



(51) International Patent Classification:
H05B 33/02 (2006.01) *F21Y 105/00* (2006.01)
H01L 51/50 (2006.01)

(21) International Application Number:
PCT/JP2011/066504

(22) International Filing Date:
13 July 2011 (13.07.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2010-166961 26 July 2010 (26.07.2010) JP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: LIGHT-EMITTING DEVICE AND LIGHTING DEVICE

FIG. 6A

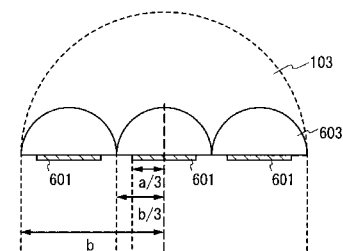
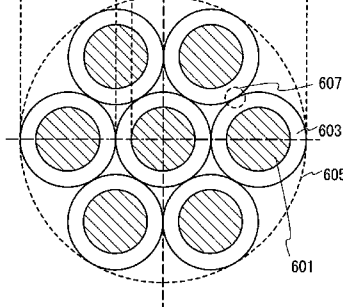


FIG. 6B



(57) Abstract: It is an object to improve light extraction efficiency in a light-emitting device and a lighting device. A light-emitting device includes a plurality of light-emitting portions, and a plurality of hemispherical components provided so as to overlap with the plurality of light-emitting portions. The plurality of hemispherical components are provided so as not to form a space therebetween in a region where the plurality of hemispherical components are adjacent to each other. When a refractive index of the hemispherical component is n and a radius of a bottom surface of the hemispherical component is b , the light-emitting portion is provided inside a circle whose radius r from a center of the bottom surface of the hemispherical component is b/n .

DESCRIPTION

LIGHT-EMITTING DEVICE AND LIGHTING DEVICE

5 TECHNICAL FIELD

[0001]

The technical field relates to a light-emitting device and a method for manufacturing the light-emitting device and also relates to a lighting device and a method for manufacturing the lighting device.

10

BACKGROUND ART

[0002]

In recent years, light-emitting devices including electroluminescence (hereinafter also referred to as EL) elements as self-luminous elements have been actively researched. The light-emitting devices are expected to be used for organic EL displays, organic EL lighting devices, and the like.

15

[0003]

Since planar light emission can be performed with an EL element, in the case of using the EL element for a lighting device, a sheet-like lighting device can be manufactured, for example (Patent Document 1).

20

[Reference]

[Patent Document]

[0004]

[Patent Document 1] Japanese Published Patent Application No. 2009-130132

25

DISCLOSURE OF INVENTION

[0005]

In the device disclosed in Patent Document 1, there is the following problem: total reflection is caused at an interface between a glass substrate and the air, and only several tens of percents of light emitted from an EL element can be extracted to the outside.

30

[0006]

In view of the above problem, it is an object to improve light extraction efficiency in a light-emitting device and a lighting device.

[0007]

In addition, it is an object to provide a novel structure of a light-emitting device and a lighting device. Further, it is an object to provide a novel method for manufacturing a light-emitting device and a lighting device.

[0008]

Light emitted from a light-emitting portion is extracted to the outside through a hemispherical component, which is a feature of an embodiment of the present invention. In other words, light is transmitted through the hemispherical component, whereby total reflection of the light is suppressed as much as possible.

[0009]

An embodiment of the present invention is a light-emitting device including a plurality of light-emitting portions, and a plurality of hemispherical components provided so as to overlap with the plurality of light-emitting portions. The plurality of hemispherical components are provided so as not to form a space therebetween in a region where the plurality of hemispherical components are adjacent to each other. That is, the plurality of hemispherical components are arranged with a closest packed structure.

[0010]

Another embodiment of the present invention is a light-emitting device including a plate-like component, a plurality of light-emitting portions provided over one surface of the plate-like component, and a plurality of hemispherical components provided over the other surface of the plate-like component so as to overlap with the plurality of light-emitting portions. The plurality of hemispherical components are provided so as not to form a space therebetween in a region where the plurality of hemispherical components are adjacent to each other.

[0011]

Another embodiment of the present invention is a light-emitting device including a plurality of light-emitting portions, and a plurality of hemispherical components provided so as to overlap with the plurality of light-emitting portions. When a refractive index of the hemispherical component is n and a radius of a bottom

surface of the hemispherical component is b , the light-emitting portion is provided inside a circle whose radius r from the center of the bottom surface of the hemispherical component is b/n .

[0012]

5 Another embodiment of the present invention is a light-emitting device including a plate-like component, a plurality of light-emitting portions provided over one surface of the plate-like component, and a plurality of hemispherical components provided over the other surface of the plate-like component so as to overlap with the plurality of light-emitting portions. When a refractive index of the hemispherical
10 component is n and a radius of a bottom surface of the hemispherical component is b , the light-emitting portion is provided inside a circle whose radius r from the center of the bottom surface of the hemispherical component is b/n .

[0013]

15 Another embodiment of the present invention is a lighting device including the above-described light-emitting device.

[0014]

In this specification, the term "light-emitting device" means all devices which perform light emission. Therefore, a lighting device including a light-emitting portion is simply called a light-emitting device in some cases.

20 [0015]

Light extraction efficiency in a light-emitting device and a lighting device can be improved.

[0016]

25 In addition, various performance of a light-emitting device and a lighting device can be improved; for example, white light emission with high quality can be achieved.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

30 FIGS. 1A and 1B illustrate an example of a light-emitting device.

FIGS. 2A and 2B each illustrate an example of a light-emitting device.

FIGS. 3A and 3B illustrate an example of a light-emitting device.

FIGS. 4A and 4B each illustrate an example of a light-emitting device.

FIGS. 5A to 5C each illustrate an example of a light-emitting device.

FIGS. 6A and 6B illustrate an example of a light-emitting device.

FIGS. 7A to 7C each illustrate an example of a light-emitting device.

5 FIGS. 8A and 8B each illustrate an example of an electronic device.

FIGS. 9A and 9B illustrate an example of a light-emitting device.

BEST MODE FOR CARRYING OUT THE INVENTION

[0018]

10 Hereinafter, embodiments will be described in detail with reference to the accompanying drawings. Since embodiments described below can be embodied in many different modes, it is easily understood by those skilled in the art that modes and details thereof can be variously changed without departing from the spirit and the scope of the present invention. Therefore, the present invention should not be construed as
15 being limited to the following description of the embodiments. In the drawings for explaining the embodiments, the same parts or parts having similar functions are denoted by the same reference numerals, and description of such parts is not repeated.

[0019]

(Embodiment 1)

20 In this embodiment, an example of a structure of a light-emitting device will be described.

[0020]

FIG. 1A is an example of a cross-sectional view of a light-emitting device, and FIG. 1B is an example of a plan view of the light-emitting device.

25 [0021]

In FIG. 1A, the light-emitting device includes a light-emitting portion (also referred to as a light-emitting region) 101 and a hemispherical component 103 provided so as to overlap with the light-emitting portion 101. Light emitted from the light-emitting portion 101 is extracted to an external portion (such as air) 105 through
30 the hemispherical component 103.

[0022]

Light is transmitted through the hemispherical component 103, whereby total

reflection of the light can be suppressed as much as possible, and thus, light extraction efficiency can be improved.

[0023]

In the vicinity of an end portion 107 of the hemispherical component 103, it is difficult to suppress total reflection of light. Specifically, in the case where a radius of a bottom surface 108 of the hemispherical component 103 is b , a refractive index of the hemispherical component 103 is n , and part of the light-emitting portion 101 is provided in a region outside a circle 109 whose radius r is b/n , light emitted from the part of the light-emitting portion 101 in the region outside the circle 109 is totally reflected at an interface between the hemispherical component 103 and the air, and it is difficult to extract the light to the outside. Note that the circle 109 is a circle whose radius r from the center of the bottom surface 108 is b/n .

[0024]

Thus, it is preferable that the light-emitting portion 101 be provided inside the circle 109 whose radius r from the center of the bottom surface 108 of the hemispherical component 103 is b/n .

[0025]

In the case where the planar shape of the light-emitting portion 101 is a circular shape and the center thereof corresponds to the center of the hemispherical component 103 as illustrated in FIGS. 1A and 1B, a radius a of the light-emitting portion 101 is preferably less than or equal to b/n ($= r$) ($a \leq b/n$).

[0026]

Alternatively, the planar shape of the light-emitting portion 101 may be an elliptical shape, a shape having a vertex, an uneven shape, or the like. In such a case, a half of the major axis of the light-emitting portion 101 a is preferably less than or equal to b/n ($= r$) ($a \leq b/n$). For example, in the case where the light-emitting portion 101 is a square as illustrated in FIG. 2A, a half of a diagonal line a may be less than or equal to b/n ($= r$) ($a \leq b/n$).

[0027]

In addition, as illustrated in FIG. 2B, the center of the light-emitting portion 101 and the center of the hemispherical component 103 may be provided at different

positions. In that case, the light-emitting portion 101 is preferably provided inside the circle 109 whose radius r is b/n .

[0028]

In addition, as illustrated in FIGS. 3A and 3B, instead of the hemispherical component, a spherical component 111 whose spherical surface is wider than a hemispherical surface may be used. With a spherical surface wider than a hemispherical surface, an area of a portion where light is extracted is increased, so that light extraction efficiency can be improved.

[0029]

Note that in the spherical component 111, a portion where the light-emitting portion 101 is formed preferably has a flat surface. Therefore, the spherical component 111 includes a spherical component a part of which has a flat surface.

[0030]

In addition, in the case of using the spherical component 111, the light-emitting portion 101 is preferably provided inside the circle 109 whose radius r from the center of a surface 113 having a maximum radius b of the spherical component 111 is b/n . Note that n is a refractive index of the spherical component 111.

[0031]

In such a manner, by adjusting the position where the light-emitting portion 101 is provided, light extraction efficiency can be improved about three times.

[0032]

In addition, as illustrated in FIGS. 9A and 9B, instead of the hemispherical component or the spherical component, a polygonal sphere-like component 121 whose bottom surface has a polygonal shape may be used. As the polygonal sphere-like component, a hexagonal sphere-like component (whose bottom surface has a hexagonal shape) as illustrated in FIG. 9A and 9B, an octagonal sphere-like component (whose bottom surface has an octagonal shape), or the like can be used. Note that the polygonal sphere-like component 121 may have a vertex at the top or the top thereof may be processed into a curved surface. When the polygonal sphere-like component 121 has a vertex at the top, it includes curved lines for connecting vertices of the polygonal bottom surface and the vertex of the top and a plurality of curved surfaces at a side surface.

[0033]

In the case of using the polygonal sphere-like component 121, the light-emitting portion 101 is preferably provided inside a circle 125 whose radius r from the center of a bottom surface 123 of the polygonal sphere-like component 121 is b'/n .

5 Note that n is a refractive index of the polygonal sphere-like component 121. Here, b' is the shortest length of a straight line for connecting the center and the circumference of the bottom surface 123.

[0034]

Next, details of the light-emitting portion 101 will be described.

10 [0035]

FIGS. 4A and 4B each illustrate a structural example of the light-emitting portion 101.

