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(54) COMPOSITE MATERIAL INCLUDING ORGANIC COMPOUND AND INORGANIC COMPOUND, LIGHT-EMITTING ELEMENT AND LIGHT-EMITTING DEVICE USING THE COMPOSITE COMPOUND, AND MANUFACTURING METHOD OF THE LIGHT-EMITTING ELEMENT

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(21) Appl. No.: **13/852,203**

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H01B 1/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/0035*** (2013.01); ***H01B 1/12*** (2013.01); ***H01B 1/127*** (2013.01)
USPC **257/40**; 252/500; 252/519.33

(57) ABSTRACT

The present invention provides a composite material having high conductivity, a light-emitting element and a light-emitting device using the composite material. Further, the present invention provides a manufacturing method of a light-emitting element which is suitable for mass production. A light-emitting element of the present invention includes a layer including a luminescent substance between a pair of electrodes. The layer including a luminescent substance has a composite material which includes an organic compound, and an inorganic compound showing an electron donating property to the organic compound. Since the light-emitting element of the present invention includes a composite material made by combining an organic compound and an inorganic compound, the carrier injecting property, carrier transporting property, and conductivity thereof are excellent, and thus, the driving voltage can be reduced.

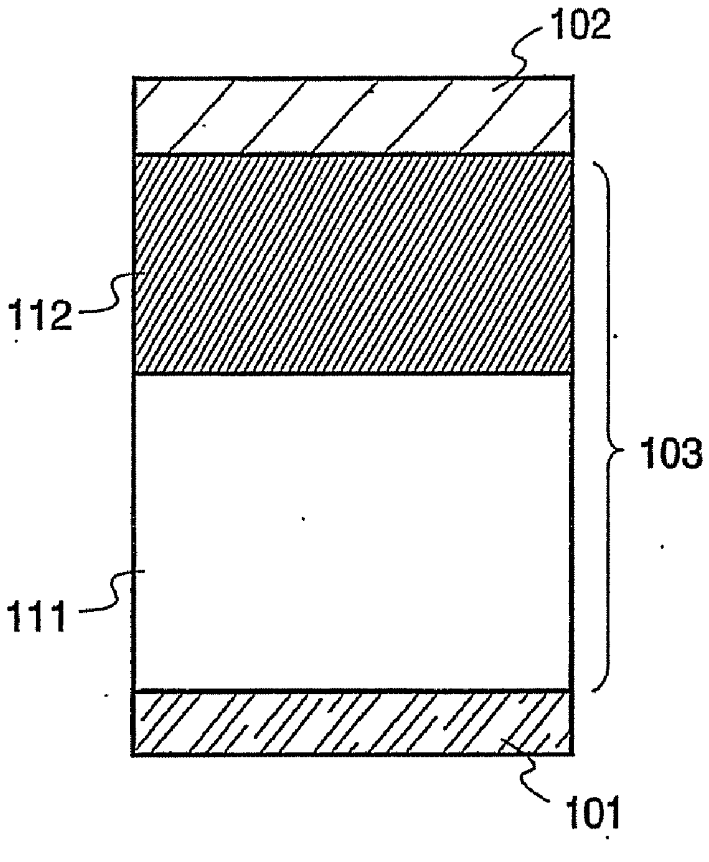


FIG. 1

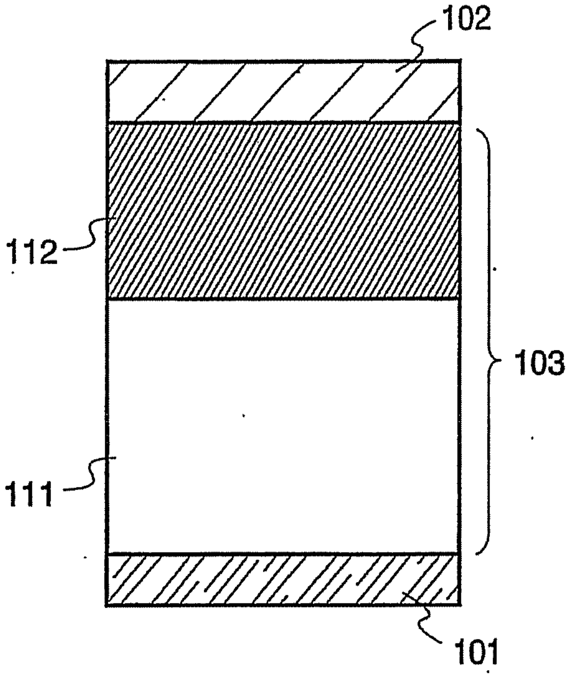


FIG. 2

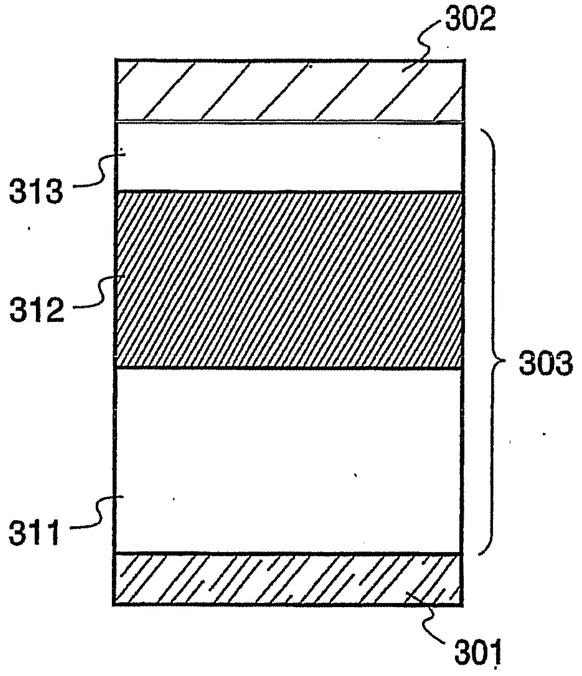


FIG. 3A

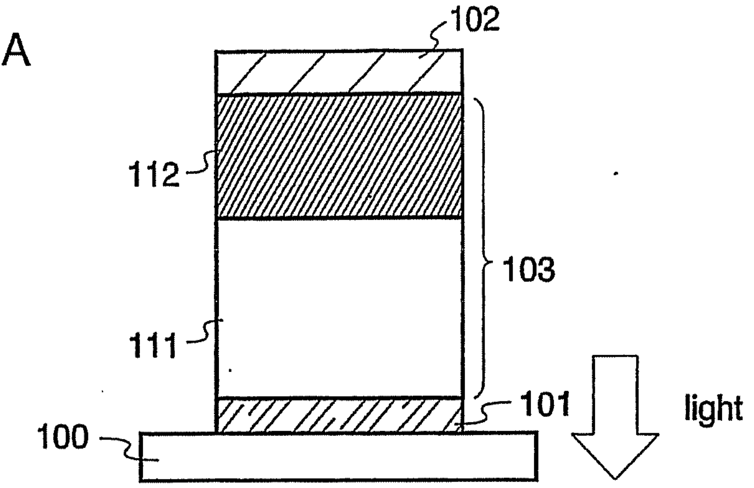


FIG. 3B

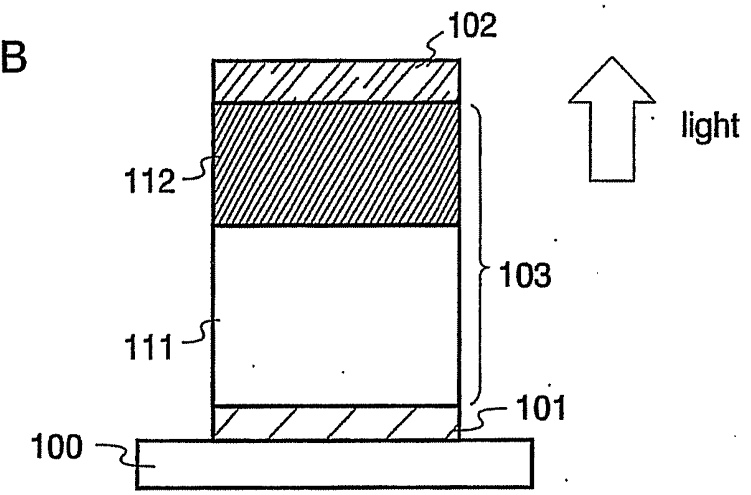


FIG. 3C

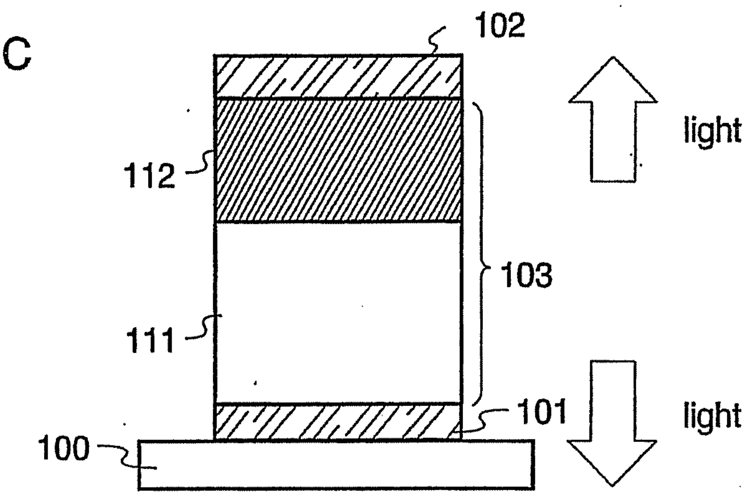


FIG. 4A

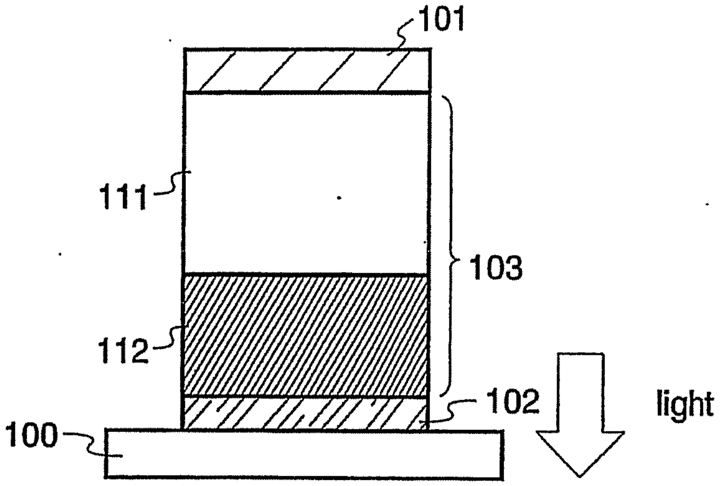


FIG. 4B

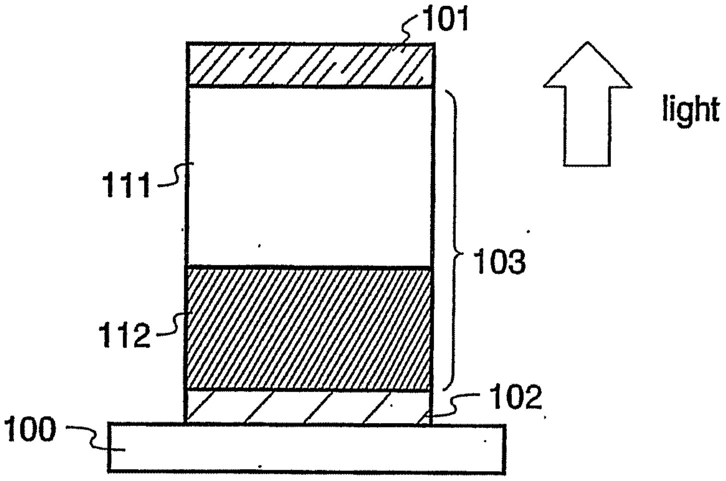


FIG. 4C

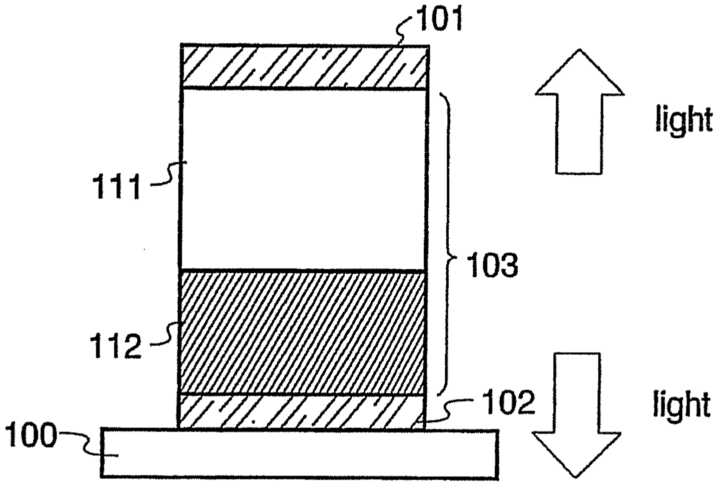


FIG. 5

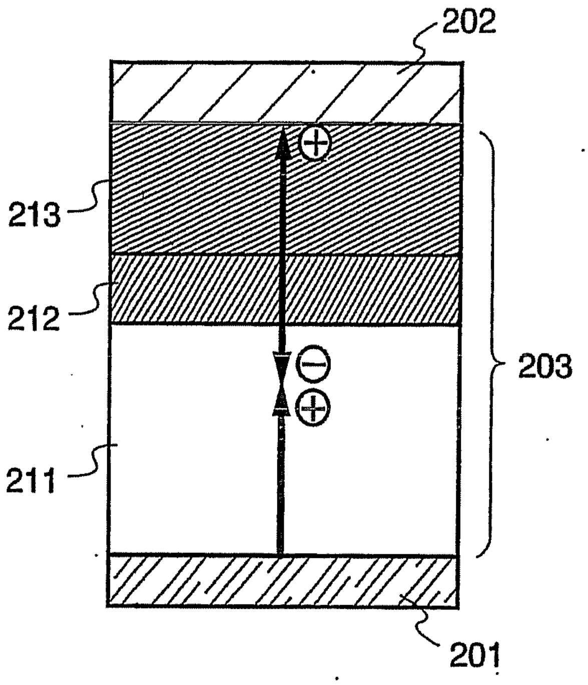


FIG. 6A

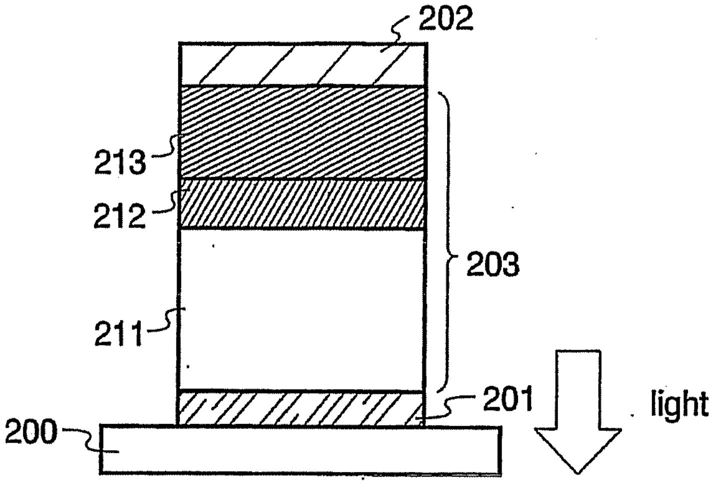


FIG. 6B

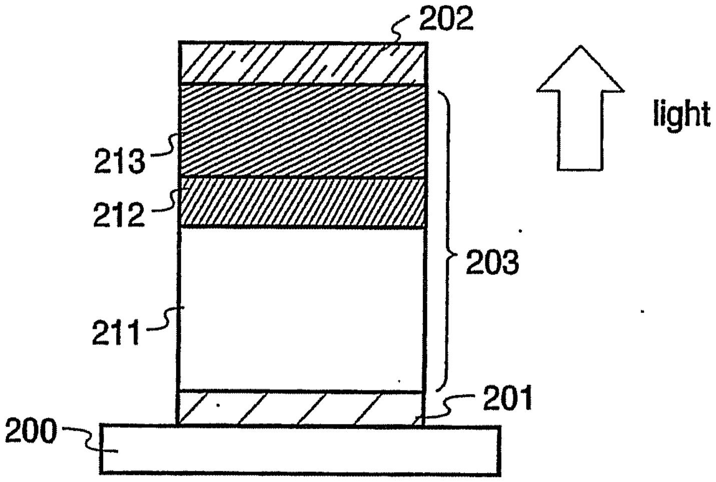


FIG. 6C

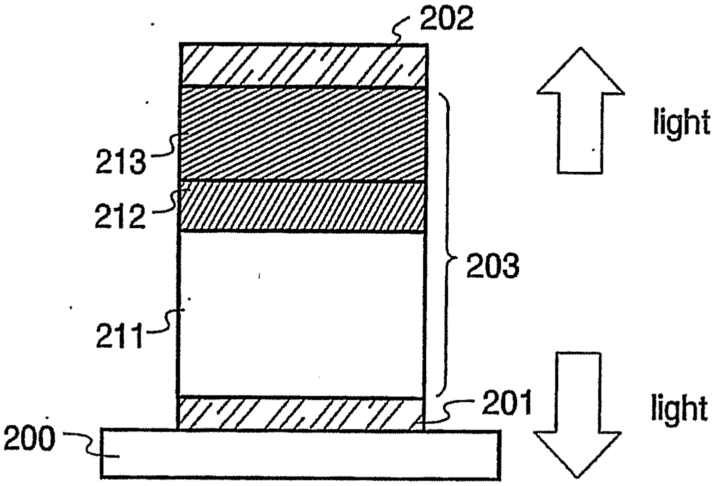


FIG. 7A

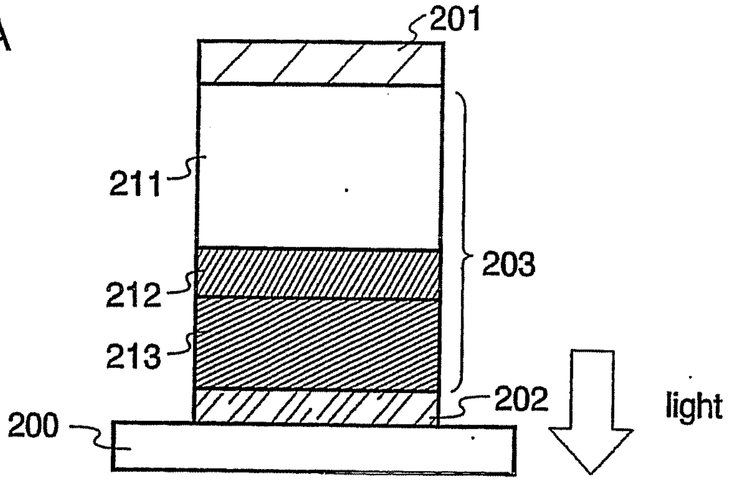


FIG. 7B

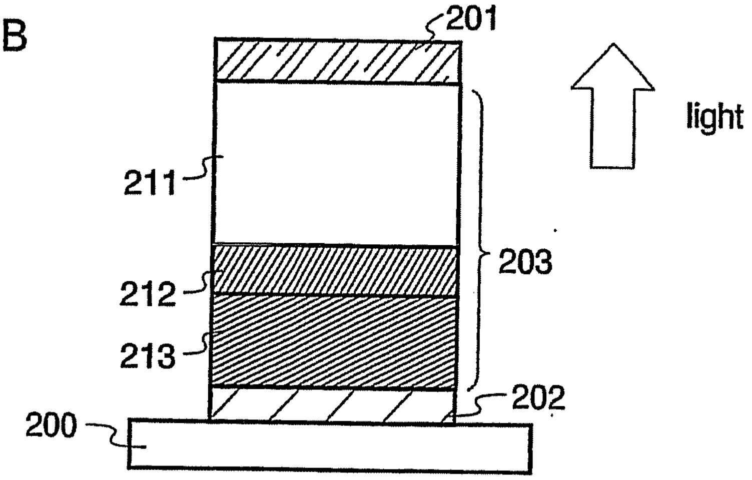


FIG. 7C

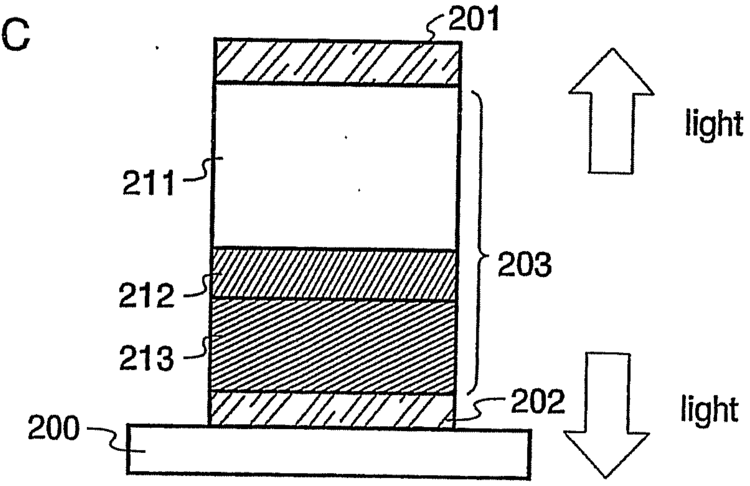


FIG. 8

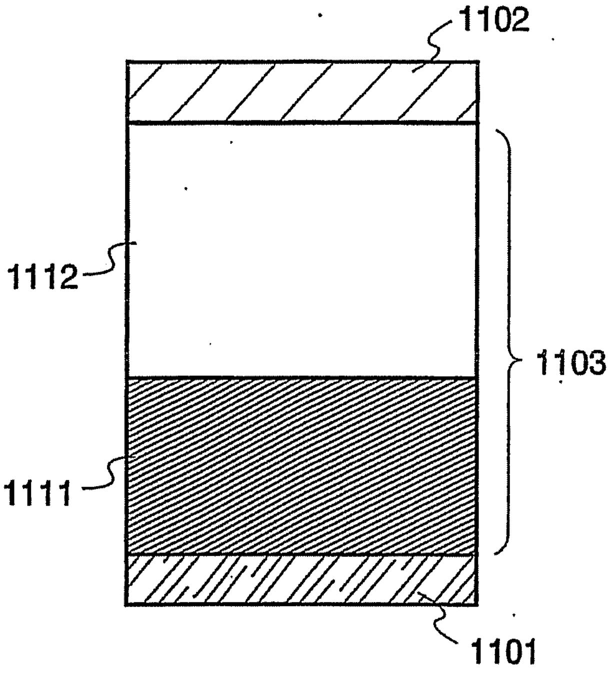


FIG. 9

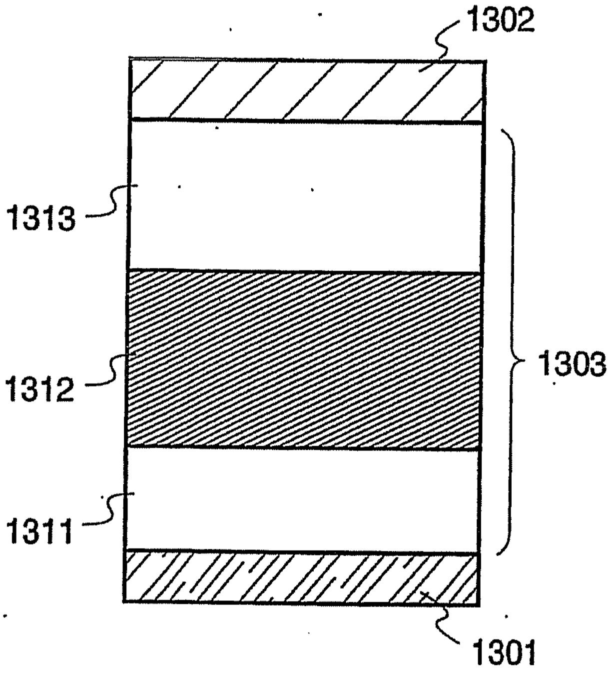


FIG. 10A

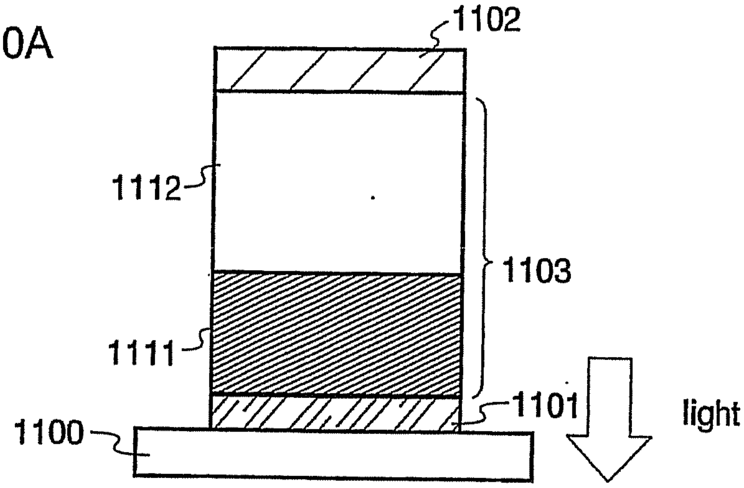


FIG. 10B

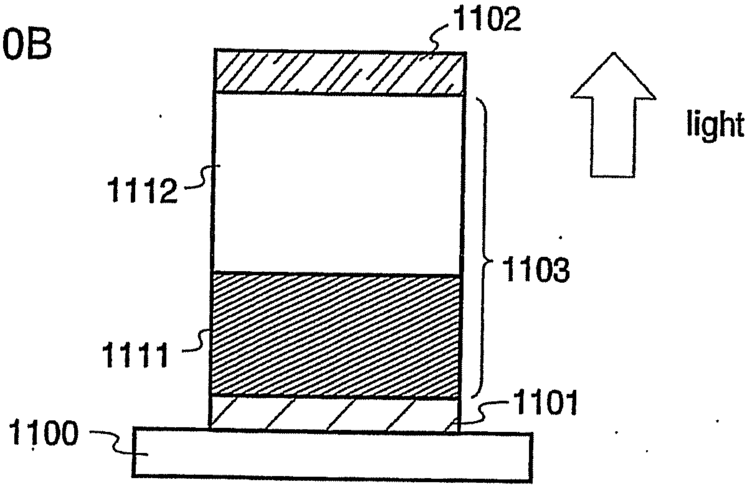


FIG. 10C

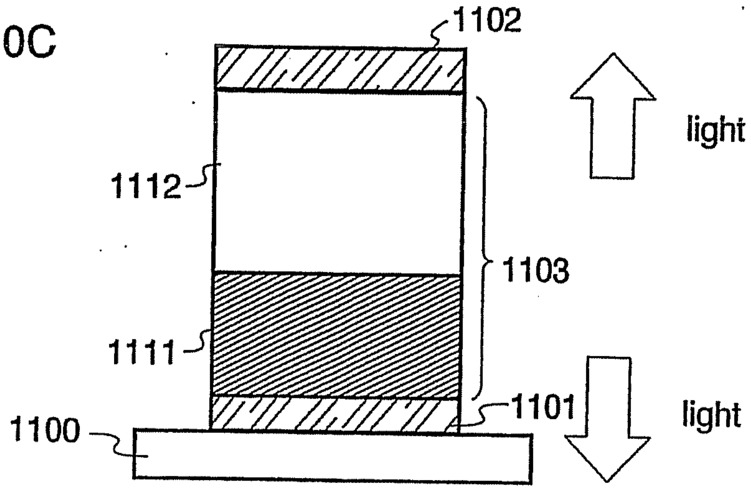


FIG. 11A

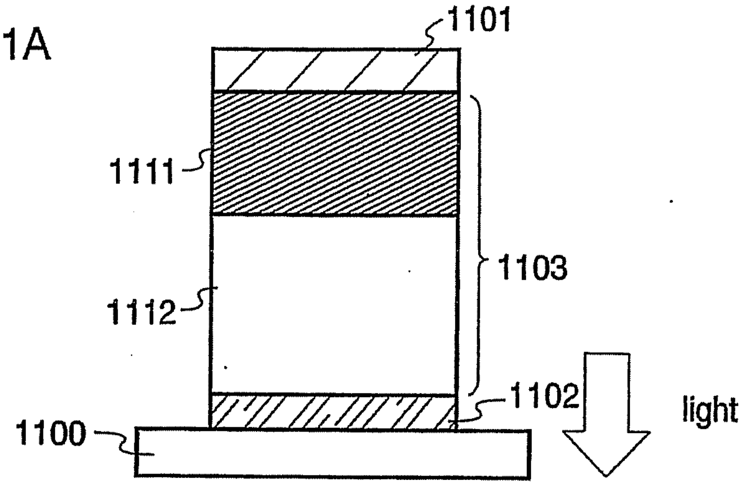


FIG. 11B

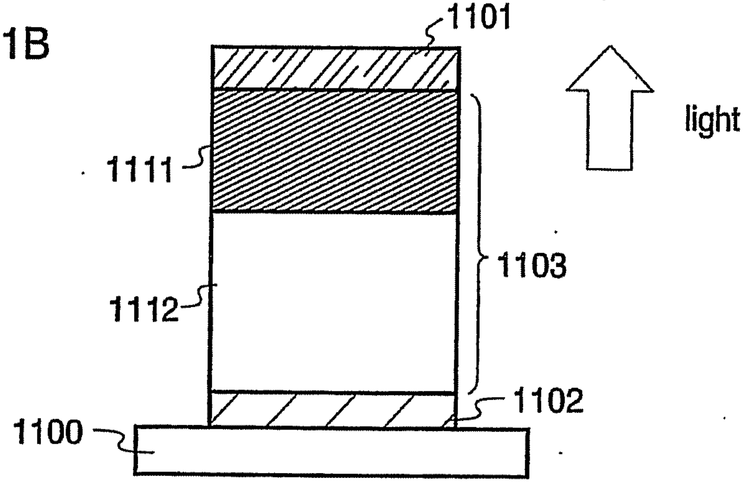


FIG. 11C

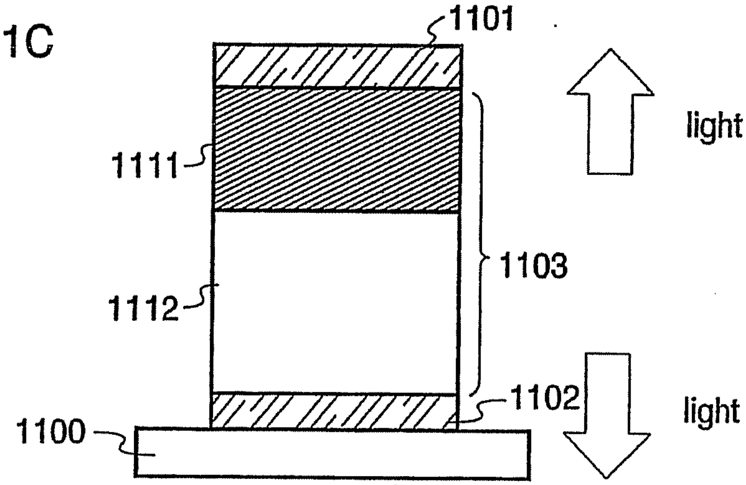


FIG. 12

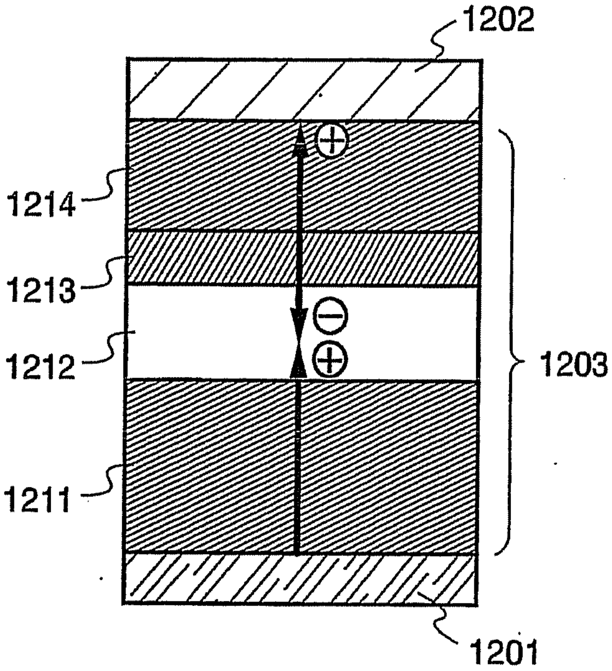


FIG. 13A

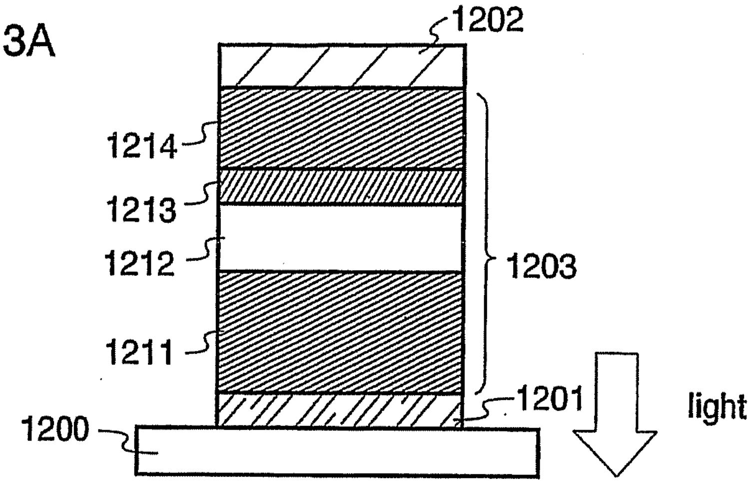


FIG. 13B

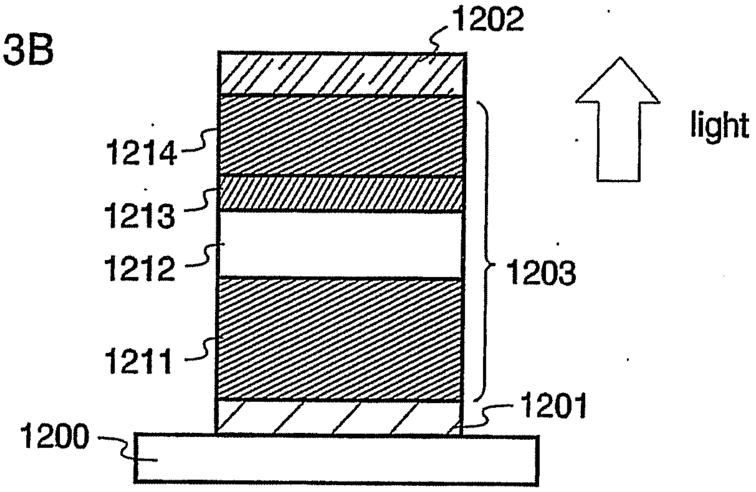


FIG. 13C

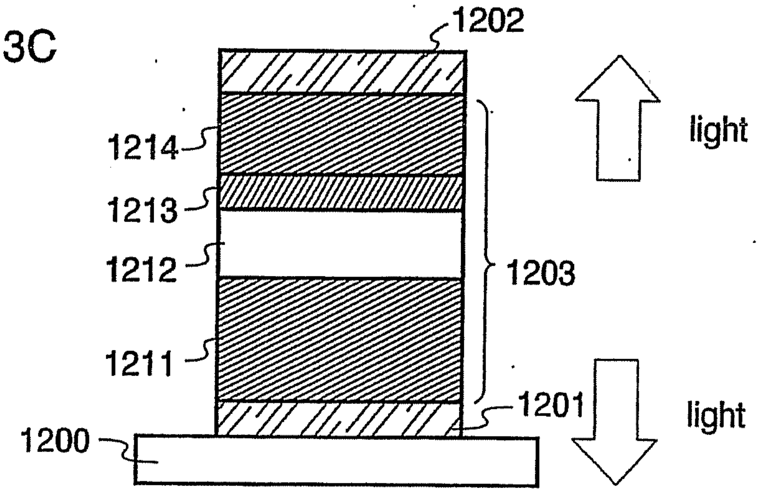


FIG. 14A

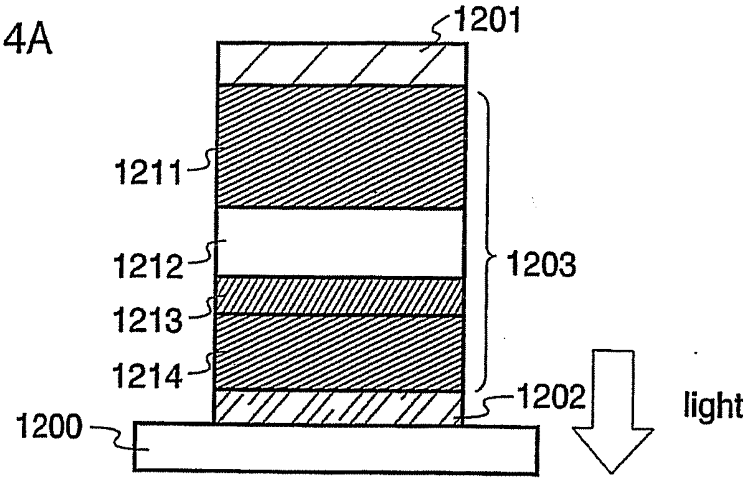


FIG. 14B

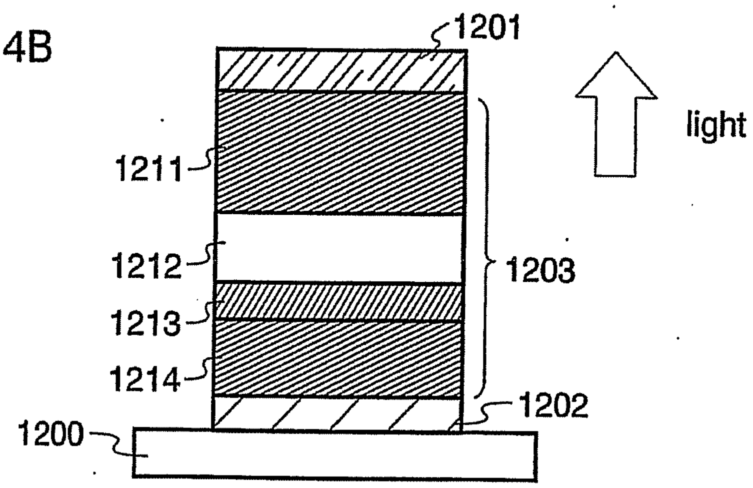


FIG. 14C

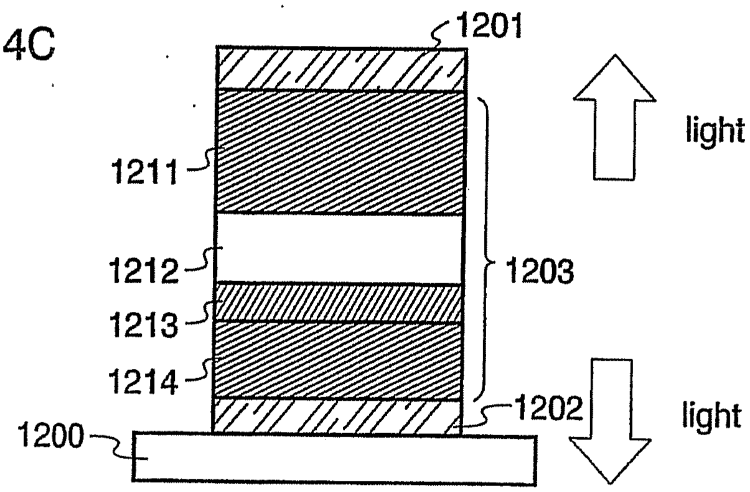


FIG. 15

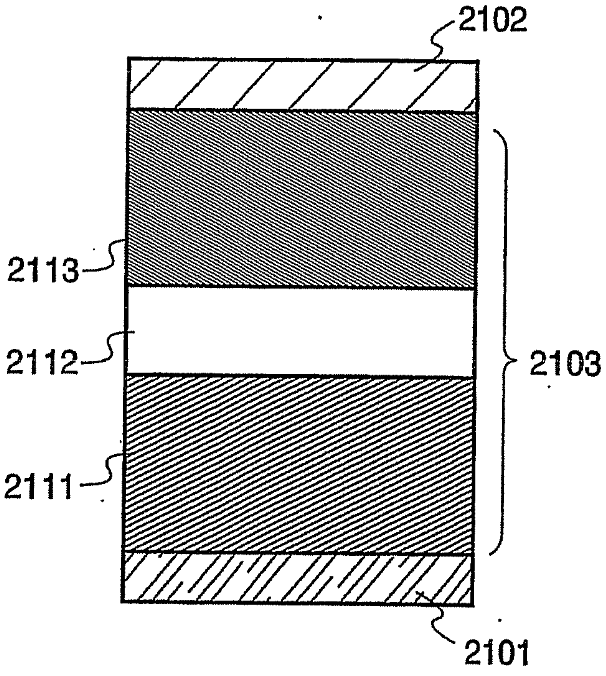


FIG. 16

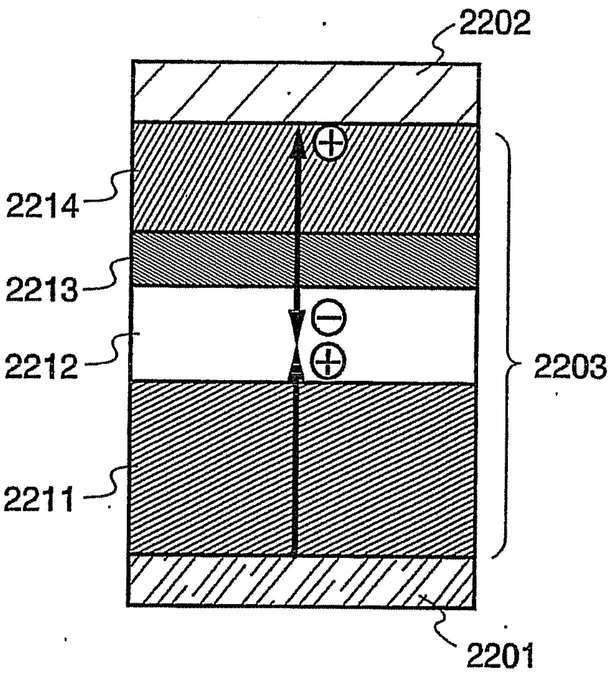


FIG. 17A

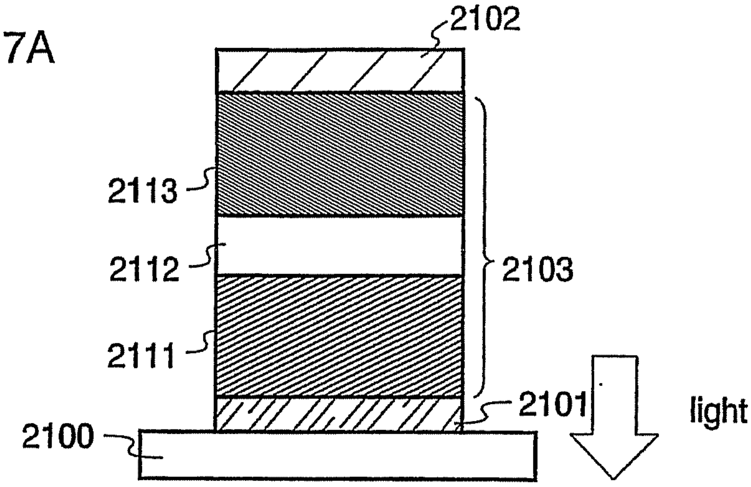


FIG. 17B

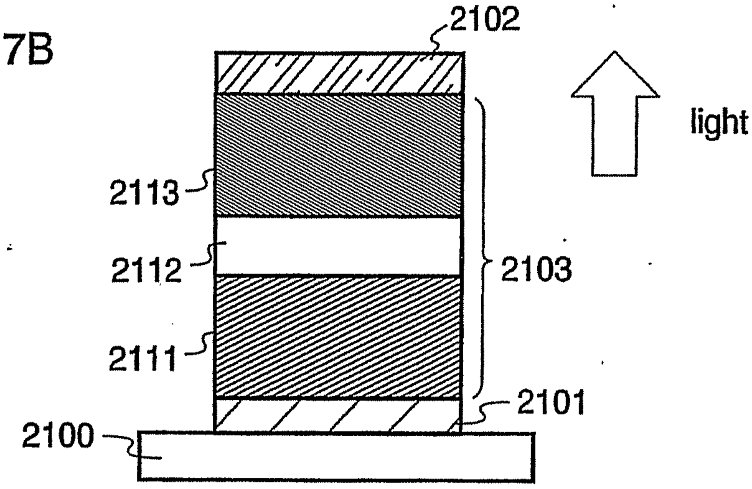


FIG. 17C

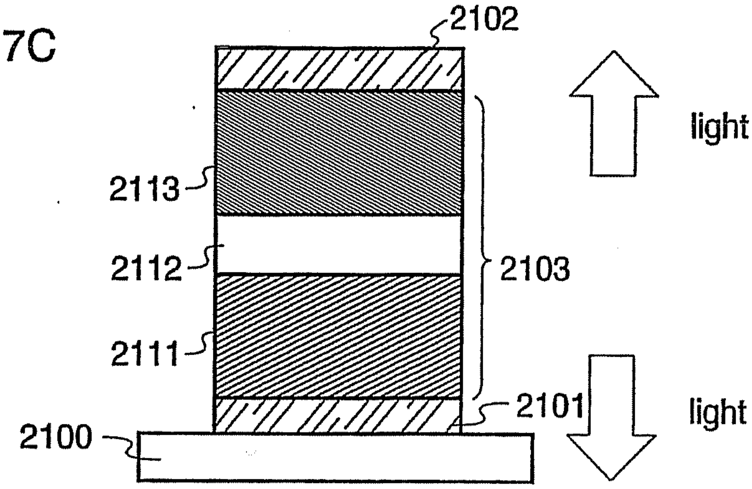


FIG. 18A

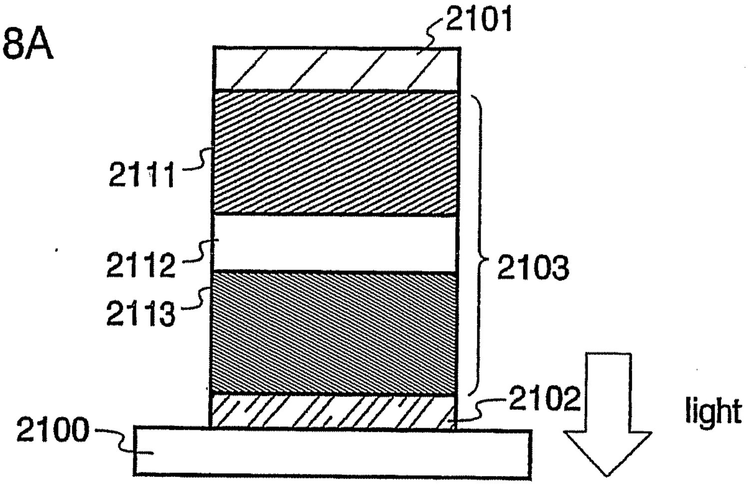


FIG. 18B

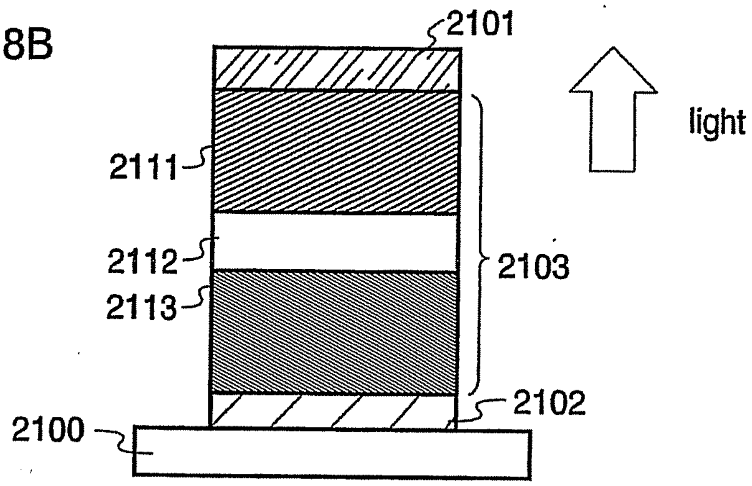


FIG. 18C

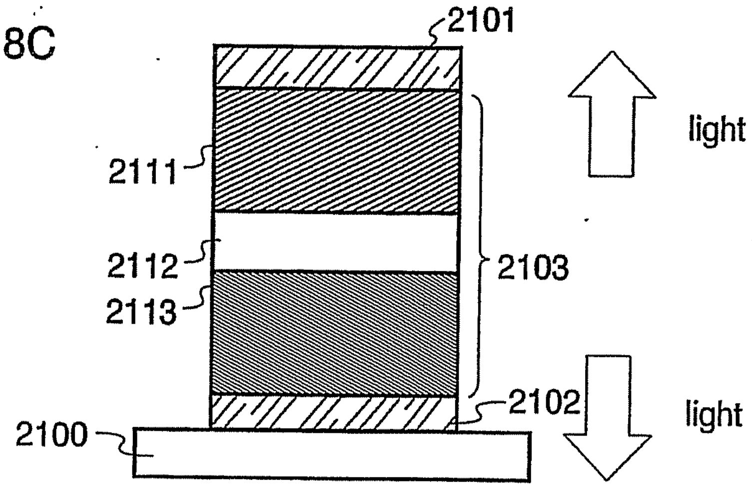


FIG. 19A

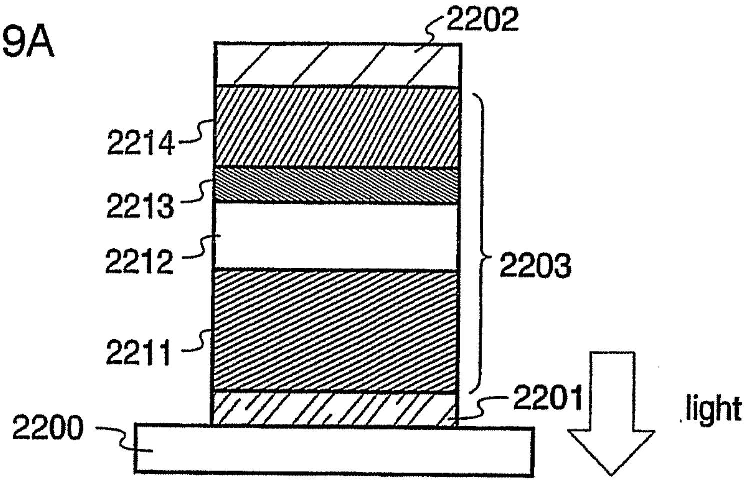


FIG. 19B

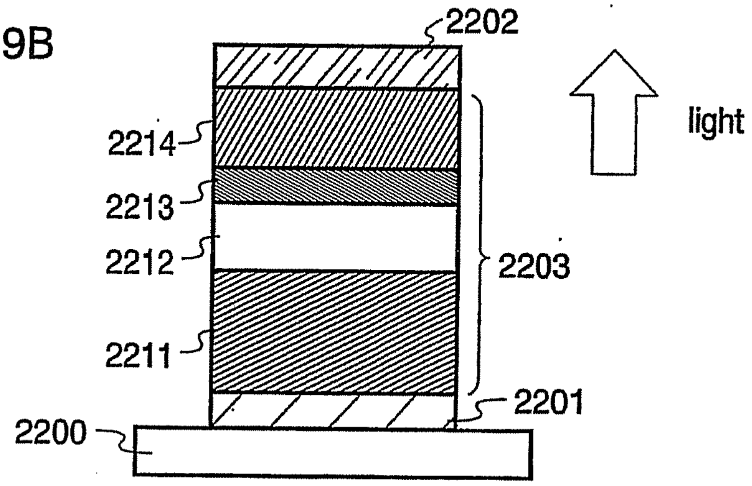


FIG. 19C

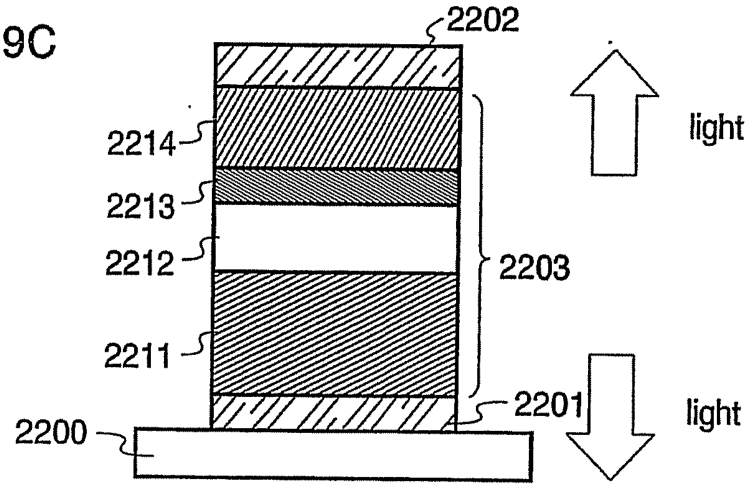


FIG. 20A

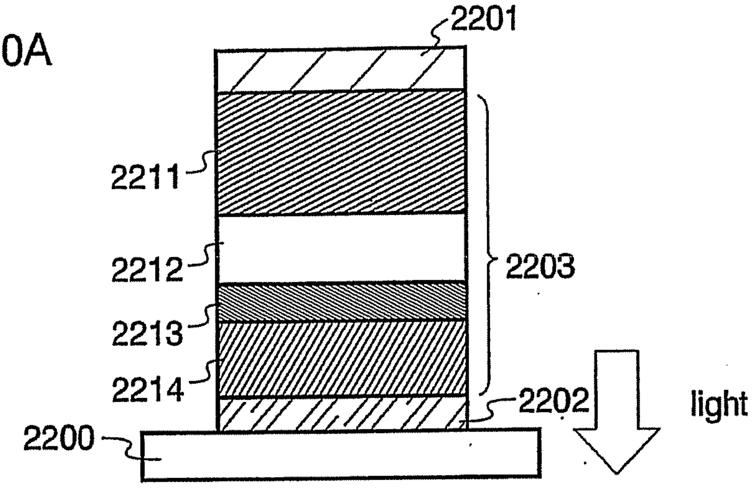


FIG. 20B

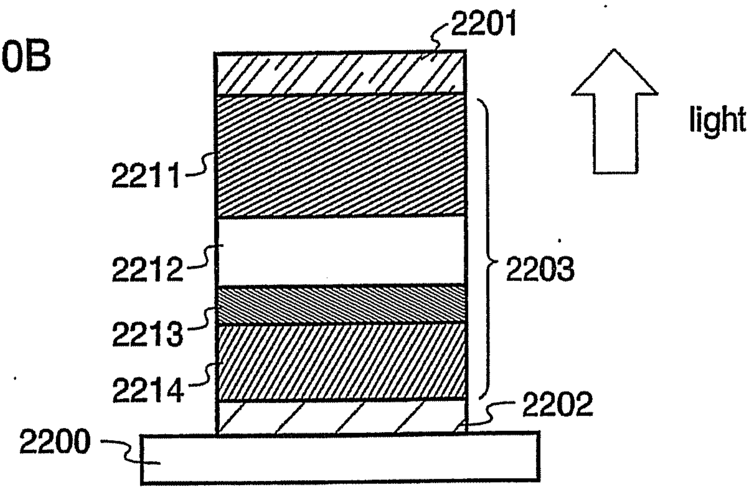


FIG. 20C

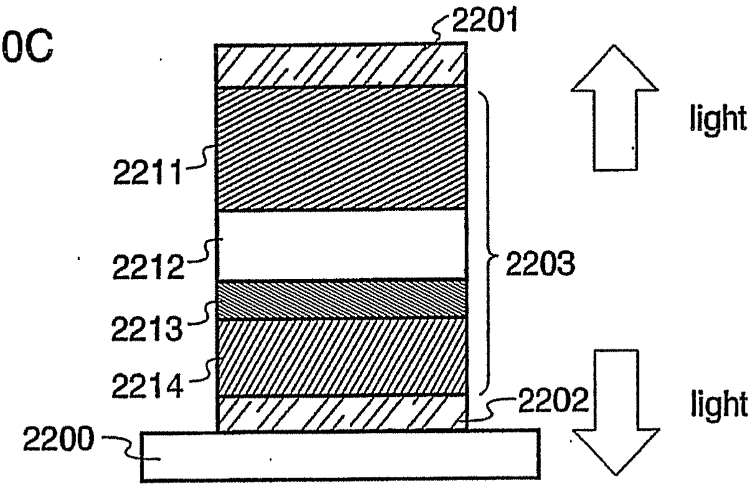


FIG. 21

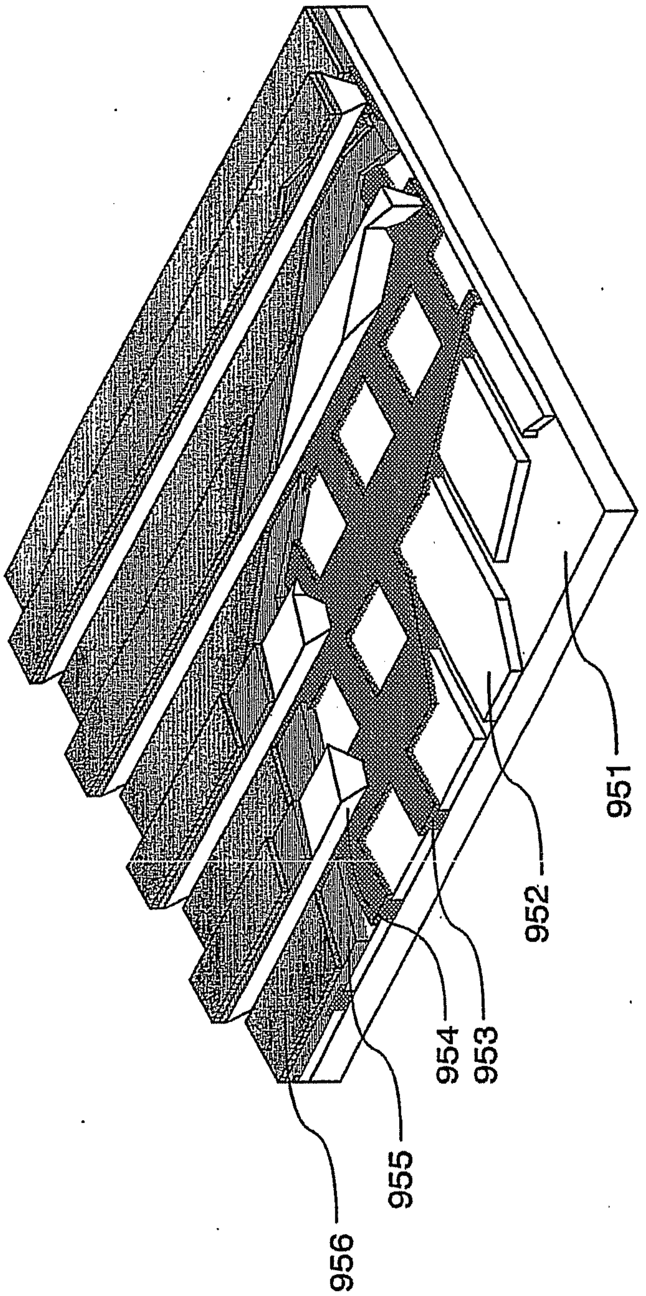


FIG. 22A

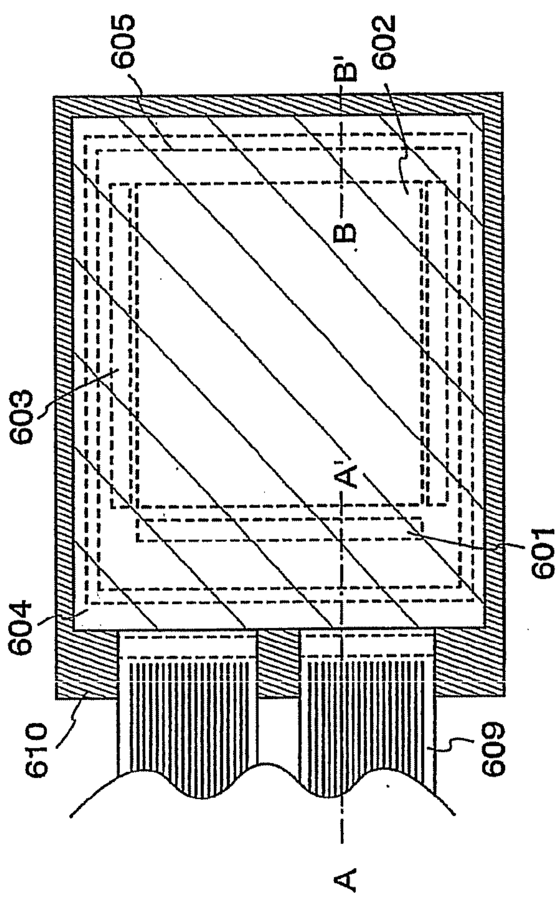


FIG. 22B

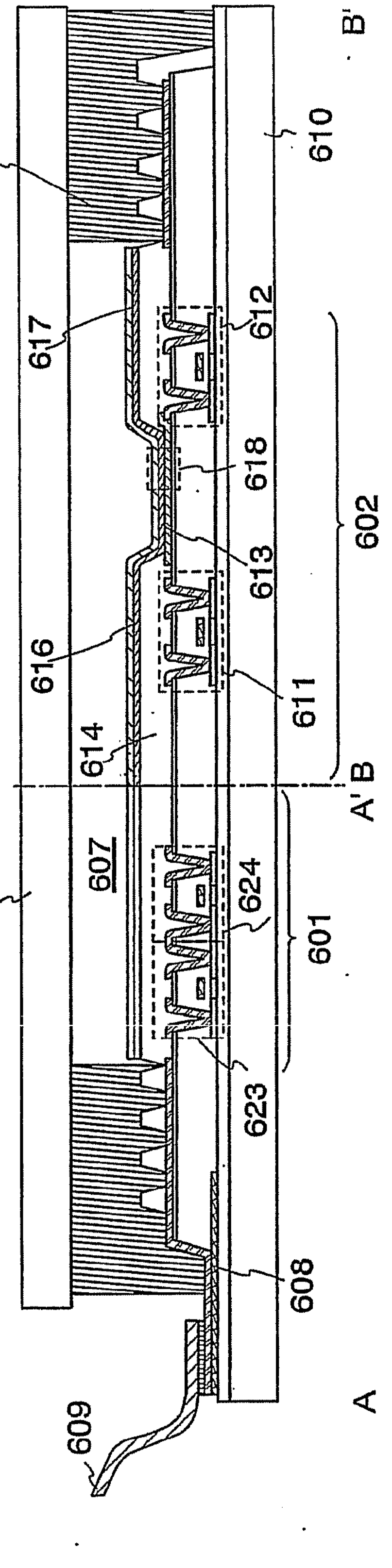


FIG. 23A

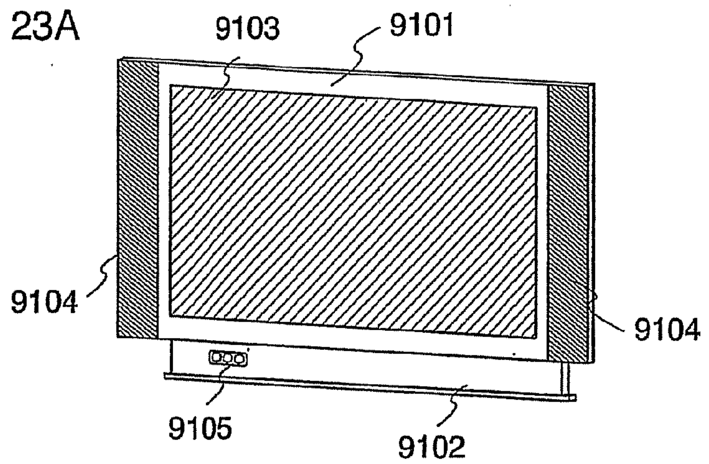


FIG. 23B

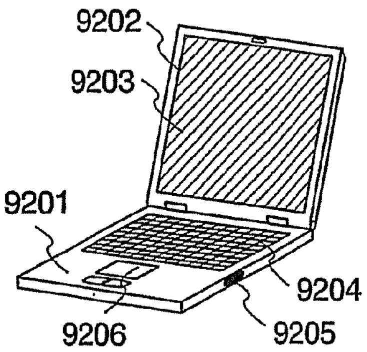


FIG. 23C

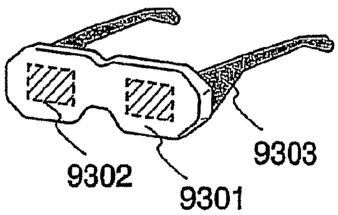


FIG. 23D

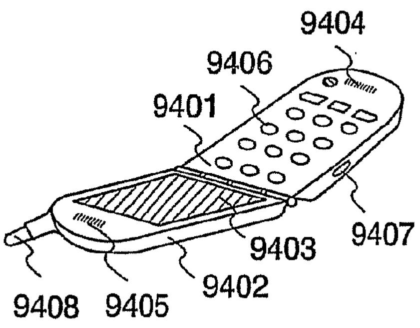


FIG. 23E

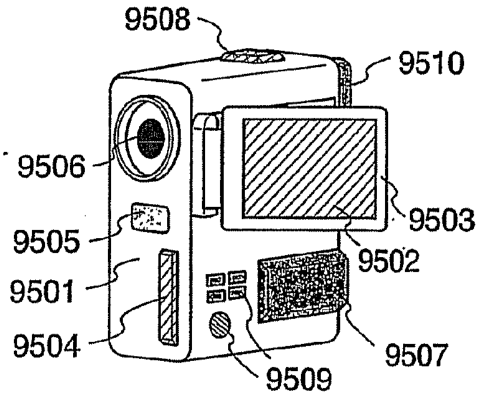


FIG. 24

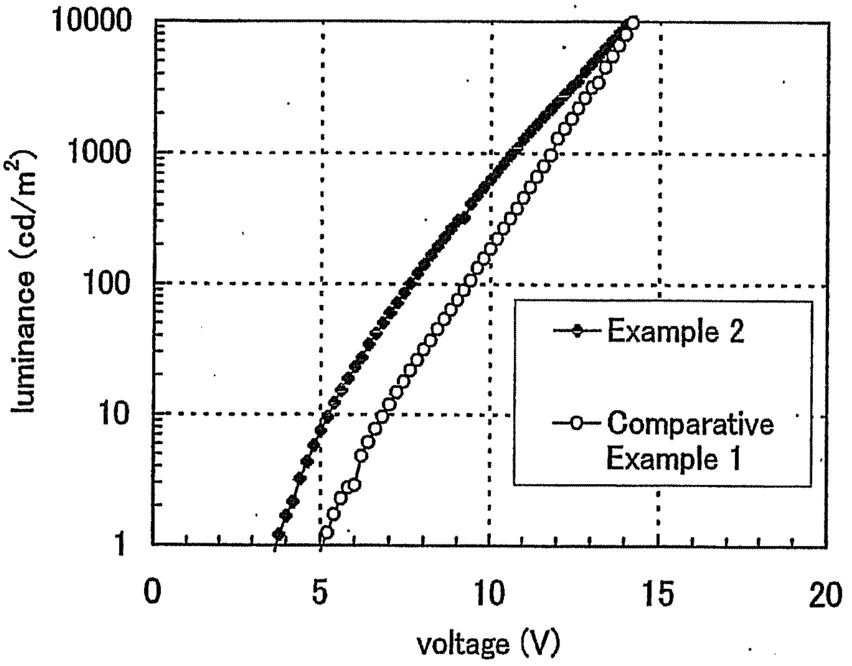

10000
1000
100
10
1
luminance (cd/m²)
0
5
10
15
20
voltage (V)
Example 2
Comparative Example 1

FIG. 25

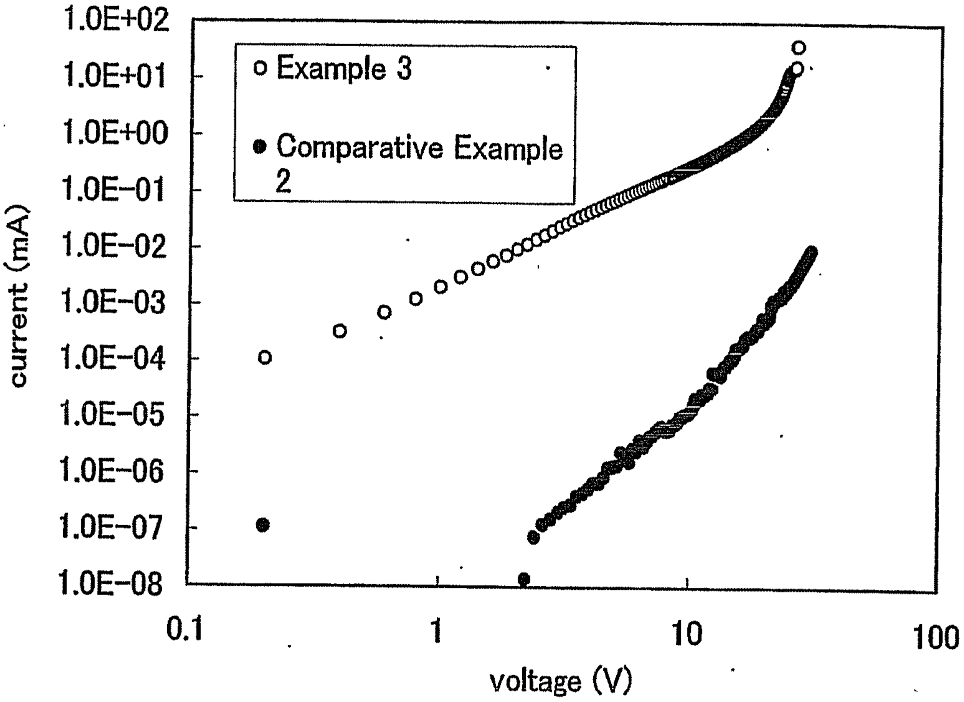

○ Example 3
● Comparative Example 2
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
current (mA)
0.1
1
10
100
voltage (V)

FIG. 26A

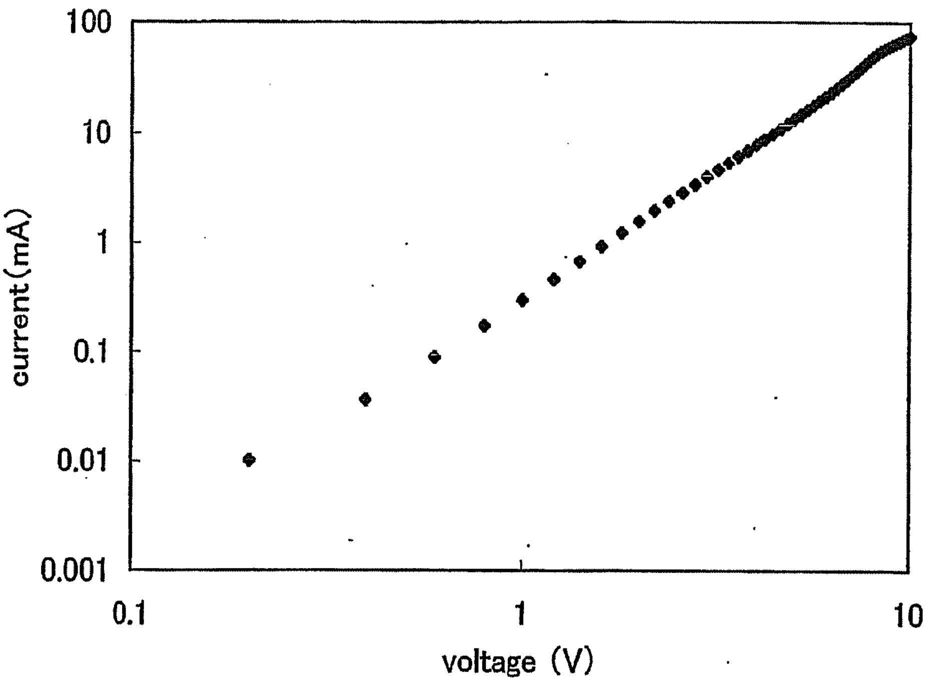


FIG. 26B

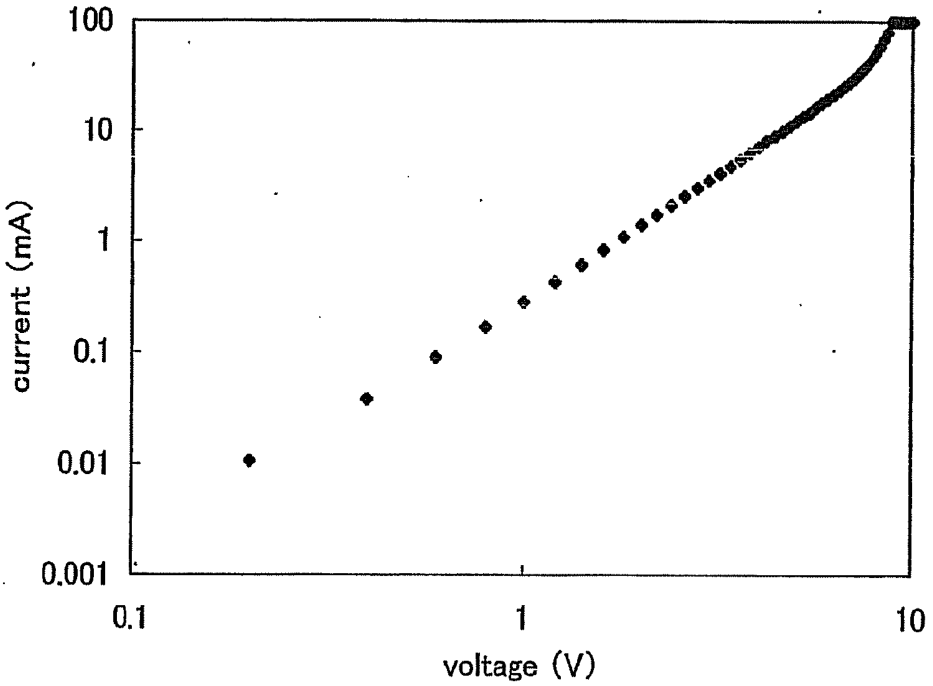


FIG. 27A

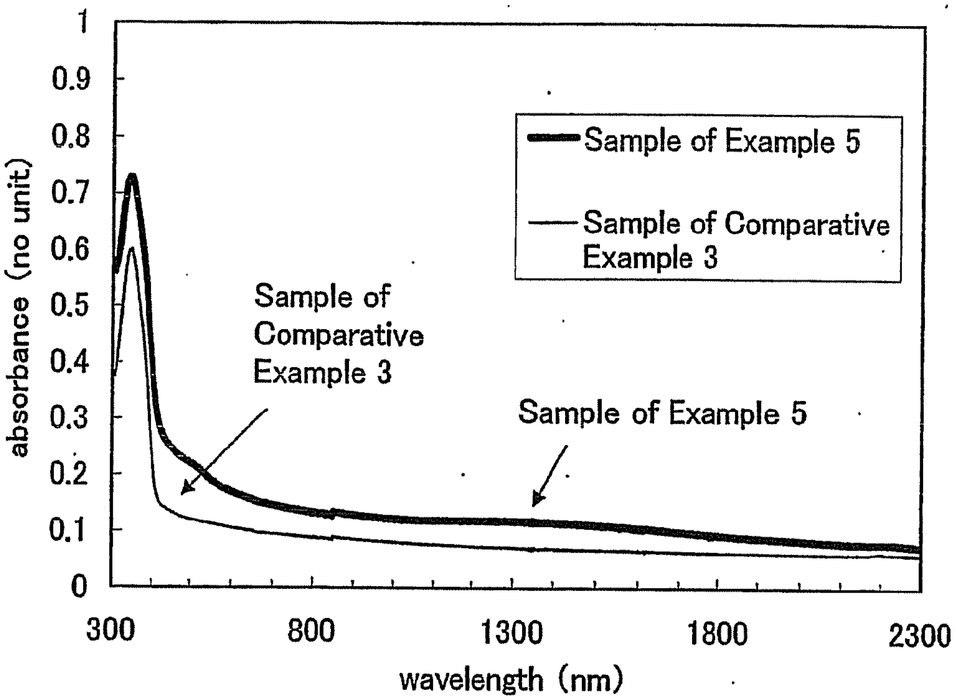
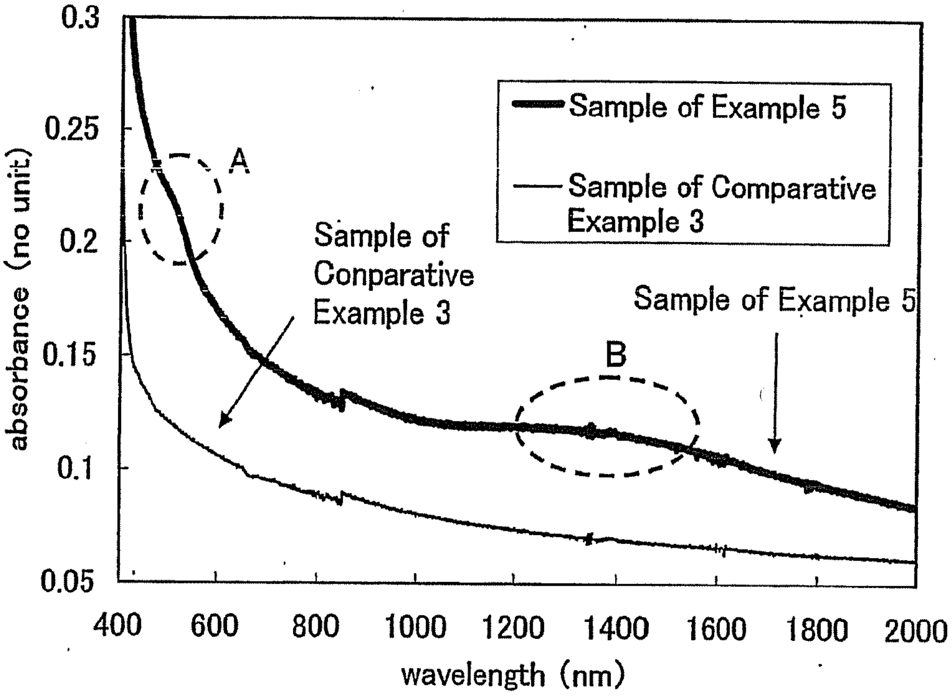


FIG. 27B



COMPOSITE MATERIAL INCLUDING ORGANIC COMPOUND AND INORGANIC COMPOUND, LIGHT-EMITTING ELEMENT AND LIGHT-EMITTING DEVICE USING THE COMPOSITE COMPOUND, AND MANUFACTURING METHOD OF THE LIGHT-EMITTING ELEMENT

TECHNICAL FIELD

[0001] The present invention relates to a composite material including an organic compound and an inorganic compound. Further, the present invention relates to a light-emitting element having a layer including a luminescent substance between a pair of electrodes, and a manufacturing method thereof. Moreover, the present invention relates to a light-emitting device using a light-emitting element.

BACKGROUND ART

[0002] A light-emitting element using a light-emitting material has features of thinness, lightness in weight, high response speed, low direct-current voltage drive, and the like, and is expected to be applied to the next-generation flat panel displays. A light-emitting device in which light-emitting elements are arranged in matrix is said to have superiority in wide viewing angle and high visibility as compared with conventional liquid crystal display devices.

[0003] A basic structure of a light-emitting element is a structure in which a layer containing a light-emitting organic compound is interposed between a pair of electrodes. By applying voltage to the element, electrons from one of the pair of electrodes and holes from the other electrode are transported to a light-emitting layer, so that current flows. The electrons and holes (i.e., carriers) are recombined, and thus, the light-emitting organic compound is excited. The light-emitting organic compound returns to a ground state from the excited state, thereby emitting light.

[0004] It is to be noted that the excited state generated by an organic compound can be a singlet excited state or a triplet excited state, and luminescence from the singlet excited state is referred to as fluorescence, and luminescence from the triplet excited state is referred to as phosphorescence.

[0005] Since light-emitting element like this is usually formed by using a thin film with a thickness approximately on the order of submicron, it is a great advantage that the light-emitting element can be manufactured to be thin and lightweight. In addition, since it takes the time on the order of microseconds or less to generate luminescence after carrier injection, it is also one of the features that the speed of response is quite fast. Further, since sufficient luminescence can be obtained at a direct-current voltage of several to several tens of volts, the power consumption is relatively low. From these advantages, light-emitting elements have attracted a lot of attention as the elements for the next-generation flat panel displays. In particular, the light-emitting elements are expected to be applied to mobile devices and the like, taking advantage of the features of thinness, lightness in weight and the like.

