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(54) LIGHT EMITTING DEVICE, DISPLAY DEVICE, AND ELECTRONIC APPLIANCE

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(52) **U.S. Cl.** **257/84**; 257/79; 257/80
(58) **Field of Search** 257/82, 84, 98, 257/79, 80

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(57) **ABSTRACT**

A light emitting device includes a substrate, and a light emitting element section formed over the substrate. The light emitting element section includes a first light emitting layer in which light is generated due to electroluminescence, one pair of electrode layers used to apply an electric field to the first light emitting layer, a second light emitting layer which absorbs light generated in the first light emitting layer and generates light having a longer wavelength than a wavelength of the absorbed light, and one pair of dielectric multilayer films which are formed under and above the second light emitting layer, respectively. A wavelength range of light which is reflected by the pair of dielectric multilayer films includes a wavelength range of light generated in the second light emitting layer.

20 Claims, 12 Drawing Sheets

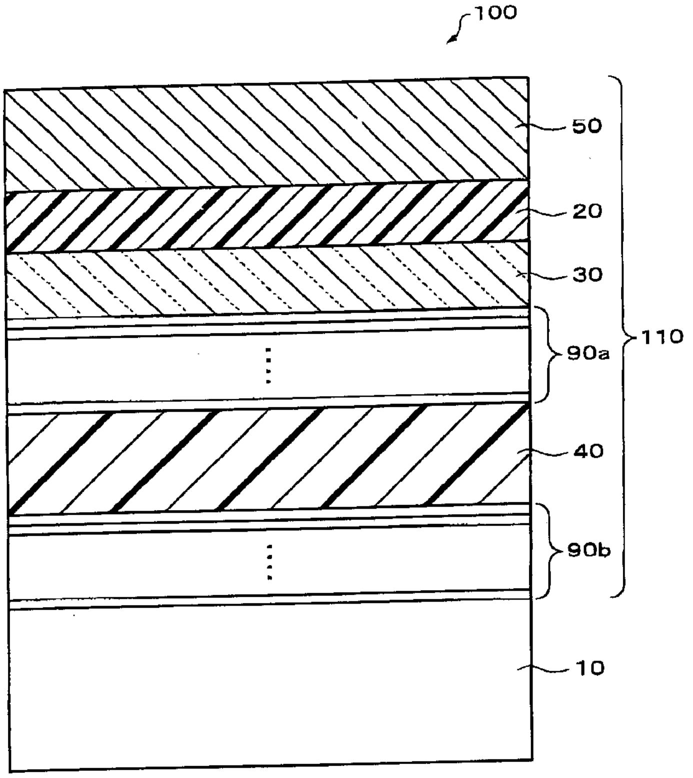


FIG. 1

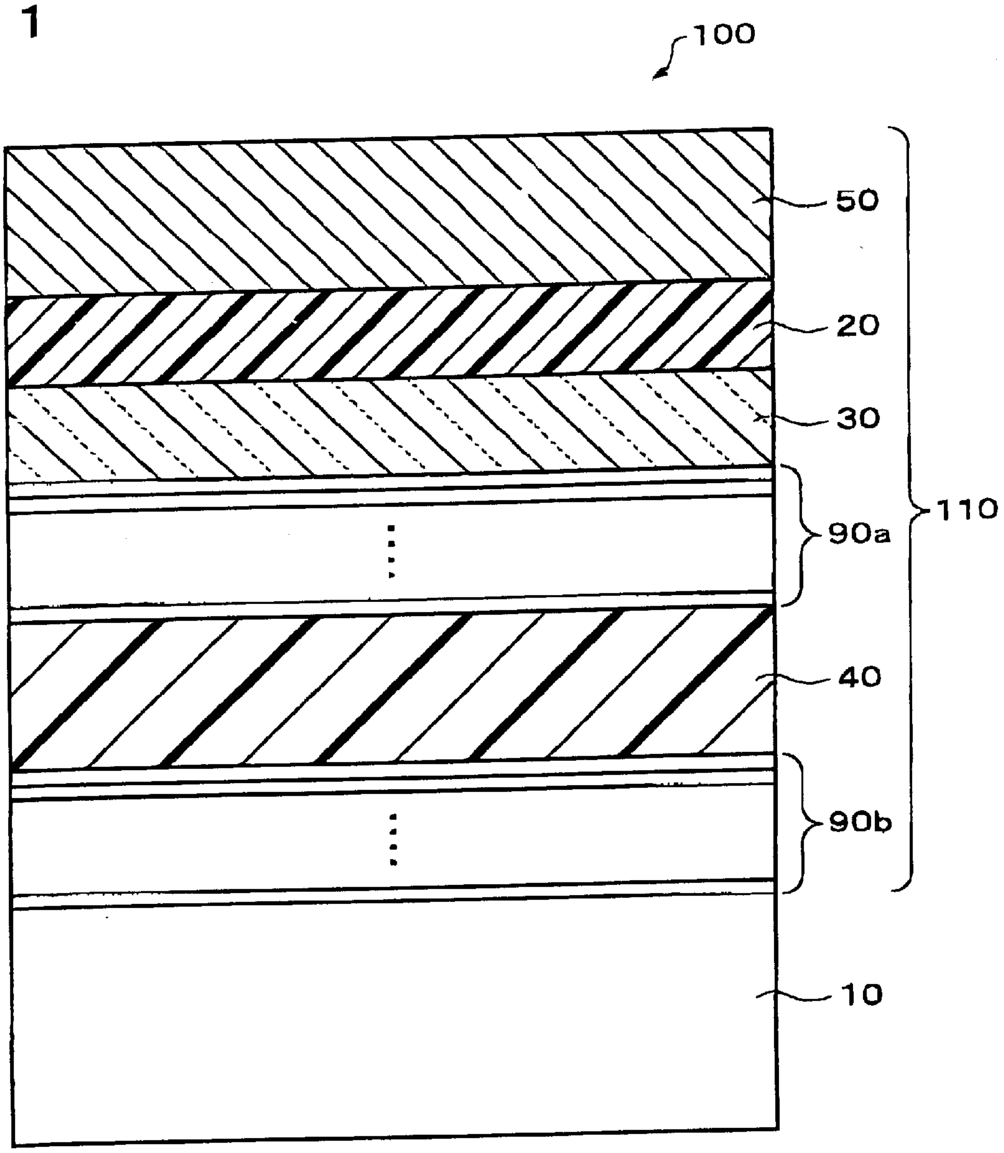


FIG. 2A

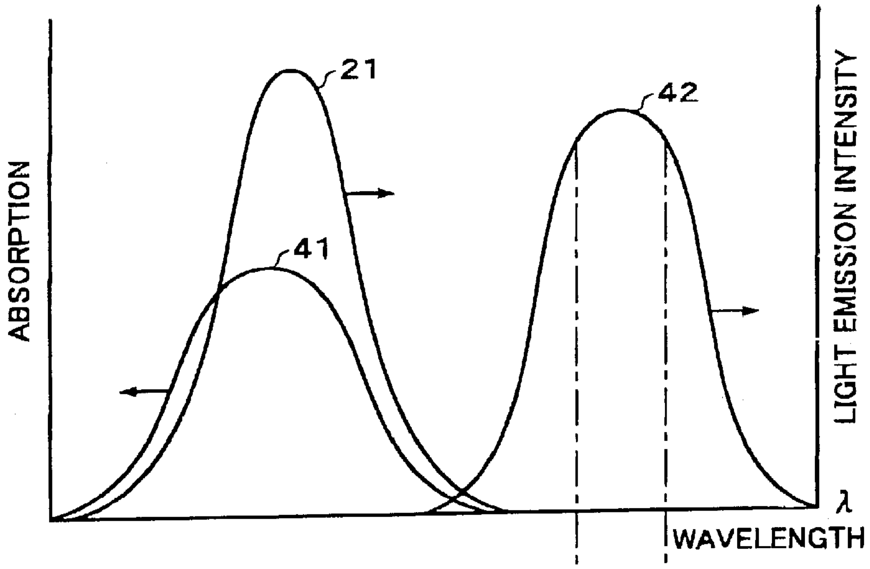