[0036]

15 The light-emitting portion 101 includes a light-emitting element (also referred to as an EL element) in which a first electrode 401, an EL layer 403, and a second electrode 405 are sequentially stacked.

[0037]

20 The first electrode 401 is provided on the hemispherical component 103 side which corresponds to a light extraction direction and is formed using a light-transmitting material. As the light-transmitting material, indium oxide, an alloy of indium oxide and tin oxide (also referred to as ITO), an alloy of indium oxide and zinc oxide (also referred to as IZO), zinc oxide, zinc oxide to which gallium is added, or the like can be used.

[0038]

25 In addition, as the first electrode 401, a metal material such as gold, platinum, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, palladium, or titanium can be used. Further, a nitride of the metal material (such as titanium nitride) or the like may be used. In the case of using the metal material (or the nitride thereof), the first electrode 401 may be thinned so as to be able to transmit light.

30 [0039]

There is no particular limitation on the structure of the EL layer 403. A layer containing a substance having a high electron-transport property (also referred to as an

electron-transport layer), a layer containing a substance having a high hole-transport property (also referred to as a hole-transport layer), a layer containing a substance having a high electron-injection property (also referred to as an electron-injection layer), a layer containing a substance having a high hole-injection property (also referred to as a hole-injection layer), a layer containing a bipolar substance (a substance having a high electron-transport property and a high hole-transport property) (also referred to as a bipolar layer), and the like may be appropriately stacked.

[0040]

In this embodiment, as illustrated in FIG. 4A, the EL layer 403 has a structure in which a hole-injection layer 701, a hole-transport layer 702, a light-emitting layer 703, an electron-transport layer 704, and an electron-injection layer 705 are sequentially stacked. Specific materials to form the above layers will be given below.

[0041]

The hole-injection layer 701 is a layer which is provided in contact with the first electrode 401 and contains a substance having a high hole-injection property. Molybdenum oxide, vanadium oxide, ruthenium oxide, tungsten oxide, manganese oxide, or the like can be used. Further, the hole-injection layer 701 can be formed using a phthalocyanine-based compound such as phthalocyanine (abbreviation: H₂Pc) or copper phthalocyanine (abbreviation: CuPc); an aromatic amine compound such as 4,4'-bis[*N*-(4-diphenylaminophenyl)-*N*-phenylamino]biphenyl (abbreviation: DPAB) or *N,N'*-bis[4-[bis(3-methylphenyl)amino]phenyl]-*N,N'*-diphenyl-[1,1'-biphenyl]-4,4'-diamine (abbreviation: DNTPD); a high molecule such as poly(ethylenedioxythiophene)/poly(styrenesulfonic acid) (PEDOT/PSS); or the like.

[0042]

Alternatively, for the hole-injection layer 701, a composite material in which an acceptor substance is mixed in a substance having a high hole-transport property can be used. Note that, by using such a substance having a high hole-transport property containing an acceptor substance, a material used to form an electrode may be selected regardless of the work function of the electrode. In other words, besides a material with a high work function, a material with a low work function can be used for the first electrode 401. As the acceptor substance, 7,7,8,8-tetracyano-2,3,5,6-tetrafluoroquinodimethane (abbreviation: F₄-TCNQ),

chloranil, and the like can be used. In addition, a transition metal oxide can be used. In addition, oxides of metals that belong to Group 4 to Group 8 of the periodic table can be used. Specifically, vanadium oxide, niobium oxide, tantalum oxide, chromium oxide, molybdenum oxide, tungsten oxide, manganese oxide, and rhenium oxide are preferable since their electron-accepting properties are high. Among these, molybdenum oxide is especially preferable since it is stable in the air and its hygroscopic property is low and is easily treated.

[0043]

As the substance having a high hole-transport property used for the composite material, any of a variety of compounds such as an aromatic amine compound, a carbazole derivative, aromatic hydrocarbon, and a high molecular compound (e.g., an oligomer, a dendrimer, or a polymer) can be used. An organic compound used for the composite material is preferably an organic compound having a high hole-transport property. Specifically, a substance having a hole mobility of greater than or equal to 10^{-6} cm²/Vs is preferably used. However, other substances than the above-described materials may be used as long as the substances have higher hole-transport properties than electron-transport properties. Organic compounds which can be used for the composite material will be specifically given below.

[0044]

As aromatic amine compounds, for example, there are *N,N'*-di(*p*-tolyl)-*N,N'*-diphenyl-*p*-phenylenediamine (abbreviation: DTDPPA), 4,4'-bis[*N*-(4-diphenylaminophenyl)-*N*-phenylamino]biphenyl (abbreviation: DPAB), *N,N'*-bis[4-[bis(3-methylphenyl)amino]phenyl]-*N,N'*-diphenyl-[1,1'-biphenyl]-4,4'-diamine (abbreviation: DNTPD), 1,3,5-tris[*N*-(4-diphenylaminophenyl)-*N*-phenylamino]benzene (abbreviation: DPA3B), and the like.

[0045]

As carbazole derivatives which can be used for the composite material, specifically, there are 3-[*N*-(9-phenylcarbazol-3-yl)-*N*-phenylamino]-9-phenylcarbazole (abbreviation: PCzPCA1), 3,6-bis[*N*-(9-phenylcarbazol-3-yl)-*N*-phenylamino]-9-phenylcarbazole (abbreviation: PCzPCA2), 3-[*N*-(1-naphthyl)-*N*-(9-phenylcarbazol-3-yl)amino]-9-phenylcarbazole

(abbreviation: PCzPCN1), and the like.

[0046]

In addition, as carbazole derivatives which can be used for the composite material, there are 4,4'-di(*N*-carbazolyl)biphenyl (abbreviation: CBP),
 5 1,3,5-tris[4-(*N*-carbazolyl)phenyl]benzene (abbreviation: TCPB),
 9-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazole (abbreviation: CzPA),
 1,4-bis[4-(*N*-carbazolyl)phenyl]-2,3,5,6-tetraphenylbenzene, and the like.

[0047]

As aromatic hydrocarbon which can be used for the composite material, there
 10 are 2-*tert*-butyl-9,10-di(2-naphthyl)anthracene (abbreviation: t-BuDNA),
 2-*tert*-butyl-9,10-di(1-naphthyl)anthracene, 9,10-bis(3,5-diphenylphenyl)anthracene
 (abbreviation: DPPA), 2-*tert*-butyl-9,10-bis(4-phenylphenyl)anthracene (abbreviation:
 t-BuDBA), 9,10-di(2-naphthyl)anthracene (abbreviation: DNA),
 9,10-diphenylanthracene (abbreviation: DPAnth), 2-*tert*-butylanthracene (abbreviation:
 15 t-BuAnth), 9,10-bis(4-methyl-1-naphthyl)anthracene (abbreviation: DMNA),
 2-*tert*-butyl-9,10-bis[2-(1-naphthyl)phenyl]anthracene,
 9,10-bis[2-(1-naphthyl)phenyl]anthracene,
 2,3,6,7-tetramethyl-9,10-di(1-naphthyl)anthracene,
 2,3,6,7-tetramethyl-9,10-di(2-naphthyl)anthracene, 9,9'-bianthryl,
 20 10,10'-diphenyl-9,9'-bianthryl, 10,10'-bis(2-phenylphenyl)-9,9'-bianthryl,
 10,10'-bis[(2,3,4,5,6-pentaphenyl)phenyl]-9,9'-bianthryl, anthracene, tetracene, rubrene,
 perylene, 2,5,8,11-tetra(*tert*-butyl)peryene, and the like. Besides these, pentacene,
 coronene, and the like can be used. In particular, an aromatic hydrocarbon which has a
 hole mobility of greater than or equal to $1 \times 10^{-6} \text{ cm}^2/\text{Vs}$ and 14 to 42 carbon atoms is
 25 preferable.

[0048]

Aromatic hydrocarbon which can be used for the composite material may have
 a vinyl skeleton. As the aromatic hydrocarbon having a vinyl group, for example,
 there are 4,4'-bis(2,2-diphenylvinyl)biphenyl (abbreviation: DPVBi),
 30 9,10-bis[4-(2,2-diphenylvinyl)phenyl]anthracene (abbreviation: DPVPA), and the like.

[0049]

In addition, a high-molecular compound such as poly(*N*-vinylcarbazole) (abbreviation: PVK), poly(4-vinyltriphenylamine) (abbreviation: PVTPA), poly[*N*-(4-{*N'*-[4-(4-diphenylamino)phenyl]phenyl-*N'*-phenylamino}phenyl)methacrylamide] (abbreviation: PTPDMA), or
5 poly[*N,N'*-bis(4-butylphenyl)-*N,N'*-bis(phenyl)benzidine] (abbreviation: Poly-TPD) can be used.

[0050]

The hole-transport layer 702 is a layer containing a substance having a high hole-transport property. As the substance having a high hole-transport property, for
10 example, the following aromatic amine compounds can be used: 4,4'-bis[*N*-(1-naphthyl)-*N*-phenylamino]biphenyl (abbreviation: NPB), *N,N'*-bis(3-methylphenyl)-*N,N'*-diphenyl-[1,1'-biphenyl]-4,4'-diamine (abbreviation: TPD), 4,4',4''-tris(*N,N*-diphenylamino)triphenylamine (abbreviation: TDATA), 4,4',4''-tris[*N*-(3-methylphenyl)-*N*-phenylamino]triphenylamine (abbreviation:
15 MTDATA), 4,4'-bis[*N*-(spiro-9,9'-bifluoren-2-yl)-*N*-phenylamino]biphenyl (abbreviation: BSPB), and the like. The substances mentioned here are mainly ones that have a hole mobility of greater than or equal to 10^{-6} cm²/V·s. However, other substances than the above-described materials may be used as long as the substances have higher hole-transport properties than electron-transport properties. The layer
20 containing a substance having a high hole-transport property is not limited to a single layer, and two or more layers containing the aforementioned substances may be stacked.

[0051]

Alternatively, a high molecular compound such as poly(*N*-vinylcarbazole) (abbreviation: PVK) or poly(4-vinyltriphenylamine) (abbreviation: PVTPA) can be used
25 for the hole-transport layer 702.

[0052]

The light-emitting layer 703 is a layer containing a light-emitting substance. The light-emitting layer 703 may be either a so-called single-film light-emitting layer containing an emission center material as its main component or a so-called host-guest
30 type light-emitting layer in which an emission center material is dispersed in a host material.