[0006] For example, when such light-emitting elements are applied to mobile devices and the like, power consumption needs to be low, and thus, further decrease in driving voltage becomes necessary. For this reason, electron injecting layers and hole injecting layers have been devised in various ways.

[0007] For example, there is a report that driving voltage is reduced by using a layer formed by co-evaporation of an organic compound and an alkali metal salt or an alkali metal oxide, as an electron injecting layer (Reference 1: Japanese Patent Laid-Open No. H10-270172).

[0008] Further, there is a report that driving voltage is reduced by using a layer combining a high molecular weight compound having an arylamine skeleton and an electron accepting compound as a hole injecting layer (Reference 2: Japanese Patent Laid-Open No. 2000-150169). It is considered that charge transfer occurs by using the high molecular weight compound having an arylamine skeleton and the electron accepting compound in combination, and thus, driving voltage is reduced.

[0009] Furthermore, there is also a report that a hole injecting layer by the conception similar to that of Reference 2 is used to achieve a light-emitting element that can operate at a low voltage, even when the thickness is as thick as 650 nm (Reference 3: Asuka Yamamori, and three others, Applied Physics Letters, vol. 72, No. 17, pp. 2147-2149 (1998)). It is reported that such materials are superior in conductivity.

[0010] However, the electron injecting layer disclosed in Reference 1 can be formed only by a vacuum evaporation method. The vacuum evaporation method is not suitable for mass-production, since it is difficult to respond to increase in substrate size.

[0011] Since the hole injecting layer disclosed in References 2 and 3 is formed by a wet method, it is easy to respond to an increase in substrate size. However, a highly acidic compound is used as an electron accepting compound, and thus, there is a problem such as corrosion of an electrode. Further, the antimony compound used in References 2 and 3 is highly toxic. Therefore, there are tears of the antimony compound having adverse affects on the environment or on human body, and thus, it is not suitable for industrial use.

DISCLOSURE OF INVENTION

[0012] In view of the above problems, it is an object of the present invention to provide a highly conductive composite material, a light-emitting element and a light-emitting device each using the composite material. Further, it is another object of the present invention to provide a manufacturing method of a light-emitting element which is suitable for mass production.

[0013] The present inventors have found that the above objects can be achieved by forming a composite material containing an organic compound, and an inorganic compound showing an electron accepting property to the organic compound by a wet method.

[0014] In the present invention, in consideration of film-quality when a film is formed by a wet method, and in the case where the organic compound is a low molecular weight compound, a composite material of the present invention further includes a material which serves as a binder (hereinafter, a binder substance). In addition, in the case where the organic compound is a high molecular weight compound (in this specification, the category of the high molecular weight compound includes compounds having middle molecular weight such as oligomer or dendrimer), a composite material of the present invention may additionally include a binder substance; however, it is not necessarily required.

[0015] In other words, a structure of the present invention is a composite material including an organic compound, a binder substance, and an inorganic compound showing an electron donating property to the organic compound.

[0016] Another structure of the present invention is a composite material including an organic compound of a high molecular weight compound, and an inorganic compound showing an electron donating property to the organic compound.

[0017] Note that, in the composite material of the present invention, the binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate, or a phenol resin. In addition, the organic compound preferably has one or plural of a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, a thiadiazole skeleton, an oxazole skeleton, and a thiazole skeleton. The inorganic compound is preferably an oxide containing an alkali metal or an alkaline earth Metal, specifically, one or plural of lithium oxide, calcium oxide, and barium oxide.

[0018] An oxide of the alkali metals or the alkaline earth metals described above may include a hydroxyl group.

[0019] In addition, a light-emitting element using the above-described composite material of the present invention is also one mode of the present invention. It should be noted that a layer including a composite material of the present invention is provided in such a location that the layer is in contact with an electrode of the light-emitting element, thereby reducing the driving voltage of the light-emitting element. Alternatively, a structure in which a layer including a composite material of the present invention and a layer generating holes are stacked, is provided in such a location that the structure is in contact with an electrode of the light-emitting element, thereby reducing the driving voltage of the light-emitting element.

[0020] A structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes an organic compound, a binder substance and an inorganic compound showing an electron donating property to the organic compound.

[0021] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein a layer which is included in the layer including a luminescent substance, and is in contact with one electrode of the pair of electrodes, includes an organic compound, a binder substance, and an inorganic compound showing an electron donating property to the organic compound.

[0022] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are each stacked sequentially; wherein the first layer includes a luminescent substance; wherein the second layer includes an organic compound, a binder substance and an inorganic compound showing an electron donating property to the organic compound; and wherein the third layer includes a material generating holes.

[0023] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron donating property to the organic compound.

[0024] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein a layer which is included in the layer including a luminescent substance, and is in contact with one electrode of the pair of electrodes, includes an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron donating property to the organic compound.

[0025] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are each stacked sequentially; wherein the first layer includes a luminescent substance; wherein the second layer includes an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron donating property to the organic compound; and wherein the third layer includes a material generating holes.

[0026] In the light-emitting element of the present invention as described above, the binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin. In addition, the organic compound has one or plural of a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, a thiadiazole skeleton, an oxazole skeleton, and a triazole skeleton. Moreover, the inorganic compound is preferably an oxide including an alkali metal or an alkaline earth metal, specifically, one or plural of lithium oxide, calcium oxide, and barium oxide is/are preferable.

