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(54) IMAGE DISPLAY DEVICE

(57) A spacer structure 22 is provided between a first substrate 10 having a phosphor screen formed thereon and a second substrate 12 provided with a plurality of electron emission sources 18 which excite the phosphor screen. The spacer structure has a plate-shaped supporting substrate 24, which is opposed to the first and second substrates and has a plurality of electron beam apertures 26 opposed individually to the electron emission sources, and a plurality of spacers 30a and 30b set up on a surface of the supporting substrate. Those electron beam apertures, among the plurality of electron beam apertures, which are situated near spacer setup positions, has an area greater than that of the other electron beam apertures.

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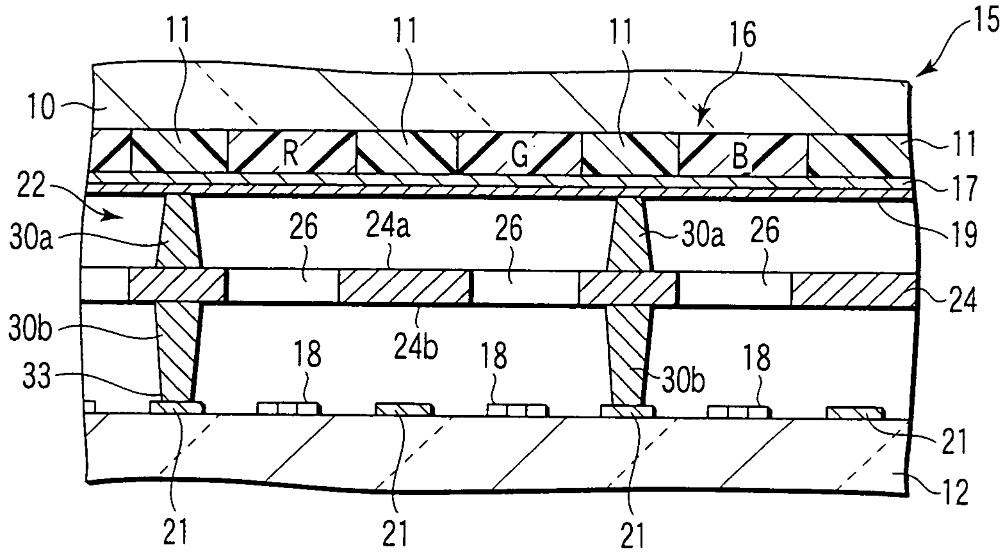
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F I G. 3

Description

Technical Field

[0001] This invention relates to an image display device provided with substrates opposed to each other and a spacer structure located between the substrates.

Background Art

[0002] In recent years, various flat image display devices have been noticed as a next generation of lightweight, thin display devices to replace cathoderay tubes (hereinafter, referred to as CRTs). For example, a surface-conduction electron emission device (hereinafter, referred to as an SED) has been developed as a kind of a field emission device (hereinafter, referred to as an FED) that serves as a flat display device.

[0003] This SED comprises a first substrate and a second substrate that are opposed to each other across a predetermined gap. These substrates have their respective peripheral portions joined together by a rectangular sidewall, thereby constituting a vacuum envelope. Three-color phosphor layers are formed on the inner surface of the first substrate. Arranged on the inner surface of the second substrate are a large number of electron emitting elements for use as electron sources, which correspond individually to pixels, individually, and excite the phosphors. Each electron emitting element is formed of an electron emitting portion, a pair of electrodes that apply voltage to the electron emitting portion, etc.

[0004] For the SED, it is important to maintain a high degree of vacuum in a space between the first substrate and the second substrate, that is, in the vacuum envelope. If the degree of vacuum is low, the life of the electron emitting elements, and hence, the life of the device shorten inevitably. Since a vacuum is maintained between the first substrate and the second substrate, moreover, atmospheric pressure acts on the first substrate and the second substrate. In order to support atmospheric pressure that acts on these substrates and maintain the gap between the substrates, therefore, a large number of plate-shaped or columnar spacers are located between the two substrates.

[0005] In order to locate the spacers over the entire surfaces of the first substrate and the second substrate, the spacers should be formed in the shape of very thin plates or very slender columns lest the phosphors on the first substrate touch the electron emitting elements on the second substrate. Since these spacers must inevitably be set very close to the electron emitting elements, a dielectric material should be used for the spacers. If a study is made to thin the first substrate and the second substrate, moreover, more spacers are needed, so that manufacture is more difficult. Described in Jpn. Pat. Appln. KOKAI Publication No. 2001-272927, for example, is a device in which a large number of columnar spacers are set up on a supporting substrate to form a spacer structure and the spacer structure is located between first and second substrates.

[0006] The spacers may possibly be aligned with regions between phosphors on the first substrate and between electron emitting elements on the second substrate by a method such that the spacers are directly attached to the regions between the phosphors or between the electron emitting elements. Alternatively, spacers may be aligned by a method such that a large number of spacers are formed with high positioning accuracy on a metal plate previously formed with electron beam apertures through which electrons pass and the spacers on the metal plate are aligned with the first substrate or the second substrate.

[0007] According to a method described in Jpn. Pat. Appln. KOKAI Publication No. 2002-082850 as the latter method, for example, two molding dies formed having a large number of holes corresponding individually to spacers in shape are brought into close contact with the obverse and reverse surfaces of a metal plate, and the holes in the molding dies are loaded with a pasty spacer forming material in this state. Further, an overflow of the spacer forming material is removed by scraping the surfaces of the molding dies with a squeegee or the like. After the spacer forming material is then cured in molding dies, according to the proposed method, the two molding dies are disengaged from the metal plate, whereupon the columnar spacers are formed on the metal plate.

[0008] If the metal plate and the molding dies are not strictly in close contact with one another as the molding dies are loaded with the spacer forming material, in the method described above, the spacer forming material inevitably gets in between the metal plate and the molding dies. In this case, spacers with normal shapes cannot be formed, and besides, the electron beam apertures of the metal plate may possibly be clogged by the oozed spacer forming material. In positions corresponding to the clogged electron beam apertures, electron beams cannot reach the phosphors, so that it is hard to display desired images.

[0009] The spacer forming material and an adhesive component having oozed out onto the metal plate are irregularly shaped and liable to form a source of electric discharge. If the oozed portions of the spacer forming material are electrified, electron beams emitted from the electron emitting elements are attracted to the oozed portions and deviated from their original trajectories. In consequence, there is a problem that the electron beams misland on the phosphor layers, so that the color purity of displayed images is reduced.

[0010] A method for manufacturing a vacuum envelope of an image display device is proposed in Jpn. Pat. Appln. KOKAI Publication No. 2001-229824. In this manufacturing method, a first substrate, a second substrate, and a spacer structure are previously set in a vacuum, and a getter is applied to a metal back layer on the first substrate in order to maintain the degree of vacuum after sealing. Thereafter, the first substrate and the second substrate are sealed together so as to hold the spacer structure between them.

[0011] In displaying an image on the SED constructed in this manner, a high voltage of, e.g., 10 kV as an electron-beam acceleration voltage is applied between the first substrate and the second substrate. If the getter is provided overlapping the metal back layer under high voltage, electric discharge easily occurs between the metal back layer and the first substrate. If the electric discharge occurs, the phosphor layers, the metal back layer, the electron emitting elements on the second substrate, etc., may possibly be broken.

[0012] In the spacer structure constructed in this manner, moreover, it is difficult to form all the spacers to the same height, so that there is a possibility of the spacer height becoming uneven. If the spacer height is uneven, it is hard for the spacers to support atmospheric pressure that acts on the first substrate and the second substrate, so that the atmospheric strength of the envelope is reduced. Further, heavier loads act on taller spacers, thereby possibly damaging the spacers. In this case, the strength of the spacer structure itself is reduced. If gaps are formed between the distal ends of short spacers and the substrates, moreover, the gaps may possibly cause electric discharge.

[0013] For the SED constructed in this manner, it is an important problem to align the spacers and the electron beam apertures with the first substrate and the second substrate. For example, the electron beam apertures in the supporting substrate and the spacers must be provided lest they intercept electrons emitted from the electron emitting elements. In particular, the supporting substrate must be aligned highly accurately with the first substrate and the second substrate lest the trajectories of electron beams from the electron emitting elements toward the phosphors be blocked by the supporting substrate. The larger and the more precise the display device, the more serious this problem is.

[0014] If the display device is made large-sized, moreover, the spacer structure that is composed of the spacers and the supporting substrate is expected to be also large-sized. With use of the existing manufacturing methods, however, it may possibly be difficult to make the spacer structure large-sized. Otherwise, the manufacturing costs of members are supposed to be high. The larger the size of the plate-shaped supporting substrate, the lower the accuracy of position coordinates for the formation of the electron beam apertures is.

Disclosure of Invention

[0015] This invention has been made in consideration of the above problems, and has an object to provide an image display device with improved display quality in which image failure attributable to oozing of a spacer forming material can be restrained.

[0016] Another object of this invention is to provide an image display device capable of restraining generation of electric discharge and enhanced in atmospheric strength.

[0017] Still another object of this invention is to provide an image display device capable of being increased in size and improved in precision.

[0018] According to an aspect of the invention, there is provided an image display device comprising: a first substrate having a phosphor screen formed thereon; a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which excite the phosphor screen; and a spacer structure which is provided between the first and second substrates and supports atmospheric pressure acting on the first and second substrates,
the spacer structure having a plate-shaped supporting substrate, which is opposed to the first and second substrates and has a plurality of electron beam apertures opposed individually to the electron emission sources, and a plurality of spacers set up on a surface of the supporting substrate, those electron beam apertures, among the plurality of electron beam apertures, which are situated near spacer setup positions having an area greater than that of the other electron beam apertures.

[0019] According to another object of the invention, there is provided an image display device comprising: a first substrate having a phosphor screen including a phosphor layer and a metal back layer provided overlapping the phosphor screen; a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which emit electrons toward the phosphor screen; a supporting substrate which is located between the first and second substrates, has a first surface in contact with the first substrate, a second surface opposed to the second substrate, and a plurality of electron beam apertures opposed to the electron emission sources, and is covered by a dielectric substance; and a plurality of spacers which are set up between the second surface and the second substrate and support atmospheric pressure acting on the first and second substrates, the supporting substrate having a plurality of height reducing portions individually in contact with the spacers and elastically deformable in a height direction of the spacers.

[0020] According to still another aspect of the invention, there is provided an image display device comprising: a first substrate having a phosphor screen including a phosphor layer, a metal back layer provided overlapping the phosphor screen, and a getter film formed overlapping the metal back layer; a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which emit electrons toward the phosphor screen; a supporting substrate which is located between the first and second substrates, has a first surface in contact with the first substrate, a second surface opposed to the second substrate, a plurality of electron beam apertures opposed to the electron emission sources, and a plurality of recesses formed in the first surface, and is covered by a dielectric substance; and a plurality of spacers which are set up between the second surface and the second substrate and support atmospheric pressure acting on the first and second substrates.

[0021] According to another aspect of the invention, there is provided an image display device comprising: a first substrate having a phosphor screen formed thereon; a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which excite the phosphor screen; and a plurality of spacer structures which are individually provided between the first and second substrates and support atmospheric pressure acting on the first and second substrates, the spacer structures each having a plate-shaped supporting substrate, which is opposed to the first and second substrates and has a plurality of electron beam apertures opposed individually to the electron emission sources, and a plurality of spacers set up on a surface of the supporting substrate.

Brief Description of Drawings

[0022]

FIG. 1 is a perspective view showing an SED according to a first embodiment of this invention;

FIG. 2 is a perspective view of the SED, broken away along line II-II of FIG. 1;

FIG. 3 is a sectional view enlargedly showing the SED;

FIG. 4 is a perspective view enlargedly showing a part of a spacer structure of the SED;

FIG. 5 is a sectional view showing a supporting substrate and molding dies used in the manufacture of the spacer structure;

FIG. 6 is a sectional view showing an assembly in which the molding dies and the supporting substrate are in close contact with one another;

FIG. 7 is a sectional view showing the molding dies in an open state;

FIG. 8 is a perspective view showing a spacer structure of an SED according to a second embodiment of this invention;

FIG. 9 is a sectional view showing an SED according to a third embodiment of this invention;

FIG. 10 is a sectional view showing an SED according to a fourth embodiment of this invention;

FIG. 11 is a perspective view of the SED, broken away along line XI-XI of FIG. 1;

FIG. 12 is a sectional view enlargedly showing the SED;

FIG. 13 is a plan view showing a supporting substrate of a spacer structure of the SED;

FIG. 14 is a sectional view enlargedly showing a part of the SED;

FIG. 15 is a plan view showing a supporting substrate of an SED according to an another embodiment of this invention;

FIG. 16 is a perspective view showing an SED according to a fifth embodiment of this invention;

FIG. 17 is a perspective view of an SED, broken away along line XVII-XVII of FIG. 16;

FIG. 18 is a sectional view enlargedly showing the SED;

FIG. 19 is a perspective view showing a second substrate and a plurality of spacer structures of the SED;

FIG. 20 is a perspective view showing a second substrate and a plurality of spacer structures of an SED according to a sixth embodiment of this invention;

FIG. 21 is a perspective view showing a second substrate and a plurality of spacer structures of an SED according to a seventh embodiment of this invention;

FIG. 22 is a sectional view showing an SED according to an eighth embodiment of this invention;

FIG. 23 is a perspective view, partially in section, showing an SED according to a ninth embodiment of this invention;

FIG. 24 is a sectional view of the SED; and

FIG. 25 is a perspective view showing a spacer structure of the SED.

Best Mode for Carrying Out the Invention

[0023] A first embodiment in which this invention is applied to an SED as a flat image display device will now be described in detail with reference to the drawings.

[0024] As shown in FIGS. 1 to 3, the SED comprises a first substrate 10 and a second substrate 12, which are formed of a rectangular glass plate each. These substrates are located opposite each other with a gap of about 1.0 to 2.0 mm between them. The first substrate 10 and the second substrate 12 have their respective peripheral edge portions joined together by a sidewall 14 of glass in the form of a rectangular frame, thereby forming a flat vacuum envelope 15 of which the inside is kept vacuum.

[0025] A phosphor screen 16 that functions as a phosphor screen is formed on the inner surface of the first substrate 10. The phosphor screen 16 is composed of phosphor layers R, G and B, which glow red, green, and blue, individually, and light shielding layers 11 arranged side by side. These phosphor layers are stripe-shaped, dot-shaped, or rectangular. A metal back 17 of aluminum or the like and a getter film 19 are successively formed on the phosphor screen 16.

[0026] Provided on the inner surface of the second substrate 12 are a large number of surface-conduction electron emitting elements 18, which individually emit electron beams as electron sources for exciting the phosphor layers R, G and B of the phosphor screen 16. These electron emitting elements 18 are arranged in a plurality of columns and a plurality of rows corresponding to individual pixels. Each electron emitting element 18 is formed of an electron emitting portion (not shown), a pair of element electrodes that apply voltage to the electron emitting portion, etc. A large number of wires 21 for supplying potential to the electron emitting elements 18 are provided in a matrix on the inner surface of the second substrate 12, and their respective end portions are led out of the vacuum envelope 15.

[0027] The sidewall 14 that functions as a joint member is sealed to the peripheral edge portion of the first substrate 10 and the peripheral edge portion of the second substrate 12 with a sealant 20 of, for example, low-melting-point glass or low-melting-point metal, whereby these substrates are joined together.

[0028] As shown in FIGS. 2 to 4, the SED comprises a spacer structure 22 that is located between the first substrate 10 and the second substrate 12. In the present embodiment, the spacer structure 22 is composed of a supporting substrate 24, formed of a rectangular metal plate located between the first and second substrates 10 and 12, and a large number of columnar spacers set up integrally on the opposite surfaces of the supporting substrate.

[0029] Specifically, the supporting substrate 24 has a first surface 24a opposed to the inner surface of the first substrate 10 and a second surface 24b opposed to the inner surface of the second substrate 12, and is located parallel to these substrates. A large number of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. The electron beam apertures 26 are arranged at first pitches in a first direction X parallel to the longitudinal direction of the vacuum envelope 15 with bridge portions 27 between them, and are also arranged at second pitches larger than the first pitches in a second direction Y perpendicular to the first direction. The electron beam apertures 26 are arrayed opposite the electron emitting elements 18, individually, and are permeated by the electron beams emitted from the electron emitting elements.

[0030] The supporting substrate 24 is formed of a metal plate of, for example, an iron-nickel-based alloy with a thickness of 0.1 to 0.3 mm. An oxide film formed of elements that constitute the metal plate, e.g., an oxide film of Fe_3O_4 and $NiFe_2O_4$, is formed on the surfaces of the supporting substrate 24. The surfaces 24a and 24b of the supporting substrate 24 and the respective wall surfaces of the electron beam apertures 26 are covered by a high-resistance film that has a discharge current limiting effect. This high-resistance film is formed of a high-resistance substance that consists mainly of glass.

[0031] A plurality of first spacers 30a are set up integrally on the first surface 24a of the supporting substrate 24 and individually situated between the electron beam apertures 26 that are arranged in the second direction Y. The respective distal ends of the first spacers 30a abut the inner surface of the first substrate 10 through the getter film 19, the metal back 17, and the light shielding layers 11 of the phosphor screen 16.

[0032] A plurality of second spacers 30b are set up integrally on the second surface 24b of the supporting substrate 24 and are individually situated between the electron beam apertures 26 that are arranged in the second direction Y. The respective distal ends of the second spacers 30b abut the inner surface of the second substrate 12. The respective distal ends of the second spacers 30b are situated individually on the wires 21 that are provided on the inner surface of the second substrate 12. The first and second spacers 30a and 30b are situated in alignment with one another and are formed integrally with the supporting substrate 24 in a manner such that the supporting substrate 24 is held between them from both sides.