[0053]

There is no particular limitation on the emission center material that is used, and known fluorescent materials or phosphorescent materials can be used. As fluorescent materials, for example, in addition to

5 *N,N'*-bis[4-(9*H*-carbazol-9-yl)phenyl]-*N,N'*-diphenylstilbene-4,4'-diamine (abbreviation: YGA2S), 4-(9*H*-carbazol-9-yl)-4'-(10-phenyl-9-anthryl)triphenylamine (abbreviation: YGAPA), and the like, there are fluorescent materials with an emission wavelength of greater than or equal to 450 nm, such as

10 4-(9*H*-carbazol-9-yl)-4'-(9,10-diphenyl-2-anthryl)triphenylamine (abbreviation: 2YGAPPA), *N*,9-diphenyl-*N*-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazol-3-amine (abbreviation: PCAPA), perylene, 2,5,8,11-tetra-*tert*-butylperylene (abbreviation: TBP), 4-(10-phenyl-9-anthryl)-4'-(9-phenyl-9*H*-carbazol-3-yl)triphenylamine (abbreviation: PCBAPA),

15 *N,N''*-(2-*tert*-butylanthracene-9,10-diyl-di-4,1-phenylene)bis[*N,N',N'*-triphenyl-1,4-phenylenediamine] (abbreviation: DPABPA), *N*,9-diphenyl-*N*-[4-(9,10-diphenyl-2-anthryl)phenyl]-9*H*-carbazol-3-amine (abbreviation: 2PCAPPA), *N*-[4-(9,10-diphenyl-2-anthryl)phenyl]-*N,N',N'*-triphenyl-1,4-phenylenediamine (abbreviation: 2DPAPPA),

20 *N,N,N',N',N'',N'',N''',N'''*-octaphenyldibenzo[*g,p*]chrysene-2,7,10,15-tetraamine (abbreviation: DBC1), coumarin 30, *N*-(9,10-diphenyl-2-anthryl)-*N*,9-diphenyl-9*H*-carbazol-3-amine (abbreviation: 2PCAPA),

25 *N*-[9,10-bis(1,1'-biphenyl-2-yl)-2-anthryl]-*N*,9-diphenyl-9*H*-carbazol-3-amine (abbreviation: 2PCABPhA), *N*-(9,10-diphenyl-2-anthryl)-*N,N',N'*-triphenyl-1,4-phenylenediamine (abbreviation: 2DPAPA),

30 *N*-[9,10-bis(1,1'-biphenyl-2-yl)-2-anthryl]-*N,N',N'*-triphenyl-1,4-phenylenediamine (abbreviation: 2DPABPhA), 9,10-bis(1,1'-biphenyl-2-yl)-*N*-[4-(9*H*-carbazol-9-yl)phenyl]-*N*-phenylanthracen-2-amine (abbreviation: 2YGABPhA), *N,N*,9-triphenylanthracen-9-amine (abbreviation: DPhAPhA), coumarin 545T, *N,N'*-diphenylquinacridone (abbreviation: DPQd), rubrene,

5,12-bis(1,1'-biphenyl-4-yl)-6,11-diphenyltetracene (abbreviation: BPT),
 2-(2-{2-[4-(dimethylamino)phenyl]ethenyl}-6-methyl-4*H*-pyran-4-ylidene)propanedinitrile
 (abbreviation: DCM1),
 2-{2-methyl-6-[2-(2,3,6,7-tetrahydro-1*H*,5*H*-benzo[*ij*]quinolizin-9-yl)ethenyl]-4*H*-pyra
 5 n-4-ylidene}propanedinitrile (abbreviation: DCM2),
N,N,N',N'-tetrakis(4-methylphenyl)tetracene-5,11-diamine (abbreviation: p-mPhTD),
 7,14-diphenyl-*N,N,N',N'*-tetrakis(4-methylphenyl)acenaphtho[1,2-*a*]fluoranthene-3,10-d
 iamine (abbreviation: p-mPhAFD),
 2-{2-isopropyl-6-[2-(1,1,7,7-tetramethyl-2,3,6,7-tetrahydro-1*H*,5*H*-benzo[*ij*]quinolizin-
 10 9-yl)ethenyl]-4*H*-pyran-4-ylidene}propanedinitrile (abbreviation: DCJTI),
 2-{2-*tert*-butyl-6-[2-(1,1,7,7-tetramethyl-2,3,6,7-tetrahydro-1*H*,5*H*-benzo[*ij*]quinolizin-
 9-yl)ethenyl]-4*H*-pyran-4-ylidene}propanedinitrile (abbreviation: DCJTB),
 2-(2,6-bis{2-[4-(dimethylamino)phenyl]ethenyl}-4*H*-pyran-4-ylidene)propanedinitrile
 (abbreviation: BisDCM), and
 15 2-{2,6-bis[2-(8-methoxy-1,1,7,7-tetramethyl-2,3,6,7-tetrahydro-1*H*,5*H*-benzo[*ij*]quinoli
 zin-9-yl)ethenyl]-4*H*-pyran-4-ylidene}propanedinitrile (abbreviation: BisDCJTM). As
 phosphorescent materials, for example, in addition to
 bis[2-(4',6'-difluorophenyl)pyridinato-*N,C*^{2'}]iridium(III)tetrakis(1-pyrazolyl)borate
 (abbreviation: FIr6) and the like, there are phosphorescent materials with an emission
 20 wavelength in the range of 470 nm to 500 nm, such as
 bis[2-(4',6'-difluorophenyl)pyridinato-*N,C*^{2'}]iridium(III)picolate (abbreviation: FIrpic),
 bis[2-(3',5'-bistrifluoromethylphenyl)pyridinato-*N,C*^{2'}]iridium(III)picolate
 (abbreviation: Ir(CF₃ppy)₂(pic)), and
 bis[2-(4',6'-difluorophenyl)pyridinato-*N,C*^{2'}]iridium(III)acetylacetonate (abbreviation:
 25 FIracac); and phosphorescent materials with an emission wavelength of greater than or
 equal to 500 nm (materials which emit green light), such as
 tris(2-phenylpyridinato)iridium(III) (abbreviation: Ir(ppy)₃),
 bis(2-phenylpyridinato)iridium(III)acetylacetonate (abbreviation: Ir(ppy)₂(acac)),
 tris(acetylacetonato)(monophenanthroline)terbium(III) (abbreviation: Tb(acac)₃(Phen)),
 30 bis(benzo[*h*]quinolinato)iridium(III)acetylacetonate (abbreviation: Ir(bzq)₂(acac)),
 bis(2,4-diphenyl-1,3-oxazolato-*N,C*^{2'})iridium(III)acetylacetonate (abbreviation:

- Ir(dpo)₂(acac)), bis[2-(4'-perfluorophenylphenyl)pyridinato]iridium(III)acetylacetonate (abbreviation: Ir(p-PF-ph)₂(acac)), bis(2-phenylbenzothiazolato-*N,C*^{2'})iridium(III)acetylacetonate (abbreviation: Ir(bt)₂(acac)), bis[2-(2'-benzo[4,5-*a*]thienyl)pyridinato-*N,C*^{3'}]iridium(III)acetylacetonate (abbreviation: Ir(btp)₂(acac)), bis(1-phenylisoquinolinato-*N,C*^{2'})iridium(III)acetylacetonate (abbreviation: Ir(piq)₂(acac)), (acetylacetonato)bis[2,3-bis(4-fluorophenyl)quinoxalinato]iridium(III) (abbreviation: Ir(Fdpq)₂(acac)), (acetylacetonato)bis(2,3,5-triphenylpyrazinato)iridium(III) (abbreviation: Ir(tppr)₂(acac)), 2,3,7,8,12,13,17,18-octaethyl-21*H*,23*H*-porphyrinatoplatinum(II) (abbreviation: PtOEP), tris(1,3-diphenyl-1,3-propanedionato)(monophenanthroline)europium(III) (abbreviation: Eu(DBM)₃(Phen)), and tris[1-(2-thenoyl)-3,3,3-trifluoroacetato](monophenanthroline)europium(III) (abbreviation: Eu(TTA)₃(Phen)). The emission center material can be selected from the above-mentioned materials or other known materials in consideration of the emission color of each light-emitting element.

[0054]

- When the host material is used, for example, the following can be used: metal complexes such as tris(8-quinolinolato)aluminum(III) (abbreviation: Alq), tris(4-methyl-8-quinolinolato)aluminum(III) (abbreviation: Alm_{q3}), bis(10-hydroxybenzo[*h*]quinolinato)beryllium(II) (abbreviation: BeB_{q2}), bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminum(III) (abbreviation: BAq), bis(8-quinolinolato)zinc(II) (abbreviation: Znq), bis[2-(2-benzoxazolyl)phenolato]zinc(II) (abbreviation: ZnPBO), and bis[2-(2-benzothiazolyl)phenolato]zinc(II) (abbreviation: ZnBTZ); heterocyclic compounds such as 2-(4-biphenyl)-5-(4-*tert*-butylphenyl)-1,3,4-oxadiazole (abbreviation: PBD), 1,3-bis[5-(*p-tert*-butylphenyl)-1,3,4-oxadiazol-2-yl]benzene (abbreviation: OXD-7), 3-(4-biphenyl)-4-phenyl-5-(4-*tert*-butylphenyl)-1,2,4-triazole (abbreviation: TAZ), 2,2',2''-(1,3,5-benzenetriyl)-tris(1-phenyl-1*H*-benzimidazole) (abbreviation: TPBI), bathophenanthroline (abbreviation: BPhen), bathocuproine (abbreviation: BCP), and 9-[4-(5-phenyl-1,3,4-oxadiazol-2-yl)phenyl]-9*H*-carbazole

(abbreviation: CO11); and aromatic amine compounds such as NPB (or a-NPD), TPD, and BSPB. In addition, condensed polycyclic aromatic compounds such as anthracene derivatives, phenanthrene derivatives, pyrene derivatives, chrysene derivatives, and dibenzo[*g,p*]chrysene derivatives can be used. Specific examples of the condensed polycyclic aromatic compound include 9,10-diphenylanthracene (abbreviation: DPAnth),

5 *N,N*-diphenyl-9-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazol-3-amine (abbreviation: CzA1PA), 4-(10-phenyl-9-anthryl)triphenylamine (abbreviation: DPhPA), 4-(9*H*-carbazol-9-yl)-4'-(10-phenyl-9-anthryl)triphenylamine (abbreviation: YGAPA), *N*,9-diphenyl-*N*-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazol-3-amine (abbreviation:

10 PCAPA),

N,9-diphenyl-*N*-{4-[4-(10-phenyl-9-anthryl)phenyl]phenyl}-9*H*-carbazol-3-amine (abbreviation: PCAPBA),

N,9-diphenyl-*N*-(9,10-diphenyl-2-anthryl)-9*H*-carbazol-3-amine (abbreviation: 2PCAPA), 6,12-dimethoxy-5,11-diphenylchrysene,

15 *N,N,N',N',N'',N''',N'''*-octaphenyldibenzo[*g,p*]chrysene-2,7,10,15-tetramine (abbreviation: DBC1), 9-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazole (abbreviation: CzPA), 3,6-diphenyl-9-[4-(10-phenyl-9-anthryl)phenyl]-9*H*-carbazole (abbreviation: DPCzPA), 9,10-bis(3,5-diphenylphenyl)anthracene (abbreviation: DPPA), 9,10-di(2-naphthyl)anthracene (abbreviation: DNA),

20 2-*tert*-butyl-9,10-di(2-naphthyl)anthracene (abbreviation: t-BuDNA), 9,9'-bianthryl (abbreviation: BANT), 9,9'-(stilbene-3,3'-diyl)diphenanthrene (abbreviation: DPNS), 9,9'-(stilbene-4,4'-diyl)diphenanthrene (abbreviation: DPNS2), and 3,3',3''-(benzene-1,3,5-triyl)tripylene (abbreviation: TPB3). From these materials or other known materials, a material may be selected which has a larger energy gap (if the

25 material emits phosphorescence, larger triplet energy) than an emission center material dispersed in the material and which has a transport property needed for the layer.