ABSORPTION
21
41
42
LIGHT EMISSION INTENSITY
λ
WAVELENGTH

FIG. 2B

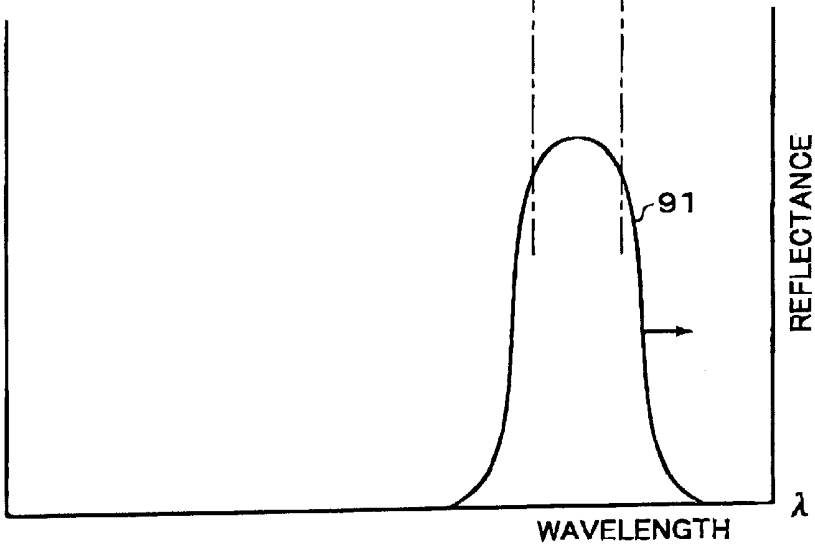

91
REFLECTANCE
λ
WAVELENGTH

FIG. 3

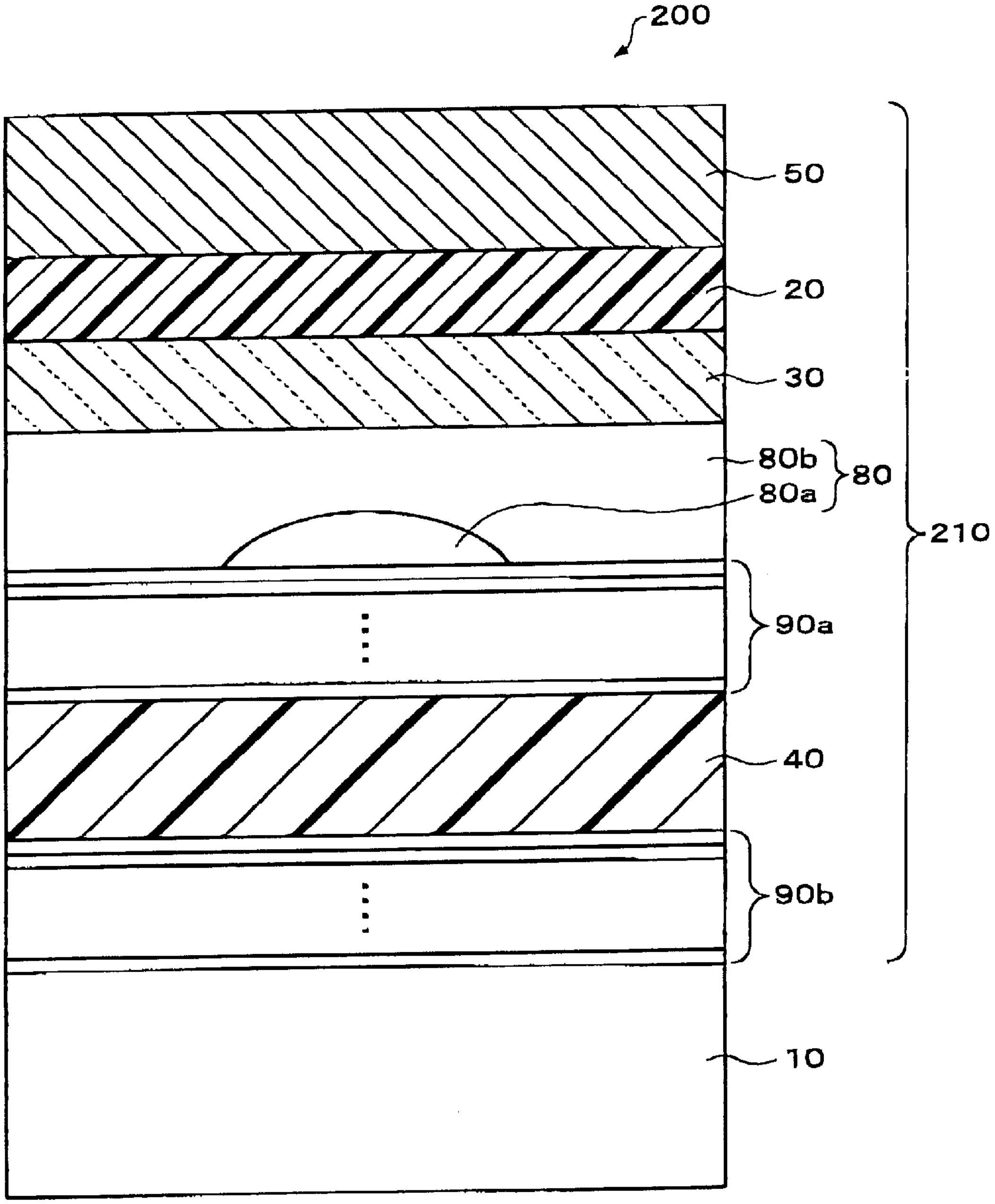


FIG. 4

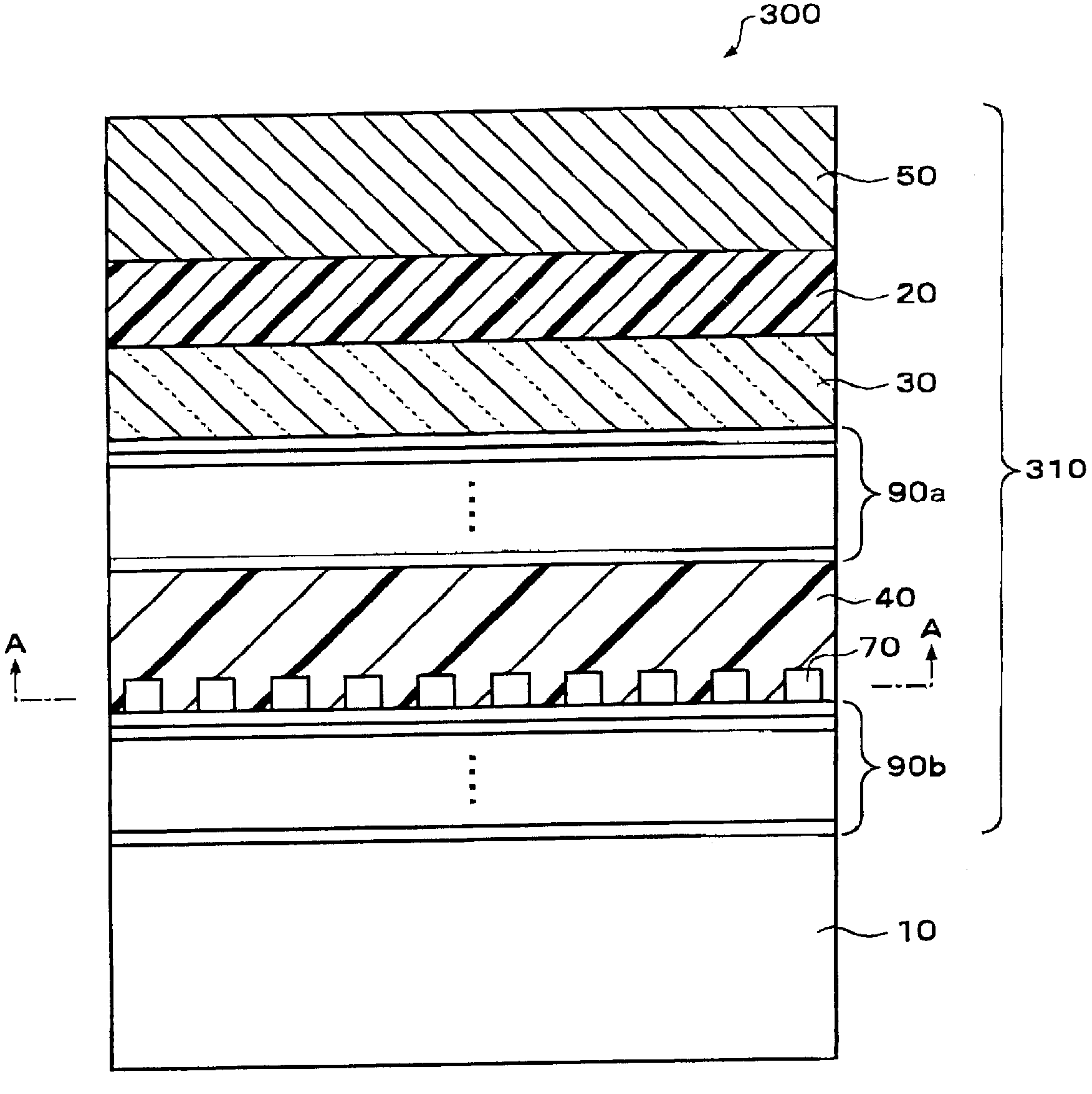


FIG. 5

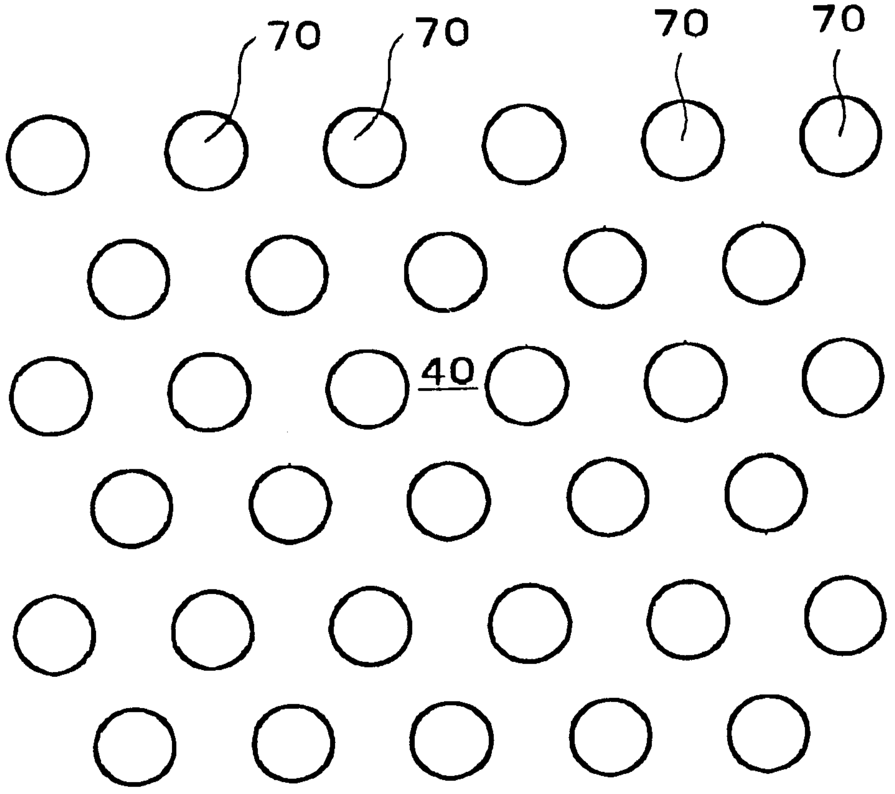


FIG. 6

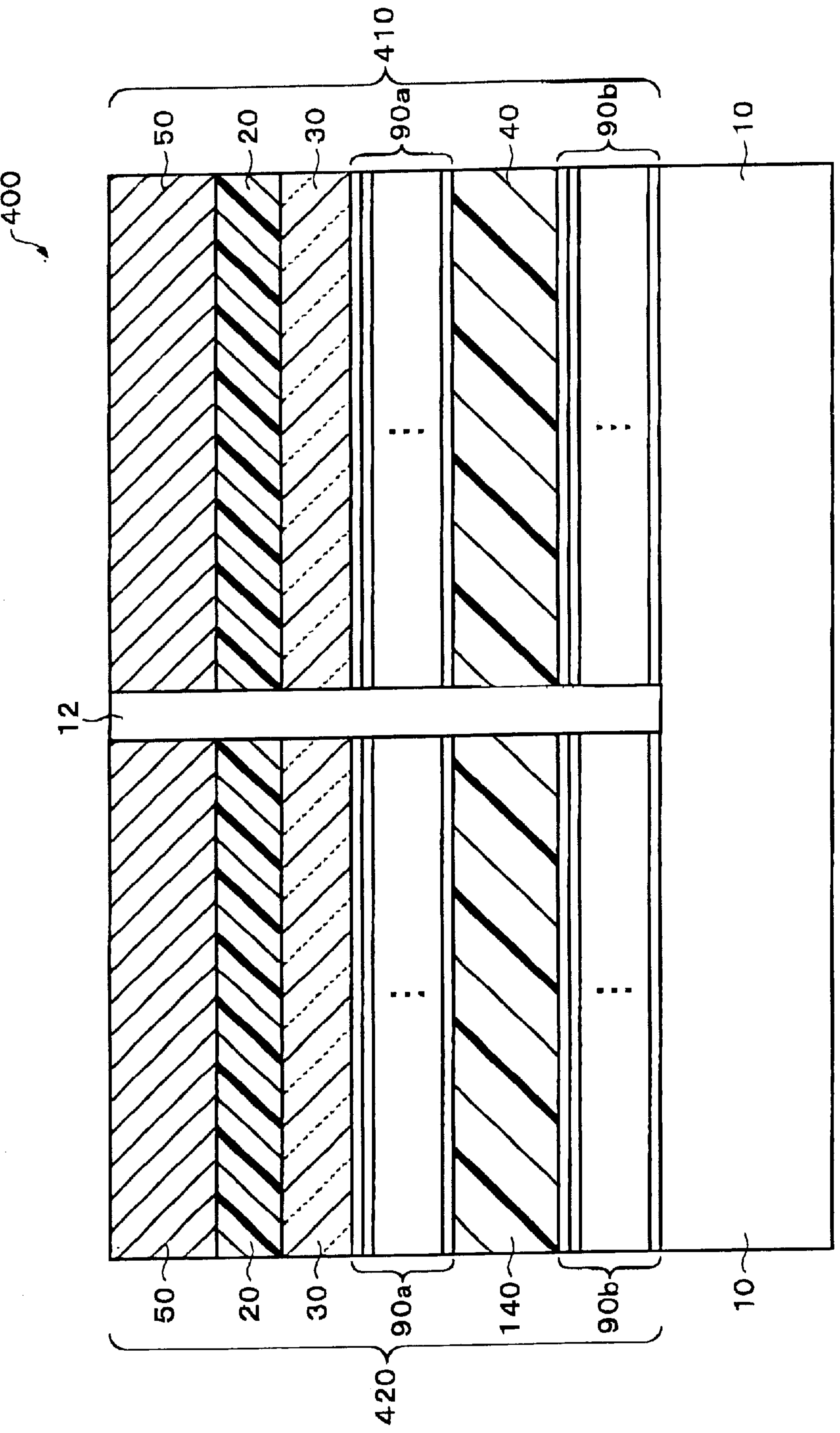


FIG. 7

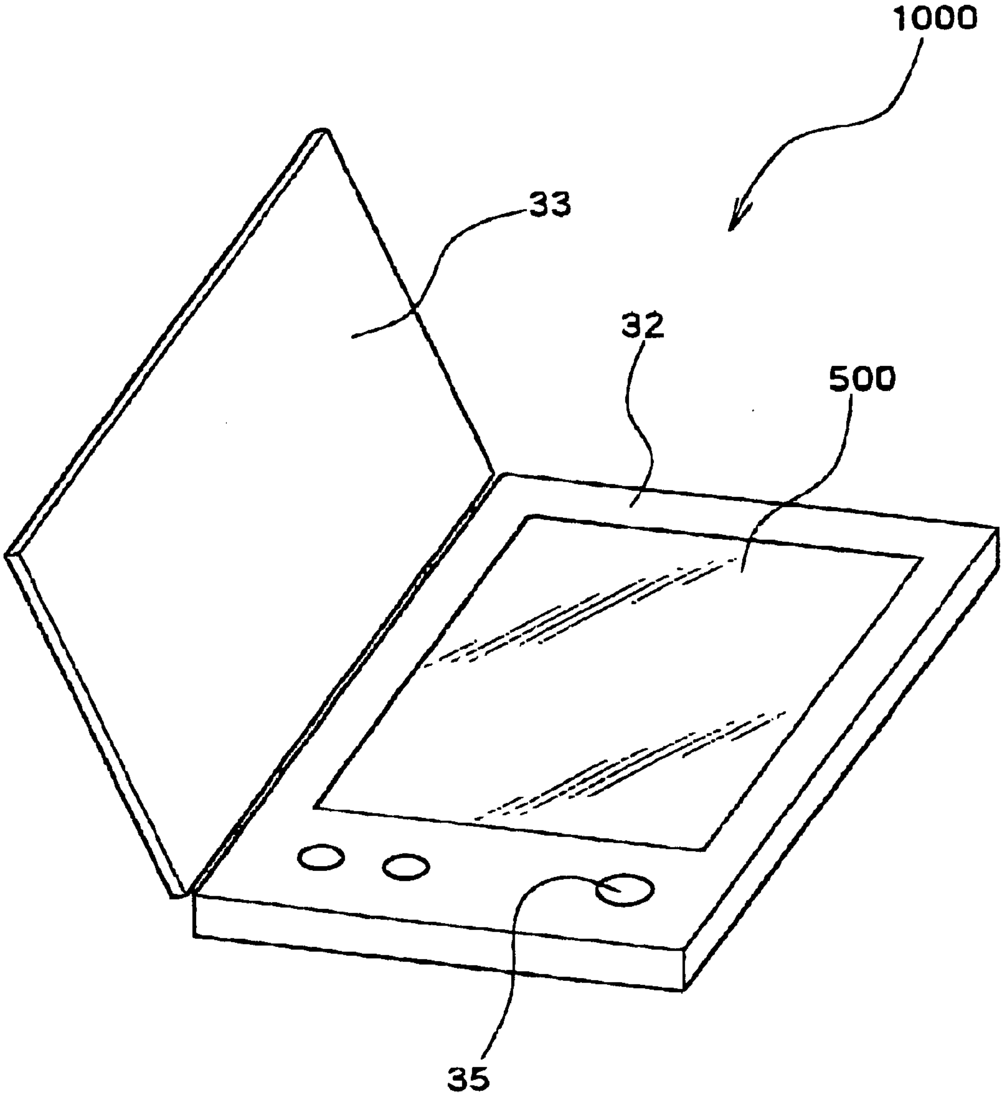


FIG. 8

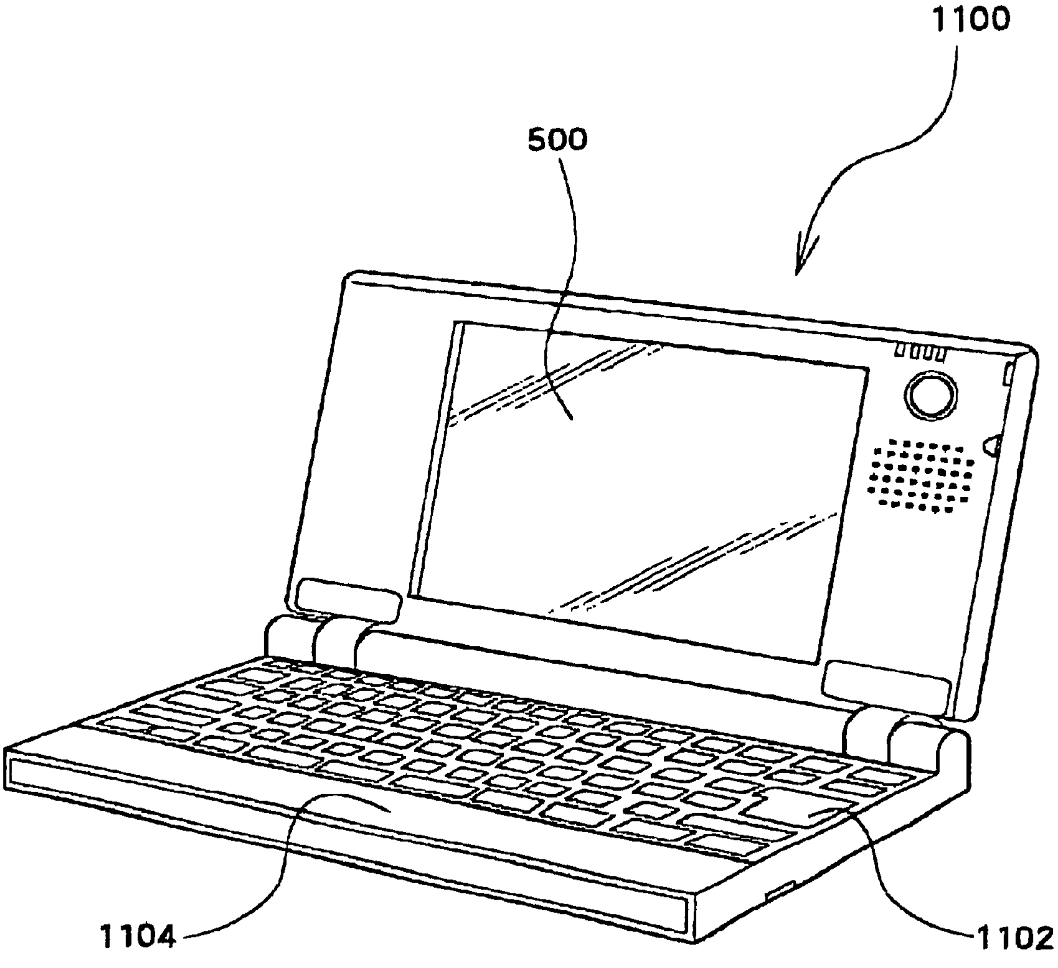


FIG. 9

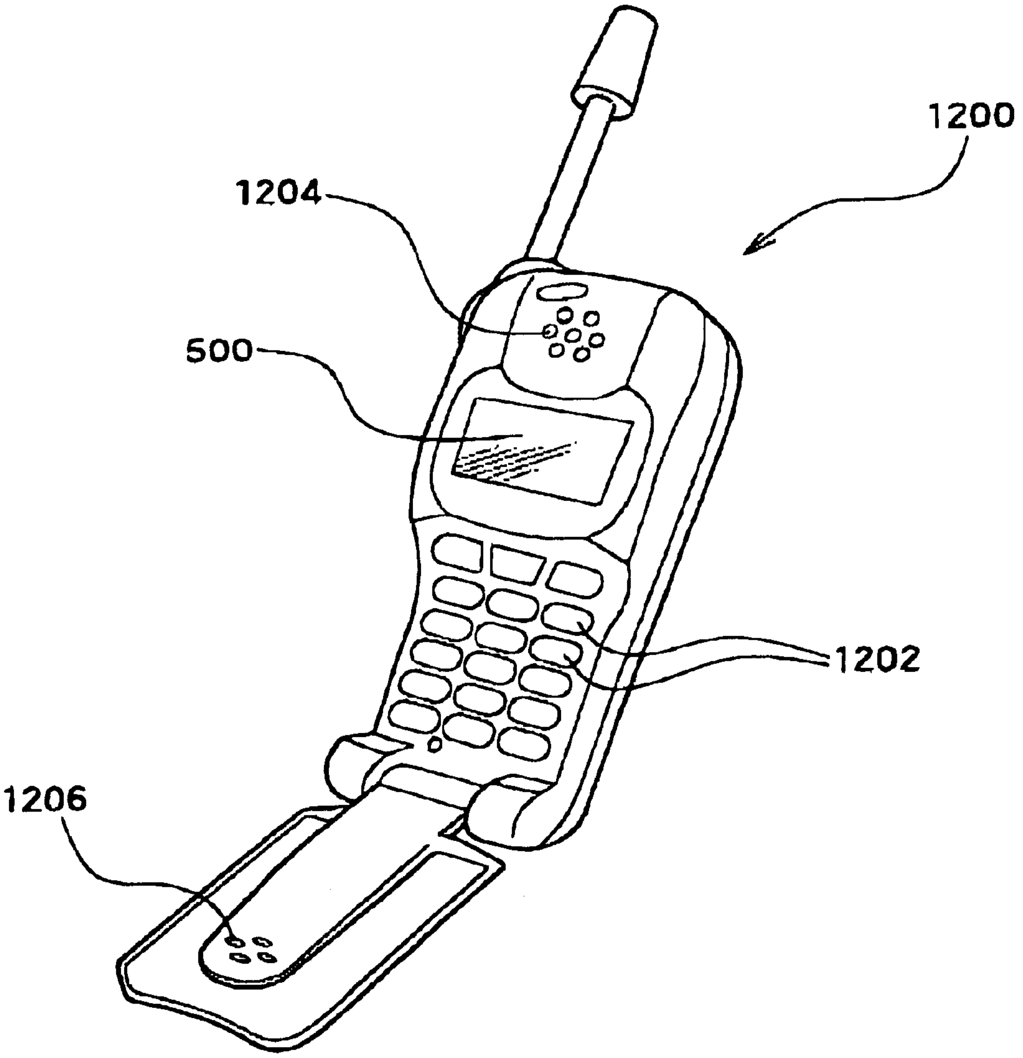


FIG. 10

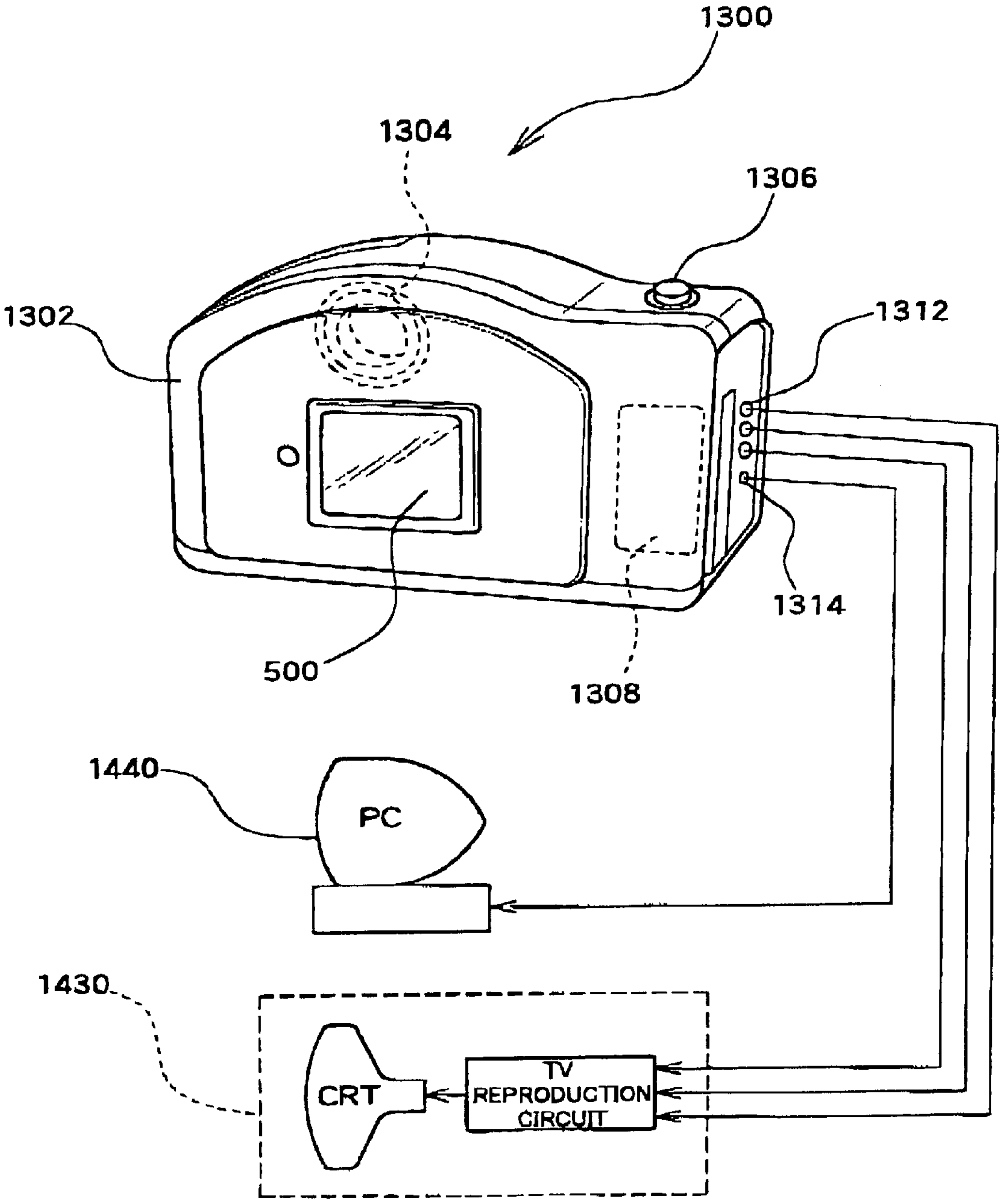

1300
1304
1306
1302
1312
1314
500
1308
1440
PC
1430
CRT
TV
REPRODUCTION
CIRCUIT

FIG. 11

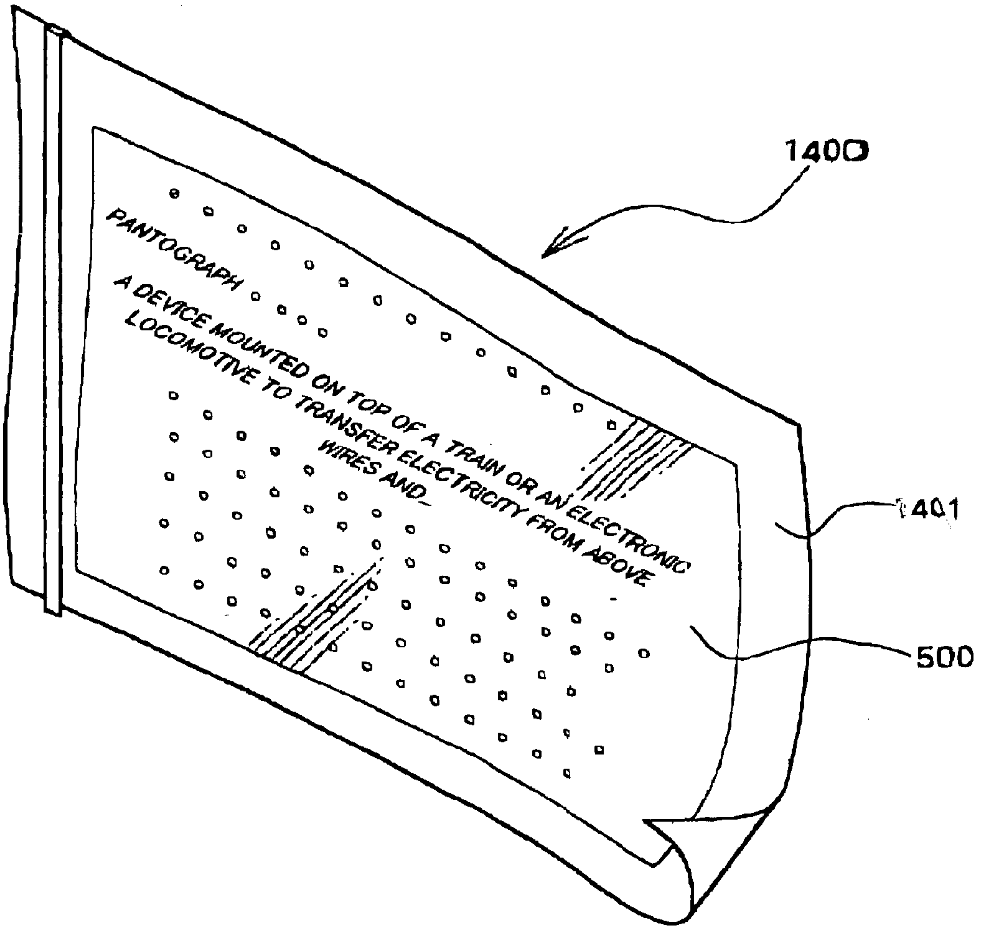