[0027] Further, a light-emitting device having a light-emitting element described above is also one mode of the present invention. Note that the category of the light-emitting element of the present invention includes an image display device and a light-emitter using a light-emitting element. In addition, a module that has a connector, for example, a flexible printed circuit (FPC), a TAB (Tape Automated Bonding) tape, or a TCP (Tape Carrier Package), attached to a light-emitting element; a module that has a printed wiring board provided at the tip of a TAB tape or a TCP; and a module that has an IC (integrated circuit) directly mounted on a light-emitting element by a COG (Chip On Glass) method, are all included in the category of the light-emitting device.

[0028] A manufacturing method of a light-emitting element according to the present invention is based on a novel concept, and is also one mode of the present invention. One feature of the present invention is that a layer including an organic compound and an inorganic compound showing an electron donating property to the organic compound, is formed by a wet method. Further, a method in which layers are formed over the first electrode and another method in which layers are formed over the second electrode, can be considered.

[0029] Therefore, a structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a first layer including a luminescent substance over a first electrode; forming, by a wet method, a second layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound over the first layer; and forming a second electrode over the second layer.

[0030] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a second layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound over a second electrode; forming a first layer including a luminescent substance over the second layer; and forming a first electrode over the first layer.

[0031] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a first layer including a luminescent substance over a first electrode; forming, by a wet method, a second layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound; forming a third layer which generates holes over the second layer; and forming a second electrode over the third layer.

[0032] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a third layer which generates holes over a second electrode; forming, by a wet method, a second layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound over the third layer; forming a first layer including a luminescent substance over the second layer; and forming a first electrode over the first layer.

[0033] In the manufacturing method of a light-emitting element described above, the second layer can be formed by applying a solution including a metal alkoxide and an organic compound and baking it. At this time, hydrolysis is preferably conducted using water, and thus, the film formed by applying the solution may be exposed to water vapor before baking.

[0034] Therefore, a structure of the present invention is a manufacturing method, of a light-emitting element, wherein the step of forming the second layer is a step of applying a solution of a metal alkoxide and an organic compound, and baking it; or a step of applying a solution including a metal alkoxide and an organic compound, exposing it to water vapor, and then, baking it.

[0035] In the method using a metal alkoxide described above, the solution may additionally include a stabilizer to prevent precipitation. As the stabilizer, β-diketones such as acetylacetone, ethyl acetoacetate, or benzoylacetone are preferred. In addition, the solution may additionally include water so as to promote hydrolysis of a metal alkoxide. The solution may also include a binder substance. As the binder substance, polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin is preferred.

[0036] Further, in the manufacturing method of a light-emitting element according to the present invention, the organic compound preferably has one or plural of a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, a thiadiazole skeleton, an oxazole skeleton, and a thiazole skeleton.

[0037] In addition, by the manufacturing method of a light-emitting element according to the present invention, a metal oxide having a strong electron donating property is formed from the metal alkoxide. Therefore, the metal is preferably an alkali metal or an alkaline earth metal. In particular, lithium, calcium, and barium are preferred.

[0038] The present inventors have found that the above described objects can be achieved by applying a composite material including an organic compound and an inorganic compound showing an electron accepting property to the organic compound, to a light-emitting element. Specifically, the present inventors have found that the objects can be achieved by employing a wet method to form the composite material when a light-emitting element is manufactured. It should be noted that a layer including the composite material is provided in such a location that the layer is in contact with an electrode of a light-emitting element, thereby lowering driving voltage of the light-emitting element. Alternatively, a structure in which a layer including a composite material of the present invention and a layer including a material generating electrons are stacked, is provided in such a location that the structure is in contact with an electrode of the light-emitting element, thereby reducing the driving voltage of the light-emitting element.

[0039] In the present invention, in consideration of film quality when a film is formed by a wet method, the composite material further includes a material which serves as a binder (hereinafter, a binder substance), in the case where the organic compound is a low molecular weight compound. In addition, in the case where the organic compound is a high molecular weight compound (in this specification, the category of the high molecular weight compound includes compounds having middle molecular weight such as oligomer or dendrimer), the composite material may further include a binder substance; however, it is not necessarily required.

[0040] Therefore, a structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes an organic compound, a binder substance and an inorganic compound showing an electron accepting property to the organic compound.

[0041] In addition, another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein a layer which is included in the layer including a luminescent substance, and is in contact with one electrode of the pair of electrodes, includes an organic compound, a binder substance, and an inorganic compound showing an electron accepting property to the organic compound.

[0042] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, a third layer, and a fourth layer, which are each stacked sequentially; wherein the first layer includes a composite material having an organic compound, a binder substance, and an inorganic compound showing an electron accepting property to the organic compound, wherein the second layer includes a luminescent substance; wherein the third layer includes a material generating electrons; and wherein the fourth layer includes a material generating holes. Note that the fourth layer can be formed using a composite material of the present invention.

[0043] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, a third layer, and a fourth layer, which are each stacked sequentially; wherein the first layer includes a material generating holes; wherein the second layer includes a luminescent substance; wherein the third layer includes a material generating electrons; and wherein the fourth layer includes a composite material having an organic compound, a binder substance, and an inorganic compound showing an electron accepting property to the organic compound.

[0044] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a high molecular weight compound, and an inorganic compound showing an electron accepting property to the organic compound.