[0033] Each of the first and second spacers 30a and 30b is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each first spacer 30a has a substantially elliptic cross-sectional shape such that the diameters of its proximal end situated on the side of the supporting substrate 24 are about 0.3 mm and 2 mm, the diameters on its extended end are 0.2 mm and 2 mm, and its height is about 0.6 mm. Each second spacer 30b has a substantially elliptic cross-sectional shape such that the diameters of its proximal end situated on the side of the supporting substrate 24 are about 0.3 mm and 2 mm, the diameters on its extended end are 0.2 mm and 2 mm, and its height is about 0.8 mm.

[0034] As shown in FIG. 4, each electron beam aperture 26 is formed having a rectangular shape. The other electron beam apertures 26 than the electron beam apertures that are situated near spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension L1 of 0.2 mm in the second direction. Among the electron beam apertures, those electron beam apertures 26a which are situated near the spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension L2 of 0.25 mm in the second direction, so that they have an area greater than that of the other electron beam apertures 26. The electron beam apertures 26a that are situated near the spacer setup positions imply electron beam apertures that face the first and second spacers 30a and 30b. In the present embodiment, the area of the three electron beam apertures 26a situated on each side of the spacers is made greater than that of the other electron beam apertures. The electron beam apertures 26a with the greater area are not limited to three in number. If necessary, four or more electron beam apertures may be arranged on each side of the spacers.

[0035] The spacer structure 22 constructed in this manner is located between the first substrate 10 and the second substrate 12. The first and second spacers 30a and 30b abut the respective inner surfaces of the first substrate 10 and the second substrate 12, thereby supporting atmospheric pressure that acts on these substrates and keeping the gap between the substrates at a predetermined value.

[0036] The SED comprises voltage supply portions (not shown) that apply voltages to the supporting substrate 24 and the metal back 17 of the first substrate 10. The voltage supply portions are connected individually to the supporting substrate 24 and the metal back 17, and apply voltages of, e.g., 12 kV and 10 kV to the supporting substrate 24 and the metal back 17, respectively. In displaying an image on the SED, an anode voltage is applied to the phosphor screen 16 and the metal back 17, and electron beams emitted from the electron emitting elements 18 are accelerated by the anode voltage and collide with the phosphor screen 16. Thereupon, the phosphor layers of the phosphor screen 16 are excited to luminescence and display the image.

[0037] The following is a description of a manufacturing method for the SED constructed in this manner. A manufacturing method for the spacer structure 22 will be described first.

[0038] As shown in FIG. 5, the supporting substrate 24 with a predetermined size and an upper die 36a and a lower die 36b, each in the form of a rectangular plate having substantially the same size as the supporting substrate, are prepared. In this case, the electron beam apertures 26 and 26a are formed by etching after the supporting substrate of Fe-50% Ni with a thickness of 0.12 mm is degreased, washed, and dried. After the entire supporting substrate 24 is oxidized, a dielectric film is formed on the surface of the supporting substrate including the respective inner surfaces of the electron beam apertures 26 and 26a. Further, a coating solution that consists mainly of glass is spread on the dielectric film, dried, and then fired, whereupon a high-resistance film is formed. Thus, the supporting substrate 24 is obtained.

[0039] The upper die 36a and the lower die 36b for use as molding dies are flat plates formed of a transparent material that transmits ultraviolet rays, e.g., clear silicone or clear polyethylene terephthalate. The upper die 36a has a flat contact surface 41a in contact with the supporting substrate 24 and a large number of bottomed spacer forming holes 40a for molding the first spacers 30a. The spacer forming holes 40a individually open in the contact surface 41a of the upper die 36a and are arranged at predetermined spaces. Likewise, the lower die 36b has a flat contact surface 41b and a large number of bottomed spacer forming holes 40b for molding the second spacers 30b. The spacer forming holes 40b individually open in the contact surface 41b of the lower die 36b and are arranged at predetermined spaces.

[0040] Subsequently, the spacer forming holes 40a of the upper die 36a and the spacer forming holes 40b of the lower die 36b are loaded with a spacer forming material 46. A glass paste that contains at least an ultraviolet-curing binder (organic component) and a glass filler is used as the spacer forming material 46. The specific gravity and viscosity of the glass paste are selected as required.

[0041] As shown in FIG. 6, the upper die 36a is positioned so that the spacer forming holes 40a filled with the spacer forming material 46 individually face regions between the adjacent electron beam apertures 26, and the contact surface 41a is brought into close contact with the first surface 24a of the supporting substrate 24. Likewise, the lower die 36b is positioned so that the spacer forming holes 40b individually face regions between the adjacent electron beam apertures 26, and the contact surface 41b is brought into close contact with the second surface 24b of the supporting substrate 24. An adhesive may be previously applied to the spacer setup positions on the supporting substrate 24 by means of a dispenser or by printing. Thus, an assembly 42 is formed having the supporting substrate 24, upper die 36a, and lower die 36b. In the assembly 42, the spacer forming holes 40a of the upper die 36a and the spacer forming holes 40b of the lower die 36b are arranged opposite one another with the supporting substrate 24 between them.

[0042] Then, ultraviolet (UV) rays are applied to the upper die 36a and the lower die 36b from ultraviolet lamps 62a and 62b that are located outside the upper and lower dies. The upper die 36a and the lower die 36b are individually formed of an ultraviolet transmitting material. Therefore, the ultraviolet rays radiated from the ultraviolet lamps 62a and 62b are transmitted through the upper die 36a and the lower die 36b and applied to the loaded spacer forming material 46. Thus, the spacer forming material 46 is ultraviolet-cured with the assembly 42 kept in a close-contact state.

[0043] Subsequently, the upper die 36a and the lower die 36b are released from the supporting substrate 24 with the cured spacer forming material 46 left on the supporting substrate 24, as shown in FIG. 7. Thereafter, the supporting substrate 24 with the spacer forming material 46 thereon is heat-treated in a heating furnace so that the binder is evaporated from the spacer forming material, and the spacer forming material is then regularly fired at about 500 to 550°C for 30 minutes to 1 hour. Thus, the spacer structure 22 is obtained having the first and second spacers 30a and 30b built-in on the supporting substrate 24.

[0044] In the manufacture of the SED, on the other hand, the first substrate 10, which is provided with the phosphor screen 16 and the metal back 17, and the second substrate 12, which is provided with the electron emitting elements 18 and the wires 21 and joined with the sidewall 14, are prepared in advance. Subsequently, the spacer structure 22 obtained in the aforesaid manner is positioned on the second substrate 12. In this state, the first substrate 10, second substrate 12, and spacer structure 22 are located in a vacuum chamber, the vacuum chamber is evacuated, and the first substrate is then joined to the second substrate with the sidewall 14 between them. Thus, the SED is manufactured having the spacer structure 22.

[0045] According to the SED constructed in this manner, those electron beam apertures 26a which are situated near the spacer setup positions, among the plurality of electron beam apertures 26 formed in the supporting substrate 24, are formed having an area greater than that of the other electron beam apertures. If the spacer forming material oozes out into the electron beam apertures 26a during the manufacture of the spacer structure, therefore, the ratio of the area covered by the spacer forming material to the overall area of the electron beam apertures is reduced. Thus, the electron beams that pass through the electron beam apertures 26a can be prevented from hitting the oozed spacer forming material. Normally, the spacer forming material having oozed out on the electron beam aperture side spreads along the end edges of the electron beam apertures. By increasing the area of the electron beam apertures 26a, therefore, the aperture end edges lengthen, so that an overflow of the spacer forming material into the electron beam apertures can be reduced. In consequence, the electron beams that pass through the electron beam apertures 26a can be prevented from hitting the oozed spacer forming material. Thus, there may be provided the SED with improved display quality in which image failure that may be caused by the oozed spacer forming material can be restrained.

[0046] According to the present embodiment, moreover, the electron beam apertures 26a are rectangular, and their dimension in the second direction for wider array pitches is enlarged, so that their area is wider than that of the other electron beam apertures. In this case, the width of the bridge portions 27 between the electron beam apertures that are arranged in the first direction X need not be reduced, so that the strength of the supporting substrate 24 can be prevented from being reduced.

[0047] The following is a description of a spacer structure 22 of an SED according to a second embodiment of this invention. Among a plurality of electron beam apertures 26 formed in a supporting substrate 24, as shown in FIG. 8, a plurality of electron beam apertures that are arranged in a first direction X in the vicinity of spacer setup positions are continuous with one another and form elongate rectangular openings 26a. In the present embodiment, the elongate openings 26a are formed individually on the opposite sides of the spacers, and each opening 26a is formed by internally connecting four electron beam apertures. The other electron beam apertures 26 than the electron beam apertures that are situated near the spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension L1 of 0.2 mm in a second direction. On the other hand, each opening 26a is formed having a dimension in the first direction X about four times that of the electron beam apertures and a dimension L2 of 0.25 mm in the second direction, so that it has an area greater than that of the other electron beam apertures 26. Each opening 26a is not limited to the size equivalent to an overall size of four electron beam apertures, but may be of a size equivalent to an overall size of two, three, or five or more electron beam apertures that are continuous with one another.

[0048] In the second embodiment, other configurations of the SED are the same as those of the foregoing first embodiment, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted.

[0049] Among the plurality of electron beam apertures 26 formed in the supporting substrate 24, according to the second embodiment described above, those electron beam apertures 26 which are situated near the spacer setup positions are formed of an elongate opening that internally connects a plurality of electron beam apertures, and have an area greater than that of the other electron beam apertures. If the spacer forming material oozes out into the electron beam apertures 26a during the manufacture of the spacer structure, therefore, the ratio of the area covered by the spacer forming material to the overall area of the electron beam apertures is reduced. Thus, the electron beams that pass through the electron beam apertures 26a can be prevented from hitting the oozed spacer forming material. Normally, the spacer forming material having oozed out on the electron beam aperture side spreads along the end edges of the electron beam apertures. By increasing the area of the electron beam apertures 26a, therefore, the aperture end edges lengthen, so that the overflow of the spacer forming material into the electron beam apertures can be reduced. In consequence, the electron beams that pass through the electron beam apertures 26a can be prevented from hitting the oozed spacer forming material. Thus, there may be provided the SED with improved display quality in which image failure that may be caused by the oozed spacer forming material can be restrained.

[0050] Although the spacer structure 22 according to the foregoing embodiment integrally comprises the first and second substrates, the second spacers 30b may alternatively be formed on the second substrate 12. Further, the spacer structure may be provided with only a supporting substrate and second spacers such that the supporting substrate is in contact with the first substrate.

[0051] In an SED according to a third embodiment of this invention, as shown in FIG. 9, a spacer structure 22 has a supporting substrate 24 formed of a rectangular metal plate and a large number of columnar spacers 30 set up integrally on only one surface of the supporting substrate. The supporting substrate 24 has a first surface 24a opposed to the inner surface of a first substrate 10 and a second surface 24b opposed to the inner surface of a second substrate 12, and is located parallel to these substrates. A large number of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. The electron beam apertures 26 are arranged at first pitches in a first direction X parallel to the longitudinal direction of a vacuum envelope 15 with bridge portions 27 between them, and are also arranged at second pitches larger than the first pitches in a second direction Y perpendicular to the first direction. The electron beam apertures 26 are arrayed opposite electron emitting elements 18, individually, and are permeated by electron beams emitted from the electron emitting elements.

[0052] The first and second surfaces 24a and 24b of the supporting substrate 24 and the respective inner wall surfaces of the electron beam apertures 26 are covered by a high-resistance film of a dielectric substance as a dielectric layer that consists mainly of glass or ceramic.

The supporting substrate 24 is provided in a manner such that its first surface 24a is in surface contact with the inner surface of the first substrate 10 with a getter film, a metal back 17, and a phosphor screen 16 between them. The electron beam apertures 26 in the supporting substrate 24 individually face phosphor layers R, G and B of the phosphor screen 16. Thus, the electron emitting elements 18 face their corresponding phosphor layers through the electron beam apertures 26.

[0053] A plurality of spacers 30 are set up integrally on the second surface 24b of the supporting substrate 24 and are situated individually between the electron beam apertures 26 that are arranged side by side in the second direction Y. Respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 or, in this case, wires 21 that are provided on the inner surface of the second substrate 12. Each of the spacers 30 is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each spacer 30 has a height of about 1.4 mm. A cross section of each spacer 30 in the direction parallel to the supporting substrate surface has a substantially elliptic shape.

[0054] Each electron beam aperture 26 of the supporting substrate 24 is rectangular. The other electron beam apertures 26 than the electron beam apertures that are situated near spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension of 0.2 mm in the second direction. Among the electron beam apertures, those electron beam apertures 26a which are situated near the spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension of 0.25 mm in the second direction, so that they have an area greater than that of the other electron beam apertures 26. In the present embodiment, the area of three electron beam apertures 26a that are situated on each side of the spacers is made larger than that of the other electron beam apertures. The electron beam apertures 26a with the greater area are not limited to three in number. If necessary, four or more electron beam apertures may be arranged on each side of the spacers.

[0055] As the respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 with the supporting substrate 24 in surface contact with the first substrate 10, the spacer structure 22 constructed in the aforesaid manner supports atmospheric pressure that acts on these substrates and keeps a gap between the substrates at a predetermined value.

[0056] In the third embodiment, other configurations are the same as those of the foregoing first embodiment, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted. The SED according to the third embodiment and its spacer structure can be manufactured by a manufacturing method identical to the manufacturing method according to the foregoing embodiment. The same function and effect of the foregoing first embodiment can be also obtained with the third embodiment.

[0057] The following is a detailed description of an SED according to a fourth embodiment of this invention.

[0058] As shown in FIGS. 10 to 12, the SED comprises a first substrate 10 and a second substrate 12, which are formed of a rectangular glass plate each. These substrates are located opposite each other with a gap of about 1.0 to 2.0 mm between them. The first substrate 10 and the second substrate 12 have their respective peripheral edge portions joined together by a rectangular sidewall 14 of glass, thereby forming a flat rectangular vacuum envelope 15 of which the inside is kept vacuum.

[0059] A phosphor screen 16 that functions as a display screen is formed substantially covering the entire surface of the first substrate 10. The phosphor screen 16 is composed of phosphor layers R, G and B, which glow red, green, and blue, individually, and light shielding layers 11 arranged side by side. These phosphor layers are stripe-shaped or dot-shaped. Further, a metal back layer 17 of aluminum or the like and a getter film 19 are successively formed on the phosphor screen 16.

[0060] Provided on the inner surface of the second substrate 12 are a large number of surface-conduction electron emitting elements 18, which individually emit electron beams as electron sources for exciting the phosphor layers R, G and B of the phosphor screen 16. The electron emitting elements 18 are arranged in a plurality of columns and a plurality of rows corresponding to individual pixels. Each electron emitting element 18 is formed of an electron emitting portion (not shown), a pair of element electrodes that apply voltage to the electron emitting portion, etc. Further, a large number of wires 21 for supplying potential to the electron emitting elements 18 are provided in a matrix on the inner surface of the second substrate 12, and their respective end portions are led out of the vacuum envelope 15.

[0061] The sidewall 14 that functions as a joint member is sealed to the peripheral edge portion of the first substrate 10 and the peripheral edge portion of the second substrate 12 with a sealant 20 of, for example, low-melting-point glass or low-melting-point metal, whereby these substrates are joined together.

[0062] As shown in FIGS. 11 and 12, the SED comprises a spacer structure 22 that is located between the first substrate 10 and the second substrate 12. The spacer structure 22 is provided with a supporting substrate 24 formed of a metal plate and a large number of columnar spacers 30 set up integrally on the supporting substrate. The supporting substrate 24 is a rectangular structure of a size corresponding to the phosphor screen 16. It has a first surface 24a opposed to the inner surface of the first substrate 10 and a second surface 24b opposed to the inner surface of the second substrate 12, and is located parallel to these substrates.

[0063] The supporting substrate 24 is formed of a metal plate of, for example, an iron-nickel-based alloy with a thickness of 0.1 to 0.25 mm. A plurality of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. Each electron beam aperture 26 has a rectangular shape measuring, e.g., 0.15 to 0.25 mm by 0.15 to 0.25 mm. If the longitudinal direction and transverse direction of the first substrate 10 and the second substrate 12 are X and Y, respectively, as shown in FIG. 13, the electron beam apertures 26 are arranged at predetermined pitches in the X-direction. With respect to the Y-direction, they are arranged at pitches larger than the pitches in the X-direction. The phosphor layers R, G and B of the phosphor screen 16 formed on the first substrate 10 and the electron emitting elements 18 on the second substrate 12 are arranged at the same pitches as the electron beam apertures 26 with respect to the X-direction and the Y-direction and face the electron beam apertures, individually.

[0064] The first and second surfaces 24a and 24b of the supporting substrate 24 and the respective inner wall surfaces of the electron beam apertures 26 are covered by a dielectric layer 37 of a dielectric substance that consists mainly of glass or the like, e.g., a Li-based alkali borate glass, with a thickness of about 40 μm.

[0065] The supporting substrate 24 is provided in a manner such that its first surface 24a is in surface contact with the getter film 19 of the first substrate 10. The electron beam apertures 26 in the supporting substrate 24 individually face the phosphor layers R, G and B of the phosphor screen 16 and the electron emitting elements 18 on the second substrate 12. Thus, the electron emitting elements 18 face their corresponding phosphor layers through the electron beam apertures 26.

