **4**.

The initiation of main discharges which occur between the cathode plate **5** and the anode lines **2** through the through holes **4** may be much faciliated when subsidiary discharges occur between the cathode plates **5** and the anode lines **9** for subsidiary discharge. More particularly, the electrons and/or metastable atoms pass through the through holes **6** and flow into the through holes **4**, which define the main discharge spaces, by the subsidiary discharges between the cathode plates **5** and the anode lines **9** for subsidiary discharge. The metastable atoms impinge against the side walls of the main discharge spaces of holes **4** so that the secondary electrons are liberated, thus resulting in the increase in electron density in the main discharge spaces. Consequently, the discharge starting or initiating voltage in the main discharge spaces behind which subsidiary discharges occur may be reduced, and by utilizing this phenomenon, a drive circuit may be made which is simple in construction. That is, the transfer of scanning of the subsidiary discharges may be accomplished by pulse waves in several phases based upon the principle of the well-known step discharge tubes. For instance, when the voltage of the magnitude sufficient to start the main discharge is impressed upon the anode lines extended in the direction of rows as the video signal only when the subsidiary discharge occurs and in synchronism with the scanning line by line of the subsidiary discharges arrayed in the direction of columns, any desired image may be displayed. According to this driving method, the number of circuits in the direction of columns may be reduced to only a few.

One of the defects of the prior art flat display panel with the above constructions is that the fabrication of the insulating plate 0.3mm to 2mm in thickness is provided with a plurality of through holes **4** which separate the main discharge spaces from one another. Owing to this reason, it is extremely difficult to fabricate a large-sized flat display panel of, for instance, 1 × 1 meter. In other words, the handling of a large-sized thin insulating plate is extremely difficult because of its low mechanical strength.



Another object is that when the phosphor material is excited by ultraviolet rays produced by the discharge, the ultraviolet rays tend to be absorbed by the gas of the average distance from one point in the main discharge spaces to the phosphor material is relatively long, thus resulting in reduced brightness. In the conventional flat display panels of the type described hereinbefore, the radius of the through holes **4** is of the order of 0.25mm so that the possibility of the ultraviolet rays emitted at the center of the main discharge space exciting the phosphor material is very low. A further defect is that it is considerably difficult to cost a phosphor material upon the inner walls of the through holes **4**.

## SUMMARY OF THE INVENTION

One of the objects of the present invention is, therefore, to provide a large-sized flat display panel which is easy to manufacture.

Another object of the present invention is to provide a highly efficient, high brilliance flat display panel.

Briefly stated, the above objects of the present invention are attained by disposing cathodes around anodes. The cathodes may serve as partition walls between the adjacent main discharge spaces so that the insulating plate provides with a plurality of through bores may be eliminated.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of one example of the prior art flat display panels;

FIG. **2** is a fragmentary front view of a first embodiment of a flat display panel in accordance with the present invention;

FIG. **3A** is a sectional view taken along the line IIIA–IIIA′ of FIG. **2**;

FIG. **3B** is a sectional view taken along the line IIIB–IIIB″ of FIG. **2**;

FIG. **3C** is a sectional view taken along the line IIIC–IIIC′ of FIG. **2**;

FIG. **3D** is a sectional view taken along the line IIID–IIID′ of FIG. **2**;

FIG. **4** is a fragmentary front view of a second embodiment of a flat display panel in accordance with the present invention, the panel being capable of displaying in color;

FIG. **5A** is a fragmentary from view of a third embodiment of the present invention;

FIG. **5B** is a sectional view taken along the line VB–VB′ of FIG. **5A**;