[0045] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein a layer which is included in the layer including a luminescent substance, and is in contact with one electrode of the pair of electrodes, includes an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron accepting property to the organic compound.

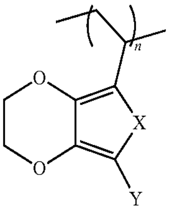
[0046] Another structure of the present invention is a light-emitting element comprising: a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, a third layer, and a fourth layer, which are each stacked sequentially; wherein the first layer includes a composite material having an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron accepting property to the organic compound, wherein the second layer includes a luminescent substance; wherein the third layer includes a material generating electrons; and wherein the fourth layer includes a material generating holes. Note that the fourth layer can be formed using a composite material of the present invention at this time.

[0047] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes, wherein the layer including a luminescent substance includes a first layer, a second layer, a third layer, and a fourth layer, which are each stacked sequentially; wherein the first layer includes a material generating holes; wherein the second layer includes a luminescent substance; wherein the third layer includes a material generating electrons; and wherein the fourth layer includes a composite material having an organic compound which is a high molecular weight compound, and an inorganic compound showing an electron accepting property to the organic compound.

[0048] In the above light-emitting element of the present invention, the binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin.

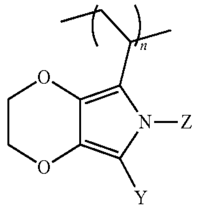
[0049] The organic compound preferably has an arylamine skeleton. Alternatively, the organic compound is preferably any one of high molecular weight compounds represented by general formulas (1) to (10).

(1)



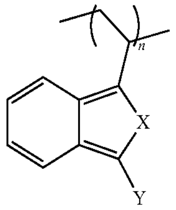
[0050] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. n is an integer of 2 or more.

(2)



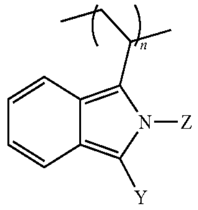
[0051] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. n is an integer of 2 or more.

(3)



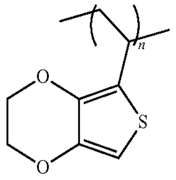
[0052] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. n is an integer of 2 or more.

(4)



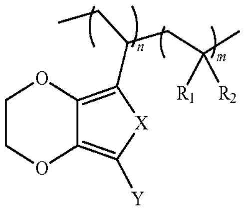
[0053] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. n is an integer of 2 or more.

(5)



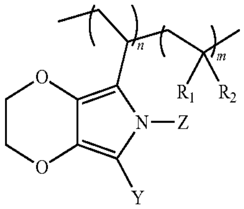
[0054] wherein n is an integer of 2 or more.

(6)



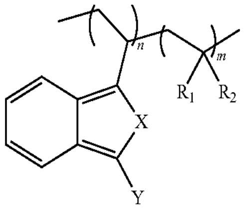
[0055] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.

(7)



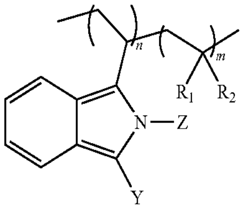
[0056] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.

(8)



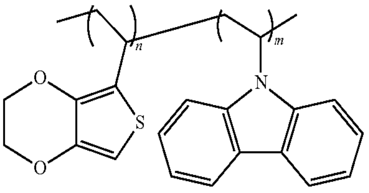
[0057] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.

(9)



[0058] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.

(10)



[0059] wherein n and m are individually an integer of 1 or more.

[0060] Moreover, in the above light-emitting element of the present invention, the inorganic compound is preferably an oxide containing a transition metal, in particular, titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, rhenium oxide, and ruthenium oxide are preferred.

[0061] Further, a light-emitting device having a light-emitting element described above is also one mode of the present invention. Note that the category of the light-emitting element of the present invention includes an image display device and a light-emitter using a light-emitting element. In addition, a module that has a connector, for example, a flexible printed circuit (FPC), a TAB (Tape Automated Bonding) tape, or a TCP (Tape Carrier Package), attached to a light-emitting element; a module that has a printed wiring board provided at the tip of a TAB tape or a TCP; and a module that has an IC (integrated circuit) directly mounted on a light-emitting element by a COG (Chip On Glass) method, are all included in the category of the light-emitting device.

[0062] A manufacturing method of a light-emitting element according to the present invention is based on a novel concept, and is also one mode of the present invention. One feature of the present invention is that a layer including a composite material which includes an organic compound described above and an inorganic compound showing an electron accepting property to the organic compound, is formed by a wet method. Also, a method in which layers are formed over the first electrode and another method in which layer are formed over the second electrode, can be considered.

[0063] A structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a first layer including an organic compound, and an inorganic compound showing an electron accepting property to the organic compound over a first electrode; forming a second layer including a luminescent substance over the first layer; and forming a second electrode over the second layer.

[0064] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a second layer including a luminescent substance over a second electrode; forming, by a wet method, a first layer including an organic compound, and an inorganic compound showing an electron accepting property to the organic compound over the second layer; and forming a first electrode over the first layer.

[0065] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a first layer including an organic compound, and an inorganic compound showing an electron accepting property to the organic compound over a first electrode; forming a second layer including a luminescent substance over the first layer; forming a third layer including a material generating electrons over the second layer; forming a fourth layer including a material generating holes over the third layer; and forming a second electrode over the fourth layer. Note that the fourth layer may be formed by a wet method, as well as the first layer, or may be formed by another method, for example an evaporation method.

[0066] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a fourth layer including a material generating holes over a second electrode; forming a third layer including a material generating electrons over the fourth layer; forming a second layer including a luminescent substance over the third layer; forming, by a wet method, a first layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound over the second layer; and forming a first electrode over the first layer. Note that the fourth layer may be formed by a wet method, as well as the first layer, or may be formed by another method, for example an evaporation method.

[0067] Another structure of the present invention is a manufacturing method of a light-emitting element comprising the steps of forming a first layer including a material generating holes over a first electrode; forming a second layer including a luminescent substance over the first layer; forming a third layer including a material generating electrons over the second layer; forming, by a wet method, a fourth layer including an organic compound and an inorganic compound showing an electron accepting property to the organic compound over the third layer; and forming a second electrode over the fourth layer. Note that the first layer may be formed by a wet method, as well as the fourth layer, or may be formed by another method, for example an evaporation method.

[0068] Another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a fourth layer including an organic compound, and an inorganic compound showing an electron donating property to the organic compound over a second electrode; forming a third layer including a material generating electrons over the fourth layer; forming a second layer including a luminescent substance over the third layer; forming a first layer including a material generating holes over the second layer; and forming a first electrode over the first layer. Note that the first layer may be formed by a wet method, as well as the fourth layer, or may be formed by another method, for example an evaporation method.

[0069] In the manufacturing method of a light-emitting element described above, the first and fourth layers can be formed by applying a solution including a metal alkoxide and an organic compound and baking it. At this time, hydrolysis is preferably conducted using water, and thus, the film formed by applying the solution may be exposed to water vapor before baking.

[0070] Therefore, a structure of the present invention is a manufacturing method of a light-emitting element, wherein the step of forming the first layer is a step of applying a solution of a metal alkoxide and an organic compound, and baking it; or a step of applying a solution of a metal alkoxide and an organic compound, exposing it to water vapor, and baking it.

[0071] Therefore, another structure of the present invention is a manufacturing method of a light-emitting element, wherein the step of forming the fourth layer is a step of applying a solution of a metal alkoxide and an organic compound, and baking it; or a step of applying a solution of a metal alkoxide and an organic compound, exposing it to water vapor, and baking it.

[0072] In the method using a metal alkoxide described above, the solution may additionally include a stabilizer to prevent precipitation. As the stabilizer, β-diketones such as acetylacetone, ethyl acetoacetate, or benzoylacetone are preferred. Also, the solution may additionally include water so as to promote hydrolysis of a metal alkoxide.

[0073] Moreover, the first and fourth layers can be formed by using a metal hydroxide, as well as by using a metal alkoxide as a raw material. In this case, there are advantageous effects of making precipitation difficult to occur, and making a reaction for forming an oxide easy to occur without conducting hydrolysis.

[0074] Thus, another structure of the present invention is a manufacturing method of a light-emitting element, wherein the step of forming the first layer is a step in which a solution including an organic compound, and a sol obtained by deflocculating a metal hydroxide is applied and baked.

[0075] Another structure of the present invention is a manufacturing method of a light-emitting element, wherein the step of forming the fourth layer is a step in which a solution including an organic compound, and a sol obtained by deflocculating a metal hydroxide is applied and baked.

[0076] In the above mentioned manufacturing method of a light-emitting element of the present invention, the solution may include a binder substance additionally. The binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin.

[0077] In the above manufacturing method of a light-emitting element, the organic compound preferably has an arylamine skeleton. Alternatively, the organic compound is any one of the high molecular weight compounds represented by general formulas (1) to (10) described above.

[0078] By the manufacturing method of a light-emitting element according to, the present invention, a metal oxide having a strong electron accepting property is formed from a first metal alkoxide, or a first metal: hydroxide obtained by deflocculation. Thus, the metal is preferably a transition metal in the above manufacturing method of a light-emitting element. In particular, titanium, vanadium, a molybdenum, tungsten, rhenium, or ruthenium is preferred.

[0079] The present inventors have found that the above described objects can be achieved by forming a light-emitting element having a structure in which a layer including a luminescent substance is sandwiched between a first composite material, which includes a first organic compound and a first inorganic compound showing an electron accepting property to the first organic compound, and a second composite material, which includes a second organic compound and a second inorganic compound showing an electron donating property to the second organic compound. Specifically, the present inventors have found that the objects can be achieved by employing a wet method to form both the first and the second composite materials when the light-emitting element is manufactured.

[0080] In the present invention, in consideration of film quality when a film is formed by a wet method, the first organic compound or the second organic compound additionally includes a material which serves as a binder (hereinafter, a binder substance), in the case where the first organic compound or the second organic compound is a low molecular weight compound. In addition, in the case where the first organic compound or the second organic compound is a high molecular weight compound (in this specification, the category of the high molecular weight compound includes compounds having middle molecular weight such as oligomer or dendrimer), the first organic compound or the second organic compound may further include a binder substance; however, it is not necessarily required.

[0081] Therefore, a structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes; wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are stacked sequentially; wherein the first layer includes a first composite material which includes a first organic compound, a first binder substance, and a first inorganic compound showing an election accepting property to the first organic compound; wherein the second layer includes a luminescent substance; and wherein the third layer includes a second composite material which includes a second organic compound, a second binder substance, and a second inorganic compound showing an electron donating property to the second organic compound.

[0082] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes; wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are stacked sequentially; wherein the first layer includes a first composite material including a first organic compound which is a high molecular weight compound, and a first inorganic compound showing an electron accepting property to the first organic compound; wherein the second layer includes a luminescent substance; and wherein the third layer includes a second composite material which includes a second organic compound, a second binder substance, and a second inorganic compound showing an electron donating property to the second organic compound.

[0083] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes; wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are stacked sequentially; wherein the first layer includes a first composite material including a first organic compound, a binder substance, and a first inorganic compound showing an electron accepting property to the first organic compound; wherein the second layer includes a luminescent substance; and wherein the third layer includes a second composite material including a second organic compound which is a high molecular weight compound, and a second inorganic compound showing an electron donating property to the second organic compound.

[0084] Another structure of the present invention is a light-emitting element comprising a layer including a luminescent substance between a pair of electrodes; wherein the layer including a luminescent substance includes a first layer, a second layer, and a third layer, which are stacked sequentially; wherein the first layer includes a first composite material including a first organic compound which is a high molecular weight compound, and a first inorganic compound showing an electron accepting property to the first organic compound; wherein the second layer includes a luminescent substance; and wherein the third layer includes a second composite material including a second organic compound which is a high molecular weight compound, and a second inorganic compound showing an electron donating property to the second organic compound.

[0085] Here, the binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin. The first organic compound is preferably a compound having an arylamine skeleton. The second organic compound preferably has one or plural of a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, a thiadiazole skeleton, an oxazole skeleton, and a thiazole skeleton.

[0086] The first inorganic compound needs to have a highly electron accepting property, and thus, it is preferably an oxide including a transition metal. In particular, titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, rhenium oxide, and ruthenium oxide are preferred.

[0087] On the other hand, the second inorganic compound needs to have a strong electron donating property, and thus, it is preferably an oxide including an alkali metal or an alkaline earth metal. In particular, lithium oxide, calcium oxide, and baiium oxide are preferred.

[0088] The oxide including a transition metal; or the oxide including an alkali metal or an alkaline earth metal described above, may include a hydroxyl group.

[0089] As for the above light-emitting element of the present invention, a light-emitting element has a structure in which the layer including a luminescent substance additionally includes a fourth layer which is in contact with the third layer, and the fourth layer is formed using a third composite material including a third organic compound, and a third inorganic compound showing an electron accepting property to the third organic compound, is also one mode of the present invention.

[0090] In this case, the third organic compound preferably has an arylamine skeleton. The third inorganic compound is preferably an oxide including a transition metal. For example, titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, rhenium oxide, and ruthenium oxide are preferred.

[0091] Further, a light-emitting device having a light-emitting element described above is also one mode of the present invention. Note that the category of the light-emitting element of the present invention includes an image display device and a light-emitter using a light-emitting element. In addition, a module that has a connector, for example, a flexible printed circuit (FPC), a TAB (Tape Automated Bonding) tape, or a TCP (Tape Carrier Package), attached to a light-emitting element; a module that has a printed wiring board provided at the tip of a TAB tape or a TCP; and a module that has an IC (integrated circuit) directly mounted on a light-emitting element by a COG (Chip On Glass) method, are all included in the category of the light-emitting device.

[0092] In addition, a manufacturing method of a light-emitting element according to the present invention is also based on a novel concept, and is also one mode of the present invention. One feature of the present invention is that the first layer and the third layer are formed by a wet method. Also, a method in which layers are formed over the first electrode and a method in which layers are formed over the second electrode can be considered.

[0093] Thus, a structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a first layer including a first organic compound and a first inorganic compound showing an electron accepting property to the first organic compound over a first electrode; forming a second layer including a luminescent substance over the first layer; forming, by a wet method, a third layer including a second organic compound, and a second inorganic compound showing an electron donating property to the second organic compound over the second layer; and forming a second electrode over the third layer.

[0094] In addition, another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a third layer including a second organic compound and a second inorganic compound showing an electron donating property to the second organic compound over a second electrode; forming a second layer including a luminescent substance over the third layer; forming, by a wet method, a first layer including a first organic compound, and a first inorganic compound showing an electron accepting property to the first organic compound over the second layer; and forming a first electrode over the first layer.

[0095] In addition, another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming, by a wet method, a first layer including a first organic compound and a first inorganic compound showing an electron accepting property to the first organic compound over a first electrode; forming a second layer including a luminescent substance over the first layer; forming, by a wet method, a third layer including a second organic compound, and a second inorganic compound showing an electron donating property to the second organic compound over the second layer; forming a fourth layer including a third organic compound and a third inorganic compound showing an electron accepting property to the third organic compound over the third layer; and forming a second electrode over the fourth layer.

[0096] In addition, another structure of the present invention is a manufacturing method of a light-emitting element, comprising the steps of forming a fourth layer including a third organic compound and a third inorganic compound showing an electron accepting property to the third organic compound over a second electrode; forming, by a wet method, a third layer including a second organic compound and a second inorganic compound showing an electron donating property to the second organic compound over the fourth layer; forming a second layer including a luminescent substance over the third layer; forming, by a wet method, a first layer including a first organic compound and a first inorganic compound showing an electron accepting property to the first organic compound over the second layer; and forming a first electrode over the first layer.

[0097] The fourth layer may be formed by a wet method, similarly to the first layer, or by another method such as an evaporation method.

[0098] In the manufacturing method of a light-emitting element described above, the first and third layers can be formed by applying a solution including a metal alkoxide and an organic compound and baking it. At this time, hydrolysis is preferably conducted using water, and thus, the film formed by applying the solution may be exposed to water vapor before baking. The fourth layer can be formed in the same manner as the first layer, when a wet method is employed.

[0099] Thus, a structure of the present invention is a manufacturing method of a light-emitting element, in which the step of forming the first layer is a step in which a solution including a first metal alkoxide and the first organic compound is applied and baked, or a step in which a solution including a first metal alkoxide and the first organic compound is applied, exposed to water vapor and baked.

[0100] Another structure of the present invention is a manufacturing method of a light-emitting element, in which the step of forming the third layer is a step in which a solution including a second alkoxide and the second organic compound is applied, and baked, or a step in which a solution including the second alkoxide and the second organic compound is applied, exposed to water vapor and baked.

[0101] Another structure of the present invention is a manufacturing method of a light-emitting element, in which the step of forming the fourth layer is a step in which a third solution including a third metal alkoxide and a third organic compound is applied and baked, or a step in which a third solution including a third metal alkoxide and a third organic compound is applied, exposed to water vapor and baked.

[0102] In the method using a metal alkoxide as described above, the first, second and third solutions may additionally include a stabilizer to prevent precipitation. As the stabilizer, β-diketones such as acetylacetone, ethyl acetoacetate, or benzoylacetone are preferred. In addition, the first, second and third solutions may additionally include water so as to promote hydrolysis of a metal alkoxide.

[0103] Moreover, the first and fourth layers can be formed using a metal hydroxide, instead of using a metal alkoxide. In this case, there are advantageous effects of making precipitation difficult to occur, and making a reaction for forming an oxide easy to occur without conducting hydrolysis.

[0104] Thus, another structure of the present invention is a manufacturing method of a light-emitting element, in which the step of forming the first layer is a step in which a first solution including the first organic compound and a sol obtained by deflocculating a first metal hydroxide is applied and baked.

[0105] Further, another structure of the present invention is a manufacturing method of a light-emitting element, in which the step of forming the fourth layer is a step in which a third solution including the third organic compound and a sol obtained by deflocculating a third metal hydroxide is applied and baked.

[0106] As described above, the above described first, third and fourth layers can be formed by a wet method using a metal alkoxide or a metal hydroxide.

[0107] In the above described manufacturing method of a light-emitting element, the first, second and third solutions may additionally include a binder substance. The binder substance is preferably polyvinyl alcohol, polymethyl methacrylate, polycarbonate or a phenol resin.

[0108] The first organic compound is preferably a compound having an arylamine skeleton. The second organic compound preferably has one or plural of a pyridine skeleton, en imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, a thiadiazole skeleton, an oxazole skeleton, and a triazole skeleton.

[0109] By the manufacturing method of a light-emitting element according to the present invention, a metal oxide having a strong electron accepting property is formed using a first metal hydroxide which is obtained by deflocculation, and a first metal alkoxide. Thus, the first metal is preferably a transition metal. In particular, titanium, vanadium, molybdenum, tungsten, rhenium, and ruthenium are preferred.

[0110] On the other hand, by the manufacturing method of a light-emitting element according to the present invention, a metal oxide with a strong electron donating property can be formed using a second metal alkoxide. Thus, the second metal is preferably an alkali metal or an alkaline earth metal. In particular, lithium, calcium, and barium are preferable.

[0111] A composite material of the present invention including an organic compound and an inorganic compound has high conductivity. A composite material of the present invention is also superior in the carrier injecting property and carrier transporting property.

[0112] Since a light-emitting element according to the present invention includes a composite material having a combination of an organic compound and an inorganic compound, it exhibits superior carrier injecting property, carrier transporting property, and conductivity. Thus, driving voltage of the light-emitting element can be lowered.

[0113] In a light-emitting device having a light-emitting element of the present invention, the light-emitting element can be driven at low voltage. Thus, power consumption can be reduced.

[0114] A light-emitting element of the present invention can be formed by a wet method. Thus, it can respond to an increase in substrate size and is suitable for mass-production.

[0115] Since a light-emitting element of the present invention employs a material that is less corrosive and harmful, effects on the environment and on the human body are low. Thus, it is suitable for mass-production.

BRIEF DESCRIPTION OF DRAWINGS

[0116] In the accompanying drawings:

[0117] FIG. **1** shows a light-emitting element of the present invention;

[0118] FIG. **2** shows a light-emitting element of the present invention;

[0119] FIGS. **3**A to **3**C each show a light-emitting element of the present invention;

[0120] FIGS. **4**A to **4**C each show a light-emitting element of the present invention;

[0121] FIG. **5** shows a light-emitting element of the present invention;

[0122] FIGS. **6**A to **6**C each show a light-emitting element of the present invention;

[0123] FIGS. **7**A to **7**C each show a light-emitting element of the present invention;

[0124] FIG. **8** shows a light-emitting element of the present invention;

[0125] FIG. **9** shows a light-emitting element of the present invention;

[0126] FIGS. **10**A to **10**C each show a light-emitting element of the present invention;

[0127] FIGS. **11**A to **11**C each show a light-emitting element of the present invention;

[0128] FIG. **12** shows a light-emitting element of the present invention;

[0129] FIGS. **13**A to **13**C each show a light-emitting element of the present invention;

[0130] FIGS. **14**A to **14**C each show a light-emitting element of the present invention;

[0131] FIG. **15** shows a light-emitting element of the present invention;

[0132] FIG. **16** shows a light-emitting element of the present invention;

[0133] FIGS. **17**A to **17**C each show a light-emitting element of the present invention;

[0134] FIGS. **18**A to **18**C each show a light-emitting element of the present invention;

[0135] FIGS. **19**A to **19**C each show a light-emitting element of the present invention;

[0136] FIGS. **20**A to **20**C each show a light-emitting element of the present invention;

[0137] FIG. **21** shows a light-emitting device;

[0138] FIGS. **22**A and **22** B each show a light-emitting device;

[0139] FIGS. **23**A to **23**E each show an electronic device;

[0140] FIG. **24** is a graph showing voltage-luminescence characteristics of the light-emitting elements shown in Example 2 and the comparative example 1;

[0141] FIG. **25** is a graph showing voltage-current characteristics of the light-emitting elements shown in Example 3 and the comparative example 2;

[0142] FIGS. **26**A and **26**B are each a graph showing voltage-current characteristics of the light-emitting elements shown in Example 4 and the comparative example 3; and

[0143] FIGS. **27**A and **27**B are each a graph showing absorption spectra of the light-emitting elements shown in Example 5 and the comparative example 4.

BEST MODE FOR CARRYING OUT THE INVENTION

[0144] Embodiment Modes according to the present invention will hereinafter be described with reference to the accompanying drawings. The present invention can be carried out in many different modes, and it is easily understood by those skilled in the art that modes and details herein disclosed can be modified in various ways without departing from the spirit and the scope of the present invention. It should be noted that the present invention should not be interpreted as being limited to the description of the embodiment modes to be given below.

[0145] As for a pair of electrodes of a light-emitting element according to the present invention, when a voltage is applied such that a potential of one electrode thereof is higher than that of the other electrode, light is emitted. At this time, one electrode having a higher potential, is referred to as an electrode serving as an anode, and the other electrode having a lower potential, is referred to as an electrode sewing as a cathode.

[0146] In this specification, a wet method is a method in which a liquid is applied to form a film.

Embodiment Mode 1

[0147] A composite material of the present invention will be described. The composite material is a material inducing an organic compound and an inorganic compound in combination.

[0148] The conductivity of a composite material of the present invention is increased by generating an interaction between an organic compound and an inorganic compound to generate carriers. This embodiment mode describes a case that electrons are generated as carriers.

[0149] A composite material for generating electrons is a composite material including an organic compound and an inorganic compound showing an electron donating property to the organic compound. By adopting this combination, electrons move into the organic compound from the inorganic compound, thereby generating electrons as carriers. As a result of the generated electrons, high conductivity can be obtained.

[0150] As an organic compound of the present invention, which is used for a composite material generating electrons, a material that is superior in electron transporting property is preferable. An organic compound having a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, an oxazole skeleton, or a thiazole skeleton is preferably used. Specifically, tris(8-quinolinolato) aluminum (Alq_3); tris(4-methyl-8-quinolinolato) aluminum ($Almq_3$); bis(10-hydroxybenzo[h]-quinolinato)beryllium ($BeBq_2$); bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminium (BAlq); bis[2-(2'-hydroxyphenyl)-benzoxazolato]zinc ($Zn(BOX)_2$); bis[2-(2'-hydroxyphenyl)-benzothiazolato]zinc ($Zn(BTZ)_2$); bathophenanthroline (BPhen), bathocuproin (BCP), 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD); 1,3-bis[5-(4-tert-butylphenyl)-1,3,4-oxadiazol-2-yl]benzene (OXD-7); 2,2',2"-(1,3,5-benzenetriyl)-tris (1-phenyl-1H-benzimidazole) (TPBI); 3-(4-biphenylyl)-4-phenyl-5-(4-tert-butylphenyl)-1,2,4-triazole (TAZ); and 3-(4-biphenylyl)-4-(4-ethylphenyl)-5-(4-tert-butylphenyl)-1,2,4-triazole (p-EtTAZ); and poly(4-vinyl pyridine) (PVPy) and the like can be given. However, the present invention is not limited to these substances.

[0151] As the inorganic compound included iii the composite material generating electrons, an oxide including an alkali metal or an alkaline earth metal is preferably used. Specifically, one or plural of lithium oxide, calcium oxide, and barium oxide is/are preferably used. A composite oxide including a skeleton of such oxides may also be used. The oxide including an alkali metal or an alkaline earth metal may include a hydroxyl group.

[0152] Since the oxide including an alkali metal or an alkaline earth metal is used, electron transfer is conducted between such a metal oxide and a pyridine skeleton or the like, thereby generating electrons as carriers. Since the electrons are generated internally, high conductivity can be obtained in applying an electric field.

[0153] A composite material of the present invention may take form in a variety of states, such as a state in which the organic compound becomes a matrix and the inorganic compound is dispersed therein, a state in which the inorganic compound becomes a matrix and the organic compound is dispersed therein, or a state in which the organic compound and the inorganic compound are contained in nearly equal amounts and bound to each other. In any state, since electron transfer is conducted between an organic compound and an inorganic compound, superior electron injecting property, electron transporting property and high conductivity can be obtained.

[0154] When a film is formed using a composite material generating electrons, a material functioning as a binder (a binder substance) may be added to improve the film quality. In particular, in the case of using a low molecular weight compound (specifically, a compound having a molecular weight of 500 or less) is used as the organic compound, a binder substance is needed in consideration of film quality. Needless to say, a binder substance may be added when a high molecular weight compound is used as the organic compound. As binder substances, polyvinyl alcohol (PVA), polymethylmethacrylate (PMMA), polycarbonate (PC), a phenol resin and the like can be given.

Embodiment Mode 2

[0155] Embodiment Mode 2 will describe a manufacturing method of a composite material generating electrons, shown in Embodiment Mode 1.

[0156] A metal alkoxide is used as a component for forming an inorganic compound. As described in Embodiment Mode 1, an oxide including an alkali metal or an alkaline earth metal is preferably used as the inorganic compound. As the metal, an alkali metal or an alkaline earth metal is preferable, specifically, lithium, calcium or barium is preferred. Note that in the case of using a composite oxide as an inorganic compound, another metal alkoxide may be added. In other words, in a case that a composite oxide including an aluminum oxide skeleton, for example, is used, an aluminum alkoxide such as aluminum triisopropoxide may additionally be added.

[0157] A sol is prepared by adding water and a chelating agent such as β-diketon as a stabilizer, into a solution in which a metal alkoxide is dissolved in a proper solvent. As the solvent, for example, tetrahydrofuran (THF), acetonitrile, dichloromethane, dichloroethane, or a mixed solvent of these ran be used, as well as lower alcohol such as methanol, ethanol, n-propanol, i-propanol, n-butanol, and sec-butanol. However, the present invention is not limited to them.

[0158] As the compound which can be used as a stabilizer, β-diketones such as acetylacetone, ethyl acetoacetate, benzoylacetone are given, for example. However, the stabilizer is provided to prevent precipitation inside a sol; however, it is not necessarily provided. In addition, water is not necessarily required, since it is added to control the progress of a reaction of the alkoxide.

[0159] Subsequently, an organic compound (or a solution of an organic compound) is mixed with the prepared sol, and stirred to obtain a first solution including the metal alkoxide and the organic compound. After that, by coating and baking the solution, a composite material generating electrons, of the present invention, can be formed as a film. As a method of applying a solution, wet methods such as a solution cast method, a dip coating method, a spin coating method, a roll coating method, a blade coating method, a wire bar coat method, a spray coating method, an ink-jet method, a screen printing method, and a gravure printing method can be adopted. However, the present invention is not limited to the methods.

[0160] It should be noted that a binder substance may be added, in advance, to the first solution, in the case of adding the binder substance. Substances described in Embodiment Mode 1 may be used as the binder substance.

Embodiment Mode 3

[0161] Embodiment Mode 3 will describe a method of forming a composite material generating electrons, as a film, by another method, which is different from that in Embodiment Mode 2.

[0162] A metal alkoxide is used as a component for forming an inorganic compound. As described in Embodiment Mode 1, an oxide including an alkali metal or an alkaline earth metal is preferably used. As the metal, an alkali metal or an alkaline earth metal is preferable, specifically, lithium, calcium or barium is preferred. Note that in a case of using a composite oxide as an inorganic compound, another metal alkoxide may be added. In other words, in a case that a composite oxide including an aluminum oxide skeleton, for example, is used, an aluminum alkoxide such as aluminum triisopropoxide may additionally be added.

[0163] A first solution including a metal alkoxide and an organic compound is obtained by dissolving the metal alkoxide and the organic compound in a proper solvent, and stirring it. As the solvent, for example, THF, acetonitrile, dichloromethane, dichloroethane, or a mixed solvent of these can be used, as well as lower alcohol such as methanol, ethanol, n-propanol, i-propanol, n-butanol, and sec-butanol. However, the present invention is not limited to them.

[0164] After that, by coating, exposing to water vapor and baking, a composite material of the present invention, can be formed as a film. As a method of applying a solution, wet methods such as a solution cast method, a dip coating method, a spin coating method, a roll coating method, a blade coating method, a wire bar coat method, a spray coating method, an ink-jet method, a screen printing method, and a gravure printing method can be adopted. However, the present invention is not limited to the methods.

[0165] As a result of exposing the solution to water vapor after applying it, a hydrolysis reaction of the metal alkoxide occurs. Then, it is baked, so that polymerization or cross-linking reaction progresses. Alternatively, irradiation of a microwave may be conducted, instead of baking, so that polymerization or cross-linking reaction can progress. Further, baking and irradiation of a microwave may be conducted together, so that polymerization or cross-linking reaction can progress.