[0066] As shown in FIGS. 11 and 12, a large number of spacers 30 are set up integrally on the second surface 24b of the supporting substrate 24. Respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 or, in this case, the wires 21 that are provided on the inner surface of the second substrate 12. Each of the spacers 30 is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each spacer 30 has a height of about 1.8 mm. A cross section of each spacer 30 in the direction parallel to the surface of the supporting substrate 24 has a substantially elliptic shape. Each of the spacers 30 is formed of a spacer forming material that consists mainly of glass as a dielectric material.

[0067] As shown in FIGS. 11 to 13, the supporting substrate 24 has a plurality of height reducing portions 54 that are formed individually in setup positions for the spacers 30. Each height reducing portion 54 has a recess 56 that is formed on the side of the first surface 24a of the supporting substrate 24. It is formed having a plate thickness equal to half or less of the plate thickness of the other parts of the supporting substrate. Thus, each height reducing portion 54 is elastically deformable in a direction substantially perpendicular to the first surface 24a, that is, in the height direction of the spacers 30. Each spacer 30 is set up corresponding to each height reducing portion 54 on the second surface 24b of the supporting substrate 24 and faces the recess 56.

[0068] The first surface 24a of the supporting substrate 24 is formed having a plurality of recesses 56 besides the recesses 56 that face the spacers 30. Any of these recesses 56 are formed between the electron beam apertures 26 in the first surface 24a.

[0069] The recesses 56 have a depth such that they can absorb unevenness in height of the spacers 30 and ensure good strength for deformation. Various methods may be considered to form the recesses 56 in the supporting substrate 24. If etching is used in the manufacture of the supporting substrate 24, for example, the recesses can be worked easily and simultaneously with the electron beam apertures by half-etching the supporting substrate. Alternatively, the recesses 56 may be formed by machining such as press molding.

[0070] In the present embodiment, each recess 56 is formed having a shape similar to that of an end face or contact surface of each spacer 30 on the side of the supporting substrate 24. The area of the recess 56 is greater than the area of the contact surface of the spacer 30. The surface of the supporting substrate 50, including the respective inner surfaces of the recesses 56, is covered by the dielectric layer 37.

[0071] In the vacuum envelope 15, the supporting substrate 24 should preferably be formed with grooves or holes that communicate with the recesses 56 lest the recesses become closed spaces.

[0072] As the respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 with the supporting substrate 24 in contact with the first substrate 10, the spacer structure 22 constructed in the aforesaid manner supports atmospheric pressure that acts on these substrates and keeps the gap between the substrates at a predetermined value.

[0073] The SED comprises voltage supply portions (not shown) that apply voltages to the supporting substrate 24 and the metal back layer 17 of the first substrate 10. Voltages of, e.g., 8 kV and 10 kV are applied to the supporting substrate and the metal back layer, respectively. In displaying an image on the SED, the electron emitting elements 18 are driven so that electron beams are emitted from optional electron emitting elements, and an anode voltage is applied to the phosphor screen 16 and the metal back layer 17. The electron beams emitted from the electron emitting elements 18 are accelerated by the anode voltage, passed through the electron beam apertures 26 of the supporting substrate 24, and then collide with the phosphor screen 16. Thereupon, the phosphor layers of the phosphor screen 16 are excited to luminescence and display the image.

[0074] The following is a description of a manufacturing method for the SED constructed in this manner. A manufacturing method for the spacer structure 22 will be described first.

[0075] After a metal plate of Fe-50% Ni with a thickness of 0.12 mm is first degreased, washed, and dried, resist films are formed individually on its opposite surfaces.

Subsequently, both surfaces of the metal plate are exposed to light, developed, and dried to form resist patterns. Thereafter, the electron beam apertures 26 measuring 0.18 by 0.18 mm are formed in predetermined positions of the metal plate by etching. At the same time, predetermined positions of the first surface side of the metal plate, that is, that surface of the metal plate which faces the first substrate 10, are half-etched to form the recesses 56 having a major-axis diameter of 3 mm and a minor-axis diameter of 0.4 mm each. Thereafter, glass frit is spread to a thickness of 40 μm over the entire surface of the supporting substrate 24, dried, and then fired, whereupon the dielectric layer 37 is formed.

[0076] Subsequently, a molding die in the form of a rectangular plate having substantially the same size as the supporting substrate 24 is prepared. The molding die is a flat plate formed of a transparent material that transmits ultraviolet rays, e.g., clear silicone consisting mainly of clear polyethylene terephthalate. The molding die has a flat contact surface in contact with the supporting substrate 24 and a large number of bottomed spacer forming holes for molding the spacers. The spacer forming holes individually open in the contact surface of the molding die and are arranged at predetermined spaces. Each spacer forming holes is formed having a length of 1 mm, width of 0.35 mm, and height of 1.8 mm corresponding to the size of each spacer. Thereafter, the spacer forming holes of the molding die are loaded with a spacer forming material. A glass paste that contains at least an ultraviolet-curing binder (organic component) and a glass filler is used as the spacer forming material. The specific gravity and viscosity of the glass paste are selected as required.

[0077] Subsequently, the molding die is positioned so that the spacer forming holes filled with the spacer forming material individually face regions between the adjacent electron beam apertures, and the contact surface is brought into close contact with the second surface 24b of the supporting substrate. Thus, an assembly is formed having the supporting substrate 24 and the molding die.

[0078] Then, ultraviolet (UV) rays are applied to the loaded spacer forming material from the outer surface side of the supporting substrate 24 and the molding die by means of, for example, an ultraviolet lamp or the like, whereupon the spacer forming material is UV-cured. In this case, the molding die is formed of clear silicone as an ultraviolet-transmitting material. Therefore, the ultraviolet rays are applied to the spacer forming material directly or through the molding die. Thus, the loaded spacer forming material can be securely cured to its inner part.

[0079] Thereafter, the molding die is separated from the supporting substrate 24 with the cured spacer forming material left on the supporting substrate 24. Then, the supporting substrate 24 with the spacer forming material thereon is heat-treated in a heating furnace so that the binder is evaporated from the spacer forming material, and the spacer forming material is then regularly fired at about 500 to 550°C for 30 minutes to 1 hour, whereupon it is vitrified. Thus, the spacer structure 22 is obtained having the spacers 30 built-in on the second surface 24b of the supporting substrate 24.

[0080] In the manufacture of the SED, on the other hand, the first substrate 10, which is provided with the phosphor screen 16 and the metal back layer 17, and the second substrate 12, which is provided with the electron emitting elements 18 and the wires 21 and joined with the sidewall 14, are prepared in advance. After the spacer structure 22 obtained in the aforesaid manner is then positioned on the second substrate 12, four corners of the supporting substrate 24 are welded individually to metallic posts that are set up individually on four corner portions of the second substrate 12. By doing this, the spacer structure 22 is fixed to the second substrate 12. The supporting substrate 24 should only be fixed in at least two spots.

[0081] Thereafter, the first substrate 10 and the second substrate 12 having the spacer structure 22 fixed thereon are located in a vacuum chamber, the vacuum chamber is evacuated, and the getter film 19 is formed on the metal back layer 17 of the first substrate. Subsequently, the first substrate is then joined to the second substrate with the sidewall 14 between them, and the spacer structure 22 is interposed between these substrates. Thus, the SED is manufactured having the spacer structure 22.

[0082] According to the SED constructed in this manner, the spacers 30 are provided only on the side of the second substrate 12 of the supporting substrate 24, so that the distance between the supporting substrate 24 and the second substrate 12 can be extended by increasing the length of each spacer. Thus, the pressure resistance between the supporting substrate and the second substrate can be improved to restrain generation of electric discharge between them.

[0083] The supporting substrate 24 has height reducing portions 54 and the spacers 30 are provided individually on the height reducing portions. As shown in FIG. 14, the height reducing portions 54 act as leaf springs or coned-disc springs. If the spacers 30 are uneven in height or the like, the height reducing portions 54 are elastically deformed in the height direction of the spacers to absorb the unevenness in height. Thus, atmospheric pressure that acts on the first substrate 10 and the second substrate 12 can be stably supported by the spacers 30, so that strength of the atmospheric strength of the vacuum envelope 15 can be enhanced. At the same time, the spacers can be prevented from being damaged by unevenness in height.

[0084] If the spacers 30 are uneven in height, moreover, production of gaps between the first substrate 10 and the respective distal ends of the spacers can be prevented, so that electric discharge that is attributable to the gaps can be restrained. Since the supporting substrate 24 is covered by the dielectric layer 37, the supporting substrate itself can also function as a shield that suppresses electric discharge. Thus, there may be obtained the SED that can restrain generation of electric discharge and is enhanced in atmospheric strength.

[0085] The first surface 24a of the supporting substrate 24 is in contact with the first substrate 10 with the getter film 19 between them. Therefore, the metal back layer 17 and the supporting substrate 24 are at the same potential, and the metal back layer 17 and the getter film 19 are sandwiched between the first substrate 10 and the supporting substrate 24. In this case, peeling of the metal back layer 17 and the getter film 19 and damage to the metal back layer and the phosphor screen can be prevented. Thus, a good image quality can be maintained for a long period of time. At the same time, the there may be obtained the SED of improved reliability that can restrain generation of electric discharge attributable to the peeled metal back layer and getter film.

[0086] The plurality of recesses 56 are formed in the first surface 24a of the supporting substrate 24 that is in contact with the getter film 19, and the recesses communicate with the interior of the vacuum envelope through grooves or holes (not shown). If the getter film 19 is covered by the supporting substrate 24, therefore, the area of contact between the supporting substrate and the getter film 19 can be reduced to increase the area of exposure of the getter film. Thus, reduction of the getter efficiency can be lowered, and a high vacuum can be maintained.

[0087] In the fourth embodiment described above, each recess 56 of the supporting substrate 24 is formed having a shape similar to that of the end face of each spacer 30. However, the recess 56 should only have an area greater than that of the end face, and its shape can be changed as required. As shown in FIG. 15, each recess 56 may be formed of a groove that extends between the electron beam apertures 26 of the supporting substrate 24 and continuously extends covering a plurality of height reducing portions 54 arranged in the direction of a major axis X. If necessary, the number of recesses 56 formed may be increased or decreased.

[0088] The following is a detailed description of an SED according to a fifth embodiment of this invention.

[0089] As shown in FIGS. 16 to 18, the SED comprises a first substrate 10 and a second substrate 12, which are formed of a rectangular glass plate each. These substrates are located opposite each other with a gap of about 1.0 to 2.0 mm between them. The first substrate 10 and the second substrate 12 have their respective peripheral edge portions joined together by a sidewall 14 of glass in the form of a rectangular frame, thereby forming a flat vacuum envelope 15 of which the inside is kept vacuum. If the direction parallel to the respective long sides of the first substrate 10 and the second substrate 12 and the direction parallel to their respective short sides are a first direction X and a second direction Y, respectively, an effective display region of the SED has a rectangular form measuring 800 mm in the first direction X by 500 mm in the second direction Y.

[0090] A phosphor screen 16 is formed on the inner surface of the first substrate 10. The phosphor screen 16 is composed of phosphor layers R, G and B (only phosphor layers G are shown), which glow red, green, and blue, individually, and light shielding layers 11 arranged side by side. These phosphor layers are stripe-shaped, dot-shaped, or rectangular. A metal back 17 of aluminum or the like and a getter film 19 are successively formed on the phosphor screen 16.

[0091] Provided on the inner surface of the second substrate 12 are a large number of surface-conduction electron emitting elements 18, which individually emit electron beams as electron sources for exciting the phosphor layers R, G and B of the phosphor screen 16. These electron emitting elements 18 are arranged in a plurality of columns and a plurality of rows corresponding to individual pixels. Each electron emitting element 18 is formed of an electron emitting portion (not shown), a pair of element electrodes that apply voltage to the electron emitting portion, etc. A large number of wires 21 for supplying potential to the electron emitting elements 18 are provided in a matrix on the inner surface of the second substrate 12, and their respective end portions are led out of the vacuum envelope 15. The sidewall 14 is sealed to the peripheral edge portion of the first substrate 10 and the peripheral edge portion of the second substrate 12 with a sealant 20 of, for example, low-melting-point glass or low-melting-point metal, whereby these substrates are joined together.

[0092] As shown in FIGS. 17 to 19, the SED comprises a plurality of, e.g., four, spacer structures 22a, 22b, 22c and 22d that are located between the first substrate 10 and the second substrate 12. Each of the spacer structures 22a, 22b, 22c and 22d is composed of a supporting substrate 24, formed of a rectangular metal plate located between the first and second substrates 10 and 12, and a large number of columnar spacers set up integrally on the opposite surfaces of the supporting substrate. The four spacer structures 22a, 22b, 22c and 22d, which have the same structure, are arranged side by side in the second direction Y with gaps between them so as to cover the entire display region.

[0093] Specifically, in the spacer structure 22b as a representative, the supporting substrate 24 has an elongate rectangular form with a length of 800 mm in the first direction X and a length of 500 mm in the second direction Y. The supporting substrate 24 has a first surface 24a opposed to the inner surface of the first substrate 10 and a second surface 24b opposed to the inner surface of the second substrate 12, and is located parallel to these substrates. A large number of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. The electron beam apertures 26 are arranged at first pitches in the first direction X with bridge portions between them, and are also arranged at second pitches larger than the first pitches in the second direction Y. The electron beam apertures 26 are arrayed opposite the electron emitting elements 18, individually, and are permeated by the electron beams emitted from the electron emitting elements.

[0094] The supporting substrate 24 is formed of a metal plate of, for example, an iron-nickel-based alloy with a thickness of 0.1 to 0.3 mm. An oxide film formed of elements that constitute the metal plate, e.g., an oxide film of Fe_3O_4 and $NiFe_2O_4$, is formed on the surfaces of the supporting substrate 24. Further, the surfaces 24a and 24b of the supporting substrate 24 and the respective wall surfaces of the electron beam apertures 26 are covered by coating layer 28 as a high-resistance film that has a preventive effect against secondary electron generation. The coating layer 28 is formed overlapping a dielectric layer 27.

[0095] The coating layer 28 contains a material such as chromium oxide whose secondary electron emission coefficient is as low as 0.4 to 2.0. There are found various such materials with low secondary electron emission coefficients, many of which exist in good conductors that generally have free electrons. In the SED, as mentioned later, however, a relatively high voltage of about 10 kV is applied between the first substrate and the second substrate, so that a material with a relatively high resistance, such as a dielectric material or semiconductor, must be selected as the coating layer. Chromium oxide is a material that has a relatively high volume resistance of about 10^5 Ωcm and a low secondary electron emission coefficient. Preferably, the supporting substrate 24 that constitutes the spacer structures 22 should have a surface resistivity of 10^7 Ωcm or more. In the present embodiment, therefore, the coating layer 28 is formed of a composite material that is prepared by mixing a glass paste and chromium oxide powder. Thus, an electric discharge restraining effect can be obtained by macroscopically increasing the surface resistivity value of the supporting substrate 24.

[0096] As shown in FIGS. 17 to 19, a plurality of first spacers 30a are set up integrally on the first surface 24a of the supporting substrate 24 and individually situated between the electron beam apertures 26 that are arranged in the second direction Y. The respective distal ends of the first spacers 30a abut the inner surface of the first substrate 10 through the getter film 19, the metal back 17, and the light shielding layers 11 of the phosphor screen 16.

[0097] A plurality of second spacers 30b are set up integrally on the second surface 24b of the supporting substrate 24 and are individually situated between the electron beam apertures 26 that are arranged in the second direction Y. The respective distal ends of the second spacers 30b abut the inner surface of the second substrate 12. The respective distal ends of the second spacers 30b are situated individually on the wires 21 that are provided on the inner surface of the second substrate 12. The first and second spacers 30a and 30b are situated in alignment with one another and are formed integrally with the supporting substrate 24 in a manner such that the supporting substrate 24 is held between them from both sides.

[0098] Each of the first and second spacers 30a and 30b is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each first spacer 30a has a substantially elliptic cross-sectional shape such that the diameters of its proximal end situated on the side of the supporting substrate 24 are about 0.3 mm and 2 mm, the diameters on its extended end are 0.2 mm and 2 mm, and its height is about 0.6 mm. Each second spacer 30b has a substantially elliptic cross-sectional shape such that the diameters of its proximal end situated on the side of the supporting substrate 24 are about 0.3 mm and 2 mm, the diameters on its extended end are 0.2 mm and 2 mm, and its height is about 0.8 mm.

[0099] The four spacer structures 22a, 22b, 22c and 22d constructed in this manner are arranged in the second direction with gaps between them in a manner such that the long sides of their respective supporting substrates 24 extend parallel to the first direction X. The supporting substrates 24 are located parallel to one another and to the first substrate 10 and the second substrate. The opposite end portions of each supporting substrate 24 in the first direction X are fixed individually to supporting members 32 that are set up on the inner surface of the second substrate 12. The first and second spacers 30a and 30b of each spacer structure abut the respective inner surfaces of the first substrate 10 and the second substrate 12, thereby supporting atmospheric pressure that acts on these substrates and keeping the gap between the substrates at a predetermined value.

[0100] The SED comprises voltage supply portions (not shown) that apply voltages to the supporting substrate 24 and the metal back 17 of the first substrate 10. The voltage supply portions are connected individually to the supporting substrate 24 and the metal back 17, and apply voltages of, e.g., 12 kV and 10 kV to the supporting substrate 24 and the metal back 17, respectively. In displaying an image on the SED, an anode voltage is applied to the phosphor screen 16 and the metal back 17, and electron beams emitted from the electron emitting elements 18 are accelerated by the anode voltage and collide with the phosphor screen 16. Thereupon, the phosphor layers of the phosphor screen 16 are excited to luminescence and display the image.

