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(54) **ORGANIC ELECTROLUMINESCENCE DISPLAY DEVICE**

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(57) **ABSTRACT**

An organic EL display device includes an anode, a cathode and a light-emitting unit disposed between the anode and the cathode. The cathode is a transparent conductive film formed on the light-emitting unit. The light-emitting unit includes a light-emitting layer, an electron transport layer disposed between the light-emitting layer and the cathode, and an electron injection layer, disposed between the electron transport layer and the cathode, which is doped with an alkali metal. A thickness of the electron injection layer is equal to or greater than two times that of the electron transport layer.

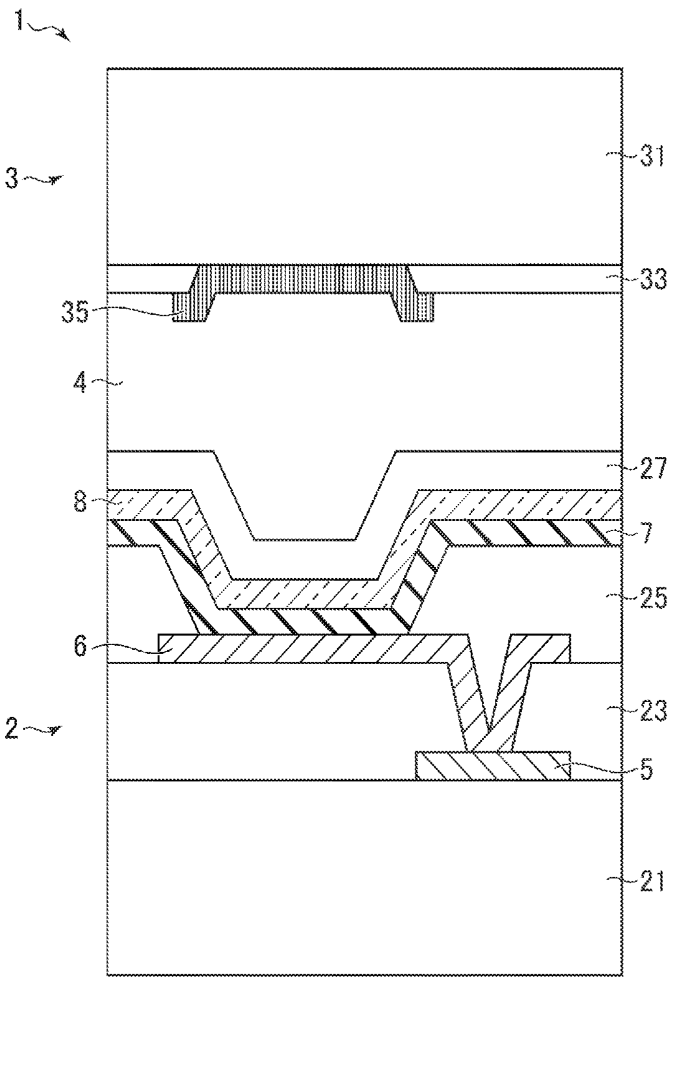


FIG.1

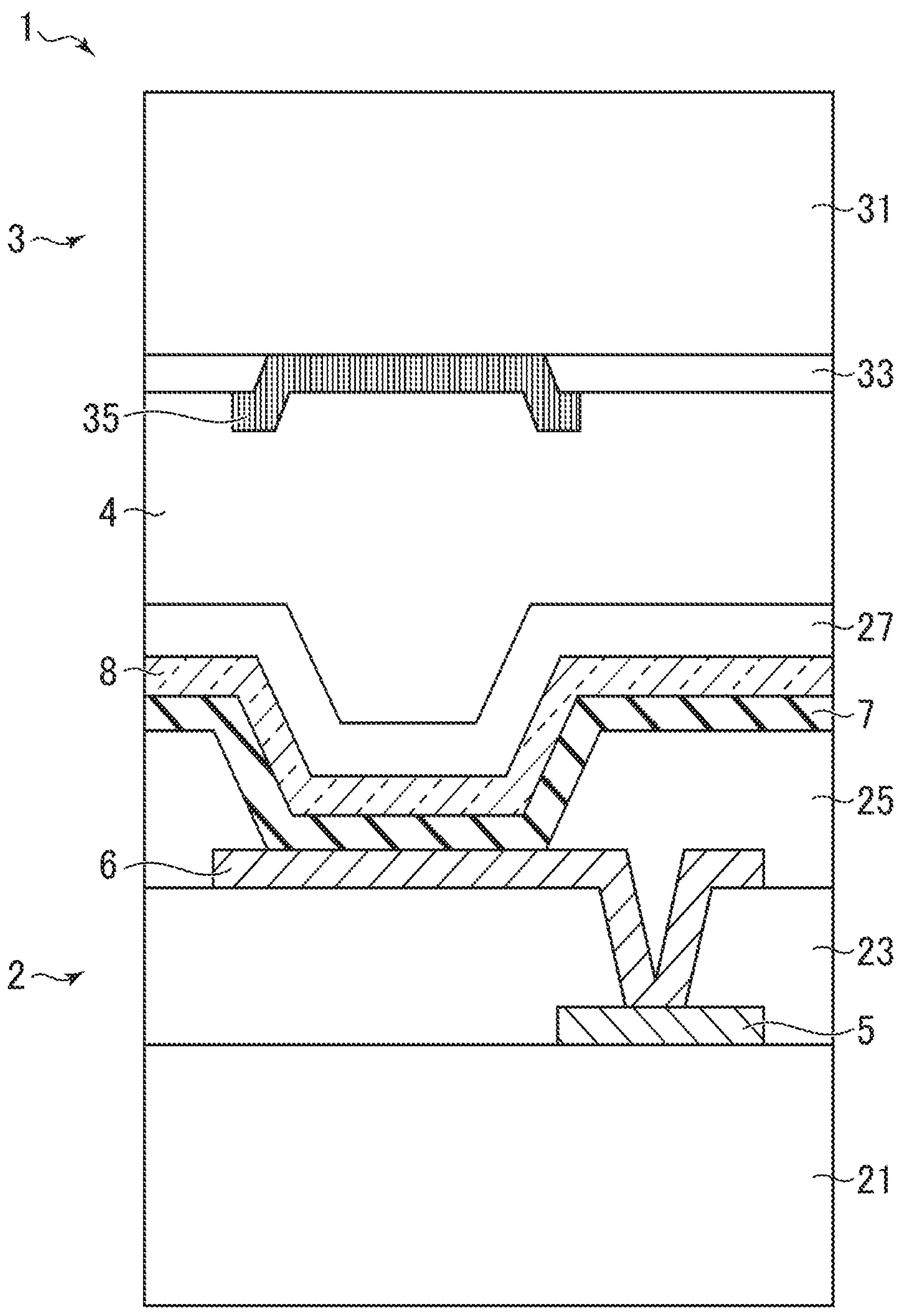


FIG.2

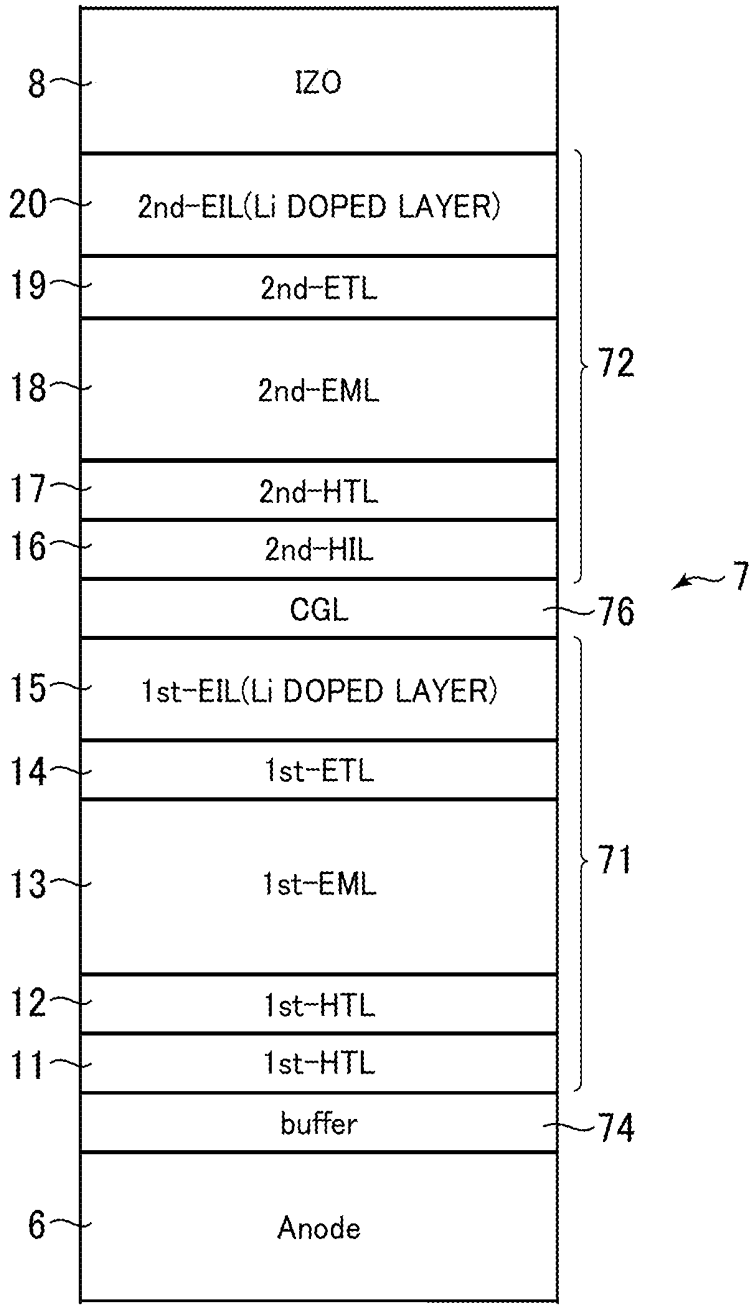

8
IZO
20
2nd-EIL(Li DOPED LAYER)
19
2nd-ETL
18
2nd-EML
17
2nd-HTL
16
2nd-HIL
72
7
CGL
76
15
1st-EIL(Li DOPED LAYER)
14
1st-ETL
13
1st-EML
71
12
1st-HTL
11
1st-HTL
buffer
74
6
Anode

