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(54) **LIGHT-EMITTING ELEMENT AND DISPLAY DEVICE HAVING THE LIGHT-EMITTING ELEMENT**

(71) Applicant: **Japan Display Inc.**, Tokyo (JP)

(72) Inventor: **Koji YASUKAWA**, Tokyo (JP)

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(57) **ABSTRACT**

Disclosed is a light-emitting element including an anode, an emission layer over the anode, an electron-transporting layer over the emission layer, a first electron-injection layer over and in contact with the electron-transporting layer, a second electron-injection layer over and in contact with the first electron-injection layer, and a cathode over and in contact with the second electron-injection layer. The electron-transporting layer includes a first organic compound having an electron-transporting property higher than a hole-transporting property and further includes at least one of lithium, a lithium complex containing an 8-quinolinol ligand, and a magnesium complex containing an 8-quinolinol ligand. The first electron-injection layer includes at least one of lithium and a lithium complex containing an 8-quinolinol ligand. The second electron-injection layer includes a lanthanoid metal.

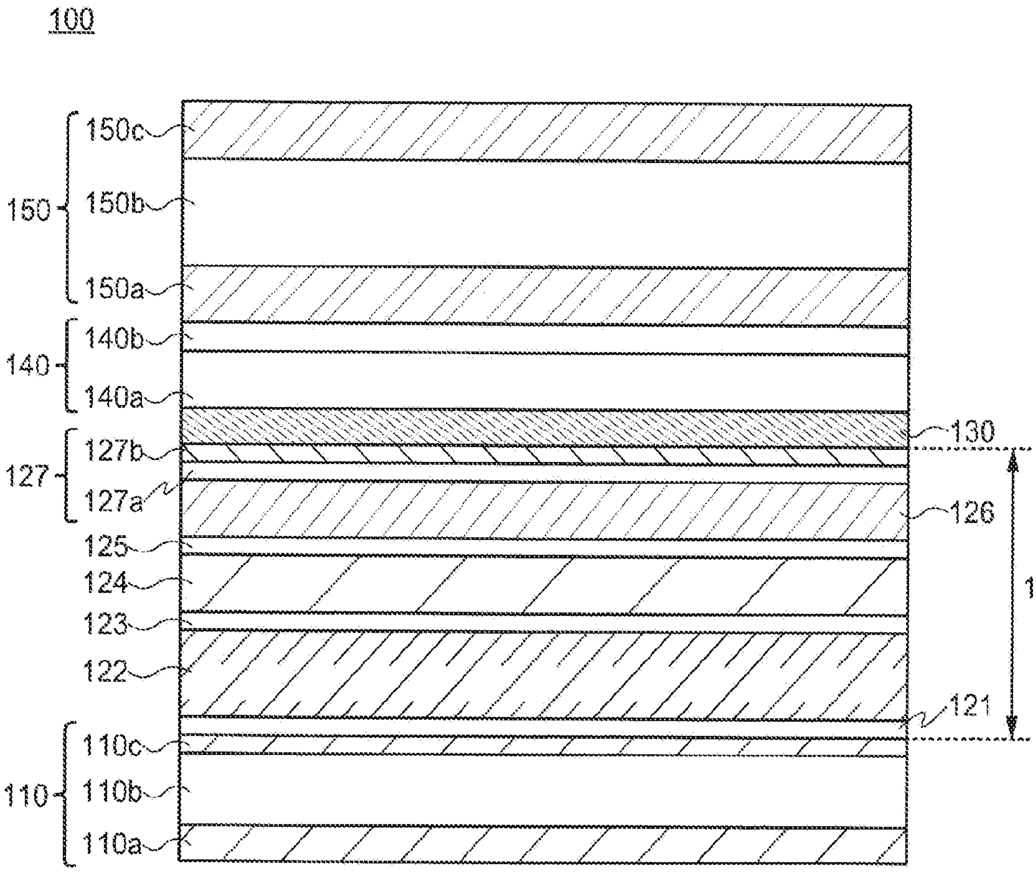

FIG. 1

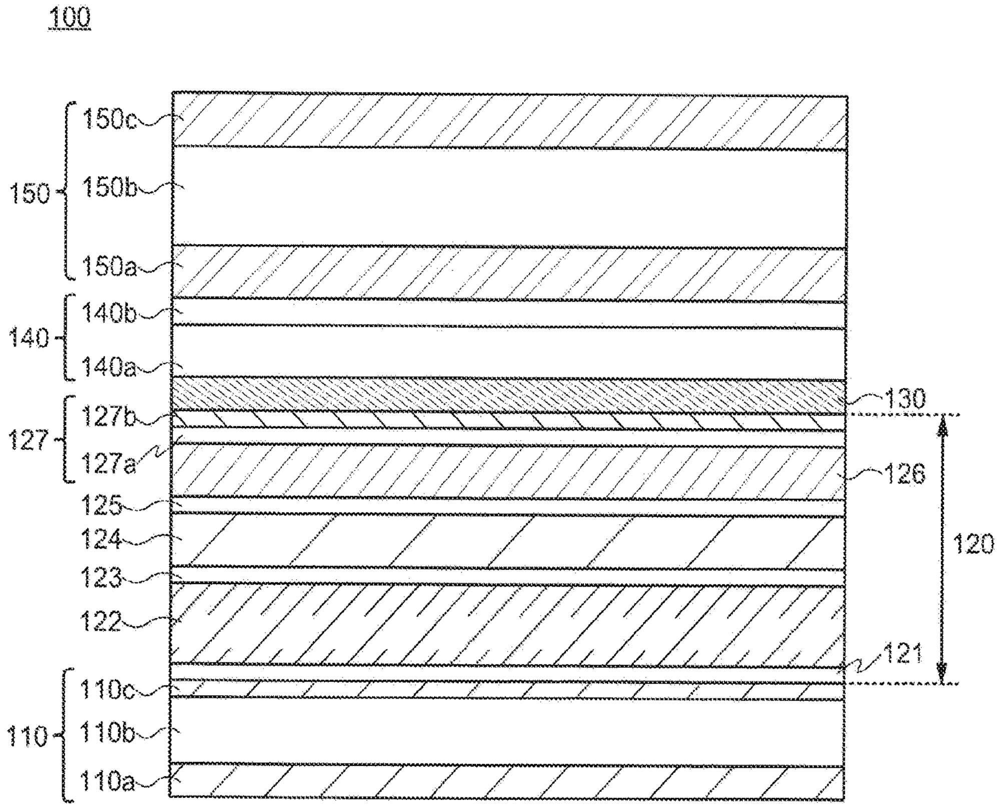
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FIG. 2

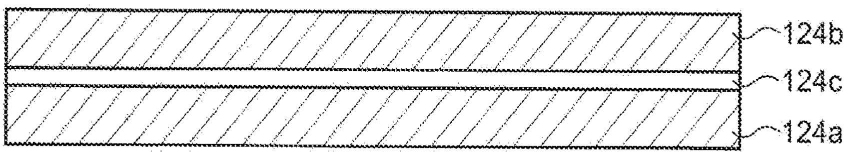
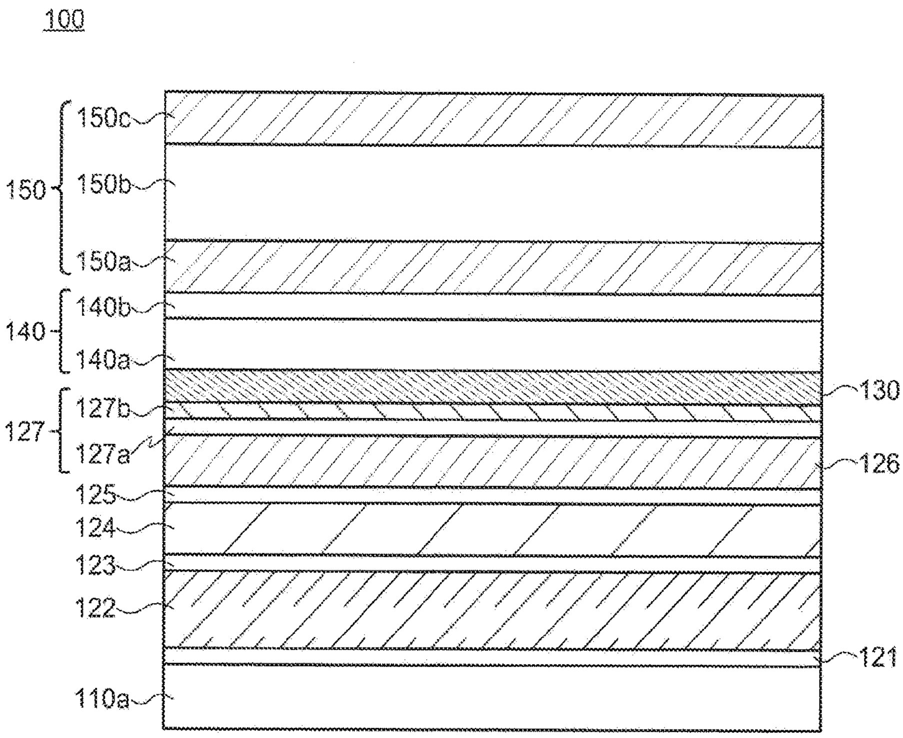


FIG. 3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121
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FIG. 4

