US 20180301869A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2018/0301869 A1
(43) Pub. Date: Oct. 18, 2018
MAEMURA

(54) LIGHT-EMITTING BODY, LIGHT-EMITTING DEVICE, ILLUMINATOR, AND METHOD FOR PRODUCING LIGHT-EMITTING BODY

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(21) Appl. No.: **15/766,914**

(22) PCT Filed: **Jul. 13, 2016**

(86) PCT No.: **PCT/JP2016/070737**

§ 371 (c)(1),
(2) Date: **Apr. 9, 2018**

(30) **Foreign Application Priority Data**

Nov. 4, 2015 (JP) 2015-217025

Publication Classification

(51) **Int. Cl.**
H01S 5/06 (2006.01)
C09K 11/77 (2006.01)

(52) **U.S. Cl.**
CPC ***H01S 5/0609*** (2013.01); *F21Y 2115/30* (2016.08); ***C09K 11/777*** (2013.01); ***C09K 11/7774*** (2013.01)

(57) **ABSTRACT**

Occurrence of luminance unevenness or color unevenness is efficiently reduced. In a light-emitting part (**10**), a first phosphor layer (La**1**) containing a first YAG phosphor (**3**), and a second phosphor layer (La**2**) containing a second YAG phosphor (**2**) are stacked on a substrate (**1**). A particle size of the first YAG phosphor is smaller than a particle size of the second YAG phosphor. The first phosphor layer is arranged on a side far from the substrate, and excitation light (E**1**) is incident on the first phosphor layer.