FIG.3

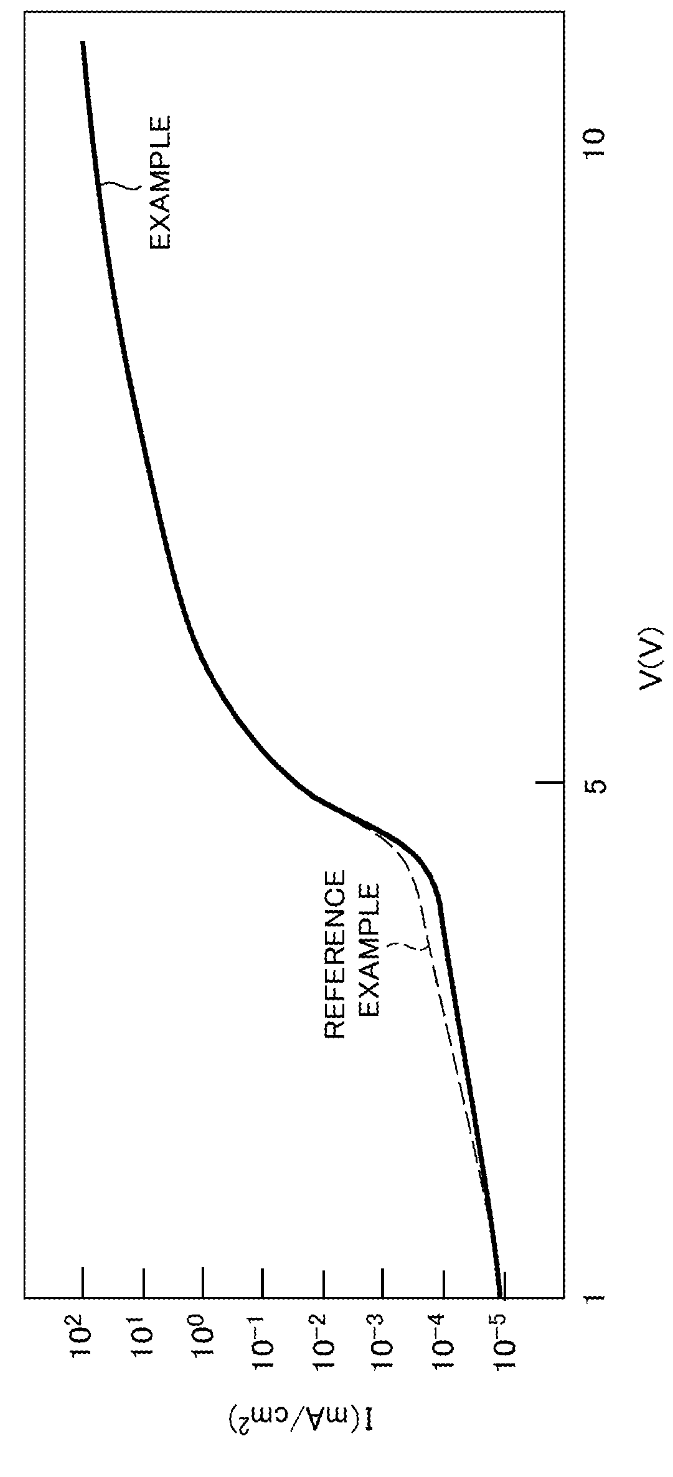

I(mA/cm²)
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
1
5
10
V(V)
EXAMPLE
REFERENCE EXAMPLE

FIG.4

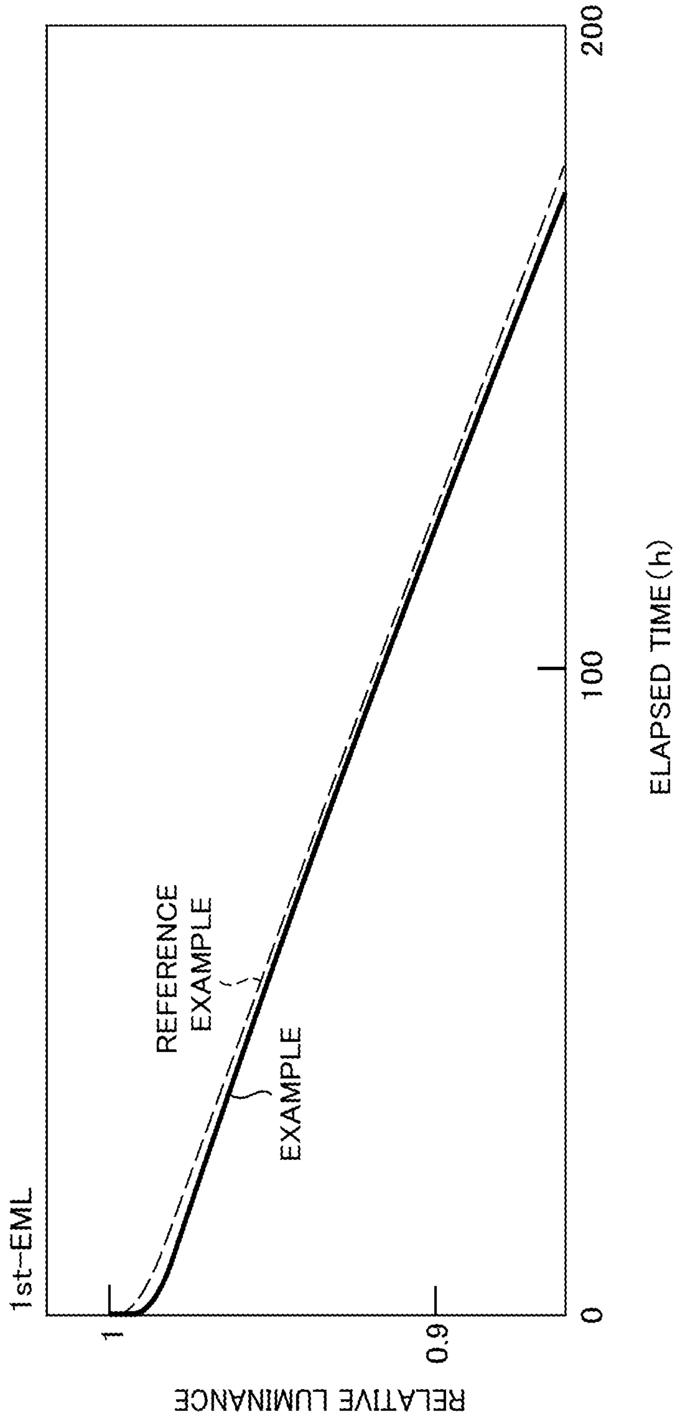

1st-EML
REFERENCE EXAMPLE
EXAMPLE
RELATIVE LUMINANCE
1
0.9
0
100
200
ELAPSED TIME (h)