[0166] It should be noted that a binder substance may be added, in advance, to the first solution, in a case of adding the binder substance. Substances described in Embodiment Mode 1 may be used as the binder substance.

[0167] In this embodiment mode, a stabilizer such as the 8-diketone as described in Embodiment Mode 2 may be added into the first solution including a metal alkoxide and an organic compound. By adding a stabilizer, multinuclear precipitation of a metal hydroxide due to moisture in the air or the like, can be suppressed. A stabilizer is not necessarily needed, if the manufacturing process is done in an environment without moisture, before being exposed to water vapor.

Embodiment Mode 4

[0168] Embodiment Mode 4 will describe a light-emitting element manufactured using a composite material of the present invention.

[0169] FIG. **1** shows a light-emitting element of the present invention. A layer including a luminescent substance **103** is sandwiched between a first electrode **101** and a second electrode **102**. The layer including a luminescent substance has a structure in which a first layer **111** and a second layer **112** are stacked. This embodiment mode describes a case that the first electrode **101** serves as an anode and the second electrode **102** serves as a cathode.

[0170] The second layer **112** is described. The second layer **112** is a layer which transports electrons to the first layer **111**, and is preferably formed with a composite material generating elections, which is shown in Embodiment Mode 1. The composite material generating electrons contains an organic compound and an inorganic compound showing an electron donating property to the organic compound. Electron transfer occurs between the organic compound and the inorganic compound, thereby generating a large number of electrons as carriers. Thus, excellent electron injecting property and electron transporting property are shown. Therefore, driving voltage of a light-emitting element can be decreased by using a composite material generating electrons of the present invention. It should be noted that, since the second layer **112** including such a composite material generating electrons has excellent electron injecting property and electron transporting property, the second layer **112** is preferably formed in a position closer to a cathode than a light-emitting layer. This embodiment mode will describe a case that the second layer **112** is provided to be in contact with the second electrode **102** serving as a cathode.

[0171] A composite material of the present invention has high conductivity. Thus, the second layer **112** can be made thicker without causing a rise or driving voltage, and short-circuiting of an element caused by dusts or the like can be prevented.

[0172] Since the above composite material includes an inorganic compound, heat-resistance of the light-emitting element can be increased.

[0173] The first layer **111** is a layer having a light-emitting function. The first layer **111** may have a single layer or a multilayer. For example, functional layers such as an electron injecting layer, an electron transporting layer, a hole blocking layer, a hole transporting layer, and a hole injecting layer may be freely combined, in addition to the light-emitting layer. In addition, a known material can be used for the first layei 111, and a low molecular weight material and a high molecular weight material can be psed. It should be noted that, as a material for forming the first layer **111**, organic compound materials containing an inorganic compound as a part can be used, as well as materials of only an organic compound. An advantageous effect that heat resistance is more enhanced, can be provided, since the first layer **111** also contains an inorganic compound.

[0174] In this embodiment mode, since the second layer **112** serves as an electron injecting layer, an electron injecting layer is not required to be provided in the first layer **111**.

[0175] A known material can be used as a hole injecting material for forming a hole injecting layer. Specifically, metal oxides such as molybdenum oxide, vanadium oxide, ruthenium oxide, and aluminum oxide are preferable. Alternatively, in a case of using an organic compound, a porphyrin based compound is effective, phthalocyanine (H_2-PC), copper phthalocyanine (CuPc) or the like can be used. In addition, a chemically doped polymer conductive compound can be used, for example, polyethylene dioxythiophene (PEDOT) which is doped with polystyrene sulfonic acid (PSS), or polyaniline (PAni) etc., can be used. A composite material may be used, in which an organic compound having an aromatic amine skeleton, such as 4,4',4"-tris(N,N-diphenylamino)-triphenylamine (TDATA); 4,4',4"-tris[N-(3-methylphenyl)-N-phenylamino]triphenylamine (MTDATA); 1,3,5-tris[N,N-bis(3-methylphenyl)amino]benzene (m-MTDAB); N,N'-diphenyl N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD); 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB); 4,4'-bis{N-(4-[N,N-bis(3-methylphenyl amino]phenyl)-N-phenylamino}biphenyl (DNTPD); 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA); or poly(4-vinyl triphenylamine) (PVTPA), and a compound showing an electron accepting property to the organic compound, are mixed. At this time, as the compound having an electron accepting property, an oxide including a transition metal such as molybdenum oxide, vanadium oxide, rhenium oxide, tungsten oxide, or ruthenium oxide is preferred.

[0176] A known material can be used as a hole transporting material for forming a hole transporting layer. As a preferable material, an aromatic amine compound (i.e., a compound having a bond of benzene ring nitrogen). As a widely used material, a star burst aromatic amine compound such as 4,4'-bis[N-(3-methylphenyl)-N-phenyl-amino]-biphenyl (TPD); or derivatives thereof, e.g., 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]-biphenyl (NPB); 4,4',4"-tris(N,N-diphenylamino)-triphenylamine (TDATA); 4,4',4"-tris[N-(3-methylphenyl)-N-phenyl-amino]-triphenylamine (MTDATA) can be given.

[0177] The light-emitting layer contains a luminescent substance. The luminescent substance is herein a substance that has an excellent light emitting efficiency and, can emit light with a predetermined wavelength. Although the light-emitting layer is not especially limited, the light-emitting layer is preferably one in that a luminescent substance is dispersed in a layer formed using a substance having a larger energy gap than that of the substance with the light emitting property. This layer can prevent light emitted from the substance with the light emitting property from quenching due to the concentration of the substance with the light emitting property. Further, the energy gap indicates an energy gap between the LUMO level and HOMO level.

[0178] The substance with the light emitting property used for forming a light-emitting layer is not especially limited. A substance having an excellent light emitting efficiency that can emit light with a predetermined emission wavelength may be, used. In order to emit red light, for example, the following substances exhibiting emission spectrum with peaks at 600 to 680 nm can be employed: 4-dicyanomethylene-2-isopropyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl) ethenyl]-4H-pyran (DCJTI); 4-dicyanomethylene-2-methyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]-4H-pyran (DCJT); 4-dicyanomethylene-2-tert-butyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]-4H-pyran (DCJTB); periflanthene; 2,5-dicyano-1,4-bis[2-(10-methoxy-1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]benzene; and the like. In order to obtain green light emission, substances exhibiting emission spectrum with peaks at 500 to 550 nm such as N,N'-dimethylquinacridon (DMQd), coumarin 6, coumarin 545T, and tris(8-quinolinolato) aluminum (Alq_3) can be employed. In order to obtain blue light emission, the following substances exhibiting emission spectrum with peaks at 420 to 500 nm can be employed: 9,10-bis(2-naphthyl)-tert-butylanthracene (t-BuDNA); 9,9'-bianthryl; 9,10-diphenylanthracene (DPA); 9,10-bis(2-naphthyl) anthracene (DNA); bis(2-methyl-8-quinolinolato)-4-phenylphenolato-gallium (BGaq); bis(2-methyl-8-quinolinolato)(4-phenylphenolato) aluminium (BAlq); and the like. In addition to the above mentioned fluorescent substances, the following phosphorescent substances can be used as substances with the light emitting properties: bis[2-(3,5-bis(trifluoromethyl)phenyl) pyridinato-N,$C^{2'}$]iridium(III) picolinate ($Ir(CF_3ppy)_2(pic)$); bis[2-(4,6-difluorophenyl)pyridinato-N,$C^{2'}$]iridium(III) acetylacetonate (FIr(acac)); bis[2-(4,6-difluorophenyl)pyridinato-N,$C^{2'}$]iridium(III) picolinate (FIr(pic)); tris(2-phenylpyridinato-N,$C^{2'}$) iridium ($Ir(ppy)_3$); and the like.

[0179] A substance used for dispersing a luminescent substance is not especially limited. For example, an anthracene derivative such as 9,10-di(2-naphthyl)-2-tert-butylanthracene (t-BuDNA); a carbazole derivative such as 4,4'-bis (N-carbazolyl)biphenyl (CBP); a metal complex such as bis [2-(2-hydroxyphenyl)pyridinato]zinc ($Znpp_2$); and bis[2-(2-hydroxyphenyl)benzoxazolato]zinc (ZnBOX); and the like can be used.

[0180] As a material with an electron transporting property that is used for forming an electron transporting layer, a known material can be used. Specifically, a typical metal complex such as tris(8-quinolinolato) aluminum (Alq_3); tris (4-methyl-8-quinolinolato) aluminum ($Almq_3$); bis(10-hydroxybenzo[h]-quinolinato) beryllium ($BeBq_2$); bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminium bis[2-(2-hydroxyphenyl)-benzoxazolate]zinc ($Zn(BOX)_2$); and bis [2-(2-hydroxyphenyl)-benzothiazolate]zinc ($Zn(BTZ)_2$) can be given. In addition, a hydrocarbon compound such as 9,10-diphenylanthracene and 4,4'-bis(2,2-diphenylethenyl)biphenyl is preferably employed. Additionally, a triazole derivative such as 3-(4-tert-butylphenyl)-4-(4-ethylphenyl)-5-(4-biphenylyl)-1,2,4-triazole; a phenanthroline derivative such as bathophenanthroline and bathocuproin may be used.

[0181] As a material with an electron injecting property that is used for forming an electron injecting layer, a known material can be used. Specifically, alkali metal salt and alkaline earth metal salt such as calcium fluoride, lithium fluoride, lithium oxide and lithium chloride are preferable. Alternatively, a layer of a material with an electron transporting property to which a donor compound such as lithium is added, for example, tris(8-quinolinolato) aluminum (Alq_3) and bathocuproin (BCP) and the like, can be employed.

[0182] In this embodiment mode, a dopant that contributes to light emission is added only to the light-emitting layer and light emitted from the dopant is only observed. However, a dopant exhibiting different light emission may be added to, for example, an electron transporting layer or a hole transporting layer. When a color of light emitted from the light-emitting layer and a color of light emitted from the dopant added to the other layer are complementary to each other, white light emission can be obtained.

[0183] By changing the kinds of the first electrode **101** and the second electrode **102**, there are different variations in the light emitting element of this embodiment mode. Schematic views of the variations are shown in FIGS. **3**A to **3**C and FIGS. **4**A to **4**C. Further, the reference numerals used in FIG. **1** are also used in FIGS. **3**A to **3**C and FIGS. **4**A to **4**C. Moreover, reference numeral **100** represents a substrate for supporting a light emitting element of the present invention.

[0184] FIGS. **3**A to **3**C each show an example in which the first layer **111** and the second layer **112** included in the layer including a luminescent substance **103** are stacked in this order over the substrate **100**. In this case, when the first electrode **101** is formed using a material having a light transmitting property and the second electrode **102** is formed using a material having a light-shielding property (in particular, light reflecting property), light can be emitted through the substrate **100** as shown in FIG. **3**A. Also, when the first electrode **101** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **102** is formed using a material having a light transmitting property, light can be emitted through the side opposite the substrate **100** as shown in FIG. **3**B. Further, when the first electrode **101** and the second electrode **102** are both formed using a material having a light transmitting property, light can be emitted toward both the substrate **100** and the side opposite the substrate as shown in FIG. **3**C.

[0185] FIGS. **4**A to **4**C each show an example in which the second layer **112** and the first layer **111** included in the layer including a luminescent substance **103** are stacked in this order over the substrate **100**. In this case, when the first electrode **101** is formed using a material having a light-shielding property (in particular, light reflecting property) and the second electrode **102** is formed using a material having a light transmitting property, light can be emitted through the substrate **100** as shown in FIG. **4**A. When the first electrode **101** is formed using a material having a light transmitting property and the second electrode **102** is formed using a material having a light-shielding property (in particular, light reflecting property), light can be emitted through the side opposite the substrate **100** as shown in FIG. **4**B. Further, when the first electrode **101** and the second electrode **102** are both formed using a material having a light transmitting property, light can be emitted toward both the substrate **100** and the side opposite the substrate **100** as shown in FIG. **4**C.

[0186] In the light emitting element of this embodiment mode, since the second layer **112** includes an organic compound and an inorganic compound showing an electron donating property to the organic compound, the second layer **112** exhibits extremely excellent electron injecting and transporting properties. Therefore, the increase in driving voltage can be suppressed even when the thickness of the second layer **112** is increased. As a consequence, short-circuiting of the light emitting element can be prevented while suppressing the increase in driving voltage. Moreover, in order to improve the color purity by an optical design, the thickness of the second layer **112** can be freely set.

[0187] Furthermore, as shown in FIGS. **3**A to **3**C, in the case where the first layer **111** and the second layer **112** are sequentially formed over the first electrode **101**, which has been formed first, and then the second electrode **102** is formed thereover by sputtering, it is possible to avoid damage to the first layer **111** in which the luminescent substance exists.

Embodiment Mode 5

[0188] Although Embodiment Mode 4 has described the case that the layer including an organic compound and an inorganic compound showing an electron donating property to the organic compound, is in contact with the cathode, Embodiment Mode 5 will describe a case that the layer including an organic compound and an inorganic compound showing an electron donating property to the organic compound, exists between the cathode and a light-emitting layer, and is not in contact with the cathode.

[0189] An example of a structure of a light emitting element of the present invention will be shown in FIG. **2**. A layer including a luminescent substance **303** is sandwiched between a first electrode **301** and a second electrode **302**. The layer containing the luminescent substance **303** includes a structure in which a first layer **311**, a second layer **312** and a third layer **313** are stacked in this order. This embodiment mode describes a case that the first electrode **301** serves as an anode, and the second electrode **302** serves as a cathode.

[0190] The first layer **311** has a function of emitting light. The same structure as that of the first layer **111**, which has been described in Embodiment Mode 4, can be applied for the first layer **311**.

[0191] The second layer **312** is a layer including an organic compound and an inorganic compound showing an electron donating property to the organic compound. The second layer **312** can have the same structure as the second layer **112** shown in Embodiment Mode 4.

[0192] The third layer **313** is a layer having a function of injecting electrons. A known material can be formed as an electron injecting material for forming an electron injecting layer. Specifically, the electron injecting materials shown in Embodiment Mode 4 can be used.

[0193] By adopting the above described structure, an increase of driving voltage can be suppressed, even when the second layer **312** becomes thick. Thus, the increase of driving voltage can be suppressed, short-circuiting of an element can be prevented, and the color purity by optical design can be realized.

Embodiment Mode 6

[0194] Embodiment Mode 6 will describe a light-emitting element having a structure different from those shown in Embodiment Modes 4 and 5 with reference to FIG. **5**.

[0195] FIG. **5** shows a structure of a light-emitting element of the present invention as one example. A layer including a luminescent substance **203** is sandwiched between a first electrode **201** and a second electrode **202**. The layer containing the luminescent substance **203** includes a structure in that a first layer **211**, a second layer **212** and a third layer **213** are stacked in this order. This embodiment mode describes a case that the first electrode **201** serves as an anode, and the second electrode **202** serves as a cathode.

[0196] The light-emitting element of this embodiment mode is operated as follows. When voltage is applied such that a potential of the first electrode **201** is higher than that of the second electrode **202**, holes are injected into the second electrode **202** from the third layer **213** while electrons are injected into the first layer **211** from the second layer **212**. Also, holes are injected into the first layer **211** from the first electrode **201**. The holes injected from the first electrode **201** and the electrons injected from the second layer **212** are recombined in the first layer **211**, so that a luminescent substance is excited. The luminescent substance emits light when returning to a ground state from the excited state.

[0197] The first electrode **201**, the second electrode **202**, the first layer **211** and the second layer **212** can have the same structures as the first electrode **101**, the second electrode **102**, the first layer **111** and the second layer **112** in Embodiment Mode 1, respectively. In other words, the first electrode can be formed using a known material, the first layer **211** includes a luminescent substance, and the second layer **212** includes an organic compound and an inorganic compound showing an electron donating property to the organic compound.

[0198] The third layer **213** is a layer generating holes. As the layer generating holes, for example, a layer containing an aromatic amine compound and a substance that shows an electron accepting property to the aromatic amine compound is preferably used. Here, the aromatic amine compound is a substance having an aryl amine skeleton. Among such aromatic amine compounds, particularly, a substance including triphenylamine in its skeleton and having a molecular weight of 400 or more is preferable. In addition, among the aromatic amine compounds including triphenylamine in their skeleton, an aromatic amine including a fused aromatic ring such as a naphthyl group in its skeleton is preferable particularly. By using an aromatic amine compound including triphenylamine and fused aromatic ring in its skeleton, heat resistance of a light-emitting element is increased. For example, an aromatic amine compound such as 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (α-NPD); 4,4'-bis[N-(3-methylphenyl)]-N-phenylamino]biphenyl (TPD); 4,4',4''-tris(N,N-diphenylamino)triphenylamine (TDATA); 4,4',4''-tris[N-(3-methylphenyl)-N-phenylamino]triphenylamine (MTDATA); and 4,4'-bis{N-[4-(N,N-di-m-tolylamino)phenyl]-N-phenylaminobiphenyl}(DNTPD); 1,3,5-tris[N,N-di(m-tolyl) amino]benzene (m-MTDAB); 4,4',4''-tris(N-carbazolyl)-triphenylamine (TCTA); 2,3bis(4-diphenylaminophenyl) quinoxaline (TPAQn); 2,2',3,3'-tetrakis(4-diphenylaminophenyl)-6,6'-bisquinoxaline (D-TriPhAQn); 2,3-bis{4-[N-(1-naphthyl)-N-phenylamino]phenyl}-dibenzo[f,h]quinoxaline (NPADiBzQn); and the like can be given. Also, the substance having the electron accepting property to the aromatic amine compound is not especially limited. For example, titanium oxide, molybdenum oxide, vanadium oxide, tungsten oxide, rhenium oxide, ruthenium oxide, chromium oxide, zirconium oxide, hafnium oxide, tantalum oxide, silver oxide, 7,7,8,8-tetracyanoquinodimethane (TCNQ), 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ), and the like can be used. The third layer **213** preferably includes the substance that shows the electron accepting property to the aromatic amine compound so that the value of a molar ratio (i.e., the substance showing the electron accepting property to the aromatic amine compound/the aromatic amine compound) is in the range of 0.5 to 2.

[0199] By utilizing the above mentioned structure, when the voltage is applied to the light emitting element, the electrons are transported in the vicinity of an interface between the second layer **212** and the third layer **213** so that electrons and holes are generated, as shown in FIG. **5**. The second layer **212** transports the electrons to the first layer **211**, and at the same time, the third layer **213** transports the holes to the second electrode **202**. That is, a combination of the second layer **212** and the third layer **213** serves as a carrier generating layer. Also, it can be said that the third layer **213** has a function of transporting holes to the second electrode **202**. Further, when another first layer and another second layer are also stacked between the third layer **213** and the second electrode **202**, a multiphoton light emitting element can be formed.

[0200] Furthermore, since the second layer **212** includes an organic compound and an inorganic compound showing an electron donating property to the organic compound, the second layer **212** exhibits extremely strong electron injecting and transporting properties. Therefore, the increase in driving voltage can be suppressed even when the thickness of the second layer **212** is increased. Thus, in the light-emitting element of this embodiment mode, since the thickness of the second layer **212** can be increased, the short-circuiting of the light emitting element can be effectively prevented. Moreover, in order to improve the color purity by an optical design, the thickness of the second layer **212** can be freely set.

[0201] Further, in the light-emitting element of this embodiment mode, by changing the kinds of the first electrode **201** and the second electrode **202**, there are many variations in the light emitting element. Schematic views of the variations are shown in FIGS. **6**A to **6**C and FIGS. **7**A to **7**C. The reference numerals used in FIG. **5** are also used in FIGS. **6**A to **6**C and FIGS. **7**A to **7**C. Reference numeral **200** represents a substrate for supporting a light emitting element of the present invention.

[0202] FIGS. **6**A to **6**C each show an example in which a layer including a luminescent substance **203** includes a first layer **211**, a second layer **212**, and a third layer **213**, which are stacked in this order over the substrate **200**. In this case, when the first electrode **201** is formed using a material with a light transmitting property and the second electrode **202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the substrate **200** as shown in FIG. **6**A. When the first electrode **201** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **202** is formed using a material with a light transmitting property, light can be emitted through the side opposite the substrate **200** as shown in FIG. **6**B. Further, when the first electrode **201** and the second electrode **202** are both formed using a material having a light transmitting property, light can be emitted through both the substrate **200** and the side opposite the substrate, as shown in FIG. **6**C.

[0203] FIGS. **7**A to **7**C each show an example in which a layer including a luminescent substance **203** includes a third layer **213**, a second layer **212** and a first layer **211**, which are stacked in this order over the substrate **200**. In this case, when the first electrode **201** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **202** is formed using a substance with a light transmitting property, light can be emitted through the substrate **200** as shown in FIG. **7**A. When the first electrode **201** is formed using a material with a light transmitting property and the second electrode **202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the side opposite the substrate **200** as shown in FIG. **7**B. Further, when the first electrode **201** and the second electrode **202** are both formed using a material with a light transmitting property, light can be emitted through both the substrate **200** and the side opposite the substrate **200**, as shown in FIG. **7**C.

Embodiment Mode 7

[0204] Embodiment Mode 7 will describe a manufacturing method of the light-emitting element shown in Embodiment Mode 4.

[0205] The first electrode **101** is formed first. The first electrode **101** can be formed using a known material by a known method.

[0206] Next, the first layer **111** is formed. The first layer **111** can be formed using a known material by a known method. In a case of employing a wet method which can respond to the increase in a substrate size, all layers included in the layer including a luminescent substance **103** can be formed by a wet method, and thus, a wet method is suitable for mass production. For example, a luminescent substance such as poly(2,5-dihexoxy-1,4-phenylenevinylene) (MEH-PPV) can be, formed by a wet method.

[0207] Then, the second layer **112** is formed. The second layer **112** can be formed by any method shown in Embodiment Modes 2 and 3. The methods shown in Embodiment Modes 2 and 3 are each a wet method, and thus the methods are suitable for the increase in substrate size.

[0208] The second electrode **102** can be formed using a known material by a known method.

[0209] In accordance with the above method, a light-emitting element of the present invention can be manufactured. Since the manufacturing method of a light-emitting element of the present invention which is employed for forming the second layer **112**, is a wet method, the method can respond to the increase in a substrate size and is suitable for mass production. In particular, when the first layer **111** is also formed by a wet method using a known polymer light-emitting material or the like, all layers included in the layer including a luminescent substance **103** can be formed by a wet method. Thus, the present invention can easily respond to the increase in a substrate size, and is suitable for mass production.

[0210] It should be noted that this embodiment mode has described the method of forming the light-emitting element from the first electrode **101** side (over the first electrode). However, the light-emitting element may be formed by stacking layers from the second electrode **102** side (over the second electrode).

Embodiment Mode 8

[0211] Embodiment Mode 8 will describe a light-emitting element of the present invention. The light-emitting element of the present invention includes a luminescent substance and a composite material between a pair of electrodes. Note that the composite material is a material including an organic compound and an inorganic compound in combination.

[0212] FIG. **8** shows an example of a structure of the light-emitting element of the present invention. A layer including a luminescent substance **1103** is sandwiched between a first electrode **1101** and a second electrode **1102**. This embodiment mode describes a case that the first electrode **1101** serves as an anode and the second electrode **1102** serves as a cathode.

[0213] The layer including a luminescent substance **1103** hss a structure in which a first layer **1111** and a second layer **1112** are stacked.

[0214] The first layer **1111** is a layer which transports holes to the second layer **1112**, and includes a composite material generating holes. The composite material generating holes contains an organic compound and an inorganic compound showing an electron accepting property to the organic compound in combination. Electron transfer occurs between the organic compound and the inorganic compound, thereby generating a large number of holes. Thus, excellent hole injecting property and hole transporting property are exhibited. Therefore, driving voltage of a light-emitting element can be decreased by using a composite material generating holes. It should be noted that, since the first layer **1111** including such a composite material generating holes has excellent hole injecting property and hole transporting property, the first layer **1111** is preferably formed in a position closer to an anode than a light-emitting layer. This embodiment mode will describe a case that the first layer **1111** is provided to be in contact with the first electrode **1101** serving as an anode.

[0215] As the organic compound included in the composite material generating holes, a compound having an excellent property of transporting generated holes is preferable, specifically, an organic compound having in aryl amine compound is preferable. More specifically, such as 4,4',4"-tris(N,N-diphenylamino)triphenylamine (TDATA); 4,4',4"-tris[N-(3-methylphenyl)-N-phenylamino]triphenylamine (MTDATA); 1,3,5-tris[N,N-bis(3-methylphenyl)amino]benzene (m-MTDAB); N,N'-diphenyl N,N'-bis-(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD); 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB); 4,4'-bis{N-(4-[N,N-bis(3-methylphenyl amino]phenyl)-N-phenylamino}biphenyl (DNTPD); 4,4',4"-tris(N-carbazolyl) triphenylamine (TCTA); or poly(4-vinyl triphenylamine) (PVTPA); poly(N-vinylcarbazole) (PVK); and the like are given. However, the present invention is not limited to these materials.

[0216] As the inorganic compound included in the composite material generating holes, an oxide including a transition metal is preferably used. Specifically, one or plural of titanium oxide, molybdenum oxide, vanadium oxide, rhenium oxide, tungsten oxide, or ruthenium oxide is/are preferred. In addition, a composite oxide including a skeleton of the oxides described above may be used. The oxide including a transition metal may have a hydroxyl group.

[0217] By using a oxide including a transition metal, electron transfer between the oxide including a transition metal and nitrogen in an arylamine skeleton is conducted, thereby generating holes. Holes exist internally, and thus high conductivity can be obtained when being applied with an electric field.

[0218] The above composite material has high conductivity and thus, the increase in driving voltage can be suppressed when the film thickness is increased. Therefore, since the first layer **1111** can be made thick without causing the increase in driving voltage, short-circuiting of an element due to dusts or the like can be suppressed.

[0219] In addition, the above composite material includes an inorganic compound, and thus, heat resistance of a light-emitting element can be increased.

[0220] The first layer **1111** may take form in a variety of states, such as a state in which the organic compound becomes a matrix and the inorganic compound is dispersed therein, a state in which the inorganic compound becomes a matrix and the organic compound is dispersed therein, or a state in which the organic compound and the inorganic compound are contained in nearly equal amounts and bound to each other. In any state, since electron transfer is conducted between an organic compound and an inorganic compound, superior hole injecting property, hole transporting property and high conductivity can be obtained.

[0221] When a film is formed using a composite material generating holes, a material serving as a binder (a binder substance) may be added to enhance the film quality. In particular, in the case of using a low molecular weight compound (specifically, a compound having a molecular weight of 500 or less) is used as the organic compound, a binder substance is needed in consideration of film quality. Needless to say, a binder substance may be added when a high molecular weight compound is used. As binder substances, polyvinyl alcohol (PVA), polymethylmethacrylate (PMMA), polycarbonate (PC), a phenol resin or the like can be given.

[0222] The second layer **1112** is a layer having a light-emitting function. The second layer **1112** may have a single layer or a multilayer. For example, functional layers such as an electron injecting layer, an electron transporting layer, a hole blocking layer, a hole transporting layer, and a hole injecting layer may be freely combined, in addition to the light-emitting layer. In addition, a known material can be used for the second layer **1112**, and a low molecular weight compound and a high molecular weight compound can be used. It should be noted that, as a material for forming the second layer **1112**, organic compound materials containing an inorganic compound as a part can be used, as well as materials including only an organic compound material. An advantageous effect that heat resistance can be more enhanced, can be provided by making the second layer **1112** contain an inorganic compound.

[0223] In this embodiment mode, since the first layer **1111** serves as a hole injecting layer, a hole injecting layer is not required to be provided in the second layer **1112**.

[0224] A known material can be used as a hole injecting material for forming a hole injecting layer. Specifically, metal oxides such as molybdenum oxide, vanadium oxide, ruthenium oxide, and aluminum oxide are preferable. Alternatively, in a case of using an organic compound, a porphyrin based compound is effective, phthalocyanine copper phthalocyanine (CuPc) or the like can be used. In addition, a chemically doped polymer conductive compound can be used, for example, polyethylene dioxythiophene (PEDOT) which is doped with polystyrene sulfonic acid (PSS), polyaniline (PAni), and the like can be used.

[0225] Known materials can be used as a hole transporting material for forming a hole transporting layer. As a preferable material, an aromatic amine compound (a compound having a bond of a benzene ring and nitrogen) is given. As a widely used material, a star burst type aromatic amine compound is given, for example, 4,4'-bis[N-(3-methylphenyl)-N-phenyl-amino]-biphenyl (TPD); a derivative thereof such as 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]biphenyl (NPB), 4,4',4''-tris(N,N-diphenyl-amino)-triphenylamine (TDATA); and 4,4',4''-tris[N-(3-methylphenyl)-N-phenyl-amino]-triphenylamine (MTDATA).

[0226] The light-emitting layer contains a luminescent substance. The luminescent substance is herein a substance that has an excellent light emitting efficiency and can emit light with a predetermined wavelength. Although the light-emitting layer is not especially limited, the light-emitting layer is preferably one in that a luminescent substance is dispersed in a layer formed using a substance having a larger energy gap than that of the substance with the light emitting property. This layer can prevent light emitted from the substance with the light emitting property from quenching due to the concentration of the substance with the light emitting property. Further, the energy gap indicates an energy gap between the LUMO level and the HOMO level.

[0227] The substance with the light emitting property used for forming a light-emitting layer is not especially limited. A substance having an excellent light emitting efficiency that can emit light with a predetermined emission wavelength may be used. In order to emit red light, for example, the following substances exhibiting emission spectrum with peaks at 600 to 680 nm can be employed: 4-dicyanomethylene-2-isopropyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]-4H-pyran (DCJTI); 4-dicyanomethylene-2-methyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]-4H-pyran (DOT); 4-dicyanomethylene-2-tert-butyl-6-[2-(1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]-4H-pyran (DCJTB); periflanthene; 2,5-dicyano-1,4-bis[2-(10-methoxy-1,1,7,7-tetramethyljulolidine-9-yl)ethenyl]benzene; and the like. In order to obtain green light emission, substances exhibiting emission spectrum with peaks at 500 to 550 nm such as N,N'-dimethylquinacridon (DMQd), coumarin 6, coumarin 545T, and tris(8-quinolinolato) aluminum (Alq$_3$) can be employed. In order to obtain blue light emission, the following substances exhibiting emission spectrum with peaks at 420 to 500 nm can be employed: 9,10-bis(2-naphthyl)-tert-butylanthracene (t-BuDNA); 9,9'-bianthryl; 9,10-diphenylanthracene (DPA); 9,10-bis(2-naphthyl)anthracene (DNA); bis(2-methyl-8-quinolinolato)-4-phenylphenolate-gallium (BGaq); bis(2-methyl-8-quinolinolato)(4-phenylphenolato) aluminium (BAlq); and the like. In addition to the above mentioned fluorescent substances, the following phosphorescent substances can be used as substances with the light emitting properties: bis[2-(3,5-bis(trifluoromethyl)phenyl)pyridinato-N,C$^{2'}$]iridium(III) picolinate (Ir(CF$_3$ppy)$_2$(pic)); bis[2-(4,6-difluorophenyl)pyridinato-N,C$^{2'}$]iridium(III) acetylacetonate (FIr(acac)); bis[2-(4,6-difluorophenyl)pyridinato-N,C$^{2'}$]iridium(III) picolinate (FIr(pic)); tris(2-phenylpyridinato-N,C$^{2'}$) iridium (Ir(ppy)$_3$); and the like.