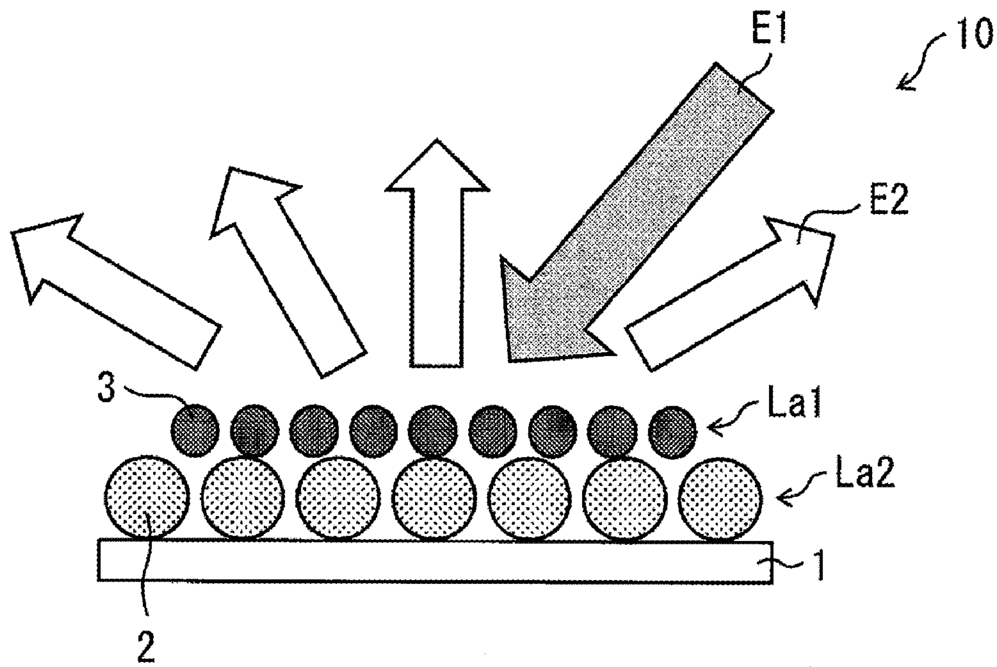


FIG. 1

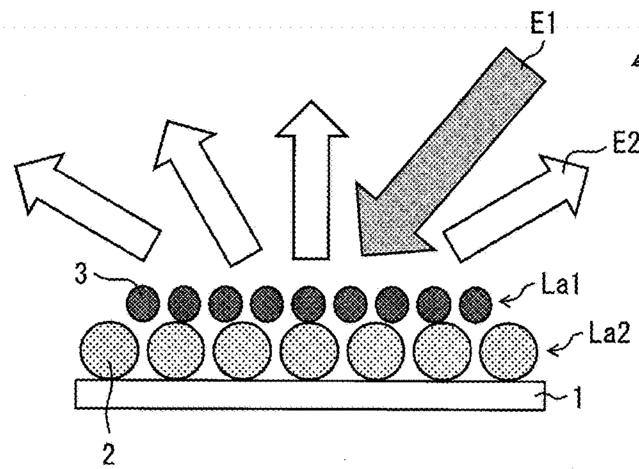


FIG. 2

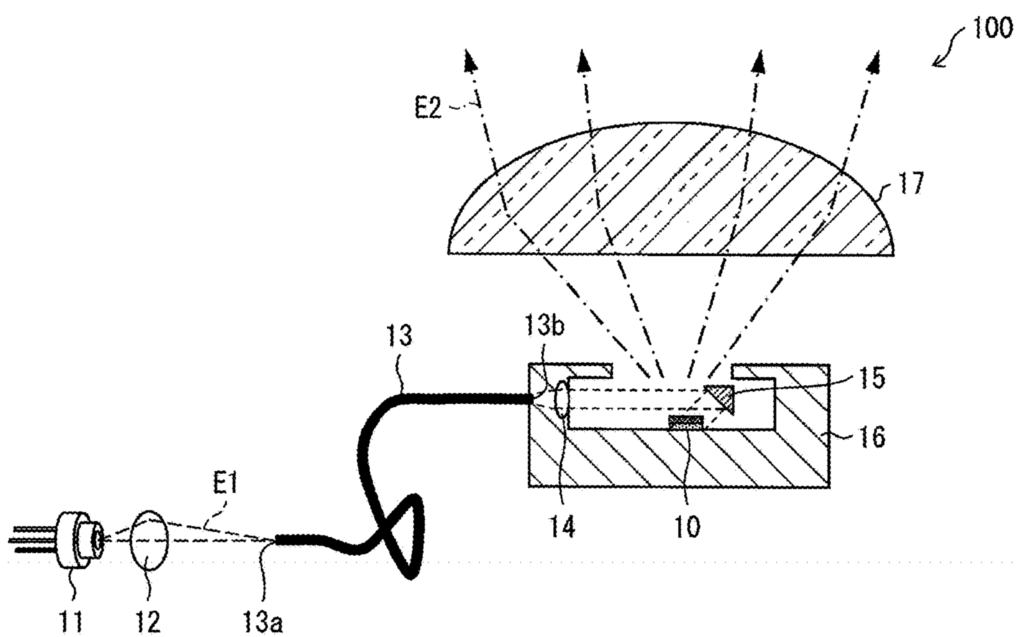


FIG. 3

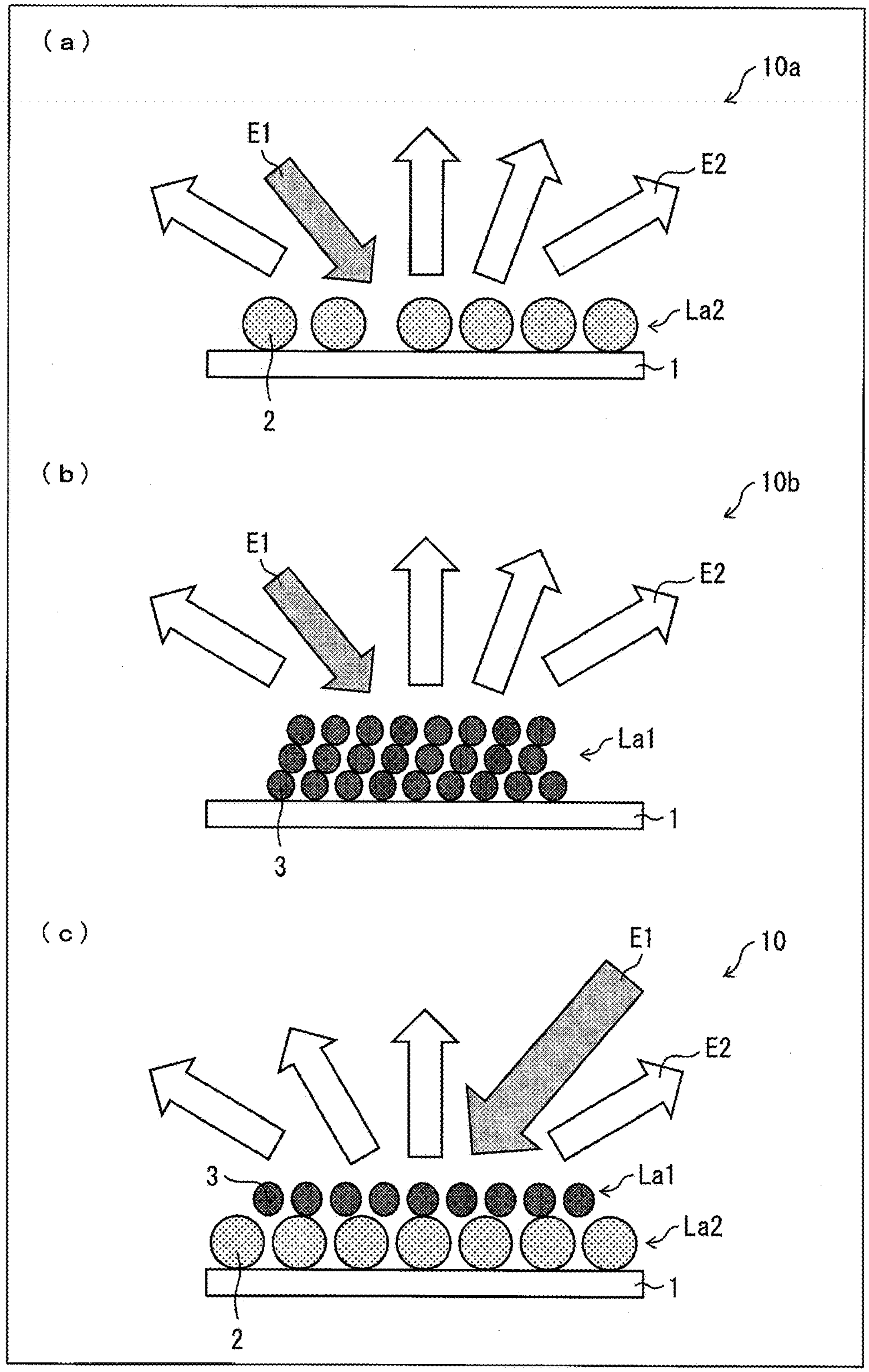


FIG. 4