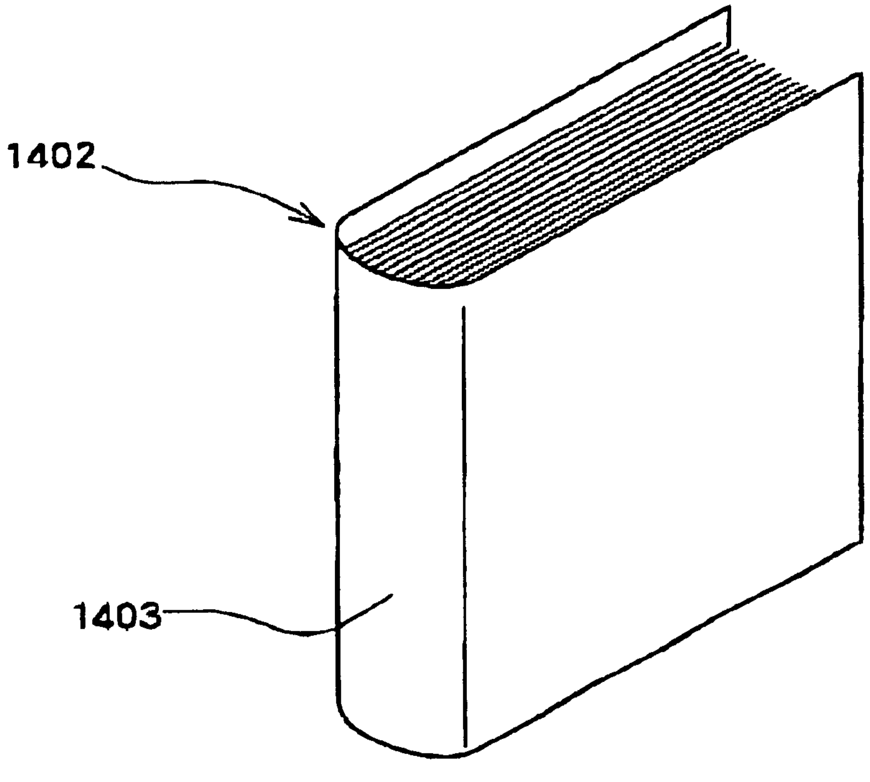

1400
PANTOGRAPH
A DEVICE MOUNTED ON TOP OF A TRAIN OR AN ELECTRONIC LOCOMOTIVE TO TRANSFER ELECTRICITY FROM ABOVE WIRES AND_
1401
500

FIG. 12



LIGHT EMITTING DEVICE, DISPLAY DEVICE, AND ELECTRONIC APPLIANCE

Japanese Patent Application No. 2001-49776, filed on Feb. 26, 2001, and Japanese Patent Application No. 2002-48116, filed on Feb. 25, 2002, are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

The present invention is related to a light emitting device using electroluminescence (EL), and related to a display device and an electronic instrument with employment of this light emitting device.

