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Light-emitting device and method for manufacturing the same

Abstract

A method for manufacturing a light-emitting device including a light-emitting element and a quantum dot configured to convert light emitted by the light-emitting element includes: preparing a base and a light-emitting element disposed on the base; forming a light reflective member surrounding the light-emitting element and including an inner surface and a top surface; forming a first barrier layer continuously covering a surface of the light-emitting element and the inner surface and the top surface of the light reflective member; forming a wavelength conversion member including the quantum dot in a region surrounded by the inner surface of the light reflective member, the light-emitting element being embedded in the wavelength conversion member; and covering, with a second barrier layer, a top surface of the wavelength conversion member and at least a portion of the first barrier layer on the top surface of the light reflective member.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims priority to Japanese Patent Application No. 2022-017177, filed on Feb. 7, 2022, and Japanese Patent Application No. 2021-208354, filed on Dec. 22, 2021, the contents of which are incorporated by references in their entireties.

BACKGROUND

(2) The present disclosure relates to a light-emitting device and a method for manufacturing the light-emitting device.

(3) A known light-emitting device that emits white light includes a light-emitting element that emits blue light, a green phosphor that emits green light (or a yellow green phosphor that emits yellow green light) when absorbing a part of the blue light emitted by the light-emitting element, and a red phosphor that emits red light when absorbing a part of the blue light emitted by the light-emitting element.

(4) In a recently developed light-emitting device, all or some of phosphors are replaced by quantum dots (QDs) (see, for example, JP2007-273498A).

(5) Quantum dots have a problem of degradation due to exposure to oxygen and moisture over time and a resulting decrease in wavelength conversion performance. An object of the present disclosure is to provide a light-emitting device that suppresses the degradation of quantum dots, and a method for manufacturing the light-emitting device.

SUMMARY

(6) A method for manufacturing a light-emitting device according to an embodiment of the present disclosure is a method for manufacturing a light-emitting device including a light-emitting element and a quantum dot configured to convert light emitted by the light-emitting element, the method including: preparing a base and a light-emitting element disposed on the base; forming a light reflective member surrounding the light-emitting element and including an inner surface and a top surface; forming a first barrier layer continuously covering a surface of the light-emitting element and the inner surface of the light reflective member and the top surface of the light reflective member; forming a wavelength conversion member including the quantum dot in a region surrounded by the inner surface of the light reflective member, the light-emitting element being embedded in the wavelength conversion member; and covering, with a second barrier layer, a top surface of the wavelength conversion member and at least a portion of the first barrier layer on the top surface of the light reflective member.

(7) In addition, a light-emitting device according to another embodiment of the present disclosure includes: a base; a light-emitting element disposed on the base; a light reflective member surrounding the light-emitting element and including an inner surface and a top surface; a first barrier layer continuously covering a surface of the light-emitting element and the inner surface of the light reflective member and the top surface of the light reflective member; a wavelength conversion member including a quantum dot and disposed in a region surrounded by the inner surface of the light reflective member; and a second barrier layer covering a top surface of the wavelength conversion member and at least a portion of the first barrier layer on the top surface of the light reflective member.

(8) According to an embodiment of the present disclosure, it is possible to provide a light-emitting device that suppresses the degradation of quantum dots, and a method for manufacturing the light-emitting device.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a cross-sectional view of an exemplary light-emitting device according to an embodiment of the present disclosure.

(2) FIG. **2** is an enlarged cross-sectional view of the light-emitting device of FIG. **1**.
(3) FIG. **3** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(4) FIG. **4** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(5) FIG. **5** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(6) FIG. **6** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(7) FIG. **7** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(8) FIG. **8** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(9) FIG. **9** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the embodiment of the present disclosure.
(10) FIG. **10** is a cross-sectional view illustrating an exemplary light-emitting device according to a first modification.
(11) FIG. **11** is a cross-sectional view illustrating an example in which a color filter is provided in the light-emitting device of FIG. **10**.
(12) FIG. **12** is a cross-sectional view illustrating an exemplary manufacturing process of a light-emitting device according to a second modification.
(13) FIG. **13** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the second modification.
(14) FIG. **14** is a cross-sectional view illustrating an exemplary manufacturing process of the light-emitting device according to the second modification.
(15) FIG. **15** is a cross-sectional view illustrating an exemplary light-emitting device according to a third modification.
(16) FIG. **16** is a cross-sectional view illustrating an exemplary light-emitting device according to a fourth modification.
(17) FIG. **17** is a cross-sectional view illustrating an exemplary manufacturing process of an exemplary light-emitting device according to another embodiment of the present disclosure.
(18) FIG. **18** is a cross-sectional view illustrating an exemplary manufacturing process of the exemplary light-emitting device according to the other embodiment of the present disclosure.
(19) FIG. **19** is a graph illustrating a spectral radiation luminance of a red quantum dot of an exemplary light-emitting device according to the present disclosure.
(20) FIG. **20** is a graph illustrating a spectral radiation luminance of a green quantum dot of the exemplary light-emitting device according to the present disclosure.
(21) FIG. **21** is a graph illustrating a spectral radiation luminance of a red quantum dot of a light-emitting device according to a comparative example.
(22) FIG. **22** is a graph illustrating a spectral radiation luminance of a green quantum dot of the light-emitting device according to the comparative example.
(23) FIG. **23** is an enlarged cross-sectional view of a main part of an exemplary image display device serving as an active matrix display.
(24) FIG. **24** is a schematic block diagram of an exemplary image display device.
(25) FIG. **25** is a schematic perspective view illustrating an exemplary image display device according to a modification.