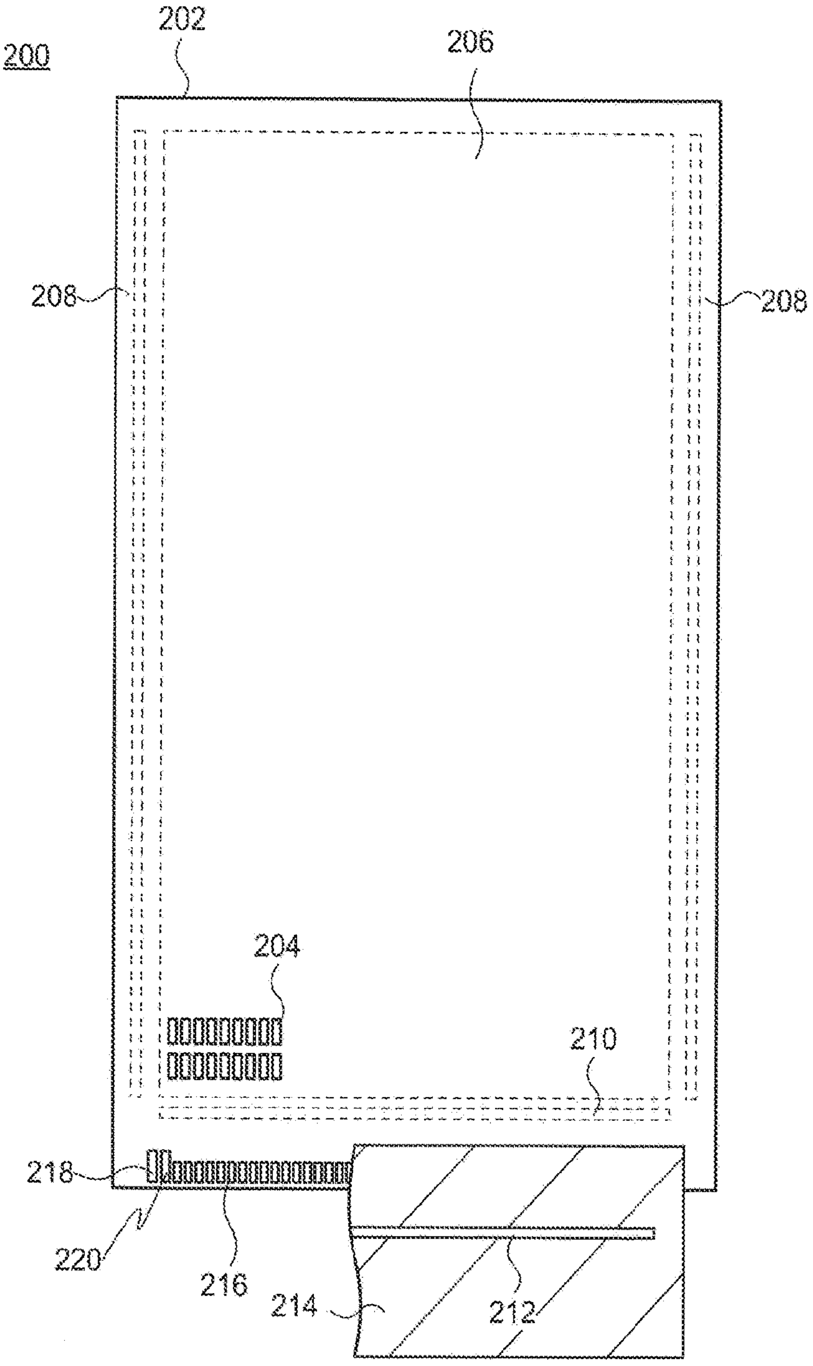


FIG. 5

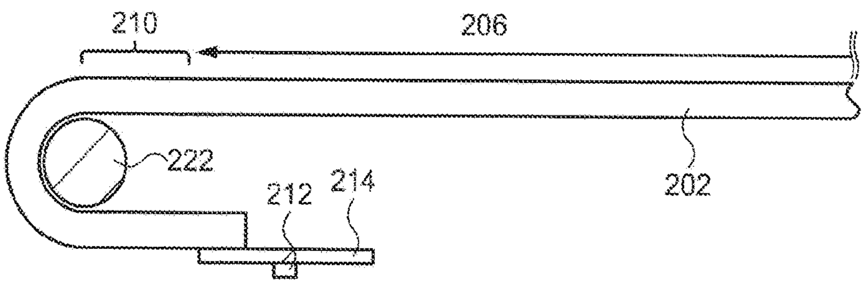
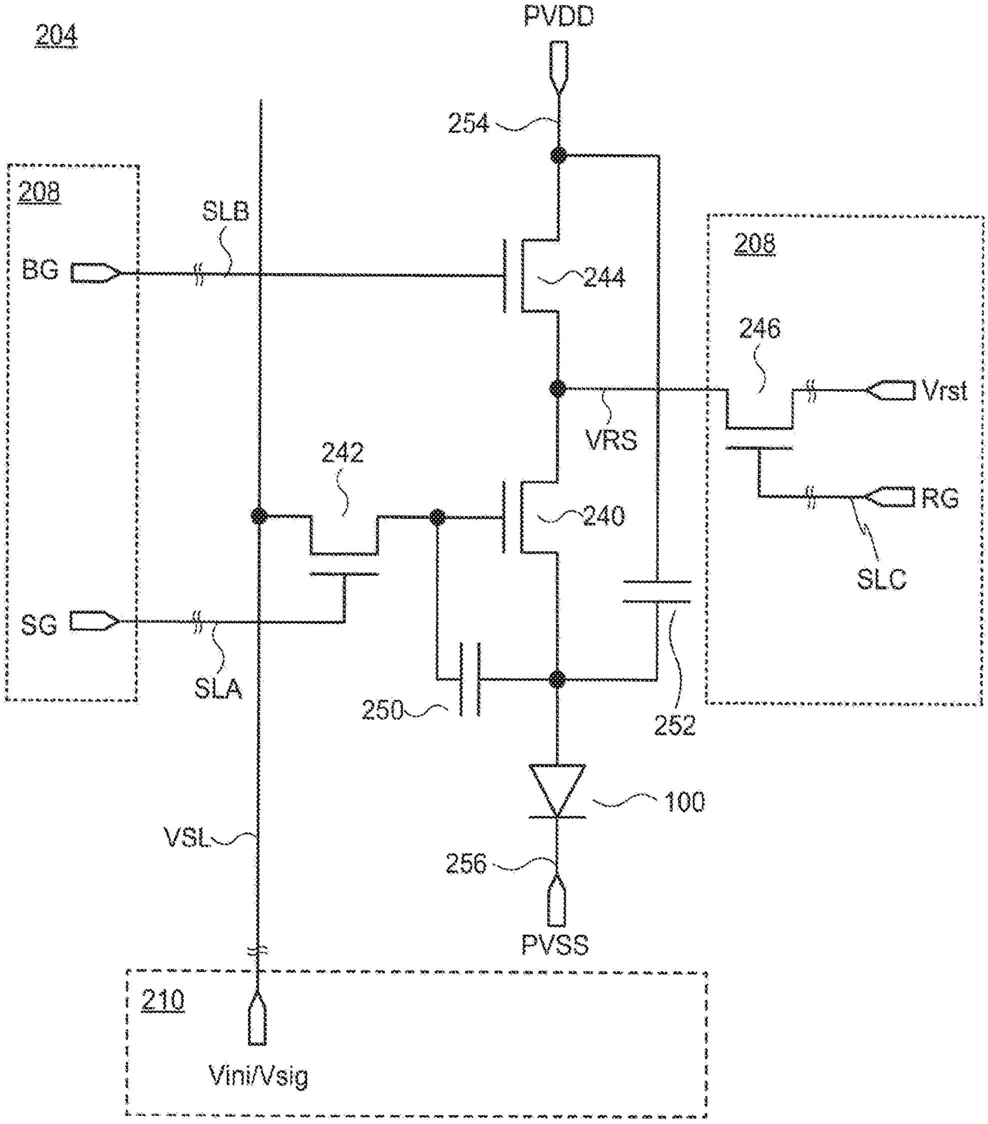


