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(54) **METHOD OF FORMING THIN FILM OF ORGANOMETALLIC COMPOUND, THIN FILM OF ORGANOMETALLIC COMPOUND, METHOD OF MANUFACTURING ORGANOELECTRONIC DEVICE EQUIPPED WITH THE SAME, ORGANOELECTRONIC DEVICE, METHOD OF MANUFACTURING ORGANIC ELECTROLUMINESCENCE, ORGANIC ELECTROLUMINESCENCE, AND ELECTRONIC APPARATUS**

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(57) **ABSTRACT**

Aspects of the invention can provide a method of fabricating an organometallic compound film capable, by stably forming a film with the organometallic compound, of increasing bonding forces of junction interfaces and of realizing a hyper thin film, the organometallic compound film, and an organoelectronic device (e.g., an organic electroluminescence device, an organic solar battery, or an organic thin film transistor) and an electronic device equipped with the organometallic compound film are provided. The method of fabricating a thin film of an organometallic compound on a substrate, can include the step of forming an organic material by a liquid phase process and the step of forming metal by a vapor phase process to form a thin film of an organometallic compound composed of the organic material and the metal.

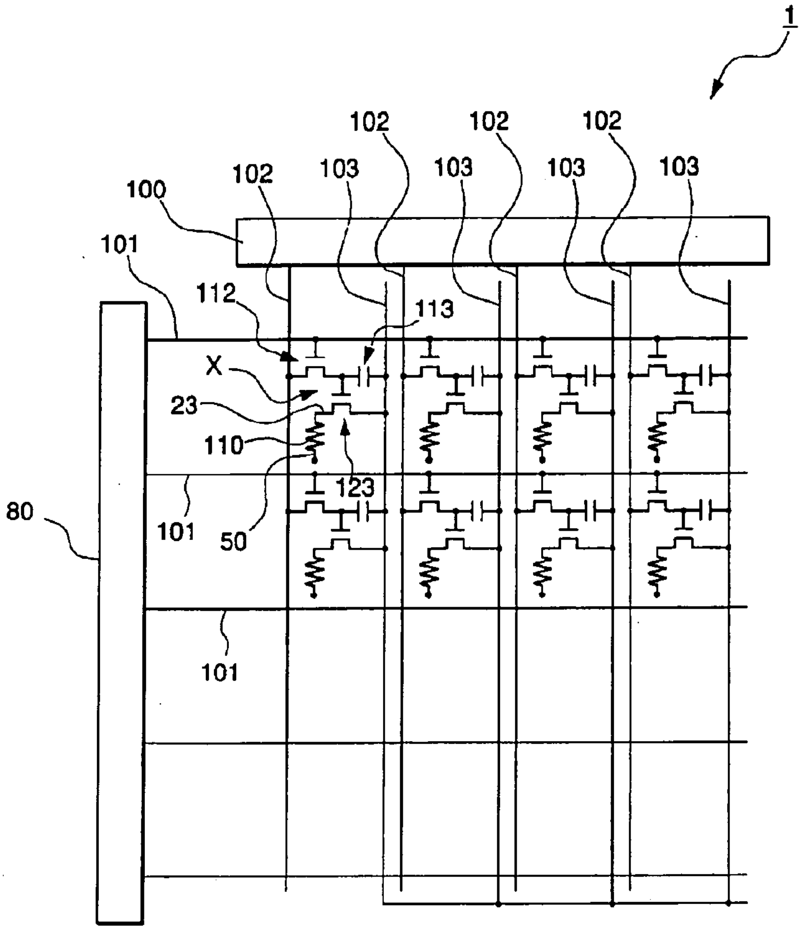

Fig.1

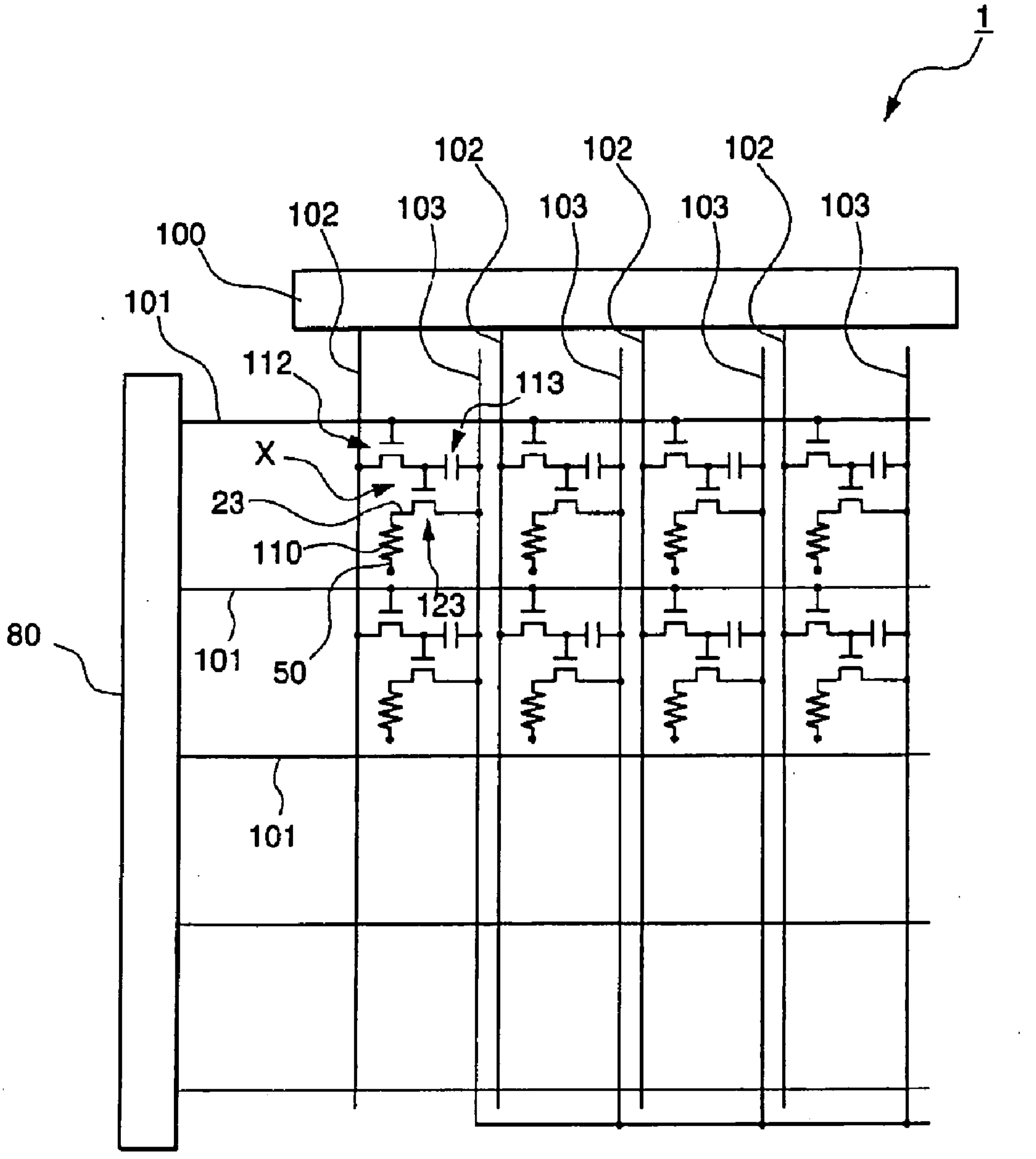
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Fig. 2

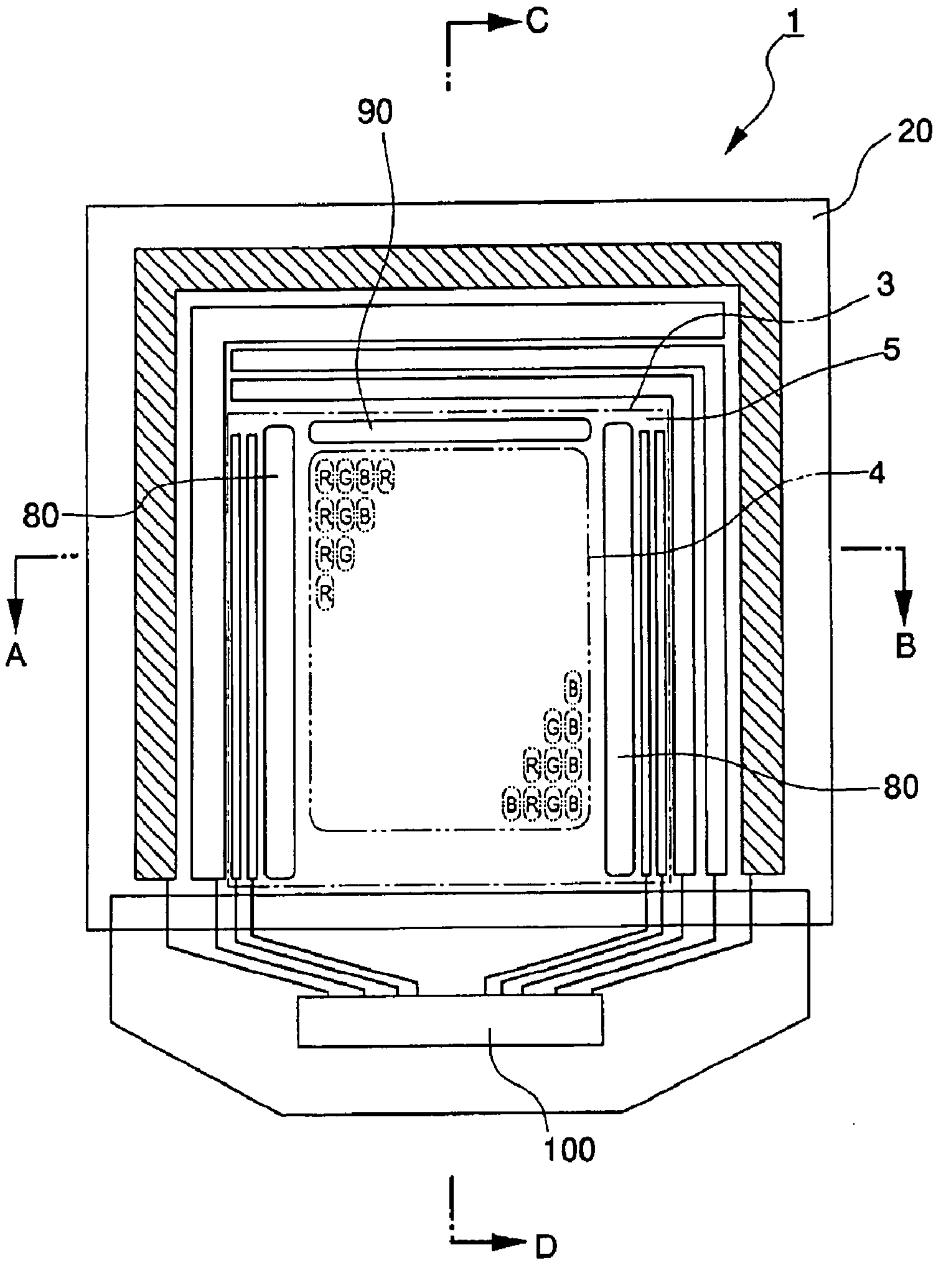

Fig. 3

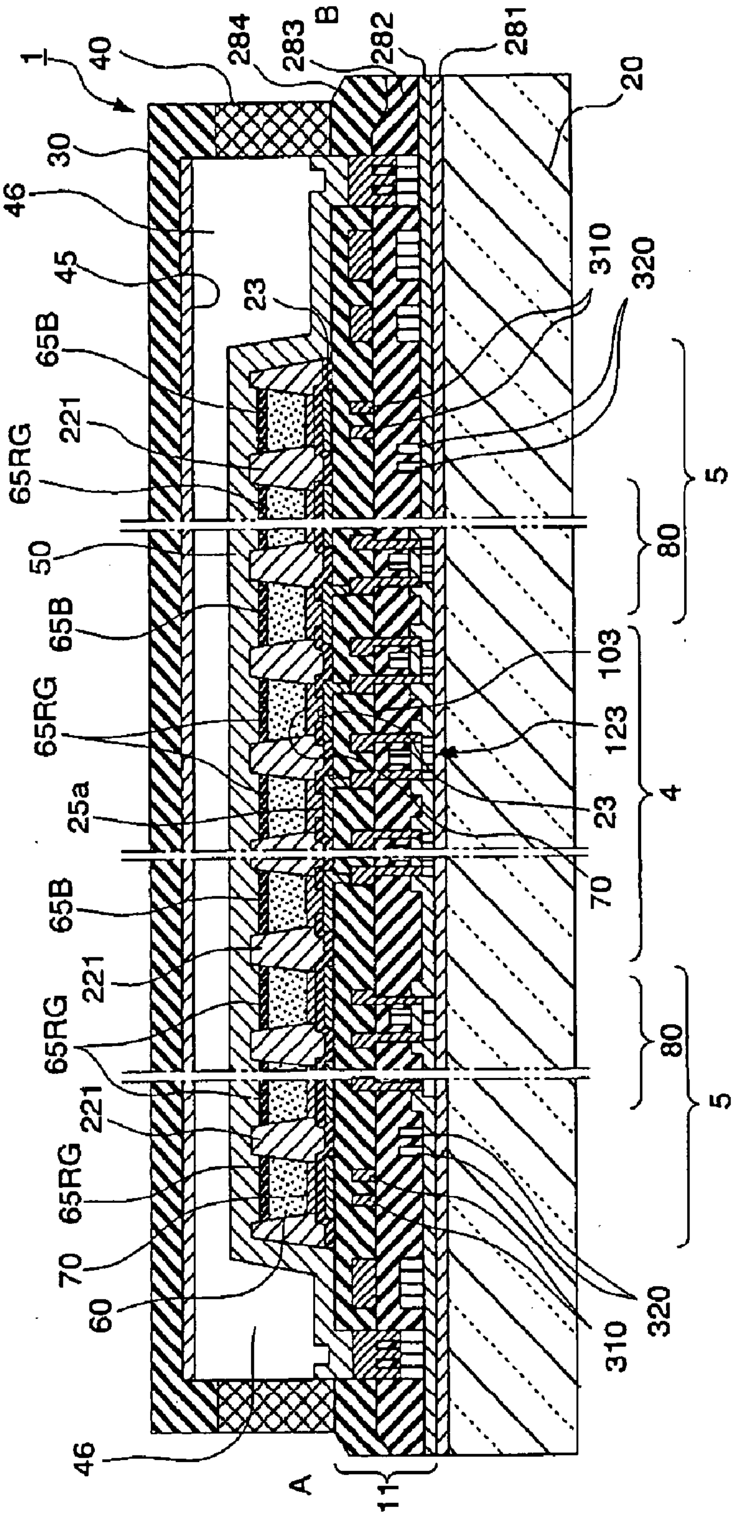
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Fig. 4

