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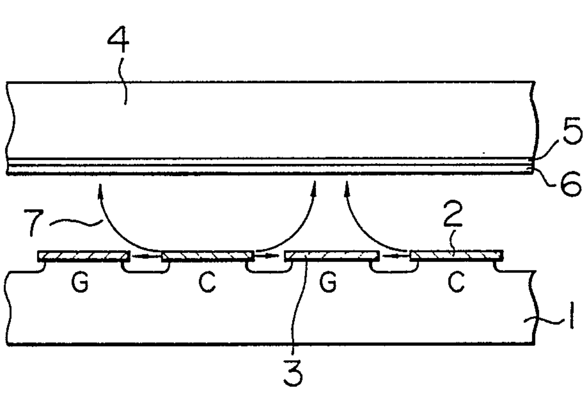
(54) **Image display apparatus and method of fabrication thereof.**

(57) An image display apparatus comprising an insulating substrate (1) having electron sources (13) controlled by X-Y matrix electrodes (10, 11) and a face plate (4) coated with a phosphor material in opposed relationship with the substrate is disclosed. An electron source at each intersection of the X-Y matrix control electrondes is made up of a plurality of cold cathodes (2) connected to an X-control electrode (10) and a plurality of gate electrodes (3) connected to a Y-control electrode (11) opposed to the cold cathodes in the same plane, and the electron source is formed on the substrate surface on other than the X- and Y-control electrodes. A voltage applied between the cold cathodes and gate electrodes arranged in opposed relations on the same surface causes a high electric field of about 10^7 V/cm at the forward end of the cold cathodes leading to an electron emission. A part of electrons thus emitted enters the anodes directly. Another part of electrons flow into the opposed gate electrodes to generate secondary electrons in the surface of the gate electrodes. The secondary electrons thus generated are accelerated by the positive voltage (anode voltage) applied to the phosphor surface of the opposed face plate and bombarded on the phosphor material, which is thus illuminated.

FIG. 1



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Description

IMAGE DISPLAY APPARATUS AND METHOD OF FABRICATION THEREOF

BACKGROUND OF THE INVENTION

The present invention relates to a thin image display apparatus using a plurality of cold cathodes.

A number of thin display apparatuses comprising a plurality of cold cathodes arranged two-dimensionally for displaying an image using X-Y matrix electrodes have been disclosed in the related art. Among them, a thin image display apparatus using a cold cathode of electric field emission type is closely watched. This thin diplay apparatus, as shown in Fig. 5A, has a substrate with the surface thereof formed of a plurality of cold cathodes of thin film field emission type in a density as high as 10^6 to 10^7 units/cm^2. As shown in Fig. 5B, these cathodes make up an X electrode 22 as one part of the matrix electrodes on the surface of a substrate 21, on which a Y electrode 24 is formed as the other part of the matrix electrodes together with an insulating layer 23. A minute aperture 25 one µm to 1.5 µm in diameter is formed in the Y electrode at each inter-section of the X-Y electrodes, and the insulating layer 23 is etched. A substrate assembly thus formed is rotated, while high a melting point metal such as tungsten or molybdenum is diagonally deposited by evaporation thereby to form a conical cold-cathode chip 26. After forming cold cathodes, the unrequired metal layer in the surface is removed to produce a plurality of electron sources of cold cathodes of thin film field emission type.

These X-Y matrix electron sources are arranged in opposed relationship with a face plate 27 coated with a phosphor material 28 to configure an image display apparatus.

This image display apparatus, which comprises as many as more than 1000 minute electron sources in each pixel, generally has a uniform characteristic in spite of possible variations in the characteristics of individual minute electron sources, thus producing a comparatively uniform brightness over the whole screen.

The aforementioned image display apparatus with its satisfactory characteristics, however, has not yet found practical applications due to the facts that a complicated production process makes a production cost high and that it is difficult to fabricate uniform cold cathodes of field emission type over an area required of a display apparatus. Another reason is that a laminated structure of an X-control electrode (cold cathode) and Y-control electrode (gate electrode) through an insulating layer therebetween leads to a large electric capacity, resulting in a heavy load imposed on a drive circuit.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a thin image display apparatus comprising an insulating substrate having two-dimensionally arranged electron source units controlled by X-Y matrix control electrodes and a face plate coated with a phosphor material arranged in opposed relationship with the insulating substrate wherein the said electron scorce units corresponding to each inter-section of X-Y matrix control electrodes includes a cold cathode connected to an X-control electrode and a gate electrode connected to a Y-control electrode opposed to the cold cathode in the same plane, the electron source being formed in the part of the substrate surface on other than at least one of the X- and Y- control electrodes.