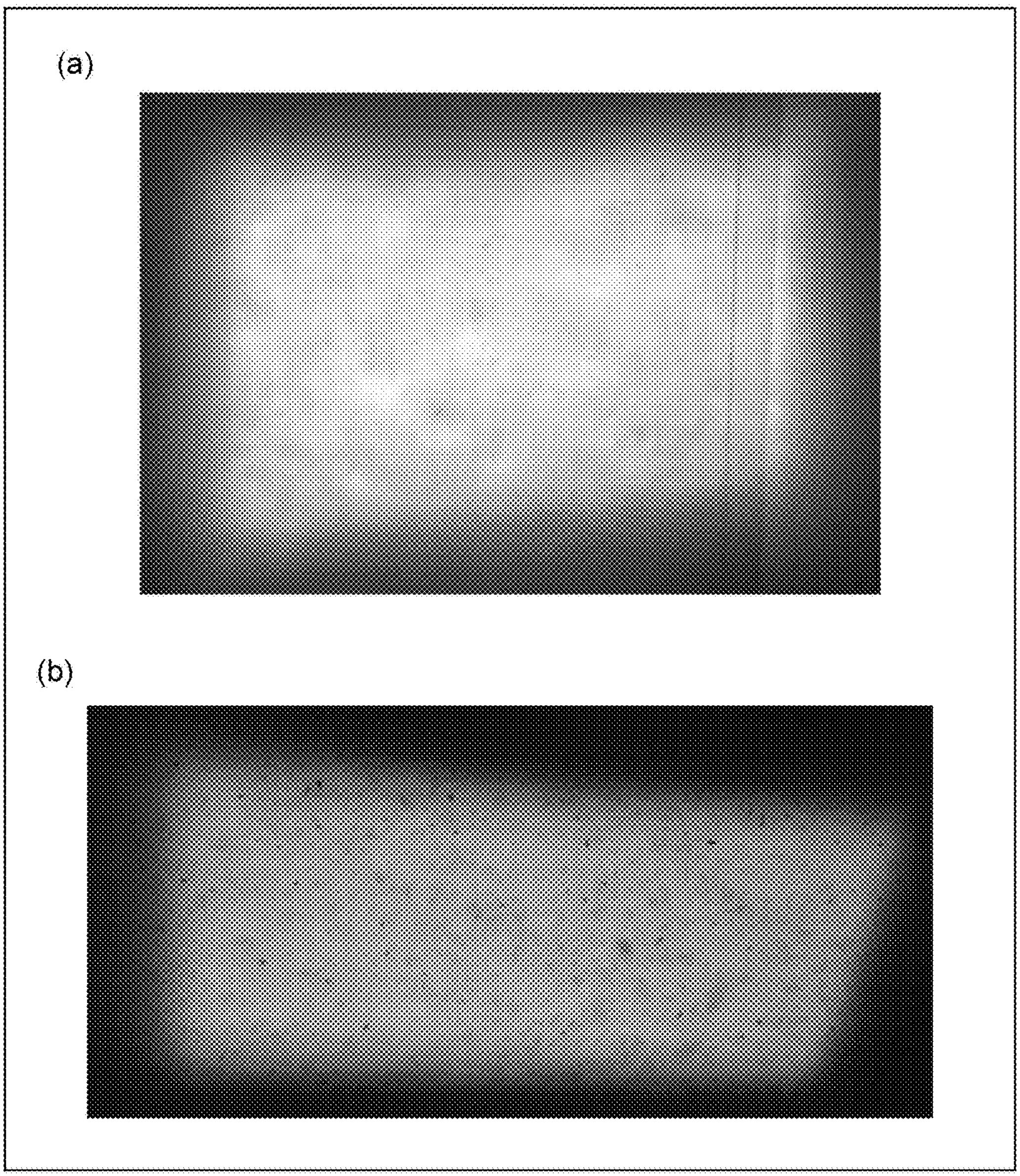


FIG. 5

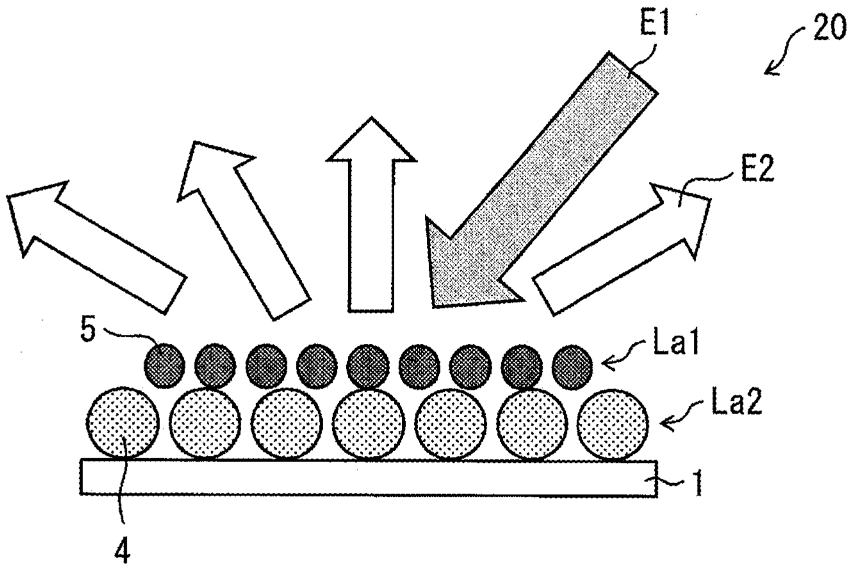


FIG. 6

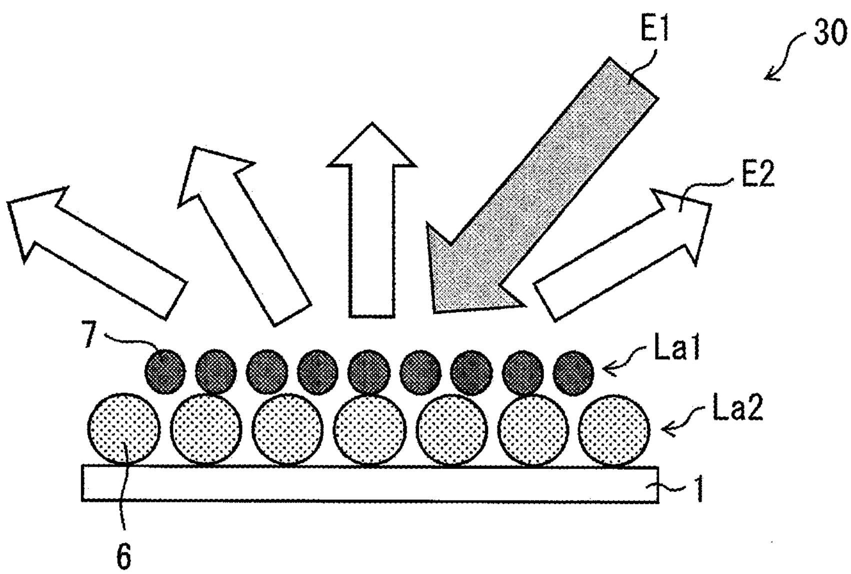


FIG. 7

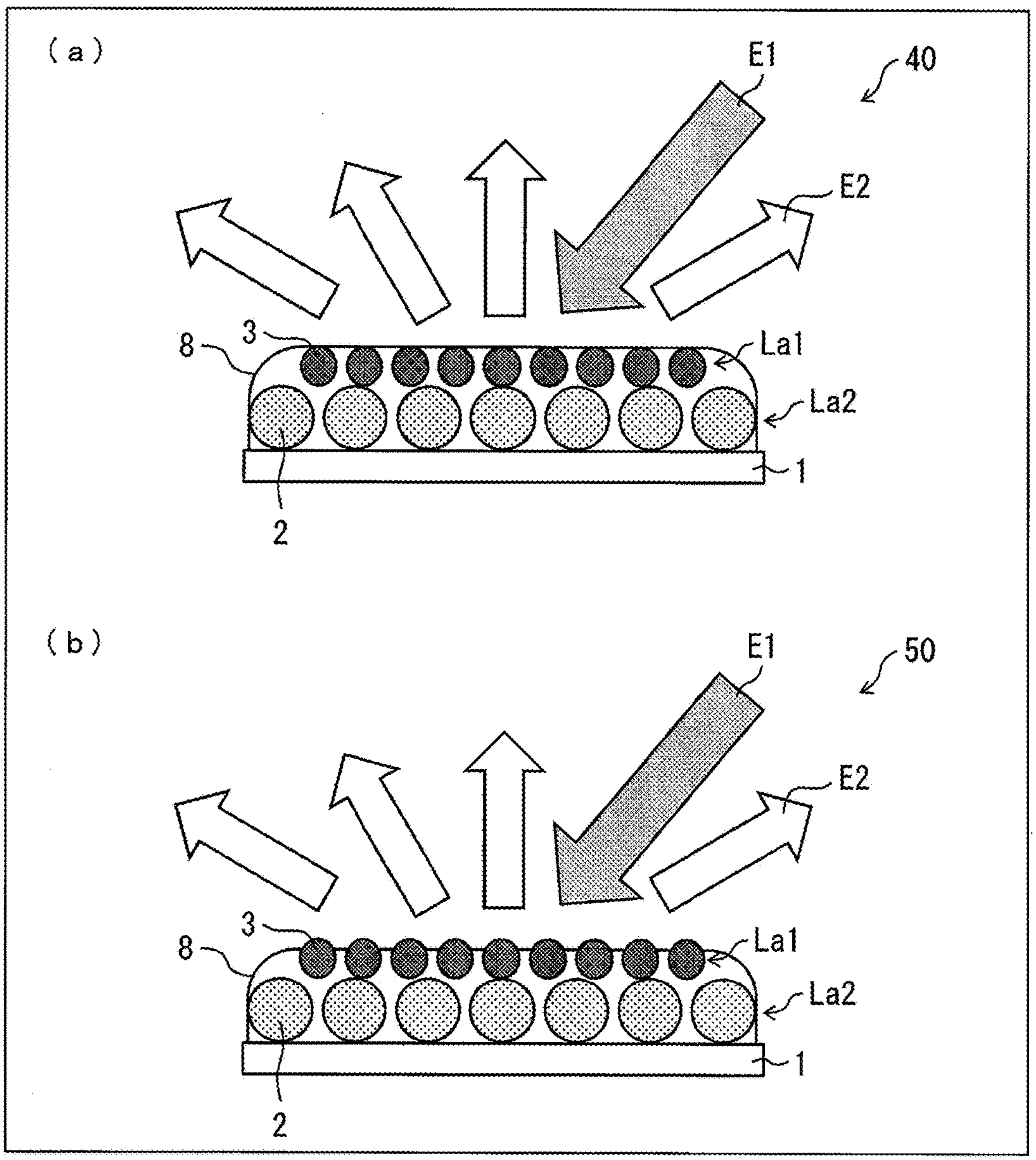


FIG. 8