[0055]

The electron-transport layer 704 is a layer which contains a substance having a high electron-transport property. For example, a layer containing a metal complex

30 having a quinoline skeleton or a benzoquinoline skeleton, such as tris(8-quinolinolato)aluminum (abbreviation: Alq),

tris(4-methyl-8-quinolinolato)aluminum (abbreviation: Alm_{q3}),
bis(10-hydroxybenzo[*h*]-quinolinato)beryllium (abbreviation: BeB_{q2}), or
bis(2-methyl-8-quinolinolato)(4-phenylphenolato)aluminum (abbreviation: BA_{lq}) can
be used. Alternatively, a metal complex having an oxazole-based or thiazole-based
5 ligand, such as bis[2-(2-hydroxyphenyl)benzoxazolato]zinc (abbreviation: Zn(BOX)₂)
or bis[2-(2-hydroxyphenyl)benzothiazolato]zinc (abbreviation: Zn(BTZ)₂), or the like
can be used. Besides the metal complexes,
2-(4-biphenyl)-5-(4-*tert*-butylphenyl)-1,3,4-oxadiazole (abbreviation: PBD),
1,3-bis[5-(*p-tert*-butylphenyl)-1,3,4-oxadiazol-2-yl]benzene (abbreviation: OXD-7),
10 3-(4-biphenyl)-4-phenyl-5-(4-*tert*-butylphenyl)-1,2,4-triazole (abbreviation: TAZ),
bathophenanthroline (abbreviation: BPhen), bathocuproine (abbreviation: BCP), or the
like can be used. The substances mentioned here are mainly ones that have an electron
mobility of greater than or equal to 10⁻⁶ cm²/V·s. Note that other substances may be
used for the electron-transport layer 704 as long as the substances have higher
15 electron-transport properties than hole-transport properties.

[0056]

Further, the electron-transport layer 704 is not limited to a single layer and may
be a stack of two or more layers containing the substances given above.

[0057]

20 Further, a layer for controlling transport of electron carriers may be provided
between the electron-transport layer 704 and the light-emitting layer 703. Specifically,
the layer for controlling transport of electron carriers is a layer formed by adding a
small amount of a substance having a high electron-trapping property to the material
having a high electron-transport property as described above; by controlling transport of
25 electron carriers with the layer, carrier balance can be adjusted. Such a structure is
very effective in suppressing problems (e.g., a reduction in element lifetime) caused by
a phenomenon in which an electron passes through the light-emitting layer 703.

[0058]

For the electron-injection layer 705, an alkali metal, an alkaline-earth metal, or
30 a compound thereof such as lithium fluoride (LiF), cesium fluoride (CsF), or calcium
fluoride (CaF₂) can be used. For example, a layer of a substance having an
electron-transport property containing an alkali metal, an alkaline earth metal, or a

compound thereof, such as Alq which contains magnesium (Mg), can be used. Note that a layer which contains a substance having an electron-transport property and further contains an alkali metal or an alkaline earth metal is preferably used for the electron-injection layer 705, in which case electron injection from the second electrode 405 can be performed efficiently.

[0059]

The second electrode 405 is provided opposite to the side where light is extracted and is formed using a reflective material. As the reflective material, a metal material such as aluminum, gold, platinum, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, or palladium can be used. Note that the second electrode 405 is also referred to as a reflective electrode.

[0060]

Note that a plurality of the above-mentioned EL layers 403 may be stacked between the first electrode 401 and the second electrode 405 as illustrated in FIG. 4B. In that case, a charge generation layer 803 is preferably provided between a first EL layer 800 and a second EL layer 801 which are stacked. The charge generation layer 803 can be formed by using the above-mentioned composite material. Further, the charge generation layer 803 may have a stacked structure including a layer containing the composite material and a layer containing another material. In that case, as the layer containing another material, a layer containing an electron-donating substance and a substance having a high electron-transport property, a layer formed of a transparent conductive film, or the like can be used. As for a light-emitting element having such a structure, problems such as energy transfer and quenching occur with difficulty, and a light-emitting element which has both high light emission efficiency and long lifetime can be easily obtained owing to expansion in the choice of materials. Moreover, a light-emitting element which provides phosphorescence from one of the EL layers and fluorescence from the other of the EL layers can be readily obtained. Note that this structure can be combined with the above-mentioned structure of the EL layer.

[0061]

The structure illustrated in FIG. 4B is particularly preferable for obtaining white light emission. A light-emitting device and a lighting device with high quality can be manufactured by combining the structure illustrated in FIG. 4A with the structure

illustrated in FIG. 4B.

[0062]

This embodiment can be combined with any of the other embodiments as appropriate.

5 [0063]

(Embodiment 2)

In this embodiment, an example of a structure of a light-emitting device and an example of a method for manufacturing the light-emitting device will be described.

[0064]

10 FIG. 5A is an example of a cross-sectional view of a light-emitting device.

[0065]

In FIG. 5A, a light-emitting portion 101 is formed at a bottom surface of a hemispherical component 103.

[0066]

15 The hemispherical component 103 is provided on the side which corresponds to a light extraction direction and is thus formed using a light-transmitting material. As the light-transmitting material, glass, resin, or the like can be used. Such a material can be formed into a hemispherical shape by using etching, an electron beam, a laser beam, a mold, or the like.

20 [0067]

As the resin, a polyester resin, a polyacrylonitrile resin, a polyimide resin, a polymethyl methacrylate resin, a polycarbonate resin, a polyethersulfone resin, a polyamide resin, a cycloolefin resin, a polystyrene resin, a polyamide imide resin, a polyvinylchloride resin, or the like can be used.

25 [0068]

The light-emitting portion 101 can have the structure illustrated in FIG. 4A or 4B.

[0069]

30 First, a first electrode 401 included in the light-emitting portion 101 is formed over the bottom surface of the hemispherical component 103. The first electrode 401 can be formed to be a single layer or a stacked layer using the above-described material by a sputtering method, a vacuum evaporation method, or the like.

[0070]

By forming the first electrode 401 into an island shape with the use of a mask or the like, the light-emitting portion 101 can be formed at the position illustrated in FIGS. 1A and 1B, FIG. 2A, or FIG. 2B. Note that the first electrode 401 can also be
5 formed into an island shape by a photolithography method.

[0071]

Next, an EL layer 403 included in the light-emitting portion 101 is formed over the first electrode 401. The EL layer 403 can be formed to be a single layer or a stacked layer using the above-described material by a vacuum evaporation method or
10 the like.

[0072]

Next, a second electrode 405 included in the light-emitting portion 101 is formed over the EL layer 403. The second electrode 405 can be formed to be a single layer or a stacked layer using the above-described material by a sputtering method, a
15 vacuum evaporation method, or the like.

[0073]

By being formed so as to cover the first electrode 401, the second electrode 405 can be improved in its function as a reflective electrode. In addition, by being formed so as to cover the EL layer 403 in a light-emitting region (the light-emitting portion 101),
20 the second electrode 405 can be improved in its function as a reflective electrode.

[0074]

Note that the second electrode 405 may be formed into an island shape without forming the first electrode 401 into an island shape. Alternatively, the first electrode 401 and the second electrode 405 may each be formed into an island shape. Further
25 alternatively, the first electrode 401, the EL layer 403, and the second electrode 405 may each be formed into an island shape.

[0075]

Although the light-emitting portion 101 is formed over the component 103 which has been formed into a hemispherical shape in FIG. 5A, the component 103 may
30 be formed into a hemispherical shape after forming the light-emitting portion 101.

[0076]

A wiring, a terminal, and the like connected to each of the electrodes are

provided as appropriate, so that the light-emitting device can be manufactured.

[0077]

FIGS. 5B and 5C are other examples of a cross-sectional view of a light-emitting device.

5 [0078]

In FIGS. 5B and 5C, the hemispherical component 103 includes a plate-like component 501 and a hemispherical component 503.

[0079]

10 Glass is preferably used for a material of the plate-like component 501, and resin is preferably used for a material of the hemispherical component 503. This is because the light-emitting portion 101 can be easily formed over glass and resin can be easily processed into a hemispherical shape. However, an embodiment of the present invention is not limited thereto, and a material for each component can be selected as appropriate.

15 [0080]

In FIG. 5B, the light-emitting portion 101 is formed over one surface of the plate-like component 501. The hemispherical component 503 is formed over the other surface of the plate-like component 501.

[0081]

20 In FIG. 5C, the light-emitting portion 101 is formed over one surface of the plate-like component 501. The hemispherical component 503 is also formed over the one surface of the plate-like component 501 so as to cover the light-emitting portion 101.

[0082]

25 The structure and the manufacturing method of the light-emitting portion 101 are similar to those in FIG. 5A.

[0083]

Note that the spherical component 111 illustrated in FIGS. 3A and 3B may be used. Alternatively, the polygonal sphere-like component 121 illustrated in FIGS. 9A and 9B may be used.

30

[0084]

Also, the hemispherical component (or the spherical component or the

polygonal sphere-like component) may have oblateness or the like caused owing to a slight error in the manufacture. A shape in which total reflection can be reduced as much as possible between the hemispherical component (or the spherical component or the polygonal sphere-like component) and the air can be employed.

5 [0085]

Note that a refractive index of the hemispherical component (or the spherical component or the polygonal sphere-like component) may be greater than or equal to a refractive index of the light-emitting layer included in the light-emitting portion. In such a manner, total reflection can be suppressed when light enters the hemispherical component (or the spherical component or the polygonal sphere-like component). In the case of the structure illustrated in FIG. 5B, light enters the plate-like component and the hemispherical component (or the spherical component or the polygonal sphere-like component) in this order; therefore, a refractive index of the hemispherical component (or the spherical component or the polygonal sphere-like component) may be greater than or equal to a refractive index of the plate-like component, and the refractive index of the plate-like component may be greater than or equal to a refractive index of the light-emitting layer. In this way, when light enters the plate-like component and the hemispherical component (or the spherical component or the polygonal sphere-like component), total reflection can be suppressed.

15 20 [0086]

This embodiment can be combined with any of the other embodiments as appropriate.

[0087]

(Embodiment 3)

25 In this embodiment, an example of a structure of a light-emitting device and an example of a method for manufacturing the light-emitting device will be described.

[0088]

FIG. 6A is an example of a cross-sectional view of a light-emitting device, and FIG. 6B is an example of a plan view of the light-emitting device.

30 [0089]

The light-emitting device illustrated in FIGS. 6A and 6B includes a plurality of light-emitting portions 601 and a plurality of hemispherical components 603 which

overlap with the plurality of light-emitting portions 601. That is, the light-emitting device illustrated in FIGS. 6A and 6B includes a plurality of elements each having a pair of the light-emitting portion 601 and the hemispherical component 603.