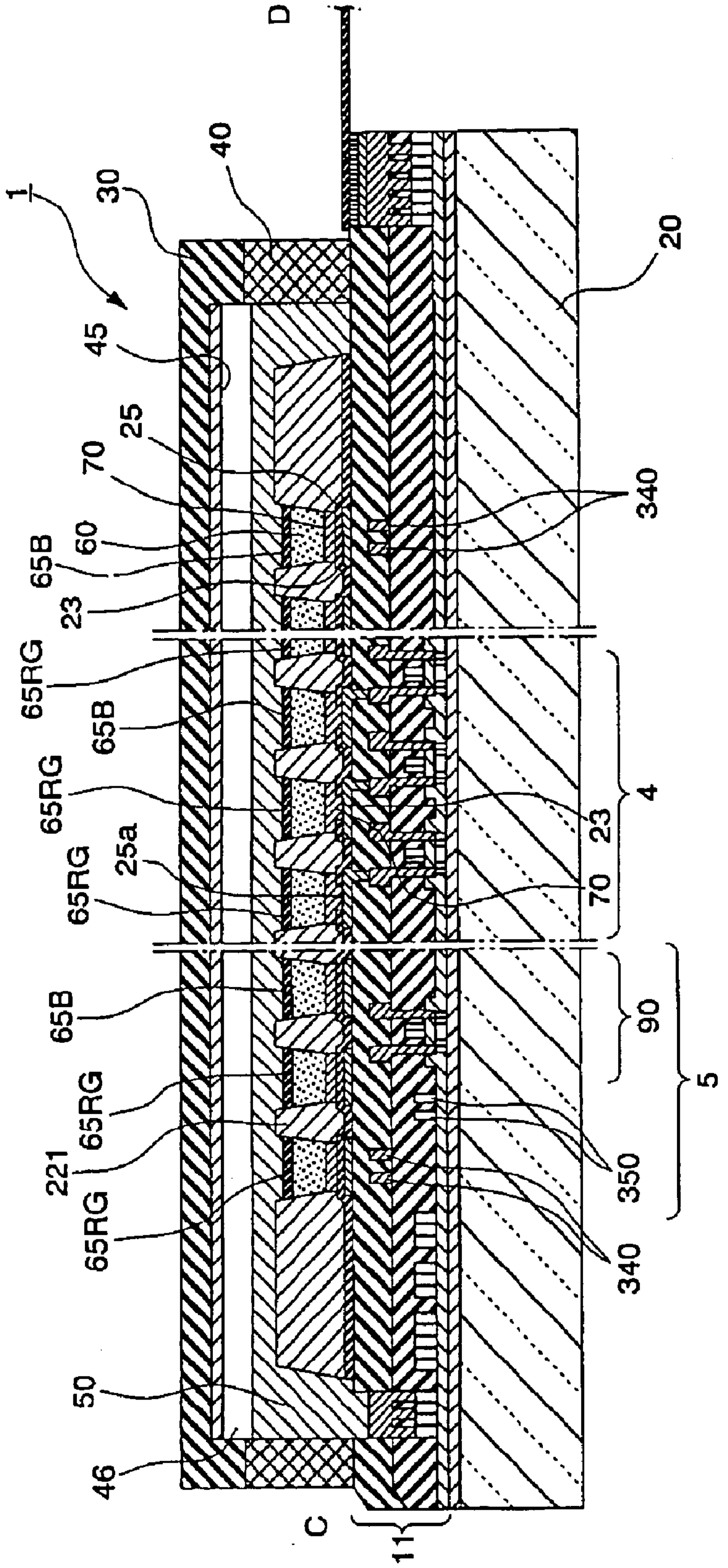
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Fig. 5

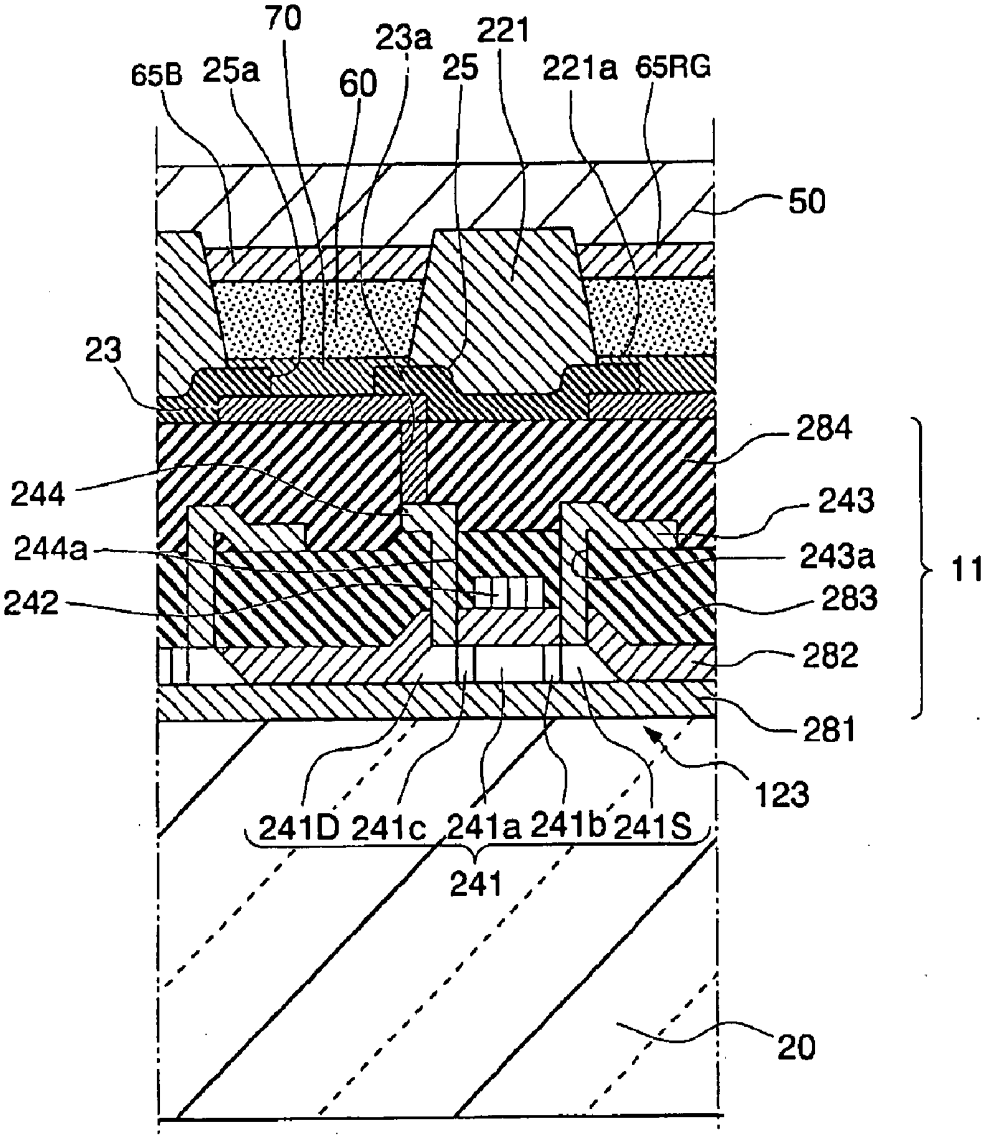
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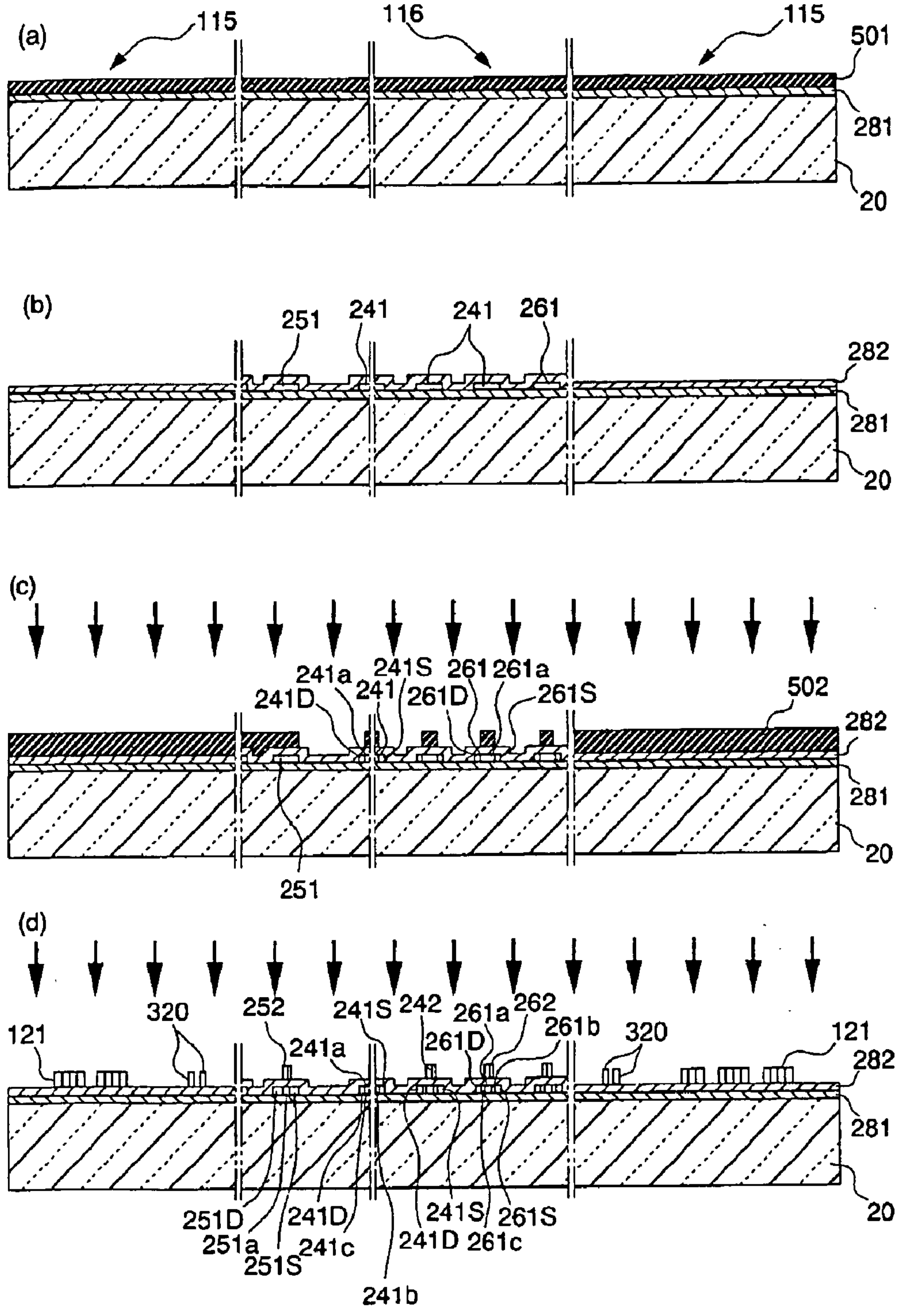
Fig. 6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(d)
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Fig. 7