DESCRIPTION OF EMBODIMENTS

(26) The present invention is described below with reference to the accompanying drawings. Note that in the following description, the terms indicating specific directions and positions (such as “upper”, “lower”, and other terms including the terms) are used as necessary, but such terms are

used for the purpose of facilitating the understanding of the invention with reference to the accompanying drawings, and the technical scope of the present invention is not limited by the meaning of the terms. In addition, the portions denoted with the same symbol in multiple drawings are the same or equivalent portions or members.
(27) Further, the embodiments described below are specific examples of the technical idea of the present invention, and the present invention is not limited to the following description. In addition, the dimensions, materials, shapes, relative positions and the like of the components described below are intended for exemplification, not for limiting the scope of the present invention unless otherwise specified. In addition, the content described in one embodiment or example is applicable to other embodiments and examples. In addition, the size, positional relationships and the like of the members illustrated in the drawings may be exaggerated for clarity of explanation.
EMBODIMENTS
(28) FIG. **1** is a cross-sectional view illustrating an exemplary light-emitting device according to an exemplary embodiment of the present disclosure. A light-emitting device **100** illustrated in this drawing includes a base **10**, a light-emitting element **20** disposed on the base **10**, a light reflective member **30** that surrounds light-emitting element **20**, and a wavelength conversion member **40**.
(29) Base **10**
(30) The base **10** comprises a support substrate for placing the light-emitting element **20**, the light reflective member **30** and the like on the top surface. A rigid substrate represented by a ceramic substrate, a SiC substrate and the like, a flexible substrate represented by a print wiring substrate, and the like may be used for the base **10**. It is preferable to use a print wiring substrate because it enables production of a flexible light-emitting device.
(31) Light-Emitting Element **20**
(32) The light-emitting element **20** is placed on the base **10**. In the example illustrated in FIG. **1**, the light-emitting element **20** is disposed on the top surface of the light reflective member **30** provided on the base **10**. While one light-emitting element **20** is provided in this example, a plurality of light-emitting elements may be disposed.
(33) A light-emitting element such as an LED and an LD may be suitably used for the light-emitting element **20**. For the LED, a semiconductor laminate including a light emission member (hereinafter also referred to simply as "semiconductor laminate") may be used. The semiconductor laminate has light emission properties, and, for such a semiconductor laminate, a laminate obtained by stacking a plurality of semiconductor layers of ZnS, SiC, GaN, GaP, InN, AlN, ZnSe, GaAsP, GaAlAs, InGaN, GaAIN, AlInGaP, AlInGaN and the like on the base by liquid phase deposition, a HVPE method or a MOCVD method, and forming a light-emitting layer in any of the semiconductor layers is used. By selecting the material of the semiconductor layer and its mixing rate, various light-emission wavelengths of the light emission member can be selected in a range from ultraviolet light to infrared light. In particular, a display device that can be suitably used in the open air requires a semiconductor laminate that can emit high luminance light. In view of this, it is preferable to select a nitride semiconductor for the material of the green and blue light emission members that emit high luminance light. For example, as the material of the light emission member, InxAlyGa.sub.1-X-YN (0≤X≤1, 0≤Y≤1, X+Y≤1) and the like may be used. The light-emitting element **20** may have a size in a range from 1 μm to 2000 μm, preferably, from 1 μm to 50 μm.
(34) Light Reflective Member **30**
(35) The light reflective member **30** is a member for reflecting light emitted by the light-emitting element **20**. Such a light reflective member **30** surrounds the light-emitting element **20**. By providing the light reflective member **30** around the light-emitting element **20**, leakage of the light of the light-emitting element **20** in unintended directions is suppressed. The light reflective member **30** can comprise or be composed of resin containing the light reflective material such as TiO.sub.2 and the like.

(36) The light reflective member **30** includes an inner surface and a top surface. In the example illustrated in FIG. **1**, the region surrounded by the inner surface of the light reflective member **30** is defined as a recess **33**. A metal layer **36** is formed in the bottom surface of the recess **33**, and the light-emitting element **20** is disposed on the metal layer **36**. The light reflective member **30** comprises a flat primary member **31** provided on the top surface of the base **10**, and a side wall member **32** provided on the primary member **31**. The region surrounded by the side wall member **32** on the primary member **31** is the recess **33**. Note that the primary member **31** and the side wall member **32** may be provided as separate members, or may be integrally formed. In the case in which they are provided as separate members, the side wall member **32** may be formed of a white dry film or the like (details are described later).

(37) The metal layer **36** is connected with an electrode formed in the light-emitting element **20** through solder and the like. In addition, the metal layer **36** is connected with an external electrode, and the driving power is supplied to the light-emitting element **20** from the external electrode through the metal layer **36**. Cu, Au and the like can be used for such a metal layer **36**.

(38) Wavelength Conversion Member **40**

(39) The wavelength conversion member **40** receives light emitted by the light-emitting element **20** and converts the wavelength of the light into different wavelengths. The wavelength conversion member **40** includes a wavelength conversion material such as quantum dots (QD) and phosphors. The quantum dots convert the light into different wavelengths in accordance with their particle sizes. For such quantum dots, quantum dots with an average particle diameter of 10 nm or less, preferably an average particle diameter in a range from 4 nm to 10 nm, are used. In addition, multiple types of quantum dots with different particle sizes may be mixed. In the example illustrated in FIG. **2**, two types of quantum dots, a first quantum dot **41** and a second quantum dot **42**, are mixed. Here, a red quantum dot with an average particle diameter of 9 nm that receives blue light of the light-emitting element and converts the received blue light into red light is used as the first quantum dot **41**, and a green quantum dot with an average particle diameter of 5 nm that receives blue light of the light-emitting element and converts the received blue light into green light is used as the second quantum dot **42**. The average particle diameter can be measured by using the scanning transmission electron microscopy HD-2000 available from Hitachi High-Tech Corporation, and the like.

(40) Specific examples of the quantum dots include CdSe and InP, which are phosphors with a perovskite structure, or semiconductor nano particles with a chalcopyrite structure. Note that $AgInSe_2$ is classified as a semiconductor nano particle with a chalcopyrite structure. The phosphors with a perovskite structure are expressed by the following expression.

$$(M1A1)_aM2_bX_c$$

(41) In the above expression, A1 represents one or more organic cations selected from the group consisting of ammonium, formamidinium, guanidium, imidazolium, pyridinium, pyrrolidinium and protonated thiourea, M1 represents one or more alkali metal cations selected from the group consisting of Cs, Rb, K, Na and Li, M2 represents one or more metal cations selected from the group consisting of Ge, Sn, Pb, Sb, Te and Bi, X represents one or more anions selected from the group consisting of chloride ion, bromide ion, iodide ion, cyanide ion, thiocyanate ion, isothiocyanate ion and sulfide ion, a represents 1 to 4, b represents 1 to 2, and c represents 3 to 9.