In EL light emitting elements using the electroluminescence (EL), since light emissions are carried out in an isotropic manner and thus, directivities of the EL light emitting elements are inappropriate, there are the following difficulties. That is, considering a specific direction of the EL light emitting element, intensity of light is lowered and emitted light cannot be utilized in high efficiencies.

BRIEF SUMMARY OF THE INVENTION

The present invention may provide a light emitting device capable of utilizing light in a higher efficiency, while increasing intensity of light along a specific direction.

The present invention may provide a display device using the above-described light emitting device, and an electronic instrument with employment of the light emitting device

A light emitting device according to one aspect of the present invention, comprises:

a substrate; and

a light emitting element section formed over the substrate,

wherein the light emitting element section includes:

a first light emitting layer in which light is generated due to electroluminescence;

one pair of electrode layers used to apply an electric field to the first light emitting layer;

a second light emitting layer which absorbs light generated in the first light emitting layer and generates light having a longer wavelength than a wavelength of the absorbed light; and

one pair of dielectric multilayer films which are formed under and above the second light emitting layer, respectively,

wherein a wavelength range of light that is reflected by the pair of dielectric multilayer films includes a wavelength range of light generated in the second light emitting layer.

In accordance with this light emitting device, after the light generated in the first light emitting layer due to the electroluminescence is absorbed by the second light emitting layer, light having longer wavelength than that of the absorbed light is generated in the second light emitting layer. The light generated in the second light emitting layer emits through the dielectric multilayer films to the substrate. As a result, it is possible to obtain a light emitting device that can emit light efficiently due to light excitation.

Also, since the wavelength range of the light that is reflected by the dielectric multilayer films includes the wavelength range of the light generated in the second light emitting layer, the light generated in the second light emitting layer is shut up between the dielectric multilayer films, so that the light propagation in the direction intersecting with the surface of the substrate can be restricted. As a result, the light having a very narrow light emission spectral width in the direction intersecting with the surface of the substrate can be obtained efficiently. Further, the light generated in the second light emitting layer may be emitted in a direction intersecting with the substrate, so that a surface light emission may be achieved.

This light emitting device of the present invention may have the following features (1) to (10):

(1) A wavelength range of the light generated in the first light emitting layer and a wavelength range of the light absorbed by the second light emitting layer may at least partially overlap with each other. In this feature, the light generated in the first light emitting layer can be absorbed by the second light emitting layer efficiently.

(2) A wavelength at a highest emission intensity in a wavelength range of the light generated in the second light emitting layer may be longer than a wavelength at a highest emission intensity in a wavelength range of the light generated in the first light emitting layer.

(3) The pair of dielectric multilayer films may include a first dielectric multilayer film and a second dielectric multilayer film,

the first dielectric multilayer film maybe formed closer to the first light emitting layer than the second dielectric multilayer film and

a reflectance of the first dielectric multilayer film may be larger than a reflectance of the second dielectric multilayer film.

In this feature, the light generated in the second light emitting layer may be emitted from the second light emitting layer toward the substrate.

(4) The first light emitting layer may include an organic light emitting material which emits light by the electroluminescence,

(5) The second light emitting layer may include a host material and a dopant material,

the host material may absorb the light generated in the first light emitting layer so that an excited state occurs, and the dopant material may be excited due to a transfer of the excited state of the host material to the dopant material, and the excited dopant material may emit light having a longer wavelength than a wavelength of the light absorbed by the host material.

(6) The second light emitting layer may include an organic light emitting material, and

the organic light emitting material may absorb the light generated in the first light emitting layer so that the organic light emitting material is excited, and the excited organic light emitting material may emit light having a longer wavelength than a wavelength of the absorbed light,

(7) A propagation direction of the light emitted from the first light emitting layer may be substantially equal to a propagation direction of the light emitted from the second light emitting layer

(8) This light emitting device may further comprise an optical member which collects the light emitted from the first light emitting layer.

In this feature, since the optical member is formed, after the light emitted from the first light emitting layer is collected, the collected light may be entered into the second light emitting layer. As a result, the utilization efficiency of light may be improved.

In this case, the optical member may be formed between the first light emitting layer and the second light emitting layer.

In this case, the optical member may be a lens layer of refractive index distribution type.

(9) The second light emitting layer may include photonic crystal that restricts light propagated in a surface direction of the substrate.

In accordance with this feature, since the photonic crystal is formed in the second light emitting layer, the light propagates in the surface direction of the substrate can be controlled in the second light emitting layer. Furthermore, the light generated in the first light emitting layer can be utilized in a higher efficiency.

In this case, the surface direction of the substrate implies a direction parallel to a surface of the substrate on which the first and second light emitting layers, and the dielectric multilayer films are stacked.

In this case, a pitch of the photonic crystal may be defined based on a wavelength of the light generated in the second light emitting layer.

(10) The light emitting device may include a plurality of the light emitting element sections, and

the second light emitting layers of the emitting element sections may generate light having different wavelengthes.

In this case, the second light emitting layers may be formed in the same level.

In this case, the light emitting element sections may be separated from one another by a bank.

This light emitting device may be applied to a display device. This display device may be applied to various sorts of electronic instruments. This light emitting device may further be applied to various sorts of electronic instruments. A concrete example of the display device and a concrete example of these electronic instruments will be discussed later.

Next, part of materials which may be employed in the respective sections of the light emitting device of the present invention will now be described. Apparently, the described materials merely are part of the materials known in this technical field, other materials than the exemplified materials may be selected.

Firsts and Second Light Emitting Layers

To obtain light having a given wavelength, the materials of the first and second light emitting layers are selected from compounds known in this field. As the materials of the first and second light emitting layers, any one of organic compounds and inorganic compounds may be employed. However, it is desirable to select the organic compounds in view of varieties of material sorts and film forming characteristics thereof.

In this case, materials which are employed in the first and second light emitting layers are selected in such a manner that the wavelength of the light generated in the second light emitting layer is longer than the wavelength of the light in the first light emitting layer. The materials for the first and second light emitting layers maybe selected in such a manner that the wavelength of the light generated in the first light emitting layer at least partially overlaps with the wavelength of the light absorbed by the second light emitting layer. Furthermore, a material in which energy transition is completed at one stage may be employed.

For instance, the first light emitting layer may be formed by employing 8-hydroxyguinoline-aluminum (Alq) and triphenyl-diamine derivative (TPD). In this case, the material of "Alq" has a function as an electron transport layer and another function as a light emitting layer, whereas the material of TPD has a function as a hole transport layer.

Also, the second light emitting layer may be formed from, for example, a material of Alq into which DCM2 has been doped. In this case, the material of DCM2 has a function of a dopant material, whereas the material of Alq owns a function of a host material. Alternatively, the second light emitting layer may be formed by a material of perylene tetracarboxylic acid dianhydride (PTCDA) into which pentacene has been doped. In this alternative case, the material of pentacene has a function of the dopant material, whereas the material of PTCDA has a function of the host material.

Dielectric Multilayer Film

In the light emitting element section, the dielectric multilayer film has a structure that materials whose refractive indexes are different from each other are alternately stacked. As a stacked layer structure, such a structure that a silicon oxide layer (SiO_2) and a silicon nitride layer (SiN_x) are alternately stacked may be exemplified, for example. Also, the dielectric multilayer film may be formed by alternately stacking two layers selected from. for instance, TiO_2, Ta_2O_5, MgF_2, and ZnS.

Electrode Layer

As the cathode, an electron injection type metal having a small work function (for example, lower than, or equal to 4 eV), an alloy, an electrically conductive compound, and a mixture of these materials may be employed. As an electrode substance, the electrode substance disclosed in Japanese Laid-open Patent Application No 8-248276 (1996) may be employed, for instance.

As the anode, a metal having a large work function (for instance, higher than, or equal to 4 eV), an alloy, an electrically conductive compound, or a mixture made of these materials may be employed. In the case that an optically transparent material is used as the anode, transparent electrically conductive materials such as CuI, ITO, SnO_2, and ZnO may be employed. To the contrary, when the transparent characteristic of the anode is not required, a metal such as gold may be employed.

Also, the respective layers constituting the light emitting device may be formed by using the method known in this technical field. For example, as to the respective layers of the light emitting device, suitable film forming methods may be selected, depending upon materials thereof. Specifically, the vapor deposition method, the spin coat method, the LB method, the ink-jet method, and the like may be used

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. **1** is a sectional view for schematically representing a light emitting device according to a first embodiment of the present invention;

FIG. **2**A is a diagram for graphically indicating an example of a wavelength range of light generated in a first light emitting layer shown in FIG. **1**, and wavelength ranges of light absorbed by a second light emitting layer and light generated in this second emitting layer shown in FIG. **1**; and FIG. **2**B is a diagram for graphically representing an example of a wavelength range of light reflected by dielectric multilayer films indicated in FIG. **1**;

FIG. **3** is a sectional view for schematically showing a light emitting device according to a second embodiment of the present invention;

FIG. **4** is a sectional view for schematically showing a light emitting device according to a third embodiment of the present invention;

FIG. **5** is a schematic diagram for illustratively showing a section of the light emitting device, taken along a line A—A of FIG. **4**;

FIG. **6** is a sectional view for schematically representing a light emitting device according to a fourth embodiment of the present invention;

FIG. **7** is a perspective view for representing a structure of an electronic book which constitutes one example of an electronic instrument according to the present invention;

FIG. **8** is a perspective view for representing a structure of a personal computer which constitutes another example of the electronic instrument according to the present invention;

FIG. **9** is a perspective view for representing a structure of a portable telephone which constitutes another example of the electronic instrument according to the present invention;

FIG. **10** is a perspective view for indicating a structure of the back side of a digital still camera which constitutes another example of the electronic instrument according to the present invention;

FIG. **11** is a perspective view for representing a structure of electronic paper which constitutes one example of the electronic instrument according to the present invention; and

FIG. **12** is a perspective view for representing a structure of an electronic notebook which constitutes another example of the electronic instrument according to the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENT

First Embodiment

Device Structure

FIG. **1** is a sectional view for schematically indicating a light emitting device **100** according to an embodiment of the present invention. FIG. **2**A is a diagram for graphically showing an example as to a wavelength range of light which is generated in a first light emitting layer **20** of the light emitting device **100** indicated in FIG. **1**, and wavelength ranges of light absorbed by a second light emitting layer **40** thereof and also light generated in this second light emitting layer **40**. FIG. **2**B is a diagram for graphically representing an example as to a wavelength range of the light which is reflected from a first dielectric multilayer film **90***a* and a second dielectric multilayer film **90***b* of the light emitting device **100** shown in FIG. **1**.