[0101] The following is a description of a manufacturing method for the SED constructed in this manner. A manufacturing method for each spacer structure 22 will be described first.

[0102] As shown in FIG. 19, the supporting substrate 24 with a predetermined size and an upper die and a lower die, each in the form of a rectangular plate having substantially the same size as the supporting substrate, are prepared. A metal plate with a plate thickness of 0.12 mm that contains 45 to 55% by weight of nickel, iron for the remainder, and unavoidable impurities is used for the supporting substrate 24. After this metal plate is degreased, washed, and dried, the electron beam apertures 26 are formed by etching. After the entire metal plate is oxidized, the dielectric layer 27 is formed on the surface of the metal plate including the respective inner surfaces of the electron beam apertures 26. Further, a coating solution that is prepared by mixing a glass paste with about 30% by weight of chromium oxide (Cr_2O_3 - α : α = -0.5 to 0.5) is spread on the dielectric layer 27 by spraying, dried, and then fired, whereupon the coating layer 28 is formed. Thus, the supporting substrate 24 is obtained. Preferably, the chromium oxide material has a particle size of 0.1 to 10 μm and purity of 98 to 99.9%.

[0103] The coating layer 28 is not limited to a coating film but may be a layer that is obtained by forming a thin film of chromium oxide on the surface of the supporting substrate by vacuum vapor deposition, sputtering, ion plating, or the zol-gel method.

[0104] The upper die and the lower die for use as molding dies are flat plates formed of a transparent material that transmits ultraviolet rays, e.g., clear silicone or clear polyethylene terephthalate. The upper die has a flat contact surface in contact with the supporting substrate 24 and a large number of bottomed spacer forming holes for molding the first spacers 30a. The spacer forming holes individually open in the contact surface of the upper die and are arranged at predetermined spaces. Likewise, the lower die has a flat contact surface and a large number of bottomed spacer forming holes for molding the second spacers 30b. The spacer forming holes individually open in the contact surface of the lower die and are arranged at predetermined spaces.

[0105] Subsequently, the spacer forming holes of the upper die and the spacer forming holes of the lower die are loaded with a spacer forming material. A glass paste that contains at least an ultraviolet-curing binder (organic component) and a glass filler is used as the spacer forming material. The specific gravity and viscosity of the glass paste are selected as required.

[0106] The upper die is positioned so that the spacer forming holes filled with the spacer forming material individually face regions between the electron beam apertures 26, and the contact surface is brought into close contact with the first surface 24a of the supporting substrate 24. Likewise, the lower die is positioned so that the spacer forming holes individually face regions between the electron beam apertures 26, and the contact surface is brought into close contact with the second surface 24b of the supporting substrate 24. An adhesive may be previously applied to the spacer setup positions on the supporting substrate 24 by means of a dispenser or by printing. Thus, an assembly is formed having the supporting substrate 24, upper die, and lower die. In the assembly, the spacer forming holes of the upper die and the spacer forming holes of the lower die are arranged opposite one another with the supporting substrate 24 between them.

[0107] Then, ultraviolet (UV) rays are applied to the upper die and the lower die from ultraviolet lamps that are located outside the upper and lower dies. The upper die and the lower die are individually formed of an ultraviolet transmitting material. Therefore, the ultraviolet rays radiated from the ultraviolet lamps are transmitted through the upper die and the lower die and applied to the loaded spacer forming material. Thus, the spacer forming material is ultraviolet-cured with the assembly kept in a close-contact state.

[0108] Subsequently, the upper die and the lower die are released from the supporting substrate 24 with the cured spacer forming material left on the supporting substrate 24. Thereafter, the supporting substrate 24 with the spacer forming material thereon is heat-treated in a heating furnace so that the binder is evaporated from the spacer forming material, and the spacer forming material is then regularly fired at about 500 to 550°C for 30 minutes to 1 hour. Thus, the spacer structure is obtained having the first and second spacers 30a and 30b built-in on the supporting substrate 24. The four spacer structures 22a, 22b, 22c and 22d are formed having the same configuration.

[0109] In the manufacture of the SED, the first substrate 10, which is provided with the phosphor screen 16 and the metal back 17, and the second substrate 12, which is provided with the electron emitting elements 18 and the wires 21 and joined with the sidewall 14, are prepared in advance. Subsequently, the spacer structures 22a, 22b, 22c and 22d obtained in the aforesaid manner are positioned on the second substrate 12 and fixed to the supporting members 32. In this state, the first substrate 10, second substrate 12, and spacer structures 22 are located in a vacuum chamber, the vacuum chamber is evacuated, and the first substrate is then joined to the second substrate with the sidewall 14 between them. Thus, the SED is manufactured having the spacer structures 22a, 22b, 22c and 22d.

[0110] According to the SED constructed in this manner, the spacer structures 22a, 22b, 22c and 22d that are divided in four with respect to the display region and formed like oblong belts measuring 800 mm by 120 mm each are arranged in the longitudinal direction or the second direction Y. Thus, each spacer structure can be aligned independently of the first and second substrates, and the alignment accuracy of the spacer structures can be made higher than in the case where the single spacer structure is used to cover the entire display region. In the present embodiment, in particular, the alignment accuracy of each spacer structure in the second direction Y for its shorter sides can be improved considerably.

[0111] At the same time, the accuracy of machining for each spacer, such as etching or laser machining, can be improved by miniaturizing the spacer structure by plural division. Further, each spacer structure can be manufactured at low cost by an existing manufacturing method. If the pixel pitches of the SED are lessened for higher precision or if the SED is made large-sized, therefore, the spacer structures can be aligned highly accurately with the electron emitting elements. Thus, a large-sized, high-precision SED can be obtained.

[0112] In the SED described above, the surfaces and peripheral edge portions of the respective supporting substrates 24 of the individual spacer structures are covered by the coating layer 28 that contains the material whose secondary electron emission coefficient ranges from 0.4 to 2.0. Even if any of electrons emitted from the electron emitting elements 18 collide with the surface of the supporting substrate 24, therefore, generation of secondary electrons on the supporting substrate surface can be reduced considerably. Thus, generation of electric discharge attributable to emission of secondary electrons can be restrained, so that it is possible to prevent breakage or degradation of the electron emitting elements, the phosphor screen, or the wires on the first substrate that are attributable to electric discharge. Further, charging of the spacers that is attributable to secondary electrons can be prevented to reduce mistracking of electron beams with respect to the phosphor layers, so that the color purity of displayed images can be improved. At the same time, the electron beams can be prevented from being attracted to gaps between adjacent supporting substrates 24, so that lines originated by the gaps can be prevented from being displayed on the screen.

[0113] In the SED described above, the number of divided spacer structures is not limited to four but may be increased or decreased as required. Further, the direction of division of the spacer structures is not limited to the second direction Y, but the spacer structures may be divided in the first direction or in both the first and second directions.

[0114] An SED according to a sixth embodiment shown in FIG. 20 is provided with five divided spacer structures 22a, 22b, 22c, 22d and 22e. A supporting substrate 24 of each spacer structure is in the form of a belt that is elongated in a second direction Y, measuring 200 mm in a first direction X by 500 mm in the second direction Y, for example. A large number of electron beam apertures 26 are formed in the supporting substrate 24. A plurality of first spacers 30a are set up integrally on a first surface 24a of the supporting substrate 24, while a plurality of second spacers 30b are set up integrally on a second surface 24b.

[0115] The five spacer structures 22a, 22b, 22c, 22d and 22e are arranged in the first direction with gaps between them in a manner such that the long sides of their respective supporting substrates 24 extend parallel to the second direction Y. The five supporting substrates 24 are located parallel to one another and to a first substrate 10 and a second substrate. The opposite end portions of each supporting substrate 24 in the second direction X are fixed to supporting members 32 that are set up on the inner surface of the second substrate 12. The first and second spacers 30a and 30b of each spacer structure abut the respective inner surfaces of the first substrate 10 and the second substrate 12, thereby supporting atmospheric pressure that acts on these substrates and keeping the gap between the substrates at a predetermined value.

[0116] In the sixth embodiment, other configurations are the same as those of the foregoing fifth embodiment, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted. The same function and effect of the foregoing fifth embodiment can be also obtained with the sixth embodiment.

[0117] In an SED according to a seventh embodiment shown in FIG. 21, a display region is formed measuring 1,200 mm in a first direction X by 750 mm in a second direction Y. The SED comprises four spacer structures 22a, 22b, 22c and 22d that are divided in the first direction X and the second direction Y. The supporting substrate 24 of each spacer structure is formed having a rectangular shape substantially similar to the shape of the first substrate 10, measuring 600 mm in the first direction X by 375 mm in the second direction Y, for example. A large number of electron beam apertures 26 are formed in the supporting substrate 24. A plurality of first spacers 30a are set up integrally on a first surface 24a of the supporting substrate 24, while a plurality of second spacers 30b are set up integrally on a second surface 24b.

[0118] The four spacer structures 22a, 22b, 22c and 22d are arranged in two rows and two columns in the first direction X and the second direction Y with gaps between them in a manner such that the long sides and short sides of their respective supporting substrates 24 extend parallel to the first direction and the second direction. The four supporting substrates 24 are located parallel to one another and to the first substrate 10 and the second substrate. Among corner portions of each supporting substrate 24, those corner portions which are opposed to the other supporting substrates 24 and situated on the peripheral edge side of the second substrate 12 are fixed to supporting members 32 that are set up on the inner surface of the second substrate 12. Specifically, those two corner portions of each supporting substrate 24 which is situated outside an effective image region are fixed to the supporting members 32. The first and second first spacers 30a and 30b of each spacer structure abut the respective inner surfaces of the first substrate 10 and the second substrate 12, thereby supporting atmospheric pressure that acts on these substrates and keeping a gap between the substrates at a predetermined value.

[0119] In the seventh embodiment, other configurations are the same as those of the foregoing fifth embodiment, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted. The same function and effect of the foregoing first embodiment can be also obtained with the seventh embodiment.

[0120] In the fifth to seventh embodiments, the plurality of spacer structures need not be formed in the same size but may be different in size.

[0121] Although each spacer structure is provided integrally with the first and second spacers and the supporting substrate(s) according to the foregoing embodiments, the second spacers 30b may alternatively be formed on the second substrate 12. Further, each spacer structure may be provided with only the supporting substrate(s) and the second spacers. In this case, the supporting substrate is in contact with the first substrate.

[0122] As shown in FIG. 22, an SED according to an eighth embodiment of this invention is provided with, for example, four divided spacer structures 22a, 22b, 22c and 22d. Each spacer structure has a supporting substrate 24 formed of a rectangular metal plate and a large number of columnar spacers 30 set up integrally on only one surface of the supporting substrate. The supporting substrate 24 has a first surface 24a opposed to the inner surface of a first substrate 10 and a second surface 24b opposed to the inner surface of a second substrate 12, and is located parallel to these substrates. A large number of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. The electron beam apertures 26 are arrayed opposite electron emitting elements 18, individually, and are permeated by electron beams emitted from the electron emitting elements.

[0123] The first and second surfaces 24a and 24b of the supporting substrate 24 and the respective inner wall surfaces of the electron beam apertures 26 are covered by a dielectric layer 27 as a dielectric layer that consists mainly of glass or ceramic, and moreover, a coating layer 28 is formed overlapping the dielectric layer. The supporting substrate 24 is provided in a manner such that its first surface 24a is in surface contact with the inner surface of the first substrate 10 with a getter film, a metal back 17, and a phosphor screen 16 between them. The electron beam apertures 26 in the supporting substrate 24 individually face phosphor layers R, G and B of the phosphor screen 16. Thus, the electron emitting elements 18 face their corresponding phosphor layers through the electron beam apertures 26.

[0124] A plurality of spacers 30 are set up integrally on the second surface 24b of the supporting substrate 24 and are situated individually between the electron beam apertures 26. Respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 or, in this case, wires 21 that are provided on the inner surface of the second substrate 12. Each of the spacers 30 is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each spacer 30 has a height of about 1.4 mm. A cross section of each spacer 30 in the direction parallel to the supporting substrate surface has a substantially elliptic shape.

[0125] The four spacer structures 22a, 22b, 22c and 22d constructed in this manner are arranged in, for example, a second direction Y with gaps between them so as to cover the entire display region. As the respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 with the supporting substrate 24 in surface contact with the first substrate 10, each spacer structure supports atmospheric pressure that acts on these substrates and keeps a gap between the substrates at a predetermined value.

[0126] In the eighth embodiment, other configurations are the same as those of the foregoing first embodiment, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted. The SED according to the eighth embodiment and its spacer structure can be manufactured by a manufacturing method identical to the manufacturing method according to the foregoing embodiment. The same function and effect of the foregoing fifth embodiment can be also obtained with the eighth embodiment.

[0127] The following is a description of a ninth embodiment of this invention.

[0128] According to the present embodiment, as shown in FIGS. 23 to 25, an SED is provided with, for example, four divided spacer structures 22a, 22b, 22c and 22d. Each spacer structure has a supporting substrate 24 formed of a rectangular metal plate and a large number of columnar spacers 30 set up integrally on only one surface of the supporting substrate. The supporting substrate 24 has a first surface 24a opposed to the inner surface of a first substrate 10 and a second surface 24b opposed to the inner surface of a second substrate 12, and is located parallel to these substrates. A large number of electron beam apertures 26 are formed in the supporting substrate 24 by etching or the like. The electron beam apertures 26 are arrayed opposite electron emitting elements 18, individually, and are permeated by electron beams emitted from the electron emitting elements.

[0129] The first and second surfaces 24a and 24b of the supporting substrate 24 of each spacer structure and the respective inner wall surfaces of the electron beam apertures 26 are covered by a dielectric layer 27 as a dielectric layer that consists mainly of glass or ceramic, and moreover, a coating layer 28 is formed overlapping the dielectric layer. The supporting substrate 24 is provided in a manner such that its first surface 24a is in surface contact with the inner surface of the first substrate 10 with a getter film, a metal back 17, and a phosphor screen 16 between them. The electron beam apertures 26 in the supporting substrate 24 individually face phosphor layers R, G and B of the phosphor screen 16. Thus, the electron emitting elements 18 face their corresponding phosphor layers through the electron beam apertures 26.

[0130] A plurality of spacers 30 are set up integrally on the second surface 24b of the supporting substrate 24 and are situated individually between the electron beam apertures 26. Respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 or, in this case, wires 21 that are provided on the inner surface of the second substrate 12. Each of the spacers 30 is tapered so that its diameter is reduced from the side of the supporting substrate 24 toward its extended end. For example, each spacer 30 has a height of about 1.4 mm. A cross section of each spacer 30 in the direction parallel to the supporting substrate surface has a substantially elliptic shape.

[0131] As shown in FIG. 25, each electron beam aperture 26 in the supporting substrate 24 is formed having a rectangular shape. The other electron beam apertures 26 than the electron beam apertures that are situated near spacer setup positions are formed having a dimension of 0.2 mm in a first direction X and a dimension L1 of 0.2 mm in a second direction. Among the electron beam apertures, those electron beam apertures 26a which are situated near the spacer setup positions are formed having a dimension of 0.2 mm in the first direction X and a dimension L2 of 0.25 mm in the second direction, so that they have an area greater than that of the other electron beam apertures 26. The electron beam apertures 26a that are situated near the spacer setup positions imply electron beam apertures that face first and second spacers 30a and 30b. In the present embodiment, the area of the three electron beam apertures 26a situated on each side of the spacers is made greater than that of the other electron beam apertures. The electron beam apertures 26a with the greater area are not limited to three in number. If necessary, four or more electron beam apertures may be arranged on each side of the spacers.

[0132] As shown in FIGS. 24 and 25, the supporting substrate 24 of each spacer structure has a plurality of height reducing portions 54 that are formed individually in the setup positions for the spacers 30. Each height reducing portion 54 has a recess 56 that is formed on the side of the first surface 24a of the supporting substrate 24. It is formed having a plate thickness equal to half or less of the plate thickness of the other parts of the supporting substrate. Thus, each height reducing portion 54 is elastically deformable in a direction substantially perpendicular to the first surface 24a, that is, in the height direction of the spacers 30. Each spacer 30 is set up corresponding to each height reducing portion 54 on the second surface 24b of the supporting substrate 24 and faces the recess 56.

[0133] The recesses 56 have a depth such that they can absorb unevenness in height of the spacers 30 and ensure good strength for deformation. Various methods may be considered to form the recesses 56 in the supporting substrate 24. If etching is used in the manufacture of the supporting substrate 24, for example, the recesses can be worked easily and simultaneously with the electron beam apertures by half-etching the supporting substrate. Alternatively, the recesses 56 may be formed by machining such as press molding.

[0134] In the present embodiment, each recess 56 is formed having a shape similar to that of an end face or contact surface of each spacer 30 on the side of the supporting substrate 24. The area of the recess 56 is greater than the area of the contact surface of the spacer 30. The surface of the supporting substrate 50, including the respective inner surfaces of the recesses 56, is covered by a dielectric layer 37.

[0135] The four spacer structures 22a, 22b, 22c and 22d constructed in this manner are arranged in, for example, the second direction Y with gaps between them so as to cover the entire display region. As the respective extended ends of the spacers 30 abut the inner surface of the second substrate 12 with the supporting substrate 24 in surface contact with the first substrate 10, each spacer structure supports atmospheric pressure that acts on these substrates and keeps a gap between the substrates at a predetermined value.