(42) In addition, the semiconductor nano particles that have a chalcopyrite structure and emit green light are expressed by the following expression, for example.

$$(Ag_pM^a_{(1-p)})_qIn_rGa_{(1-r)}S_{(q+3)/2}$$

(43) Here, p, q and r meet $0<p\leq1$, $0.20<q\leq1.2$, and $0<r<1$. M^a represents alkali metal.

(44) The semiconductor nano particles (first semiconductor) expressed by the above-described expression may have a second semiconductor including Ga and S disposed on the surface. When irradiated with light of a wavelength of 365 nm, the semiconductor nano particle exhibits band edge emission with a light emission peak wavelength in a wavelength range from 475 nm to 560

nm. The ratio (In/(In+Ga)) of the number of In atoms with respect to the total number of In and Ga atoms in the first semiconductor is, for example, in a range of equal to or greater than 0.01 and smaller than 1, preferably in a range from 0.1 to 0.99. In addition, the ratio (Ag/(In+Ga)) of the number of Ag atoms with respect to the total number of In and Ga atoms is, for example, in a range from 0.3 to 1.2, preferably in a range from 0.5 to 1.1. The ratio (S/(Ag+In+Ga)) of the number of S atoms with respect to the total number of Ag, In and Ga atoms is, for example, in a range from 0.8 to 1.5, preferably in a range from 0.9 to 1.2. The half width in the light emission spectrum of the semiconductor nano particle is, for example, 45 nm or less, preferably 40 nm or less or 35 nm or less. Preferably, the lower limit of the half width is, for example, 15 nm or greater. In addition, preferably, the lifetime of the light emission of the main component (band edge emission) is 200 ns or less.

(45) Further, the semiconductor nano particles with a chalcopyrite structure that emit red light are expressed by the following expression, for example.

(Ag.sub.pCu.sub.(1-p)).sub.qIn.sub.rGa.sub.(1-r)S.sub.(q+3)/2

(46) Here, p, q and r meet 0<p<1, 0.20<q≤1.2, and 0<<1.

(47) The semiconductor nano particles (first semiconductor) expressed by the above-described expression may have a second semiconductor including Ga and S disposed on the surface. When irradiated with light of a wavelength of 365 nm, the semiconductor nano particle exhibits band edge emission having a light emission peak wavelength in a wavelength range from 600 nm to 680 nm. The ratio (Cu/(Cu+Ag)) of the number of Cu moles with respect to the total number of Cu and Ag moles in the composition of the first semiconductor is in a range of equal to or greater than 0.01 and smaller than 1.0, preferably in a range from 0.03 to 0.99, more preferably in a range from 0.05 to 0.5. In addition, for example, the ratio ((Cu+Ag)/(Cu+Ag+In+Ga)) of the total number of Cu and Ag moles with respect to the total number of Cu, Ag, In and Ga moles in the composition of the first semiconductor is in a range of equal to or greater than 0.1 and smaller than 1.0, preferably in a range from 0.2 to 0.99. The ratio (In/(In+Ga)) of the number of In atoms with respect to the total number of In and Ga atoms in the first semiconductor is, for example, in a range of equal to or greater than 0.01 and smaller than 1, preferably in a range from 0.1 to 0.99. In addition, the ratio (Ag/(In+Ga)) of the number of Ag atoms with respect to the total number of In and Ga atoms is, for example, in a range from 0.1 to 1.2, preferably in a range from 0.2 to 1.1. In addition, the ratio ((Ag+Cu)/(In+Ga)) of the total number of Ag and Cu atoms with respect to the total number of In and Ga atoms is, for example, in a range from 0.1 to 1.2, preferably in a range from 0.2 to 1.0. The ratio (S/(Ag+In+Ga)) of the number of S atoms with respect to the total number of Ag, In and Ga atoms is, for example, in a range from 0.8 to 1.5, preferably in a range from 0.9 to 1.2. The ratio (S/(Ag+Cu+In +Ga)) of the number of S atoms with respect to the total number of Ag, Cu, In and Ga atoms is, for example, in a range from 0.8 to 1.5, preferably in a range from 0.9 to 1.2. In addition, the half width in the light emission spectrum of the semiconductor nano particle is, for example, 70 nm or less, preferably 65 nm or less or 60 nm or less. Preferably, the lower limit of the half width is, for example, 15 nm or greater. In addition, preferably, the lifetime of the light emission of the main component (band edge emission) is 200 ns or less.

(48) The wavelength conversion member **40** is disposed at least on the light-emitting element **20** in a region surrounded by the inner surface of the light reflective member **30**. In the example illustrated in FIG. **1**, the light-emitting element **20** is embedded by filling the wavelength conversion member **40** in the recess **33** of the light reflective member **30**. In addition, preferably, the top surface of the wavelength conversion member **40** and the top surface of the light reflective member **30** are formed on substantially the same plane. In this manner, in providing a color filter **50** on the top surface of the wavelength conversion member **40**, the film thickness can be maintained at a constant thickness, and the advantage of uniform filter effect can be achieved. In addition, since the second barrier layer described later can be provided in a flat manner, the gas barrier property is improved.