FIG. **6A** is a front view of a fourth embodiment of the present invention; and

FIG. **6B** is a sectional view taken along the line VIB–VIB′ of FIG. **6A**.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **2** and **3**, anode lines **2′** are disposed upon the insulating substrate **7** in parallel with each other, vertically spaced apart from each other by a predetermined distance, and covered with an insulating layer **11** provided with an array of through holes **12** so as to partly expose the anode lines **2′** as main discharge anode electrodes. The phosphor material **10** is coated around each of the main discharge anode electrodes **2′**. The cathode plates **5** are disposed at right angles to the subsidiary discharge anode line slots **8**, and

are provided with a row of through holes **13** formed coaxially of the through holes through which the anode electrodes **12** are exposed. Therefore, the main discharge anode electrodes **12** are located substantially at the centers of the through holes **13** of the cathode plates **5**. The through holes **13** define the main discharge spaces while the slots **8**, the subsidiary discharge spaces. A gas communication passage **14** is formed in each of the cathode plates **5** in opposed relation with and at a right angle to the slot **8** of the insulating substrate **7** so that a pair of main discharge spaces **13** on each side of the slot **8** may be communicated with the slot **8** or subsidiary discharge space. Gas is filled into the main discharge spaces **13**, the subsidiary discharge spaces **8**, and the gas flow or communication passages **14** all of which are hermetically sealed from the surrounding atmosphere.

According to the present invention, a ceramic or glass plate a few millimeters to one centimeter in thickness is used as the insulating substrate **7** while a glass plate 3mm to one centimeter in thickness, as the transparent insulating substrate **1**. Thus, the large-sized substrates **1** and **7** with sufficient mechanical strength may be used. Furthermore, according to the present invention, the main discharge spaces **13** except those paired are separated from one another by the cathode plates **5** so that the prior art insulating plate provided with a plurality of through holes may be eliminated. The through holes **13**, 0.2mm to 1mm in diameter, of the cathode plate **5**, may be easily formed by suitable etching techniques so that the fabrication of the flat display panels in accordance with the present invention may be much facilitated.

The anode lines **2'** are spaced apart from each other preferably by a pitch of 0.3 to 1.5mm while the depth of the slots **8** is preferably about one-half to three-quarters of the pitch. It is preferable to seal into the main and subsidiary discharge spaces **13** and **8** and the gas flow passages **14** a rare gas, mercury vapor, or mixture thereof, such as Xe, He-Xe, Ne-Xe, Ar-Hg, or He-Ar-Hg. The pressure of the sealed gas or gas mixture depends upon the pitch of the anode lines and the gas or gas mixture, but it is preferably several tens to several hundred torrs.

In general, the resonance line or radiation with the highest intensity is when phosphor materials are excited by using ultraviolet rays, but they are very easily absorbed. For instance, when the resonance line or radiation propagates over 0.3mm in Xe gas at 100 torrs, it is subjected to absorption 100 times at an average. Absorption involves the transition between the excited states or levels. If the distance from the point at which the resonance line is emitted to the phosphor material is long, the excitation efficiency of the phosphor material is lowered. However, according to the present invention, the thickness of the cathode plates **5** may be made only about 0.1mm in thickness so that the ultraviolet rays emitted throughout the negative glow range may be efficiently utilized.

Moreover, each subsidiary discharge controls a pair of main discharges intercommuniated through the passage **14** of the cathode plate **5** so that the power consumption of the subsidiary discharges may be remarkably reduced, with the resulting improvement in the overall efficiency.

It is to be understood that various modifications of the first embodiment may be effected. For instance, the passages **14** may be formed in the insulating substrate **7**. In this case, the portions of the insulating layer **11** corresponding to the passages **14** formed in the insulating substrate **7** must be removed as with the case of the anode lines **2'**. In other words, it suffices that the passages **14** are formed between the insulating substrate **7** and the cathode plates **5** so as to intercommunicate the through holes **13** and the slots **8**. Furthermore, instead of coating the phosphor material **10** upon the insulating layer **11**, it may be coated over the inner walls of the through holes **13** or upon the transparent insulating substrate **1**.

FIG. **4** shows one embodiment of a color display panel in accordance with the present invention in which are arrayed three kinds of anode lines **2'-G**, **2'-B**, and **2'-R** for exciting phosphor materials to emit green, blue, and red rays, respectively. Voltages are impressed upon anode electrodes **12-G**, **12-B**, and **12-R**. The cathode plates **5** are provided with a large number of triangular groups each consisting of three kinds of through holes **13-G**, **13-B**, and **13-R** which define the main discharge spaces and whose inner walls are coated with phosphor materials (not shown) capable of emitting green, blue, and red light rays, respectively. The main discharge spaces **13-G**, **13-B**, and **13-R** are communicated with the subsidiary discharge spaces through communication passages **14-G**, **14-B**, and **14-R**, respectively. Except for the above-described arrangements, the color display panel shown in FIG. **4** is substantially similar in construction to the first embodiment. The mode of operation is readily understood by those skilled in the art so that no explanation shall be made in this specification.