[0136] In the ninth embodiment, other configurations are the same as those of the foregoing first, fourth, and eighth embodiments, so that like reference numerals are used to designate like portions, and a detailed description thereof is omitted. The SED according to the ninth embodiment and its spacer structure can be manufactured by a manufacturing method identical to the manufacturing method according to the foregoing embodiments. The same function and effect of the foregoing first, fourth, and fifth embodiment can be also obtained with the ninth embodiment.

[0137] The present invention is not limited directly to the embodiments described above, and its components may be embodied in modified forms without departing from the scope or spirit of the invention. Further, various inventions may be made by suitably combining a plurality of components described in connection with the foregoing embodiments. For example, some of the components according to the embodiments may be omitted. Furthermore, components according to different embodiments may be combined as required.

[0138] The diameter and height of the spacers and the dimensions, materials, etc., of the other components are not limited to the foregoing embodiments, but may be suitably selected as required. Further, this invention is not limited to image display devices that use surface-conduction electron emitting elements as electron sources, but may be also applied to image display devices that use other electron sources, such as the field-emission type, carbon nanotubes, etc.

Industrial Applicability

[0139] There may be provided an image display device with improved display quality in which the area of those electron beam apertures which are situated near spacer setup positions, among a plurality of electron beam apertures formed in a supporting substrate, is made greater than that of the other electron beam apertures, whereby image failure attributable to oozing of a spacer forming material can be restrained. Further, there may be provided an image display device capable of restraining generation of electric discharge and enhanced in atmospheric strength.

[0140] Since a plurality of divided spacer structures are arranged for miniaturization, the positioning accuracy and machining accuracy for each spacer structure can be improved, and manufacturing costs can be reduced. Thus, a large-sized, high-precision image display device can be obtained.

Claims

1. An image display device comprising:

   a first substrate having a phosphor screen formed thereon;
   a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which excite the phosphor screen; and
   a spacer structure which is provided between the first and second substrates and supports atmospheric pressure acting on the first and second substrates,
   the spacer structure having a plate-shaped supporting substrate, which is opposed to the first and second substrates and has a plurality of electron beam apertures opposed individually to the electron emission sources, and a plurality of spacers set up on a surface of the supporting substrate, those electron beam apertures, among the plurality of electron beam apertures, which are situated near spacer setup positions having an area greater than that of the other electron beam apertures.

2. An image display device according to claim 1, wherein the electron beam apertures are arranged side by side at first pitches in a first direction with bridging portions therebetween and arranged side by side at second pitches greater than the first pitches in a second direction perpendicular to the first direction, the spacers being located between the electron beam apertures arranged in the second direction, and wherein those electron beam apertures, among the plurality of electron beam apertures, which are situated near the spacer setup positions have a diameter in the second direction greater than that of the other electron beam apertures.

3. An image display device according to claim 2, wherein those electron beam apertures, among the plurality of electron beam apertures, which are arranged side by side in the first direction near the spacer setup positions are formed of openings continuous with one another.

4. An image display device according to any one of claims 1 to 3, wherein the supporting substrate has a first surface opposed to the first substrate and a second surface opposed to the second substrate, and the spacers include a plurality of first spacers set up on the first surface and a plurality of second spacers set up on the second surface.

5. An image display device according to any one of claims 1 to 3, wherein the supporting substrate has a first surface in contact with the first substrate and a second surface opposed to the second substrate across a gap, and the spacers are set up on the second surface and each have a distal end portion abutting the second substrate.

6. An image display device comprising:

   a first substrate having a phosphor screen including a phosphor layer and a metal back layer provided overlapping the phosphor screen;
   a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which emit electrons toward the phosphor screen;
   a supporting substrate which is located between the first and second substrates, has a first surface in contact with the first substrate, a second surface opposed to the second substrate, and a plurality of electron beam apertures opposed to the electron emission sources, and is covered by a dielectric substance; and
   a plurality of spacers which are set up between the second surface and the second substrate and support atmospheric pressure acting on the first and second substrates,
   the supporting substrate having a plurality of height reducing portions individually in contact with the spacers and elastically deformable in a height direction of the spacers.

7. An image display device according to claim 6, wherein each of the height reducing portions has a recess formed in the first surface of the supporting substrate.

8. An image display device comprising:

   a first substrate having a phosphor screen including a phosphor layer, a metal back layer provided overlapping the phosphor screen, and a getter film formed overlapping the metal back layer;
   a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which emit electrons toward the phosphor screen;
   a supporting substrate which is located between the first and second substrates, has a first surface in contact with the first substrate, a second surface opposed to the second substrate, a plurality of electron beam apertures opposed to the electron emission sources, and a plurality of recesses formed in the first surface, and is covered by a dielectric substance; and
   a plurality of spacers which are set up between the second surface and the second substrate and support atmospheric pressure acting on the first and second substrates.

9. An image display device according to claim 8, wherein the recesses include positions opposed to the spacers on the first surface of the supporting substrate and are formed between the electron beam apertures.

10. An image display device according to any one of claims 6 to 9, **characterized in that** the recesses have an area greater than an area of contact surfaces of the spacers in contact with the supporting substrate.

11. An image display device according to claim 10, wherein each said recess has a shape similar to that of the contact surface of each of the spacers in contact with the supporting substrate.

12. An image display device according to claim 7 or 8, wherein the recesses are formed of grooves extending between the electron beam apertures, individually.

13. An image display device according to claim 7 or 8, **characterized in that** each said recess is formed by half-etching.

14. An image display device comprising:

a first substrate having a phosphor screen formed thereon;
a second substrate located opposite the first substrate across a gap and provided with a plurality of electron emission sources which excite the phosphor screen; and
a plurality of spacer structures which are individually provided between the first and second substrates and support atmospheric pressure acting on the first and second substrates,
the spacer structures each having a plate-shaped supporting substrate, which is opposed to the first and second substrates and has a plurality of electron beam apertures opposed individually to the electron emission sources, and a plurality of spacers set up on a surface of the supporting substrate.

15. An image display device according to claim 14, wherein the respective supporting substrates of the plurality of spacer structures are arranged parallel to one another with gaps therebetween.

16. An image display device according to claim 14 or 15, wherein at least the peripheral edge portion of each said supporting substrate is covered by a coating layer which contains a material having a secondary electron emission coefficient of 0.4 to 2.0.

17. An image display device according to claim 16, wherein the supporting substrate has a dielectric layer which covers the surface thereof, and the coating layer is formed overlapping the dielectric layer.

18. An image display device according to claim 14 or 15, wherein the supporting substrate of each said spacer structure has a first surface opposed to the first substrate and a second surface opposed to the second substrate, and the spacers include a plurality of first spacers set up on the first surface and a plurality of second spacers set up on the second surface.

19. An image display device according to claim 14 or 15, wherein the supporting substrate of each said spacer structure has a first surface in contact with the first substrate and a second surface opposed to the second substrate across a gap, and the spacers are set up on the second surface and each have a distal end portion abutting the second substrate.

20. An image display device according to claim 14, wherein the spacers are columnar spacers.

21. An image display device according to claim 14, wherein the first and second substrates are each formed in the shape of a rectangle having long sides and short sides, and the plurality of spacer structures are arranged side by side in a direction parallel to the respective short sides of the first and second substrates.

22. An image display device according to claim 14, wherein the first and second substrates are each formed in the shape of a rectangle having long sides and short sides, and the plurality of spacer structures are arranged side by side in a direction parallel to the respective long sides of the first and second substrates.

23. An image display device according to claim 14, wherein the first and second substrates are each formed in the shape of a rectangle having long sides and short sides, and the plurality of spacer structures are arranged side by side in a direction parallel to the respective long sides of the first and second substrates and in a direction parallel to the short sides.

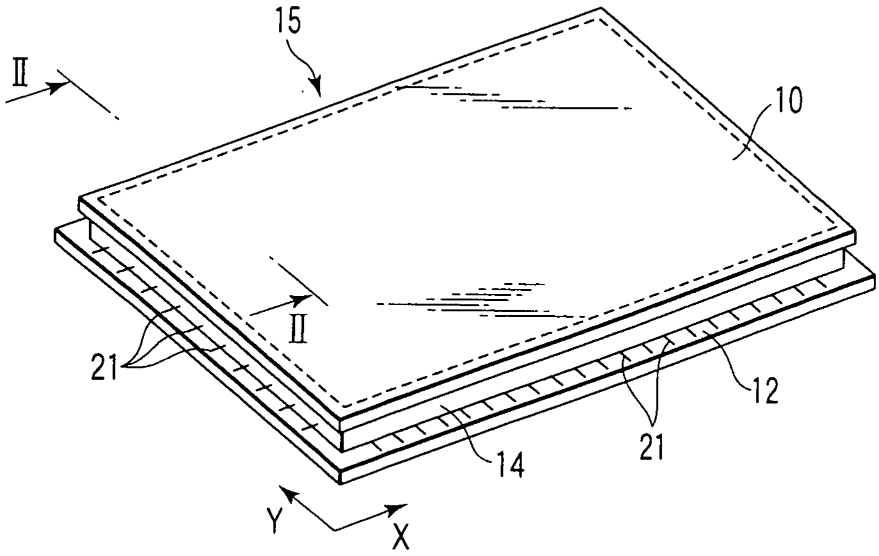
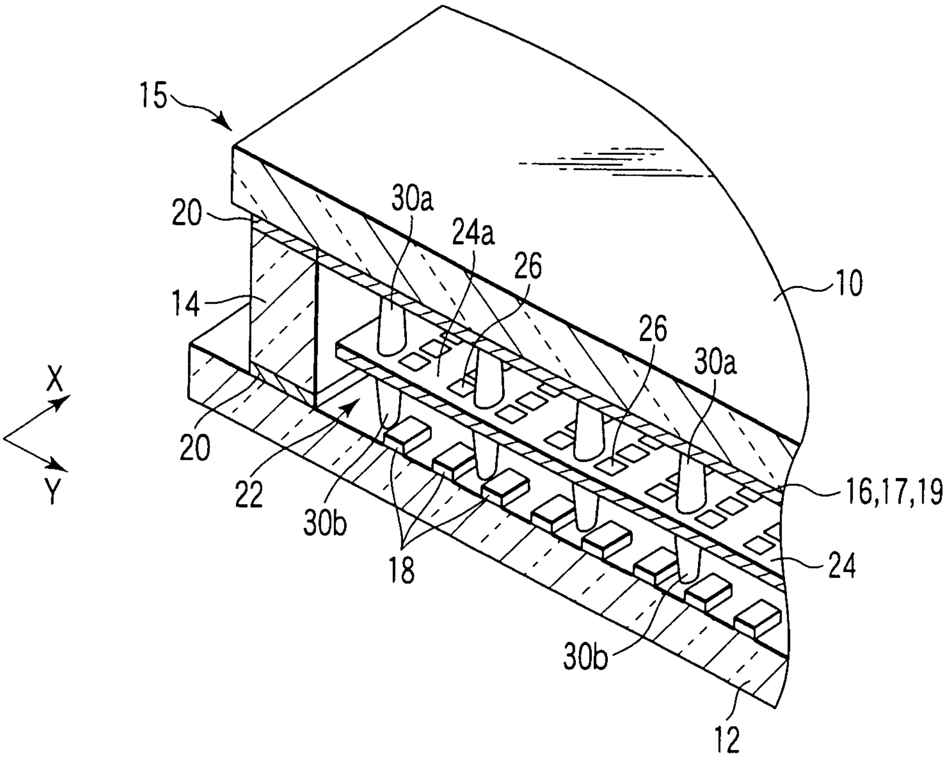

15
Ⅱ
10
Ⅱ
21
12
21
14
Y
X

FIG.1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30a
24a
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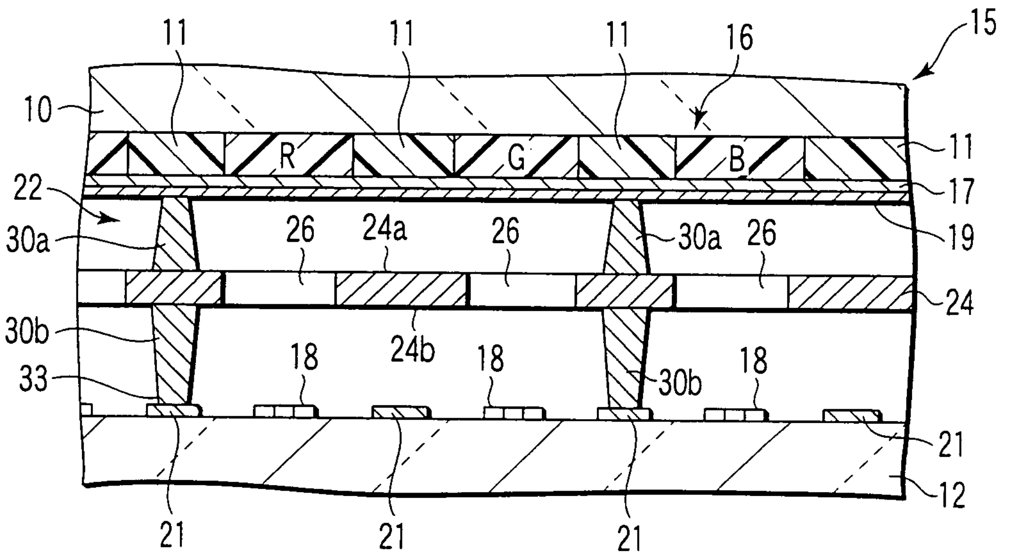
30b
12

FIG.2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16
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G
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17
22
19
30a
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12
21
21
21

FIG. 3

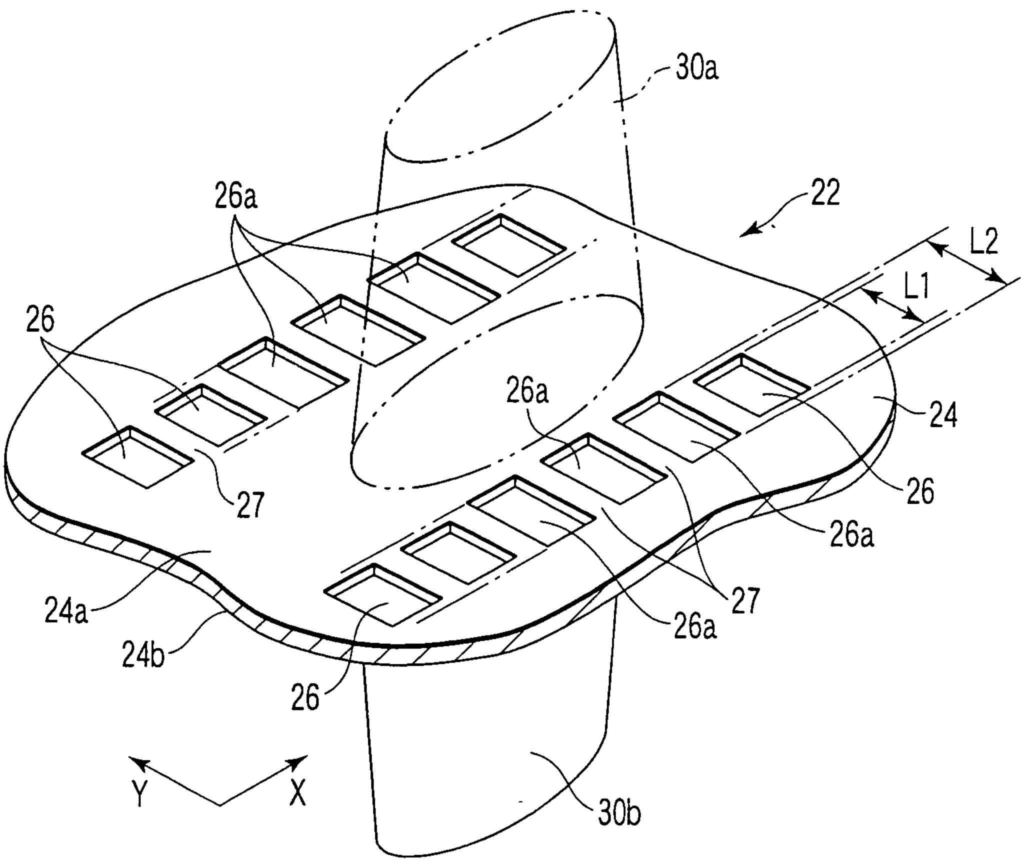
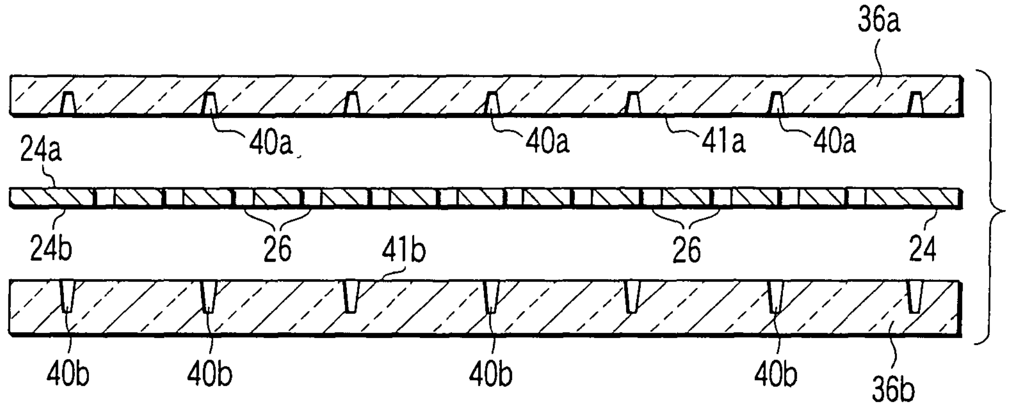