(49) First Barrier Layer **34**
(50) Further, the light-emitting device **100** includes a first barrier layer **34** and a second barrier layer **35** that cover a part or all of the surface of the light-emitting device **100**. The first barrier layer **34** comprises a member with a gas barrier property. In addition, a moisture barrier property may be provided. The first barrier layer **34** continuously covers the surface of the light-emitting element **20** and the inner surface and top surface of the light reflective member **30**. In this manner, the first barrier layer **34** suppresses degradation of the quantum dots included in the wavelength conversion member **40** due to entry of the oxygen and moisture included in the outside air into the wavelength conversion member **40** through the light reflective member **30**. Preferably, the oxygen permeability of the first barrier layer **34** is 1×10.sup.−2 g/m.sup.2/day or less. The oxygen permeability can be measured by a differential pressure method (JIS K 7126-1). For such a first barrier layer **34**, AlN.sub.a, AlO.sub.b, SiO.sub.c, SiN.sub.a (1/3≤a≤1, 0.5≤b≤1.5, 0.5≤ c≤2, 1/3<d≤4/3) and the like, and combinations thereof can be used. In addition, preferably, the average film thickness of the first barrier layer **34** is in a range from 100 nm to 200 nm, but this is not limitative. The average film thickness can be measured by using Dektak XTL Stylus Profiler System available from BRUKER Corporation, and the like.
(51) Second Barrier Layer **35**
(52) The second barrier layer **35** continuously covers the top surface of the wavelength conversion member **40**, and at least a portion of the first barrier layer **34** on the top surface of the light reflective member **30**. The second barrier layer **35** may also comprise or be composed of a member with a gas barrier property, and, for example, AlN.sub.a, AlO.sub.b, SiO.sub.c, SiN.sub.d (⅓≤a≤1, 0.5≤b≤1.5, 0.5≤c≤2, ⅓<d≤4/3) and the like, and combinations thereof, can be used. In addition, the average film thickness of the second barrier layer **35** is in a range from 100 nm to 200 nm, but this is not limitative. Preferably, the first barrier layer **34** and the second barrier layer **35** comprise or are composed of the same material. In addition, preferably, the thickness of the first barrier layer **34** is the same as the thickness of the second barrier layer **35**, or the first barrier layer **34** is thicker than the second barrier layer **35**. In this manner, the first barrier layer **34** is more easily provided on the inner surface of the light reflective member **30**, and the effect of suppressing the degradation of the wavelength conversion member **40** is achieved. Note that the first barrier layer **34** and the second barrier layer **35** may have a multi-layer structure. With a multi-layer structure, local degradation of the gas barrier property due to pin holes, foreign matters and the like generated during the formation of the gas barrier film can be avoided.
(53) As illustrated in the enlarged cross-sectional view of FIG. **2**, the gas barrier property for the quantum dots can be increased by covering the wavelength conversion member **40** including the quantum dots with the first barrier layer **34** and the second barrier layer **35**, and covering the top surface of the light reflective member **30** located around the recess **33** with the first barrier layer **34** and the second barrier layer **35** in an overlapping manner. In this manner, it is possible to improve the reliability of the quantum dots, which are easily degraded by outside air and moisture.
(54) Color Filter **50**
(55) The color filter **50** may be provided on the second barrier layer **35**. The color filter **50** is a member for absorbing the light emitted from the light-emitting element **20** but has not been absorbed by the wavelength conversion member **40**. For such a color filter **50**, a pigment color resist and the like can be used.
(56) Method for Manufacturing Light-Emitting Device
(57) A method for manufacturing the above-described light-emitting device is described with reference to FIGS. **3** to **9**. The following describes a method of manufacturing a light-emitting device that emits white light through color mixture by combining the light-emitting element **20** that emits blue light and the wavelength conversion member **40** including quantum dots that receive the blue light of the light-emitting element **20** and emit red light and green light.
(58) First, the base **10** and the light-emitting element **20** disposed on the base **10** are prepared, and

the light reflective member **30** is formed to surround this light-emitting element **20**. For example, a print wiring substrate with a thickness of 100 μm is prepared as the base **10**, and on the top surface of the base **10**, silicone resin in which TiO.sub.2 particles are mixed is applied and cured as the primary member **31** of the light reflective member **30**. Further, the metal layer **36** is formed by Cu plating on a part of the primary member **31**, and a blue LED is mounted on this metal layer **36** as the light-emitting element **20**. In this state, as illustrated in FIG. **3**, the region where the side wall member **32** is not formed is protected with a resist **60** on the top surface of the primary member **31**. An acrylic-resin based photoresist and the like can be used for the resist **60**. Then, as illustrated in FIG. **4**, resin for forming the side wall member **32** of the light reflective member **30** is applied from above the resist **60**. Here, as with the primary member **31**, silicone resin in which TiO.sub.2 particles are mixed is applied and cured. Thereafter, as illustrated in FIG. **5**, the surface of the silicone resin is cut to expose the resist **60**. Further, as illustrated in FIG. **6**, the side wall member **32** is formed by removing the resist **60** through reactive ion etching (RIE).
(59) Subsequently, as illustrated in FIG. **7**, the first barrier layer **34** is formed to continuously cover the top surface and inner surface of the light reflective member **30** and the surface of the light-emitting element **20**. Here, a layer comprising or composed of Al.sub.2O.sub.3, SiO.sub.2, SiN or the like, or a combination thereof is formed through sputtering such that the layer has an average film thickness of 150 nm. Through the sputtering, the film thickness of the formed first barrier layer **34** can be accurately controlled.
(60) Further, after covering with the first barrier layer **34**, the wavelength conversion member **40** is formed in the recess **33**. Here, as illustrated in FIG. **8**, a wavelength conversion member including green quantum dots with an average particle diameter of 5 nm that perform the wavelength conversion of the blue light of the light-emitting element **20** into green light, and red quantum dots with an average particle diameter of 9 nm that perform the wavelength conversion of the blue light into red light is filled into the recess **33** through photolithography, and cured. This provides the advantage of forming the wavelength conversion member including the quantum dots in precise patterns and film thicknesses. Note that the method of forming the wavelength conversion member is not limited to photolithography, and, for example, an ink-jet method of jetting and applying a wavelength conversion member material including quantum dots from an ink-jet nozzle, and the like may also be used. In this manner, an appropriate amount of the wavelength conversion member can be filled into the recess **33**, and the advantage of efficiently filling the wavelength conversion member to the appropriate location while avoiding the waste of the material can be achieved. In this manner, the ink-jet system is advantageous in terms of cost and efficiency.
(61) Thereafter, the second barrier layer **35** is provided. Here, as illustrated in FIG. **9**, a layer comprising or composed of Al.sub.2O.sub.3, SiO.sub.2, SiN or the like, or a combination thereof is formed through sputtering such that the layer has an average film thickness of 150 nm.
(62) Finally, the color filter **50** is formed on the second barrier layer **35**. Here, as the color filter **50**, a pigment-based color resist is applied over the recess **33** of the light reflective member **30** and its nearby top surface of the light reflective member **30**. In this manner, the light-emitting device **100** illustrated in FIG. **1** is obtained.
(63) In addition, the color filter is not limited to the plate-shape, and may be formed in a lens shape. The lens-shaped color filter can be formed by patterning a negative-type photoresist material in which pigment is dispersed and the like into a lens shape through photolithography.
FIRST MODIFICATION
(64) Further, the examples of FIG. **1** and the like illustrate the light-emitting device **100** that uses a blue light-emitting diode as the light-emitting element **20**, combines the first quantum dot **41** as the red quantum dot for receiving the blue light of this light-emitting element **20** and converting the received blue light into red light and the second quantum dot **42** as the green quantum dot for receiving the blue light and converting the received blue light into green light, and emits white light by mixing the blue light of the light-emitting element **20**, the red light of the first quantum dot **41**