FIG. 6



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Vini/Vsig

FIG. 7

200

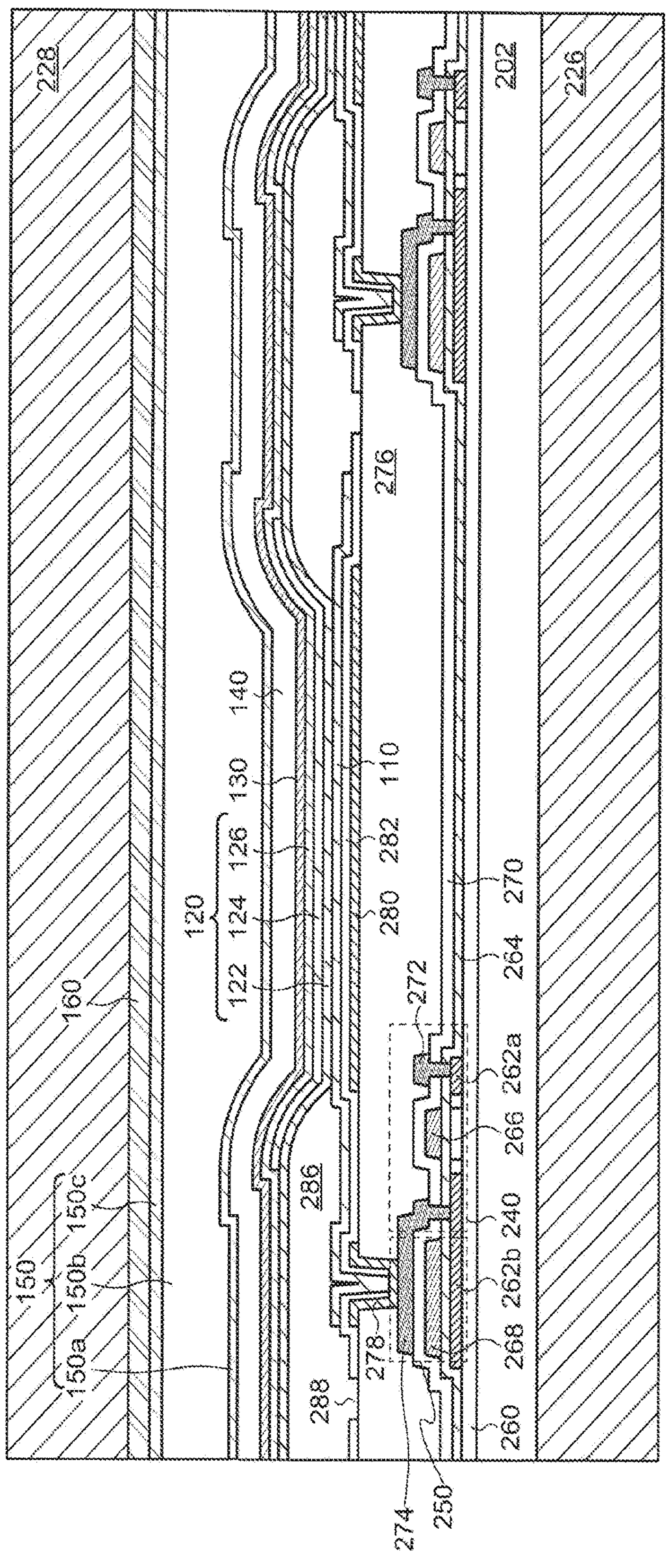
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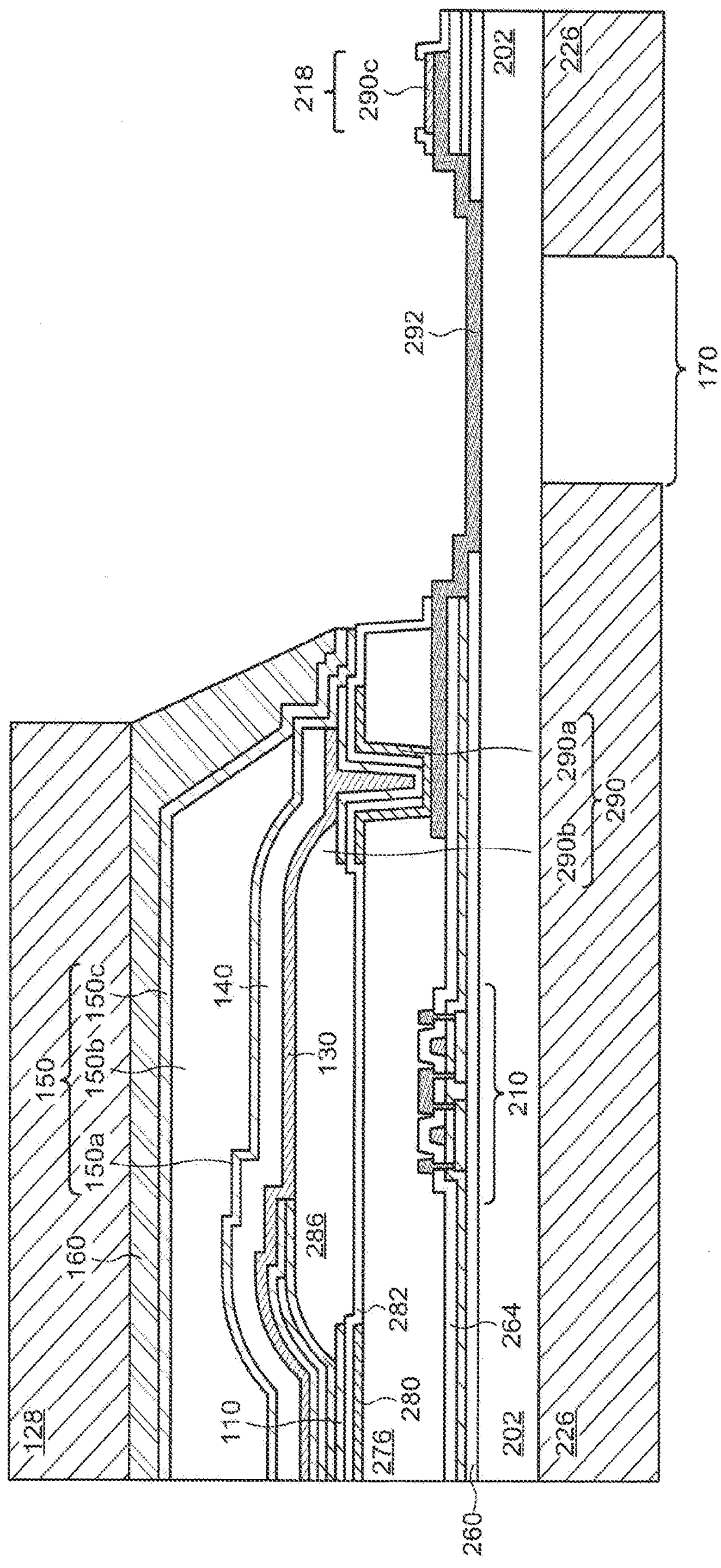
FIG. 8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LIGHT-EMITTING ELEMENT AND DISPLAY DEVICE HAVING THE LIGHT-EMITTING ELEMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims the benefit of priority from the prior Japanese Patent Application No. 2017-153912, filed on Aug. 9, 2017, the entire contents of which are incorporated herein by reference.

FIELD

[0002] An embodiment of the present invention relates to a light-emitting element and a display device having the light-emitting element.

BACKGROUND

[0003] An organic EL (Electroluminescence) display device is represented as an example of a display device. An organic EL display device possesses a plurality of organic light-emitting elements (hereinafter, referred to as light-emitting elements) formed over a substrate, and each light-emitting element has an electroluminescence layer (hereinafter, referred to as an EL layer) including an organic compound between a pair of electrodes (cathode and anode) as a fundamental structure. A potential difference provided between the pair of electrodes allows holes and electrons to be supplied to the EL layer. The holes and electrons are recombined in the EL layer, giving an excited state of an organic compound. A function as a display device is attained by utilizing the emission obtained when the excited state is radiatively deactivated to a ground state.

[0004] An EL layer is generally structured by a stack of a plurality of layers having a variety of functions (hereinafter, referred to as functional layers), and a hole-injection layer, a hole-transporting layer, an emission layer, an electron-transporting layer, an electron-injection layer, and the like are represented as the functional layers. When the holes and electrons are injected to the EL layer, an energy barrier is generated due to a difference between a work function of the electrode and a level of the highest occupied molecular orbital (HOMO) or the lowest unoccupied molecular orbital (LUMO) of the layer (hole-injection layer or electron-injection layer) in contact with the electrode. The EL layer is designed so as to reduce this energy barrier, thereby giving a display device with a reduced operation voltage and low power consumption. For example, Japanese Patent Application Publication No. 2007-36176 discloses a light-emitting element in which two electron-injection layers are disposed between a cathode and an emission layer in order to reduce an electron-injection barrier.

SUMMARY

[0005] An embodiment of the present invention is a light-emitting element. The light-emitting element possesses an anode, an emission layer over the anode, an electron-transporting layer over the emission layer, a first electron-injection layer over and in contact with the electron-transporting layer, a second electron-injection layer over and in contact with the first electron-injection layer, and a cathode over and in contact with the second electron-injection layer. The electron-transporting layer includes a first organic compound having an electron-transporting property higher than a hole-transporting property and further includes at least one of lithium, a lithium complex containing an 8-quinolinol ligand, and a magnesium complex containing an 8-quinolinol ligand. The first electron-injection layer includes at least one of lithium and a lithium complex containing an 8-quinolinol ligand. The second electron-injection layer includes a lanthanoid metal.