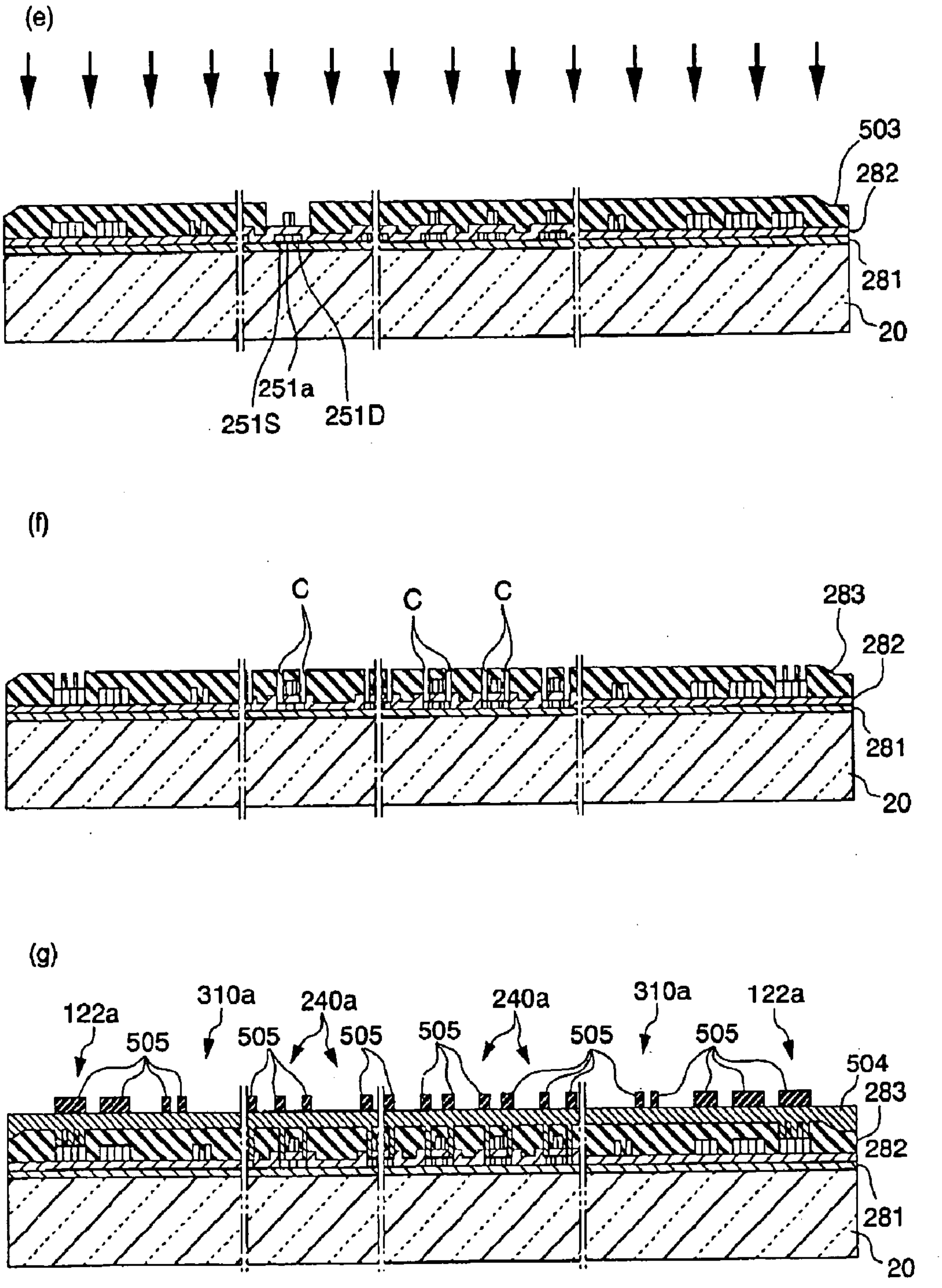
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Fig. 8

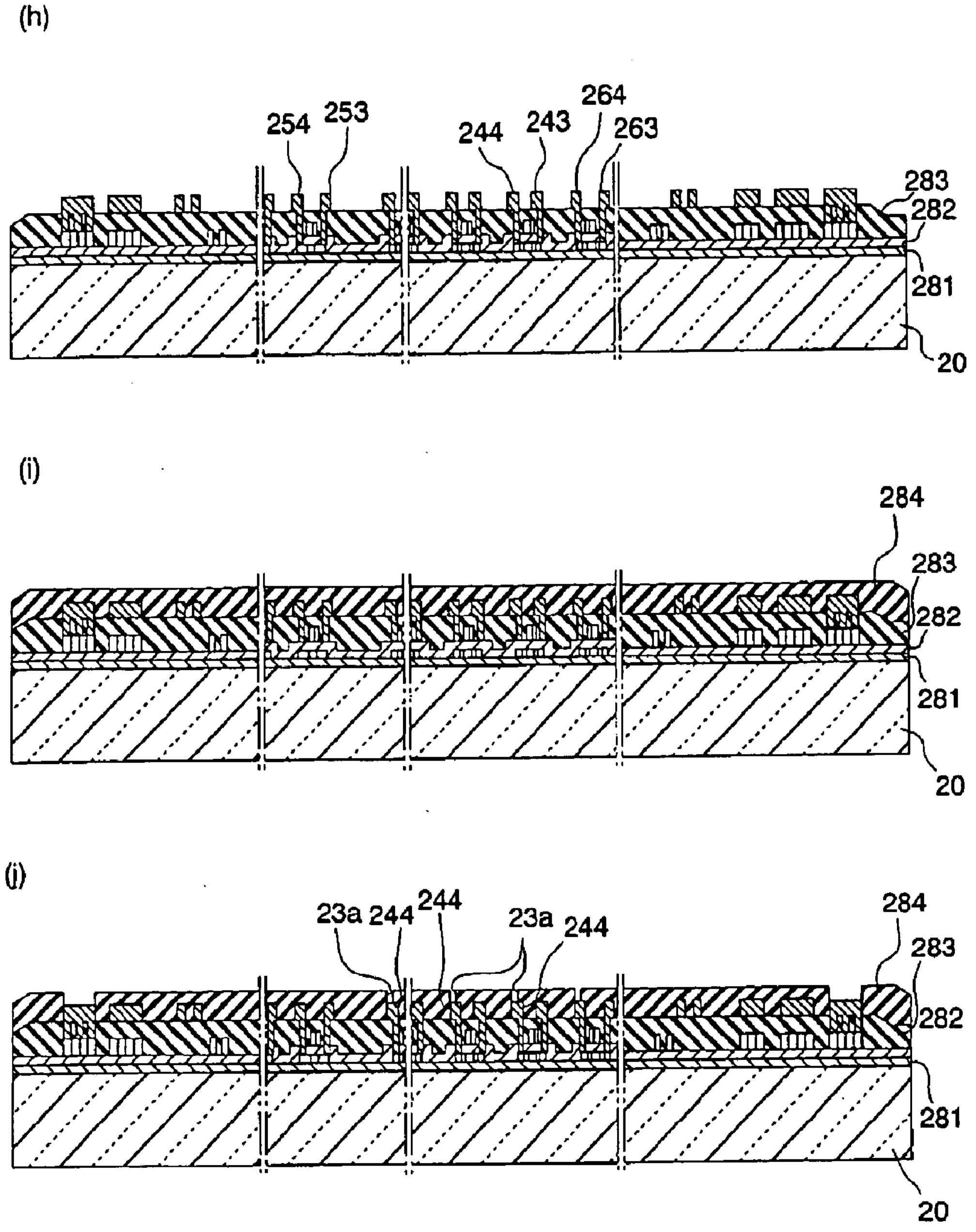
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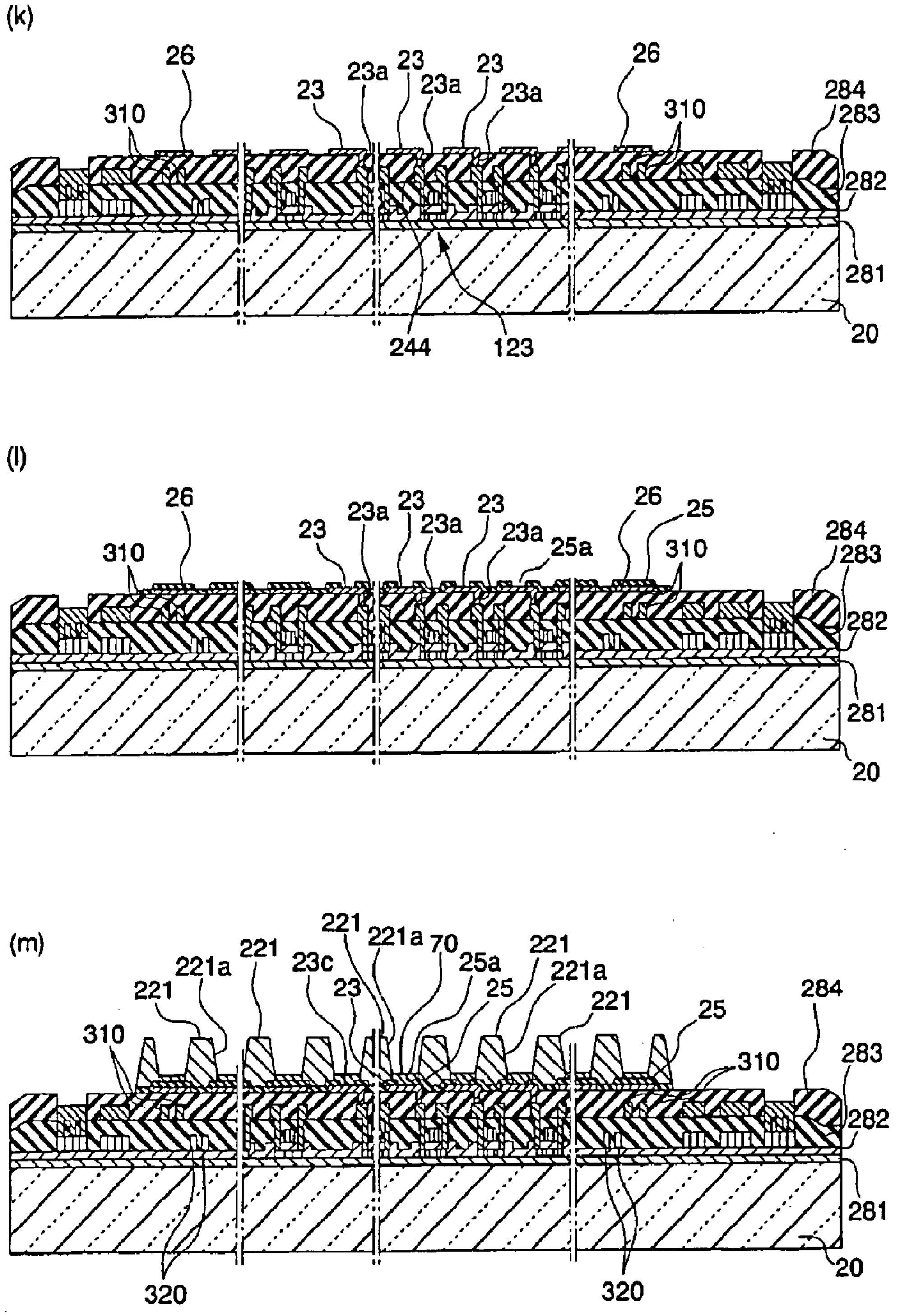
Fig. 9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(m)
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Fig. 10