and the green light the second quantum dot **42**. Note that the present disclosureis also applicable to a light-emitting device using other combinations. For example, as illustrated in the cross-sectional view of FIG. **10** as a first modification, the following three blue light-emitting diodes are prepared as the light-emitting element **20**: a first light-emitting element **20***a*, a second light-emitting element **20***b*, and a third light-emitting element **20***c*. Blue light-emitting diodes of the same type may be used for the first light-emitting element **20***a*, the second light-emitting element **20***b*, and the third light-emitting element **20***c*. Then, a first light emission region **81** is configured in which the first quantum dot **41***a*, which is the red quantum dot that receives the blue light and converts the received blue light into red light, is disposed around the first light-emitting element **20***a*. On the other hand, a second light emission region **82** is configured in which the second quantum dot **42***b*, which is the green quantum dot that receives the blue light and converts the received blue light into green light, is disposed around the second light-emitting element **20***b*. The first barrier layer **34** and the second barrier layer **35** are provided to the first light emission region **81** and the second light emission region **82**. Meanwhile, the third light-emitting element **20***c* is disposed as a third light emission region **83**. In the third light emission region **83**, the quantum dot is not provided, and therefore the first barrier layer **34** and the second barrier layer **35** need not be provided. The light-emitting device **100**B configured in this manner can emit white light by mixing the red light of the first light emission region **81**, the green light of the second light emission region **82** and the blue light of the third light emission region **83**.
(65) In addition, a color filter may be provided also in the light-emitting device including a plurality of such light emission regions. Such an example is illustrated in the cross-sectional view of FIG. **11**. As illustrated in this drawing, the color filter **50**B comprising or composed of a negative-type photoresist material in which pigments are dispersed and the like can be applied on the top surface of each light emission region, and the individual color filter **50**B can be formed into a lens shape through photolithography.
SECOND MODIFICATION
(66) Further, the light-emitting device may include a black matrix. The black matrix is a light blocking member for improving parting by covering the periphery of the light emission region with black. The black matrix may comprise or be composed of a resin material that contains black pigment or the like serving as a light shielding material so as to have a light-shielding property, or the like. In addition, the black matrix is not limited to the resin, and may comprise or be composed of metal.
(67) As an example of the method for manufacturing the light-emitting device including the black matrix, a procedure of forming a light-emitting device according to Modification **2** obtained by adding a black mask to the light-emitting device of FIG. **10** is described below with reference to FIGS. **12** to **14**. First, as illustrated in FIG. **12**, the first light emission region **81** in which the first light-emitting element **20***a* is disposed, the second light emission region **82** in which the second light-emitting element **20***b* is disposed, and the third light emission region **83** in which the third light-emitting element **20***c* is disposed are formed. Here, the same procedure as that of the above-described procedure of FIG. **6** can be used for forming the side wall member **32** on the light reflective member **30**.
(68) Subsequently, the black matrix **85** is formed on the top surface of each side wall member **32** of FIG. **12**. Here, a negative-type photoresist material in which black pigment is dispersed and the like as the light-shielding resin making up the black matrix **85** is applied by a method such as photolithography. The black matrix **85** is provided with a thickness of 1 μm to 10 μm.
(69) In this state, through the same procedure as the procedure described above with reference to FIGS. **7** to **9**, the first barrier layer **34** and the second barrier layer **35** are formed to the first light emission region **81** and the second light emission region **82**. Further, a color filter is formed on each light emission region as necessary. In the example illustrated in FIG. **14**, a plate-shaped color filter **50**C is formed on each of the first light emission region **81** and the second light emission

region **82**. In this manner, the light-emitting device **100**C provided with the black matrix **85** can be obtained.

THIRD AND FOURTH MODIFICATIONS

(70) In the above-described first and second modifications, an example of a light-emitting device in which only the blue light-emitting diode is used as the light-emitting element, and white light is obtained by mixing the red light of the first light emission region **81**, the green light of the second light emission region **82** and the blue light of the third light emission region **83**. Note that in the present disclosure, the light-emitting device is not limited to the configuration using the light-emitting element of one type, and the light-emitting device may be configured with a plurality of light-emitting elements that emit light of different colors. For example, as in FIG. **15** illustrating a light-emitting device **100**D according to a third modification, in the second light emission region **82**, a second light-emitting element **20***b*′ that emits green light may be disposed instead of the configuration used in FIG. **10** and the like in which a green quantum dot that receives the blue light and converts the received blue light into green light is disposed. Alternatively, as in FIG. **16** illustrating a light-emitting device **100**E according to a fourth modification, in the first light emission region **81**, the first light emission region **81** may be configured in which a first light-emitting element **20***a*′ that emits green light and a first quantum dot **41***a*′ that is the red quantum dot that receives the green light and converts the received green light into red light are disposed, instead of the configuration used in FIG. **15** and the like in which the first light-emitting element **20***a* that is a blue light-emitting diode and the red quantum dot that receives the blue light and converts the received blue light into red light are disposed. For the first light-emitting element **20***a*′, a green light-emitting diode of the same type as the second light-emitting element **20***b*′ disposed in the second light emission region **82** may be used. Further, a color filter **50**D may be added to the first light emission region **81**. Each of the light-emitting device **100**D according to the third modification and the light-emitting device **100**E according to the fourth modification can emit white light by mixing the red light of the first light emission region **81**, the green light of the second light emission region **82** and the blue light of the third light emission region **83**.