FIG.5

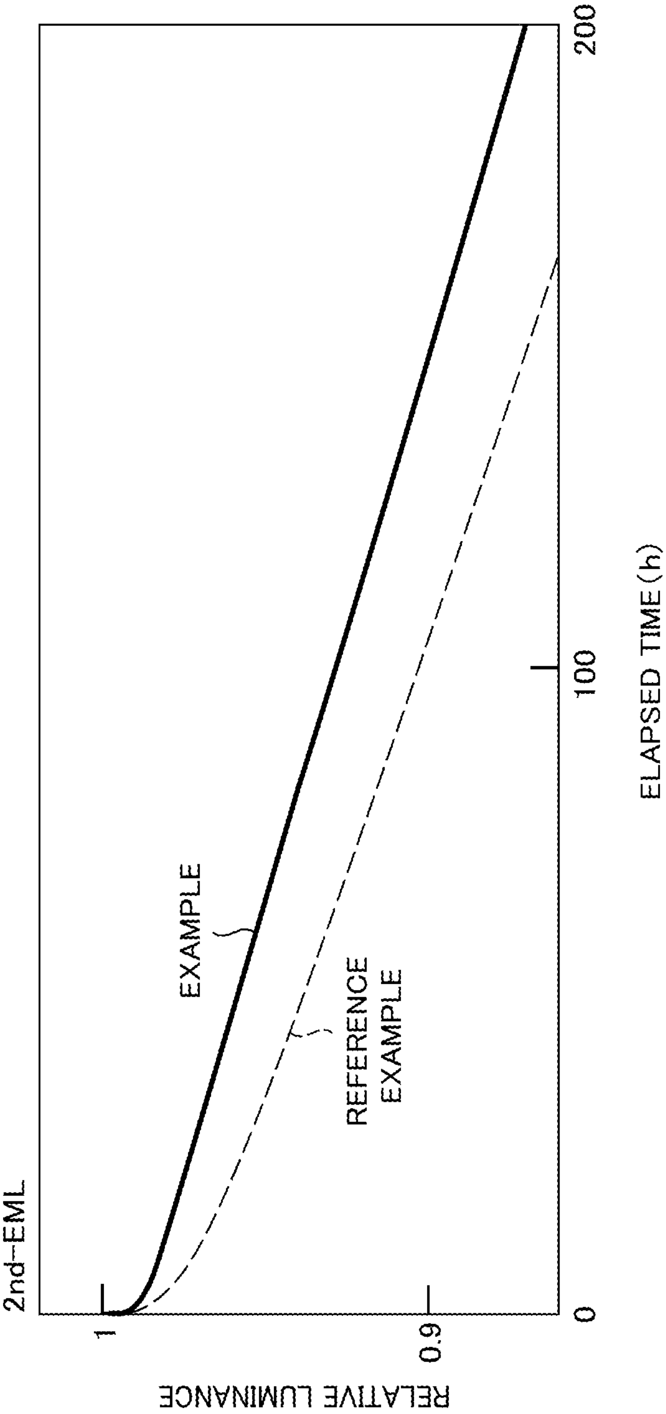

2nd-EML
EXAMPLE
REFERENCE EXAMPLE
RELATIVE LUMINANCE
1
0.9
0
100
200
ELAPSED TIME (h)