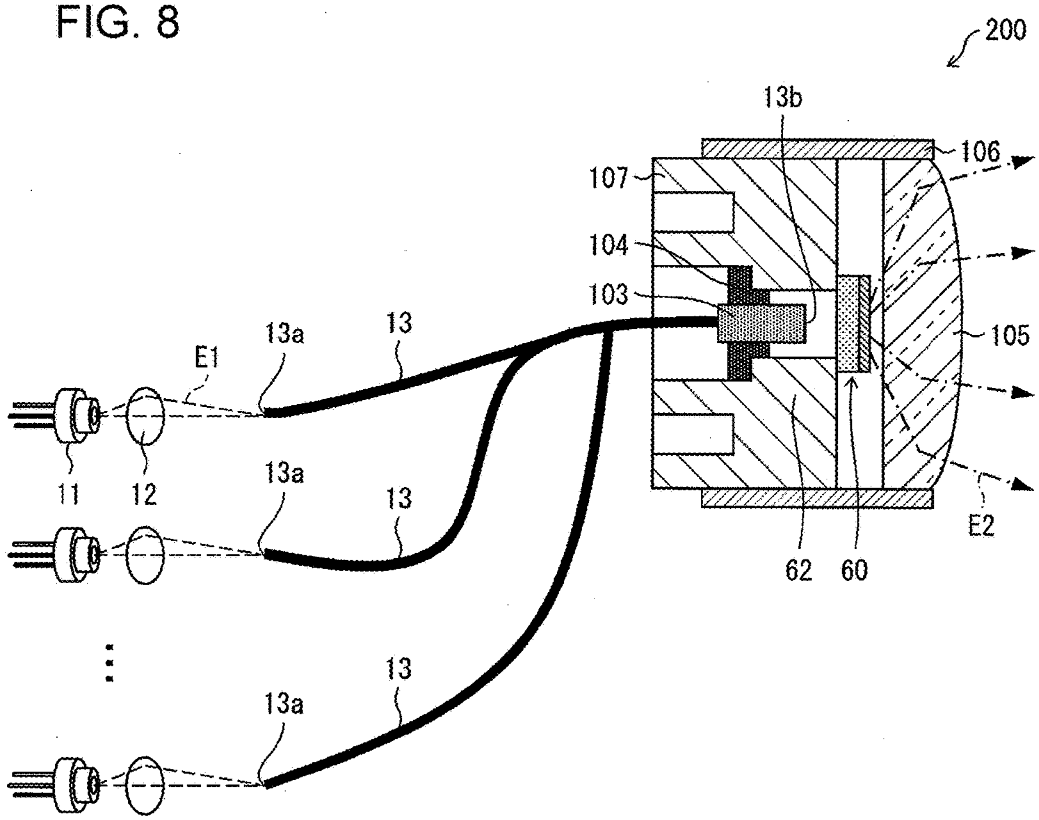
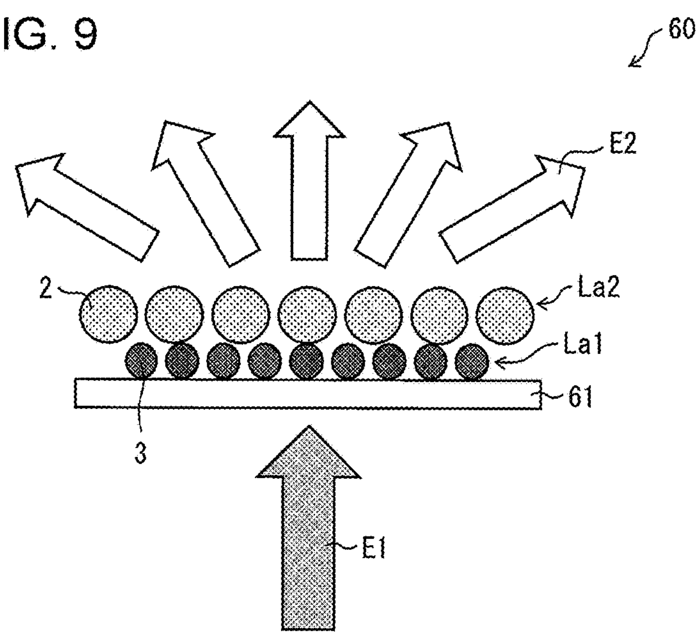

200
13b
106
107
104
103
13a
13
E1
105
11
12
13a
13
62
60
E2
13a
13

FIG. 9


60
E2
2
La2
La1
61
3
E1

LIGHT-EMITTING BODY, LIGHT-EMITTING DEVICE, ILLUMINATOR, AND METHOD FOR PRODUCING LIGHT-EMITTING BODY

TECHNICAL FIELD

[0001] The present invention relates to a light-emitting body or the like that receives excitation light and emits fluorescence.