(71) In the above-described examples, the method of forming the side wall member **32** using the resist is described. Note that the present disclosure is not limited to the above-mentioned method of manufacturing the light-emitting device, and other methods may be appropriately used. For example, the side wall member may be formed by using a white dry film as described above. Here, an example in which the side wall member is formed by using a white dry film is described with reference to FIGS. **17** to **18**.

(72) First, the base **10** and the light-emitting element **20** are prepared. Subsequently, the primary member **31** of the light reflective member **30** is formed on the top surface of the base **10**. Further, the metal layer **36** is formed on a part of the primary member **31**, and the light-emitting element **20** is mounted on this metal layer **36**. Up to this point, the same procedure as that of the above-described method can be used.

(73) Subsequently, as illustrated in FIG. **17**, a white dry film **70** is bonded to the entire top surface of the primary member **31**. For the white dry film **70**, a negative-type photoresist material such as acrylate resin containing a light reflective material such as titanium oxide, and the like may be used. In this state, development is performed by performing photolithography, and thus unnecessary portions in the white dry film **70** are removed. Here, as illustrated in FIG. **18**, the region in which the side wall member **32** will not be formed is removed, and thus the white dry film **70** that has not been removed becomes the side wall member **32**. Thereafter, through the same procedure as the procedure described above with reference to FIGS. **7** to **9**, the first barrier layer **34**, the second barrier layer **35** and the like are provided. In this manner, the light-emitting device **100** illustrated in FIG. **1** is obtained.

EXAMPLES

(74) The light-emitting device including the first barrier layer and the second barrier layer that is

obtained in the above-mentioned manner was produced as a device according to an example, and a light-emitting device that includes neither a first barrier layer nor a second barrier layer was produced as a device according to a comparative example, and their characteristics were compared with each other. Here, the light-emitting devices according to the example and the comparative example were left in an environment of normal temperature (approximately 20° C.) for 10 days (240 hours) immediately after the production, and then their spectral radiation luminance of red quantum dots and spectral radiation luminance of green quantum dots were measured with an XYZ filter method by using 2D-spectroradiometer SR-5100HM available from with Topcon Technohouse Corporation. The measurement results are illustrated in the graphs of FIGS. **19** to **22**. In these drawings, FIGS. **19** and **20** illustrate measurement results of the light-emitting device according to the example, and FIGS. **21** and **22** illustrate measurement results of the light-emitting device according to the comparative example. In addition, FIGS. **19** and **21** illustrate the spectral radiation luminance of the red quantum dots, and FIGS. **20** and **22** illustrate the spectral radiation luminance of the green quantum dots. Further, in each drawing, the waveform of an initial state immediately after the production of the light-emitting device is illustrated with solid line, and the waveform of a state after 10 days has passed is illustrated with broken line. As illustrated in the drawings, it was confirmed that the spectral radiation luminance of each of the red quantum dot and green quantum dot significantly decreased in the comparative example, while in the example, substantially the same spectral radiation luminance was maintained and the effect of suppressing the degradation of the quantum dots with the first barrier layer and the second barrier layer was achieved.

APPLICATION EXAMPLES

(75) The structure disclosed in the present disclosure is applicable to passive matrix array and active matrix array displays for image display. As an example of such light-emitting devices, the enlarged cross-sectional view of FIG. **23** illustrates a main part of an image display device serving as an active matrix display. An image display device **200** illustrated the drawing includes a base **210**, a light-emitting element **220** disposed on the base **210**, a light reflective member **230** surrounding the light-emitting element **220**, a wavelength conversion member **240**, and a color filter **250**. The surface of the light-emitting element **220** and the inner surface and top surface of the light reflective member **230** are continuously covered with a first barrier layer **234**. In addition, the top surface of the wavelength conversion member **240** and a region of the first barrier layer **234** provided on the top surface of the light reflective member **230** are continuously covered with a second barrier layer **235**. Further, in the wavelength conversion member **240**, a first quantum dot **241** and a second quantum dot **242** are mixed.

(76) Here, in each pixel illustrated in FIG. **23**, the first quantum dot **241** and the second quantum dot **242** are mixed, and thus white light obtained by mixing the blue light emission of the light-emitting element **220**, the red wavelength conversion output light of the first quantum dot **241**, and the green wavelength conversion output light of the second quantum dot **242** is generated. Alternatively, blue, red, green sub-pixels may be provided as described later by optionally providing a blue light-transmissive color filter, a red light-transmissive color filter, and a green light-transmissive color filter. Note that as described above, by further providing a so-called black matrix between the color filters **50**, the external light visibility can be improved by suppressing external light reflection.