FIG.6

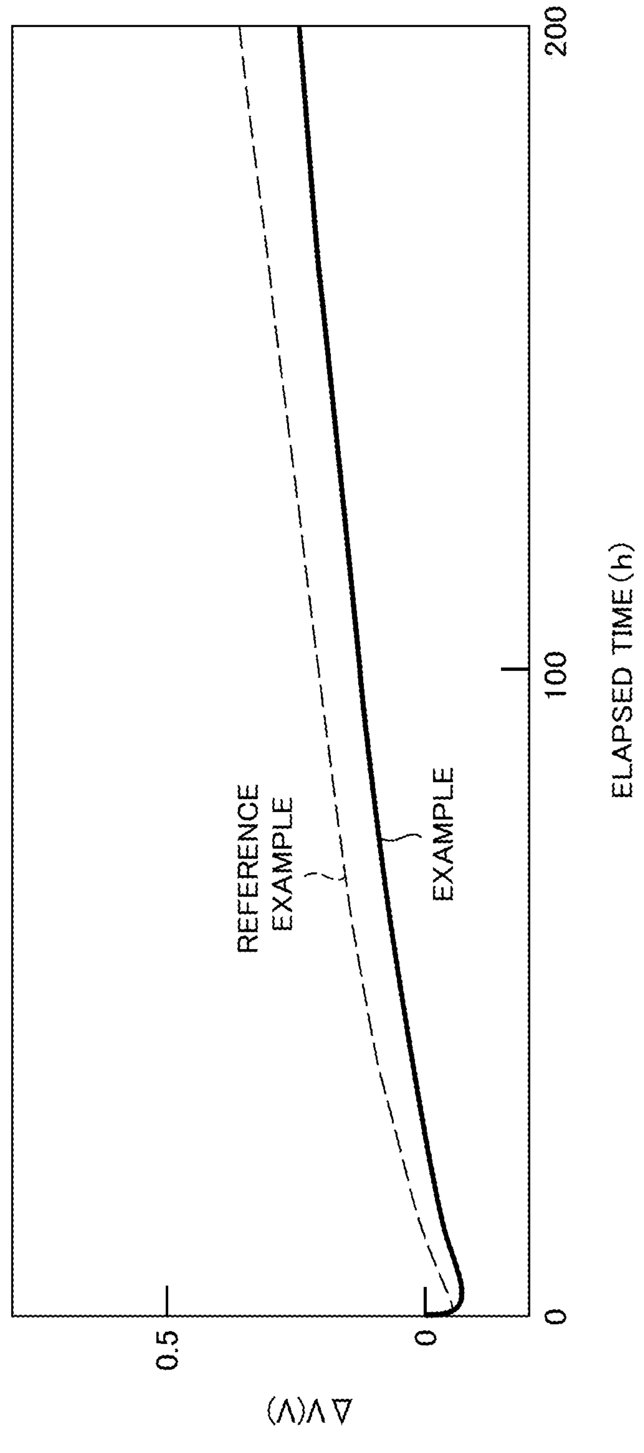


FIG.7

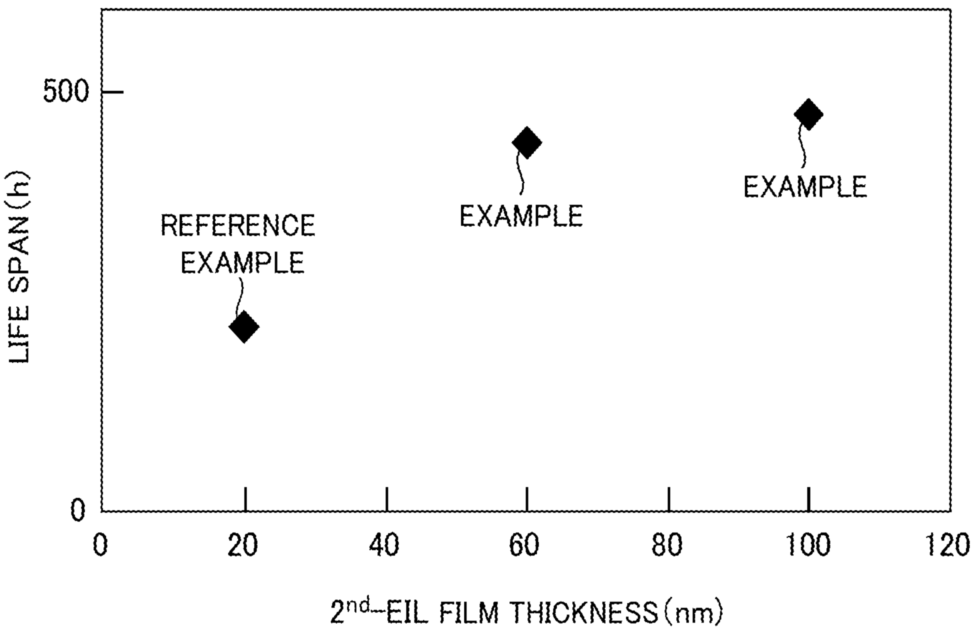
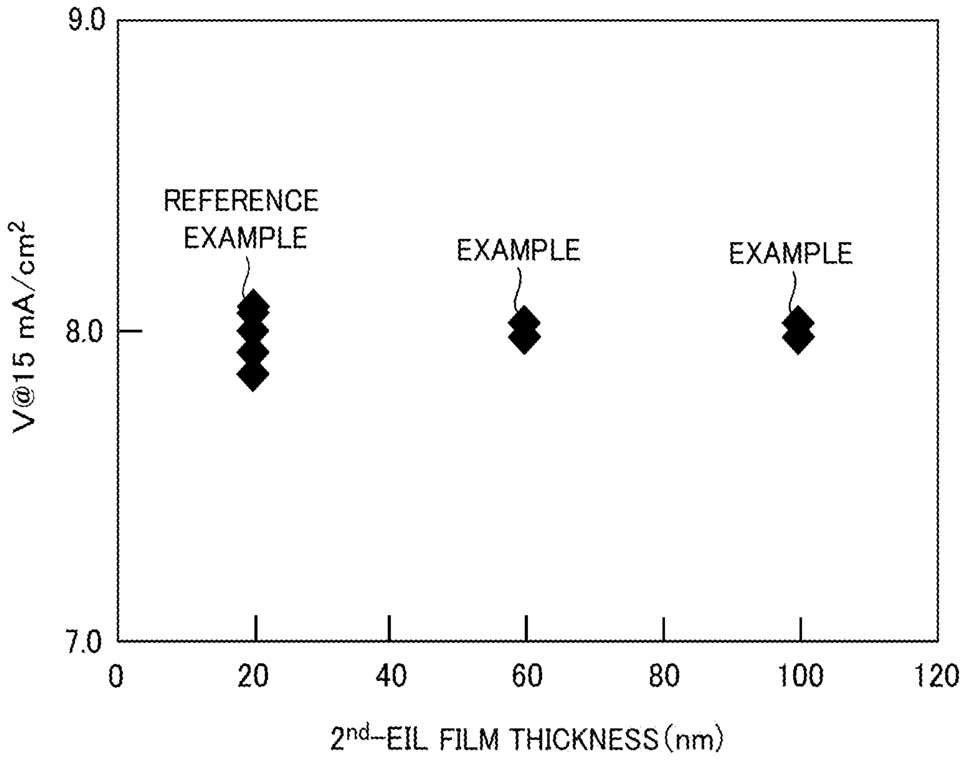

500
0
LIFE SPAN(h)
REFERENCE EXAMPLE
EXAMPLE
EXAMPLE
0
20
40
60
80
100
120
2nd-EIL FILM THICKNESS(nm)

FIG.8


9.0
8.0
7.0
V@15 mA/cm2
REFERENCE
EXAMPLE
EXAMPLE
EXAMPLE
0
20
40
60
80
100
120
2nd-EIL FILM THICKNESS (nm)

# ORGANIC ELECTROLUMINESCENCE DISPLAY DEVICE

## CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority from the Japanese Application JP2016-58847 filed on Mar. 23, 2016, the content of which is hereby incorporated by reference into this application.

## BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an organic EL display device.

[0004] 2. Description of the Related Art

[0005] In a top-emission type organic EL display device, a transparent conductive film constituted of an indium zinc oxide (IZO) or the like is formed as a cathode on a light-emitting unit including a light-emitting layer (see JP 2009-295822 A). Such a transparent conductive film is generally formed by a sputtering method.

## SUMMARY OF THE INVENTION

[0006] Incidentally, in a light-emitting unit having a transparent conductive film formed thereon, the life span of a light-emitting layer may be short, and the inventors have found that the cause is because materials of the transparent conductive film are diffused inside the light-emitting unit during the formation of the transparent conductive film and the light-emitting layer is damaged.

[0007] The invention is contrived in view of the above problem, and an object thereof is to provide an organic EL display device capable of achieving an increase in the life span of a light-emitting layer.

[0008] An organic EL display device includes an anode, a cathode and a light-emitting unit disposed between the anode and the cathode. The cathode is a transparent conductive film formed on the light-emitting unit. The light-emitting unit includes a light-emitting layer, an electron transport layer disposed between the light-emitting layer and the cathode, and an electron injection layer, disposed between the electron transport layer and the cathode, which is doped with an alkali metal. A thickness of the electron injection layer is equal to or greater than two times that of the electron transport layer.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a diagram schematically illustrating a cross-section structure example of an organic EL display device according to an embodiment of the invention.