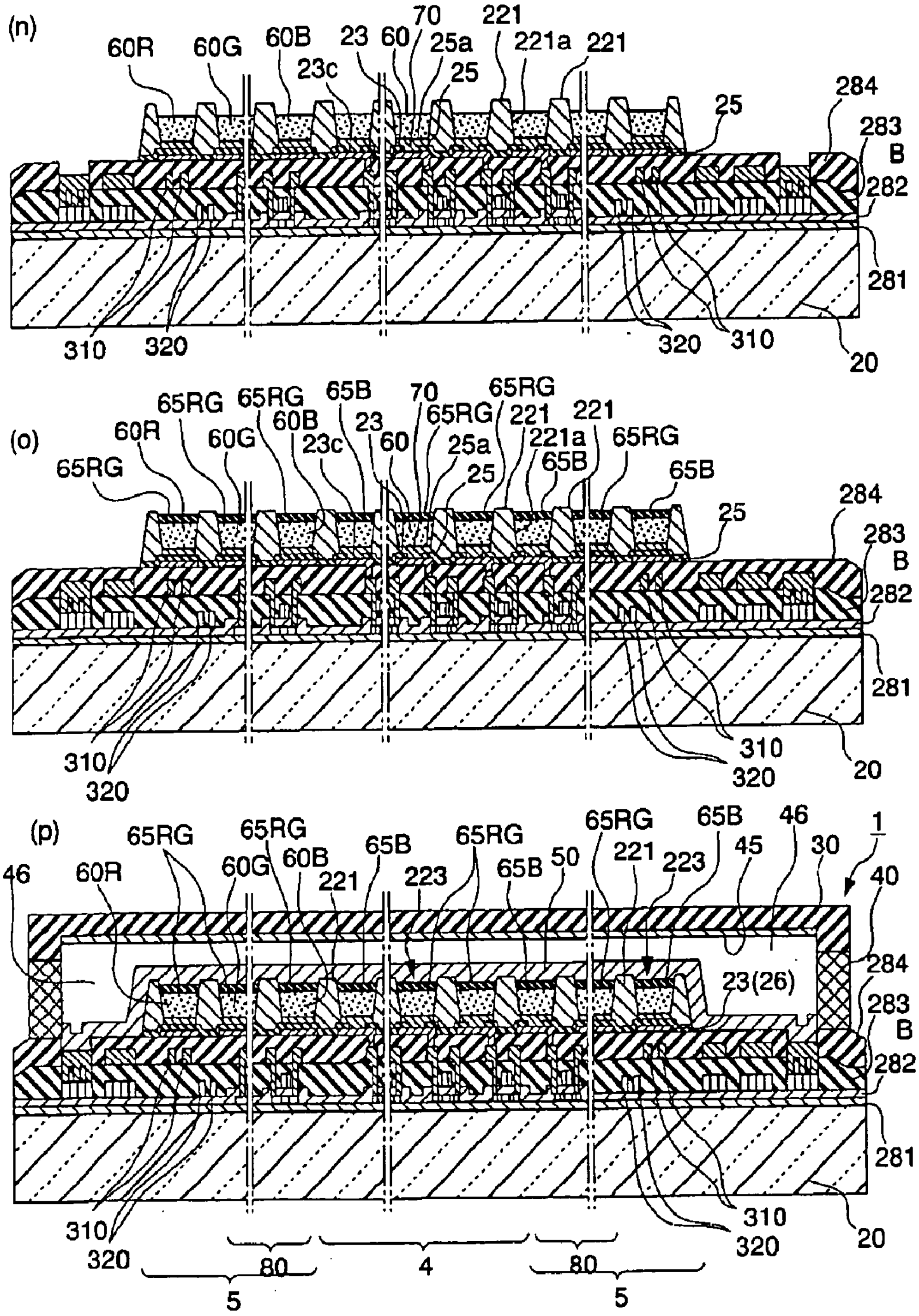
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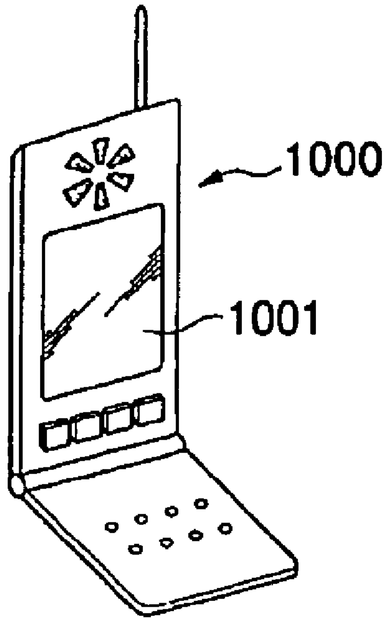
Fig. 11



METHOD OF FORMING THIN FILM OF ORGANOMETALLIC COMPOUND, THIN FILM OF ORGANOMETALLIC COMPOUND, METHOD OF MANUFACTURING ORGANOELECTRONIC DEVICE EQUIPPED WITH THE SAME, ORGANOELECTRONIC DEVICE, METHOD OF MANUFACTURING ORGANIC ELECTROLUMINESCENCE, ORGANIC ELECTROLUMINESCENCE, AND ELECTRONIC APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of Invention

[0002] Aspects of the invention can relate to a method of forming a thin film of an organometallic compound, a thin film of an organometallic compound, a method of manufacturing an organoelectronic device (e.g., an organic electroluminescence device, an organic solar battery, or an organic thin film transistor), an organoelectronic device, and an electronic apparatus.

[0003] 2. Description of Related Art

[0004] There have been various kinds of related organometallic compounds (organometallic complexes) whose applications have been widely spread to various fields. For example, related organic electroluminescence devices (hereinafter referred to as an organic EL device) having chelate complexes embedded in their compound structures and solar batteries. See, for example, Appl. Phys. Lett., 51,913 (1987) and Japanese Unexamined Patent Publication No. 1-220380.

[0005] In such applications as organic ELs and solar batteries, there are many examples in which laminated structures formed of thin film metallic complexes bound with electrodes. From the present view point, a method of stably fabricating thin films is very significant.

[0006] In related fabrication methods of, such thin films, the thin films have been fabricated using materials already combined as complexes by, for example, previously mixing ligands with metals. And, as fabrication processes of such thin films, not only vapor phase processes such as a vacuum deposition process but also liquid phase processes in which materials are deposited as their solutions have been used.

SUMMARY OF THE INVENTION

[0007] However, as a matter of fact, some of organometallic compound (organometallic complex) materials are so unstable as to be decomposed under influence of heat or the like during the forming processes to lose their functions. In particular, stacked structures are easy to be influenced in junction interfaces of the layers.

[0008] Aspects of the invention can provide a method of fabricating an organometallic compound film capable, by stably forming a film with the organometallic compound, of increasing bonding forces of junction interfaces and of realizing a hyper thin film, the organometallic compound film, and an organoelectronic device (e.g., an organic electroluminescence device, an organic solar battery, or an organic thin film transistor) and an electronic apparatus.

[0009] To achieve the above object, the invention can adopt the following exemplary configurations. A method of fabricating a thin film of an organometallic compound according to the invention is a method of fabricating a thin film of an organometallic compound on a substrate and can include the step of forming an organic matter by a liquid phase process and the step of forming metal by a vapor phase process to form a thin film of an organometallic compound composed of the organic matter and the metal.

[0010] Here, a liquid phase process is also called a wet process or a wet deposition process, and is a process of making a substrate and a liquid material be contacted with each other, and denotes an inkjet (droplet discharge) method, a spin-coat method, a slit-coat method, a dip-coat method, a spray deposition method, a printing method, a liquid discharge method, and so on. Note that after executing the liquid phase process, a thermal process for desiccating and heating the liquid material is generally executed.

[0011] In contrast, a vapor phase process is a process for depositing a desired gas material on a substrate in vacuum or in a vapor phase atmosphere, and denotes z vapor deposition process, a sputtering process, a CVD (chemical vapor deposition) process or the like.

[0012] Further, an organic matter denotes a ligand of a complex or the like, but is not limited thereto, what is more suitable for deposition by a liquid phase process because its molecule is easy to be decomposed by a vapor phase process. Further, metal denotes the central metal in a complex, but is not limited thereto, what is more suitable for deposition by a vapor phase process. Note that the order of the step of forming an organic matter and the step of forming metal is not limited for the present.

[0013] According to the invention, by depositing a desired organic matter by a liquid phase process and depositing a desired metal by a vapor phase process, a stable organometallic layer can be formed in the junction interface between the organic matter and the metal. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed only in the junction interface, a very thin film of, for example, one molecule thick can be formed.

[0014] Further, assuming an organic matter is A and metal is B, by depositing the organic matter A by a liquid phase process and depositing metal B by a vapor phase process, the organometallic compound MAn (n denotes the valence of the metal M) can be formed simultaneously with the deposition.

[0015] Further, in the method of fabricating an organometallic compound thin film, a thin film of an organometallic compound can preferably be formed by forming an organic matter and then forming metal on the organic matter. Thus, the organometallic compound thin film can be formed in accordance with the previously formed organic matter. Further, if an inkjet method is used as a liquid phase process for forming an organic matter, the organic matter can be formed in a predetermined pattern, and accordingly, the thin film of the organometallic compound having a predetermined pattern can be formed.

[**0016**] Further, in the method of fabricating an organometallic compound thin film, a thin film of an organometallic compound is preferably formed by forming metal and then forming an organic matter on the metal. Thus, the organometallic compound thin film can be formed in accordance with the previously formed metal.

[**0017**] Further, in the method of fabricating an organometallic compound thin film, the liquid phase process is preferably a droplet discharge method. Thus, the organic matter can selectively be positioned and deposited by a droplet discharge method. Further, a number of kinds of organic matters can separately be coated in accordance with the kind of the object of droplet ejection.

[**0018**] Further, an organometallic compound of the invention is formed by the method of fabricating an organometallic compound thin film described previously. Therefore, the same advantages as described are obtained.

[**0019**] Further, the organometallic compound thin film according to the invention preferably has the thickness of one of equal to and less than 1 nm. Thus, a very thin film with the thickness of about one molecule can be formed.

[**0020**] Further, a method of fabricating an organoelectronic device according to the invention can include the step of forming an organic functional layer, the step of forming a charge transfer layer; and the step of forming an electrode. The step of forming a charge transfer layer comprises the step of forming an organic matter by a liquid phase process and the step of forming metal by a vapor phase process, whereby forming a thin film of an organometallic compound composed of the organic matter and the metal.

[**0021**] According to the invention, by depositing a desired organic matter by a liquid phase process and depositing a desired metal by a vapor phase process, a stable organometallic complex layer can be formed in the junction interface between the organic matter and the metal. Therefore, if an unstable organic material is used, the conventional problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed only in the junction interface, a very thin film of, for example, one molecule thick can be formed.

[**0022**] Note that, in the invention, a charge transfer layer can denote an electron injection layer or an electron transfer layer which are film layers for supplying electrons to an organic functional layer and having an electron injection property or an electron transfer property, or a hole blocking layer for blocking electron holes and making them stay in an organic functional layer. Alternatively, it can denote a hole injection layer or a hole transfer layer which are film layers for supplying electron holes to an organic functional layer and having an electron hole injection property or an electron hole transfer property.

[**0023**] Further, in the method of fabricating an organoelectronic device, the organometallic compound can be preferably an organometallic complex, and the central atom of the organometallic complex preferably can include the same metallic element as at least one of composing elements of the electrode, and further, the organometallic complex is preferably a β-diketone complex.

[**0024**] Here, organometallic complexes having various structures, such as chelate complexes or crown ether complexes can be used. Among the above, complexes having the β-diketone based ligand (β-diketone complexes) are preferable because they are acidity reagents and multidentate ligands with oxygen to form stable metallic complexes.

[**0025**] Further, by using the same element for the central atom of the complex as the element composing the electrode, the bonding force of the interfacial surface therebetween can be further increased to provide a further enhanced charge transfer effect. In this case, it is sufficient that the complex takes the composing element of the cathode adjacent to the interfacial surface as its center atom, and if the cathode is formed of a plurality of thin films laminated with each other, it is enough that the center atom of the complex is the same as the composing element of the thin film disposed nearest to the electron injection layer out of the layers.

[**0026**] Further if the electron injection efficiency needs to be enhanced as a electronic device, the cathode can be preferably composed of a certain metallic element with low work function (e.g., alkali metal, alkali-earth metal, magnesium, or rare-earth elements). Note that such metallic elements are enough to present at least in the interfacial surface with the electron injection layer, and if, for example, the cathode is formed of a plurality of films laminated with each other, it is enough that only the nearest film to the electron injection layer is composed of the low work function metal element described above. Further, if the center atom of the complex is composed of the same metallic element with low work function (e.g., alkali metal, alkali-earth metal, magnesium, rare-earth elements), adhesiveness between the cathode and the electron injection layer can be enhanced, and electron injection barriers can also be reduced, resulting in a further enhanced light emission efficiency.

[**0027**] Further, in the method of fabricating an organoelectronic device, a thin film of an organometallic compound can be preferably formed by forming an organic matter and then forming metal on the organic matter in the step of forming a charge transfer layer. Thus, the organometallic compound thin film can be formed in accordance with the previously formed organic matter. Further, if an inkjet method (a droplet discharge method) is used as a liquid phase process for forming an organic matter, the organic matter can be formed in a predetermined pattern, and accordingly, the thin film of the organometallic compound having a predetermined pattern can be formed.

[**0028**] Further, in the method of fabricating an organoelectronic device, a thin film of an organometallic compound is preferably formed by forming metal and then forming an organic matter on the metal in the step of forming a charge transfer layer. Thus, the organometallic compound thin film can be formed in accordance with the previously formed metal. Further, if an inkjet method is used as a liquid phase process for forming an organic matter, the organic matter can be formed in a predetermined pattern, and accordingly, the thin film of the organometallic compound having a predetermined pattern can be formed.

[**0029**] Further, in the method of fabricating an organoelectronic device, the liquid phase process is preferably a droplet discharge method. Thus, the organic matter can selectively be positioned and deposited by a droplet discharge method. Therefore, for example, the organic matter can selectively be formed only on the predetermined kind of organic functional layer. Further, a number of kinds of organic matters can separately be coated in accordance with the kind of the object of droplet ejection.

[0030] Further, an organoelectronic device according to the invention can be fabricated by the method of fabricating an organoelectronic device described above.

[0031] According to the invention, by depositing a desired organic matter by a liquid phase process and depositing a desired metal by a vapor phase process, a stable organometallic complex layer can be formed in the junction interface between the organic matter and the metal. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed only in the junction interface, a very thin film of, for example, one molecule thick can be formed.