[0006] An embodiment of the present invention is a display device including a pixel. The pixel possesses a light-emitting element including an anode, an emission layer over the anode, an electron-transporting layer over the emission layer, the electron-transporting layer, a first electron-injection layer over and in contact with the electron-transporting layer, a second electron-injection layer over and in contact with the first electron-injection layer, and a cathode over and in contact with the second electron-injection layer. The electron-transporting layer includes a first organic compound having an electron-transporting property higher than a hole-transporting property and further includes at least one of lithium, a lithium complex containing an 8-quinolinol ligand, and a magnesium complex containing an 8-quinolinol ligand. The first electron-injection layer includes at least one of lithium and a lithium complex containing an 8-quinolinol ligand. The second electron-injection layer includes a lanthanide metal.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. **1** is a schematic cross-sectional view of a light-emitting element according to an embodiment of the present invention;

[0008] FIG. **2** is a schematic cross-sectional view of an emission layer of a light-emitting element according to an embodiment of the present invention;

[0009] FIG. **3** is a schematic cross-sectional view of a light-emitting element according to an embodiment of the present invention;

[0010] FIG. **4** is a schematic top view of a display device according to an embodiment of the present invention;

[0011] FIG. **5** is a schematic side view of a display device according to an embodiment of the present invention;

[0012] FIG. **6** is an example of an equivalent circuit of a pixel in a display device according to an embodiment of the present invention;

[0013] FIG. **7** is a schematic cross-sectional view of a light-emitting element according to an embodiment of the present invention; and

[0014] FIG. **8** is a schematic cross-sectional view of a light-emitting element according to an embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0015] Hereinafter, the embodiments of the present invention are explained with reference to the drawings. The invention can be implemented in a variety of different modes within its concept and should not be interpreted only within the disclosure of the embodiments exemplified below.

[0016] The drawings may be illustrated so that the width, thickness, shape, and the like are illustrated more schematically compared with those of the actual modes in order to provide a clearer explanation. However, they are only an example, and do not limit the interpretation of the invention. In the specification and the drawings, the same reference number is provided to an element that is the same as that which appears in preceding drawings, and a detailed explanation may be omitted as appropriate.

[0017] In the present specification and claims, when a plurality of films is formed by processing one film, the plurality of films may have functions or rules different from each other. However, the plurality of films originates from a film formed as the same layer in the same process and has the same layer structure and the same material. Therefore, the plurality of films is defined as films existing in the same layer.

[0018] In the specification and the claims, unless specifically stated, when a state is expressed where a structure is arranged "over" another structure, such an expression includes both a case where the substrate is arranged immediately above the "other structure" so as to be in contact with the "other structure" and a case where the structure is arranged over the "other structure" with an additional structure therebetween.

First Embodiment

[0019] A structure of a light-emitting element **100** according to an embodiment of the present invention is explained by using FIG. **1** to FIG. **3**.

1. Structure

[0020] A schematic cross-sectional view of the light-emitting element **100** is shown in FIG. **1**. The light-emitting element **100** is structured by an anode **110**, a cathode **130** over the anode **110**, and an EL layer **120** positioned between the anode **110** and the cathode **130**. The EL layer **120** possesses an emission layer **124**, an electron-transporting layer **126**, and an electron-injection layer **127**. The electron-injection layer **127** has a structure in which two layers (a first electron-injection layer **127***a* and a second electron-injection layer **127***b*) are stacked. The first electron-injection layer **127***a* is in contact with the electron-transporting layer **126**, while the second electron-injection layer **127***b* is in contact with the first electron-injection layer **127***a* and the cathode **130**. The EL layer **120** may further include a hole-injection layer **121** over the anode **110**, a hole-transporting layer **122** over the hole-injection layer **121**, an electron-blocking layer **123** over the hole-transporting layer **122**, and a hole-blocking layer **125** over the emission layer **124**, and the like. Note that a substrate for supporting the light-emitting element **100** and a variety of circuits for driving the light-emitting element **100** are omitted in this cross-sectional view.

1-1. Anode

[0021] The anode **110** is an electrode provided to inject holes to the EL layer **120**, and it is preferred that a surface thereof have a relatively high work function. As a specific material, a conductive oxide capable of transmitting visible light, such as indium-tin oxide (ITO) and indium-zinc oxide (IZO) is represented, and the material may further include silicon. The light-emitting element **100** demonstrated in FIG. **1** has a structure in which light emission obtained from the emission layer **124** is extracted through the cathode **130**. Therefore, the anode **110** may further include a film containing a metal with high reflectance with respect to visible light, such as silver and aluminum. For example, the anode **110** may have a stacked-layer structure of a first conductive film **110***a* containing a conductive oxide, a second conductive film **110***b* containing a metal such as silver and aluminum, and a third conductive film **110***c* containing a conductive oxide as shown in FIG. **1**.

1-2. Hole-Injection Layer

[0022] It is possible to use a compound to which holes are readily injected, that is, a compound readily oxidized (an electron-donating compound) in the hole-injection layer **121**. In other words, a compound with a shallow HOMO level can be used. For example, an aromatic amine such as a benzidine derivative and a triarylamine, a carbazole derivative, a thiophene derivative, and a phthalocyanine derivative such as copper phthalocyanine, and the like can be used. Alternatively, a polythiophene derivative or a polyaniline derivative can be used, and poly(2,3-ethylenedioxythiophene)/poly(styrenesulfonic acid) is represented as an example. Alternatively, a mixture of an electron-donating compound such as the aforementioned aromatic amine and carbazole derivative as well as an aromatic hydrocarbon with an electron acceptor. As an electron acceptor, a transition-metal oxide such as vanadium oxide and molybdenum oxide, a nitrogen-containing heteroaromatic compound, a heteroaromatic compound having a strong electron-withdrawing group such as a cyano group, and the like are represented. These materials and the mixtures exhibit a small hole-injection barrier from the anode **110** because they have a low ionization potential. Thus, these materials and the mixture contribute to reduction of the driving voltage of the light-emitting element **100**.

1-3. Hole-Transporting Layer

[0023] The hole-transporting layer **122** has a function to transport holes injected to the hole-injection layer **121** to a side of the emission layer **124**, and materials the same as or similar to the materials usable in the hole-injection layer **121** can be used. For example, it is possible to use a material having a HOMO level deeper than that of the hole-injection layer **121** by approximately equal to or less than 0.5 eV or equal to or less than 0.3 eV. Since the materials described above have a hole-transporting property higher than an electron-transporting property, the holes are efficiently transported to a side of the emission layer **124**, by which a low driving voltage of the light-emitting element **100** can be realized.

1-4. Electron-Blocking Layer

[0024] The electron-blocking layer **123** has a function to inhibit electrons injected form the cathode **130** from passing through the emission layer **124** and being injected to the hole-transporting layer **122** without contributing to recombination so that the electrons are confined in the emission layer **122** and energy transfer from an excited state obtained in the emission layer **124** to the molecules in the hole-transporting layer **122** is prevented. Therefore, a material is preferred which has a hole-transporting property larger than or similar to an electron-transporting property, which has a LUMO level shallower than that of the molecules in the emission layer **124**, and which has a large band gap. Specifically, it is preferred that a difference in LUMO level between the molecules included in the electron-blocking layer **123** and the molecules included in the emission layer **124** be equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. In addition, a difference in band gap between the molecules included in the electron-blocking layer **123** and the molecules included in the emission layer **124** is preferred to be equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. In the case where an emission material is a phosphorescent material, it is preferred to use a material having a triplet level higher than that of the emission material by equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. More specifically, a carbazole derivative, an arylamine derivative, a thiophene derivative, or the like having a relatively small conjugation system is represented.

1-5. Emission Layer

[0025] The emission layer **124** is a layer supplying a space for recombination of the holes and electrons, and the light emission is obtained from this layer. The emission layer **124** may be composed of a single compound or have a so-called host-guest type structure. In the case of the host-guest type, a stillbene derivative, a condensed aromatic compound such as an anthracene derivative, a carbazole derivative, a metal complex including a quinolinol ligand, an aromatic amine, and a nitrogen-containing heteroaromatic compound such as a phenanthroline derivative, and the like can be used, for example. The guest functions as an emission material in the emission layer **124** of the host-guest type, and a fluorescent material such as a coumarin derivative, a pyran derivative, a quinacridone derivative, a tetracene derivative, a pyrene derivative, and an anthracene derivative or a phosphorescent material such as an iridium-based orthometal complex can be used. When the emission layer **124** is composed of a single compound, the host material described above can be used. In this case, the host material serves as an emission material.

1-6. Hole-Blocking Layer

[0026] The hole-blocking layer **125** has a function to inhibit holes injected form the anode **110** from passing through the emission layer **124** and being injected to the electron-transporting layer **126** without contributing to recombination so that the holes are confined in the emission layer **124** and energy transfer from an excited state obtained in the emission layer **124** to the molecules in the electron-transporting layer **126** is prevented. Moreover, as described below, since the electron-transporting layer **126** has a relatively high density of carrier electrons, and a quenching phenomenon readily occurs when an emission position in the emission layer **124** is close to the electron-transporting layer **126**. In this case, formation of the hole-blocking layer **125** prevents the quenching phenomenon, by which a decrease in emission efficiency can be prevented.

[0027] It is preferred to use, for the hole-blocking layer **125**, a material which has an electron-transporting property higher than or similar to a hole-transporting property, which has a HOMO level deeper than that of the molecules in the emission layer **124**, and which has a large band gap. Specifically, it is preferred that a difference in HOMO level between the molecules included in the hole-blocking layer **125** and the molecules included in the emission layer **124** be equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. Furthermore, it is preferred that a difference in band gap between the molecules included in the hole-blocking layer **125** and the molecules included in the emission layer **124** be equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. When the emission material is a phosphorescent material, it is preferred to use a material having a triplet level higher than that of the emission material by equal to or more than 0.2 eV, equal to or more than 0.3 eV, or equal to or more than 0.5 eV. More specifically, a phenanthroline derivative, an oxadiazole derivative, a triazole derivative, a metal complex with a relatively large band gap (e.g., equal to or more than 2.8 eV) such as bis(2-methyl-8-qunolinolato)(4-hydroxybiphenyl)aluminum, and the like are represented.