[0010] FIG. **2** is a diagram schematically illustrating a laminated structure example of an organic film included in the organic EL display device.

[0011] FIG. **3** is a diagram illustrating the current-voltage characteristics of the organic film.

[0012] FIG. **4** is a diagram illustrating transition of the luminance of a first light-emitting layer included in the organic film.

[0013] FIG. **5** is a diagram illustrating transition of the luminance of a second light-emitting layer included in the organic film.

[0014] FIG. **6** is a diagram illustrating transition of an increment of a voltage required for causing a predetermined current to flow to the organic film.

[0015] FIG. **7** is a diagram illustrating a relationship between the thickness of a second electron injection layer and the life span of the second light-emitting layer.

[0016] FIG. **8** is a diagram illustrating a relationship between the thickness of the second electron injection layer and a voltage required for causing a predetermined current to flow to the organic film.

## DETAILED DESCRIPTION OF THE INVENTION

[0017] Hereinafter, each embodiment of the invention will be described with reference the accompanying drawings. The disclosure is merely illustrative, and appropriate changes without departing from the spirit of the invention which can be readily conceived by those skilled in the art are naturally contained in the scope of the invention. In addition, in order to make the description clearer, the drawings may be schematically shown for the width, thickness, shape and the like of each unit as compared to the embodiment, but are merely illustrative, and are not intended to limit the interpretation of the invention. In addition, in the present specification and each drawing, the same components as those described in the previous drawings are denoted by the same reference numerals and signs, and thus the detailed description thereof may not be given.