[0032] Further, an electronic apparatus according to the invention is equipped with the organoelectronic device described above. Thus, an electronic apparatus which can enjoy a long life and obtain a blight display can be provided.

[0033] Further, a method of fabricating an organic EL device can include the step of forming a blue light emitting layer, a green light emitting layer, and a red light emitting layer. The step of forming a first electron injection layer on the blue light emitting layer, and the step of forming a second electron injection layer and a third electron injection layer respectively on the green light emitting layer and the red light emitting layer. The step of forming a second electron injection layer and a third electron injection layer can include the step of forming an organic matter by a liquid phase process and the step of forming metal by a vapor phase process, and the second electron injection layer and the third electron injection layer comprise an organometallic compound comprising the organic matter and the metal.

[0034] In this case, to realize full color display by the organic EL device, as organic light emitting layers having mutually different colors, the blue, green, and red light emitting layers are disposed in a plane on the substrate. However, if the plural light emitting layers are provided, the most suitable complex material may be different with respect to each of the light emitting layers. Therefore, if the structure described above is adopted, the most suitable complex is preferably selected in accordance with each of the light emitting layers, and a number of kinds of selected complex are preferably included in a mixed manner in the electron injection layer. By making all of the most suitable complexes for respective light emitting layers be included in the electron injection layer, the electron injection layer which provides an excellent electron injection effect for every light emitting element can be formed. Further, color balance can be adjusted by alter the mixing ratio of each complex. In other words, it is possible that the electron injection layers are respectively provided for the light emitting layers, and each of the electron injection layers provided for the respective light emitting layers includes only the complex selected for the corresponding light emitting layer. By thus configuration, materials can be designed to be best suitable for each of the light emitting layers, and color balance of each light emitting layer can easily be adjusted.

[0035] Therefore, according to the invention, since the organometallic compound formed by depositing desired organic matter by a liquid phase process, and by depositing desired metal by a vapor phase process, becomes the second electron injection layer and the third electron injection layer, a stable organometallic complex layer can be formed in the junction interface between the organic matter and the metal. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed only in the junction interface, a very thin film of, for example, one molecule thick can be formed. Accordingly, since the light emission efficiency of each of blue, green, and red light emitting layers is improved, the colored light emission with high contrast and good depth can be realized.

[0036] Further, in the method of fabricating an organic EL device according to the invention, the organometallic compound can be preferably an organometallic complex, and the central atom of the organometallic complex preferably comprises the same metallic element as at least one of composing elements of the electrode, and further, the organometallic complex is preferably a β-diketone complex. Here, organometallic complexes having various structures such as chelate complexes or crown ether complexes can be used. Among the above, complexes having the â-diketone based ligand (â-diketone complexes) are preferable because they are acidity reagents and multidentate ligands with oxygen to form stable metallic complexes.

[0037] Further, by using the same element for the central atom of the complex as at least one of the element composing the second cathode or the third cathode, the bonding force of the interfacial surface therebetween can be further increased to provide a further enhanced electron injection effect. In this case, it is sufficient that the complex takes the composing element of the cathode adjacent to the interfacial surface as its center atom, and if, for example, the cathode is formed of a plurality of thin films laminated with each other, it is enough that the center atom of the complex is the same as the composing element of the thin film disposed nearest to the electron injection layer out of the layers.

[0038] Further, in the method of fabricating an organic EL device according to the invention a thin film of an organometallic compound is preferably formed by forming an organic matter and then forming metal on the organic matter in the step of forming a second electron injection layer and a third electron injection layer. Thus, the organometallic compound thin film, namely the second electron injection layer and the third electron injection layer can be formed in accordance with the previously formed organic matter. Further, if an inkjet method (a droplet discharge method) is used as a liquid phase process for forming an organic matter, the organic matter can be formed in a predetermined pattern, and accordingly, the thin film of the organometallic compound can selectively be formed to form the second electron injection layer and the third electron injection layer having a predetermined pattern.

[0039] Further, in the method of fabricating an organic EL device according to the invention a thin film of an organometallic compound is preferably formed by forming metal and then forming an organic matter on the metal in the step of forming a second electron injection layer and a third electron injection layer. Thus, the organometallic compound thin film can be formed in accordance with the previously formed metal. Further, if an ink-jet method is used as a liquid phase process for forming an organic matter, the organic matter can be formed in a predetermined pattern, and accordingly, the thin film of the organometallic compound can selectively be formed to form the second electron injection layer and the third electron injection layer having a predetermined pattern.

[0040] Further, in the method of fabricating an organic EL device according to the invention, the liquid phase process can be preferably a droplet discharge method. Thus, the first electron injection layer, the second electron layer, and the third electron injection layer can selectively be formed by a droplet discharge method.

[0041] Accordingly, a first electron transfer layer can selectively be formed only on the light emitting layer for emitting a blue beam, a second electron transfer layer can selectively be formed only on the light emitting layer for emitting a green beam, and a third electron transfer layer can selectively be formed only on the light emitting layer for emitting a red beam.

[0042] Further, an organic EL device according to the invention can be fabricated by the method of fabricating an organic EL device described above.

[0043] According to the invention, since the organometallic compound formed by depositing desired organic matter by a liquid phase process, and by depositing desired metal by a vapor phase process, becomes the second electron injection layer and the third electron injection layer, a stable organometallic complex layer can be formed in the junction interface between the organic matter and the metal. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed only in the junction interface, a very thin film of, for example, one molecule thick can be formed. Accordingly, since the light emission efficiency of each of blue, green, and red light emitting layers is improved, the colored light emission with high contrast and good depth can be realized.

[0044] Further, an electronic apparatus according to the invention is equipped with the organic EL device described above. Thus, an electronic apparatus capable of providing display, in which the colored light emission with high contrast and good depth can be realized, can be provided.

[0045] Further, an organoelectronic device according to the invention can be equipped with the organometallic compound thin film described above. Therefore, the same advantages as described are obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] The invention will be described with reference to the accompanying drawings, wherein like numerals reference like elements, and wherein:

[0047] **FIG. 1** is a schematic view showing a wiring structure of an organic EL device according to the invention;

[0048] **FIG. 2** is a plan view schematically showing a configuration of an organic EL device according to the invention;

[0049] **FIG. 3** is a cross-sectional view along the A-B line shown in **FIG. 2**;

[0050] **FIG. 4** is a cross-sectional view along the C-D line shown in **FIG. 2**;

[0051] **FIG. 5** is a cross-sectional view showing a relevant part of **FIG. 3** enlarged;

[0052] **FIG. 6** is a cross-sectional view for explaining a fabrication method of an organic EL device in the order of the process steps;

[0053] **FIG. 7** is a cross-sectional view for explaining the process steps following **FIG. 6**;

[0054] **FIG. 8** is a cross-sectional view for explaining the process steps following **FIG. 7**;

[0055] **FIG. 9** is a cross-sectional view for explaining the process steps following **FIG. 8**;

[0056] **FIG. 10** is a cross-sectional view for explaining the process steps following **FIG. 9**; and

[0057] **FIG. 11** is a perspective view showing an electronic apparatus according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0058] Hereinafter, an organic EL device according to an exemplary embodiment of the invention is described.

[0059] **FIG. 1** is a view schematically showing an interconnection structure of the organic EL device according to the embodiment. The organic EL device **1** is an active matrix type of display device using thin film transistors (hereinafter abbreviated as TFT) as switching elements.

[0060] The organic EL device (an organoelectronic device equipment) **1** has, as shown in **FIG. 1**, a structure in which a plurality of scanning lines **101**, a plurality of data lines **102** each extending in a direction traversing the respective scanning lines **101** with the right angle, and a plurality of power supply lines **103** each extending in parallel to the respective data lines **102** are disposed, wherein a pixel area X is provided in each of intersections of the plurality of scanning lines **101** with the plurality of data lines **102**.

[0061] A data line driver circuit **100** equipped with a shift register, a level shifter, a video line, and an analog switch is connected to the data lines **102**. Further, a scanning line driver circuit **80** equipped with a shift register and a level shifter is connected to the scanning lines **101**.

[0062] Furthermore, in each pixel area X, there are provided a switching TFT **112** to which a scanning signal is supplied at its gate electrode via the scanning lines **101**, a hold capacitor **113** for holding a pixel signal supplied from the data lines **102** via the switching TFT **112**, a drive TFT **123** to which the pixel signal held by the hold capacitor **113** is supplied at its gate electrode, a pixel electrode (anode) **23** to which a drive current flows from the power supply lines **103** when electrically connected to the power supply lines via the switching TFT **112**, and a functional layer **110** sandwiched between the pixel electrode **23** and a cathode **50**. The pixel electrode **23**, the cathode **50**, and the functional layer **110** form a light emitting element (organic EL element).

[0063] According to the organic EL device **1**, when the scanning lines **101** is driven to turn on the switching TFT **112**, the current potential of the data line **102** is held by the hold capacitor **113**, and the on/off state of the drive TFT **123** is determined in accordance with the state of the hold capacitor **113**. Then, a current flows from the power supply line **103** to the pixel electrode **23** via the channel of the drive TFT **123**, and further to the cathode **50** via the functional layer **110**. The functional layer emits light in accordance with the current flowing therethrough.

[0064] Hereinafter, a specific structure of the organic EL device **1** according to the exemplary embodiment is described with reference to **FIGS. 2 through 5**.

[0065] Firstly, referring to **FIG. 2**, a planar structure of the organic EL device according to the embodiment is explained.

[0066] The organic EL device **1** of the embodiment can include a substrate having an electrically insulating property, a pixel electrode region (not shown in the drawings) having the pixel electrodes connected to the switching TFT (not shown in the drawings) and disposed on the substrate **20** in a matrix, the power supply lines (not shown in the drawings) disposed in the periphery of the pixel electrode region and connected to each of the pixel electrodes, and a pixel section **3** (inside the chain dashed line shown in **FIG. 2**) shaped nearly rectangular in plan view and disposed at least on the pixel electrode region. Note that in the invention, a substance which includes the substrate **20**, various circuits formed thereon, such as a switching TFT, and an interlayer insulating film is referred to as a base body. (denoted by reference numeral **200** in **FIGS. 3 and 4**).

[0067] The pixel section **3** is zoned into an actual display region **4** (inside the chain double dashed lines shown in **FIG. 2**) located in a center area thereof and a dummy region **5** (a region between the chain dashed lines and the chain double dashed lines) disposed around the actual display region **4**.

[0068] In the actual display region **4**, display areas R, G, B each including the pixel electrode are disposed in a matrix spaced in both A-B and C-D directions.

[0069] Further, in both sides of the actual display region **4** in **FIG. 2**, there are provided scanning line driver circuits **80**, **80**. These scanning line driver circuits **80**, **80** are disposed beneath the dummy region **5**.

[0070] Further, above the actual display region **4** in **FIG. 2**, there is disposed a testing circuit **90**. The testing circuit **90** is a circuit for examining the operating condition of the organic EL device **1**, and is equipped with, for example, an examination data output means (not shown in the drawings) for outputting the examination results to the outside to allow examination of quality or defects of display devices while manufacturing or when shipping. Note that the examination circuit **90** is also disposed beneath the dummy region **5**.

[0071] To the scanning line driver circuits **80** and the examination circuit **90**, their drive voltages are applied from a predetermined power source section via a drive voltage conducting section **310** (See **FIG. 3**.) and a drive voltage conducting section **340** (See **FIG. 4**.). Further, drive control signals and drive voltages for the scanning driver circuits **80** and the examination circuit **90** are supplied or applied from a predetermined main driver or the like for controlling the operation of the organic EL device **1** via a drive signal conducting section **320** (See **FIG. 3**.) and a drive voltage conducting section **350** (See **FIG. 4**.). Note that the drive control signals in this case are command signals issued by the main driver or the like in relation to the control of the scanning line driver circuits **80** and examination circuit **90** issuing the signals.

[0072] Hereinafter, a cross-sectional structure of the present organic EL device is described referring to **FIGS. 3 through 5**. **FIGS. 3 and 4** are cross-sectional views along the A-B line shown in **FIG. 2**, and **FIG. 5** shows an enlarged view of a characterizing part thereof.

[0073] The present organic EL device **1** is formed of the substrate **20** and a sealing substrate **30** bonded to each other via sealing resin **40** in between.

[0074] Since so called bottom-emission type of organic EL devices have structures in which the emitted light is taken out from the substrate **20** side, transparent or translucent materials are adopted as the substrate **20**. For example, glass, quartz, resin (plastics, plastic films), and so forth can be cited as such materials, and in particular, soda glass which is inexpensive is preferably used.

[0075] In contrast, in case of a top-emission type of organic EL devices, since the structures are taken in which the emitted light is taken out from the sealing substrate **30** side opposite substrate **20**, either of transparent substrates or opaque substrates can be used as the substrate **20**. As a material of the opaque substrate, for example, thermoset resin, thermoplastic resin, and so on can be cited in addition to ceramics such as alumina, or metal sheets such as stainless sheets with insulating treatment such as surface oxidization.