The third embodiment of the present invention shown in FIGS. **5A** and **5B** is substantially similar in construction to the first embodiment except that a main discharge electrode **12'** is extended through each through hole of the insulating layer **11** into the corresponding through hole **13** of the cathode plate **5**. The height of the main discharge electrode **12'** extending into the through hole **13** may be arbitrarily selected. For instance, the main discharge electrode **12'** may be slightly extended beyond the surface of the phosphor material **10**.

The advantages of the third embodiment over the first embodiment attained by extending the main discharge electrodes **12** through the insulating layer **11** may be summarized as follows:

1. The diffusion loss of the charge particles diffused into the surrounding insulating layer may be reduced so that both the discharge starting and maintaining voltages may be lowered.

2. The discharge distance or gap may be shortened so that the time required for the ions and electrons to travel from one electrode to the other may be considerably reduced with the resulting improvement in rise time of the discharge.

3. The variation in discharge starting and maintaining voltages may be minimized.

The fourth embodiment shown in FIGS. **6A** and **6B** is substantially similar in construction to the first or third embodiment described hereinbefore except that the subsidiary discharge anode lines **9** are disposed in the slots **8** and are spaced apart from the bottoms thereof by a very small distance. Reference numeral **15** denotes a sealout such as glass having a low vitrification

point for hermetically sealing the main and subsidiary discharge spaces and their communication passages.

In the first through fourth embodiments of the present invention, instead of the circular through holes **13** of the cathode plates **5**, they may have any configuration such as square or rectangular so that the phosphor material coating area may be increased, thereby increasing brilliance.

Next, one example of the method for manufacture of flat display panels in accordance with the present invention will be described hereinafter. First, the anode lines **2'** are formed upon the insulating substrate **7** such as soda glass by printing or vacuum evaporation techniques. Thereafter, glass powder of a low melting point is applied over the insulating substrate **7** in a desired pattern by printing or masking techniques, and then sintered to form the insulating layer **11**. In the third step, the subsidiary slots **8** are formed by machining.

Meanwhile, the cathode plates **5** are made of, for instance, Fe-Ni alloy, are etched so that the through holes **13** of a desired configuration or pattern may be formed. Thereafter, the cathode plates **5** are bonded to the transparent insulating plate **1** made of, for instance, a transparent soda glass with glass of a low vitrification point. The subassembly of the transparent insulating plate **1** and the cathode plates **5** is registered with the insulating substrate **7**, and then the adhesive **15** is applied to attain the desired hermetic sealing. Thereafter, the main and subsidiary discharge spaces **13** and **8** and their communication passages **14** are evacuated through a pipe by a vacuum pump while the panel assembly is heated for a predetermined time. Then, a purified gas or gas mixture is filled into the assembly at a desired pressure, and then the pipe **16** is sealed.

While we have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

What is claimed is:

**1.** A flat display panel comprising

a. an insulating substrate provided with a plurality of slots formed in parallel with each other and spaced apart from each other by a predetermined distance, said slots defining subsidiary discharge spaces,

b. a plurality of first electrodes each of which is disposed in each of said plurality of slots, respectively,

c. a plurality of second electrodes disposed upon said insulating substrate adjacent to said slots,

d. a plurality of third electrodes spaced apart from said second electrodes by a predetermined distance, said third electrodes intersecting said second electrodes at predetermined angles, a through hole being formed through said third electrodes at each point at which said third electrodes intersect said second electrodes, the main discharges occurring between said third and second electrodes while the subsidiary discharges occur between said third and first electrodes,

e. a phosphor material disposed within each of the through holes of said third electrodes,

f. a transparent insulating substrate disposed in contact with said third electrodes for hermetically sealing a discharge gas or discharge gas mixture filled into said slots of said insulating substrate and into said through holes of said third electrodes, and

g. each group consisting of at least two of said through holes which are formed in the same third electrode being hydraulically communicated with each other and with one of said slots of said insulating substrate.