[0018] FIG. **1** is a diagram schematically illustrating a cross-section structure example of an organic EL display device **1** according to an embodiment of the invention. In the same drawing, hatching of insulating films **23** and **25** or the like is omitted in order to make the cross-section structures easier to understand. FIG. **2** is a diagram schematically illustrating a laminated structure example of an organic film **7** (organic EL element) included in the organic EL display device **1**.

[0019] The organic EL display device **1** includes an array substrate **2** and an opposite substrate **3** which is opposite to the array substrate **2**. The array substrate **2** and the opposite substrate **3** are bonded to each other with a filling material **4** interposed therebetween. In the organic EL display device **1**, a top-emission type is adopted in which light is emitted in the direction of the opposite substrate **3** with respect to the array substrate **2**. In the following description, the direction of the opposite substrate **3** with respect to the array substrate **2** is set to an upward direction.

[0020] The array substrate **2** is a laminate having an insulating film and a conductor layer laminated on a transparent substrate **21** constituted of a flexible resin such as, for example glass or polyimide A lower electrode **5** is, for example, an electrode connected to a TFT, not shown, for driving a pixel. The lower electrode **51** is formed of a conductive metal such as, for example, aluminum, silver, copper, nickel, or titanium.

[0021] The lower electrode **5** is covered with an insulating film **23**. An anode **6** corresponding to each pixel is disposed on the insulating film **23**. An opening for connecting the anode **6** to the lower electrode **5** is formed on the insulating film **23**. The insulating film **23** is formed of an organic insulating material such as, for example, an acrylic resin, and the surface thereof is planarized. The anode **6** is formed of a conductive metal such as, for example, aluminum, silver, copper, nickel, or titanium, and has a reflecting surface.

**[0022]** The insulating film **23** and the anode **6** are covered with an insulating film **25**. An opening having the anode **6** exposed to the bottom is formed in the insulating film **25**. The insulating film **25** is also called a pixel separation film, a bank or a rib. The insulating film **25** is formed of a transparent organic material such as, for example, an acrylic resin. The anode **6** exposed to the bottom of the opening of the insulating film **25** is covered with the organic film **7** including a light-emitting layer. The details of the organic film **7** will be described later.

**[0023]** The organic film **7** is covered with a cathode **8**. The cathode **8** is a transparent conductive film which is formed of a transparent conductive material such as, for example, an indium zinc oxide (IZO) or an indium tin oxide (ITO). The cathode **8** is covered with a sealing film **27**. The sealing film **27** is formed of an inorganic insulating material such as, for example, a silicon oxide or a silicon nitride.

**[0024]** In the opposite substrate **3**, a transparent substrate **31** constituted of a flexible resin such as, for example, glass or polyimide is provided with a black matrix **33** having an opening corresponding to each pixel formed therein and a color filter **35** filled into the opening. The opposite substrate **3** may not be provided.

**[0025]** As shown in FIG. **2**, the organic film **7** includes a first light-emitting unit **71** and a second light-emitting unit **72**. The first light-emitting unit **71** is disposed on a side close to the anode **6**, and the second light-emitting unit **72** is disposed on a side close to the cathode **8**. A buffer layer **74** is disposed between the anode **6** and the first light-emitting unit **71**. A separation layer **76** is disposed between the first light-emitting unit **71** and the second light-emitting unit **72**.

**[0026]** The first light-emitting unit **71** includes a first hole injection layer **11** (1st-HIL), a first hole transport layer **12** (1st-HTL), a first light-emitting layer **13** (1st-EML), a first electron transport layer **14** (1st-ETL), and a first electron injection layer **15** (1st-EIL), in order from the side close to the anode **6**.

**[0027]** The second light-emitting unit **72** includes a second hole injection layer **16** (2nd-HIL), a second hole transport layer **17** (2nd-HTL), a second light-emitting layer **18** (2nd-EML), a second electron transport layer **19** (2nd-ETL), and a second electron injection layer **20** (2nd-EIL), in order from the side close to the anode **6**.

**[0028]** In the present embodiment, the organic film **7** is provided with two light-emitting units **71** and **72**, but the number of light-emitting units may be one. In addition, in the present embodiment, for example, the emission color of the first light-emitting layer **13** is yellow, the emission color of the second light-emitting layer **18** is blue, and the light-emitting layers are configured to emit white light as a whole, but the emission color is not limited thereto.

**[0029]** An example of materials of the first light-emitting layer **13** and the second light-emitting layer **18** which are capable of being used includes various emission materials of a fluorescent material such as Alq3 (tris(8-quinolinolato) aluminum), a phosphorescent material such as "tris(2-phenylpyridinato-N, C2') iridium (III)"(Ir(ppy)3), "tris(1-phenylisoquinoline) iridium (III)" (Ir(piq)3), or "bis[2-(4',6'-difluorophenyl) pyridinato-N, C2'] iridium (III) picolinate" (FIrpic), or the like.

**[0030]** An Example of materials of the first hole transport layer **12** and the second hole transport layer **17** which are capable of being used includes a material such as NPB(4, 4'-bis[N-(1-naphthyl)-N-phenylamino] biphenyl) or TPD(N, N'-bis(3-methylphenyl)-N, N'-diphenyl-[1,1'-biphenyl]-4,4'-diamine).

**[0031]** An example of materials of the first electron transport layer **14** and the second electron transport layer **19** which are capable of being used includes a material such as Alq3 or BCP (bathocuproine).

**[0032]** An example of materials of the first electron injection layer **15** and the second electron injection layer **20** which are capable of being used includes an electron injection material doped with an alkali metal. An example of the electron injection material capable of being used includes an organic material such as Alq3 (tris(8-quinolinolato) aluminum) or BCP (bathocuproine). An example of the alkali metal to be exemplified includes Li, Na, K, Rb, Cs, or Fr.

**[0033]** The respective layers included in the organic film **7** are formed by, for example, a method such as a vacuum vapor deposition method, an application method, or a printing method. Further, the cathode **8** constituted of a transparent conductive material such as an indium zinc oxide (IZO) is formed on the second light-emitting unit **72** of the organic film **7**, that is, on the second electron injection layer **20** by a sputtering method.