(77) The base **210** includes a circuit board **211**, an intermediate layer **212**, an interlayer insulating film **213**, a planarizing film **214**, and a gate insulating film **216**. The circuit board **211** is an Si circuit board using Si. A transistor **215** is provided in a part of the Si circuit board. In addition, the transistor **215** is electrically connected with a metal layer **236** via a through hole and/or a through electrode. On the other hand, the interlayer insulating film **213** is interposed for the purpose of electrical insulation at the intermediate layer **212**. Note that for the circuit board **211**, glass or resin substrate provided with a low-temperature polycrystal Si transistor or the like may be used instead

of the Si circuit board provided with the transistor **215**.
(78) FIG. **24** is a schematic block diagram illustrating the image display device **200**. The image display device **200** illustrated in this drawing includes a display region **2**. Sub-pixels **202** are arranged in the display region **2**. The sub-pixels **202** are arranged in a matrix. For example, n sub-pixels **202** are arranged along the X axis, and m sub-pixels **202** are arranged along the Y axis.
(79) A pixel **201** includes a plurality of the sub-pixels **202** that emit light of different colors. A sub-pixel **202**R emits red light. A sub-pixel **202**G emits green light. A sub-pixel **202**B emits blue light. With the sub-pixels **202**R, **202**G and **202**B of the three types that emit light at the desired luminance, the emission color and luminance of one pixel **201** are set.
(80) One pixel **201** includes three sub-pixels, **202**R, **202**G and **202**B, and the sub-pixels **202**R, **202**G and **202**B are linearly arranged on the X axis as illustrated in FIG. **24**, for example. In each pixel **201**, sub-pixels of the same color may be arranged on the same line, or sub-pixels of different colors may be arranged on respective lines as in this example.
(81) The image display device **200** further includes a power source line **3** and a ground line **4**. The power source line **3** and the ground line **4** are arranged in a matrix along the arrangement of the sub-pixels **202**. The power source line **3** and the ground line **4** are electrically connected with each sub-pixel **202**, and supply power to each sub-pixel **202** from the direct current power source connected between a power source terminal **3***a* and a GND terminal **4***a*. The power source terminal **3***a* is provided at an end portion of the power source line **3** and the GND terminal **4***a* is provided at an end portion of the ground line **4**, and the power source terminal **3***a* and the GND terminal **4***a* are connected with the direct current power supply circuit provided outside the display region **2**. The power source terminal **3***a* is supplied with a positive voltage with respect to the GND terminal **4***a*.
(82) The image display device **200** further includes a scan line **6** and a signal line **8**. The scan line **6** is arranged in a direction parallel to the X axis. That is, the scan line **6** is arranged along the arrangement of the sub-pixels **202** in the row direction. The signal line **8** is arranged in a direction parallel to the Y axis. That is, the signal line **8** is arranged along the arrangement of the sub-pixels **202** in the column direction.
(83) The image display device **200** further includes a row selection circuit **5** and a signal voltage output circuit **7**. The row selection circuit **5** and the signal voltage output circuit **7** are provided along the outer edge of the display region **2**. The row selection circuit **5** is provided along the outer edge of the display region **2** in the Y-axis direction. The row selection circuit **5** is electrically connected with the sub-pixel **202** of each column through the scan line **6**, and supplies a selection signal to each sub-pixel **202**.
(84) The signal voltage output circuit **7** is provided along the outer edge of the display region **2** in the X-axis direction. The signal voltage output circuit **7** is electrically connected with the sub-pixel **202** of each row through the signal line **8**, and supplies a signal voltage to each sub-pixel **202**.
(85) The sub-pixels **202** includes the light-emitting element **220**, a selection transistor **224**, a driving transistor **226**, and a capacitor **228**. In FIG. **24**, the selection transistor **224** may be represented by T**1**, the driving transistor **226** may be represented by T**2**, and the capacitor **228** may be represented by Cm.
(86) The light-emitting element **220** is connected in series with the driving transistor **226**. In the present embodiment, the driving transistor **226** is a p-channel TFT, and the anode electrode of the light-emitting element **220** is connected with the drain electrode of the driving transistor **226**. The main electrodes of the driving transistor **226** and the selection transistor **224** are the drain electrode and the source electrode. The anode electrode of the light-emitting element **220** is connected with the p-semiconductor layer of the semiconductor laminate. The cathode electrode of the light-emitting element **220** is connected with the n-semiconductor layer of the semiconductor laminate. The series circuit of the light-emitting element **220** and the driving transistor **226** is connected between the power source line **3** and the ground line **4**. The driving transistor **226** corresponds to the transistor **215** in FIG. **23**, and the light-emitting element **220** corresponds to a light-emitting

element **222** in FIG. **24**. The current flowing through the light-emitting element **222** is determined by the voltage applied between the gate and source of the driving transistor **226**, and the light-emitting element **222** emits light at the luminance corresponding to the flowing current.
(87) The selection transistor **224** is connected between the gate electrode of the driving transistor **226** and the signal line **8** through the main electrode. The gate electrode of the selection transistor **224** is connected with the scan line **6**. The capacitor **228** is connected between the gate electrode of the driving transistor **226** and the power source line **3**.
(88) The row selection circuit **5** selects one row from the arrangement of the sub-pixels **202** of m rows, and supplies a selection signal to the scan line **6**. The signal voltage output circuit **7** supplies a signal voltage with a required analog voltage value to each sub-pixel **202** of the selected row. A signal voltage is applied between the gate and source of the driving transistor **226** of the sub-pixel **202** of the selected row. The signal voltage is held by the capacitor **228**. The driving transistor **226** supplies a current corresponding to the signal voltage through the light-emitting element **220**. The light-emitting element **220** emits light at the luminance corresponding to the flowing current.
(89) The row selection circuit **5** sequentially switches the row to be selected and supplies the selection signal. That is, the row selection circuit **5** scans the row in which the sub-pixels **202** are arranged. The current corresponding to the signal voltage flows through the light-emitting element **220** of the sequentially scanned sub-pixels **202**, and thus light is emitted. The luminance of the sub-pixels **202** is determined by the current flowing through the light-emitting element **220**. The sub-pixel **202** emits light with the gradation based on the determined luminance, and an image is displayed in the display region **2**.
(90) Note that while a low-cost structure that can collectively form the wavelength conversion members **240** by providing the same wavelength conversion member **240** in each sub-pixel to generate white light is described above in the application example, the wavelength conversion member **240** may have a different structure for each of blue, red, and green sub-pixels. In this case, the blue sub-pixel is not provided with the wavelength conversion function, the red sub-pixel is provided with the red wavelength conversion function, and the green sub-pixel is provided with the green wavelength conversion function. In such a case, blue light can be efficiently emitted to the outside, and thus the power consumption at the time of light emission can be reduced.
(91) MODIFICATION
(92) In addition, the image display device may be configured by stacking separate plate members and/or laminar members. Example of such a configuration is illustrated in FIG. **25**. In an image display device **300** illustrated in this drawing, a plate-shaped or laminar shaped side wall member **330** including a large number of light-emitting elements **320** is overlaid on the primary member **314**, which is also a planarizing film of a circuit layer **310**. A plurality of recesses are provided in the side wall member **330**, and the light-emitting element **320** is embedded in each recess. In the recess, a wavelength conversion member sealed with a first barrier layer and a second barrier layer is also provided. In addition, a color filter is provided at the position corresponding to each recess on the side wall member **330**. A depression is formed at a position corresponding to each light-emitting element **320** in the circuit layer **310** and the primary member **314**, and a connecting terminal corresponding to each light-emitting element **320** is provided inside the depression.
(93) With the configuration obtained by stacking the circuit layer **310** and the side wall member **330**, the image display device **300** can handle the circuit layer **310** and the side wall member **330** including a large number of light-emitting elements **320** and the wavelength conversion member, as separate members. This can improve yield and reduce costs. The reason for this is that the circuit layer **310** and the side wall member **330** can be stacked after the circuit layer **310** and the side wall member **330** are separately subjected to defect inspection and defectives are removed and repaired.
(94) It should be apparent to those with an ordinary skill in the art that while various preferred examples of the invention have been shown and described, it is contemplated that the invention is not limited to the particular examples disclosed. Rather, the disclosed examples are merely