BACKGROUND ART

[0002] In recent years, there has been actively studied a light-emitting device that uses a semiconductor light-emitting element, for example, a light-emitting diode (LED) or a semiconductor laser (laser diode, LD), as an excitation light source. The light-emitting device uses, as illumination light, fluorescence that is generated by irradiating a light-emitting part containing a phosphor with excitation light that is generated from an excitation light source of the semiconductor light-emitting element. An example of such a light-emitting device may be a light-emitting device described in PTL 1.

[0003] PTL 1 discloses a semiconductor light-emitting device provided with a resin layer containing a phosphor provided on a light-emitting element. In this semiconductor light-emitting device, light emitted from the light-emitting element and light whose wavelength is converted by the phosphor are transmitted through the resin layer and are radiated to the outside. Also, PTL 1 discloses a configuration in which a phosphor having a relatively large particle size is arranged on the light-emitting element and a phosphor having a relatively small particle size is dispersed in the resin layer; and a configuration in which the resin layer contains therein a scattering material.

CITATION LIST

Patent Literature

[0004] PTL 1: Japanese Unexamined Patent Application Publication No. 2009-135136 (published on Jun. 18, 2009)

SUMMARY OF INVENTION

Technical Problem

[0005] However, with the invention described in PTL 1, if the phosphor is dispersed in the resin layer, heat is generated in the resin layer that is separated from the light-emitting element, and the heat is not efficiently released. Moreover, if the resin layer contains the scattering material, light beams are decreased by multiple scattering, or excitation light not absorbed by the phosphor and reflected by the phosphor is increased.

[0006] The present invention is made in light of the above-described problems, and an object of the invention is to provide a light-emitting body capable of efficiently reducing occurrence of luminance unevenness or color unevenness. A second object of the invention is to provide a light-emitting body capable of efficiently releasing the heat generated from a phosphor.

Solution to Problem

[0007] To address the above-described problems, a light-emitting body according to an aspect of the invention includes

[0008] a first phosphor layer containing a first phosphor that receives excitation light and emits first fluorescence; and

[0009] a second phosphor layer containing a second phosphor that receives the excitation light and emits second fluorescence, in which

[0010] the first and second phosphor layers are stacked on a substrate,

[0011] a particle size of the first phosphor is smaller than a particle size of the second phosphor, and

[0012] the first phosphor layer is arranged on a side far from the substrate, and the excitation light is incident on the first phosphor layer.

[0013] Furthermore, to address the above-described problems, a light-emitting body according to another aspect of the invention includes

[0014] a first phosphor layer containing a first phosphor that receives excitation light and emits first fluorescence; and

[0015] a second phosphor layer containing a second phosphor that receives the excitation light and emits second fluorescence, in which

[0016] the first and second phosphor layers are stacked on a substrate,

[0017] a particle size of the first phosphor is smaller than a particle size of the second phosphor, and

[0018] the first phosphor layer is arranged on the substrate, and the excitation light is incident on the first phosphor layer.

Advantageous Effects of Invention

[0019] According to the aspect of the invention, occurrence of luminance unevenness or color unevenness can be efficiently reduced in light to be emitted. Also, according to the other aspect of the invention, the heat generated from the phosphor can be efficiently released.

BRIEF DESCRIPTION OF DRAWINGS

[0020] FIG. **1** illustrates an outline configuration of a light-emitting part according to Embodiment 1.

[0021] FIG. **2** illustrates an outline configuration of an illuminator according to Embodiment 1.

[0022] FIG. **3**(*a*) and FIG. **3**(*b*) illustrate an outline configuration of a light-emitting part according to a comparative example of Embodiment 1, and FIG. **3**(*c*) illustrates an outline configuration of the light-emitting part according to Embodiment 1.

[0023] FIG. **4** provides illustrations for explaining a difference in projection pattern of illumination light due to a difference in particle size of a phosphor stacked on a substrate, FIG. **4**(*a*) illustrating an experimental result of a light-emitting part according to an example, FIG. **4**(*b*) illustrating an experimental result of a light-emitting part according to a comparative example.

[0024] FIG. **5** illustrates an outline configuration of a light-emitting part according to Embodiment 2.

[0025] FIG. **6** illustrates an outline configuration of a light-emitting part according to Embodiment 3.

[0026] FIG. **7**(*a*) and FIG. **7**(*b*) each illustrate an outline configuration of a light-emitting part according to Embodiment 4.

[0027] FIG. **8** illustrates an outline configuration of an illuminator according to Embodiment 5.

[0028] FIG. **9** illustrates an outline configuration of a light-emitting part according to Embodiment 5.

DESCRIPTION OF EMBODIMENTS

Embodiment 1

[0029] An embodiment of the present invention is described as follows with reference to FIGS. **1** to **4**.

<Outline Configuration of Illuminator **100**>

[0030] FIG. **2** illustrates an outline configuration of an illuminator **100** according to this embodiment. As illustrated in FIG. **2**, the illuminator **100** includes a light-emitting part **10** (light-emitting body), a laser element **11**, a first lens **12**, an optical fiber **13**, a second lens **14**, a mirror **15**, a casing **16**, and a projecting lens **17** (projecting part). The light-emitting part **10** and the laser element **11** form, a basic configuration of a light-emitting device. Also, the light-emitting part **10**, the laser element **11**, and the projecting lens **17** form a basic configuration of an illuminator.

[0031] The illuminator **100** projects illumination light E**2** including at least fluorescence that is emitted from the light-emitting part **10** when excited by excitation light E**1** emitted from the laser element **11**, in a specific direction by the projecting lens **17**. While this embodiment is described such that the illumination light E**2** includes the excitation light E**1** and the fluorescence, only the fluorescence may be projected as the illumination light E**2**.