**[0034]** Hereinafter, more detailed contents of the present embodiment will be described.

**[0035]** Generally, in a case where a transparent conductive film such as an IZO is formed on a light-emitting unit by a sputtering method, the life span of a light-emitting layer included in the light-emitting unit may be short. The life span of the light-emitting layer is indicated by, for example, a time which will be taken until the luminance of light emitted by the light-emitting layer deteriorates to a predetermined level.

**[0036]** For example, in the laminated structure of FIG. **2**, blue light emitted by the second light-emitting layer **18** of the second light-emitting unit **72** having the cathode **8** formed thereon deteriorates faster than yellow light emitted by the first light-emitting layer **13** of the first light-emitting unit **71**, and thus there is a concern of a shift in color being caused as if white light is yellowish.

**[0037]** The inventors have found that the cause of the life span of alight-emitting layer being shortened is because, when a transparent conductive film such as an IZO is formed on a light-emitting unit by a sputtering method, indium (In) which is a material of the transparent conductive film is diffused inside the light-emitting unit and the light-emitting layer is damaged.

**[0038]** In order to suppress damage to the light-emitting layer due to such diffusion of indium (In), the inventors have come to realize an idea of making the distance between the transparent conductive film and the light-emitting layer larger than in the related art.

**[0039]** For example, in the laminated structure of FIG. **2**, in a case where the distance between the cathode **8** and the second light-emitting layer **18** is made larger, the following three kinds are considered: increasing only the thickness of the second electron transport layer **19**, increasing only the thickness of the second electron injection layer **20**, and increasing both the thicknesses of the second electron transport layer **19** and the second electron injection layer **20**.

[0040] However, increasing the thickness of a layer leads to an increase in electrical resistance, and eventually leads to an increase in power consumption. Therefore, there is also a problem in that the distance between the cathode **8** and the second light-emitting layer **18** is made larger in order to suppress damage to the second light-emitting layer **18**, while an increase in electrical resistance is suppressed insofar as possible.

[0041] Consequently, in the present embodiment, the ratio of the thickness of the second electron injection layer **20** to the thickness of the second electron transport layer **19** is made relatively large. With such a configuration, it can be understood that the effect of being able to suppressing even an increase in electrical resistance while suppressing damage to the second light-emitting layer **18** is obtained. It is considered that this is because the second electron injection layer **20** is doped with an alkali metal such as Li, and the electrical resistance of the second electron injection layer **20** is smaller than that of the second electron transport layer **19**.

[0042] Specifically, the thickness of the second electron injection layer **20** is preferably equal to or greater than two times that of the second electron transport layer **19**, more preferably equal to or greater than 2.5 times, and is further more preferably equal to or greater than three times. With such a configuration, the effect can be obtained. On the other hand, even in a case where the second electron injection layer **20** is made excessively thick, the effect is saturated. Therefore, the thickness of the second electron injection layer **20** is preferably equal to or less than six times that of the second electron transport layer **19**, and is more preferably equal to or less than five times.

[0043] In addition, the thickness of the second electron injection layer **20** is preferably equal to or greater than 35 nm, more preferably equal to or greater than 45 nm, and is further more preferably equal to or greater than 55 nm. With such a configuration, the effect can be obtained. On the other hand, even in a case where the second electron injection layer **20** is made excessively thick, the effect is saturated. Therefore, the thickness of the second electron injection layer **20** is preferably equal to or less than 120 nm, and is more preferably equal to or less than 100 nm.

[0044] In addition, the thickness of the second electron transport layer **19** is preferably equal to or less than 20 nm, more preferably equal to or less than 15 nm, and is further more preferably equal to or less than 10 nm. With such a configuration, the effect can be obtained. On the other hand, in order to exhibit the function of the second electron transport layer **19**, the thickness of the second electron transport layer **19** is preferably equal to or greater than 5 nm.

[0045] The thicknesses of the second electron transport layer **19**, the second electron injection layer **20** and the cathode **8** are determined on the basis of optical distances. Therefore, in a case where the thickness of the second electron injection layer **20** is increased, it is preferable to reduce the thickness of the cathode **8** accordingly. For this reason, in the present embodiment, the ratio of the thickness of the second electron injection layer **20** to the thickness of the cathode **8** is made relatively large.

[0046] Specifically, the thickness of the second electron injection layer **20** is preferably equal to or greater than one-eighth of that of the cathode **8**, more preferably equal to or greater than one-sixth, and is further more preferably equal to or greater than one-fourth. With such a configuration, the effect can be obtained while suppressing the total thickness of the second electron injection layer **20** and the cathode **8**. On the other hand, even in a case where the second electron injection layer **20** is made excessively thick, the effect is saturated. Therefore, the thickness of the second electron injection layer **20** is preferably equal to or less than one-half of the cathode **8**, and is more preferably equal to or less than one-third.

[0047] In addition, the thickness of the cathode **8** is preferably equal to or less than 260 nm, more preferably equal to or less than 250 nm, and is further more preferably equal to or less than 240 nm. With such a configuration, the effect can be obtained. In addition, the time of formation of the cathode **8** can be shortened by making the cathode **8** relatively thin. On the other hand, in order to exhibit the function of the cathode **8**, the thickness of the cathode **8** is preferably equal to or greater than 180 nm, and is more preferably equal to or greater than 200 nm.

[0048] Hereinafter, an example and a reference example will be described with reference to FIGS. **3** to **8**.

[0049] Here, in the example, the thickness of the cathode **8** is set to 240 nm, the thickness of the second electron injection layer **20** is set to 60 nm, and the thickness of the second electron transport layer **19** is set to 20 nm. On the other hand, in the reference example, the thickness of the cathode **8** is set to 280 nm, the thickness of the second electron injection layer **20** is set to 20 nm, and the thickness of the second electron transport layer **19** is set to 20 nm. The thicknesses of the respective layers other than these three layers are set to be the same as each other, and the materials of the respective layers are also set to be the same as each other. The second electron injection layer **20** having a thickness of 20 nm is sufficient to exhibit the electron injection function of the second electron injection layer **20**.

[0050] FIG. **3** is a diagram illustrating the current-voltage (I-V) characteristics of the organic film **7**. According to this, a current-voltage characteristic curve of the example and a current-voltage characteristic curve of the reference example are substantially the same as each other. Particularly, both the curves are substantially the same as each other in a range of 7 V to 9 V used in light emission. In the example, the second electron injection layer **20** is made thicker than in the reference example, but an increase in voltage due to this is not shown.