[0228] A substance used for dispersing a luminescent substance is not especially limited. For example, an anthracene derivative such as 9,10-di(2-naphthyl)-2-tert-butylanthracene (t-BuDNA); a carbazole derivative such as 4,4'-bis(N-carbazolyl)biphenyl (CBP); a metal complex such as bis[2-(2-hydroxyphenyl)pyridinato]zinc (Znpp$_2$); and bis[2-(2-hydroxyphenyl)benzoxazolato]zinc (ZnBOX); and the like can be used.

[0229] As a material with an electron transporting property that is used for forming an electron transporting layer, a known material can be used. Specifically, a typical metal complex such as tris(8-quinolinolato) aluminum (Alq$_3$); tris(4-methyl-8-quinolinolato) aluminum (Almq$_3$); bis(10-hydroxybenzo[h]-quinolinato)beryllium (BeBq$_2$); bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminium (BAN); bis[2-(2-hydroxyphenyl)-benzoxazolate]zinc (Zn(BOX)$_2$); and bis[2-(2-hydroxyphenyl)-benzothiazolate]zinc (Zn(BTZ)$_2$) can be given. In addition, a hydrocarbon compound such as 9,10-diphenylanthracene or 4,4'-bis(2,2-diphenylethenyl)biphenyl is also preferable. Additionally, a triazole derivative such as 3-(4-tert-butylphenyl)-4-(4-ethylphenyl)-5-(4-biphenyl)-1,2,4-triazole; a phenanthroline derivative such as bathophenanthroline or bathocuproin may be used.

[0230] As a material with an electron injecting property that is used for forming an electron injecting layer, a known material can be used. Specifically, alkali metal salt and alkaline earth metal salt such as calcium fluoride, lithium fluoride, lithium oxide and lithium chloride are preferable. Alternatively, a layer of a material with an electron transporting property such as tris(8-quinolinolato)aluminum (Alq$_3$) or bathocuproin (BCP), to which a donor compound such as lithium is added, can be employed.

[0231] In this embodiment mode, a dopant that contributes to light emission is added only to the light-emitting layer, and light emitted from the dopant is only observed. However, a dopant exhibiting different light emission may be added to, for example, an electron transporting layer or a hole transporting layer. When a color of light emitted from the light-emitting layer and a color of light emitted from the dopant added to another layer are complementary to each other, white light emission can be obtained.

[0232] By changing the kinds of the first electrode **1101** and the second electrode **1102**, there are different variations in the light emitting element of this embodiment mode. Schematic views of the variations are shown in FIGS. **10**A to **106** and FIGS. **11**A to **11**C. Further, the reference numerals used in FIG. **8** are also used in FIGS. **10**A to **10**C and FIGS. **11**A to **11**C. Moreover, reference numeral **1100** represents a substrate for supporting a light emitting element of the present invention.

[0233] FIGS. **10**A to **10**C each show an example in which the first layer **1111** and the second layer **1112** included in the layer including a luminescent substance **1103** are stacked in this order over the substrate **1100**. In this case, when the first electrode **1101** is formed using a material having a light transmitting property and the second electrode **1102** is formed using a material having a light-shielding property (in particular, light reflecting property), light can be emitted through the substrate **1100** as shown in FIG. **10**A. Also, when the first electrode **1101** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **1102** is formed using a material having a light transmitting property, light can be emitted through the side opposite the substrate **1100** as shown in FIG. **10**B. Further, when the first electrode **1101** and the second electrode **1102** are both formed using a material having a light transmitting property, light can be emitted toward both the substrate **1100** and the side opposite the substrate **1100** as shown in FIG. **10**C.

[0234] FIGS. **11**A to **11**C each show an example in which the second layer **1112** and the first layer **1111** included in the layer including a luminescent substance **1103** are stacked in this order over the substrate **1100**. In this case, when the first electrode **1101** is formed using a material having a light-shielding property (in particular, light reflecting property) and the second electrode **1102** is formed using a material having a light transmitting property, light can be emitted through the substrate **1100** as shown in FIG. **11**A. When the first electrode **1101** is formed using a material having a light transmitting property and the second electrode **1102** is formed using a material having a light-shielding property (in particular, light reflecting property), light can be emitted through the side opposite the substrate **1100** as shown in FIG. **11**B. Further, when the first electrode **1101** and the second electrode **1102** are both formed using a material having a light transmitting property, light can be emitted toward both the substrate **1100** and the side opposite the substrate **1100** as shown in FIG. **11**C.

[0235] In the light emitting element of this embodiment mode, since the first layer **1111** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound, the first layer **1111** exhibits extremely excellent hole injecting and transporting properties. Therefore, the increase in driving voltage can be suppressed even when the thickness of the first layer **1111** is increased. As a consequence, short-circuiting of the light emitting element can be prevented while suppressing the increase in driving voltage. Moreover, in order to improve the color purity by an optical design, the thickness of the first layer **1111** can be freely set.

[0236] Furthermore, as shown in FIGS. **11**A to **11**C, in the case where the second layer **1112** and the first layer **1111** are sequentially formed over the second electrode **1102**, which has been formed first, and then the first electrode **1101** is formed thereover by sputtering, it is possible to avoid damage to the second layer **1112** including the luminescent substance.

[0237] Since a light-emitting element of the present invention employs a material that is less corrosive and harmful, effects on the environment and on the human body are low.

Embodiment Mode 9

[0238] Embodiment Mode 9 will describe a method for forming a film of a composite material generating holes, which is shown in Embodiment Mode 8.

[0239] A metal alkoxide is used as a component for forming an inorganic compound. As described in Embodiment Mode 8, an oxide including a transition metal is preferably used as the inorganic compound. As the metal, a transition metal is preferable, specifically, titanium, vanadium, molybdenum, tungsten, rhenium, and ruthenium are preferred. Note that in the case of using a composite oxide as the inorganic compound, another metal alkoxide may be added. In other words, in a case that a composite oxide including an aluminum oxide skeleton, for example, is used, an aluminum alkoxide such as aluminum triisopropoxide may be additionally added.

[0240] A sol is prepared by adding water and a chelating agent such as β-diketon as a stabilizer, into a solution in which a metal alkoxide is dissolved in a proper solvent. As the solvent, for example, THF, acetonitrile, dichloromethane, dichloroethane, or a mixed solvent of these can be used, as well as lower alcohol such as methanol, ethanol, n-propanol, n-butanol, and sec-butanol. However, the present invention is not limited to them.

[0241] As the compound which can be used as a stabilizer, β-diketones such as acetylacetone, ethyl acetoacetate, and benzoylacetone are given, for example. However, the stabilizer is provided to prevent precipitation inside a sol; however, it is not necessarily provided.

[0242] The amount of water to be added is preferably with 2 or more and 6 or less equivalent weights with respect to a metal alkoxide, since the metal alkoxide generally has divalent to hexavalent. However, water is not necessarily required, since water is used to control the progress of a reaction of a metal alkoxide.

[0243] Subsequently, a solution of an organic compound is mixed with the prepared sol, and stirred to obtain a solution including the metal alkoxide and the organic compound. After that, by coating and baking the solution, a composite material of the present invention can be formed as a film. As a method of applying a solution, wet methods such as a solution cast method, a dip coating method, a spin coating method, a roll coating method, a blade coating method, a wire bar coat method, a spray coating method, an ink-jet method, a screen printing method, and a gravure printing method can be adopted. However, the present invention is not limited to the methods.

[0244] It should be noted that a binder substance may be added, in advance, to the first solution, in a case of adding the binder substance. Substances described in Embodiment Mode 8 may be used as the binder substance.

Embodiment Mode 10

[0245] Embodiment Mode 10 will describe a method of forming a composite material generating holes, as a film, by another method, which is different from that in Embodiment Mode 9.

[0246] A metal alkoxide is used as a component for forming an inorganic compound. As described in Embodiment Mode 8, an oxide including a transition metal is preferably used as an inorganic compound. As the metal, a transition metal is preferable, specifically, titanium, vanadium, molybdenum, tungsten, rhenium, and ruthenium are preferred. Note that in a case of using a composite oxide as the inorganic compound, another metal alkoxide may be further added. In other words, in the case that a composite oxide including an aluminum oxide skeleton, for example, is used, an aluminum alkoxide such as aluminum triisopropoxide may be additionally added.

[0247] By dissolving a metal alkoxide and an organic compound in a proper solvent, and stirring it, a first solution including the metal alkoxide and the organic compound is obtained. As the solvent, for example, THF, acetonitrile, dichloromethane, dichloroethane, or a mixed solvent of these can be used, as well as lower alcohols such as methanol, ethanol, n-propanol, i-propanol, n-butanol, and sec-butanol. However, the present invention is not limited to them.

[0248] After that, by applying the solution, exposing it to water vapor and baking it, a composite material of the present invention, can be obtained. As a method of applying a solution, wet methods such as a solution cast method, a dip coating method, a spin coating method, a roll coating method, a blade coating method, a wire bar coat method, a spray coating method, an ink-jet method, a screen printing method, and a gravure printing method can be adopted. However, the present invention is not limited to the methods.

[0249] As a result of exposing the solution to water vapor after being applied, a hydrolysis reaction of the metal alkoxide occurs. Then, it is baked, so that polymerization or cross-linking reaction progresses. Alternatively, irradiation of a microwave may be conducted, instead of baking, so that polymerization or cross-linking reaction can progress. Further, baking and irradiation of a microwave may be conducted together, so that polymerization or cross-linking reaction can progress.

[0250] It should be noted that a binder substance may be added, in advance, to the solution, in the case of adding the binder substance. Substances described in Embodiment Mode 8 may be used as the binder substance.

[0251] In this embodiment mode, a stabilizer such as the β-diketone as described in Embodiment Mode 9 may be added into the solution including a metal alkoxide and an organic compound. By adding a stabilizer, multinuclear precipitation of the metal hydroxide due to moisture in the air or the like, can be suppressed. A stabilizer is not necessarily needed, if the manufacturing process is done in an environment without moisture, before being exposed to water vapor.

Embodiment Mode 11

[0252] Embodiment Mode 11 will describe a method of forming a composite material generating holes, as a film, by another method, which is different from those in Embodiment Modes 9 and 10.

[0253] As a component for forming an inorganic compound, an ammonia water is dropped into a water solution of acid salt including a metal to obtain multinuclear precipitation of a metal hydroxide. Note that, in a case of applying a composite oxide as an inorganic compound, another metal salt may additionally be added. In other words, when a composite oxide including a skeleton of an aluminum oxide is applied, aluminum salt such as aluminum chloride may additionally be added.

[0254] Acid such as acetic acid is added into the obtained precipitation to be refluxed, and it is deflocculated to obtain a sol. A solution of an organic compound (or an organic compound) is added into the obtained sol and was stirred. Thus, a first solution including the sol obtained by deflocculating a metal hydroxide, and the organic compound can be obtained. After that, by coating and baking the solution, a first composite material of the present invention can be formed as a film. As a method of applying a solution, wet methods such as a solution cast method, a dip coating method, a spin coating method, a roll coating method, a blade coating method, a wire bar coat method, a spray coating method, an ink-jet method, a screen printing method, and a gravure printing method can be adopted. However, the present invention is not limited to the methods.

[0255] It should be noted that a binder substance may be added, in advance, to the solution, in a case of adding the binder substance. Substances described in Embodiment Mode 8 may be used as the binder substance.

Embodiment Mode 12

[0256] Embodiment Mode 12 will describe a manufacturing method of the light-emitting element shown in Embodiment Mode 8.

[0257] The first electrode **1101** is formed first. The first electrode **1101** can be formed using a known material by a known method. Specifically, a metal compound such as indium tin oxide (ITO), indium tin oxide including silicon (ITSO), indium oxide including zinc oxide of 2 to 20 wt % (IZO), or a titanium nitride; a metal such as Cr, W, Zn, Pt, Al, or Ag; or an alloy thereof, etc, is preferably used. For example, indium Oxide-zinc oxide (IZO) can be formed by a sputtering method using indium oxide into which zinc oxide of 1 to 20 wt % is added, as a target. In addition, indium oxide-zinc oxide including tungsten oxide and zinc oxide (IWZO) can be formed by a sputtering method using indium oxide into which tungsten oxide of 0.5 to 5 wt % and zinc oxide of 0.1 to 1 wt % are added, as a target.

[0258] Next, the first layer **1111** is formed. The first layer **1111** can be formed by any one of the methods shown in Embodiment Modes 9 to 11. The methods shown in Embodiment Modes 9 to 11 are each a wet method, and thus, can respond to the increase in a substrate size.

[0259] Then, the second layer **1112** is formed. The second layer **1112** can be formed using a known material by a known method. When the second layer **1112** is formed by a wet method, all layers included in the layer including a luminescent substance **1103** can be formed by a wet method, and thus, it can respond to the increase in a substrate size. Thus, the manufacturing method using a wet method is suitable for mass production. For example, a luminescent substance such as poly (2,5-dihexoxy-1,4-phenylenevinylene) (MEH-PPV) can be formed by a wet method.

[0260] The second electrode **1102** can be formed using a known material by a known method. Specifically, the materials mentioned when the first electrode **1101** is described above can be used. One or both of the first electrode **1101** and the second electrode **1102** may have a light-transmitting property.

[0261] In accordance with the above method, a light-emitting element of the present invention can be manufactured. Since the manufacturing method of a light-emitting element of the present invention can form the first layer **1111** by a wet method, it can respond to the increase in a substrate size and is suitable for mass production. In particular, when the second layer **1112** is also formed using a known polymer light-emitting material or the like by a wet method, all layers included in the layer including a luminescent substance **1103** can be formed by a wet method, and thus, it can respond to the increase in a substrate size. Thus, the manufacturing method using a wet method is suitable for mass production.

[0262] This embodiment mode has described a method for forming an element from the first electrode **1101** side (over the first electrode **1101**). However, a light-emitting element may be formed by forming layers sequentially from the second electrode **1102** side (over the second electrode **1102**).

Embodiment Mode 13

[0263] Although Embodiment Mode 8 has described the case that the layer including an organic compound and an inorganic compound showing an electron accepting property to the organic compound, is in contact with the anode, Embodiment Mode 13 will describe a case that the layer including an organic compound and an inorganic compound showing an electron accepting property to the organic compound, exists between the anode and a light-emitting layer, and is not in contact with the anode.

[0264] An example of a structure of a light emitting element of the present invention will be shown in FIG. **9**. A layer including a luminescent substance **1303** is sandwiched between a first electrode **1301** and a second electrode **1302**. The layer containing the luminescent substance **1303** includes a structure in which a first layer **1311**, a second layer **1312** and a third layer **1313** are stacked in this order. This embodiment mode describes a case that the first electrode **1301** serves as an anode, and the second electrode **1302** serves as a cathode.

[0265] The first layer **1311** is a layer having a function of injecting holes. A known material can be formed as a hole injecting material for forming a hole injecting layer. Specifically, the hole injecting materials shown in Embodiment Mode 8 can be used.

[0266] The second layer **1312** is a layer including an organic compound and an inorganic compound showing an electron accepting property to the organic compound. The second layer **1312** can have the same structure as the first layer **1111** shown in Embodiment Mode 8.

[0267] The third layer **1313** has a function of emitting light. The same structure as that of the second layer **1112**, which has been described in Embodiment Mode 8, can be applied for the third layer **1313**.

[0268] By adopting the above described structure, an increase of driving voltage can be suppressed, even when the second layer **1312** becomes thick. Thus, the increase of driving voltage can be suppressed, short-circuiting of an element can be prevented, and the color purity by optical design can be realized.

Embodiment Mode 14

[0269] FIG. **12** shows an example of a structure of a light-emitting element having a structure different from that shown in Embodiment Mode 8, with reference to FIG. **12**.

[0270] FIG. **12** shows a structure of a light-emitting element of the present invention as one example. A layer including a luminescent substance **1203** is sandwiched between a first electrode **1201** and a second electrode **1202**. The layer containing the luminescent substance **1203** includes a structure in which a first layer **1211**, a second layer **1212**, a third layer **1213**, and a fourth layer **1214** are stacked in this order. This embodiment mode describes a case that the first electrode **1201** serves as an anode, and the second electrode **1202** serves as a cathode.

[0271] The light-emitting element of this embodiment mode is operated as follows. When voltage is applied such that a potential of the first electrode **1201** is higher than that of the second electrode **1202**, holes are injected into the second electrode **1202** from the fourth layer **1214** while electrons are injected into the second layer **1212** from the third layer **1213**. Also, holes are injected into the first layer **1211** from the first electrode **1201**, and then, injected into the second layer **1212** from the first layer **1211**. The holes injected from the first layer **1211** and the electrons injected from the third layer **1213** are recombined in the second layer **1212**, so that a luminescent substance is excited. The luminescent substance emits light when returning to a ground state from the excited state.

[0272] The first electrode **1201**, the second electrode **1202**, the first layer **1211** and the second layer **1212** can have the same structures as the first electrode **1101**, the second electrode **1102**, the first layer **1111** and the second layer **1112** in Embodiment Mode 8, respectively. In other words, the first electrode can be formed using a known material, the first layer **1211** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound, and the second layer **1212** includes a luminescent substance.

[0273] The third layer **1213** includes a material having a donor level for generating electrons. As such a layer, a layer including an electron transporting substance rind a substance showing an electron donating property to the substance, is given. Herein, the electron transporting substance is a substance which has a property of transporting electrons rather than holes. The electron transporting substance is not especially limited, and for example, 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD); 1,3-bis[5-(p-tert-butylphenyl)-1,3,4-oxadiazol-2-yl]benzene (OXD-7); 3-(4-tert-butylphenyl)-4-phenyl-5-(4-biphenylyl)-1,2,4-triazole (TAZ); and 3-(4-tert-butylphenyl)-4-(4-ethylphenyl)-5-(4-biphenylil)-1,2,4-triazole (p-EtTAZ); bathophenanthroline (BPhen), bathocuproin (BCP); and the like can be used, as well as metal complexes such as tris(8-quinolinolato) aluminum (Alq_3); tris(4-methyl-8-quinolinolato) aluminum ($Almq_3$); bis(10-hydroxybenzo[h]-quinolinato)beryllium ($BeBq_2$); bis(2-methyl-8-quinolinolato)(4-phenylphenolato) aluminium (BAN); bis[2-(2-hydroxyphenyl)-benzoxazolate] zinc ($Zn(BOX)_2$); and bis[2-(2-hydroxyphenyl)-benzothiazolato]zinc ($Zn(BTZ)_2$). In addition, the substance showing an electron donating property to the electron transporting substance is not especially limited, and for example, alkali metals such as lithium and cesium, alkaline earth metals such as magnesium and calcium, rare-earth metal such as erbium and ytterbium, and the like can be used. Further, a substance selected from alkali metal oxides or alkaline earth metal oxides, such as lithium oxides (Li_2O), calcium oxides (CaO), sodium oxide (Na_2O), potassium oxide (K_2O), and magnesium oxide (MgO), may be used as the substance showing an electron donating property to an electron transporting substance. Note that alkali metal oxides, alkaline earth metal oxides, and the like are easy to treat, since they are less reactive. In addition, the second layer **312** may be a layer formed of an n-type semiconductor such as zinc oxide, zinc sulphide, zinc selenide, tin oxide or titanium oxide.

[0274] The fourth layer **1214** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound. Therefore, the inorganic compounds described in Embodiment Mode 8 can be used as the inorganic compound included in the fourth layer. However, the inorganic compound included in the fourth layer **1214** may be the same as the one included in the first layer **1211**, or different from the one included in the first layer **1211**.

[0275] By adopting such a structure, as shown in FIG. **12**, electron transfer is conducted in the vicinity of an interface between the third layer **1213** and the fourth layer **1214** by applying a voltage, and electrons and holes are generated. Then, the third layer **1213** transports electrons into the second layer **1112**, and at the same time, the fourth layer **1214** transports holes into the second electrode **1102**. In other words, a combination of the third layer **1213** and the fourth layer **1214** serves as a carrier generating layer. In addition, it can be said that the fourth layer **1214** has a function of transporting holes to the second electrode **1102**. It should be noted that a multiphoton type light-emitting element can also be obtained by further stacking another second layer and another third layer between the fourth layer **1214** and the second electrode **1202**.

[0276] Since the first layer **1211** or the fourth layer **1214** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound, the first layer **1211** or the fourth layer **1214** exhibits extremely excellent hole injecting and transporting properties. Therefore, the increase in driving voltage be suppressed even when the thickness the first layer **1211** is increased. Thus, in the light-emitting element of the present invention, it is possible that the opposites sides of the second layer **1212** having a light-emitting function, i.e., the first electrode side and the second electrode side of the second layer **1212**, can be made extremely thicker. In other words, the distance between the first electrode and the second electrode can be made large. As a consequence, short-circuiting of the light emitting element can be prevented. Moreover, in order to improve the color purity by an optical design, the thicknesses in the both sides of the first electrode side and the second electrode side of the second layer **1212** can be freely set. Furthermore, in the case where, after forming the layer including a luminescent layer **1203**, the first electrode **1201** or the second electrode **1202** is formed by sputtering, it is possible to avoid damage to the second layer **1212** including the luminescent substance. Further, by forming the first layer **1211** and the fourth layer **1214** using the same material, the layers formed with the same material are located at the opposite sides of the layer including a luminescent substance **1203**, i.e., the first electrode side and the second electrode side thereof. Thus, it can be expected that stress strain can be suppressed.

[0277] Further, in the light-emitting element of this embodiment mode, by changing the kinds of the first electrode **1201** and the second electrode **1202**, there are many variations in the light emitting element. Schematic views of the variations are shown in FIGS. **13**A to **13**C and FIGS. **14**A to **14**C. The reference numerals used in FIG. **12** are also used in FIGS. **13**A to **13**C and FIGS. **14**A to **14**C. Reference numeral **1200** represents a substrate for supporting a light emitting element of the present invention.

[0278] FIGS. **13**A to **13**C each show an example in which a layer including a luminescent substance **1203** includes a first layer **1211**, a second layer **1212**, a third layer **1213**, and a fourth layer **1214**, which are stacked in this order over the substrate **1200**. In this case, when the first electrode **1201** is formed using a material with a light transmitting property and the second electrode **1202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the substrate **1200** as shown in FIG. **13**A. When the first electrode **1201** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **1202** is formed using a material with a light transmitting property, light can be emitted through the side opposite the substrate **1200** as shown in FIG. **13**B. Further, when the first electrode **1201** and the second electrode **1202** are both formed using a material having a light transmitting property, light can be emitted through both the substrate **1200** and the side opposite the substrate, as shown in FIG. **13**C.

[0279] FIGS. **14**A to **14**C each show an example in which a layer including a luminescent substance **1203** includes a fourth layer **1214**, a third layer **1213**, a second layer **1212** and a first layer **1211**, which are stacked in this order over the substrate **1200**. In this case, when the first electrode **1201** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **1202** is formed using a substance with a light transmitting property, light can be emitted through the substrate **1200** as shown in FIG. **14**A. When the first electrode **1201** is formed using a material with a light transmitting property and the second electrode **1202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the side opposite side the substrate **1200** as shown in FIG. **14**B. Further, when the first electrode **1201** and the second electrode **1202** are both formed using a material with a light transmitting property, light can be emitted through both the substrate **1200** and the side opposite the substrate **1200**, as shown in FIG. **14**C.

[0280] When the light-emitting element in this embodiment mode is formed, it can be formed in accordance with the method described in Embodiment Mode 12. In other words, the first electrode **1201**, the second electrode **1202**, the second layer **1212** and the third layer **1213** can be formed by a known method, and the first layer **1211**, and the fourth layer **1214** each can be formed by appropriately adopting any one of the methods described in Embodiment Modes 9 to 12. The fourth layer **1214** may be formed by another method, for example, an evaporation method.

[0281] Further, when the fourth layer **1214** is formed using a composite material of the present invention by a wet method, the first layer **1211** may be formed by a known method such as an evaporation method. In addition, in the case of forming the fourth layer **1214** by a wet method, the first layer **1211** is not necessarily required.

[0282] After forming the first electrode **1201**, the first layer **1211**, the second layer **1212**, the third layer **1213**, and the fourth layer **1214** may be sequentially formed, and then, the second electrode **1202** may be formed. Alternatively, after forming the second electrode **1202** first, the fourth layer **1214**, the third layer **1213**, the second layer **1212**, and the first layer **1211** may be sequentially formed, and then, the first electrode may be formed.

[0283] In addition, it is possible that the first layer **1211** includes a material having a donor level for generating electrons, the third layer **1213** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound, and the fourth layer **1214** includes a material having a donor level for generating electrons. In this case, since the third layer **1213** includes an organic compound and an inorganic compound showing an electron accepting property to the organic compound, it has an excellent hole transporting property. Therefore, the driving voltage of the light-emitting element can be reduced. In addition, the third layer **1213** can be freely set for the sake of enhancement in color purity by an optical design.

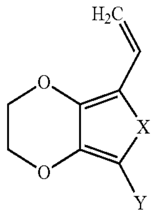
Embodiment Mode 15

[0284] Embodiment Mode 15 will describe, in detail, an organic compound included in a composite material generating holes of the present invention.

[0285] As the organic compound included in a composite material generating holes of the present invention, any of low molecular weight compounds, middle molecular weight compounds, and high molecular weight compounds can be used, as long as they are each an organic compound having an arylamine skeleton. In this embodiment mode, a high molecular weight compound, which is an organic compound included in a composite material generating holes of the present invention, is described.

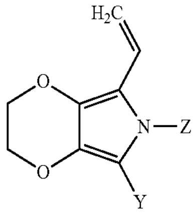
[0286] As the high molecular weight compound, high molecular weight compounds with vinyl monomer, which are represented by the following general formulas or structural formulas (11) to (15).

(11)



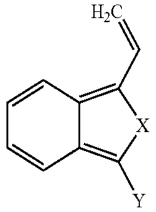
[0287] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents any a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent.

(12)



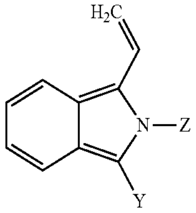
[0288] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group.

(13)



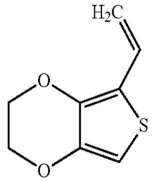
[0289] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent.

(14)



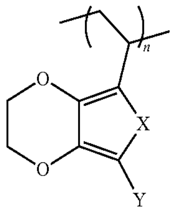
[0290] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents a hydrogen atom, an alkyl group, or a substituted or unsubstituted aryl group.

(15)

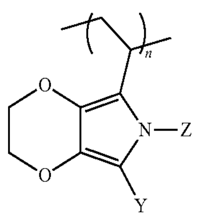


[0291] Specifically, high molecular weight compounds which are polymers represented by the following general formulas or structural formulas (1) to (5), can be used.

(1)

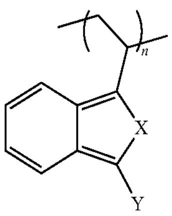


[0292] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. n is an integer of 2 or more.



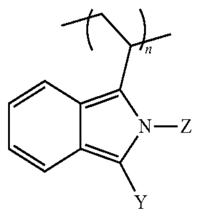
(2)

[0293] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. n is an integer of 2 or more.



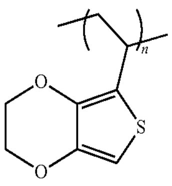
(3)

[0294] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a, silyl group having an alkyl group or an aryl group as a substituent. n is an integer of 2 or more.



(4)

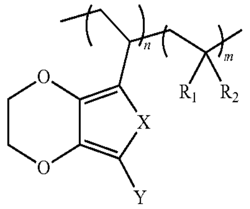
[0295] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. n is an integer of 2 or more.



(5)

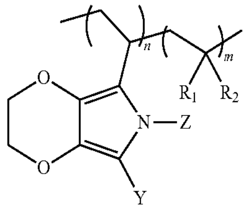
[0296] wherein n is an integer of 2 or more.

[0297] Further, high molecular weight compounds which are copolymers represented by the following general formulas or structural formulas (6) to (10), can be used.



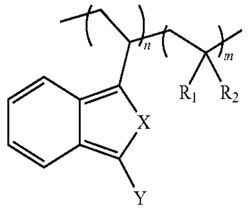
(6)

[0298] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.



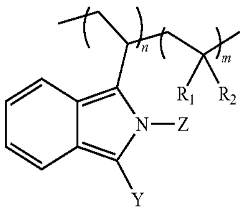
(7)

[0299] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents one of a hydrogen atom, an alkyl group, and a substituted or unsubstituted aryl group. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.



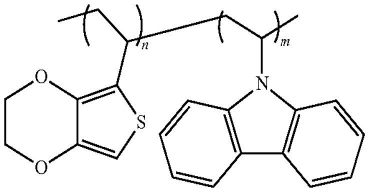
(8)

[0300] wherein X represents an oxygen atom (O) or a sulfur atom (S). Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.



(9)

[0301] wherein Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent. Z represents a hydrogen atom, an alkyl group, or a substituted or unsubstituted aryl group. R_1 represents a hydrogen atom or an alkyl group. R_2 represents a substituted or unsubstituted aryl group, an ester group, a cyano group, an amide group, an alkoxy group, an oxycarbonyl alkyl group, or a diaryl amino group. n and m are individually an integer of 1 or more.



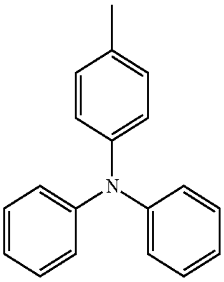
(10)

[0302] wherein n and m are individually an integer of 1 or more.