[0090]

5 Further, as illustrated in FIG. 6B, the plurality of elements are arranged with a closest packed structure. Seven elements are illustrated in FIG. 6B, but the number of the elements is not limited thereto; it is sufficient as long as the light-emitting device includes a plurality of elements. Alternatively, the plurality of hemispherical components 603 may be integrated to form one component (also referred to as an
10 integrated component). An integrated component includes a plurality of hemispherical portions.

[0091]

Since part of the hemispherical component 603 exists between the adjacent light-emitting portions 601 in FIGS. 6A and 6B, the area of a light-emitting region is
15 about a third as compared to the case where the hemispherical component 603 is not used. When the area of the light-emitting region is reduced to a third, current is also reduced to a third, so that power consumption (i.e., voltage $\times$ current) is reduced to a third.

[0092]

20 However, since light extraction efficiency is improved about three times by using the hemispherical component 603 as described above, total luminous flux remains substantially the same even through the area of the light-emitting region is reduced to a third.

[0093]

25 In addition, in consideration of a relation "energy efficiency (lm/W) = total luminous flux (lm) / consumed power (W)", energy efficiency can be improved about three times in the light-emitting device illustrated in FIGS. 6A and 6B.

[0094]

In addition, a radius of the hemispherical component 603 in FIGS. 6A and 6B
30 is a third the radius b of the hemispherical component 103 in FIGS. 1A and 1B. The elements are arranged with a closest packed structure inside a circle 605 having the

radius b . By arranging the elements as illustrated in FIGS. 6A and 6B, light extraction efficiency equal to that in FIGS. 1A and 1B can be obtained, while the thickness of a cross section of the light-emitting device can be reduced to a third. That is, a thin light-emitting device having high light extraction efficiency can be provided.

5 [0095]

Here, the closest packed structure means a structure in which in a portion 607 where the plurality of hemispherical components are adjacent to each other, a space is not formed as much as possible but also includes a structure in which some spaces are formed owing to a slight error in the manufacture. In addition, it is sufficient as long as the plurality of hemispherical components are arranged with a closest packed structure, and it is not always necessary to define the circle 605 as in FIG. 6B. Further, by using the polygonal sphere-like component 121 illustrated in FIGS. 9A and 9B, since the bottom surface thereof has a polygonal shape, a space between the plurality of polygonal sphere-like components can be smaller.

15 [0096]

Note that the position and the structure of the light-emitting portion 601 are similar to those in FIGS. 1A and 1B, FIGS. 2A and 2B, and FIGS. 3A and 3B.

[0097]

Next, an example of a method for manufacturing a light-emitting device including a plurality of elements will be described.

20 [0098]

FIG. 7A is an example of a cross-sectional view of a light-emitting device.

[0099]

In FIG. 7A, light-emitting portions 601 are formed at bottom surfaces of a plurality of hemispherical components 603 arranged with a closest packed structure. As described above, the plurality of hemispherical components 603 may be integrated to form one component. With an integrated component, the light-emitting device can be easily manufactured.

[0100]

30 The light-emitting portion 601 can have the structure illustrated in FIG. 4A or 4B.

[0101]

First, a first electrode 401 included in the light-emitting portion 601 is formed over the hemispherical component 603. The first electrode 401 can be formed to be a single layer or a stacked layer using the above-described material by a sputtering method, a vacuum evaporation method, or the like.

5 [0102]

By forming the first electrode 401 into an island shape with the use of a mask or the like, the light-emitting portion 601 can be formed at the position illustrated in FIGS. 1A and 1B, FIG. 2A, or FIG. 2B. Note that the first electrode 401 can also be formed into an island shape by a photolithography method.

10 [0103]

Next, an EL layer 403 included in the light-emitting portion 601 is formed over the first electrode 401. The EL layer 403 can be formed to be a single layer or a stacked layer using the above-described material by a vacuum evaporation method or the like.

15 [0104]

Next, a second electrode 405 included in the light-emitting portion 601 is formed over the EL layer 403. The second electrode 405 can be formed to be a single layer or a stacked layer using the above-described material by a sputtering method, a vacuum evaporation method, or the like.

20 [0105]

By being formed so as to cover the first electrode 401, the second electrode 405 can be improved in its function as a reflective electrode. In addition, by being formed so as to cover the EL layer 403 in a light-emitting region (the light-emitting portion 601), the second electrode 405 can be improved in its function as a reflective electrode.

25 [0106]

Note that the second electrode 405 may be formed into an island shape without forming the first electrode 401 into an island shape. Alternatively, the first electrode 401 and the second electrode 405 may each be formed into an island shape. Further alternatively, the first electrode 401, the EL layer 403, and the second electrode 405 may each be formed into an island shape.

30

[0107]

Although the light-emitting portion 601 is formed over the component 603

which has been formed into a hemispherical shape in FIG. 7A, the component 603 may be formed into a hemispherical shape after forming the light-emitting portion 601.

[0108]

A wiring, a terminal, and the like connected to each of the electrodes are provided as appropriate, so that the light-emitting device can be manufactured.

[0109]

FIGS. 7B and 7C are other examples of a cross-sectional view of a light-emitting device.

[0110]

In FIGS. 7B and 7C, the light-emitting device includes a plate-like component 700 and a plurality of hemispherical components 603.

[0111]

Glass is preferably used for a material of the plate-like component 700, and resin is preferably used for a material of the hemispherical component 603. This is because the light-emitting portion 601 can be easily formed over glass and resin can be easily processed into a hemispherical shape. However, an embodiment of the present invention is not limited thereto, and a material for each component can be selected as appropriate.

[0112]

In FIG. 7B, the plurality of light-emitting portions 601 are formed over one surface of the plate-like component 700. The hemispherical components 603 are formed over the other surface of the plate-like component 700 so as to overlap with the plurality of light-emitting portions 601.

[0113]

In FIG. 7C, the plurality of light-emitting portions 601 are formed over one surface of the plate-like component 700. The hemispherical components 603 are also formed over the one surface of the plate-like component 700 so as to cover the plurality of light-emitting portions 601.

[0114]

The structure and the manufacturing method of the light-emitting portion 601 are similar to those in FIG. 7A.

[0115]

Note that the spherical component 111 illustrated in FIGS. 3A and 3B may be used.

[0116]

5 In addition, some of the hemispherical components (or the spherical components or the polygonal sphere-like components) may also have oblateness or the like caused owing to a slight error in the manufacture. For example, the top or the side surface of the component may have a flat surface. A shape in which total reflection can be reduced as much as possible between the hemispherical component (or the spherical component or the polygonal sphere-like component) and the air can be employed.

[0117]

15 Note that a refractive index of the hemispherical component (or the spherical component or the polygonal sphere-like component) may be greater than or equal to a refractive index of the light-emitting layer included in the light-emitting portion. In such a manner, total reflection can be suppressed when light enters the hemispherical component (or the spherical component or the polygonal sphere-like component). In the case of the structure illustrated in FIG. 7B, light enters the plate-like component and the hemispherical component (or the spherical component or the polygonal sphere-like component) in this order; therefore, a refractive index of the hemispherical component (or the spherical component or the polygonal sphere-like component) may be greater than or equal to a refractive index of the plate-like component, and the refractive index of the plate-like component may be greater than or equal to a refractive index of the light-emitting layer. In this way, when light enters the plate-like component and the hemispherical component (or the spherical component or the polygonal sphere-like component), total reflection can be suppressed.

[0118]

This embodiment can be combined with any of the other embodiments as appropriate.

[0119]

30 (Embodiment 4)

In this embodiment, examples of an electronic device will be described.

[0120]

FIG. 8A illustrates an example in which the light-emitting device according to the present invention is used for a desk lamp which is a lighting device. The desk lamp includes a housing 1001 and a light source 1003. The light-emitting device according to the present invention is used as the light source 1003.

5 [0121]

FIG. 8B illustrates an example in which the light-emitting device according to the present invention is used for an indoor lighting device. The lighting device includes a housing 1101 and a light source 1103. The light-emitting device according to the present invention is used as the light source 1103.

10 [0122]

This embodiment can be combined with any of the other embodiments as appropriate.

EXPLANATION OF REFERENCE

15 [0123]

101: light-emitting portion, 103: hemispherical component, 105: external portion, 107: end portion, 108: bottom surface, 109: circle, 111: spherical component, 113: surface, 121: polygonal sphere-like component, 123: bottom surface, 125: circle, 401: first electrode, 403: EL layer, 405: second electrode, 501: plate-like component, 503: hemispherical component, 601: light-emitting portion, 603: hemispherical component, 605: circle, 607: portion, 700: plate-like component, 701: hole-injection layer, 702: hole-transport layer, 703: light-emitting layer, 704: electron-transport layer, 705: electron-injection layer, 800: EL layer, 801: EL layer, 803: charge generation layer, 1001: housing, 1003: light source, 1101: housing, 1103: light source

25

[0124]

This application is based on Japanese Patent Application serial no. 2010-166961 filed with Japan Patent Office on July 26, 2010, the entire contents of which are hereby incorporated by reference.

CLAIMS

1. A light-emitting device comprising:

a plurality of light-emitting portions; and

5 a plurality of hemispherical components provided so as to overlap with their respective light-emitting portions,

wherein the plurality of hemispherical components are provided so as not to form a space therebetween in a region where the plurality of hemispherical components are adjacent to each other.

10

2. A light-emitting device comprising:

a plurality of light-emitting portions; and

a plurality of hemispherical components provided so as to overlap with their respective light-emitting portions,

15 wherein the plurality of hemispherical components are arranged with a closest packed structure.

3. The light-emitting device according to claim 1 or 2, further comprising:

a plate-like component,

20 wherein the plurality of light-emitting portions are provided over one surface of the plate-like component, and

wherein the plurality of hemispherical components are provided over the other surface of the plate-like component.

25 4. A light-emitting device comprising:

a light-emitting portion; and

a hemispherical component provided so as to overlap with the light-emitting portion,

30 wherein a refractive index of the hemispherical component is n and a radius of a bottom surface of the hemispherical component is b , and

wherein the light-emitting portion is provided inside a circle whose radius r from a center of the bottom surface of the hemispherical component is b/n .

5. The light-emitting device according to claim 4, further comprising:

a plate-like component,

wherein the light-emitting portion is provided over one surface of the plate-like

5 component, and

wherein the hemispherical component is provided over the other surface of the plate-like component.

6. The light-emitting device according to claim 5,

10 wherein the plate-like component comprises glass, and

wherein the hemispherical component comprises resin.

7. A light-emitting device comprising:

a plurality of light-emitting portions; and

15 a plurality of hemispherical components provided so as to overlap with their respective light-emitting portions,

wherein a refractive index of each of the plurality of hemispherical components is n and a radius of a bottom surface of each of the plurality of hemispherical components is b , and

20 wherein each of the plurality of light-emitting portions is provided inside a circle whose radius r from a center of the bottom surface of each of the plurality of hemispherical components is b/n .