**2.** A flat display panel as defined in claim **1** wherein said first electrodes are subsidiary anodes, said second electrodes are main anodes, and said third electrodes are cathodes.

**3.** A flat display panel as defined in claim **1** wherein said second electrodes are main anodes and extended through said through holes of said third electrodes.

**4.** A flat display panel comprising

a. an insulating substrate provided with a plurality of slots formed in parallel with each other and spaced apart from each other by a predetermined distance,

b. a plurality of first electrodes each of which is disposed in each of said plurality of slots, respectively,

c. a plurality of second electrodes disposed upon said insulating substrate adjacent to said slots, respectively,

d. a plurality of third electrodes spaced apart from said second electrode by a predetermined distance, said third electrodes intersecting said second electrode, a through hole being formed through said third electrodes at each point at which said third electrodes intersect said second electrodes, a plurality of communication passages being formed in each of said third electrodes in such a way that each of said communication passages bridges across each of said slots of said insulating substrate and hydraulically communicates each group consisting of at least two of said through holes, which are formed in the same third electrode and located on each side of and above said each slot, with said each slot,

e. a phosphor material disposed in each of said through holes,

f. a transparent insulating substrate disposed in contact with said third electrodes for hermetically seating a discharge gas or gas mixture filled into said through holes of said third electrodes and said slots of said insulating substrate, whereby said slots define the subsidiary discharge spaces in which the subsidiary discharges between said first and third electrodes occur while said through holes define the main discharge spaces in which the main discharges between said second and third electrodes occur.

**5.** A flat display panel as defined in claim **4** wherein said first electrodes disposed in said slots of said insulating substrate are spaced apart from the bottoms of said slots by a predetermined distance.

**6.** A flat display panel comprising

a. an insulating substrate provided with a plurality of slots which define the subsidiary discharge spaces,

b. a plurality of subsidiary discharge anodes disposed in said plurality of slots, respectively,

c. a plurality of anode lines disposed upon said insulating substrate and covered with an insulating layer having a plurality of openings such that desired portions of said anode lines may be exposed through said openings,

d. a plurality of cathode plates disposed so as to intersect said slots of said insulating substrate at predetermined angles and provided with a plurality of through holes formed at the locations corresponding to said exposed portions of said anode lines,

e. a transparent insulating substrate whose one major surface is placed into contact with said cathode plates for hermetically sealing a discharge gas or discharge gas mixture filled in said slots of said insulating substrate and said through holes of said cathode plates,

f. a phosphor material disposed in each of said through holes, and

g. a plurality of communication passages formed between said cathode plates and said insulating substrate in such a way that each of said communication passages may hydraulically communicate at least two through holes formed in the same cathode plate with one of said slots of said insulating substrate.

7. A flat display panel comprising

a. an insulating substrate provided with a plurality of slots which define the subsidiary discharge spaces,

b. a plurality of subsidiary discharge anodes disposed within said slots, respectively,

c. a plurality of anode lines disposed upon said insulating substrate and covered with an insulating layer having a plurality of openings such that only desired portions of said anode lines may be exposed through said openings,

d. a plurality of cathode plates disposed so as to intersect said slots of said insulating substrate at predetermined angles and provided with a plurality of through holes formed so as to expose said desired portions of said anode lines, said through holes defining the main discharge spaces, each of said cathode plates being provided with a plurality of communication passages each of which bridge across each of said slots of said insulating substrate and hydraulically communicates at least two of said through holes formed in the same cathode plate with each said slot,

e. a transparent insulating substrate whose one major surface is placed into contact with said cathode plates for hermetically sealing a discharge gas or discharge gas mixture filled in said through holes of said cathode plates and said slots of said insulating substrate, and

f. a phosphor material disposed within each of said through holes of said cathode plates.

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