[0076] As the sealing substrate **30**, for example, plate like members having electrically insulating property can be adopted. In particular, in case of top-emission type, transparent substrates such as glass substrates, quartz substrates, resin substrates, can be adopted as the sealing substrate **30**. Further, a sealing resin **40** is made, for example, of thermoset resin or ultraviolet curing resin, and in particular, preferably of epoxy resin which is a kind of thermoset resin.

[0077] Further, above the substrate **20**, there can be formed a circuit section **11** including the drive TFT **123** for driving the pixel electrode **23**, and so on, on which the light emitting element is provided. The light emitting element is formed of the pixel electrode **23**, the functional layer **110** composed mainly of the light emitting layer **60**, and the cathode **50** all stacked in this order.

[0078] The pixel electrode **23** functions as an anode for supplying positive holes to the light emitting layer **60**, and is made of, for example, in case of the bottom-emission type, transparent conductive materials, such as ITO (indium tin oxide), indium oxide-zinc oxide amorphous transparent conductive film (Indium Zinc Oxide: IZO (registered trade mark)) (proposed by Idemitsu Kosan Co. Ltd.) can be used. Further, in case of the top-emission type, not only such a transparent conductive material but also a light reflecting or opaque conductive material, such as aluminum (Al) or silver (Ag) can be utilized.

[0079] As the light emitting layer, known luminescence materials capable of generating fluorescence or phosphorescence can be used. Specifically, (poly)fluorene derivatives (PF), (poly) para-phenylenevinylene derivatives (PPV), polyphenylene derivatives (PP), poly-para-phenylene derivatives (PPP), polyvinylcarbazole (PVK), polythiophene derivatives, polydialkylfluorene (PDAF), polyfluorenebenzothiadiazole (PFBT), polyalkylthiophene (PAT), or polysilane-based materials such as polymethylphenylsilane (PMPS) can preferably be used.

[0080] Further, the above polymeric materials can be used with polymeric materials such as perylene dye, coumarin dye, or rhodamine dye, or with small molecular materials such as rubrene, perylene, 9,10-diphenylanthracene, tetraphenyl butadiene, nile red, coumarin 6, or quinacridone doped thereto.

[0081] Note that polymer denotes polymerized substance having a larger molecular weight than so-called small molecular having a molecular weight of about few hundreds, and the polymeric materials mentioned above include, in addition to generally-called polymers which are polymerized substances having molecular weights of no less than 10000, oligomeric substances called oligomer having molecular weights of no larger than 10000.

[0082] In the exemplary embodiment, light emitting layers respectively corresponding to R (red), G (green), and B (blue) are disposed in a plane for each pixel to realize full-color display.

[0083] Further, in the exemplary embodiment, a hole injection/transfer layer **70** (See **FIG. 5**.) can be provided between the pixel electrode **23** and the light emitting layer **60** as required. By providing the hole injection/transfer layer, electrons moving through the light emitting layer **60** can effectively be blocked to increase probability of recombining electrons with holes inside the light emitting layer. As the hole injection/transfer layer **70**, materials having low injection barrier with the pixel electrode **23** and high hole mobility are preferably used. As such materials, for example, polythiophene derivatives, polypyrrole derivatives, or materials derived from doping these materials can be used. Specifically, dispersion liquid of 3,4-polyethelenedioxithiophene/polystyrene-sulfonic-acid (PEDOT/PSS) (Product mane: Bytron-p, produced by Bayer MaterialScience AG), which is dispersion liquid made by dispersing 3,4-polyethelenedioxithiophene in polystyrene-sulfonic-acid and then further dispersed in water, is used, for example.

[0084] The cathode **50** has, as shown in **FIGS. 3 through 5**, the larger area than the total area of the actual display region **4** and the dummy region **5**, and is formed so as to cover these regions. As the cathode **50**, for example, in case of top-emission type, transparent conductive materials are used. As such transparent conductive materials, co-deposition film of bathocuproine (BCP) and cesium (Cs) can preferably be used. In this case, in order to provide further conductivity, a structure having an ITO layer stacked thereon is preferably adopted. Note that, instead of the co-deposition film of BCP and Cs, very thin film (e.g., a thin film having thickness of about 5 nm) of Ca can be formed with ITO layer stacked thereon. Further, in case of the top-emission type, not only such a transparent conductive material, but also a light reflecting or opaque conductive material, such as Al can also be used.

[0085] In this case, in order to increase electron injection efficiency, the cathode preferably includes a metallic element (e.g., alkaline metals, alkaline-earth metals, magnesium, rare-earth elements (except Pm)) with low work function as a composing element. Note that such metallic elements are enough to present on the interfacial surface with the light emitting layer **60**, and if, for example, the cathode is formed of a plurality of films laminated with each other, it is enough that only the nearest film to the light emitting layer **60** is composed of the low work function metal element described above. Specifically, by forming Ca film of about 20 nm and then forming Al film of about 200 nm thereon, a cathode with high electron injection efficiency can be obtained. In this case, Al film has an additional function of a reflecting layer for emitting generated light from a side of the substrate **20**.

[0086] Further, in the exemplary embodiment, in order for increasing efficiency of injecting electron from the cathode **50** to the light emitting layer **60**, between the cathode **50** and the light emitting layer **60**, there are formed electron injection layers (charge transfer layers) **65**B, **65**RG for injecting and transferring electron for each of light emitting layers **60** respectively emitting red (R), green (G), and blue (B) beams, wherein the electron injection layer **65**B is formed for the light emitting layer **60** emitting blue (B) beam, and the electron injection layer **65**RG is formed for the light emitting layers **60** respectively emitting red (R) and green (G) beams.

[0087] The electron injection layer **65**B is made of LiF (lithium fluoride). Note that other compounds than LiF can be used, and preferably, compounds such as oxides, fluorides, or chlorides including one of metallic elements selected from 1A or 2A group of the periodic table or rare-earth elements, for example, Li, Na, K, Rb, Cs, Mg, Ca, Sr, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.

[0088] Further, the electron injection layer **65**RG can be made of an organometallic complex which is an organometallic compound expressed by a following general equation where M denotes a central atom, A denotes a chelate ligand made of an organic material, and B denotes a neutral ligand. MA_nB_m (n: the balence of the central atom, m: a natural number) As such a metallic complex, complexes of various structures such as chelate complexes or crown ether complexes can be used.

[0089] Specifically, as the chelate ligand A, β-diketone based ligands, such as acetylacetone (acac), dipivaloylmethane (dpm), hexafluoroacetylacetone (hfa), 2,2,6,6,-tetramethyl-3,5-octanedioacetone (TMOD), thenoyltrifluoroacetone (TTA), or 1-phenyl-3-isohepti-1,3-propanedione (Product name: LIX54, LIX51, produced by Henkel KGaA), quinolinol based ligends such as 8-quinolinol (oxine), 2-methil-8-quinolinol, phosphoric acid based ligands such as trioctylhofphineoxide (TOPO), tributyl phosphate (TBP), isobutyl methyl ketone (MBK), or bis(2-ethylhexyl)phosphoric acid (D2EHPA), carboxylic acid based ligands such as acetic acid or benzoic acid, or diphenylthiocarbazone ligand can preferably be used.

[**0090**] Among the above, complexes having the β-diketone based ligand (β-diketone complexes) are preferable because they are acidity reagents and multidentate ligands with oxygen to form stable metallic complexes.

[**0091**] Further, as the neutral ligands, heterocyclicamine, pyridine (py), or the like such as 2,2'-bipyridine (bpy), 1,10-phenanthroline (phen), 2,9-dimethyl-1,10-phenanthroline (dmp), bathophenanthroline (b-phen), bathocuproine (bcp) can preferably be used.

[**0092**] Note that, in the electron injection layer **65**RG, in order to increase the bonding force of the electron injection layer **65**RG and the cathode **50**, the center atom M can be composed of the same metallic element as the metallic element forming the cathode **50**. In this case, it is sufficient that the center atom M is the same as the composing element of the cathode which is located near the interfacial surface with the electron injection layer **65**RG, and if the cathode is formed of a plurality of thin films laminated with each other, it is enough that the center atom M is the same as the composing element of the thin film disposed nearest to the electron injection layer out of the layers. Specifically, if the cathode **50** is formed of a single layer film of Al, $Al(acac)_2$ having the same metallic element in the center atom is used as the complex mentioned above. Further, if the cathode **50** is formed of a laminated film of Ca and Al, $Ca(acac)_2$ or the like having Ca, which is disposed nearer to the electron injection layer, as the center atom, if a co-deposition film of BCP and Cs is used as the cathode **50**, Cs(acac) or the like is used for the complex mentioned above.

[**0093**] Note that, if the cathode **50** is composed of a certain metallic element with low work function, the center atom M of the complex is to be composed of a metallic element such as alkali metal, alkali-earth metal, magnesium, rare-earth elements, since such complexes have high electron affinity and small electron injection barriers, the light emission efficiency is further enhanced.

[**0094**] As described above, in the exemplary embodiment, suitable materials to the respective light emitting layers are mixed in the electron injection layer. In other words, if a plurality of kinds of light emitting layers, R, G, and B are provided in each pixel, as is the case with the exemplary embodiment, the most suitable material for each light emitting layer, for example, LiF for the electron injection layer **65**B, an organometallic complex for the electron injection layer **65**RG, is formed. As described above, by mixing the suitable organometallic complexes to the respective light emitting layer in the corresponding electron injection layers **65**B, **65**RG to compensate functions among each other, the light emitting efficiency can further be enhanced. Note that, although LiF is adopted as the electron injection layer **65**B, a complex having Li as the center metal can also be adopted.

[**0095**] Alternatively, it is possible to select the most suitable material and metallic complex for each light emitting layer and to selectively provide it to the corresponding light emitting layer. In other words, it is possible that the electron injection layers are respectively provided for the light emitting layers, and each of the electron injection layers provided for the respective light emitting layers includes only the complex selected for the corresponding light emitting layer. By this configuration, materials are designed to be best suitable for each of the light emitting layers. Further, in this case, color balance of each light emitting layer can easily be adjusted.

[**0096**] Still further, the organometallic complexes can be used alone or also mixedly with conventional materials having electron transferring properties. As such known electron transferring materials, cyclopentadiene derivatives, oxadiazole derivatives, bisstyrylbenzene derivatives, p-phenylene compounds, phenantroline derivatives, and triazole derivatives can be cited. Further, the thickness of the electron injection layer **65**RG is preferably 0.1 nm through 1.0 nm for ensuring necessary conductivity.

[**0097**] Hereinafter, a configuration of the circuit section for driving the light emitting elements is described referring to **FIG. 5**.

[**0098**] Under the light emitting elements, there is provided circuit section **11**, as shown in **FIG. 5**. The circuit section **11** is formed on the substrate **20** to compose the base body **200**. Namely, a priming protective layer **281** consisting mainly of SiO_2 is formed on a surface of the substrate **20** as a priming, above which a silicon layer **241** is formed. On a surface of the silicon layer **241**, there is formed a gate insulation layer **282** consisting mainly of SiO_2 or SiN.

[**0099**] Further, an area of the silicon layer **241** overlapping a gate electrode **242** across the gate insulation layer **282** is defined as channel region **241***a*. Note that the gate electrode **242** is a part of the scanning line **101** not shown in the Figure. Meanwhile, on the surface of the gate insulation layer **282** which covers the silicon layer **241** and has the gate electrode **242** formed thereon, there is formed a first interlayer insulation layer **282** consisting mainly of SiO_2.

[**0100**] Further, in the silicon layer **241**, adjacent to the source side of the channel region **241***a*, there are provided a low-concentration source region **241***b* and a high-concentration source region **241**S, and adjacent to the drain side of the channel region **241***a*, there are provided low-concentration drain region **241***c* and high-concentration drain region **241**D, which makes a so-called LDD (Lightly Doped Drain) structure. Out of these elements, the high-concentration source region **241**S is connected to a source electrode **243** via a contact hole **243***a* which opens through the gate insulation layer **282** and the first interlayer insulation layer **283**. The source electrode **243** is formed as a part of the power supply lines **103** (See **FIG. 1**. In **FIG. 5**, it is located at the source electrode **243** and extends in a direction perpendicular to the sheet.). Meanwhile, the high-concentration drain region **241**D is connected to a drain electrode **244** consisting of the same layer as the source electrode **243** via a contact hole **244***a* which opens through the gate insulation layer **282** and the first interlayer insulation layer **283**.

[**0101**] The upper surface of the first interlayer insulation layer **283**, on which the source electrode **243** and the drain electrode **244** are formed, is covered with a second interlayer insulation layer **284** consisting mainly of, for example, an acrylic resin component. As the second interlayer insulation layer **284**, other materials than the acrylic insulation films, for example, silicic compounds such as SiN or SiO_2 can be used as well. As described above, if silicic compounds having high gas barrier properties, particularly silicic nitrogen compounds are used as the second interlayer insulation layer **282**, oxygen or water can be prevented from entering into the light emitting layer **60** from the substrate side even with the substrate **20** made of resin having high moisture permeability to lengthen the life of the light emitting elements.