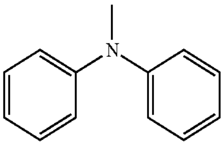
[0303] In the vinyl monomers represented by the above general formulas or structural formulas (11) to (15), vinyl groups contributing polymerization, which are conjugated with an aromatic substituent such as thiophene or a furan skeleton, are active in polymerization. In addition, since a thiophene ring, a furan skeleton, and a pyrrole ring are hetero aromatic rings that have excess electrons, the vinyl groups have an improved electron density. Therefore, the vinyl monomers represented by the above general formulas or structural formulas (11) to (15) easily give polymers by radical polymerization or cation polymerization. Additionally, in the vinyl monomers represented by the above general formulas (11) to (14), the solubility is increased by making Y in the formula a substituent other than a hydrogen atom, for example, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent.

[0304] In addition, in the polymers represented by the general formulas or structural formulas (1) to (5), n is preferably an integer of 10 or more from the viewpoint of improvement in heat resistance. Further, in the copolymers represented by the general formulas or structural formulas (6) to (10), the sum of n and m is preferably an integer of 10 or more (however, n is an integer of 1 or more) from the viewpoint of improvement in heat resistance.

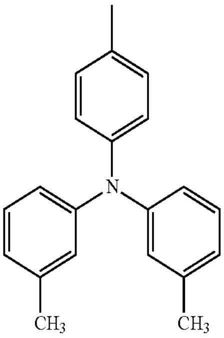
[0305] In the copolymer represented by the structural formula (10), a material that has aryl amine as a side chain can be used, other than vinyl carbazole. For example, it is possible to cite a copolymer represented by the general formula (8), wherein a material in which R_1 is a hydrogen atom, and R_2 is a substance represented by any one of the following structural formulas (16), (17), (18), and (19).



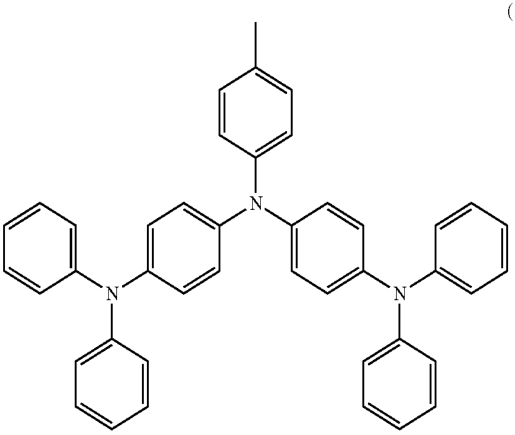
(16)



(17)



(18)



(19)

Embodiment Mode 16

[0306] A light-emitting element of the present invention will be explained. The light emitting-element of the present invention includes a luminescent substance and a composite material between a pair of electrodes. A composite material is a material made by combining an organic compound and an inorganic compound.

[0307] FIG. **15** shows a structure of a light-emitting element of the present invention as an example. In the light-emitting element, a layer including a luminescent substance **2103** is interposed between a first electrode **2101** and a second electrode **2102**. The structure of the layer including a luminescent substance **2103** is a stacked structure of a first layer **2111**, a second layer **2112**, and a third layer **2113**. This embodiment mode explains a case when the first electrode **2101** functions as an anode and the second electrode **2102** functions as a cathode.

[0308] The first layer **2111** takes on a function of transporting holes to the second layer **2112**, and contains a hole-generating first composite material. This hole-generating first composite material is made by combining a first organic compound, and a first inorganic compound showing an election-accepting property to the first organic compound. By the transfer of electrons between the first organic compound and the first inorganic compound, a large number of holes are generated. For this reason, excellent hole-injecting property and hole-transporting property are exhibited. Therefore, by using the hole-generating first composite material, the driving voltage of a light-emitting element can be reduced.

[0309] As the first organic compound included in the hole-generating first composite material, it is desirable to use a compound having an excellent property of transporting the generated holes, and the use of an organic compound having an arylamine skeleton is preferred. More specifically, organic compounds such as 4,4'4"-tris(N,N-diphenylamino)triphenylamine (TDATA); 4,4',4"-tris[N-(3-methylphenyl)-N-phenylamino]triphenylamine (MTDATA); 1,3,5-tris[N,N-bis(3-methylphenyl)amino]benzene (m-MTDAB); N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD); 4,4'-bis[N-(1-naphthyl)phenylamino]biphenyl (NPB); 4,4'-bis(N-{4-[N,N-bis(3-methylphenyl)amino]phenyl}-N-phenylamino)biphenyl (DNTPD); 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA); poly(4-vinyltriphenylamine) (PVTPA); and poly(N-vinylcarbazole) (PVK) may be given, but is not limited to these organic compounds.

[0310] As the first inorganic compound included in the hole-generating first composite material, it is preferable to use an oxide containing a transition metal. Specifically, it is preferable to use one or plural of titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, rhenium oxide, or ruthenium oxide. It also may be a composite oxide including a skeleton of these oxides. Further, the oxide containing a transition metal may have a hydroxyl group.

[0311] By using an oxide containing a transition metal, electron transfer is carried out between the oxide containing a transition metal and nitrogen of an arylamine skeleton, and holes can be generated. Since holes are generated internally, high conductivity can be obtained when an electric field is applied.

[0312] Also, since the first composite material has high conductivity, increase in driving voltage can be suppressed even when the thickness increases. Therefore, since the thickness of the first layer **2111** can be increased without increasing the driving voltage, short-circuiting of the light-emitting element caused by unwanted particles, dusts or the like, can be suppressed.

[0313] Further, because the first composite material contains an inorganic compound, heat resistance of the light-emitting element can be improved.

[0314] Incidentally, the first layer **2111** may take form in a variety of states, such as a state in which the first organic compound becomes a matrix and the first inorganic compound is dispersed therein, a state in which the first inorganic compound becomes a matrix and the first organic compound is dispersed therein, or a state in which the first organic compound and the first inorganic compound are contained in nearly equal amounts and bound to each other. Regardless of the state, however, electrons will be transferred between the first organic compound and the first inorganic compound, and excellent hole-injecting and hole-transporting properties, as well as high conductivity can be obtained.

[0315] Further, when the hole-generating first compound material is used to form a film, a material that serves as a binder (a binder substance) may be added in order to improve the quality of the film. Especially, when a compound with a low molecular weight (specifically, a compound having a molecule weight of 500 or less) is used as the first organic compound, a binder substance becomes necessary for the sake of film quality. Needless to say, a binder substance may also be added when using a high molecular weight compound. As a binder substance, polyvinyl alcohol (PVA), polymethyl methacrylate (PMMA), polycarbonate (PC), a phenol resin, and the like can be given.

[0316] Here, the third layer **2113** will be explained. The third layer **2113** takes on a function of transporting electrons to the second layer **2112**, and includes an electron-generating second composite material. The electron-generating second composite material is made by combining a second organic compound, and a second inorganic compound showing an electron-donating property to the second organic compound. By the transfer of electrons between the second organic compound and the second inorganic compound, a large number of electrons are generated. For this reason, excellent electron-injecting property and electron-transporting property are exhibited. Therefore, by using the electron-generating second composite material, the driving voltage of a light-emitting element can be reduced.

[0317] As the second organic compound included in the electron-generating second composite material, it is desirable that it be a material having an excellent property of transporting the generated electrons, and it is preferable to use an organic compound having a pyridine skeleton, an imidazole skeleton, a triazole skeleton, an oxadiazole skeleton, an oxazole skeleton, or a thiazole skeleton. More specifically, organic compounds such as tris(8-quinolinolato)aluminum (Alq_3); tris(4-methyl-8-quinolinolato)aluminum ($Almq_3$); bis(10-hydroxybenzo [h]quinolinato)beryllium ($BeBq_2$); bis (2-methyl-8-quinolinolato)(4-phenylphenolato)aluminum (BAlq); bis[2-(2'-hydroxyphenyl)benzoxazolato]zinc ($Zn(BOX)_2$); bis[2-(2'-hydroxyphenyl)benzothiazolato]zinc ($Zn(BTZ)_2$); bathophenanthroline (BPhen); bathocuproin (BCP); 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (PBD); 1,3-bis[5-(4-tert-butylphenyl)-1,3,4-oxadiazol-2-yl]benzene (OXD-7); 2,2',2"-(1,3,5-benzenetriyl)-tris (1-phenyl-1H-benzimidazole) (TPBI); 3-(4-biphenylyl)-4-phenyl-5-(4-tert-butylphenyl)-1,2,4-triazole (TAZ); 3-(4-biphenylyl)-4-(4-ethylphenyl)-5-(4-tert-butylphenyl)-1,2,4-triazole (p-EtTAZ); and poly(4-vinylpyridine) (PVPy) may be given, but is not limited to these organic compounds.

[0318] As the second inorganic compound contained in the electron-generating second composite material, it is preferable to use an oxide containing an alkali metal or an alkaline earth metal. Specifically, it is preferable to use one or plural of lithium oxide, calcium oxide, and barium oxide. Also a composite oxide including a skeleton of these oxides may be used. Further, the oxide containing an alkali metal or an alkaline earth metal may have a hydroxyl group.

[0319] By using an oxide containing an alkali metal or an alkaline earth metal, electron transfer is carried out between the oxide containing an alkali metal or an alkaline earth metal, and a pyridine skeleton or the like, and electrons can be generated. Since electrons are generated internally, high conductivity can be obtained when an electric field is applied.

[0320] Also, since the second composite material has high conductivity, increase in driving voltage can be suppressed even when the thickness increases. Therefore, since the thickness of the third layer **2113** can be increased without increasing the driving voltage, short-circuiting of the light-emitting element caused by unwanted particles, dust and the like, can be suppressed.

[0321] Further, because the second composite material contains an inorganic compound, heat resistance of the light-emitting element can be improved.

[0322] Incidentally, the third layer **2113** may take form in a variety of states, such as a state in which the second organic compound becomes a matrix and the second inorganic compound is dispersed therein, a state in which the second inorganic compound becomes a matrix and the second organic compound is dispersed therein, or a state in which the second organic compound and the second inorganic compound are contained in nearly equal amounts and bound to each other. Regardless of the state, however, electrons will be transferred between the second organic compound and the second inorganic compound, and excellent electron-injecting and electron-transporting properties as well as high conductivity can be obtained.

[0323] Further, when the electron-generating second compound material is used to form a film, a material that serves as a binder (a binder substance) may be added in order to improve the quality of the film. When a compound with a low molecular weight (specifically, a compound having a molecule weight of 500 or less) is used as the second organic compound, a binder substance becomes necessary for the sake of film quality. Needless to say, a binder substance may also be added when using a high molecular weight compound for the second organic compound. As the binder substance, polyvinyl alcohol (PVA), polymethyl methacrylate (PMMA), polycarbonate (PC), a phenol resin, and the like can be given.

[0324] The second layer **2112** takes on a light-emitting function, and it is acceptable as long as the layer contains at least a luminescent substance. As for the luminescent substance, a known material can be used. Further, besides a luminescent substance, another material may be included in the second layer **2112**. For example, in the same way as the first layer **2111** or third layer **2113**, it may include an inorganic compound as well as an organic compound having a light-emitting property. By the second layer also having a structure containing an inorganic compound, an effect of improving heat resistance can be obtained.

[0325] In the light-emitting element explained in this embodiment mode, the first layer **2111** or the third layer **2113** exhibits extremely strong carrier-injecting and carrier-transporting properties. It also has high conductivity. Consequently, the light-emitting element of this embodiment mode can suppress the increase in driving voltage, and a layer between the second layer having a light-emitting function and the first electrode, and a layer between the second layer having a light-emitting function and the second electrode, can be made thick. In other words, it becomes possible to make the distance between the first electrode and the second electrode wide, and can prevent short-circuiting in the light-emitting element.

[0326] In a case of forming the first electrode **2101** or the second electrode **2102** by sputtering after forming the layer including a luminescent substance **2103**, damage to the second layer **2112**, which includes the luminescent substance, can be reduced.

[0327] Since the increase in driving voltage can be suppressed even if the film thickness of the first layer **2111** or the third layer **2113** is increased, the film thickness of the first layer **2111** and the third layer **2113** can be freely set, and the light extraction efficiency from the second layer **2112** can be improved. Also, film thicknesses of the first layer **2111** and the third layer **2113** can be set to improve the color purity of light emission from the second layer **2112**.

[0328] Further, because the light-emitting element of the present invention has materials with low toxicity and harmful effects, effects on the environment and the human body can be reduced.

[0329] There are many variations in the light-emitting element of this embodiment mode, by changing the types of the first electrode **2101** or the second electrode **2102**. These variations are shown in the schematic views of FIGS. **17**A to **17**C and **18**A to **18**C. The reference numerals use in FIG. **15** are also used in FIGS. **17**A to **17**C and **18**A to **18**C. Also, reference numeral **2100** represents a substrate supporting the light-emitting element of the present invention.

[0330] FIGS. **17**A to **17**C are examples of a case in which the layer including a luminescent substance **2103** has a structure in which the first layer **2111**, the second layer **2112**, and the third layer **2113** are sequentially formed over the substrate **2100**. By the first electrode **2101** having a light-transmitting property, and by the second electrode **2102** having a light-shielding property (specifically a light-reflecting property), light is emitted through the substrate **2100**, as in FIG. **17**A. Also, by the first electrode **2101** having a light-shielding property (especially a light-reflecting property), and by the second electrode **2102** having a light-transmitting property, light is emitted from the side opposite the substrate **2100**, as in FIG. **17**B. Further, by the first electrode **2101** and the second electrode **2102** both having light-transmitting properties, light is emitted from the opposite sides of the light-emitting element, i.e., both the side of the substrate **2100** and the opposite side the substrate **2100**, as shown in FIG. **17**C.

[0331] FIGS. **18**A to **18**C are examples of a case in which the layer including a luminescent substance **2103** has a structure in which the third layer **2113**, the second layer **2112**, and the first layer **2111** are formed in this order over the substrate **2100**. When the first electrode **2101** has a light-shielding property (especially a light-reflecting property), and when the second electrode **2102** has a light-transmitting property, light is extracted from the substrate **2100** side, as shown in FIG. **18**A. Also, when the first electrode **2101** has a light-transmitting property, and when the second electrode **2102** has a light-shielding property (especially a light-reflecting property), light is extracted from the side opposite the substrate **2100**, as shown in FIG. **18**B. Furthermore, when both the first electrode **2101** and second electrode **2102** have light-transmitting properties, light can be emitted from the opposite sides of the light-emitting element, i.e., the substrate **2100** side and the side opposite the substrate **2100** as shown in FIG. **18**C.

Embodiment Mode 17

[0332] Embodiment Mode 17 will describe a manufacturing method of the light-emitting element shown in Embodiment Mode 16.

[0333] The first electrode **2101** is formed first. The first electrode **2101** can be formed using a known material by a known method. Specifically, a metal compound such as indium tin oxide (ITO), indium tin oxide including silicon (ITSO), indium oxide including zinc oxide of 2 to 20 wt % (IZO), titanium nitride; a metal such as Cr, W, Zn, Pt, Al, or Ag; or an alloy thereof, etc, is preferably used. For example, indium oxide-zinc oxide (IZO) can be formed by a sputtering method using indium oxide into which zinc oxide of 1 to 20 wt % is added, as a target. In addition, indium oxide-tin oxide including tungsten oxide and zinc oxide (IWZO) can be formed by a sputtering method using indium oxide into which tungsten oxide of 0.5 to 5 wt % and zinc oxide of 0.1 to 1 wt % are added, as a target.

[0334] Next, the first layer **2111** is formed. The first layer **2111** can be formed by any one of the methods shown in Embodiment Modes 9 to 11. The methods shown in Embodiment Modes 9 to 11 are each a wet method, and thus, can respond to the increase in a substrate size.

[0335] Then, the second layer **2112** is formed. The second layer **2112** can be formed using a known material by a known method. When the second layer **2112** is formed by a wet method, which can respond to the increase in a substrate size, all layers included in the layer including a luminescent substance **2103** can be formed by a wet method. Thus, the manufacturing method using a wet method is suitable for mass production. For example, a luminescent substance such as poly(2,5-dihexoxy-1,4-phenylenevinylene) (MEH-PPV) can be formed by a wet method.

[0336] Subsequently, the third layer **2113** is formed. The third layer **2113** cap be formed by any of the methods shown in Embodiment Modes 2 and 3. Since the methods shown in Embodiment Modes 2 and Tare each a wet method, they can respond to the increase in a substrate size.

[0337] The second electrode **2102** can be formed using a known material by a known method. Specifically, the materials mentioned when the first electrode **2101** is described above can be used. One or both of the first electrode **2101** and the second electrode **2102** may have a light-transmitting property.

[0338] In accordance with the above method, a light-emitting element of the present invention can be manufactured. Since the manufacturing method of a light-emitting element of the present invention can form the first layer **2111** and the third layer **2113** by a wet method, it can respond to the increase in a substrate size and is suitable for mass production. Specifically, when the second layer **2112** is also formed using a known polymer light-emitting material or the like by a wet method, all layers in the layer including a luminescent substance **2103** can be formed by a wet method, and thus, it can respond to the increase in a substrate size. Thus, the present invention is suitable for mass production.

[0339] In this embodiment mode, a method for forming layers from the first electrode **2101** side (over the first electrode **2101**) has been described. However, a light-emitting element may be formed by forming layers sequentially from the second electrode **2102** side (over the second electrode **2102**). That is, it is possible to form the light-emitting element of the present invention by forming the second electrode **2102** first, forming the third layer **2113**, the second layer **2112**, and the first layer **2111** sequentially and then forming the first electrode **2101**.

Embodiment Mode 18

[0340] Embodiment Mode 18 will describe alight-emitting element having a structure different from that shown in Embodiment Mode 16 with reference to FIG. **16**.

[0341] FIG. **16** shows an example of the structure of the light-emitting element of the present invention. A layer including a luminescent substance **2203** is sandwiched between a first electrode **2201** and a second electrode **2202**. The layer including a luminescent substance **2203** has a structure in which a first layer **2211**, a second layer **2212**, a third layer **2213** and a fourth layer **2214** are sequentially stacked. In this embodiment mode, the first electrode **2201** serves as an anode, and the second electrode **2202** serves as a cathode.

[0342] The first electrode **2201**, the second electrode **2202**, the first layer **2211**, the second layer **2212**, and the third layer **2213** can have the same structures as the respective layers in Embodiment Mode 16 (i.e., FIG. **15**). In other words, the first electrode can be formed using a known material, the first layer **2211** includes a composite material having a first organic compound and a first inorganic compound showing an electron accepting property to the first organic compound, the second layer **2212** includes a luminescent substance, and the third layer **2213** includes a composite material having a second organic compound and a second inorganic compound showing an electron donating property to the second organic compound. The difference between the light-emitting element in this embodiment mode and that in Embodiment Mode 16 is that the fourth layer **2214** is formed between the third layer **2213** and the second electrode **2202**.

[0343] The fourth layer **2214** includes at least a third composite material having a third organic compound and a third inorganic compound showing an electron accepting property to the third organic compound. Thus, the first organic compounds described in Embodiment Mode 1 can be used as the third organic compound, and the first inorganic compounds described in Embodiment Mode 1 can be used as the third inorganic compound. However, the third organic compound may be the same as or different from the first organic compound, and the third inorganic compound may be the same as or different from the first inorganic compound.

[0344] By adopting such a structure, as shown in FIG. **16**, electron transfer is conducted in the vicinity of an interface between the third layer **2213** and the fourth layer **2214** by applying a voltage, and electrons and holes are generated. Then, the third layer **2213** transports electrons into the second layer **2112**, and at the same time, the fourth layer **2214** transports holes into the second electrode **2102**. In other words, a combination of the third layer **2213** and the fourth layer **2214** serves as a carrier generating layer. In addition, it can be said that the fourth layer **2214** has a function of transporting holes to the second electrode **2102**. It should be noted that a multiphoton type light-emitting element can also obtained by stacking another second layer and another third layer between the fourth layer **2214** and the second electrode **2202**.

[0345] Since the first layer **2211** or the fourth layer **2214** exhibits extremely excellent hole injecting and transporting properties. Thus, in the light-emitting element of this embodiment mode, it is possible that the opposites sides of the second layer having a light-emitting function, i.e., the first electrode side and the second electrode side of the second layer, can be made extremely thicker. In other words, the distance between the first electrode and the second electrode can be made large. As a consequence, short-circuiting of the light emitting element can be prevented. Furthermore, like an example shown in FIG. **16**, in a case where the second electrode **2202** is formed by sputtering, it is possible to avoid damage to the second layer **2212** including the luminescent substance. Further, by forming the first layer **2211** and the fourth layer **2214** using the same material, the layers formed with the same material are located at the opposite sides of the layer including a luminescent substance **2203**, i.e., the first electrode side and the second electrode side thereof. Thus, it can be expected that stress strain can be suppressed.

[0346] Further, in the light-emitting element of this embodiment mode, by changing the kinds of the first electrode **2201** and the second electrode **2202**, there are many variations in the light-emitting element. Schematic views of the variations are shown in FIGS. **19**A to **19**C and FIGS. **20**A to **20**C. The reference numerals used in FIG. **16** are also used in FIGS. **19**A to **19**C and FIGS. **20**A to **20**C. Reference numeral **2200** represents a substrate for supporting a light-emitting element of the present invention.

[0347] FIGS. **19**A to **19**C each show an example in which a layer including a luminescent substance **2203** includes a first layer **2211**, a second layer **2212**, a third layer **2213**, and a fourth layer **2214**, which are stacked in this order over the substrate **2200**. In this case, when the first electrode **2201** is formed using a material with a light transmitting property and the second electrode **2202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the substrate **2200** as shown in FIG. **19**A. When the first electrode **2201** is formed using a material with a light-shielding property (in particular, light-reflecting property) and the second electrode **2202** is formed using a material with a light transmitting property, light can be emitted through the side opposite the substrate **2200** as shown in FIG. **19**B. Further, when the first electrode **2201** and the second electrode **2202** are both formed using a material having a light transmitting property, light can be emitted through both the substrate **2200** and the side opposite the substrate, as shown in FIG. **19**C.

[0348] FIGS. **20**A to **20**C each show an example in which a layer including a luminescent substance **2203** includes a fourth layer **2214**, a third layer **2213**, a second layer **2212** and a first layer **2211**, which are stacked in this order over the substrate **2200**. In this case, when the first electrode **2201** is formed using a material with a light-shielding property (in particular, light reflecting property) and the second electrode **2202** is formed using a substance with a light transmitting property, light can be emitted through the substrate **2200** as shown in FIG. **20**A. When the first electrode **2201** is formed using a material with a light transmitting property and the second electrode **2202** is formed using a material with a light-shielding property (in particular, light reflecting property), light can be emitted through the side opposite the substrate **2200** as shown in FIG. **20**B. Further, when the first electrode **2201** and the second electrode **2202** are both formed using a material with a light transmitting property, light can be emitted through both the substrate **2200** and the side opposite the substrate **2200**, as shown in FIG. **20**C.

[0349] When the first layer **2211** includes a composite material of the second organic compound and the second inorganic compound showing an electron donating property to the second organic compound, the second layer **2212** includes a luminescent substance, the third layer **2213** includes a composite material of the first organic compound and the first inorganic compound showing an electron accepting property to the first organic compound, and the fourth layer **2214** includes the composite material of the second organic compound and the second inorganic compound showing an electron donating property to the second organic compound, the same effect can be obtained. In this case, the first layer **2211** or the fourth layer **2214** shows an extremely strong electron injecting property and an extremely high electron transporting property. Thus, a layer between the first electrode and the second layer having a light-emitting function, and a layer between the second electrode and the second layer having a light-emitting function, can be made much thicker, thereby preventing short-circuiting of the light-emitting element. Further, damages to the second layer can be reduced. In addition, stress strain can be suppressed.

[0350] When the light-emitting element in this embodiment mode is formed, it can be formed in accordance with the method described in Embodiment Mode 7. In other words, the first electrode **2201**, the second electrode **2202**, and the second layer **2212** can be formed by a known method, and the first layer **2211**, the third layer **2213**, and the fourth layer **2214** can each formed by appropriately adopting any one of the methods described in Embodiment Modes 2, 3 and 9 to 11. The fourth layer **2214** may be formed by another method, for example, an evaporation method.

[0351] After forming the first electrode **2201**, the first layer **2211**, the second layer **2212**, the third layer **2213**, and the fourth layer **2214** may be sequentially formed, and then, the second electrode **2202** may be formed. Alternatively, after forming the second electrode **2202**, the fourth layer **2214**, the third layer **2213**, the second layer **2212**, and the first layer **2211** may be sequentially formed, and then, the first electrode may be formed.

Embodiment Mode 19

[0352] Embodiment Mode 19 will describe a light-emitting device having a light-emitting element of the present invention.

[0353] This embodiment mode describes a light-emitting device having a light-emitting element of the present invention in its pixel portion with reference to FIGS. **22**A and **22**B. FIG. **22**A is a top view of the light-emitting device, while FIG. **22**B is a cross-sectional view taken along A-A' and B-B' in FIG. **22**A. Reference numeral **601** shown by a dotted line denotes a driver circuit portion (source side driver circuit); **602**, a pixel portion; **603**, a driver circuit portion (gate side driver circuit); **604**, a sealing substrate; **605**, a sealing material; and **607**, a space surrounded by the sealing material **605**.

[0354] Reference numeral **608** denotes a wiring for transmitting signals to be inputted into the source side driver circuit portion **601** and the gate side driver circuit portion **603** and receiving signals such as a video signal, a clock signal, a start signal, and a reset signal from an FPC (flexible printed circuit) **609** serving as an external input terminal. Although only the FPC is illustrated here, a print wiring board (PWB) may be attached to this FPC, and the light-emitting device in this specification may include not only the light-emitting device itself but also the light-emitting device with the FPC and/or the PWB attached thereto.

[0355] Next, the cross-sectional structure is described with reference to FIG. **22**B. The driver circuit portion and the pixel portion are formed over an element substrate **610**. In this embodiment mode, the source side driver circuit portion **601**, which is the driver circuit portion, and one pixel of the pixel portion **602** are shown.

[0356] In the source side driver circuit portion **601**, a CMOS circuit is formed in which an n-channel TFT **623** and a p-channel TFT **624** are combined. Further, the TFT forming the driver circuit may be formed with a known CMOS circuit, PMOS circuit, or NMOS circuit using TFTs. Although this embodiment mode shows an example of forming the pixel portion and the driver circuit formed over the same substrate, the present invention is not limited to this, and the driver circuit can also be formed outside, not over the same substrate as the pixel portion.

[0357] The pixel portion **602** is formed with a plurality of pixels including a switching TFT **611**, a current controlling TFT **612**, and a first electrode **613** connected electrically with a drain of the current controlling TFT. An insulator **614** is formed to cover the end portions of the first electrode **613**. Here, a positive photosensitive acrylic resin film is used.

[0358] In order to improve the coverage, the insulator **614** is formed to have a curved surface with curvature at its upper or lower end portion. For example, in the case of using positive photosensitive acrylic for the insulator **614**, only the upper end portion of the insulator **614** preferably has a curved surface with a radius of curvature of 0.2 to 3 μm. The insulator **614** may be formed with either a negative type, which becomes insoluble to the etchant by the irradiation of light, or a positive type, which becomes soluble to the etchant by the irradiation of light.

[0359] A layer including a luminescent substance **616** and a second electrode **617** are formed over the first electrode **613**. The first electrode **613** serving as an anode is preferably formed with a material having a high work function. For example, a single layer of an indium tin oxide (ITO) film, an indium tin oxide film containing silicon, an indium oxide film containing zinc oxide (ZnO) of 2 to 20 wt %, a titanium nitride film, a chromium film, a tungsten film, a Zn film, a Pt film, a stacked layer of a titanium nitride film and a film mainly containing aluminum, a three-layer stacked structure of a titanium nitride film, a film mainly containing aluminum and a titanium nitride film, and the like can be used. Note that, when a stacked structure is employed, resistance of a wiring is low and a favorable ohmic contact is obtained.

[0360] The layer including a luminescent substance **616** includes a composite material generating carriers shown in Embodiment Mode 8. Specifically, the first composite material including the first organic compound and the first inorganic compound showing an electron accepting property to the first organic compound, and the second composite material including the second organic compound and the second inorganic compound showing an electron donating property to the second organic compound are included in the layer including a luminescent substance **616**. These composite materials generating carriers can be formed by the methods shown in Embodiment Modes 2, 3 and 9 to 11. Since the methods are each a wet method, they can respond to the increase in a substrate size. When other layers included in the layer including a luminescent substance **616** than the layer of the composite material generating carriers, are formed by a wet method, all layers included in the layer including a luminescent substance **616** can be formed by a wet method. Thus, it is suitable for mass production.

[0361] In addition, a known material can be used, as a material which can be combined with the composite material generating carriers, and a low molecular weight compound, a middle molecular weight (including oligomer or dendrimer), or a high molecular weight compound may be used.

[0362] The composite material generating carriers shown in Embodiment Mode 1 has an excellent carrier injecting property and an excellent carrier transporting property, because electron transfer is conducted between the organic compound and the inorganic compound. Thus, the driving voltage of a light-emitting element can be reduced.

[0363] As the material for the second electrode (cathode) **617** formed over the layer including a luminescent material **616**, a material having a low work function is preferable. For example, Al, Mg, Li, Ca, an alloy or compound such as MgAg, MgIn, LiF, AlLi, CaF_2 or calcium nitride or the like can preferably be used. When light generated in the layer including a luminescent material **616** passes through the second electrode **617**, a stacked layer of a thin metal film having a thin thickness, and a transparent conductive film (such as ITO, indium oxide including zinc oxide of 2 to 20 wt %, indium tin oxide including silicon, zinc oxide (ZnO) or the like) can be used as the second electrode (cathode) **617**.

[0364] Further, a light-emitting element **618** is provided in the space **607** surrounded with the element substrate **610**, the sealing substrate **604**, and the sealing material **605** by pasting the sealing substrate **604** and the element substrate **610** using the sealing material **605**. The space **607** may be filled with an inert gas (Such as nitrogen or argon), or the sealing material **605**.

[0365] An epoxy based resin is preferably used for the sealing material **605**. It is preferable that these materials do not transmit oxygen or moisture as much as possible. As the material for the sealing substrate **604**, a glass substrate, a quartz substrate, a plastic substrate made of FRP (Fiberglass-Reinforced Plastics), PVF (polyvinyl fluoride), mylar, polyester, acrylic, or the like can be used.

[0366] As thus described, a light-emitting device having a light-emitting element of the present invention can be obtained.