30a
22
26a
L2
L1
26
26a
24
27
26
26a
24a
27
24b
26a
26
Y
X
30b

FIG. 4


36a
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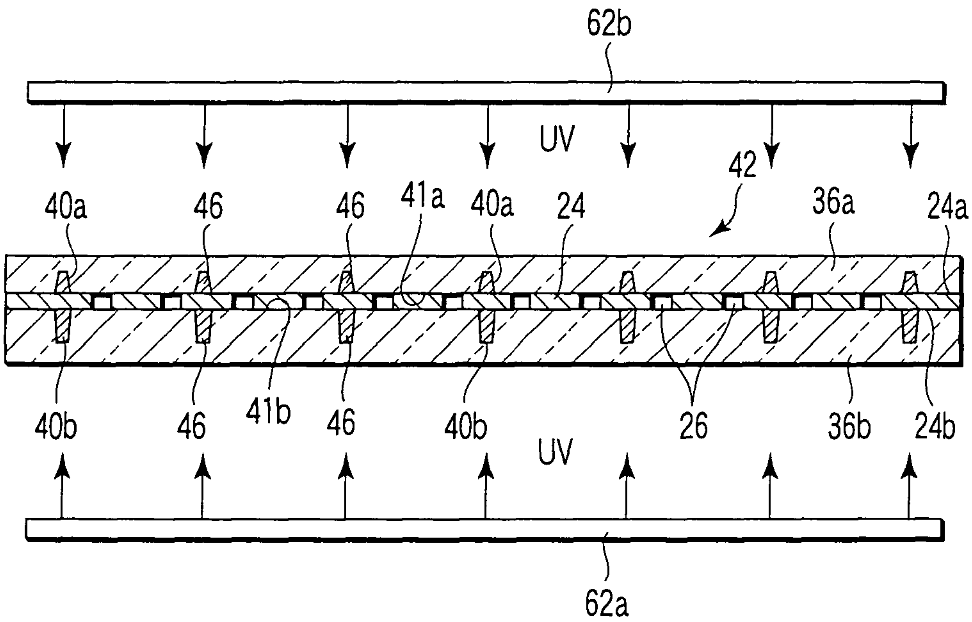
24a
24b
26
41b
26
24
40b
40b
40b
40b
36b

FIG. 5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42
40a
46
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41a
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40b
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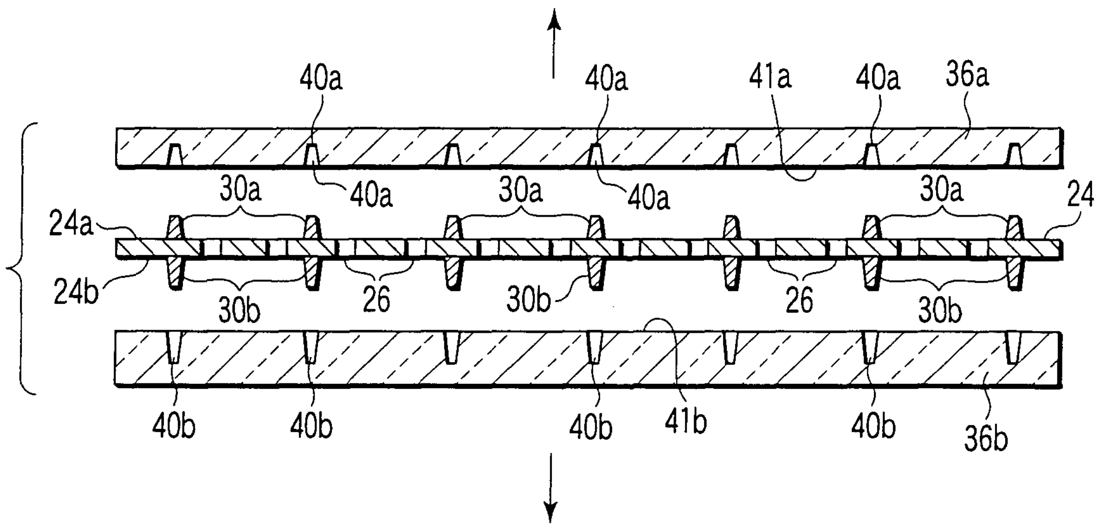
24b
UV
62a

FIG. 6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30a
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30b
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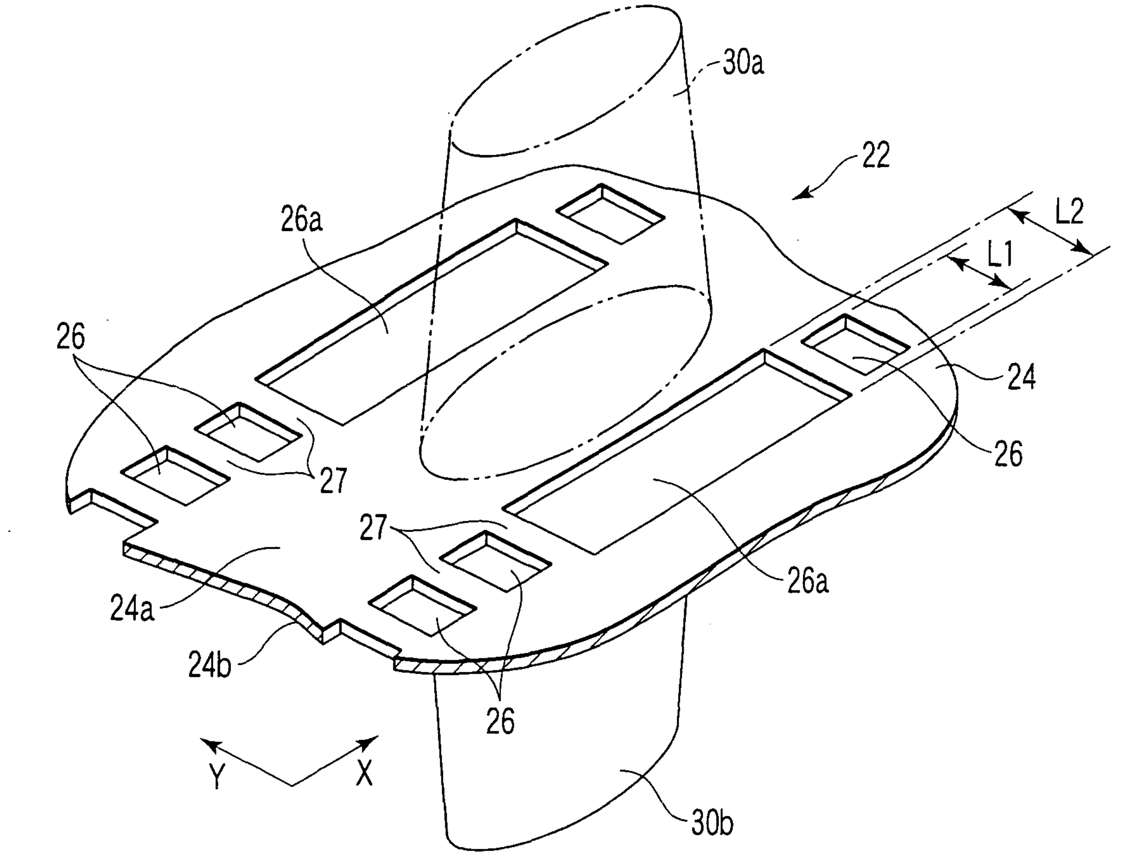
41b
40b
36b

FIG. 7


30a
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L1
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27
26a
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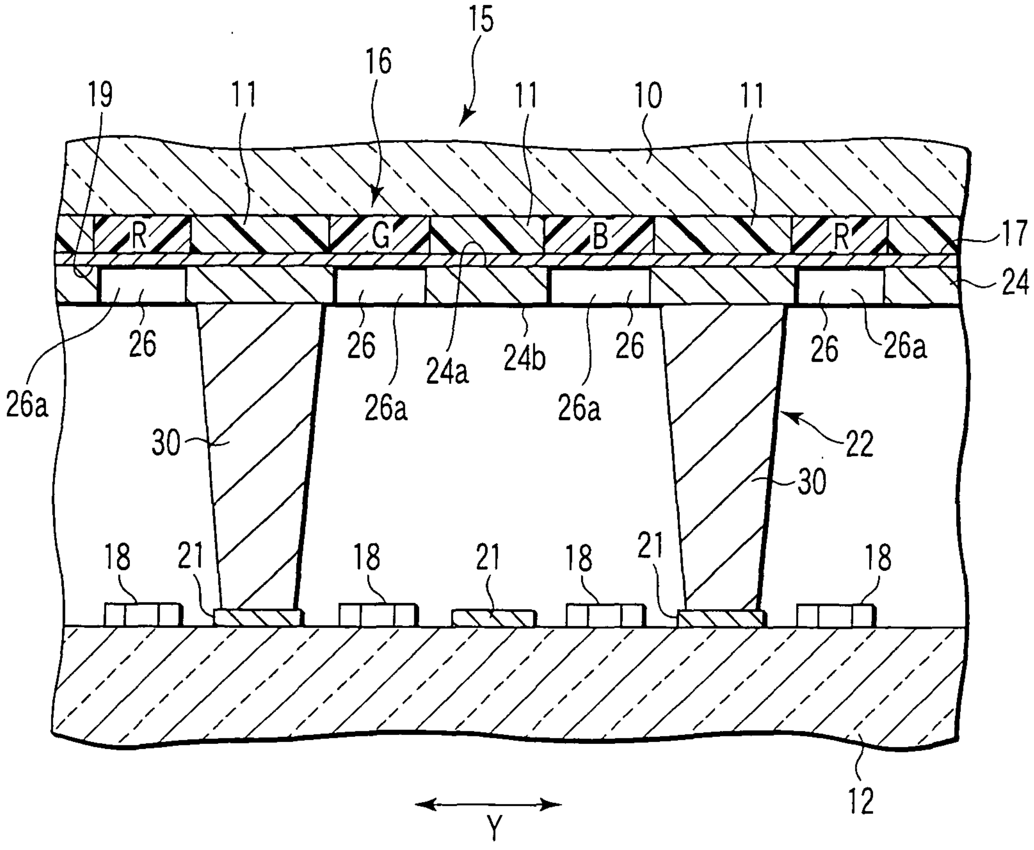
24b
26
Y
X
30b

FIG. 8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G
B
R
17
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26
26a
24a
24b
26a
26a
26a
30
22
30
18
21
18
21
18
21
18
12
Y

F I G. 9

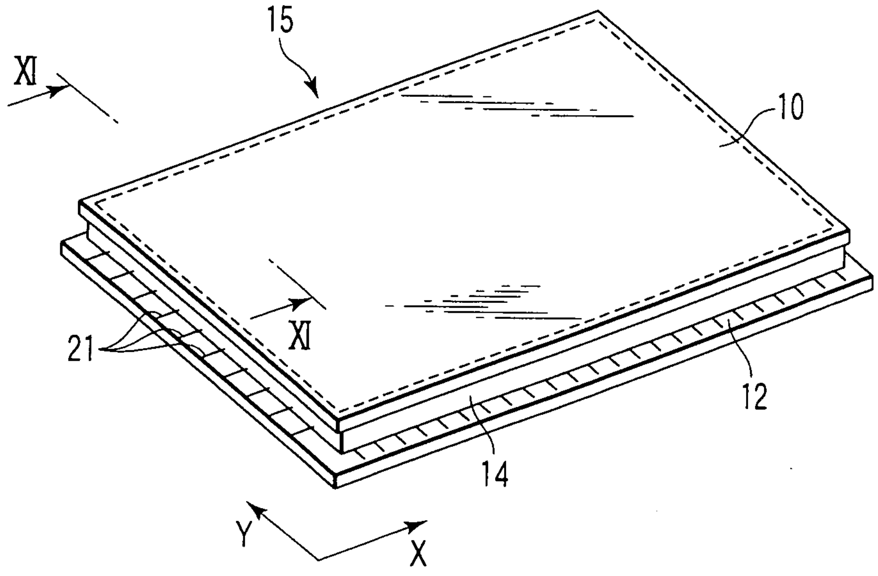


FIG. 10

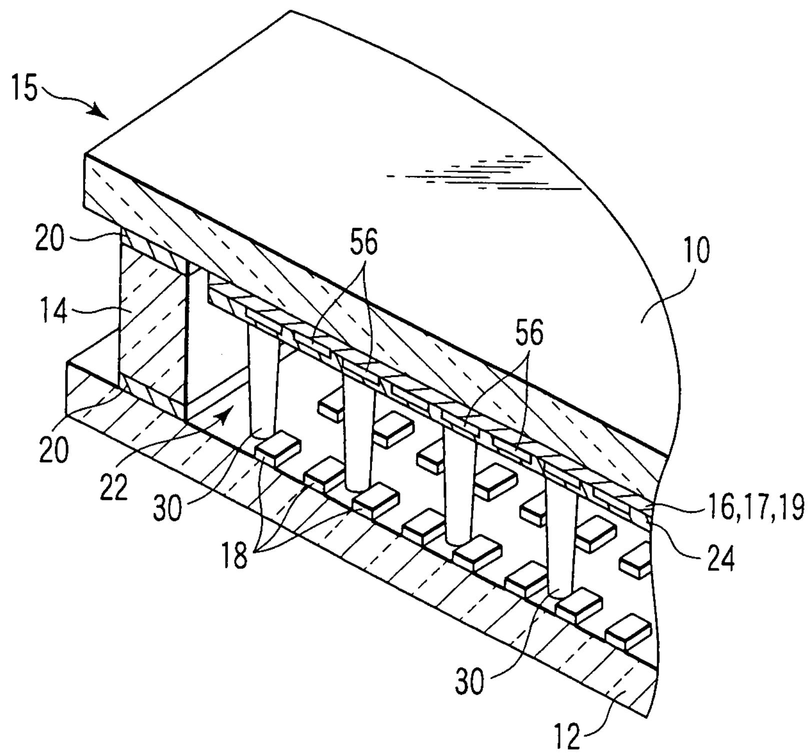
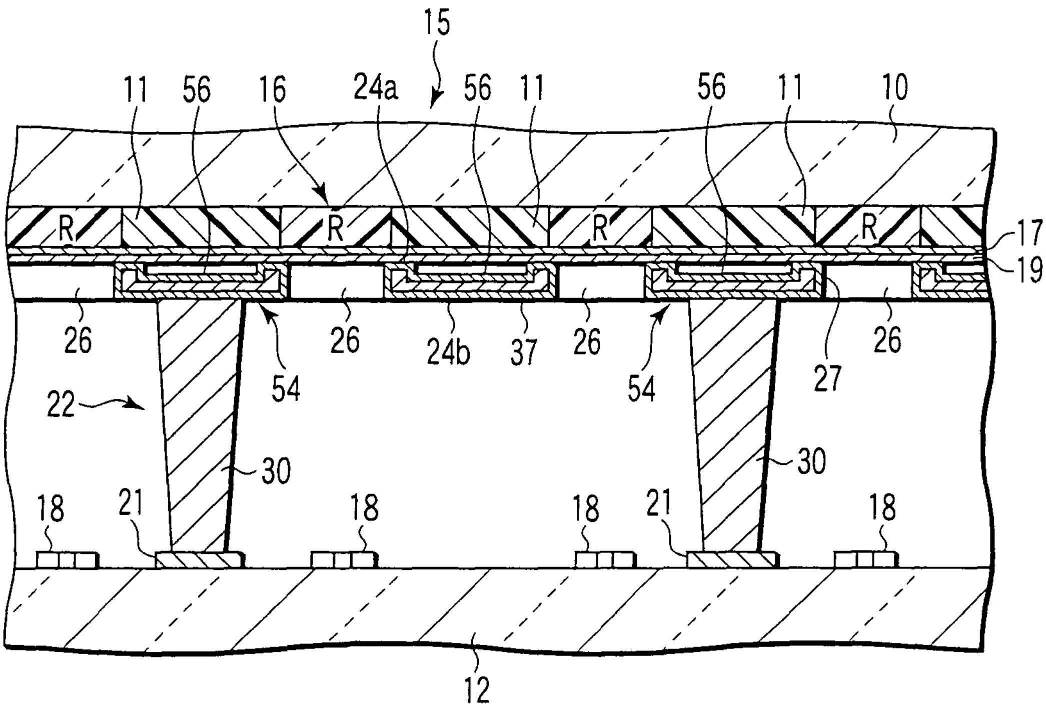


FIG. 11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24a
56
11
56
11
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R
R
R
R
17
19
26
26
24b
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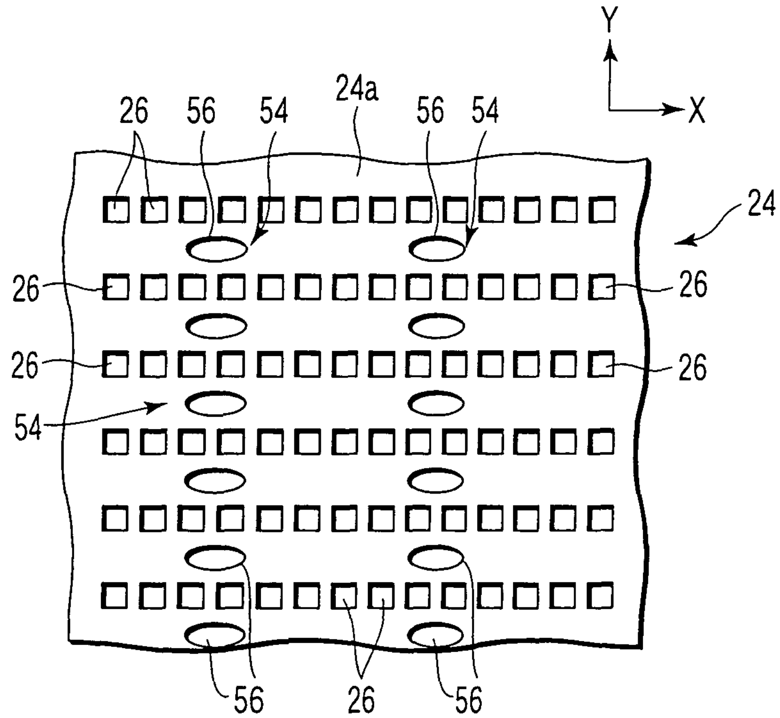
18
21
18
12