[0102] And, on the surface of the second interlayer insulation layer **284**, there is formed the pixel electrode **23** made of ITO, which is connected to the drain electrode **244** via a contact hole **23***a* provided through the second interlayer insulation layer **284**. Namely, the pixel electrode **23** is connected to the high-concentration drain region **241**D of the silicon layer **241** via the drain electrode **244**.

[0103] Note that TFT (TFT for driver circuits) included in the scanning line driver circuit **80** and the examination circuit **90**, that is, for example, N-channel type or P-channel type of TFT forming inverters included in shift registers of such circuits have substantially the same structure as the driver TFT **123** described above except that they are not connected to the pixel electrodes **23**.

[0104] On the surface of the second interlayer insulation layer **284**, where the pixel electrodes **23** are formed, there is provided, in addition to the pixel electrodes **23**, a bank structure comprising the lyophilicity control layer **25** described above and an organic bank layer **221**. The lyophilicity control layer **25** consists mainly of a lyophilic material such as, for example, SiO2, and the organic bank layer **221** is made of, for example, acrylic or polyimide. And, above the pixel electrode **23** and inside an opening **25***a* provided in the lyophilicity control layer **25** and inside an opening **221***a* defined by the organic bank **221**, there are stacked the hole injection/transfer layer **70** and the light emitting layer **60** in this order. Note that the word lyophilic subject to the lyophilicity control layer **25** of the exemplary embodiment means that it has relatively higher lyophilicity in comparison to at least the material forming the organic bank layer, i.e., acrylic or polyimide.

[0105] The layers up to the second interlayer insulation layer **284** above the substrate **20** as described above form the circuit section **11**.

[0106] Hereinafter, as an exemplary embodiment of the invention, an example of a fabrication method of the organic EL device **1** described above is described with reference to **FIGS. 6 through 9**. Note that each of cross-sectional views shown in **FIGS. 6 through 9** corresponds to a cross-sectional view along the A-B line shown in **FIG. 2**.

[0107] Firstly, as shown in **FIG. 6**(*a*), the priming protective layer **281** is formed on the surface of the substrate **20**. And then, after an amorphous silicon layer **501** is formed on the priming protective layer **281** using an ICVD process, a plasma CVD process, or the like, the amorphous silicon layer **501** is turned to be a polysilicon layer by growing crystal grain using a laser annealing process or a rapid thermal process.

[0108] Then, as shown in **FIG. 6**(*b*), the polysilicon layer is patterned by a photolithography process to form discrete silicon layers **241**, **251**, and **261**. In these discrete silicon layers, the silicon layer **241** is formed inside the display region to compose the driver TFT **123** connected to the pixel electrode **23**, and the silicon layers **251** and **261** form P-channel type and N-channel type of TFT (TFT for driver circuit) included in the scanning line driver circuit **80**.

[0109] Next, the gate insulation layer **282** is formed over the whole of the silicon layers **241**, **251**, and **261**, and the priming protective layer **281** with a silicon oxide film having thickness of about 30 nm to 200 nm using a plasma CVD process, a thermal oxidation method, or the like. Note that, when the gate insulation layer is formed using a thermal oxidation process, crystallization of the silicon layers **241**, **251**, and **261** can be executed to obtain polysilicon layers.

[0110] Further, if channel doping is to be carried out on the silicon layers **241**, **251**, and **261**, for example, boron ion is implanted at this timing with dose amount of about 1×10^{12} cm^{-2}. As a result, the silicon layers **241**, **251**, and **261** become low concentration P-type silicon layers having impurity concentration (estimated based on the impurities remaining after activation annealing) of about 1×10^{17} cm^{-3}.

[0111] Then, an ion implanting selection mask is formed on a part of channel layers of the P-channel type of TFT and the N-channel type of TFT followed by implanting the phosphorous ion with dose amount of about 1×10^{15} cm^{-2} in this situation. As a result, the high concentration impurities are introduced in a self-aligning manner to the patterning mask, and, as shown in **FIG. 6**(*c*), the high concentration source regions **241**S and **261**S, and the high concentration drain regions **241**D and **261**D are respectively formed in the silicon layers **241** and **261**.

[0112] Then, as shown in **FIG. 6**(*c*), a conductive layer **502** for forming gate electrodes made of doped silicon or silicide film, or a metal film, such as an aluminum film, a chromium film, or tantalum film is formed over the whole surface of the gate insulation layer **282**. The thickness of the conductive layer **502** is about 500 nm. After then, using a patterning method, as shown in **FIG. 6**(*d*), a gate electrode **252** for forming the P-channel type of driver circuit TFT, a gate electrode **242** for forming the pixel TFT, and a gate electrode **262** for forming the N-channel type of driver circuit TFT are formed. Further, a drive control signal conducting section **320** (**350**) and a first layer **121** of a cathode power supply line are also formed at the same time. Note that, in this case, the drive control signal conducting section **320** (**350**) is disposed in the dummy region **5**.

[0113] Subsequently, as shown in **FIG. 6**(*d*), using the gate electrodes **242**, **252**, and **262** as masks, phosphorous ion is implanted to the silicon layers **241**, **251**, and **261** with dose amount of about 4×10^{13} cm^{-2}. As a result, the low concentration impurities are introduced in a self-aligning manner to the gate electrodes **242**, **252**, and **262**, and, as shown in **FIG. 6**(*d*), the low concentration source regions **241***b* and **261***b*, and the low concentration drain regions **241***c* and **261***c* are respectively formed in the silicon layers **241** and **261**. Further, low concentration impurity regions **251**S and **251**D are formed in the silicon layer **251**.

[0114] Subsequently, as shown in **FIG. 7**(*e*), an ion implanting selection mask for covering other portion than the P-channel type of driver circuit TFT **252** is formed. Using the ion implanting selection mask **503**, boron ion is implanted to the silicon layer **251** with dose amount of about 1.5×10^{15} cm^{-2}. As a result, since the gate electrode **252** for forming the P-channel type of driver circuit TFT also functions as the mask, the high concentration impurity can be doped to the silicon layer **251** in a self-aligning manner. Accordingly, the low concentration impurity regions **251S** and **251D** is counterdoped to become a source region and a drain region of the P-channel type of driver circuit TFT.

[0115] And then, as shown in **FIG. 7**(*f*), the first interlayer insulation layer **283** is formed over the entire surface of the substrate **20**, and contact holes C are formed at corresponding positions to the source electrode and the drain electrode of each TFT by patterning the first interlayer insulation layer **283** with a photolithography process.

[0116] Then, as shown in **FIG. 7**(*g*), the conductive layer **504** made of metal, such as aluminum, chromium, or tantalum is formed so as to cover the first interlayer insulation layer **283**. The thickness of the conductive layer **504** is about 200 nm through 800 nm. After then, a patterning mask **505** is formed so as to cover a region **240***a* where the source electrode and the drain electrode of each TFT are to be formed, a region **310***a* where the drive voltage conducting section **310** (**340**) is to be formed, and a region **122***a* where a second layer of the cathode power supply line, and then the source electrodes **243**, **252**, and **263**, and the drain electrodes **244**, **254**, and **264** shown in **FIG. 8**(*h*) are formed by patterning the conductive layer **504**.

[0117] Subsequently, as shown in **FIG. 8**(*i*), the second interlayer insulation layer **284** covering the first interlayer insulation layer **283** having the above element formed thereon is formed using, for example, a polymeric material, such as acrylic resin. The second interlayer insulation layer **284** is preferably formed with thickness of about 1 through 2 μm. Note that the second interlayer insulation layer can be made of SiN or SiO_2, wherein the thickness of the SiN film is preferably 200 nm, and the thickness of the SiO_2 film is preferably 800 nm.

[0118] Then, as shown in **FIG. 8**(*j*), a corresponding portion of the second interlayer insulation layer **284** to the drain electrode **244** of the driver TFT is removed by etching to form a contact hole **23***a*.

[0119] After then, a conductive film for forming the pixel electrode **23** is formed so as to cover the entire surface of the substrate **20**. And then, by patterning the transparent conductive film, as shown in **FIG. 9**(*k*), the pixel electrode **23** electrically connected to the drain electrode **244** via contact hole **23***a* of the second interlayer insulation layer **284** is formed, and, at the same time, a dummy patterns **26** in the dummy region are formed as well. Note that in **FIGS. 3 and 4**, the name of pixel electrode **23** is used as a generic name of both pixel electrode **23** and dummy pattern **26**.

[0120] The dummy pattern **26** is structured not to be connected to the metal interconnections in the lower layer passing through the second interlayer insulation layer **284**. Namely, the dummy patterns **26** are disposed like islands and have substantially the same shapes as those of the pixel electrodes **23** formed in the actual display region. Of course, it can take a different structure from the shape of the pixel electrode **23** formed in the display region. Note that, in this case, the dummy pattern **26** at least includes what is located above the drive voltage conducting section **310** (**340**).

[0121] Subsequently, as shown in **FIG. 9**(*l*), the lyophilicity control layer **25**, which is a insulating layer, is formed on the pixel electrode **23**, the dummy pattern **26**, and the second interlayer insulation layer. Note that, in the pixel electrode **23**, the lyophilicity control layer is formed with an opening corresponding to a part of the pixel electrode **23**, and therefore, hole transfer from the pixel electrode **23** is allowed through the opening **25***a* (See also **FIG. 3**.). In contrast, in the dummy pattern **26** which is not provided with opening **25***a*, the insulation layer (lyophilicity control layer) **25** functions as a hole transfer blocking layer to prevent holes form moving therethrough.

[0122] Subsequently, in the lyophilicity control layer **25**, BM (black matrix) is formed in hollow section provided between two different pixel electrodes **23**. Specifically, a film of chromium metal is formed on the hollow section of the lyophilicity control layer **25** using a sputtering process.

[0123] And then, as shown in **FIG. 9**(*m*), the organic bank layer **221** is formed so as to cover a predetermined position of the lyophilicity control layer **25**, specifically the BM. In specific method of forming the organic bank layer, an organic material layer is formed by depositing solution using various deposition processes such as spin coating method or dip coating method, the solution being made by dissolving a resist such as acrylic resin or polyimide resin in a solvent. Note that any materials can be used to form the organic material layer providing that the material does not dissolve in solvent of the ink described below and is easy to be patterned by etching or the like.

[0124] Then, opening **221***a* of the organic bank is formed by simultaneously etching the organic material layer with a photolithography technology or the like to form the organic bank layer **221** having a wall surface in the opening section **221***a*. Note that, in this case, the organic bank layer **221** includes at least what positions above the drive control signal conducting section **320**.

[0125] Subsequently, an area expressing lyophilicity and an area expressing lyophobicity are formed on a surface of the organic bank layer **221**. In the exemplary embodiment, every region is formed by plasma process steps. More specifically, the plasma process steps can include a preheat step, a lyophilicity providing step for making the upper surface of the organic bank layer **221**, the wall surface of the opening section **221***a*, the electrode surface **23***c* of the pixel electrode **23**, and the upper surface of the lyophilicity control layer **25** lyophilic, a lyophobicity providing step for making the upper surface of the organic bank layer and the wall surface of the opening section lyophobic, and a cooling step.

[0126] That is, a base material (the substrate **20** including bank structure and so forth) is heated to a predetermined temperature, for example, somewhere between 70 and 80 degree, and then, as the lyophilicity providing step, treated by a plasma process (O_2 plasma process) using oxygen as reactive gas in the atmospheric air. Subsequently, as the lyophobicity providing step, a plasma process (CF_4 plasma process) is executed in the atmospheric air using tetrafluoromethane as reactive gas, and then the base material, which has been heated for the plasma process, is cooled to the room temperature, which makes lyophilicity and lyophobicity be provided to the predetermined portions.

[**0127**] Note that, although in the CF_4 plasma process, the electrode surface **23**_c_ of the pixel electrode **23** and the lyophilicity control layer **25** are also somewhat influenced, they are kept lyophilic because ITO, the material of the pixel electrode **23**, SiO2, TiO2, the material for composing the lyophilicity control layer, or the like has a poor affinity to fluorine, and accordingly, a hydroxyl group provided in the lyophilicity providing step is not substituted with a fluorine group.

[**0128**] Subsequently, a hole injection/transfer layer forming step is executed to form the hole injection/transfer layer **70**. In the hole injection/transfer layer forming step, an ink-jet method is preferably adopted as a droplet ejection method. In short, using the inkjet method, a hole injection/transfer layer forming material is selectively provided on the electrode surface **23**_c_ and then deposited. Subsequently, a drying process and a thermal treatment are executed to form the hole injection/transfer layer **70** on the pixel electrode **23**. As the material forming the hole injection/transfer layer **70**, for example, solution of PEDOT: PSS with a polar solvent, such as isopropyl alcohol is used.