[0032] Also, the illuminator according to this application can be applied to an illuminator, such as a vehicle headlight (for example, a headlight of an automobile) or a downlight. The downlight is an illuminator installed at a ceiling of a structure, such as a house or a conveyance. Alternatively, the illuminator according to this application may be provided as a headlamp of a mobile object other than the vehicle (for example, person, ship, aircraft, submarine, or rocket), or may be provided as a search light, a projector, or indoor illumination equipment (stand lamp etc.) other than the downlight.

[0033] The laser element **11** is an excitation light source that emits the excitation light E**1** (laser light) that excites a first phosphor and a second phosphor contained in the light-emitting part **10**. The laser element **11** is excitation light of blue light having a peak wavelength in an oscillation wavelength range from 440 nm to 450 nm (or 490 nm or shorter). In this embodiment, the excitation light E**1** to be emitted has, for example, a peak wavelength of 450 nm.

[0034] The oscillation wavelength range may be appropriately selected in accordance with the kinds of the first phosphor and the second phosphor contained in the light-emitting part **10** (that is, the excitation wavelengths of the first phosphor and the second phosphor). For example, the wavelength range of visible light can be selected. Also, while the single laser element **11** is provided in this embodiment, the number of laser elements **11** may be determined in accordance with, for example, the output. The output of the laser element **11** may be appropriately selected in accordance with the specifications of the illuminator **100**. If a plurality of laser elements **11** are used, the excitation intensity can be increased.

[0035] Also, for example, an LED may be used as the excitation light source according to this specification.

[0036] Although not illustrated, the laser element **11** includes an electrode terminal. A wire is connected to the electrode terminal. The laser element **11** is connected to a power supply circuit for driving, via the wire and the electrode terminal. Further, although not illustrated, to release the heat generated during operation of the laser element **11**, a heat releasing mechanism, such as a heat sink or a cooling jig, may be provided for the laser element **11**. For the heat releasing mechanism, a metal material, such as aluminum, having high heat conductivity may be used.

[0037] The first lens **12** condenses the excitation light E**1** emitted from the laser element **11**. Then, the excitation light E**1** condensed by the first lens **12** is incident on an incidence end **13***a* of the optical fiber **13**. That is, the first lens **12** functions as a light guide member that guides the excitation light E**1** to the optical fiber **13**. In other words, the laser element **11** is optically coupled to the optical fiber **13** via the first lens **12**.

[0038] The optical fiber **13** is a light guide member that guides the excitation light E**1** emitted from the laser element **11** to the mirror **15** via the second lens **14**. The optical fiber **13** has the incidence end **13***a* that receives the excitation light E**1** emitted from the laser element **11**, and an emission end **13***b* that emits the excitation light E**1** incident from the incidence end **13***a*. The excitation light E**1** condensed by the first lens **12** is emitted from the emission end **13***b* of the optical fiber **13**, transmitted through the second lens **14**, and emitted to the mirror **15**.

[0039] If a plurality of laser elements **11** exist, incidence ends **13***a* of the plurality of optical fibers **13** may be provided so as to face corresponding laser elements **11**. The plurality of optical fibers **13** may be, for example, a fiber bundle. Alternatively, even if the plurality of laser-elements **11** exist, a single optical fiber **13** may be employed. In this case, excitation light E**1** emitted from the plurality of laser elements **11** may be coupled to the single optical fiber **13** by using members, such as a lens and a mirror. For a light guide member that optically couples the laser-element **11** and the light-emitting part **10** to one another, a member other than the optical fiber **13** may be used. The kind of the light guide member is not limited.

[0040] The second lens **14** is a light guide member that controls the excitation light E**1** emitted from the emission end **13***b* of the optical fiber **13** so as to be substantially parallel light, and guides the substantially parallel light to the mirror **15**. That is, the optical fiber **13** is optically coupled to the mirror **15** via the second lens **14**.

[0041] The mirror **15** reflects the excitation light E**1** transmitted through the second lens **14**, and causes the excitation light E**1** to be incident on the light-emitting part **10**. The mirror **15** is arranged in such a manner that the reflected excitation light E**1** is incident on the light-emitting part **10**.

[0042] The light-emitting part **10** receives the excitation light E**1** reflected by the mirror **15** and emits fluorescence. To be specific, the light-emitting part **10** emits fluorescence because the first phosphor and the second phosphor contained in the light-emitting part **10** are excited by the excitation light E**1**. The detailed configuration of the light-emitting part **10** will be described later.

[0043] Alternatively, the excitation light E**1** emitted from, the laser element **11** may be directly incident on the light-emitting part **10** without passing through the first lens **12**, the optical fiber **13**, and the second lens **14**.

[0044] The casing **16** mainly supports the light-emitting part **10**, the second lens **14**, and the mirror **15**. The material of the casing **16** may be, for example, aluminum. In this case, the heat generated from the light-emitting part **10** can be efficiently released to the outside of the casing **16**. Alternatively, the casing **16** may be formed by coating a member made of a certain member, such, as copper (Cu), stainless steel, or magnesium (Mg), with silver (Ag) or aluminum (Al).