1-7. Electron-Transporting Layer

[0028] The electron-transporting layer **126** has function to transport the electrons injected from the cathode **130** to the electron-injection layer **127** to a side of the emission layer **124**. Here, the electron-transporting layer **126** is a mixed layer including two materials. One of the materials is an organic compound (first organic compound) having an electron-transporting property, and the other is a material exhibiting an electron-donating property with respect to the first organic compound.

[0029] A compound having an electron-transporting property is a compound having an electron-transporting property higher than a hole-transporting property and is selected from a substituted or unsubstituted aluminum complex, a substituted or unsubstituted beryllium complex, a substituted or unsubstituted zinc complex, a substituted or unsubstituted oxadiazole derivative, a substituted or unsubstituted triazole derivative, a substituted or unsubstituted silacyclopentadiene derivative, a substituted or unsubstituted anthracene derivative, a substituted or unsubstituted pyrene derivative, a substituted or unsubstituted perylene derivative, a substituted or unsubstituted phenanthroline derivative, and the like. As the metal complex described above, a metal complex having an 8-qunolinole ligand, such as tris(8-quinolinolato)aluminum (Alq) and bis(8-quinolinolato)beryllium, is exemplified. Here, a substituted or unsubstituted aluminum complex, a substituted or unsubstituted beryllium complex, and a substituted or unsubstituted zinc complex mean a complex having a ligand to which a substituent is introduced or a complex having an unsubstituted ligand. As a substituent, an alkyl group having 1 to 4 carbon atoms and an aryl group such as a phenyl group and a naphthyl group are represented.

[0030] An electron donor is a lithium metal (0 valent lithium), a lanthanide metal (0 valent lanthanide), or a metal complex having an 8-quinolinol ligand. As a lanthanide metal, ytterbium is represented. The metal complex has lithium or magnesium as a central metal, and a substituent may be introduced on the ligand. For example, (8-quinolinolato)lithium (hereinafter, referred to as Liq) and bis(8-quinolinolato)magnesium (hereinafter, referred to as Mgq) are represented as the metal complex.

[0031] In the electron-transporting layer **126** having such a structure, lithium (including lithium dissociated from Liq), Mg dissociated from Mgq, and ytterbium have a high electron-donating property, and charge transfer to the first organic compound occurs to form a charge-transfer complex. Hence, the anion radicals of the first organic compounds exist in the electron-transporting layer **126**, increasing the electron density as a carrier. Accordingly, the electron-transporting layer **126** has a high electron-transporting property and is able to efficiently transport electrons injected from the second electron-injection layer **127***b* to the emission layer **124**, which contributes to a decrease of the driving voltage of the light-emitting element **100**.

1-8. Electron-Injection Layer

[0032] The electron-injection layer **127** has a function to promote electron injection from the cathode **130** to the EL layer **120**. In the present embodiment, the electron-injection layer **127** has the first electron-injection layer **127***a* and the second electron-injection layer **127***b* in contact with each other.

[0033] The first electron-injection layer **127***a* includes a lithium metal or a lithium complex having an 8-quinolinol ligand, such as Liq. Alternatively, the first electron-injection layer **127***a* is composed of one of a lithium metal and a lithium complex having an 8-quinolinol ligand.

[0034] The second electron-injection layer **127***b* includes a lanthanide metal or is composed of a lanthanide metal. As a lanthanide metal, ytterbium is represented.

1-9. Cathode

[0035] The cathode **130** functions as a light-extracting electrode which injects electrons to the EL layer **120** and transmits the light emitted from the emission layer **124**. Simultaneously, the cathode **130** is configured to partly reflect the light from the emission layer **124**. Therefore, a microcavity is formed between the cathode **130** and the second conductive film **110***b*, and the light obtained in the emission layer **124** interferers and is amplified between the cathode **130** and the second conductive film **110***b*. As a result, a color purity of the emission color can be improved, and the luminance of the light-emitting element **100** in the front direction can be increased.

[0036] It is preferred to use a metal with a relatively low work function and a high conductivity for the cathode **130**. Specifically, silver, magnesium, or an alloy thereof is used. As described above, the cathode **130** is configured to partly reflect and partly transmit the light emitted from the emission layer **124**. Hence, a thickness of the cathode **130** is 5 nm to 30 nm or 10 nm to 20 nm, and typically 15 nm.

[0037] A thickness of each functional layer described above may be appropriately determined. For example, a thickness of the hole-injection layer **121** is equal to or larger than 5 nm and equal to or smaller than 50 nm, equal to or larger than 10 nm and equal to or smaller than 30 nm, or equal to or larger than 10 nm and equal to or smaller than 20 nm, and typically 10 nm. A thickness of the hole-transporting layer **122** is equal to or larger than 50 nm and equal to or smaller than 300 nm, equal to or larger than 100 nm and equal to or smaller than 200 nm, or equal to or larger than 110 nm and equal to or smaller than 150 nm. The thicknesses of the hole-injection layer **121** and the hole-transporting layer **122** may be appropriately adjusted in accordance with an emission wavelength of the emission material. Specifically, the thicknesses may be adjusted so that an optical distance from the emission position in the emission layer **124** to a surface of the second conductive film **110***b* is equal to or close to an integral multiple of half of the emission peak wavelength (half wavelength) of the emission material. This configuration allows the light emitted from the emission layer **124** and the light reflected at the surface of the second conductive film **110***b* to amplify each other, by which the emission spectrum can be narrowed, and the emission intensity can be increased.

[0038] Thicknesses of the electron-blocking layer **123** and the hole-blocking layer **125** are each equal to or larger than 5 nm and equal to or smaller than 20 nm or equal to or larger than 5 nm and equal to or smaller than 15 nm, and typically 10 nm. A thickness of the emission layer **124** is equal to or larger than 5 nm and equal to or smaller than 40 nm, equal to or larger than 10 nm and equal to or smaller than 35 nm, or equal to or larger than 10 nm and equal to or smaller than 30 nm, and typically 15 nm. A thickness of the electron-transporting layer **126** is equal to or larger than 5 nm and equal to or smaller than 40 nm, equal to or larger than 10 nm and equal to or smaller than 30 nm, or equal to or larger than 15 nm and equal to or smaller than 30 nm, and typically 25 nm. Thicknesses of the first electron-injection layer **127***a* and the second electron-injection layer **127***b* are each equal to or larger than 0.5 nm and equal to or smaller than 5 nm or equal to or larger than 1 nm and equal to or smaller than 3 nm, and typically 1 nm.

[0039] As described above, the light-emitting element **100** is a so-called top-emission type light-emitting element in which the emitted light is extracted from the cathode **130**. In this case, it is preferred to control the thickness of each layer so that a total thickness of the hole-blocking layer **125**, the electron-transporting layer **126**, the first electron-injection layer **127***a*, and the second electron-injection layer **127***b* is 25 nm to 30 nm. With this configuration, the interference effect and amplification effect of the light emission can be more efficiently obtained, thereby improving emission efficiency and color purity.

[0040] The anode **110** is prepared with a chemical vapor deposition (CVD) method, an evaporation method, or a sputtering method. Each functional layer and the cathode **130** are prepared with an ink-jet method, a spin-coating method, a printing method, or an evaporation method. The cathode **130** may be formed with a sputtering method.

[0041] As described above, in the light-emitting element **100** with such a structure, the electron-transporting layer **126** has a high electron mobility due to the high electron-carrier concentration thereof. Hence, the electrons injected to the second electron-injection layer **127***b* are readily transported to the emission layer **124**. Accordingly, implementation of the present embodiment enables production of a light-emitting element with a low driving voltage and reduced power consumption.

[0042] When the cathode **130** is prepared over the second electron-injection layer **127***b* with an evaporation method, vapor of magnesium or silver vaporized in an evaporation source collides with the second electron-injection layer **127***b* and then is cooled to be deposited, resulting in the first electron-injection layer **127***a*. The collision energy at that time causes a reaction of a part of the metal in the cathode **130** with the lanthanide metal to form an alloy, which leads to a decrease in an electron-injection barrier from the cathode **130** to the second electron-injection layer **127***b*. Similarly, when the first electron-injection layer **127***a* is formed, the material vaporized in an evaporation source collides with the electron-transporting layer **126** and is cooled to be deposited, resulting in the first electron-injection layer **127***a*. At this time, the lithium metal included in the first electron-injection layer **127***a* partly enters into the electron-transporting layer **126** by the collision energy. Similarly, in the case where the first electron-injection layer **127***a* is formed by using Liq, a part of Liq included in the first electron-injection layer **127***a* is decomposed by the collision energy, which allows a part of the lithium resulting from the collision to enter the inside of the electron-transporting layer **126**. Accordingly, the electron density of the electron-transporting layer **126** is further increased, and the electron-transporting property of the electron-transporting layer **126** is improved. Hence, the driving voltage of the light-emitting element **100** can be further reduced.

1-10. Other Structures

[0043] As shown in FIG. **1**, the light-emitting element **100** may further possess, as an optional structure, a cap layer **140** and a sealing layer (hereinafter, referred to as a passivation film) **150**.