[**0129**] Note that, in order to form the hole injection/transfer layer **70** by the ink-jet method, firstly the inkjet head (not shown in the drawings) is filled with the hole injection/transfer layer forming material, then an ejection nozzle of the inkjet head is positioned to face the electrode surface **23**_c_ positioned in the opening section **25**_a_ provided to the lyophilicity control layer **25**, and then droplets of which the amount of volume per one droplet is controlled are ejected to the electrode surface **23**_c_. And then the ejected droplets are dried for evaporating dispersion medium or solvent contained in the material to form the hole injection/transfer layer **70**.

[**0130**] In this case, the droplets ejected from the ejection nozzle spread on the electrode surface **23**_c_ treated to have lyophilicity to fill the opening section **25**_a_ of the lyophilicity control layer **25**. Meanwhile, on the upper surface of the organic bank layer **221** treated to have lyophobicity, the droplet is repelled and never attached. Accordingly, if the droplet is shifted from a predetermined ejection point and partially provided on the surface of the organic bank layer **221**, the surface is not wetted with the droplet, and the repelled droplet is drawn into the opening section **25**_a_ of the lyophilicity control layer **25**.

[**0131**] Note that, on and after the hole injection/transfer layer forming step, every step is preferably executed under an atmosphere of inactive gas, such as nitrogen or argon to prevent oxidization or moisture absorption of various materials and formed elements.

[**0132**] Subsequently, as shown in **FIG. 10**(_n_), an organic EL layer forming step is executed to form the organic EL layer **60**. In this step, as is the case with forming of the hole injection/transfer layer **70**, the inkjet method is preferably adopted as a droplet ejection method. That is, a light emitting layer forming material is ejected on the hole injection/transfer layer **70** using the inkjet method, and then a drying process and a thermal treatment are executed to form the light emitting layer **60** in the opening section **221**_a_ provided in the organic bank layer **221**, namely on the pixel region. Note that, in the organic EL layer forming step, in order to prevent the hole injection/transfer layer **70** from redissolving, as solvent of the material ink used for forming the organic EL layer, nonpolar solvent which dose not dissolve the hole injection/transfer layer **70**. Further, forming of the light emitting layer **60** is carried out with respect to each color.

[**0133**] Then, as shown in **FIG. 10**(O), an electron injection layer forming step is executed to form the electron injection layer **65**B, **65**R on the organic EL layer **60**.

[**0134**] Here, as the electron injection layer **65**B, LiF is deposited by a mask evaporation process or a known liquid phase process.

[**0135**] Further, in the electron injection layer **65**RG, acetylacetonate (acac), which is to be a ligand of an organometallic complex, is deposited by a liquid phase process, and further Ca, which is to be a central metal of an organometallic complex, is deposited by a vapor phase process so as to contact the acetylacetonate (acac). As described above, one of the features of the invention is to use both liquid process and vapor process in forming organometallic complexes (organometallic compounds).

[**0136**] In more detail, after depositing acetylacetonate on the light emitting layer **60** using the inkjet method, a thin film of Ca is formed on the entire surface by an evaporation process. According to this, a layer of a stable organometallic complex can be formed in the junction interface between acetylacetonate and Ca. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction interface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed on only the junction interface, very thin films of, for example, one molecule thick can be formed.

[**0137**] Note that Ca can be deposited on an upper layer of the electron injection layer **65**B made of LiF. Since the Ca thin film is a material for forming the cathode **50** described below, if Ca is deposited during the electron injection layer forming step, the Ca thin film is no more necessary to be deposited in the later steps, thus realizing simplification of the process.

[**0138**] Subsequently, as shown in **FIG. 10**(_p_), a cathode forming step is executed using an evaporation process to form the cathode **50**. In this step, firstly a low work function metal (e.g., Ca) is formed as a film in the entire exposed area of the electron injection layer using an evaporation process or a sputtering process, and then metal (e.g., Al) having higher work function is formed thereon as a film. Thus, the cathode **50** composed of a stacked film of Ca and Al (or ITO) is formed.

[**0139**] And, finally, a sealing step is executed to form the sealing substrate **30**. In the sealing step, after inserting desiccating agent **45** inside the sealing substrate **30**, the sealing substrate **30** and substrate **20** are adhered with each other by an adhesive **40** to complete the sealing. Note that the sealing step is preferably executed in an atmosphere of inactive gas, such as nitrogen, argon, or helium.

[0140] As described above, in the exemplary embodiment, while forming the electron injection layer **65**RG, acetylacetonate is formed as a film by a liquid phase process, and further Ca is formed as a film by a vapor phase process, thus stable calcium acetylacetonate $Ca(acac)_2$ can be formed at the junction interface. Therefore, if an unstable organic material is used, the problem of decomposition or loss of function of the organic material caused by an influence of heat applied during the film forming process is no more occurs. Further, in a laminated structure, no influence is exerted to a junction surface of each layer. Accordingly, organometallic compounds can stably be formed as a film, thus increasing the bonding force of the junction interface. Further, since the complex layer is formed on only the junction interface, very thin films of, for example, one molecule thick can be formed.

[0141] Further, since the electron injection layer **65**RG, **65**B are so formed that the light emission characteristics of the light emitting layer **60** are optimized with respect to each of emitted light colors, R (red) and G (green), and B (blue). Further, by altering the mixture ratio, the color balance can be adjusted. In other words, it is possible that the electron injection layers are respectively provided for the light emitting layers, and each of the electron injection layers provided for the respective light emitting layers includes the complex selected for the corresponding light emitting layer. By this configuration, materials are designed to be best suitable for each of the light emitting layers, and further, color balance of each light emitting layer can easily be adjusted.

[0142] Further, in the embodiment, since complexes having the β-diketone based ligand (β-diketone complexes) are adopted, because they are acidity reagents and multidentate ligands with oxygen, stable metallic complexes can be formed.

[0143] Further, by composing such complexes to have the same metal in the central atom as composing element of the cathode, namely by adopting Ca as the central atom, the bonding force of the interfacial surface can be increased to enhance the electron injection effect.

[0144] Note that, in the above embodiment, although Ca is deposited after acetylacetonate is deposited on the light emitting layer **60** in the step of forming the electron injection layer **65**RG, the Ca thin film can be formed in advance, and then acetylacetonate can be deposited thereon. Thus, the same advantages as described above can be obtained, and further, an organic EL device with the reversed structure can be formed. The reverse structure, here, denotes a structure in which the positional relationship of the cathode and the anode is reversed, namely, the substrate **20**, cathode **50**, electron injection layer **65**B, **65**RG, light emitting layer **60**, hole injection/transfer layer **70**, and pixel electrode **23** are stacked from the substrate side in this order. By thus structured, a top-emission type of organic EL device, in which the emitted light is taken out from the pixel electrode **23** side, can be provided. Accordingly, the aperture ratio can be increased to achieve a wider light emission area. Note that, in this case, a transparent material should be adopted as the sealing substrate **30**.

[0145] Further, in the above exemplary embodiment, although an organic EL device and a fabrication method of the organic EL device, it should be understood that the invention is not limited thereto.

[0146] For example, the invention can be applied to a organometallic compound thin film used for photoelectrochemical cells, such as solar cells and a fabrication method therefor.

[0147] In forming organic compounds, such as a single molecule color fixing agent for composing such a photoelectrochemical cell, by adopting the fabrication method of the organometallic complexes (organometallic compounds) described above, the organometallic compounds can stably be formed as films, and the bonding force of the junction interface can be increased.

[0148] Hereinafter, an exemplary embodiment of an electronic apparatus equipped with the organic EL device according to the invention. An electronic apparatus according to the invention can be equipped with the organic EL device described above as a display section, what is shown in **FIG. 11** can specifically be cited.

[0149] **FIG. 11** is a perspective view showing an example of a cellular phone. In **FIG. 11**, a reference numeral **1000** denotes a body of the cellular phone, and a reference numeral **1001** denotes the display section applying the organic EL device.

[0150] Since the electronic apparatus shown in **FIG. 11** is equipped with the display section having the organic EL device, it can enjoy a long life and obtain a blight display.

[0151] It should be understood that the invention is not limited to the exemplary embodiments described above, but can be modified in various manners to be practiced within a scope or spirit of the invention.

[0152] For example, although the polymer material is used as the light emitting layer **60** in the above embodiment, small molecule materials can also be used instead of the polymer materials. Further, the structure of the circuit section **11** is merely an example, and other structure can also be taken. Still further, although an example in which the organic EL device according to the invention is used as a display device is described above as the embodiment, the light emitting layer can be formed all over the substrate, and the device can be used as a back light (lighting installation) for transmissive liquid crystal devices.

What is claimed is:

1. A method of fabricating a thin film of an organometallic compound on a substrate, comprising:

forming an organic matter by a liquid phase process; and

forming metal by a vapor phase process to form the thin film of the organometallic compound composed of the organic matter and the metal.

2. The method of forming the thin film of the organometallic compound according to claim 1, the step of forming the metal being executed after the step of forming an organic matter to form the thin film of the organometallic compound.

3. The method of forming the thin film of the organometallic compound according to claim 1, the step of forming metal being executed prior to the step of forming an organic matter to form the thin film of the organometallic compound.

4. The method of forming the thin film of the organometallic compound according to claim 1, the liquid phase process being a droplet discharge method.

5. An organometallic compound thin film formed by the method according to claim 1.

6. The organometallic compound thin film according to claim 5, a thickness of the organometallic compound thin film being one of equal to and less than 1 nm.

7. A method of fabricating an organoelectronic device, comprising:

forming an organic functional layer;

forming a charge transfer layer; and

forming an electrode;

forming a charge transfer layer further including:

forming an organic matter by a liquid phase process; and

forming metal by a vapor phase process to form the thin film of the organometallic compound composed of the organic matter and the metal.

8. The method of fabricating an organoelectronic device according to claim 7, the organometallic compound being an organometallic complex.

9. The method of fabricating an organoelectronic device according to claim 7, a central atom of the organometallic complex including a same metallic element as at least one of composing elements of the electrode.

10. The method of fabricating an organoelectronic device according to claim 8, the organometallic complex being a β-diketone complex.

11. The method of fabricating an organoelectronic device according to claim 7, in the step of forming a charge transfer layer, the step of forming metal being executed after the step of forming an organic matter to form the thin film of an organometallic compound.

12. The method of fabricating an organoelectronic device according to claim 7, in the step of forming a charge transfer layer, the step of forming metal being executed prior to the step of forming an organic matter to form a thin film of an organometallic compound.

13. The method of fabricating an organoelectronic device according to claim 7, the liquid phase process being a droplet discharge method.

14. An organoelectronic device fabricated by the method of fabricating an organoelectronic device according to claim 7.

15. An electronic apparatus equipped with the organoelectronic device according to claim 14.

16. A method of fabricating an organic electroluminescence device, comprising:

forming a blue light emitting layer, a green light emitting layer, and a red light emitting layer;

forming a first electron injection layer on the blue light emitting layer;

forming a second electron injection layer and a third electron injection layer, respectively, on the green light emitting layer and the red light emitting layer;

forming a second electron injection layer and a third electron injection layer including:

forming an organic matter by a liquid phase process;

forming metal by a vapor phase process; and

the second electron injection layer and the third electron injection layer being organometallic compounds including the organic matter and the metal.

17. The method of fabricating an organic electroluminescence device according to claim 16, the organometallic compound being an organometallic complex.

18. The method of fabricating an organic electroluminescence device according to claim 17, a central atom of the organometallic complex including a same metallic element as at least one of composing elements of an electrode.

19. The method of fabricating an organic electroluminescence device according to claim 17, the organometallic complex being a β-diketone complex.

20. The method of fabricating an organic electroluminescence device according to claim 16, in the step of forming a second electron injection layer and a third electron injection layer, the step of forming metal being executed after the step of forming an organic matter to form a thin film of an organometallic compound.

21. The method of fabricating an organic electroluminescence device according to claim 16, in the step of forming a second electron injection layer and a third electron injection layer, the step of forming metal being executed prior to the step of forming an organic matter to form a thin film of an organometallic compound.

22. The method of fabricating an organic electroluminescence device according to claim 16, the liquid phase process being a droplet discharge method.

23. An organic electroluminescence device fabricated by the fabrication method according to claim 16.

24. An electronic apparatus equipped with the organic electroluminescence device according to claim 23.

25. An organoelectronic device equipped with the organometallic compound thin film formed by the method according to claim 1.

* * * * *

专利名称(译)	形成有机金属化合物薄膜的方法，有机金属化合物薄膜，制造有机电子器件的有机电子器件的制造方法，有机电子器件，制造有机电致发光的方法，有机电致发光和电子设备		
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摘要(译)

本发明的方面可以提供一种制造有机金属化合物膜的方法，该方法能够通过稳定地形成具有有机金属化合物的膜，增加结界面的结合力并实现超薄膜，有机金属化合物膜和有机电子器件。（例如，有机电致发光器件，有机太阳能电池或有机薄膜晶体管）和配备有有机金属化合物膜的电子器件。在基板上制造有机金属化合物薄膜的方法可包括通过液相工艺形成有机材料的步骤和通过气相工艺形成金属以形成有机金属化合物薄膜的步骤有机材料和金属。