8. A light-emitting device comprising:

25 a plate-like component;

a plurality of light-emitting portions provided over one surface of the plate-like component; and

a plurality of hemispherical components provided over the other surface of the plate-like component so as to overlap with their respective light-emitting portions with
30 the plate-like component interposed therebetween,

wherein a refractive index of each of the plurality of hemispherical components is n and a radius of a bottom surface of each of the plurality of

hemispherical components is b , and

wherein each of the plurality of light-emitting portions is provided inside a circle whose radius r from a center of the bottom surface of each of the plurality of hemispherical components is b/n .

5

9. The light-emitting device according to claim 3 or 8,
wherein the plate-like component comprises glass, and
wherein each of the plurality of hemispherical components comprises resin.

10

10. The light-emitting device according to claim 7 or 8, wherein the plurality of hemispherical components are arranged with a closest packed structure.

11. A lighting device comprising the light-emitting device according to any one of claims 1, 2, 4, 7, and 8.

15

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FIG. 1A

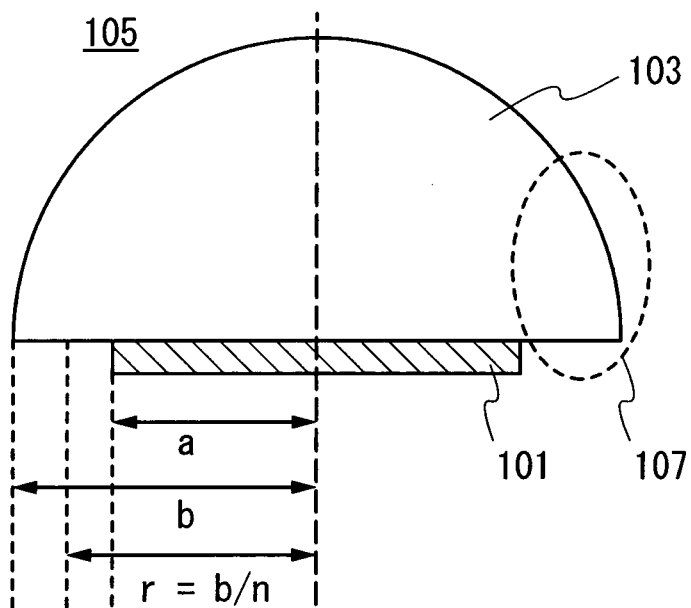


FIG. 1B

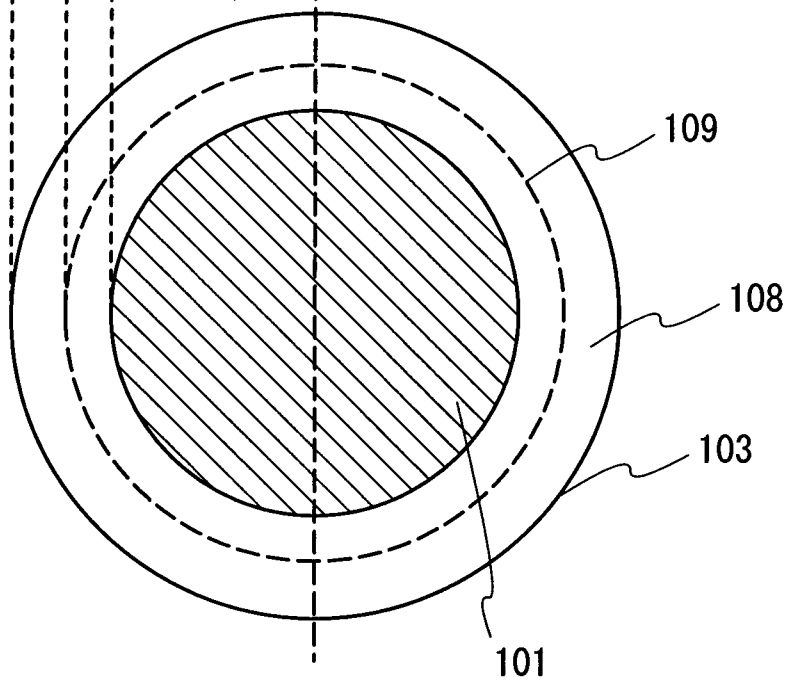


FIG. 2A

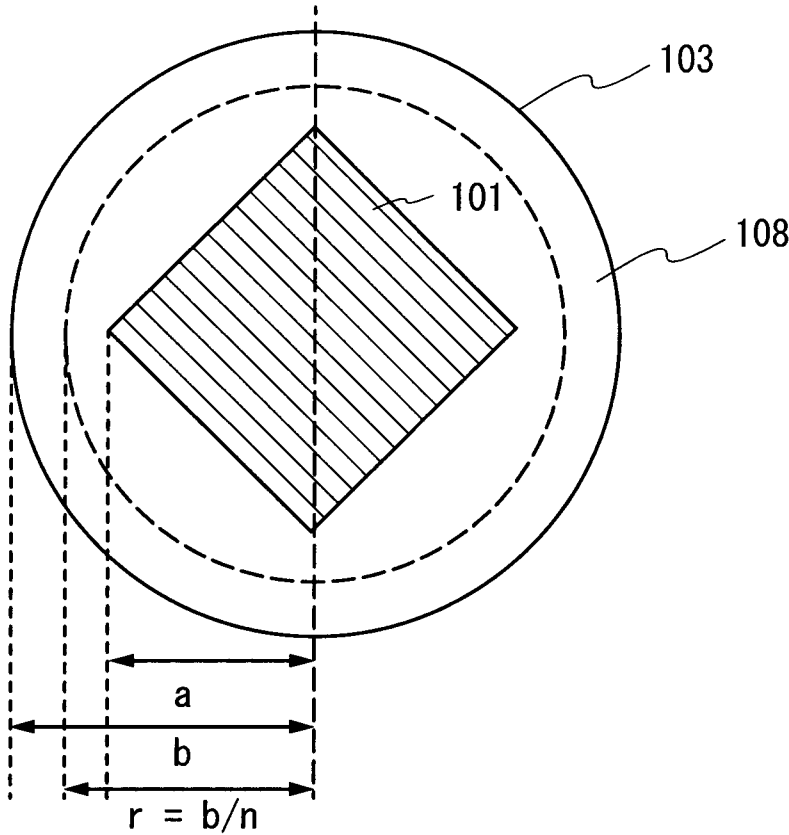
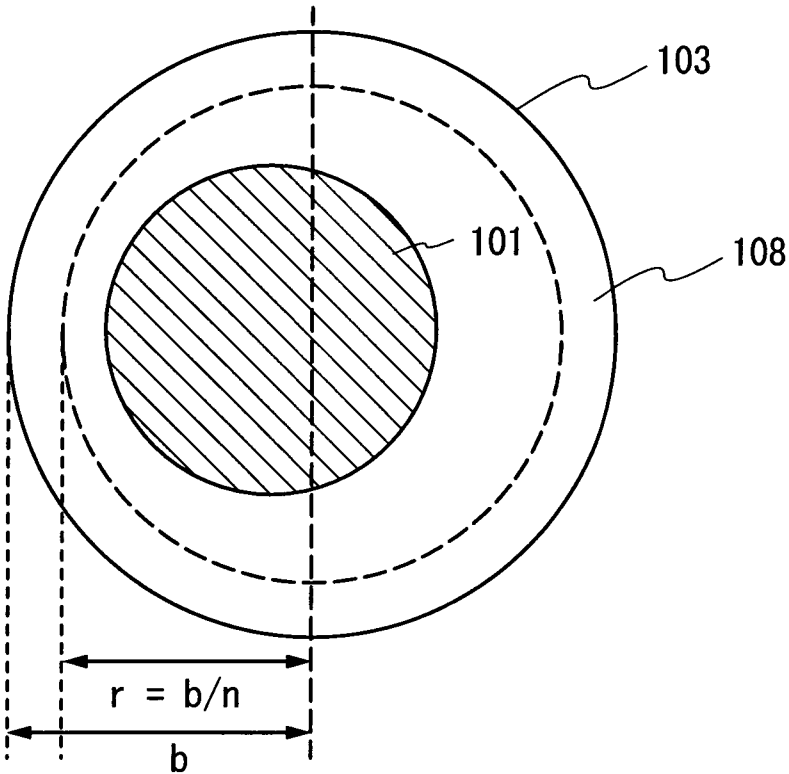


FIG. 2B



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FIG. 3A

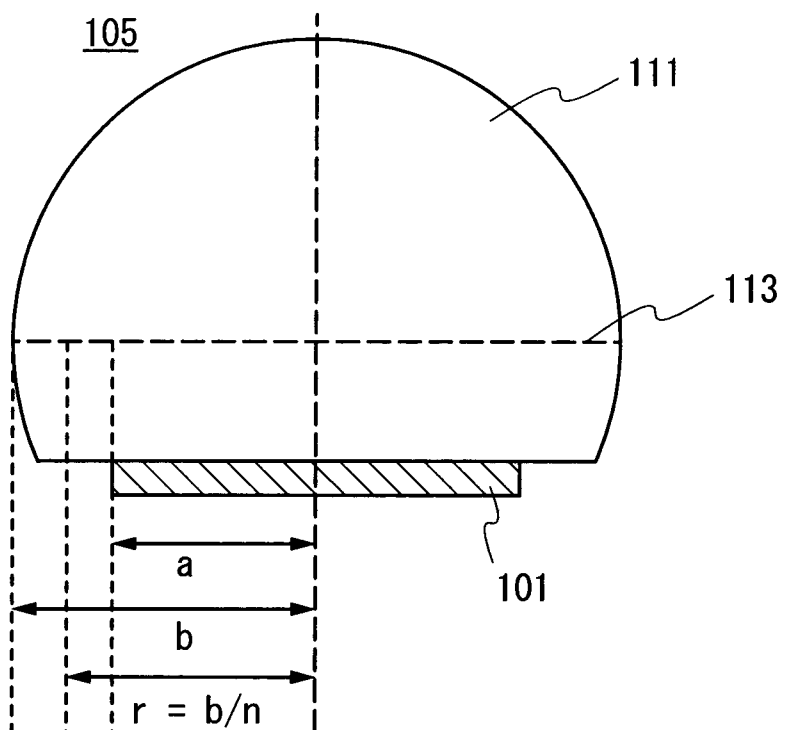
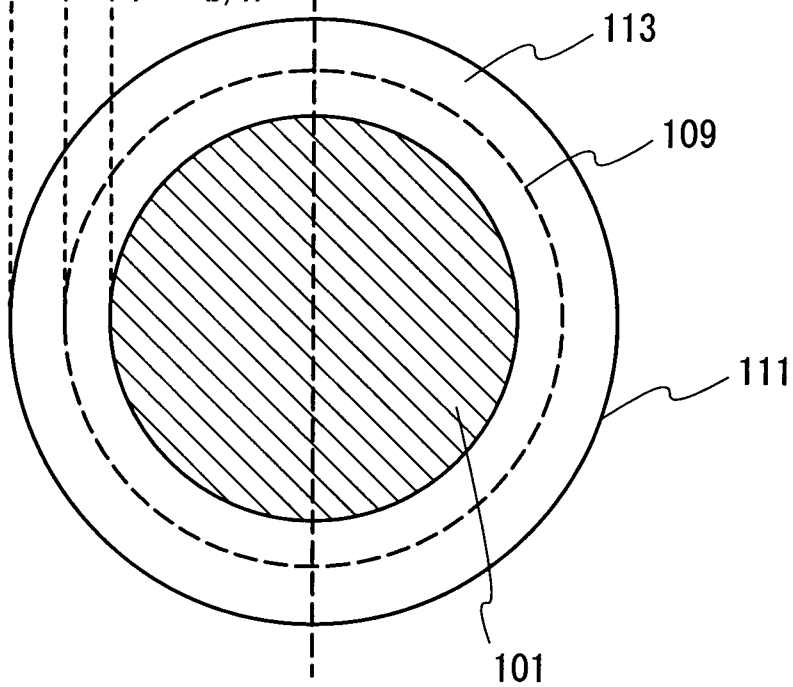