[0044] In the case where the cap layer **140** is disposed, the cap layer **140** is formed so as to be in contact with the cathode **130**. The cap layer **140** may have a single-layer structure or a two-layer structure of a first cap layer **140***a* and a second cap layer **140***b* as shown in FIG. **1**. The formation of the cap layer **140** allows an additional formation of a microcavity over the cathode **130**. Therefore, the light passing through the cathode **130** is further amplified by the interference effect through repeated reflection between a bottom surface (i.e., an interface between the cap layer **140** and the cathode **130**) of the cap layer **140** and a top surface thereof.

[0045] The first cap layer **140***a* may include a material having a high transmittance and a relatively high refraction index in the visible region. As an example of such a material, an organic compound is represented. As an organic compound, a polymer material is representative, and a polymer material including sulfur, halogen, or phosphorous is exemplified. As a polymer including sulfur, a polymer having a substituent such as a thioether, a sulfone, and a thiophene in the main or side chain is given. As a polymer material including phosphorous, a polymer material including a phosphorous acid, a phosphoric acid, or the like in the main or side chain, a polyphosphazene, or the like is represented. As a polymer material including halogen, a polymer material including bromine, iodine, or chlorine as a substituent is exemplified. Alternatively, the first cap layer **140***a* may include an inorganic compound, and titanium oxide, zirconium oxide, chromium oxide, aluminum oxide, indium oxide, ITO, IZO, lead sulfide, zinc sulfide, silicon nitride, and the like are exemplified as an inorganic compound. A mixture of the inorganic compound and the polymer material may be used.

[0046] The second cap layer **140***b* may include a material having a high transmittance and a relatively low refractive index in the visible region. As an example, a polymer including fluorine is represented. As a polymer material including fluorine, polytetrafluoroethylene, poly(vinylidene fluoride), and a derivative thereof as well as a poly(vinyl ether), a polyimide, a poly(methacrylic ester), a poly(acrylic ester), and a polysiloxane which include fluorine in the main chain or side chain, and the like are represented.

[0047] The refractive indexes of the materials and the thicknesses of the first cap layer **140***a* and the second cap layer **140***b* are adjusted as appropriate so that an optical distance of the cap layer **140** is the same as or close to an odd multiple of one fourth of an emission peak wavelength of the emission layer **124**. This structure reduces the full-width half-maximum of the obtained emission and enables improvement of color purity and a luminance of the light-emitting element **100** in a front direction.

[0048] The passivation film **150** has a function to prevent the entrance of impurities such as water and oxygen from the outside to the light-emitting element **100**, thereby improving reliability of the light-emitting element **100**. The passivation film **150** is formed so as to be in contact with the cap layer **140**. When the cap layer **140** is not provided, the passivation film **150** is disposed so as to be in contact with the cathode **130**.

[0049] The structure of the passivation film **150** is arbitrarily determined, and the passivation film **150** may have a three-layer structure shown in FIG. **1**. In this case, the passivation film **150** may possess a first layer **150***a*, a second layer **150***b*, and a third layer **150***c*. For example, the first layer **150***a* and the third layer **150***c* can be formed with an inorganic compound including silicon nitride, silicon oxide, or the like, and the second layer **150***b* can be formed with an organic compound including an acrylic resin.

2. Modified Example

[0050] The structure of the light-emitting element **100** according to the present embodiment is not limited to that described above. For example, although the emission layer **124** has a single layer in the example demonstrated in FIG. **1**, the emission layer **124** may be composed of a plurality of emission layers. Specifically, the emission layer **124** may have a structure in which a first emission layer **124***a* and a second emission layer **124***b* are stacked as shown in FIG. **2**. The first emission layer **124***a* and the second emission layer **124***b* may include the same emission material, or the emission materials may be selected to give emission colors different from each other.

[0051] The first emission layer **124***a* and the second emission layer **124***b* may be in contact with each other or may be stacked via a charge-generation layer **124***c*. As the charge-generation layer **124***c*, a stacked structure of a mixed layer of the aforementioned compound exhibiting an electron-transporting property and the electron donor and a mixed layer of the electron-donating compound and the electron acceptor may be employed. The use of such a structure allows production of the light-emitting element **100** having an almost doubled current efficiency.

[0052] The light-emitting element **100** may be configured so that the light is extracted from the anode **100**. In this case, the second conductive film **110***b* which efficiently reflects visible light is not formed in the anode **110**, but the first conductive film **110***a* (or the third conductive film **110***c*) including ITO or IZO is employed as shown in FIG. **3**. On the other hand, the cathode **130** is formed at a thickness which allows visible light to be efficiently reflected. For example, the light-emitting element **100** may be configured so that the thickness of the cathode **130** is equal to or larger than 30 nm and equal to or smaller than 300 nm, equal to or larger than 50 nm and equal to or smaller than 200 nm, or equal to or larger than 100 nm and equal to or smaller than 200 nm.

Second Embodiment

[0053] In the present embodiment, a structure of a display device **200** arranged with a plurality of pixels **204** having the light-emitting element **100** is described. An explanation of the structures the same as or similar to those of the First Embodiment may be omitted.

[0054] A schematic top view of the display device **200** is shown in FIG. **4**. The display device **200** possesses a substrate **202** and a variety of patterned insulating films, semiconductor films, and conductive films thereover. A plurality of pixels **204** and driver circuits (gate-side driver circuits **208** and source-side driver circuit **210**) for driving the pixels **204** are formed by these insulating films, semiconductor films, and conductive films. The plurality of pixels **204** is periodically arranged and defines a display region **206**. As described below, the light-emitting element **100** is disposed in each pixel **204**.

[0055] The gate-side driver circuits **208** and the source-side driver circuit **210** are arranged outside the display region **206** (peripheral region). A variety of wirings **292** (not illustrated in FIG. **4**) formed with the patterned conductive films extends from the display region **206**, the gate-side driver circuits **208**, and the source-side driver circuit **210** to a side of the substrate **202** and is exposed at a vicinity of an edge portion of the substrate **202** to form terminals such as image-signal terminals **216** and power-source terminals **218** and **220**. These terminals are electrically connected to a flexible printed circuit substrate (FPC) **214**. In the example shown here, a driver IC **212** having an integrated circuit formed over a semiconductor substrate is mounted over the FPC **214**. Image signals are supplied from an external circuit (not illustrated) through the driver IC **212** and FPC **214** and transmitted to the gate-side driver circuits **208** and the source-side driver circuit **210** through the image-signal terminals **216**. A power source supplied to the light-emitting elements **100** in the pixels **204** is provided to the display device **200** through the FPC **214** and the power-source terminals **218** and **220**. A high potential (PVDD) is provided to the power-source terminals **220**, while a potential PVSS lower than PVDD is provided to the power-source terminals **218**. Signals based on these image signals and potentials are supplied to each pixel **204**, by which the pixels **204** are controlled and operated. The configuration of the driver circuits and the driving IC **212** is not limited to that of FIG. **4**. For example, the driver IC **112** may be mounted over the substrate **202**, and the function of the source-side driver circuit **210** may be integrated with the driver IC **212**.

[0056] Use of a flexible substrate as the substrate **202** provides the display device **200** with flexibility. For example, the display device **200** can be folded between the terminals and the display region **206** so that the FPC **214** and the terminals connected thereto overlap with the display region **206** as shown in a side view of FIG. **5**. At this time, a spacer **222** may be disposed to stabilize the folded structure. At least a part of an outer circumference of the spacer **222** is covered by the substrate **202**.

2. Structure of Pixel

2-1. Pixel Circuit

[0057] A pixel circuit including the light-emitting element **100** is structured with a variety of patterned insulating films, semiconductor films, and conductive films in each pixel **204**. The structure of the pixel circuit can be arbitrarily selected, and an example is demonstrated as an equivalent circuit in FIG. **6**.

[0058] The pixel circuit shown in FIG. **6** includes a driving transistor **240**, a first switching transistor **242**, a second switching transistor **244**, a storage capacitor **250**, and a supplementary capacitor **252** in addition to the light-emitting element **100**. The light-emitting element **100**, the driving transistor **240**, and the second switching transistor **244** are connected in series between a high-potential power-source line **254** and a low-potential power-source line **256**. PVDD and PVSS are respectively supplied to the high-potential power-source line **254** and the low-potential power-source line **256**.

[0059] In the present embodiment, the driving transistor **240** is assumed to be an n-channel type, and input-output terminals on a side of the high-potential power-source line **254** and a side of the light-emitting element **100** are defined as a drain and a source, respectively. The drain of the driving transistor **240** is electrically connected to the high-potential power-source line **254** through the second switching transistor **244**, and the source thereof is electrically connected to the anode **110** of the light-emitting element **100**.

[0060] A gate of the driving transistor **240** is electrically connected to a first signal line VSL through the first switching transistor **242**. Operation (on/off) of the first switching transistor **242** is controlled with a scanning signal SG supplied to a first scanning signal line SLA connected to a gate thereof. When the first switching transistor **242** is on, a potential of the first signal line VSL is provided to the gate of the driving transistor **240**. An initialization signal Vini and an image signal Vsig are provided to the first signal line VSL at a predetermined timing. The initialization signal Vini is a signal giving an initialization potential with a constant level. The on/off of the first switching transistor **242** is controlled at a predetermining timing while synchronizing with the first signal line VSL, and a potential based on the initialization signal Vini or the image signal Vsig is provided to the gate of the driving transistor **240**.