FIG. 12


Y
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24a
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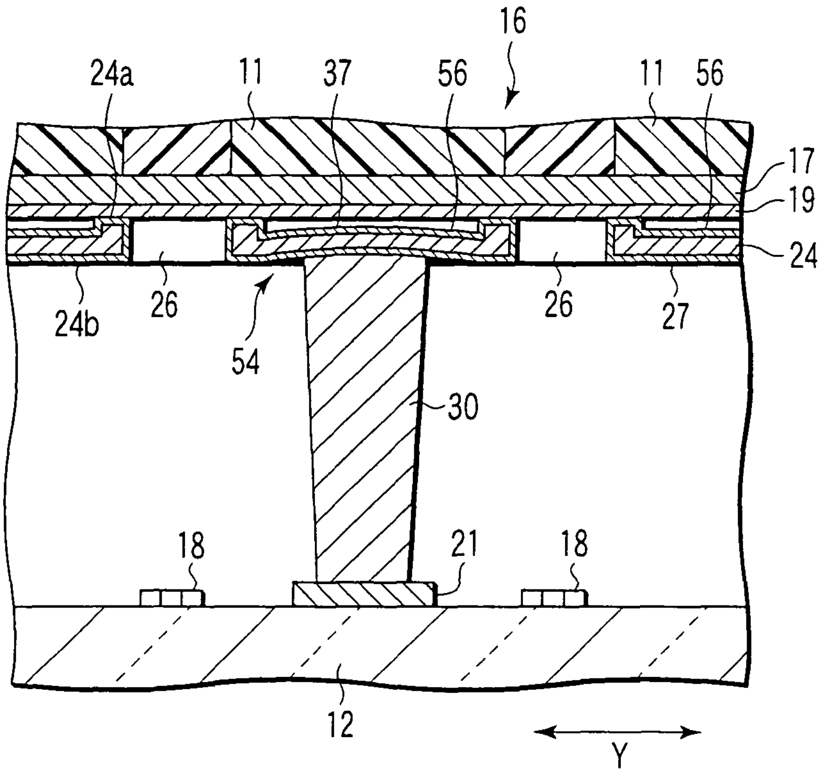
26
26
54
56
26
56

FIG. 13


16
24a
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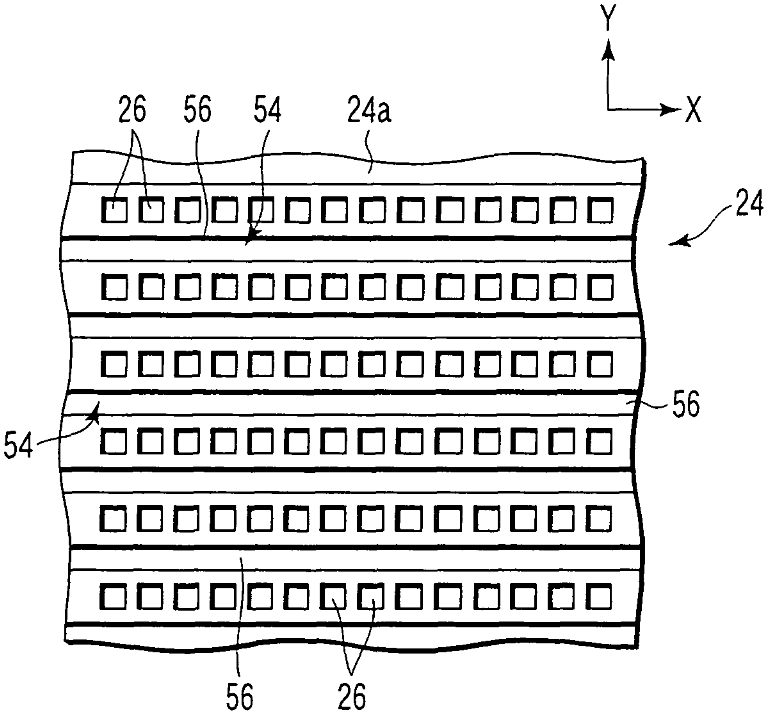
56
11
56
17
19
24
24b
26
54
26
27
30
18
21
18
12
Y

FIG. 14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56
54
24a
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56
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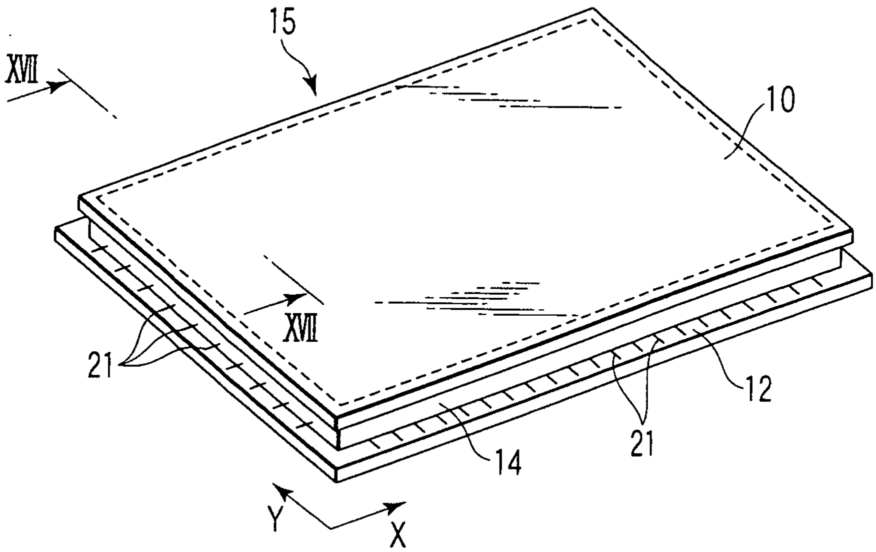
56
26

FIG. 15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XVII
10
XVII
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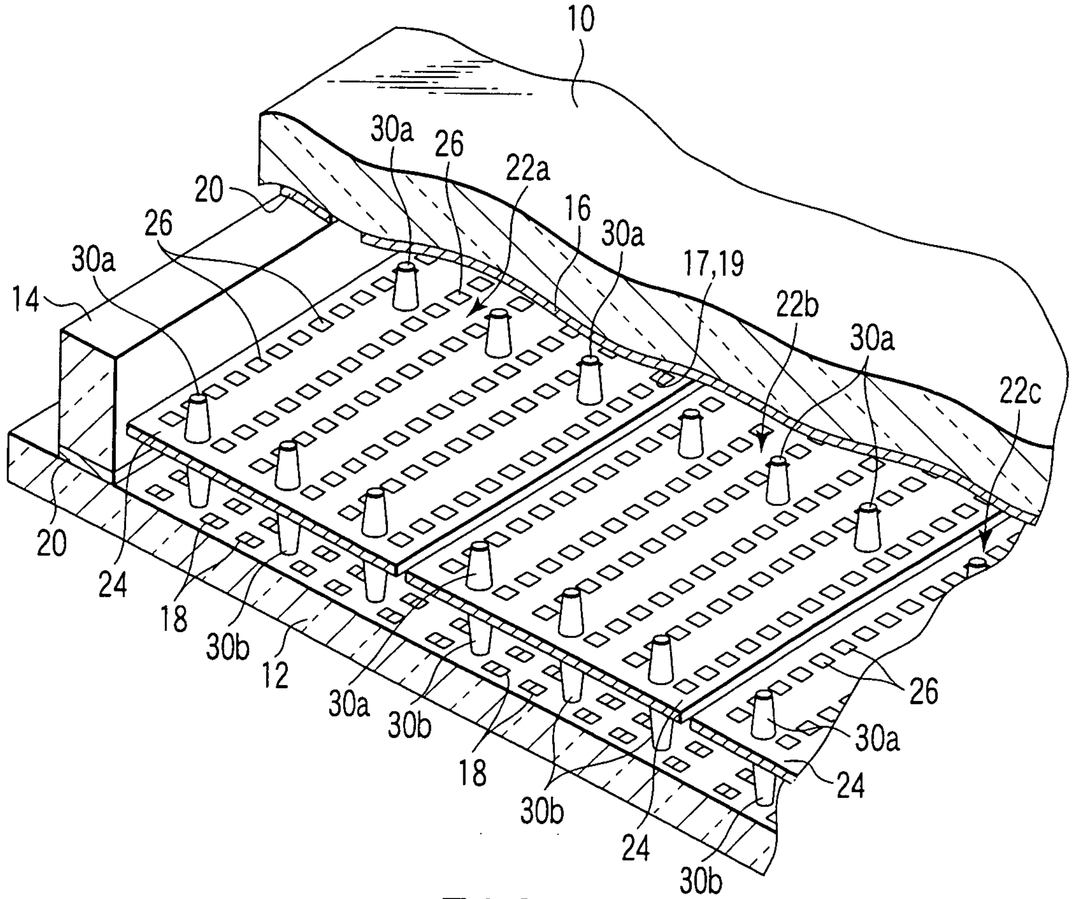
12
21
14
Y
X

FIG. 16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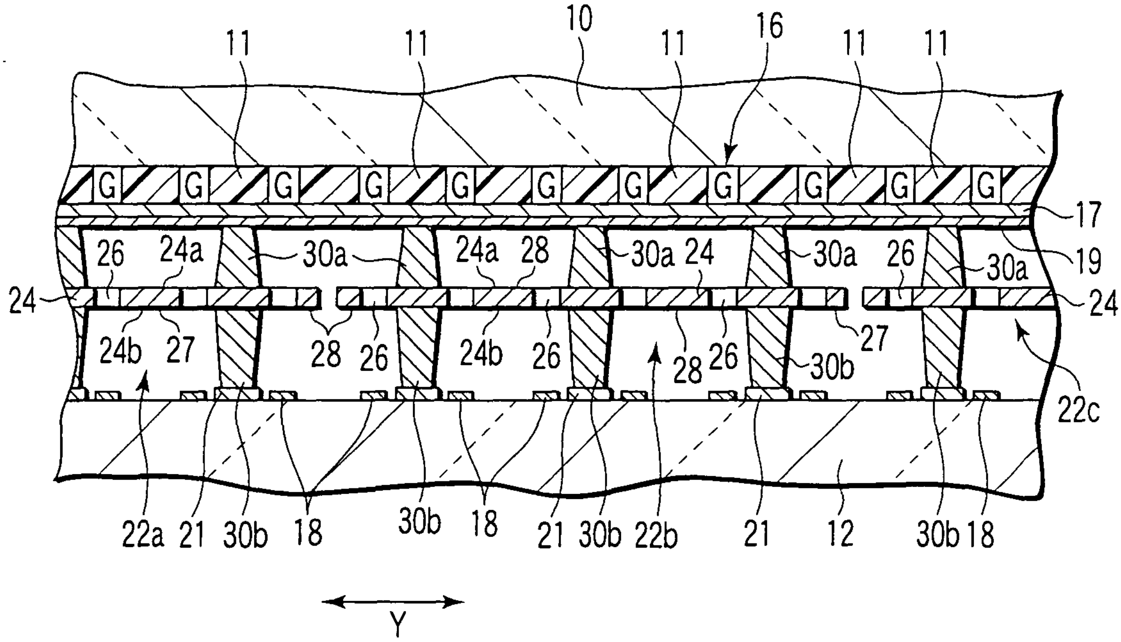
30a
26
22a
20
16
30a
26
17,19
30a
22b
14
30a
22c
20
24
18
30b
12
30a
30b
26
18
30a
30b
24
24
30b

FIG. 17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11
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16
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G
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19
26
24a
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24a
28
30a
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30a
26
30a
24
24
24b
27
28
26
24b
26
28
26
30b
27
22c
22a
21
30b
18
30b
18
21
30b
22b
21
12
30b
18
Y