illustrative of the inventive concepts and should not be interpreted as limiting the scope of the invention. All suitable modifications and changes falling within the spirit of the invention are intended to be encompassed by the appended claims.

INDUSTRIAL APPLICABILITY

(95) The light-emitting device and the method for manufacturing the light-emitting device of the present invention suitable for large displays, medium-sized monitors for smartphones, tablets and in-vehicle use, or small screens such as HMDs and smart glass screens, for example.

Claims

1. A method for manufacturing a light-emitting device including a light-emitting element and a quantum dot configured to convert light emitted by the light-emitting element, the method comprising: preparing a base and a light-emitting element having a surface and disposed on the base; forming a light reflective member having an inner surface and a top surface and surrounding the light-emitting element; forming a first barrier layer continuously covering the surface of the light-emitting element and the inner surface of the light reflective member and the top surface of the light reflective member; forming a wavelength conversion member having a top surface and including the quantum dot in a region surrounded by the inner surface of the light reflective member, the light-emitting element being embedded in the wavelength conversion member; and covering, with a second barrier layer, the top surface of the wavelength conversion member and at least a portion of the first barrier layer on the top surface of the light reflective member.
2. The method according to claim 1, further comprising providing a color filter on the second barrier layer.
3. The method according to claim 1, wherein the first barrier layer and the second barrier layer comprise or are composed of the same material.
4. The method according to claim 1, wherein a thickness of the first barrier layer is the same as or greater than a thickness of the second barrier layer.
5. The method according to claim 1, wherein the top surface of the wavelength conversion member and the top surface of the light reflective member are formed on the same plane.
6. The method according to claim 1, wherein the forming of the wavelength conversion member comprises forming the wavelength conversion member including the quantum dot by photolithography.
7. The method according to claim 1, wherein the forming of the wavelength conversion member comprises jetting a wavelength conversion member material including the quantum dot from an ink-jet nozzle.
8. The method according to claim 1, wherein the forming of the first barrier layer comprises forming of the first barrier layer by sputtering.
9. The method according to claim 1, wherein an average film thickness of the first barrier layer and/or an average film thickness of the second barrier layer is in a range from 100 nm to 200 nm.
10. The method according to claim 1, wherein the first barrier layer and/or the second barrier layer comprises AlN_a, AlO_b, SiO_c or SiN_a ($⅓\leq a\leq 1$, $0.5\leq b\leq 1.5$, $0.5\leq c\leq 2$, $⅓\leq d\leq 4/3$), or a combination thereof.
11. The method according to claim 1, wherein an oxygen permeability of the first barrier layer and/or the second barrier layer is 1×10^{-2} $g/m^2/day$ or less.
12. A light-emitting device comprising: a base; a light-emitting element having a surface and disposed on the base; a light reflective member having an inner surface and a top surface and surrounding the light-emitting element; a first barrier layer continuously covering the surface of the light-emitting element and the inner surface of the light reflective member and the top surface of the light reflective member; a wavelength conversion member having a top surface and including a quantum dot and disposed in a region surrounded by the inner surface of the light reflective

member; and a second barrier layer covering the top surface of the wavelength conversion member and at least a portion of the first barrier layer on the top surface of the light reflective member.

13. The light-emitting device according to claim 12, further comprising a color filter provided on the second barrier layer.

14. The light-emitting device according to claim 12, wherein the first barrier layer and the second barrier layer comprise or are composed of the same material.

15. The light-emitting device according to claim 12, wherein a thickness of the first barrier layer is the same as or greater than a thickness of the second barrier layer.

16. The light-emitting device according to claim 12, wherein the top surface of the wavelength conversion member and the top surface of the light reflective member are formed on the same plane.

17. The light-emitting device according to claim 12, wherein an average film thickness of the first barrier layer and/or an average film thickness of the second barrier layer is in a range from 100 nm to 200 nm.

18. The light-emitting device according to claim 12, wherein the first barrier layer and/or the second barrier layer comprises at least one selected from the group consisting of AlN.sub.a, AlO.sub.b, SiO.sub.c and SiN.sub.a (⅓≤a≤1, 0.5≤b≤1.5, 0.5≤c≤2, 1/3≤d≤4/3), and a combination thereof.

19. The light-emitting device according to claim 12, wherein an oxygen permeability of the first barrier layer and/or the second barrier layer is 1×10.sup.−2 g/m.sup.2/day or less.