[0061] A second signal line VRS is electrically connected to the drain of the driving transistor **240**. A reset potential Vrst is supplied to the second signal line VRS through a reset transistor **246**. A timing at which the reset signal Vrst is applied through the reset transistor **246** is controlled by a reset signal RG provided to a third signal line SLC.

[0062] The storage capacitor **250** is disposed between the source and drain of the driving transistor **240**. One terminal of the supplementary capacitor **252** is connected to the source of the driving transistor **240**, and the other terminal is connected to the high-potential power-source line **254**. The supplementary capacitor **252** may be formed so that the other terminal is connected to the low-potential power-source line **256**. The storage capacitor **250** and the supplementary capacitor **252** are provided to maintain a source-drain voltage Vgs corresponding to the image signal Vsig when the image signal Vsig is provided to the gate of the driving transistor **240**.

[0063] The source-side driver circuit **210** outputs the initialization signal Vini or the image signal Vsig to the first signal line VSL. The gate-side driver circuits **208** output the scanning signal SG, a scanning signal BG, and the reset signal RG to the first scanning line SLA, a second scanning line SLB, and the third signal line SLC, respectively.

2-2. Cross-Sectional Structure

[0064] A structure of the pixel **204** is explained by using a cross-sectional structure in FIG. **7**. In FIG. **7**, the cross-sectional structures of the driving transistor **240**, the storage capacitor **250**, the supplementary capacitor **252**, and the light-emitting element **100** of the pixel circuits of adjacent two pixels **204** formed over the substrate **202** are illustrated.

[0065] Each element included in the pixel circuit is disposed over the substrate **202** through an undercoat **260**. The driving transistor **240** includes a semiconductor film **262**, a gate insulating film **264**, a gate electrode **266**, a drain electrode **272**, and a source electrode **274**. The gate electrode **266** is arranged to intersect at least a part of the semiconductor film **262** via the gate insulating film **264**, and a channel is formed in a region where the gate electrode **266** overlaps with the semiconductor film **262**. The semiconductor film **262** further possesses a drain region **262***a* and a source region **262***b* sandwiching the channel.

[0066] A capacitor electrode **268** existing in the same layer as the gate electrode **266** is formed to overlap with the source region **262***b* through the gate insulating film **264**. An interlayer insulating film **270** is disposed over the gate electrode **266** and the capacitor electrode **268**. Openings reaching the drain region **262***a* and the source region **262***b* are formed in the interlayer insulating film **270** and the gate insulating film **264**, and the drain electrode **272** and the source electrode **274** are arranged so as to cover the openings. A part of the source electrode **274** overlaps with a part of the source region **262***b* through the interlayer insulating film **270**, and the storage capacitor **250** are structured by the part of the source region **262***b*, the gate insulating film **264**, the capacitor electrode **268**, the interlayer insulating film **270**, and the part of the source electrode **274**.

[0067] A leveling film **276** is further provided over the driving transistor **240** and the storage capacitor **250**. The leveling film **276** has an opening reaching the source electrode **274**, and a connection electrode **278** covering this opening and a part of a top surface of the leveling film **276** is formed to be in contact with the source electrode **274**. The supplementary capacitor electrode **280** is further disposed over the leveling film **276**. The connection electrode **278** and the supplementary capacitor electrode **280** may be simultaneously formed and can exist in the same layer. A capacitor insulating film **282** is formed to cover the connection electrode **278** and the supplementary capacitor electrode **280**. The capacitor insulating film **282** does not cover a part of the connection electrode **278** in the opening of the leveling film **176** to expose a top surface of the connection electrode **278**. This structure enables an electrical connection between the anode **110** formed over the connection electrode **278** and the source electrode **274** via the connection electrode **278**. An opening **288** may be formed in the capacitor insulating film **282** to allow contact of a partition wall **286** formed thereover with the leveling film **276**. Impurities in the leveling film **276** can be removed through the opening **288**, thereby improving reliability of the light-emitting element **100**. Note that the formation of the connection electrode **278** and the opening **288** is optional.

[0068] The anode **110** is disposed over the capacitor insulating film **282** to cover the connection electrode **278** and the supplementary capacitor electrode **280**. The capacitor insulating film **282** is sandwiched by the supplementary capacitor electrode **280** and the anode **110**, and the supplementary capacitor **252** is configured by this structure. The anode **110** is shared by the supplementary capacitor **252** and the light-emitting element **100**.

[0069] The partition wall **286** is provided over the anode **110** to cover an edge portion of the anode **110**. The EL layer **120** and the cathode **130** thereover are arranged so as to cover the partition wall **286**. The structures of the anode **110**, the cathode **130**, and the EL layer **120** are the same as those described in the First Embodiment. The structure of the EL layer **120** may be the same in all of the pixels **204**, or the EL layer **120** may be formed so that a part of the structure is different between adjacent pixels **204**. For example, the pixels **204** may be configured so that the structure or material of the emission layer **124** is different but other layers have the same structure between adjacent pixels **204**. Furthermore, the pixels **204** may be configured so that the thickness of the hole-transporting layer **122** in addition to the structure and material of the emission layer **124** are different but other layers have the same structure between adjacent pixels **204**. The cathode **130** covers the plurality of pixels **204**. That is, the cathode **130** is shared by the plurality of pixels **204**. Note that the hole-transporting layer **122**, the emission layer **124**, and the electron-transporting layer **126** are demonstrated as the representative functional layers in FIG. **7** for visibility.

[0070] The cap layer **140** is disposed over the cathode **130**. The cap layer **140** also covers the plurality of pixels **204** so as to be shared by the plurality of pixels **204**. In the case where the cap layer **140** is provided with the interference and amplification effects of the light from the emission layer **124** as described above, the cap layer **140** may be configured so that the thickness thereof is different between adjacent pixels **204**. The passivation film **150** for protecting the light-emitting elements **100** is arranged over the cap layer **140**. A film (hereinafter, referred to as a resin film) **160** including a resin is disposed over the passivation film **150**. The display device **200** further possesses supporting films **226** and **228** sandwiching the structure from the substrate **202** to the resin film **160**, and appropriate physical strength is provided by the supporting films **226** and **228**.

[0071] The supporting films **226** and **228** are respectively fixed to the substrate **202** and the resin film **160** with an adhesive layer which is not illustrated.

3. Terminals and Wirings

[0072] FIG. **8** schematically shows an example of a cross-sectional structure focusing on the region from an edge portion of the display region **206** (lower portion of the display region **206** in FIG. **4**) to the power-source terminals **218** and **220** and the image-signal terminals **216**. Here, the cross-sections of a part of the display region **206**, the source-side driver circuit **210**, the power-source terminal **218**, and the wiring **292** electrically connecting the display region **206** to the power-source terminal **218** are illustrated.

[0073] As shown in FIG. **8**, the supporting film **226** is divided into two portions by removing a part thereof, and an undersurface of the substrate **202** is exposed between the divided portions. The portion where the supporting film **226** is removed has high flexibility, and the three-dimensional structure demonstrated in FIG. **5** can be provided to the display device **200** by utilizing this portion to fold the substrate **202**. Hereinafter, the portion where the supporting film **226** is removed is called a bent region **170**.

[0074] The undercoat **260** extends to the power-source terminal **218** from the pixel **204**, and a part of the undercoat **260** is removed in the bent region **170** and at a vicinity thereof. That is, the undercoat **260** is divided in the bent region **170**. Similar to the undercoat **260**, the gate insulating film **264** and the interlayer insulating film **270** formed in the display region **206** also extend in a direction toward the power-source terminal **218** and are each divided in the bent region **170**. Semiconductor elements such as a transistor are provided in the source-side driver circuit **210**, and a variety of circuits such as an analogue circuit are structured by the semiconductor elements.

[0075] The wiring **292** extends to the edge portion of the substrate **202** from the display region **206**. The cathode **130** provided in the display region **206** is electrically connected to the wiring **292** in an opening formed in the leveling film **276**. Specifically, the leveling film **276** has the opening reaching the wiring **292** between the display region **260** and the power-source terminal **218**, and a contact electrode **290** including a first contact electrode **290***a* and a second contact electrode **290***b* over the first contact electrode **290***a* is arranged so as to cover this opening. The cathode **130** is electrically connected to the wiring **292** through the second contact electrode **290***b* and the first contact electrode **290***a*.

[0076] The wiring **292** further forms the power-source terminals **218** and **220** and the image-signal terminals **216** at the vicinity of the edge portion of the substrate **202**. Surfaces of these terminals may be covered with the protection electrodes **290***c* existing in the same layer as the first contact electrode **290***a*. As described above, these terminals are input with a variety of signals for driving the pixels **204**.

[0077] As described in the First Embodiment, the light-emitting element **100** possesses: the electron-transporting layer **126** which is a mixed layer of an organic compound having an electron-transporting property and an electron donor selected from lithium, a lithium complex having a quinolinol ligand, and a magnesium complex having a quinolinol ligand; the first electron-injection layer **127***a* including lithium or a lithium complex having a quinolinol ligand, such as Liq; and the second electron-injection layer **127***b* including a lanthanide metal. Therefore, the light-emitting element **100** exhibits a low driving voltage and has reduced power consumption. Hence, introduction of the light-emitting element **100** to each pixel **204** enables the display device **200** to demonstrate low power consumption. That is, implementation of the present embodiment allows production of a display device having a low driving voltage and low power consumption.