The light emitting device **100** has a substrate **10**, and a light emitting element section **110** formed on the substrate **10**. This light emitting element section **110** has a cathode **50**, the above-described first light emitting layer **20**, and anode **30**, the above-described second light emitting layer **40**, and also the above-described first and second dielectric multilayer films **90***a* and **9***b*.

The first light emitting layer **20** is manufactured by a material capable of emitting light therefrom due to the electroluminescence. As the material for constituting the first light emitting layer **20**, the above-described materials may be employed.

The anode **30** and the cathode **50** are provided so as to apply an electric field to the first light emitting layer **20**. When the electric field is applied to the first light emitting layer **20** by the anode **30** and the cathode **50**, light may be generated due to the electroluminescence. The light generated in the first light emitting layer **20** is propagated through the anode **30** and the first dielectric multilayer film **90***a*, and then, is absorbed by the second light emitting layer **40**.

The anode **30** may be constituted by using a transparent conductive material. As a transparent electrode material, the above-described material such as ITO may be employed.

The cathode **50** is formed on the first light emitting layer **20**. Since the cathode **50** is formed on the first light emitting layer **20**, it is possible to avoid such an operation that the light generated in the second light emitting layer **40** is absorbed by the cathode **50**.

Also, the second light emitting layer **40** is formed under the anode **30**. Furthermore, one pair of dielectric multilayer films (namely, first and second dielectric multilayer films **90***a* and **90***b*) are formed under and above this second light emitting layer **40**.

In the second light emitting layer **40**, the light generated in the first light emitting layer **20** is absorbed, and thereafter, light having a longer wavelength than that of this absorbed light is emitted. In other words, as graphically shown in FIG. 2A, a wavelength at the highest emission intensity in a wavelength range **42** of the light generated in the second light emitting layer **40** is longer than a wavelength at the highest emission intensity in another wavelength range **21** of the light generated in the first light emitting layer **20**.

It should be understood that at least a portion of the wavelength range **21** of the light generated in the first light emitting layer **20** is overlapped with a portion of a wavelength range **41** of the light absorbed by the second light emitting layer **40**. In this structure of the light emitting device **100**, the light generated in the first light emitting layer **20** can be absorbed by the second light emitting layer **40** in a high efficiency. In order that the light generated in the first light emitting layer **20** may be absorbed by the second light emitting layer **40** in a higher efficiency, as represented in FIG. 2A, the wavelength range **21** of the light generated in the first light emitting layer **20** may be made substantially coincident with the wavelength range **41** of the light absorbed by the second light emitting layer **40**.

Also, in the light emitting device **100** according to this first embodiment. the second light emitting layer **40** had a host material and a dopant material. The host material may absorb the light generated in the first light emitting layer **20**, and may cause an excited state which occurs due to this light absorption to be Foerster-transferred to the above-described dopant material (note that this excited state is transferred in Foerster transfer mode and Dexter transfer mode, depending upon material under use). As a result, the dopant material is excited and the excited dopant material changes to a state whose energy level is lower than that of this excited state, the above-described dopant material may emit light having a wavelength longer than the wavelength of the light absorbed by the host material.

As the host material and the dopant material, which are capable of realizing an effect, for example, “Alq” may be employed as the host material, and “DCM2” may be employed as the dopant material.

Alternatively, instead of the employment of the above-described host material and dopant material, the second light emitting layer **40** may be formed by employing a single organic light emitting material, while this single organic light emitting material may absorb the light generated in the first light emitting layer **20** and further may emit light having a wavelength longer than the wavelength of the absorbed light. The organic light emitting material is excited by absorbing the light generated in the first light emitting layer **20**, and when the state of this excited organic light emitting material changes to a state of lower energy level, this organic light emitting material may emit the light having a wavelength longer than that of the above-described light absorbed by this organic light emitting material.

The first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b* are made of such a structure that materials having refractive indexes different from each other are alternately stacked, for instance, which is similar to a stacked layer made of a silicon oxide layer and a silicon nitride layer. Each of layers which are alternately stacked may be formed in such a manner that a thickness of each layer is made nearly equal to “$\lambda/(4n)$.” In this formula, symbol “λ” indicates a given wavelength located within the wavelength range **42** of the light generated in the second light emitting layer **40**, and symbol "n" denotes a refractive index of the film.

The first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b* reflect thereon the light having a wavelength located in a given wavelength. In other words, a given wavelength range implies a wavelength range of light which is reflected by the first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b*. The wavelength ranges of the light which is reflected by the first and second dielectric multilayer films **90***a* and **90***b* are defined based upon the wavelength range of the light generated in the second light emitting layer **40**. As a consequence, as indicated in FIG. **2**B, the first and second dielectric multilayer films **90***a* and **90***b* are formed in such a manner that a reflectance **91** of the light reflected by the first and second dielectric multilayer films **90***a* and **90***b* is included in the wavelength range **42** of the light generated in the second light emitting layer **40**. In accordance with this structure, since the light generated in the second light emitting layer **40** can be enclosed between the first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b*, it is possible to increase alight emitting efficiency in this given wavelength. In order to furthermore increase this light emitting efficiency, the wavelength range of the light which is reflected by the first and second dielectric multilayer films **90***a* and **90***b* may be made substantially equal to the wavelength range of the light generated in the second light emitting layer **40**.

Also, in the light emitting device **100** according to this first embodiment, the first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b* are formed in such a manner that the reflectance of the first dielectric multilayer film **90***a* becomes larger than the reflectance of the second dielectric multilayer film **90***b*. In this case, the first dielectric multilayer film **90***a* implies one of the dielectric multilayer films which is formed closer to the first light emitting layer **20** than the other dielectric multilayer film. In accordance with this structure, the light emitted from the second light emitting layer **40** may be emitted from the second light emitting layer **40** toward the substrate **10**.

In the light emitting device **100** according to this first embodiment, since the light emitted from the second light emitting layer **40** is enclosed between the first and second dielectric multilayer films **90***a* and **90***b*, the propagation of the light along a direction intersecting with the surface of the substrate **10** may be controlled.

Also, in the light emitting device **100** according to this first embodiment, the first light emitting layer **20** and the second light emitting layer **40** are manufactured in such a manner that the propagation direction of the light emitted from the first light emitting layer **20** becomes substantially equal to the propagation direction of the light emitted from the second light emitting layer **40**.

Device Operation

Next, operations of this light emitting device **100** will now be explained.

Since a preselected electric field is applied between the anode **30** and the cathode **50**, electrons are injected from the cathode **50** into the first light emitting layer **20** and also holes are injected from the anode **30** into this first light emitting layer **20**. Since the electrons and the holes are recoupled with each other within the first light emitting layer **20**, excitons are produced. When the excitons are deactivated, light may be emitted.

Subsequently, the light generated in the first light emitting layer **20** is emitted from the first light emitting layer **20**, and is propagated through the anode **30** and the first dielectric multilayer film **90***a* to be entered into the second light emitting layer **40**. In this case, the light entered into the second light emitting layer **40** is absorbed by the host material included in the second light emitting layer **40**. The excited state which is produced by absorbing this light is moved to the dopant material in the Foerster movement, so that the above-described dopant material is excited. When the excited state of this excited dopant material changes to the state whose energy level is lower than that of the excited dopant material, light may be emitted. At this time, this emitted light has a longer wavelength than that of the light which is absorbed by the host material. After the light generated in this second light emitting layer **40** has been enclosed between the first dielectric multilayer film **90***a* and the second dielectric multilayer film **90***b*, the light may be emitted from the second light emitting layer **40** toward of the substrate **10**.

Effect

In accordance with the light emitting device **100** of this first embodiment, the light which is generated in the first emitting layer **20** due to the electroluminescence is absorbed by the second light emitting layer **40**, and thereafter, the light having the longer wavelength than that of this absorbed light is generated in the second light emitting layer **40**. In other words, after the charge injected into the first light emitting layer **20** has been converted into the light in the high efficiency, the material included in the second light emitting layer **40** is excited by this light. Thereafter, in the case the excited state of this material changes to the state whose energy level is lower than that of this excited state, this excited material may emit the light having the longer wavelength than that of the light converted in the first light emitting layer. This light is propagated through the first and second dielectric multilayer films **90***a* and **90***b*, and then, is emitted to the substrate **10**. As a result, it is possible to obtain the light emitting device capable of emitting the light in a high efficiency by the light excitation.

Also, in accordance with the light emitting device **100** of this first embodiment, since the wavelength range of the light reflected by the first and second dielectric multilayer films **90***a* and **90***b* involves the wavelength of the light generated in the second light emitting layer **40**, the light generated in the second light emitting layer **40** is enclosed between the first and second dielectric multilayer films **90***a* and **90***b*, so that the propagation of the light along the direction intersecting with the surface of the substrate **10** can be controlled. In other words, the spontaneous emission of the light along the direction intersecting with the surface of the substrate **10** may be restricted by the first and second dielectric multilayer films **90***a* and **90***b*. As a consequence, in the direction intersected with the surface of the substrate **10**, light whose emission spectral width is very narrow can be obtained in the high efficiency. Also, since the light may be emitted along the direction intersected with the surface of the substrate **10**, a so-called "surface light emission" may be achieved

Furthermore, the first dielectric multilayer film **90***a* is formed adjacent to the cathode **30** in the light emitting device **100**. As a consequence, since the second light emitting layer **40** is formed apart from the cathode **30**, the absorption amount of the light generated in the second light emitting layer **40** by the cathode **30** can be reduced.

On the other hand, in the case the light emitting device **100** according to this first embodiment is employed in a display device (will be explained later), the light is required to be emitted to the substrate **10** so as to improve the utilization efficiency of the light. In the light emitting device **100** according to this first embodiment, the reflectance of the first dielectric multilayer film **90***a* is made larger than the reflectance of the second dielectric multilayer film **90***b*. As a result, since the light can be emitted to the substrate **10** with a top priority, the utilization efficiency of the light can be increased. As a consequence, the light emitting device **100** according to this first embodiment may be applied to a display device.

Display Device and Electronic Instrument

The light emitting device **100** according to this first embodiment may be applied to a display device **500**. This display device **500** having the light emitting device **100** may be applied to an electronic instrument. FIG. **7** to FIG. **12** are perspective views schematically showing an example of electronic instruments to which the display device **500** having the light emitting device **100** is applied, respectively. It should also be noted that not only the light emitting device **100** of this first embodiment, but also other light emitting devices **200** to **400** according to a second embodiment through a fourth embodiment of the present invention (will be discussed later) are applied to the display device **500**.