FIG. 18

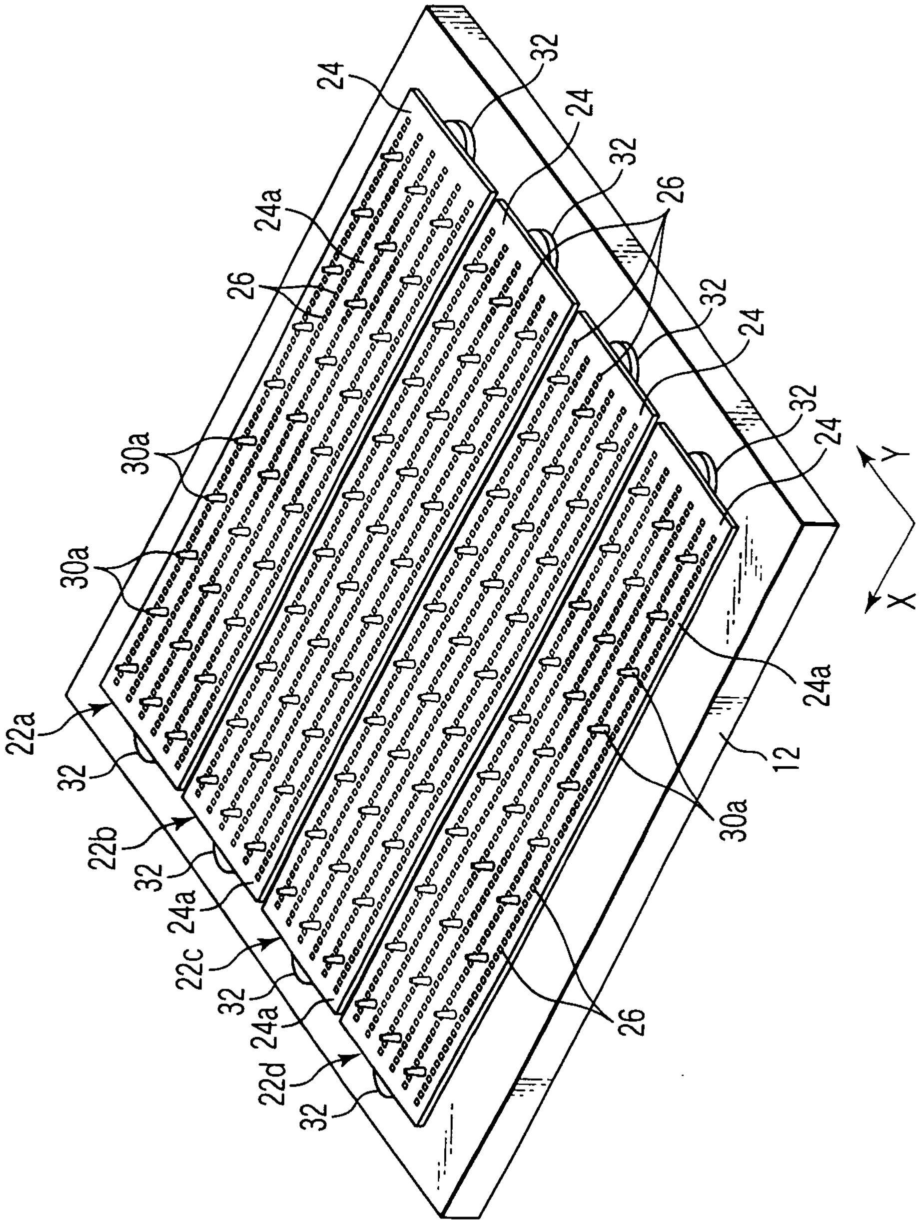


FIG. 19

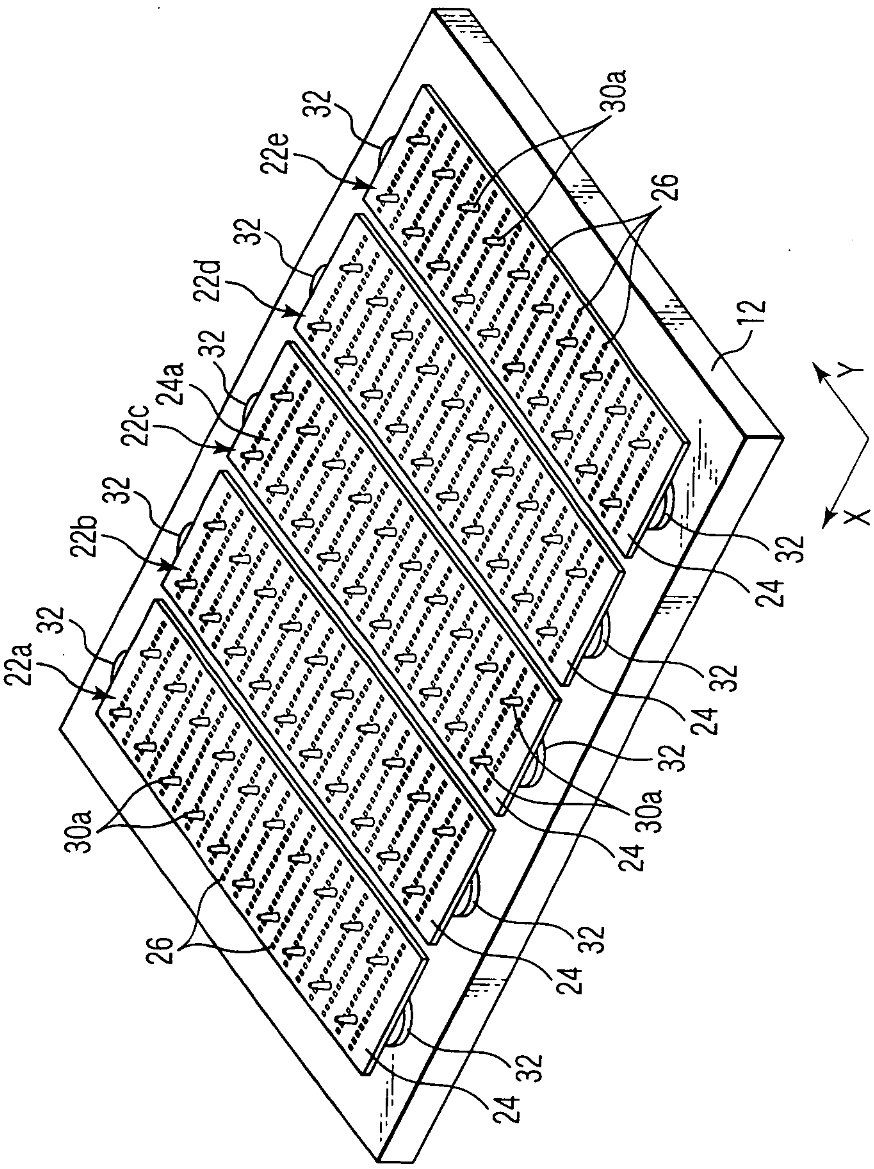


FIG. 20

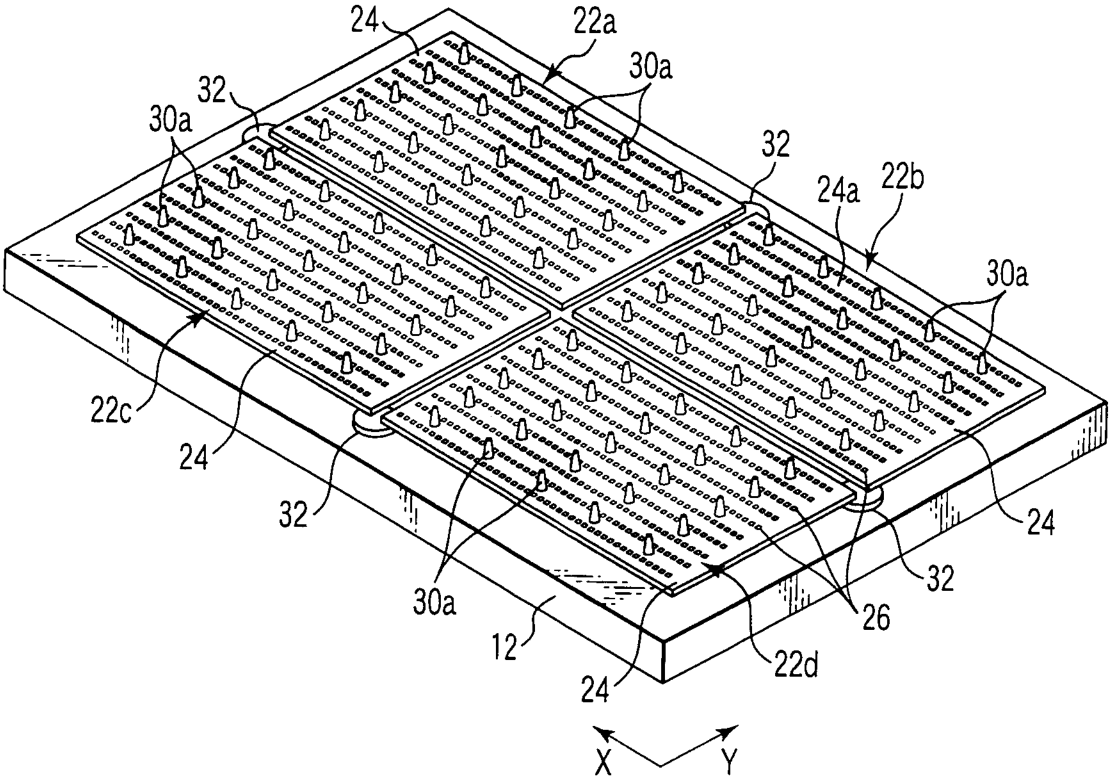
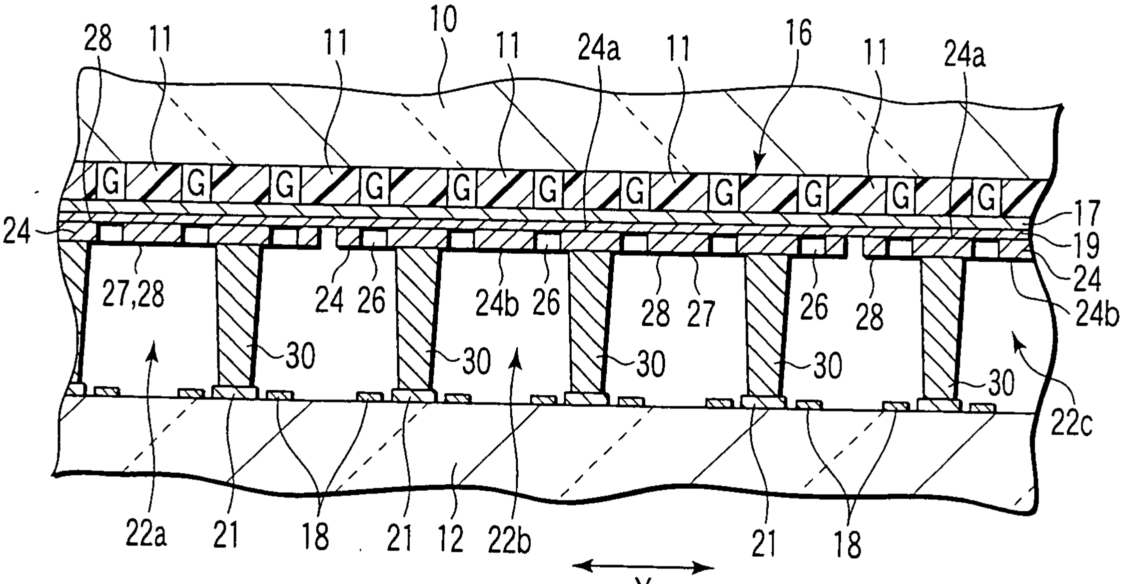

24
22a
30a
32
30a
32
24a
22b
30a
22c
24
32
24
32
30a
26
12
24
22d
X
Y

FIG. 21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11
24a
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24a
G
17
19
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24b
22c
27,28
24
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24b
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27
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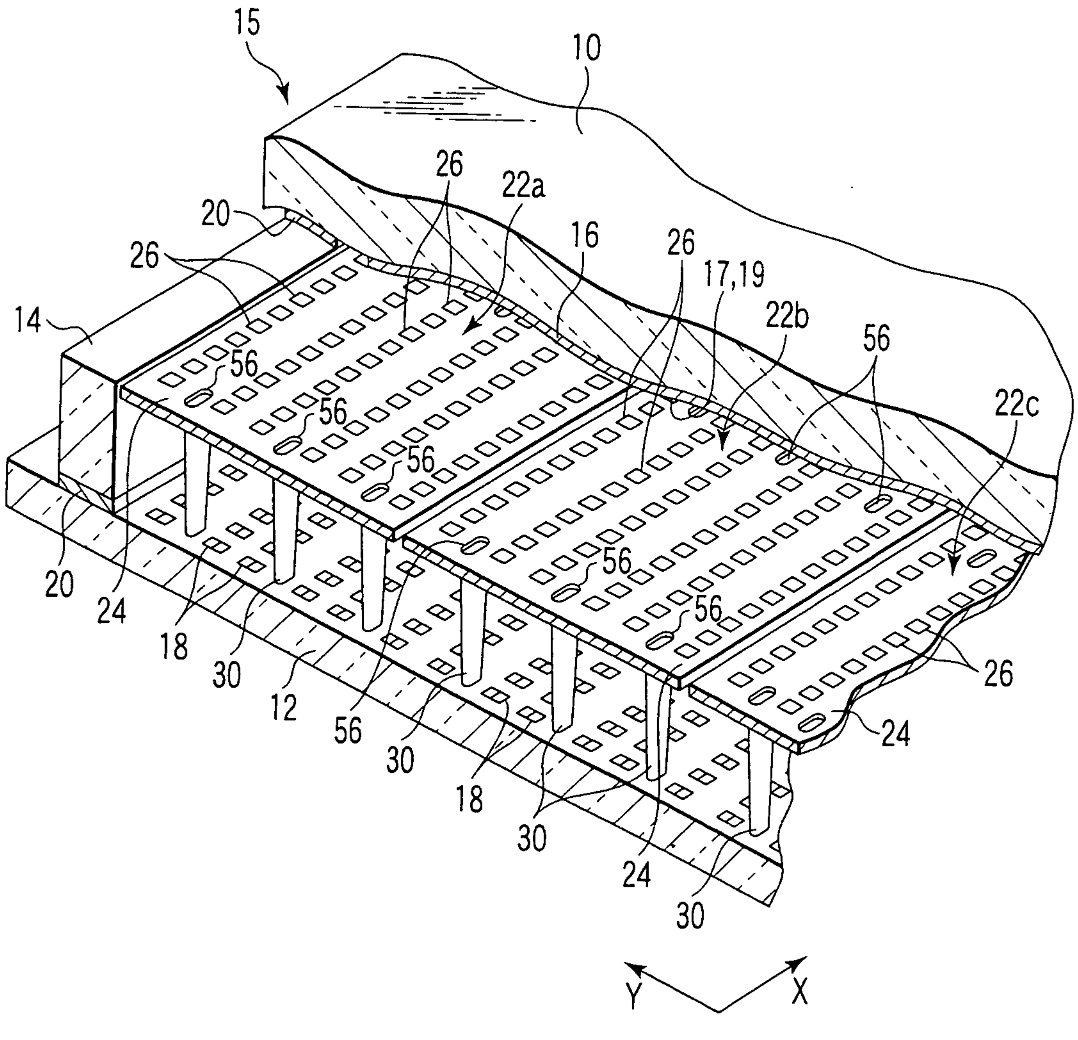
28
30
22a
21
18
21
12
22b
21
18
Y

FIG. 22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22a
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16
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17,19
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22b
14
56
56
56
56
22c
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56
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24
18
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12
56
30
18
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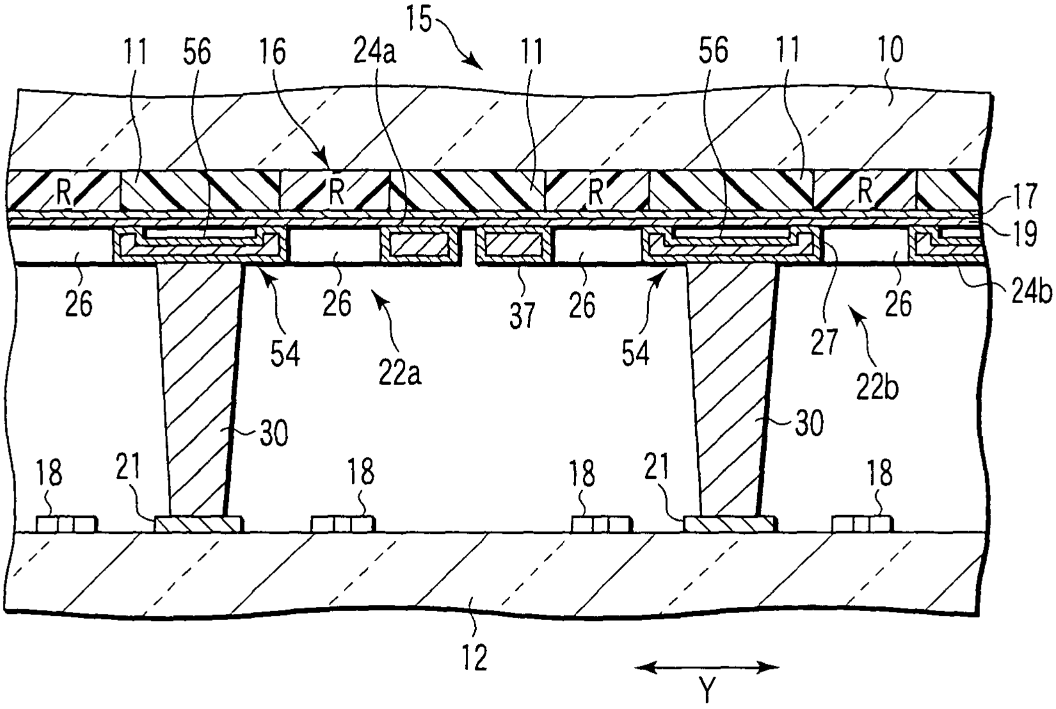
24
30
26
24
Y
X

F I G. 23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24a
11
56
11
10
R
R
R
R
17
19
24b
26
26
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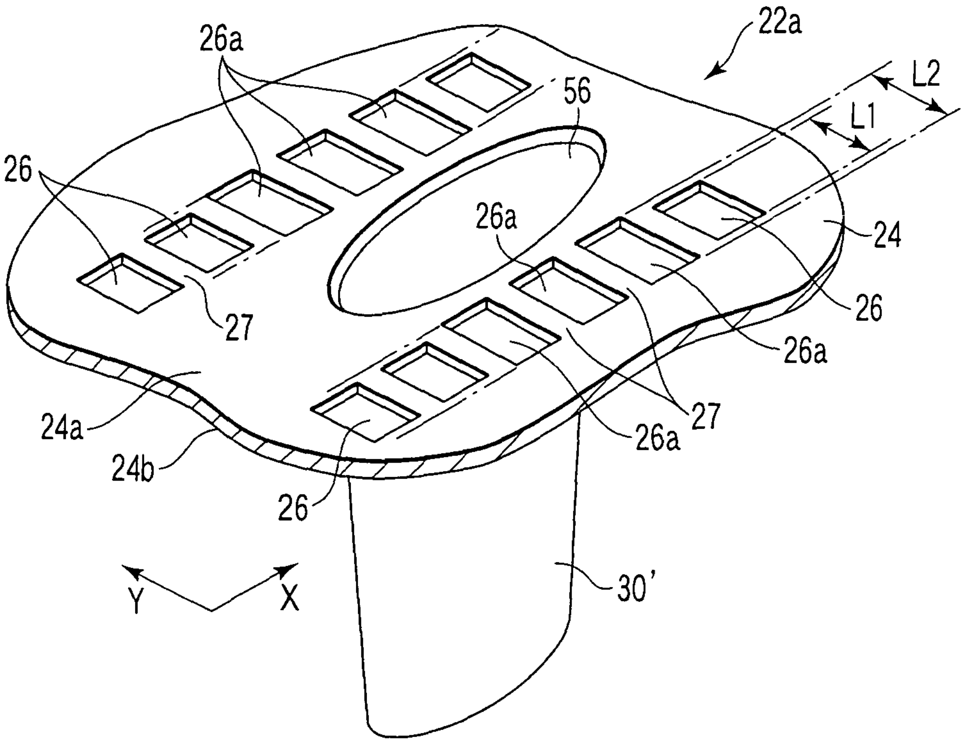
26
26
54
22a
54
27
22b
30
30
18
21
18
18
21
18
12
Y

F I G. 24


26a
22a
L2
56
L1
26
26a
24
27
26
26a
24a
27
24b
26a
26
Y
X
30'

F I G. 25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/001360

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H01J31/12, 29/87

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H01J31/12, 29/87

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2005
Kokai Jitsuyo Shinan Koho	1971-2005	Toroku Jitsuyo Shinan Koho	1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 10-269970 A (Canon Inc.), 09 October, 1998 (09.10.98), Par. Nos. [0017] to [0021], [0049]; Figs. 1 to 8 (Family: none)	14-16,21-23 17-20
Y	JP 2003-297266 A (Toshiba Corp.), 17 October, 2003 (17.10.03), Par. Nos. [0023], [0028] to [0030]; Figs. 2, 3 (Family: none)	17-20
A	JP 2003-51255 A (Toshiba Corp.), 21 February, 2003 (21.02.03), Full text; all drawings (Family: none)	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 18 May, 2005 (18.05.05)	Date of mailing of the international search report 31 May, 2005 (31.05.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/001360

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-63859 A (Toshiba Corp.), 28 February, 2002 (28.02.02), Full text; all drawings (Family: none)	1-5
A	JP 2003-272546 A (Matsushita Electric Industrial Co., Ltd.), 26 September, 2003 (26.09.03), Par. Nos. [0049] to [0050]; Fig. 10 & EP 903768 A2 & US 6320310 B1	6-13
A	WO 2002/23578 A1 (Hitachi, Ltd.), 21 March, 2002 (21.03.02), Full text; all drawings (Family: none)	1-23
A	JP 2002-334670 A (Hitachi, Ltd.), 22 November, 2002 (22.11.02), Par. Nos. [0022] to [0037]; Figs. 1, 2 & US 2002/167265 A1	14-23

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/001360

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The "special technical feature" of the invention in claims 1-5 relates to increase of an area of electron beam passing holes in the vicinity of spacer standing positions. The "special technical feature" of the invention in claims 6-13 and 14-23 relates to installation of a height modifying part on each of supporting boards and installation of a plurality of spacer structures between a first and a second boards. Since these inventions do not have a technical relationship, including one or more of the same or corresponding special technical features, these inventions are not so linked as to form a single general inventive concept.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (January 2004)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001272927 A **[0005]**
- JP 2002082850 A **[0007]**
- JP 2001229824 A **[0010]**