Upon application of a voltage between the cold cathode and the gate electrode arranged in opposed relationship with each other on the same surface in the manner mentioned above, a high electric field of approximately 10^7 V/cm is formed at the forward end of the cold cathode and electrons are emitted. A part of the electrons thus emitted enters the anode directly. Another part of the electrons flow into the opposite gate electrode thereby to generate secondary electrons in the surface of the gate electrode. The secondary electrons thus generated are accelerated by a positive voltage (hereinafter called the "anode voltage") applied to the phosphor face of the opposed face plate and bombarded on the phosphor material to emit light.

The apparatus according to the present invention in which a plurality of cold cathodes of planar field emission type are formed on the surface of an insulating substrate defined by X-control electrodes and Y-control electrodes, has the advantages (1) that the electric capacity between the electrodes is extremely reduced (to 1/20 to 1/30 of the related art), (2) that the production cost is low since cold cathodes and gate electrodes are capable of being formed at the same time, and (3) that crosstalks are very small.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partial sectional view of an image display apparatus according to an embodiment of the present invention.

Fig. 2 is a sectional view of the essential parts of an electron source section according to the same embodiment.

Fig. 3 is a plan view schematically showing an electrode arrangement according to the same embodiment.

Fig. 4 is a perspective view of the essential parts of two-dimensional electron sources as configured according to another embodiment of the present invention.

Figs. 5A and 5B are a perspective view and an enlarged perspective view of the essential parts respectively of a matrix display apparatus of electric field emission type related to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A partial sectional view of an image display apparatus according to the present invention is shown in Fig. 1. The image display apparatus comprises a glass substrate 1 having an electron source for electric field emission at each intersection of X-Y matrix electrodes, and a face plate 4 coated with phosphor material in opposed relationship with the glass substrate 1. The glass substrate 1 has cold cathode 2 and gate electrodes 3 arranged face to face on the surface. When a positive voltage of, say, 100 V is applied to the gate electrodes 3 with respect to the cold cathodes 2, electron beams 7 are emitted. A part of electrons thus emitted flows into the gate electrodes 3, while the other part is accelerated by a high voltage of, say, 500 V applied to an anode 5 and hits a phosphor surface thereby to cause the phosphor to emit light.

An enlarged perspective view of an electron source is shown in Fig. 2. A multiplicity of saw-toothed protrusions 8 are formed in the surface of the cold cathode 2 opposed to the gate electrode 3. Further, the surface of the glass substrate 1 has a recess 9 between the cold cathode 2 and the gate electrode 3 to facilitate formation of a high electric field at the forward end of the cold cathode 2.

Fig. 3 shows a part of electrode arrangement. X-control electrodes X_1, X_2, X_3, ... X_n and Y-control electrodes Y_1, Y_2, Y_3, ... Y_n make up matrix control electrodes. A plurality of electron sources 13 are formed on the substrate surface defined by these control electrodes. Each electron source 13, which is configured as shown in Fig. 2, includes a cold cathode 2 connected to an X-control electrode and a gate electrode 3 connected to a Y-control electrode.

This construction of the electron sources 15 not overlaid on the X- or Y-control electrodes is a reduction of 1/20 to 1/30 of the area required by the prior art for superposing the electrodes on each other through an insulating layer. As a result, the probability of short-circuiting between electrodes due to a pinhole in the insulating layer and the electric capacity are decreased to 1/20 to 1/30.

Now, a method of fabricating two-dimensional electron sources will be explained. A film of such a metal as nickel is deposited by evaporation to the thickness of 0.5 μm over the whole surface of the glass substrate, and formed in stripes by photolithography. Electrodes are formed to the width of 0.1 mm. An SiO_2 film as thick as 1 μm is deposited as an insulating layer by the CVD process, and a part of the insulating film over an X-control electrode is removed to form a window for connecting to a cold cathode. Further, a tungsten film is deposited by evaporation to the thickness of 0.2 μm, so that a cold cathode 2, a gate electrode 3 and a Y-control electrode are formed simultaneously by photolithography. The Y-control electrode is made as wide as 0.5 mm.