Example

[0078] In the present example, fabrication of the light-emitting element **100** described in the First Embodiment and evaluation of the performance thereof are demonstrated. Specifically, blue-emissive light-emitting elements 1 to 4 as the light-emitting element according to the embodiment of the present invention and a blue-emissive light-emitting element 5 as a comparative example were fabricated.

[0079] Each of the light-emitting elements 1 to 4 is one of the light-emitting elements **100** of the First Embodiment, and their structures are the same as one another except for the structures of the electron-transporting layer **126** and the first electron-injection layer **127***a*. The electron-transporting layers **126** and the electron-injection layers **127***a* of these elements are shown in FIG. **1**. The light-emitting element 5 is different from the light-emitting elements 1 and 2 in that the first electron-injection layer **127***a* is not provided (see Table 1).

TABLE 1

Structures of the light-emitting elements 1 to 5

	Electron-transporting layer				
	Compound with electron-trans-portiong property	Electron donor	Volume ratio	First electron-injection layer	Second electron-injection layer
Light-emitting element 1	Alq	Liq	1:1	Li	Yb
Light-emitting element 2	Alq	Liq	1:1	Liq	Yb
Light-emitting element 3	Alq	Liq	9:1	Liq	Yb
Light-emitting element 4	Alq	Yb	9:1	Liq	Yb
Light-emitting element 5	Alq	Liq	1:1	—	Yb

[0080] The driving voltage, the emission efficiency, and the time for 5% luminance deterioration (Lt95) of each element are summarized in Table 2. Here, the driving voltage and the emission efficiency are values when current flows in the light-emitting element at a current density of 10 mA/cm^2. Lt95 is a time when the light-emitting element is driven at a constant current of 15 mA/cm^2 at 30° C. and the luminance becomes 95% of the initial luminance.

TABLE 2

Performance of light-emitting elements 1 to 5

	Driving voltage (V)	Emission efficiency (Cd/A)	Lt95 (h)
Light-emitting element 1	4.4	4.6	400
Light-emitting element 2	4.8	4.5	500
Light-emitting element 3	4.5	4.4	550
Light-emitting element 4	4.6	4.6	500
Light-emitting element 5	5.2	3.7	300

[0081] As can be clearly understood from Table 2, all of the light-emitting elements 1 to 4 which are the light-emitting elements 100 according to an embodiment of the present invention can be driven at a low voltage and exhibits high emission efficiency and reliability. In contrast, it was confirmed that, with respect to the light-emitting element 5 without the first electron-injection layer **127***a*, the driving voltage is increased, and the emission efficiency is low. In addition, a decrease in reliability was observed. From these results, it was revealed that implementation of an embodiment of the present invention allows production of a light-emitting element which can be driven at a low voltage and shows low power consumption and a display device including the same.

[0082] The aforementioned modes described as the embodiments of the present invention can be implemented by appropriately combining with each other as long as no contradiction is caused. Furthermore, any mode which is realized by persons ordinarily skilled in the art through the appropriate addition, deletion, or design change of elements or through the addition, deletion, or condition change of a process is included in the scope of the present invention as long as they possess the concept of the present invention.

[0083] It is properly understood that another effect different from that provided by the modes of the aforementioned embodiments is achieved by the present invention if the effect is obvious from the description in the specification or readily conceived by persons ordinarily skilled in the art.

What is claimed is:

1. A light-emitting element comprising:
an anode;
an emission layer over the anode;
an electron-transporting layer over the emission layer, the electron-transporting layer including:
a first organic compound having an electron-transporting property higher than a hole-transporting property; and
at least one of lithium, a lithium complex containing an 8-quinolinol ligand, and a magnesium complex containing an 8-quinolinol ligand;
a first electron-injection layer over and in contact with the electron-transporting layer, the first electron-injection layer including at least one of lithium and a lithium complex containing an 8-quinolinol ligand;
a second electron-injection layer over and in contact with the first electron-injection layer, the second electron-injection layer including a lanthanoid metal; and
a cathode over and in contact with the second electron-injection layer.

2. The display device according to claim **1**,
wherein the lanthanoid metal is ytterbium.

3. The display device according to claim **1**,
wherein the first organic compound includes one of a substituted or unsubstituted aluminum complex, a substituted or unsubstituted beryllium complex, a substituted or unsubstituted zinc complex, a substituted or unsubstituted oxadiazole derivative, a substituted or unsubstituted triazole derivative, a substituted or unsubstituted silacyclopentadiene derivative, a substituted or unsubstituted anthracene derivative, a substituted or unsubstituted pyrene derivative, a substituted or unsubstituted perylene derivative, and a substituted or unsubstituted phenanthroline derivative.

4. The display device according to claim **1**,
wherein the lithium complex containing an 8-quinolinol ligand and the magnesium complex containing an 8-quinolinol ligand are (8-quinolinolato)lithium and bis(8-quinolinolato)magnesium, respectively.

5. The display device according to claim **1**,
wherein the first electron-injection layer includes lithium or (8-quinolinolato)lithium.

6. The display device according to claim **1**,
wherein the second electron-injection layer includes ytterbium.

7. The display device according to claim **1**,
wherein the cathode includes magnesium and silver.

8. The display device according to claim **1**,
wherein the cathode is configured to partly reflect and partly transmit visible light.

9. The display device according to claim **1**, further comprising a hole-blocking layer between and in contact with the emission layer and the electron-transporting layer.

10. The display device according to claim **9**,
wherein a total thickness of the hole-blocking layer, the electron-transporting layer, the first electron-injection layer, and the second electron-injection layer is equal to or larger than 25 nm and equal to or smaller than 35 nm.

11. A display device comprising a pixel having a light-emitting element, the light-emitting element including:
an anode;
an emission layer over the anode;
an electron-transporting layer over the emission layer, the electron-transporting layer including:
a first organic compound having an electron-transporting property higher than a hole-transporting property; and
at least one of lithium, a lithium complex containing an 8-quinolinol ligand, and a magnesium complex containing an 8-quinolinol ligand;
a first electron-injection layer over and in contact with the electron-transporting layer, the first electron-injection layer including at least one of lithium and a lithium complex containing an 8-quinolinol ligand;
a second electron-injection layer over and in contact with the first electron-injection layer, the second electron-injection layer containing a lanthanide metal; and
a cathode over and in contact with the second electron-injection layer.

12. The display device according to claim **11**,
wherein the lanthanide metal is ytterbium.

13. The display device according to claim **11**,
wherein the first organic compound includes a substituted or unsubstituted aluminum complex, a substituted or unsubstituted beryllium complex, a substituted or unsubstituted zinc complex, a substituted or unsubstituted oxadiazole derivative, a substituted or unsubstituted triazole derivative, a substituted or unsubstituted silacyclopentadiene derivative, a substituted or unsubstituted anthracene derivative, a substituted or unsubstituted pyrene derivative, a substituted or unsubstituted perylene derivative, and a substituted or unsubstituted phenanthroline derivative.

14. The display device according to claim **11**,
wherein the lithium complex containing an 8-quinolinol ligand and the magnesium complex containing an 8-quinolinol ligand are (8-quinolinolato)lithium and bis(8-quinolinolato)magnesium, respectively.

15. The display device according to claim **11**,
wherein the first electron-injection layer includes lithium or (8-quinolinolato)lithium.

16. The display device according to claim **11**,
wherein the second electron-injection layer includes ytterbium.

17. The display device according to claim **11**,
wherein the cathode includes magnesium and silver.

18. The display device according to claim **11**,
wherein the cathode is configured to partly reflect and partly transmit visible light.

19. The display device according to claim **11**, further comprising a hole-blocking layer between and in contact with the emission layer and the electron-transporting layer.

20. The display device according to claim **19**,
wherein a total thickness of the hole-blocking layer, the electron-transporting layer, the first electron-injection layer, and the second electron-injection layer is equal to or larger than 25 nm and equal to or smaller than 35 nm.

* * * * *

patsnap

专利名称(译)	发光元件和具有该发光元件的显示装置		
公开(公告)号	US20190051853A1	公开(公告)日	2019-02-14
申请号	US16/021688	申请日	2018-06-28
[标]申请(专利权)人(译)	株式会社日本显示器		
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[标]发明人	YASUKAWA KOJI		
发明人	YASUKAWA, KOJI		
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摘要(译)

本发明公开了一种发光元件，包括阳极，阳极上方的发光层，发光层上方的电子传输层，电子传输层上方和与之接触的第一电子注入层，第二电子注入在第一电子注入层上方并与第二电子注入层接触并与第二电子注入层接触的阴极与第一电子注入层接触并接触。电子传输层包括具有高于空穴传输性的电子传输性的第一有机化合物，并且还包括锂，含有8-羟基喹啉配体的锂配合物和含有8-的镁配合物中的至少一种。喹啉醇配体。第一电子注入层包含锂和含有8-羟基喹啉配体的锂配合物中的至少一种。第二电子注入层包括镧系金属。