[0367] Since a light-emitting element of the present invention uses an organic compound, and an inorganic compound which can transfer electrons with the organic compound, the conductivity is high and the driving voltage can be reduced. Therefore, power consumption can be reduced.

[0368] In addition, since the conductivity of the composite material included in a light-emitting element of the present invention is high, the thickness of the layer including a luminescent substance **616** can be made thicker without increasing the driving voltage. Thus, short-circuiting of an element, to be caused by dusts or the like can be suppressed. Therefore, a light-emitting device with fewer defects can be provided.

[0369] As set forth above, an active light-emitting device which controls the driving of the light-emitting element using a transistor has been described in this embodiment mode. In addition, a passive light-emitting device which drives a light-emitting element without providing a driving element such as a transistor may be employed. FIG. **21** shows a perspective view of a passive light-emitting device which is manufactured in accordance with the present invention. In FIG. **21**, a layer including a luminescent substance **955** is provided between an electrode **952** and an electrode **956** over a substrate **951**. An edge portion of the electrode **952** is covered with an insulating layer **953**. A partition layer **954** is provided over the insulating layer **953**. The sidewalls of the partition layer **954** are aslope such that the distance between both sidewalls is gradually narrowed toward the surface of the substrate. That is, a cross section in a short side of the partition layer **954** is a trapezoidal shape, and a lower side (the side is in contact with the insulating layer **953**) is shorter than an upper side (the side is not in contact with the insulating layer **953**). By providing the partition layer **954** in this manner, defects of the light-emitting element due to static charge and the like can be prevented. In addition, by utilizing the light-emitting element of the present invention, which operates at low driving voltage, for a passive light-emitting devith, the passive light-emitting device can be driven at lower power consumption.

Embodiment Mode 20

[0370] Embodiment mode 20 will describe various electronic devices each including a light-emitting device formed using a light-emitting element of the present invention as a part thereof.

[0371] Electronic devices manufactured using a light-emitting device having a light-emitting element of the present invention are, for example, cameras such as video cameras or digital cameras, goggle type displays, navigation systems, sound reproduction devices (such a car audios or audio components), computers, game machines, mobile information terminals (such as mobile computers, cell phones, portable game machines, or electronic books), image reproduction devices utilizing a recording medium (such as devices which can reproduce a recording medium such as a digital versatile disk (DVD) and is equipped with a display device capable of displaying the image) and the like. These electronic devices are specifically shown in FIGS. **23**A to **23**E.

[0372] FIG. **23**A shows a television receiving machine including a casing **9101**, a supporting stand **9102**, a display portion **9103**, speaker portions **9104**, a video input terminal **9105**, and the like. The television receiving machine of the present invention is manufactured by using a light-emitting device having a light-emitting element of the present invention for the display portion **9103**. By using the light-emitting device of the present invention, a television receiving machine with low power consumption and having a display portion with few defects can be provided. It is to be noted that the television receiving machine includes all types of information display devices, e.g., a display device for a computer, one for TV broadcast reception, one for advertisement display, and so on.

[0373] FIG. **23**B shows a computer including a main body **9201**, a casing **9202**, a display portion **9203**, a keyboard **9204**, an external connection port **9205**, a pointing mouse **9206**, and the like. The computer of the present invention is manufactured by using a light-emitting device having a light-emitting element of the present invention for the display portion **9203**. By using the light-emitting device of the present invention, a computer with low power consumption and having a display portion with few defects can be provided.

[0374] FIG. **23**C shows a goggle-type display including a main body **9301**, display portions **9302**, arm portions **9303**, and the like. The goggle-type display of the present invention is manufactured by using a light-emitting device having a light-emitting element of the present invention for the display portion **9302**. By using the light-emitting device of the present invention, a goggle-type display with low power consumption and having a display portion with few defects can be provided.

[0375] FIG. **23**D shows a cell phone including a main body **9401**, a casing **9402**, a display portion **9403**, an audio input portion **9404**, an audio output portion **9405**, operation keys **9406**, an external connection port **9407**, an antenna **9408**, and the like. The cell phone of the present invention is manufactured by using a light-emitting device having a light-emitting element of the present invention for the display portion **9403**. By using the light-emitting device of the present invention, a cell phone with low power consumption and having a display portion with few defects can be provided. In addition, the power consumption can be suppressed by displaying white characters against black in the display portion **9403**.

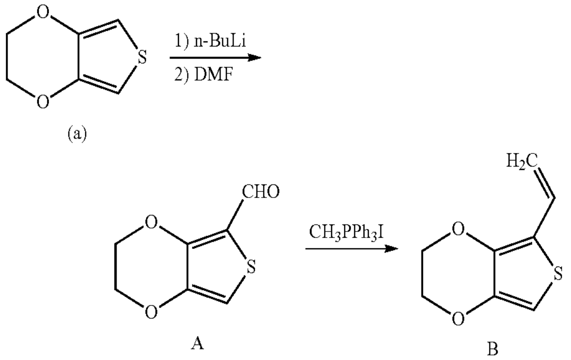
[0376] FIG. **23**E shows a camera including a main body **9501**, a display portion **9502**, a casing **9503**, an external connection port **9504**, a remote control receiving portion **9505**, an image receiving portion **9506**, a battery 9507, an audio input portion **9508**, operation keys **9509**, an eyepiece portion **9510**, and the like. The camera of the present invention is manufactured by using a light-emitting device having a light-emitting element of the present invention for the display portion **9502**. By using the light-emitting device of the present invention, a camera with low power consumption and having a display portion with few defects can be provided.

[0377] As thus described, a light-emitting device having a light-emitting element according to the present invention can be applied in an extremely wide range, and the light-emitting device can be applied to electronic devices of every field. By using a light-emitting device having a light-emitting element of the present invention, electronic devices with low power consumption and few defects can be provided.

Example 1

Synthesis Example 1

[0378] In the present synthesis example, synthesis of a compound shown by the structural formula (15), 2-ethenyl-3,4-ethylenedioxythiophene, will be described. The synthesis scheme (a) is shown as follows.



[0379] Under a nitrogen atmosphere, a 1.58 N hexane solution of n-butyllithium (158 mL, 0.1 mol) was dropped, at −78° C., into a dried tetrahydrofuran (130 mL) solution of 3,4-ethylenedioxythiophene (13.8 g, 0.1 mol). After the dropping, stirrings was performed at −78° C. for 45 minutes. After adding dried DMF (7.3 g, 0.1 mol) to this suspension, the reaction mixture was heated at 45° C. for 2 hours. About 100 mL of 1 N HCl was added to the reaction mixture, and stirring was continued further for 10 minutes. The reaction solution was extracted with ether, and the ether was removed. By recrystallizing the residue, with hexane, 2-formyl-3,4-ethylenedioxythiophene (a compound A in the synthesis scheme (a), 13.21 g, yield: 84%) was obtained.

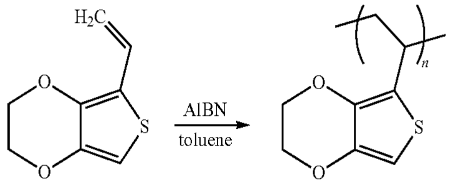
[0380] Under a nitrogen atmosphere, a 1.58 N hexane solution of n-butyllithium (49 mL, 78 mmol) was dropped, at

−40° C., into a dried THF solution of a methyltriphenylphosphonium iodide salt (78 mmol). After the dropping, and then cooling to −78° C., a dried THF solution (70 mL) of 2-formyl-3,4-ethylenedioxythiophene (the compound A in the synthesis scheme (a)) was added to this reaction mixture. After that, the reaction mixture was brought back to a room temperature, and stirred for 24 hours. The reaction solution was extracted with ether, and the ether was removed. By purifying the residue by silica-gel chromatography (developing solvent: hexane/ethyl acetate), 2-ethenyl-3,4-ethylenedioxythiophene represented by the structural formula (5) (a compound B in the synthesis scheme (a), 6.93 g, yield: 58%) was obtained. Here is NMR data of the compound B. ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.70 (dd, J=11, 18 Hz, 1H), 6.18 (s, 1H), 5.48 (q, J=18 Hz, 1H), 5.06 (d, J=11 Hz, 1H), 4.18-4.25 (m, 4H).

Synthesis Example 2

[0381] In the present synthesis example, an example of homopolymerization of 2-ethenyl-3,4-ethylenedioxythiophene represented by the structural formula (15) will be described. The synthesis scheme (b) is shown below.

(b)

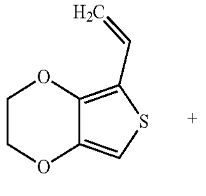


[0382] Under nitrogen, 2-ethenyl-3,4-ethylenedioxythiophene (1.3 g) was dissolved in 1 mL of toluene, and azobisisobutyronitrile (32.8 mg) dissolved in 1 mL of toluene was added thereto. The reaction solution was left at 60° C. for 24 hours. By putting the reaction solution in excess ethanol, and filtering and drying generated precipitation, a corresponding polymer, poly(2-ethenyl-3,4-ethylenedioxythiophene), was obtained. Yield: 50 mg (yield: 36%). The decomposition temperature and glass transition temperature of this compound under a nitrogen atmosphere were 340° C. and 158° C., respectively. The ionization potential was 5.60 eV.

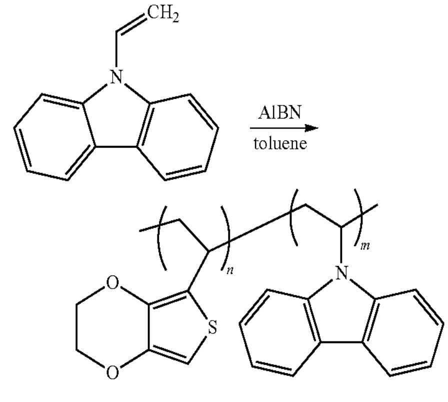
Synthesis Example 3

[0383] In the present synthesis example, an example of copolymerization of 2-ethenyl-3,4-ethylenedioxythiophene represented by the structural formula (15) and N-vinylcarbazole in a solution will be described. The synthesis scheme (c) is shown below.

(c)



-continued

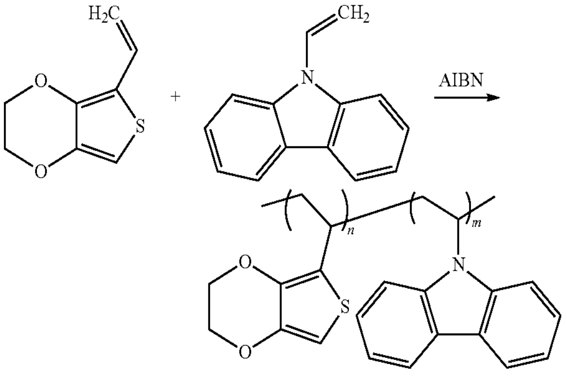


[0384] Under nitrogen, 2-ethenyl-3,4-ethylenedioxythiophene (0.4 mmol) and N-vinylcarbazole (3.6 mmol) were dissolved in 1 mL of toluene, and azobisisobutyronitrile (0.2 mmol) dissolved in 1 mL of toluene was added thereto. The reaction solution was left at 60° C. for 24 hours. By putting the reaction solution in excess methanol, and filtering and drying generated precipitation, a polymer shown by the general formula (10), poly(2-ethenyl-3,4-ethylenedioxythiophene-co-N-vinylcarbazole), was obtained. Yield: 79 mg (yield: 32%). The 5% weight loss temperature of this copolymer under a nitrogen atmosphere was 190° C. In addition, in a differential scanning calorimetry measurement (DSC measurement), no grass transition temperature was shown at this temperature or less.

Synthesis Example 4

[0385] In the present synthesis example, an example of bulk copolymerization of 2-ethenyl-3,4-ethylenedioxythiophene represented by the structural formula (15) and N-vinylcarbazole will be described. The synthesis scheme (d) is shown below.

(d)



[0386] Under nitrogen, azobisisobutyronitrile (0.29 mmol) was added to 2-ethenyl-3,4-ethylenedioxythiophene (0.57 mmol) and N-vinylcarbazole (5.24 mmol) to react at 80° C. for 48 hours. By reprecipitating a generated polymer with methanol, a copolymer shown by the general formula (10) was isolated. Yield: 230 mg (yield: 21%).

Example 2

[0387] Example 2 will concretely describe a light-emitting element of the present invention. An element structure is described with reference to FIG. **8**.

[0388] A glass substrate over which indium tin oxide including silicon was formed to have a thickness of 110 nm, was prepared. The formed indium tin oxide including silicon serves as a first electrode **1101** in this example.

[0389] A solution in which PVK of 0.125 g, TPD of 0.125 g, and titanium (IV) tetra isopropoxide of 0.02 g are dissolved in 25 mL of toluene, was prepared. This solution was dropped onto the prepared substrate. The substrate was spin-coated with this solution at 800 rpm for 5 seconds and then, at 1200 rpm for 60 seconds. Further, it was baked at 50° C. in the air, and then, at 50° C. for 30 minutes under vacuum to form a composite material. Thus, the first layer **1111** was obtained.

[0390] The second layer **1112** was formed. The second layer **1112** was formed with a hole transporting layer, a light-emitting layer, an election transporting layer and an electron injecting layer.

[0391] As described above, the substrate provided with the first layer **1111** was fixed on a substrate holder in a vacuum evaporation apparatus in such a way that the surface provided with the first layer is on the downside. Then, NPB was deposited with a thickness of 10 nm by a vacuum evaporation method using resistance heating to form a hole transporting layer. Next, a light-emitting layer in which coumarin 6 was added into Alq_3, was formed. At this time, a co-evaporation method in which Alq_3 and coumarin 6 were evaporated by resistance heating at the same time, was employed to adjust so that the mass ratio of Alq_3 and coumarin 6 was 1:0.003. The film thickness was made to be 37.5 nm. Further, an Alq_3 film was formed as an electron transporting layer with a thickness of 37.5 nm, and a CaF_2 film was formed as an electron injecting layer with a thickness of 1 nm. Both films were formed by a vacuum evaporation method using resistance heating.

[0392] As described above, after forming the second layer **1112**, Al was deposited to have a thickness of 200 nm as the second electrode **1102**. In this manner, a light-emitting element of the present invention was obtained.

[0393] FIG. **24** shows a voltage-luminance characteristic of a light-emitting element of the present invention. As shown in FIG. **24**, the voltage needed to obtain luminance of 1000 cd/m^2 was 10.6 V. In addition, the current efficiency at this time was 13.0 cd/A.

Comparative Example 1

[0394] A comparative example is shown concretely, in which a conventional hole injecting layer was used instead of the first layer **1111** in the above light-emitting element. The hole injecting layer in the comparative example 1 was obtained by preparing a solution in which titanium (IV) tetra isopropoxide was removed from the solution shown in Example 2, and applying and baking the solution in the same way. In addition, the first electrode **1101**, the second electrode **1102** and the second layer **1112** were the same as those in Example 2.

[0395] FIG. **24** also shows a voltage-luminance characteristic of a light-emitting element as the comparative example 1. As shown in FIG. **24**, the voltage needed to obtain luminance of 1000 cd/m^2 was 11.8 V. The voltage was higher than that of Example 2 by 1V. It should be noted that the current efficiency at this time was 13.6 cd/A, and the current efficiency was almost the same. Therefore, it could be understood that, by applying the present invention, the driving voltage can be decreased without changing the current efficiency.

Example 3

[0396] Example 3 shows a measurement example of electric characteristics of a composite material generating holes, in which 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) was used as an organic compound having an excellent hole transporting property; poly(methyl methacrylate) (PMMA) was used as a binder substance; and titanium oxide (TiO_x) was used as an inorganic compound showing an electron accepting property to the organic compound. Moreover, as a comparative example, an example in which electric characteristics of a material which does not include TiO_x was measured, is also shown.

[0397] A solution for coating was prepared in which PMMA (Mw=996000) of 0.125 g, NPB of 0.125 g (0.21 mmol), and titanium (IV) tetra isopropoxide, which is a raw material of TiO_x, of 0.060 g (0.21 mmol) were dissolved in 25 mL of a mixed solvent in which chloroform and toluene were dissolved in the ratio of 1:1.

[0398] In addition, a substrate in which a transparent electrode (indium tin silicon oxide, ITSO) having a 2-mm square was formed, was prepared, and rinsed with ultrasonic wave using acetone, pure water, and ethanol in this order. Thereafter, it was rinsed by boiled ethanol, and was finally exposed to UV ozone treatment for 370 seconds.

[0399] Then, the solution which had been prepared was made to pass through a 0.45 μm filter and was dropped onto a substrate. The substrate was spin-coated with the solution at 1000 rpm for 60 seconds. The spin-coated substrate and a beaker filled with pure water were put in an electric heating furnace, and were heated at 40° C. for 2 hours to conduct hydrolysis with water vapor. Further, after the beaker filled with pure water was taken out of the furnace, the substrate was baked at 120° C. for 1.5 hours while evacuating air from the furnace by a rotary pump. In this way, a composite material generating holes which were formed with NPB, PMMA and titanium oxide was obtained. The film thickness was 100 nm.

[0400] Lastly, an electrode of Al was formed to have a thickness of 100 nm over the formed composite material by a vacuum evaporation method. A single layer element for measurement of electric characteristics, having an element structure shown below, was manufactured.

[0401] In other words, a transparent electrode (ITSO) was formed, a composite material generating holes (100 nm), which was formed from NPB, PMMA and titanium oxide, was formed, and then, Al (100 nm) was formed to manufacture a light-emitting element of the present example.

[0402] A measurement of a voltage-current characteristic was conducted to the element manufactured as described above by forwardly biasing to the ITSO. FIG. **25** shows a measurement result. In FIG. **25**, the horizontal axis represents voltage (unit: V) and the vertical axis represents current (unit: mA). As shown in FIG. **25**, the composite material generating holes of the present invention exhibits an excellent voltage-current characteristic. Specifically, current of 0.1 mA (i.e., current density of 2.5 mA/cm^2) flows at 5.8 V, and sufficient current for driving a light-emitting element flows.

Comparative Example 2

[0403] For comparison, a material in which an inorganic compound (titanium oxide) was removed from the material of Example 3, or a material which was formed with an organic compound (NPB) and a binder substance (PMMA) only, was formed over the same substrate as that in Example 3. In this way, a comparative element was manufactured.

[0404] A manufacturing method of a comparative element is described below. A solution for coating was prepared in which PMMA (Mw=996000) of 0.125 g and NPB of 0.125 g (0.21 mmol) were dissolved in 25 mL of a mixed solvent in which chloroform and toluene were dissolved in the ratio of 1:1.

[0405] Then, the prepared solution passed through a 0.45 μm filter and was dropped onto the same substrate as that in Example 3. The substrate was spin-coated with the solution at 620 rpm for 60 seconds. The spin-coated substrate was put in an electric heating furnace, and was heated at 120° C. for 1.5 hours while evacuating air from the furnace by a rotary pump. The film thickness was 100 nm.

[0406] Lastly, Al was deposited as an electrode to have a thickness of 100 nm by a vacuum evaporation method, and a comparative element having an element structure shown below was manufactured.

[0407] In other words, a transparent electrode (ITSO) was formed, a material (100 nm), which was formed from NPB and PMMA was formed, and then, Al (100 nm) was formed to manufacture a comparative element.

[0408] A measurement of a voltage-current characteristic was conducted to the comparative element by forwardly biasing to the ITSO. FIG. **25** shows the measurement result of the comparative example 2. As shown in FIG. **25**, in the comparative element of the comparative example 2, almost no current flow until the voltage becomes 2.4 V, and the same electric characteristic is shown as that of a conventional organic compound which exhibits the rise of the voltage-current characteristic at 2.4 V or more. In addition, the amount of current flowing in the comparative element when a certain voltage was applied, was inferior by 3 to 5 digits to the element manufactured in Example 3, although the thickness of the comparative element was almost the same as that of the element manufactured in Example 3.

Example 4

[0409] Example 4 shows a measurement example of electric characteristics of a composite material generating holes, in which 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) was used as an organic compound having an excellent hole transporting property; poly(methyl methacrylate) (PMMA) was used as a binder substance; and vanadium oxide (VO_x) was used as an inorganic compound showing an electron accepting property to the organic compound.

[0410] A solution was prepared in which PMMA (Mw=996000) of 0.25 g and NPB of 0.243 g (0.41 mmol) were dissolved in 50 mL of a mixed solvent in which 25 mL of chloroform and 25 mL of toluene were mixed. The solution was divided equally into two solutions of 25 mL. Vanadium (V) triisopropoxide of 0.051 g (0.21 mmol), which is a raw material of VO_x, and ethyl acetoacetate of 0.025 g (0.19 mmol) as a stabilizer, were mixed into one solution of them, to obtain a solution I. It should be noted that the other solution of 25 mL is a solution II (the solution II was used in Example 5.)

[0411] In addition, a substrate in which a transparent electrode (indium tin silicon oxide, ITSO) having a 2-mm square was formed was prepared, and rinsed with ultrasonic wave using acetone, pure water, and ethanol in this order. Thereafter, it was rinsed by boiled ethanol, and was exposed to UV ozone treatment finally for 370 seconds.

[0412] Next, the prepared solution I passed through a 0.45 μm filter and was dropped onto the substrate. The substrate was spin-coated with the solution at 1100 rpm for 60 seconds, while rotating the substrate. The spin-coated substrate and a beaker filled with pure water were put in an electric heating furnace, and were heated at 40° C. for 2 hours to conduct hydrolysis with water vapor. Further, after the beaker filled with pure water was taken out of the furnace, the substrate was baked at 120° C. for 1.5 hours while evacuating air from the furnace by a rotary pump. In this way, a composite material generating holes which were formed with NPB, PMMA and vanadium oxide was obtained. The film thickness was 100 nm.

[0413] Lastly, an electrode of Al was formed to have a thickness of 100 nm over the formed composite material by a vacuum evaporation method. A single layer element for measurement of electric characteristics, having an element structure shown below, was manufactured.

[0414] In other words, a transparent electrode (ITSO) was formed, a composite material generating holes (100 nm), which was formed from NPB, PMMA and vanadium oxide, was formed, and then, Al (100 nm) was formed to manufacture a light-emitting element of the present example.

[0415] A measurement of a voltage-current characteristic was conducted to the element manufactured as described above. FIG. **26**A shows a voltage-current characteristic in a case that a forward bias is applied to the ITSO, in other words, a voltage is applied so that the ITSO become a positive bias, while FIG. **26**B shows a voltage-current characteristic in a case that a reverse bias is applied to the ITSO, in other words, a voltage is applied so that the ITSO become a negative bias. In FIGS. **26**A and **26**B, the horizontal axis represents voltage (unit: V) and the vertical axis represents current (unit: mA). As shown in FIGS. **26**A and **26**B, the composite material generating holes of the present example exhibits an excellent voltage-current characteristic. Specifically, current of 0.1 mA (i.e., current density of 2.5 mA/cm^2) flows at as small as 0.6 V in the forward bias, and sufficient current for driving a light-emitting element flows.

[0416] In addition, in both cases of forward bias and reverse bias, almost the same voltage-current characteristics were exhibited. This means that the composite material generating holes of the present invention can have an ohmic contact with both ITSO and Al.

Example 5

[0417] In order to examine the factor that the composite material formed in the above example 4 (a composite material including NPB, PMMA and vanadium oxide) has an extremely excellent electric characteristic, the absorption spectrum was measured in Example 5. In addition, for comparison, the absorption spectrum of a material which does not include vanadium oxide (i.e., a material formed with NPB and PMMA) was also measured.

[0418] The solution I prepared in Example 4 passed through a filter of 0.45 μm, and was dropped onto a quartz substrate. The quartz substrate was spin-coated with the solution at 200 rpm for 2 seconds then, at 2000 rpm for 60 seconds, and at 3000 rpm for 10 seconds while rotating the substrate. The spin-coated substrate and a beaker filled with pure water were put in an electric heating furnace, and were heated at 40° C. for 2 hours to conduct hydrolysis with water vapor. Further, after the beaker filled with pure water was taken out of the furnace, the substrate was baked at 120° C. for 1.5 hours while evacuating air from the furnace by a rotary pump. In this way, a composite material generating holes which were formed with NPB, PMMA and vanadium oxide was obtained on the quartz substrate.

Comparative Example 3

[0419] The solution II prepared in Example 4 passed through a filter of 0.45 μm, and was dropped onto a quartz substrate. The quartz substrate was spin-coated with the solution at 200 rpm for 2 seconds, at 2000 rpm for 60 seconds, and at 3000 rpm for 10 seconds while rotating the substrate. The spin-coated substrate was put in an electric heating furnace, and was heated 120° C. for 1.5 hours while evacuating air from the furnace by a rotary pump. In this way, a material which was formed with NPB, and PMMA was obtained on the quartz substrate.

[0420] The absorption spectra of the sample formed in Example 5 as described above and the sample formed in the comparative example 3 were measured. The obtained results are shown in FIG. **27**A. In addition, an enlarged view of FIG. **27**A is shown in FIG. **27**B. As shown in FIG. **27**B, it can be understood that the composite material generating holes of the present invention has new notable absorption peaks in the vicinity of 500 nm (the circle shown by a dashed line A) and 1400 nm (the circle shown by a dashed line B), as compared with the comparative sample. This suggests that vanadium oxide draws electrons from NPB, and thus, a kind of charge transfer complex is made in the composite material generating holes of the present invention. In other words, it can be considered that holes are generated in NPB and this contributes to high conductivity of the composite material.

[0421] This application is based on Japanese Patent Application serial no. 2004-353452 filed in Japan Patent Office on Dec. 6, 2004, Japanese Patent Application serial no. 2004-353449 filed in Japan Patent Office on Dec. 6, 2004 and Japanese Patent Application serial no. 2004-353450 filed in Japan Patent Office on Dec. 6, 2004, the entire contents of which are hereby incorporated by reference.

1-158. (canceled)

159. A composite material including:

an organic compound;

a binder substance; and

an inorganic compound showing an electron accepting property to the organic compound.

160. The composite material according to claim **159**, wherein the binder substance is polyvinyl alcohol), poly(methyl methacrylate), polycarbonate, or a phenol resin.

161. The composite material according to claim **159**, wherein the organic compound has an arylamine skeleton.

162. The composite material according to claim **159**, wherein the inorganic compound is selected from titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, and rhenium oxide.

163. A composite material comprising:

a polymer; and

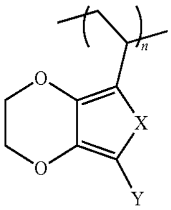
an inorganic compound showing an electron accepting property to the polymer.

164. The composite material according to claim **163**, wherein the inorganic compound is selected from titanium oxide, vanadium oxide, molybdenum oxide, tungsten oxide, and rhenium oxide.

165. The composite material according to claim **163**,

wherein the polymer is represented by general formula (1), and

(1)



wherein:

X represents an oxygen atom or a sulfur atom;

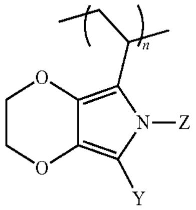
Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent; and

n is an integer of 2 or more.

166. The composite material according to claim **163**,

wherein the polymer is represented by general formula (2), and

(2)



wherein:

Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent;

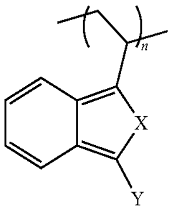
Z represents a hydrogen atom, an alkyl group, or a substituted or unsubstituted aryl group; and

n is an integer of 2 or more.

167. The composite material according to claim **163**,

wherein the polymer is represented by general formula (3), and

(3)



wherein:

X represents an oxygen atom or a sulfur atom;

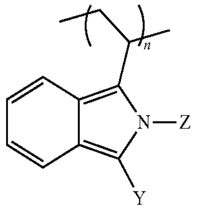
Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent; and

n is an integer of 2 or more.

168. The composite material according to claim **163**,

wherein the polymer is represented by general formula (4), and

(4)



wherein:

Y represents a hydrogen atom, an alkyl group, an aryl group, or a silyl group having an alkyl group or an aryl group as a substituent;

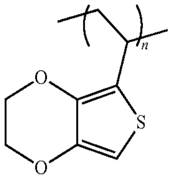
Z represents a hydrogen atom, an alkyl group, or a substituted or unsubstituted aryl group; and

n is an integer of 2 or more.

169. The composite material according to claim **163**,

wherein the polymer is represented by general formula (5), and

(5)



wherein n is an integer of 2 or more.

170. A light-emitting element comprising:

an anode and a cathode; and

a layer interposed between the anode and the cathode, the layer including an organic compound, a binder substance, and an inorganic compound showing an electron accepting property to the organic compound.

171. The light-emitting element according to claim **170**, wherein the layer is in contact with the anode.

172. The light-emitting element according to claim **170**, further comprising an electron generating layer,

wherein the electron generating layer comprises a substance having an electron transporting property and a material showing an electron donating property to the substance having an electron transporting property.

173. The light-emitting element according to claim **170**, further comprising a second layer,

wherein the second layer comprises a second organic compound and a second inorganic compound showing an electron accepting property to the second organic compound, and

wherein the second layer is in contact with the cathode.

174. The light-emitting element according to claim **170**, further comprising a third layer,

wherein the third layer is configured to emit white light.

175. A light-emitting element comprising:

an anode and a cathode; and

a layer interposed between the anode and the cathode, the layer including a polymer and an inorganic compound showing an electron accepting property to the polymer.

176. The light-emitting element according to claim **175**, wherein the layer is in contact with the anode.

177. The light-emitting element according to claim **175**, further comprising an electron generating layer,

wherein the electron generating layer comprises a substance having an electron transporting property and a material which shows an electron donating property to the substance having an electron transporting property.

178. The light-emitting element according to claim **175**, further comprising a second layer,

wherein the second layer comprises an organic compound and a second inorganic compound showing an electron accepting property to the organic compound, and

wherein the second layer is in contact with the cathode.

179. The light-emitting element according to claim **175**, further comprising a third layer,

wherein the third layer is configured to white light.

* * * * *

专利名称(译)	包含有机化合物和无机化合物的复合材料，使用该复合化合物的发光元件和发光装置，以及发光元件的制造方法		
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外部链接	Espacenet USPTO		

摘要(译)

本发明提供具有高导电性的复合材料，发光元件和使用该复合材料的发光装置。此外，本发明提供适合于大规模生产的发光元件的制造方法。本发明的发光元件包括在一对电极之间包含发光物质的层。包含发光物质的层具有复合材料，该复合材料包括有机化合物和对有机化合物显示出电子给予性的无机化合物。由于本发明的发光元件包括通过组合有机化合物和无机化合物制成的复合材料，因此载流子注入性，载流子传输性和导电性优异，因此可以降低驱动电压。