FIG. **7** is a perspective view showing a construction of an electronic book **1000** as an example of an electronic instrument according to this embodiment. The electronic book **1000** has a book-shaped frame **32**, and a cover **33** which can be opened/closed on this frame **32**. The display device **500** is provided on this frame **32** under a condition that a display surface of this display device **500** is exposed from a surface of this frame **32**. Further, an operation section **35** is provided on this frame **32**. A controller, a counter, and a memory (not shown) are provided in the frame **32**. In this embodiment, the display device **500** is equipped with a pixel section (not shown) formed by filling thin elements with electronic ink, and a peripheral integrated circuit (not shown) that is unified with this pixel section. This peripheral circuit is provided with a decoding type scan driver and a data driver.

FIG. **8** is a perspective view showing a construction of a personal computer **1100** as another example of the electronic instrument according to this embodiment. The personal computer **1100** includes a main body **1104** equipped with a keyboard **1102**, and a display section eqipped with the above-described display device **500**.

FIG. **9** is a perspective view showing a construction of a portable telephone **1200** as another example of the electronic instrument according to this embodiment. This portable telephone **1200** is equipped with the above-described display device **500**, and a receiver **1204**, a transmitter **1206**, in addition to a plurality of operation buttons **1202**.

FIG. **10** is a perspective view showing a construction of a digital still camera **1300** as another example of the electronic instrument according to this embodiment. FIG. **10** shows the construction of the digital still camera **1300**, and further, a connection between the digital still camera **1300** and an external electronic instrument in a simple manner.

A photographic camera usually exposes a film by using an optical image of an object, but the digital still camera **1300** conducts electro-optical conversion of an optical image of an object using CCD and generates an image signal. In this camera structure, the above-described display device **500** is provided on the back side of the digital still camera **1300**, and displays an object based on the. image signal from CCD. In other words, the display device **500** functions as a finder to display an object. A light receiving section **1304** including an optical lens, the CCD, or the like is provided on an viewer side (namely, a back side in FIG. **10**) of the case **1302**. In the case that a photographer confirms an object displayed on the display device **500** and depresses a shutter bottom **1306**, the image signal from the CCD at this time instant is transferred and stored into a memory of a circuit board **1308**. A video signal output terminal **1312** and an input/output element **1314** used for data communications are provided on a side surface of the case **1302** of this digital still camera **1300**. Then, as indicated in FIG. **10**, a TV monitor **1430** is connected to the video signal output element **1312**, and a personal computer **1440** is connected to the input/output element **1314** used for data communications, if required. Furthermore, the image signal stored in the memory of the circuit board **1308** can be outputted to the TV monitor **1430** or the personal computer **1440** by the given operation.

FIG. **11** is a perspective view showing a construction of electronic paper **1400** as another example of the electronic instrument according to this embodiment. In FIG. **11**, the electronic paper **1400** includes a main component **1401** formed of a rewritable sheet having a feel and flexibility similar to a real paper, and a display section equipped with the above-described display device **500**.

FIG. **12** is a perspective view showing a construction of an electronic notebook **1402** as another example of the electronic instrument according to this embodiment. As shown in FIG. **12**, the electronic notebook **1402** has a plurality of sheets of the electronic paper **1400** of FIG. **11** bound by a cover **1403**. The electronic notebook **1402** can change displayed content of the electronic paper **1400** in a bound state by providing a display data input means in the cover **1403**.

In addition to these electronic book **1000** of FIG. **7**. personal computer **1100** of FIG. **8**, portable phone **1200** of FIG. **9**, digital still camera **1300** of FIG. **10**, electronic paper **1400** of FIG. **11** and electronic notebook **1402** of FIG. **12**, it should be noted that various other instruments such as a liquid crystal TV, a view-finder or monitor type of video tape recorder, a car navigation device, a pager, an electronic pocket notebook, an electronic calculator, a wordprocessor, a workstation, a TV phone, a POS terminal, an IC card, a mini-disk player, or a device provided with a touch panel can be provided as other examples. It goes without saying that the display device **500** can be used as a display unit of these electronic instruments.

Second Embodiment

Device Structure

FIG. **3** is a sectional view for schematically indicating a light emitting device **200** according to a third embodiment of the present invention.

The light emitting device **200** has a substrate **10**, and a light emitting element section **210** formed on the substrate **10**. The light emitting device **200** has a different structure from that of the light emitting device **100** according to the first embodiment. That is, an optical member capable of collecting light emitted from the first light emitting layer **20** is provided between the anode **30** and the first dielectric multilayer film **90***a*. Other constructions of this light emitting device **200** are similar to those of the above-described light emitting device **100** according to the first embodiment, and therefore, explanations thereof are omitted.

A lens layer **80** owns a function as the optical member capable of collecting light emitted from the first light emitting layer **20**. The lens layer **80** is constituted by a high refractive index section **80***a* and a low refractive index section $\mathbf{80}_b$, and has a function as a refractive-index distribution type lens. In this case, a refractive index of the high refractive index section **80***a* is larger than a refractive index of the low refractive index section **80***b*. The high refractive index section **80***a* has a convex shape, and is formed on the first dielectric multilayer film **90***a*. Also, the low refractive index section **80***b* is formed in such a manner that the high refractive index section **80***a* is embedded into this low refractive index section **80***b*. As a manufacturing method of this lens layer **80**, the below-mentioned manufacturing methods may be employed:

(1) First, fluid-shaped articles of resin are jetted on the first dielectric multilayer film **90***a* by using either a dispenser nozzle or an ink-jet head, the fluid-shaped articles are positioned on the first dielectric multilayer film **90***a*, and thereafter, are hardened, so that the high refractive index section **80***a* is formed. The fluid-shaped articles of the resin used in this manufacturing method may be selected from the fluid-shaped article having a precursor of the above-described thermosetting resin, or a precursor of ultraviolet hardening type resin. In this case, the above-described fluid-shaped articles are hardened in accordance with characteristics of these fluid-shaped articles. Subsequently, the low refractive index section **80***b* is stacked in such a manner that the high refractive index section **80***a* is embedded into this low refractive index section **80***b*. Then, the lens layer **80** constructed of the high refractive index section **80***a* and the low refractive index section **80***b* may be formed in accordance with the above-described manufacturing steps.

(2) As a material used to manufacture the lens layer **80**. quartz glass into which germanium has been added is employed. Ultraviolet rays are emitted to a layer made of this quartz glass so as to manufacture a portion having a high refractive index. In this case, a glass layer portion whose refractive index is increased by irradiating the ultraviolet rays within this quartz glass layer may constitute the high refractive index section **80***a*, whereas the remaining glass layer portion may constitute the low refractive index section **80***b*. Thus, the lens layer **80** is manufactured in accordance with the above-described manufacturing steps.

It should also be noted that the optical member capable of collecting the light emitted from the first light emitting layer **20** is not limited to the lens layer **80**, but any other members may be employed which has a function capable of collecting the light emitted from the first light emitting layer **20**.

Device Operation

Next, operations of this light emitting device **200** will now be explained.

Since a preselected electric field is applied between the anode **30** and the cathode **50**, electrons are injected from the cathode **50** into the first light emitting layer **20** and also holes are injected from the anode **30** into this first light emitting layer **20**. Since the electrons and the holes are recoupled with each other within the first light emitting layer **20**, excitons are produced. When the excitons are deactivated, light may be emitted.

Subsequently, the light generated in the first light emitting layer **20** is emitted from the first light emitting layer **20**, and is entered into the lens layer **80**. This entered light is collected by the high refractive index section **80***a*, and thereafter, is propagated through the first dielectric multilayer film **90***a* to be entered into the second light emitting layer **40**. The succeeding operations and effects of this light emitting device **200** are similar to those of the light emitting device **100** according to the first embodiment, and therefore, explanations thereof are omitted.

Effect

While the light emitting device **200** of the second embodiment owns operations and effects which are substantially similar to those of the light emitting device **100** of the first embodiment, since the lens layer **80** is formed between the first light emitting layer **20** and the second light emitting layer **40**, the light emitted from the first light emitting layer **20** can be collected and thereafter can be entered into the second light emitting layer **40**. As a result, the utilization efficiency of the light can be improved.

Third Embodiment

Device Structure

FIG. **4** is a sectional view for schematically indicating a light emitting device **300** according to a third embodiment of the present invention. FIG. **5** is a sectional view showing this light emitting device **300**, taken along a line A—A of FIG. **4**.

As indicated in FIG. **4**, the light emitting device **300** has a substrate **10**, and a light emitting element section **310** formed on this substrate **10**. The light emitting device **300** owns a different structure from that of the light emitting device **100** according to the first embodiment. That is, photonic crystal **70** is provided inside a second light emitting layer **40**. other structural elements of this light emitting device **300** are similar to those of the light emitting device **100** according to the first embodiment, and therefore, descriptions thereof are omitted.

In the light emitting device **300**, the photonic crystal **70** is arranged in a preselected pitch. As represented in FIG. **4** and FIG. **5**, in the light emitting device **300** of this third embodiment, such an example is illustrated. That is, the photonic crystal **70** is arranged in a triangular-lattice shape. The pitch of the photonic crystal **70** may be defined based upon a wavelength of light which is generated in the second light emitting layer **40**. Assuming now that an effective refractive index in the second light emitting layer **40** is equal to "n_{eff}", the pitch "d" of this photonic crystal **70** is formed as follows:

$$d=\lambda/4n_{eff}$$

In this equation, symbol "λ" indicates a given wavelength of light whose wavelength is located within the wavelength **42** of the light emitted from the second light emitting layer **40**. Also, $n_{eff}=n_1*n_2/(n_1+n_2)$ in which symbols "n_1" and "n_2" indicate refractive indexes of two sorts of media which constitute the photonic crystal. As described above, since the pitch of the photonic crystal **70** is defined based upon the wavelengths of the light generated in the second light emitting layer **40**, the light which is propagated along a direction of a surface of the substrate **10** in the second light emitting layer **40** may be restricted. It should also be noted that this surface direction of the substrate **10** implies a direction which is located in parallel to a surface in the substrate **10**, on which the first and second light emitting layers **20** and **40**, and also the first and second dielectric multilayer films **90***a* and **90***b* and the like are stacked.

There is no specific limitation in a method for manufacturing the above-described photonic crystal **70**, and therefore, the forming methods known in this technical field may be employed. Typical forming methods of this photonic crystal **70** will now be exemplified as follows:

(1) Forming Method by Lithography

Either negative resist or positive resist is exposed by using ultraviolet rays, or X-rays, and the exposed resist is developed. Then, the developed resist layer is patterned, so that photonic crystal is formed. The patterning techniques with employment of the resist as either polymethyl methacrylate or novolac resin are described in, for example, Japanese Laid-open Patent Applications No. 6-224115 (1994) and No. 7-20637 (1995).