FIG. 3B



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FIG. 4A

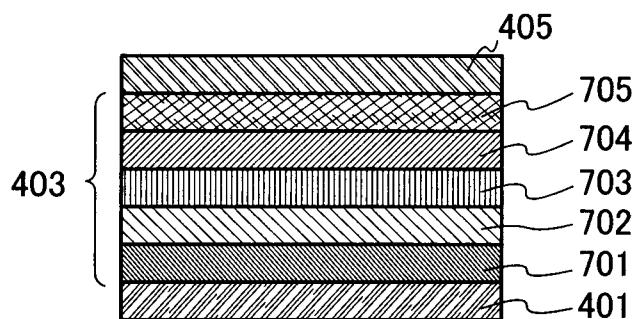
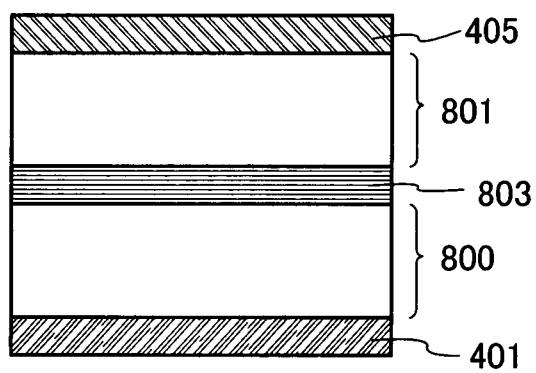


FIG. 4B



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FIG. 5A

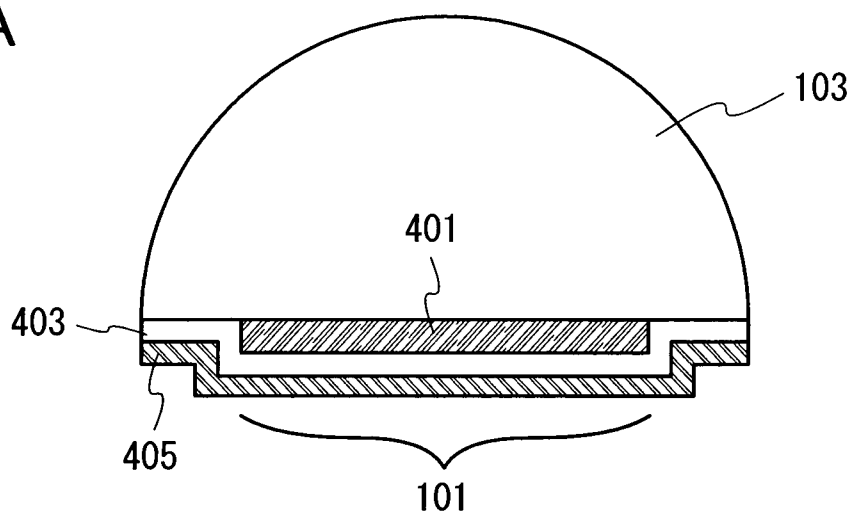


FIG. 5B

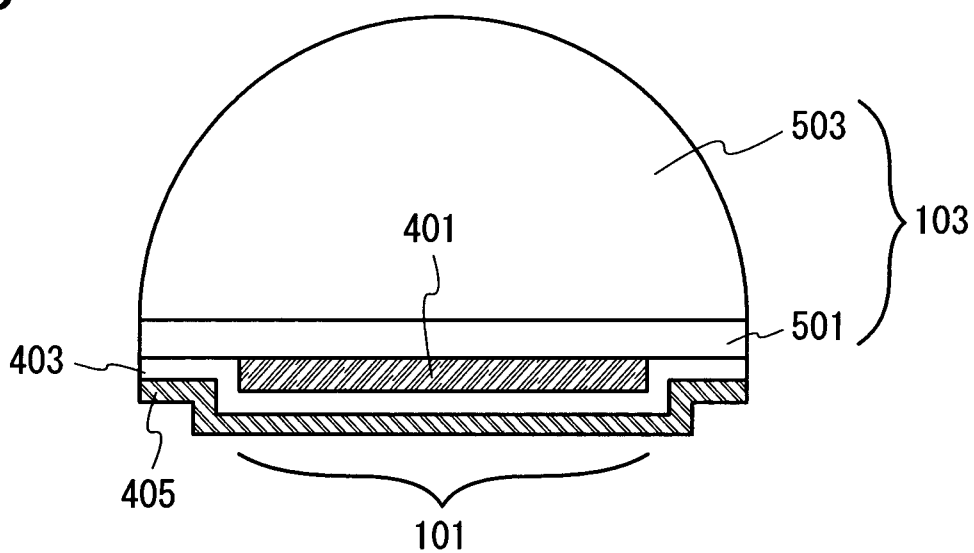


FIG. 5C

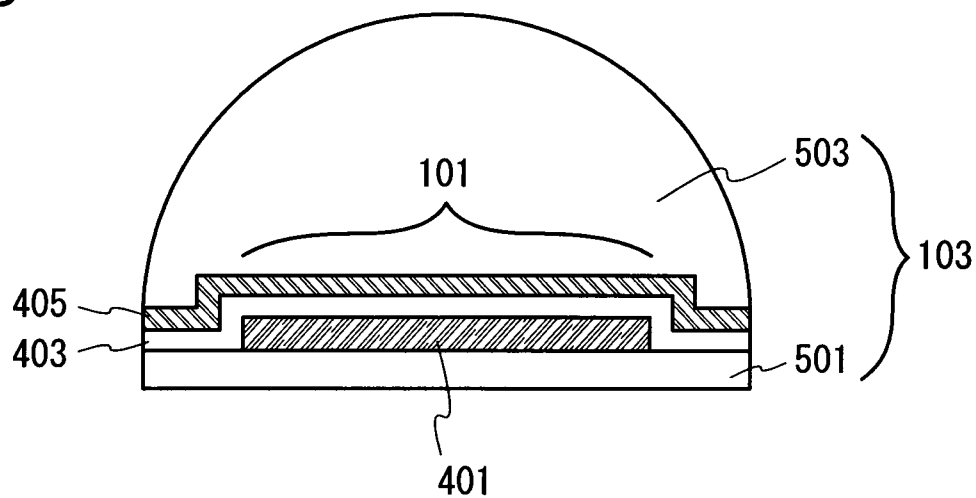


FIG. 6A

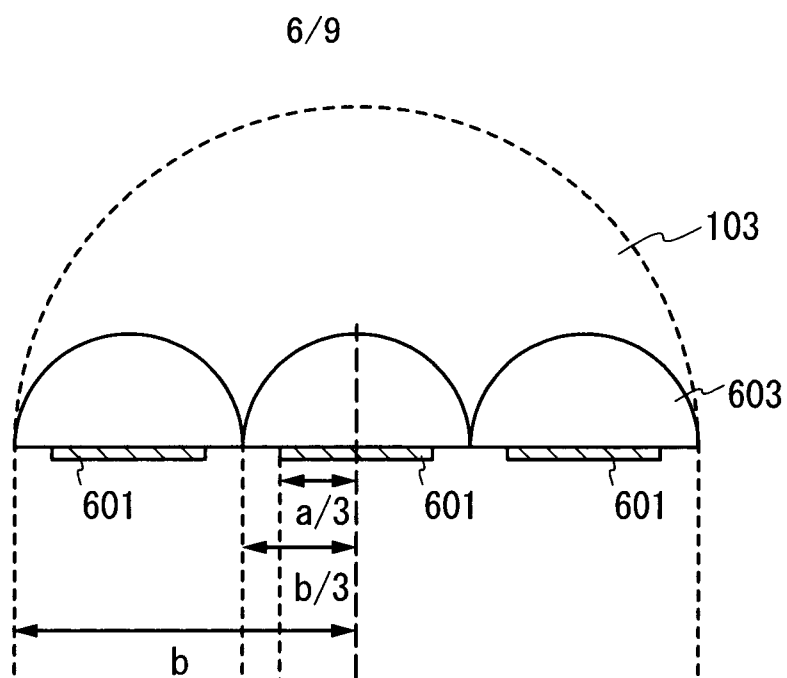
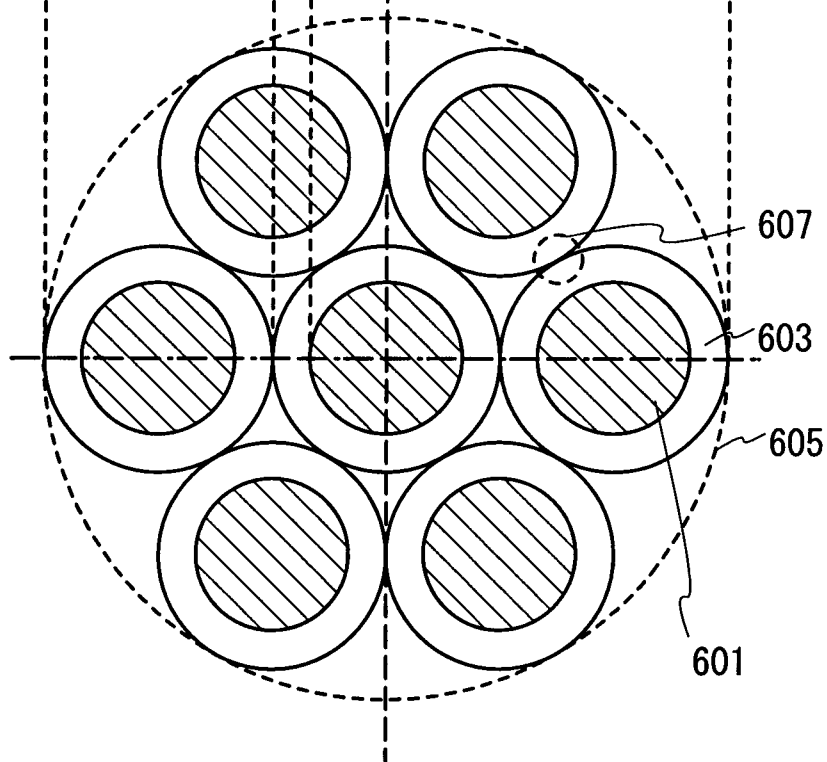