[0051] FIG. **4** is a diagram illustrating transition of the luminance of the first light-emitting layer **13** included in the organic film **7**. The luminance of light emitted by the first light-emitting layer **13** is measured by, for example, spectroscopically dispersing light from the organic film **7**, and extracting a component corresponding to the emission color (for example, yellow) of the first light-emitting layer **13**. According to this, the rate of deterioration in luminance of the example and the rate of deterioration in luminance of the reference example are substantially the same as each other. It is considered that this is because, when the cathode **8** such as an IZO is formed on the organic film **7** by a sputtering method, indium (In) is not diffused to the first light-emitting layer **13**, and damage does not occur in the first light-emitting layer **13**.

[0052] FIG. **5** is a diagram illustrating transition of the luminance of the second light-emitting layer **18** included in the organic film **7**. The luminance of light emitted by the second light-emitting layer **18** is measured by, for example, spectroscopically dispersing light from the organic film **7**, and extracting a component corresponding to the emission color (for example, blue) of the second light-emitting layer **18**. According to this, the rate of deterioration in luminance of the example is gentler than the rate of deterioration in luminance of the reference example. That is, the deterioration in luminance is slower in the example than in the reference example. For example, in a case where times which will be taken until the luminance deteriorates to 95% are compared with each other, the time is 1.5 times longer in the example than in the reference example. It is considered that this is because, since the second electron injection layer **20** is thicker in the example than in the reference example, indium (In) is not likely to be diffused to the second light-emitting layer **18** and the second light-emitting layer **18** is not likely to be damaged, when the cathode **8** such as an IZO is formed on the organic film **7** by a sputtering method.

**[0053]** FIG. **6** is a diagram illustrating transition of an increment ΔV in a voltage required for causing a predetermined current to flow to the organic film **7**. The predetermined current is, for example, 15 mA/cm2. According to this, an increment in a voltage of the example is smaller than an increment in a voltage of the reference example. That is, in the example, the voltage required for causing a predetermined current to flow does not increase as in the reference example. In other words, in the example, electrical resistance is smaller than in the reference example. It is considered that this is because, in the example the second electron transport layer **19** is not made thicker than in the reference example, an increase in electrical resistance is suppressed by increasing the thickness of the second electron injection layer **20** having small electrical resistance which is doped with an alkali metal such as Li, and in addition thereto, an increase in electrical resistance due to damage to the second light-emitting layer **18** is also suppressed by increasing the thickness of the second electron injection layer **20**.

**[0054]** FIG. **7** is a diagram illustrating a relationship between the thickness of the second electron injection layer **20** and the life span of the second light-emitting layer **18**. The thickness of the second electron injection layer **20** is 20 nm, 60 nm, and 100 nm. The life span of the second light-emitting layer **18** is set to, for example, a time which will be taken until luminance deteriorates to 95%. According to this, the life span is relatively short in a case where the thickness of the second electron injection layer **20** is 20 nm (reference example), and the life span is relatively long in a case of 60 nm and 100 nm (example). In addition, the life span increases in a case where the thickness of the second light-emitting layer **18** is 20 to 60 nm, and the life span is saturated in a case of 60 to 100 nm.

**[0055]** FIG. **8** is a diagram illustrating a relationship between the thickness of the second electron injection layer **20** and a voltage required for causing a predetermined current to flow to the organic film **7**. In the same drawing, the voltage required for causing a predetermined current to flow to the organic film **7** is plotted at every predetermined time interval. The predetermined current is, for example, 15 mA/cm2. According to this, a change in voltage is relatively large in a case where the thickness of the second electron injection layer **20** is 20 nm (reference example), and a change in voltage is relatively small in a case of 60 nm and 100 nm (example).

**[0056]** It should be understood that various modifications and alterations can be conceived by those skilled in the art within the spirit of the invention, and that such modifications and alterations also belong to the scope of the invention. For example, those skilled in the art can appropriately modify each of the embodiments described above by addition, deletion or design change of components, or by addition, omission or condition change of processes, and such modifications are also encompassed within the scope of the invention as long as they fall within the spirit of the invention.

**[0057]** While there have been described what are at present considered to be certain embodiments of the invention, it will be understood that various modifications may be made thereto, and it is intended that the appended claims cover all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

**1**. An organic EL display device comprising:
an anode;
a cathode; and
a light-emitting unit disposed between the anode and the cathode,
wherein the cathode is a transparent conductive film formed on the light-emitting unit,
the light-emitting unit includes
a light-emitting layer,
an electron transport layer disposed between the light-emitting layer and the cathode, and
an electron injection layer, disposed between the electron transport layer and the cathode, which is doped with an alkali metal, and
a thickness of the electron injection layer is equal to or greater than two times that of the electron transport layer.

**2**. The organic EL display device according to claim **1**, wherein the thickness of the electron injection layer is equal to or greater than 35 nm.

**3**. The organic EL display device according to claim **1**, wherein a thickness of the electron transport layer is equal to or less than 20 nm.

**4**. The organic EL display device according to claim **1**, wherein the thickness of the electron injection layer is equal to or greater than one-eighth of that of the cathode.

**5**. An organic EL display device comprising:
an anode;
a cathode; and
a light-emitting unit disposed between the anode and the cathode,
wherein the cathode is a transparent conductive film formed on the light-emitting unit,
the light-emitting unit includes
a light-emitting layer, and
an electron injection layer, disposed between the light-emitting layer and the cathode, which is doped with an alkali metal, and
a thickness of the electron injection layer is equal to or greater than 35 nm.

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|---|---|---|---|
| 专利名称(译) | 有机电致发光显示装置 | | |
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| 优先权 | 2016058847 2016-03-23 JP | | |
| 外部链接 | Espacenet USPTO | | |


**摘要(译)**

有机EL显示装置包括阳极，阴极和设置在阳极和阴极之间的发光单元。阴极是形成在发光单元上的透明导电膜。发光单元包括发光层，设置在发光层和阴极之间的电子传输层，以及设置在电子传输层和阴极之间的电子注入层，其掺杂有碱金属。电子注入层的厚度等于或大于电子传输层的厚度的两倍。