The protrusions of the cold cathod are set at an interval of 2 μm from the gate electrode. There are approximately 500 protrusions 8 per electron source unit (which correspond to one pixel). As the next process, the whole substrate is immersed in a buffer etching solution to form a recess 9 at the forward end of the cold cathode as shown in Fig. 2.

The electrode material for forming an X-control electrode is not limited to nickel metal, but may preferably take the form of aluminum, titanium, gold-chromium alloy or other metal material which has a high adhesion with the glass substrate and low in resistivity. Also, a silver electrode or a gold electrode may be formed by the screen printing process or the like. The SiO_2 film used as an insulating layer may be replaced by another material of high insulation characteristic such as SiN, SiO or Al_2O_3. Instead of tungsten, on the other hand, tantalum, molybdenum or an alloy or carbide thereof having a high melting point may be used as a material of the cold cathode with equal effect.

In this way, a glass substrate having electron sources units 13 in the number of 480 x 660 arranged in matrix are disposed in opposed relations with a face plate coated with a ZnO:Zn phosphor material at intervals of 0.3 mm, and the surrounding parts are sealed with frit glass of a low melting point. The resulting assembly is evacuated to produce an image display apparatus with a screen size of 10 inches.

When a voltage of 150 V is applied to the Y-control electrodes (video signal modulation electrodes) as against the X-control electrodes (vertical scanning electrodes), an electron emission current of about 10 μA is produced for each pixel. Also, upon application of 500 V to the surface of the phosphor material with an image displayed by line-at-a-time driving method, a screen brightness of approximately 50 fL is obtained.

In place of the ZnO:Zn phosphor material used according to the present embodiment, the three primary colors of red, green and blue may be arranged in stripes to produce a color image.

An electrode configuration of a two-dimensional electron source according to another embodiment is shown as a perspective view in Fig. 4. Stripe electrodes 10 having a width of 0.1 mm and thickness of 3 μm are formed by the screen printing method on the surface of the glass substrate 1. As the next step, frit glass of low melting point is laid to the thickness of 1 μm by screen printing at intersections of the stripe electrodes 10 and Y-control electrodes to form an insulating layer 12. In similar fashion, Y-control electrodes 11 having a width of 0.05 mm and thickness of 1 μm are formed in stripes. Further, a cold cathode material WSi_2 is formed by sputtering over the whole surface, and cold cathodes 2 and gate electrodes 3 are formed at the same time by photolithograhy.

As shown in Fig. 4, the cold cathodes 2 and the gate electrodes 3 are engaged in comb, and the sides of these electrodes opposed to each other are arranged in parallel to the X-control electrodes (perpendicular to the longitudinal direction of the Y-control electrodes). This arrangement causes emitted electron beams to widen somewhat along the longitudinal direction of the Y-control electrodes but not substantially along the perpendicular direction thereof. As a result, electron beams are prevented from hitting the phosphor material corresponding to adjacent Y-control electrodes, so that what are called crosstalks rarely occur, thus producing a high-definition image display apparatus. In particular, color mixing is effectively prevented in a color image display apparatus configured by three-color phosphor materials in stripes.

In this way, a glass substrate 1 making up a two-dimensional electron source and a face plate coated with a phosphor material are sealed with each other in opposed relations and evacuated in the same manner as in the first embodiment thereby to test produce an image display apparatus, which is capable of displaying a clear image substantially free of crosstalks like the first embodiment.

Claims

1. An image display apparatus comprising an insulating substrate (1) having two-dimensionally arranged electron source units (13) controlled by X-Y matrix control electrodes (10, 11) and a face plate (4) coated with a phosphor material and arranged in opposed relationship with the insulating substrate, wherein the said electron source corresponding to each intersection of the X-Y matrix control electrodes consist of at least an electron source of planer field emission type including at least a cold cathode (2) and a gate electrode (3).

2. An image display apparatus according to Claim 1, wherein the said electron source units are formed in the same plane at a part other than on the X-control electrode and/or Y-control electrode.

3. An image display apparatus according to Claim 1, wherein a multiplicity of protrusions (8) are formed at the part of the cold cathode opposed to the gate electrode.

4. An image display apparatus according to Claim 1, wherein at least a part of the insulating substrate (12) at the forward ends of the protrusions of the cold cathode is removed.

5. An image display apparatus according to any one of Claims 1 to 3, wherein cold cathodes and gate electrodes are formed in the fashion of comb and engaged with each other.

6. An image display apparatus according to Claim 4, wherein the sides of the electrodes opposed to each other are perpendicular to the longitudinal direction of the Y-control electrode (longitudinal direciton of the X-control electrode).