FIG. 6B



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FIG. 7A

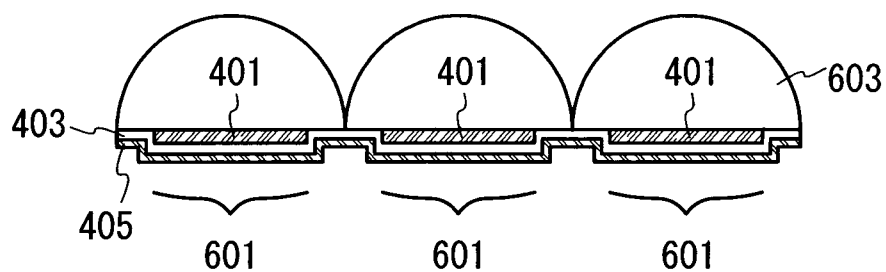


FIG. 7B

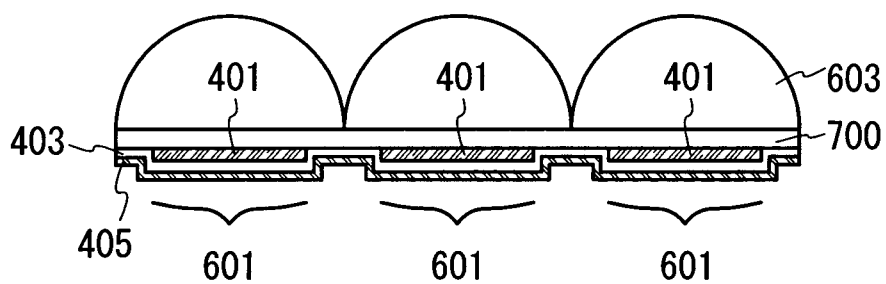


FIG. 7C

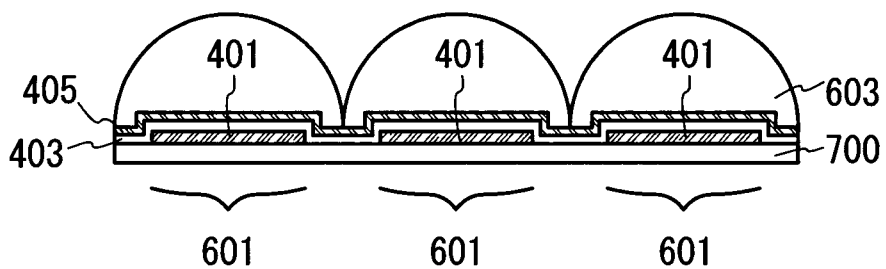


FIG. 8A

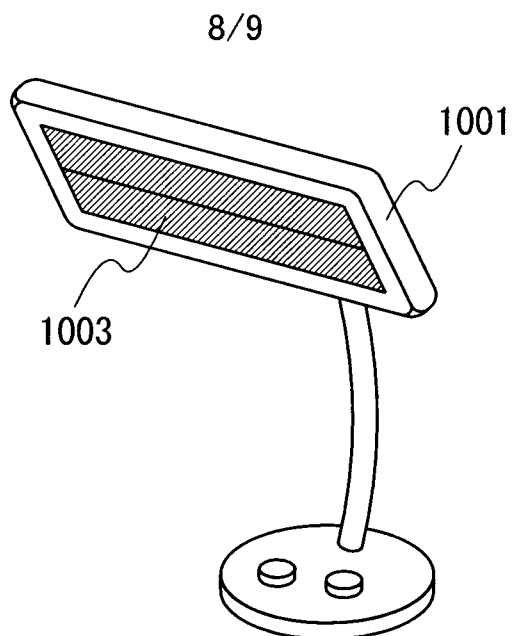
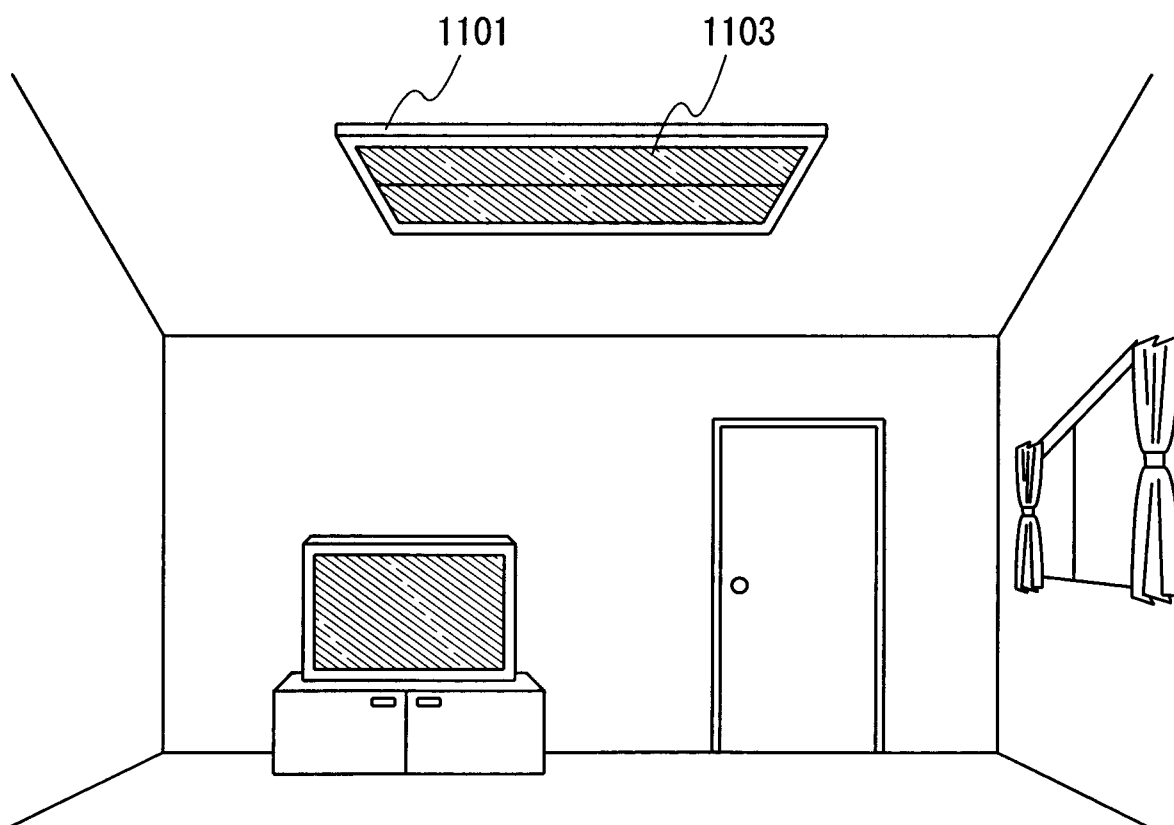


FIG. 8B



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FIG. 9A

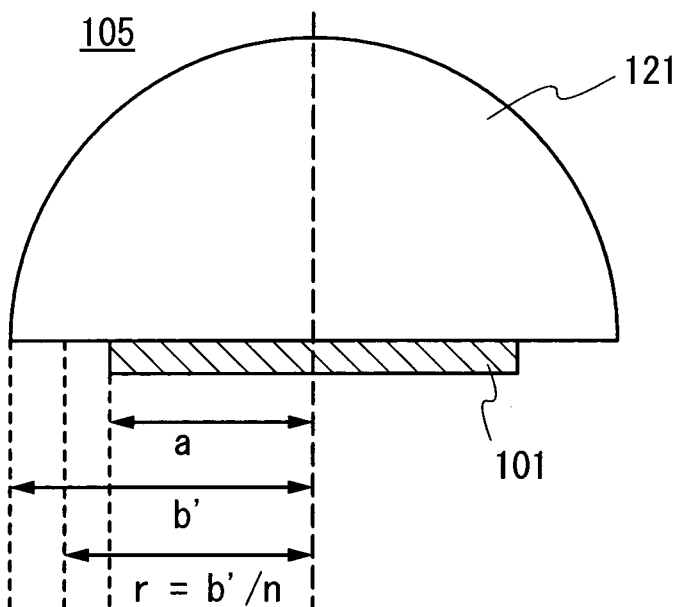
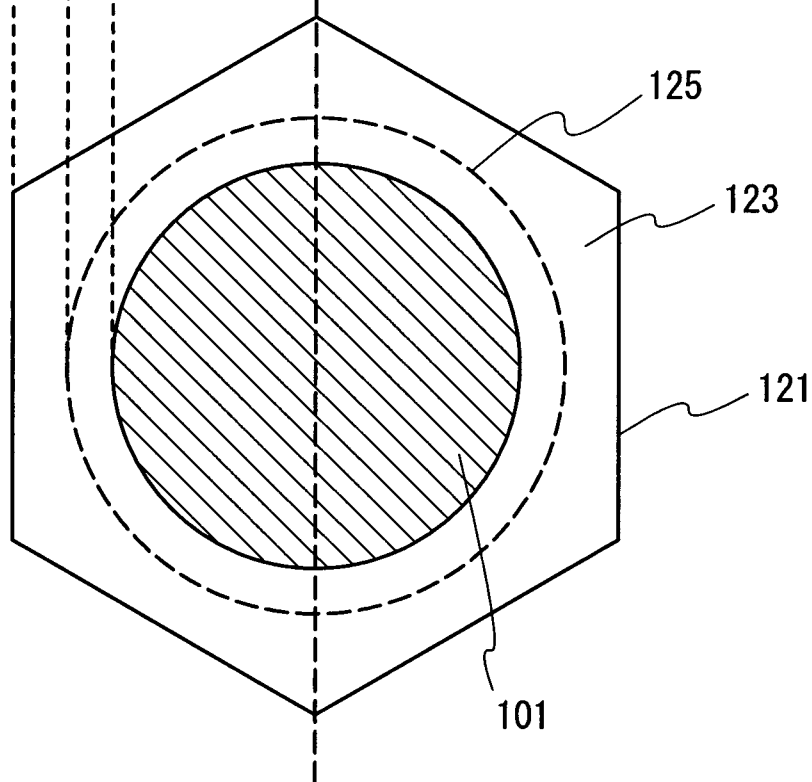


FIG. 9B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/066504

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H05B33/02 (2006.01) i, H01L51/50 (2006.01) i, F21Y105/00 (2006.01) n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H05B33/02, H01L51/50, F21Y105/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2011
 Registered utility model specifications of Japan 1996-2011
 Published registered utility model applications of Japan 1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2003-150082 A	1-3, 11
Y	(MATSHUSHITA DENKI SANNGYO KABUSHIKI KAISHA) 2003.05.21, [0110], [0120], [0121], [0145], [0156], [1305], FIG.8, 9, 17 (Family:none)	4-10
Y	JP 2009-051200 A (SEIKO EPSON KABUSHIKI KAISHA) 2009.03.12, [0018], [0031], [0039], FIG.1, 5 (Family:none)	4-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

23.08.2011

Date of mailing of the international search report

06.09.2011

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/066504

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2773720 B1 (NIHON DENKI KABUSHIKI KAISHA) 1998.04.24, FIG.1 (Family:none)	1-11
A	JP 2003-317931 A (CANON KABUSHIKI KAISHA) 2003.11.07, [0009], [0026], FIG.14 (Family:none)	1-11