Also, the techniques capable of patterning polyimide by way of the photolithography are described in, for instance, Japanese Laid-open Patent Applications No. 7-181689

(1995) and No. 1-221741 (1989). Furthermore, the techniques capable of forming photonic crystal made of either polymethyl methacrylate or titanium oxide on a glass substrate by utilizing laser ablation are described in, for example, Japanese Laid-open Patent Application No. 10-59743 (1998).

(2) Forming Method by Stamping

The photonic crystal **70** may be formed by employing a hot stamping method with employment of thermoplastic resin (see Japanese Laid-open Patent Application No. 6-201907 (1994)), a stamping method with employment of ultraviolet hardening type resin (see Japanese Laid-open Patent Application No. 10-279439 (1998)), a stamping method with employment of electron beam hardening type resin (see Japanese Laid-open Patent Application No. 7-235075 (1995)), and so on

(3) Forming Method by Etching

While the lithography technique and the etching technique are utilized, a thin-films selectively removed to be patterned, so that the photonic crystal **70** can be formed.

The various forming methods of the photonic crystal **70** have been described. In summary, the photonic crystal may be constructed of at least two regions which own different refractive indexes from each other. For example, this photonic crystal may be formed by employing, for instance, a method of forming two regions by employing two sorts of materials having different refractive indexes from each other, and another method of forming two regions having different refractive indexes from each other by partially denaturing one sort of material.

Device Operation

Since operations of the light emitting device **300** according to this third embodiment are similar to those of the light emitting device **100** according to the first embodiment except that the light propagated along the surface direction of the substrate **10** is defined by the photonic crystal **70**. descriptions thereof are omitted.

Effect

While the light emitting device **300** of the third embodiment owns operations and effects which are substantially similar to those of the light emitting device **100** of the first embodiment, since the photonic crystal **70** is formed in the second light emitting layer **40**, the light propagated along the surface direction of the substrate **10** can be restricted in the second light emitting layer **40**. This photonic crystal **70** is defined based upon the wavelength of the light generated in the second light emitting layer **40** As a result, the emissions of the light which is propagated along the surface direction of the substrate **10** can be restricted. Furthermore, the light generated in the first light emitting layer **20** can be utilized in a higher efficiency.

Fourth Embodiment

Device Structure

FIG. **6** is a sectional view for schematically indicating a light emitting device **400** according to a fourth embodiment of the present invention.

The light emitting device **400** of this fourth embodiment has a substrate **10**, and light emitting element sections **410** and **420** formed on this substrate **10**. The light emitting device **400** owns a different structure from that of the light emitting device **100** according to the first embodiment. That is, a plurality of light emitting element sections (light emitting element sections **410** and **420**) are formed on the substrate **10**. Other structural elements of this light emitting device **400** are similar to those of the light emitting device **100** according to the first embodiment, and therefore, descriptions thereof are omitted.

The light emitting element sections **410** and **420** are formed on the substrate **10**, and are separated from each other by a bank **12** formed on the substrate **10**. Second light emitting layers **40** and **140** are formed in the light emitting element sections **410** and **420**, respectively. It should be noted that in this fourth embodiment, any layers other than these second light emitting layers **40** and **140** in the light emitting element sections **410** and **420** are formed by way of the same manufacturing steps, respectively.

The second light emitting layers **40** and **140** are formed at the same level. The second light emitting layers **40** and **140** have light emitting materials, the light emitting wavelengths of which are different from each other. As a result, the wavelength of the light generated in the second light emitting layer **40** is different from the wavelength of the light generated in the second light emitting layer **140**. In this case, film thicknesses of dielectric multilayer films which are formed in the light emitting element sections **410** and **420** are defined based upon the wavelengths of the light generated in the second light emitting layers **40** and **140**. As a consequence, the film thicknesses of the dielectric multilayer films which are formed in the light emitting element sections **410** and **420** respectively should be made as the film thicknesses corresponding to the wavelengths of the light generated in the second light emitting layers **40** and **140**. As a result, in the case the wavelengths of the light generated in the second light emitting layers **40** and **140** are largely different from each other, there are some possibilities that a difference between the film thicknesses of the dielectric multilayer films which are formed in the respective light emitting element sections **410** and **420** may become large.

However, if high reflection factor ranges of the dielectric multilayer films **90***a* and **90***b* which constitute the light emitting element sections **410** and **420** are made wide, then these dielectric multilayer films **90***a* and **90***b* may be commonly employed in the light emitting element sections **410** and **420**.

Also, since the high reflection factor ranges of the dielectric multilayer films **90***a* and **90***b* which constitute the light emitting element sections **410** and **420** are made wide, these dielectric multilayer films **90***a* and **90***b* maybe commonly employed in the light emitting element sections **410** and **420**.

Device Operation

Operations of this light emitting device **400** according to the fourth embodiment are similar to those of the light emitting device **100** according to the first embodiment, and therefore, explanations thereof are omitted.

Effect

The light emitting device **400** according to this fourth embodiment owns a similar effect to that of the light emitting device **100** according to the first embodiment. Furthermore, in the case that while the high reflection factor ranges of the dielectric multilayer films **90***a* and **90***b* which constitute the light emitting element sections **410** and **420** are made wide, these dielectric multilayer films **90***a* and **90***b* are commonly used in the light emitting element sections **410** and **420**, when the light emitting element sections **410** and **420** are formed, only the second light emitting layers **40** and **140** maybe separately formed by employing the ink-jet method and the like.

It should also be noted that when an organic compound is employed as the light emitting material which constitutes the first light emitting layer **20** in the light emitting device according to each of the above-described embodiments, a hole transport layer may be provided between the anode **30** and the first light emitting layer **20**, if necessary. As a material of this hole transport layer, any proper material may be selectively employed from the hole injection materials of the known optical conductive material, or the materials used in a hole injection layer of an organic light emitting device. The material of the hole transport layer may have a function capable of injecting holes, or a function having a barrier characteristic of electrons, while this material may be made of either an organic material or an inorganic material. A concrete example of this material used in the hole transport layer may be exemplified in, for instance, Japanese Laid-open Patent Application No. 8-248276 (1996).

Also, an electron transport layer may be provided between the anode **50** and the first light emitting layer **20**, if necessary. As a material of this electron transport layer. any material may be employed if this material has a function capable of transporting electrons injected from the anode **50** to the first light emitting layer **20**, so that this material may be selected from the known substances. A concrete material example may be exemplified in, for example, Japanese Laid-open Patent Application No. 8-248276 (1996).

What is claimed is:

1. A light emitting device comprising:

a substrate; and

a light emitting element section formed over the substrate,

wherein the light emitting element section includes:

a first light emitting layer in which light is generated due to electroluminescence;

one pair of electrode layers used to apply an electric field to the first light emitting layer;

a second light emitting layer which absorbs light generated in the first light emitting layer and generates light having a longer wavelength than a wavelength of the absorbed light; and

one pair of dielectric multilayer films which are formed under and above the second light emitting layer, respectively,

wherein a wavelength range of light that is reflected by the pair of dielectric multilayer films includes a wavelength range of light generated in the second light emitting layer.

2. The light emitting device as defined in claim **1**, wherein light generated in the second light emitting layer is emitted in a direction intersecting with the substrate.

3. The light emitting device as defined in claim **1**, wherein a wavelength range of light generated in the first light emitting layer and a wavelength range of light absorbed by the second light emitting layer at least partially overlap with each other.

4. The light emitting device as defined in claim **1**, wherein a wavelength at a highest emission intensity in a wavelength range of light generated in the second light emitting layer is longer than a wavelength at a highest emission intensity in a wavelength range of light generated in the first light emitting layer.

5. The light emitting device as defined in claim **1**,

wherein the pair of dielectric multilayer films include a first dielectric multilayer film and a second dielectric multilayer film,

wherein the first dielectric multilayer film is formed closer to the first light emitting layer than the second dielectric multilayer film, and

wherein a reflectance of the first dielectric multilayer film is larger than a reflectance of the second dielectric multilayer film.

6. The light emitting device as defined in claim **1**, wherein the first light emitting layer includes an organic light emitting material which emits light by the electroluminescence.

7. The light emitting device as defined in claim **1**,

wherein the second light emitting layer includes a host material and a dopant material,

wherein the host material absorbs light generated in the first light emitting layer so that an excited state occurs, and the dopant material is excited due to a transfer of the excited state of the host material to the dopant material, and

wherein the excited dopant material emits light having a longer wavelength than a wavelength of light absorbed by the host material.

8. The light emitting device as defined in claim **1**,

wherein the second light emitting layer includes an organic light emitting material, and

wherein the organic light emitting material absorbs light generated in the first light emitting layer so that the organic light emitting material is excited, and the excited organic light emitting material emits light having a longer wavelength than a wavelength of the absorbed light.

9. The light emitting device as defined in claim **1**, wherein a propagation direction of light emitted from the first light emitting layer is substantially equal to a propagation direction of light emitted from the second light emitting layer.

10. The light emitting device as defined in claim **1**, further comprising an optical member which collects light emitted from the first light emitting layer.

11. The light emitting device as defined in claim **10**, wherein the optical member is formed between the first light emitting layer and the second light emitting layer.

12. The light emitting device as defined in claim **10**, wherein the optical member is a lens layer of refractive index distribution type.

13. The light emitting device as defined in claim **1**, wherein the second light emitting layer includes photonic crystal that restricts light propagated in a surface direction of the substrate.

14. The light emitting device as defined in claim **13**, wherein a pitch of the photonic crystal is defined based on a wavelength of light generated in the second light emitting layer.

15. The light emitting device as defined in claim **1**,

wherein the light emitting device includes a plurality of the light emitting element sections, and

wherein the second light emitting layers of the emitting element sections generate light having different wavelengthes.

16. The light emitting device as defined in claim **15**, wherein the second light emitting layers are formed in the same level.

17. The light emitting device as defined in claim **15**, wherein the light emitting element sections are separated from one another by a bank.

18. A display device to which the light emitting device as defined in claim **1** is applied.

19. An electronic instrument to which the display device as defined in claim **18** is applied.

20. An electronic instrument to which the light emitting device as defined in claim **1** is applied.

* * * * *

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摘要(译)

发光装置包括基板和形成在基板上的发光元件部分。发光元件部分包括：第一发光层，其中由于电致发光而产生光;一对电极层，用于向第一发光层施加电场;第二发光层，其吸收在第一发光层中产生的光。发光层和产生波长比吸收光的波长长的光，和一对电介质多层膜分别形成在第二发光层下面和上面。由该对电介质多层膜反射的光的波长范围包括在第二发光层中产生的光的波长范围。