7. A method of fabricating an image display apparatus according to Claim 1, comprising the steps of forming X-control electrodes in stripes on the surface of an insulating substrate, forming an insulating layer at least at a part of the X-control electrodes crossing the Y-control electrodes, and forming cold cathodes, gate electrodes and the Y-control electrodes at the same time by photolithography.

8. A method of fabricating an image display apparatus according to Claim 1, comprising the steps of forming X-control electrodes and Y-control electrodes, depositing a film of cold cathode material over the whole surface, and forming cold cathodes and gate electrodes simultaneously by photolithography.

FIG. 1

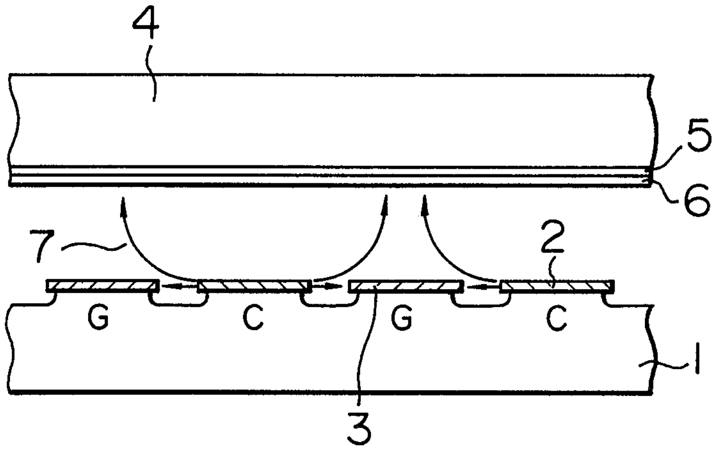

FIG. 2

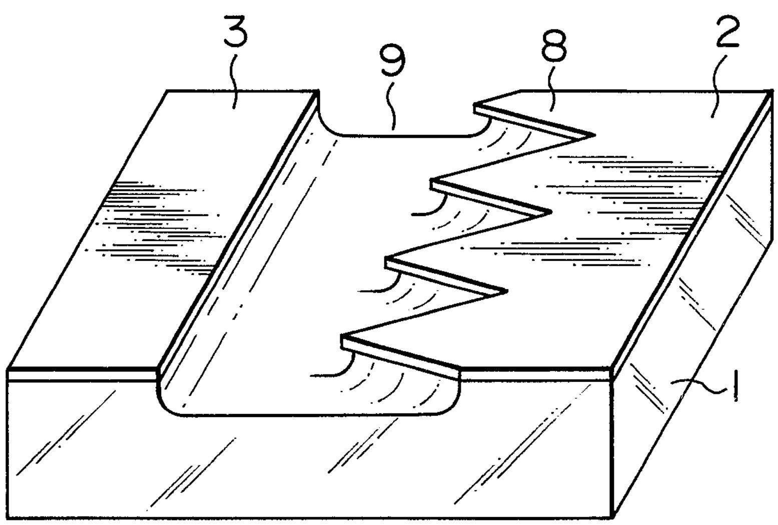

FIG. 3

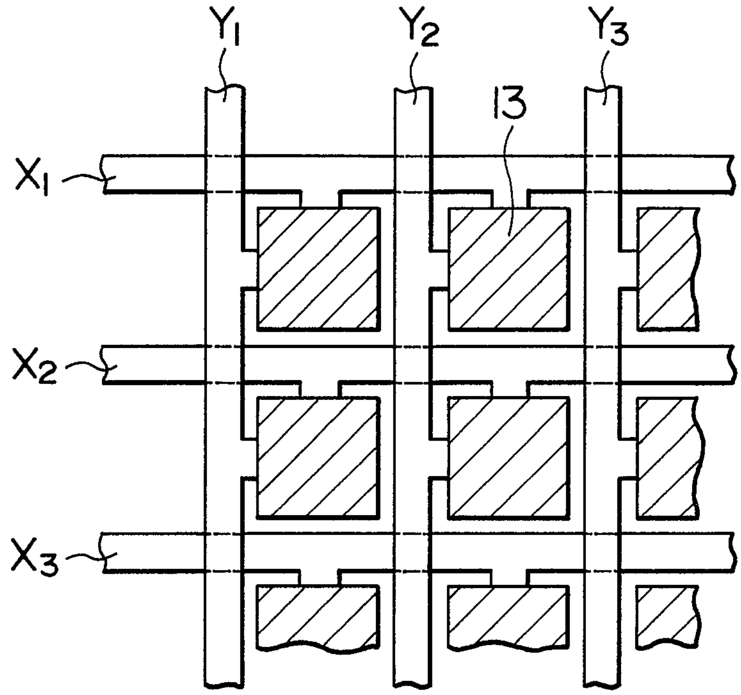

FIG. 4

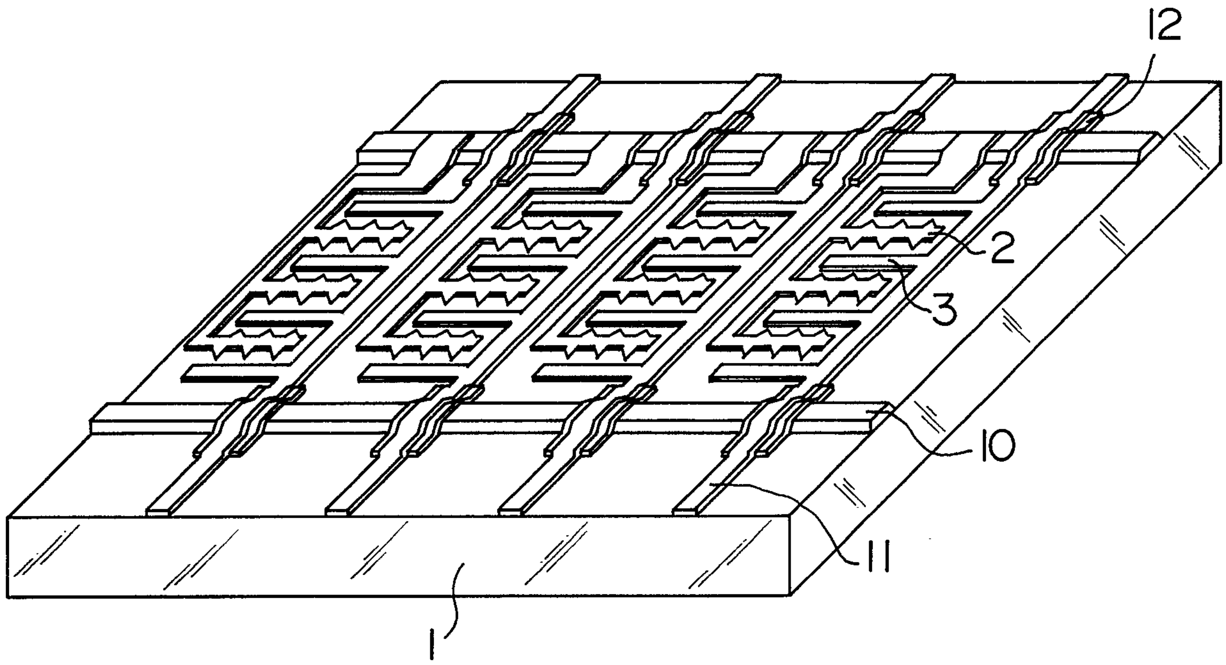

FIG. 5A

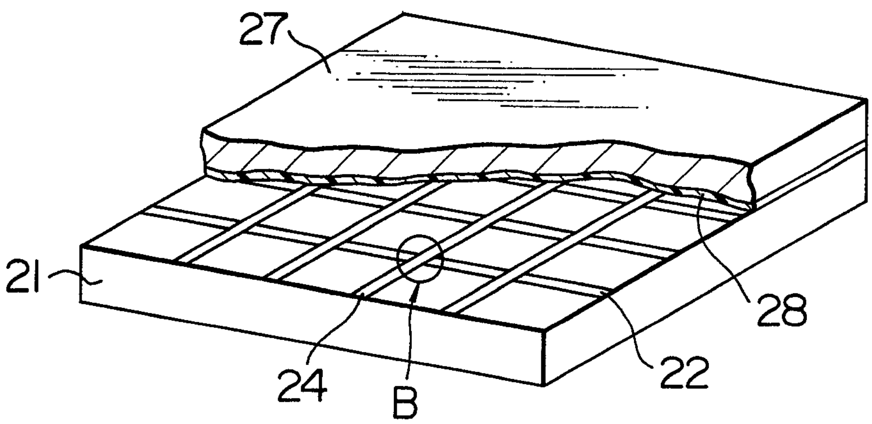

FIG. 5B