[0045] The projecting lens **17** is a projecting member (projection optical system) that projects the illumination light E**2** including at least the fluorescence emitted from the light-emitting part **10** to the outside. The projecting lens **17** is arranged to face the light-emitting part **10**. The projecting lens **17** projects the illumination light E**2** emitted from the light-emitting part **10** in a predetermined angle range by refracting the illumination light E**2**. In this embodiment, the illumination light E**2** including the fluorescence and the excitation light E**1** scattered by the light-emitting part **10** is projected by the projecting lens

[0046] In this embodiment, a convex lens is used as the projecting lens **17**. The projecting lens **17** may be either of a spherical lens and an aspherical lens. The material of the projecting lens **17** is appropriately selected from, for example, acrylic resin, polycarbonate, silicon resin, borosilicate glass, BK7, and quartz. The projecting lens **17** may be a single lens as illustrated in FIG. **2** or a plurality of lenses.

[0047] The projection optical system may have another configuration, such as a projector type configuration using both a mirror and a convex lens, or a configuration using a reflector (concave mirror), instead of the projecting lens **17**. The reflector is, for example, a parabolic mirror (parabolic reflector) having a reflective curved surface including at least a portion of a partial curved surface that is obtained by cutting a reflective curved surface which is defined by rotating a parabola around a symmetric axis of the parabola as a rotation axis, in a plane parallel to the rotation axis. If the reflector is used as the projection optical system, the light-emitting part **10** is arranged at a substantially focal position of the reflector.

<Specific Configuration of Light-Emitting Part **10**>

[0048] Next, a specific configuration of the light-emitting part **10** is described with reference to FIG. **1**. FIG. **1** illustrates an outline configuration of the light-emitting part **10** of reflective type. As illustrated in FIG. **1**, the light-emitting part **10** includes a substrate **1**, and a phosphor film including a first phosphor layer La**1** and a second phosphor layer La**2**.

[0049] The first phosphor layer La**1** is a layer containing a particulate first phosphor that receives the excitation light E**1** and emits first fluorescence. The second phosphor layer La**2** is a layer containing a particulate second phosphor that receives the excitation light E**1** and emits second fluorescence. The first phosphor layer La**1** and the second phosphor layer La**2** are stacked on the substrate **1**. That is, the light-emitting part **10** has a double-layer structure.

[0050] In this embodiment, as illustrated in FIG. **1**, the first phosphor layer La**1** and the second phosphor layer La**2** are stacked on the substrate **1** in that order from an incidence side of the excitation light E**1**. That is, the first phosphor layer La**1** is arranged on a side far from the substrate **1**. The excitation light E**1** is incident on a surface of the first phosphor layer La**1** (an upper surface of the first phosphor layer La**1**) on a side opposite to a surface of the first phosphor layer La**1** facing the second phosphor layer La**2**. Then, the illumination light E**2** including the first fluorescence and the second fluorescence is emitted from the upper surface of the first phosphor layer La**1**. That is, in the light-emitting part **10**, the surface on which the excitation light E**1** is mainly incident and the surface from which the fluorescence is mainly emitted to the outside are the same surface. In this application, such a light-emitting part is called a “reflective-type” light-emitting part.

[0051] For the first phosphor and the second phosphor, for example, an oxynitride-based phosphor (for example, SiALON phosphor) may be used. The oxynitride-based phosphor has high heat resistance against laser light with high output (and/or optical density) emitted from the laser element **11**, and hence is optimal for a laser illumination light source. Alternatively, for the first phosphor and the second phosphor, a YAG-based (yttrium-aluminum-garnet-based) phosphor may be used. Still alternatively, a nitride phosphor or the like may be used as the first phosphor and the second phosphor.

[0052] In this embodiment, the first phosphor and the second phosphor each are a yellow luminescent phosphor that emits yellow light, which is a YAG-based phosphor (for example, YAG:Ce phosphor). The YAG:Ce phosphor emits yellow fluorescence with a peak wavelength of about 550 nm. In this embodiment, the first phosphor is named first YAG phosphor **3**. Also, the second phosphor is named second YAG phosphor **2**. Alternatively, a Ca-α-SiAlON:Eu phosphor may be used as the first phosphor and the second phosphor being the yellow luminescent phosphor.

[0053] In this embodiment, the light-emitting part **10** contains the first YAG phosphor **3** and the second YAG phosphor **2**. By irradiating the first YAG phosphor **3** and the second YAG phosphor **2** with excitation light E**1** of 450 nm (blue) (or excitation light E**1** of near blue having a peak wavelength in a wavelength range from 440 nm to 490 nm), white light (so-called quasi white light) as the illumination light E**2** can be obtained. For example, the illumination light of a headlamp; has to be white having a chromaticity in a prescribed range. This is determined by law. The illuminator **100** can transmit white light as the illumination light E**2**, and hence the illuminator **100** can be applied as a headlamp (vehicle headlight).

[0054] The first phosphor and the second phosphor do not have to be of the same kind, and may be phosphors of two or more kinds. For example, although described later according to Embodiment 2, the light-emitting part **10** may contain a green luminescent phosphor and a red luminescent phosphor, and the white light may be obtained by irradiating the phosphors with the excitation light E**1** of blue or near blue. Also, the light-emitting part **10** may contain blue, green, and red phosphors, and by irradiating the phosphors with excitation light E**1** of 405 nm (that is, blue violet excitation light), white light may be generated as the illumination light E**2**. In this case, the laser element **11** emits blue violet excitation light. Also, in this case, by providing a filter that cuts the excitation light E**1** of 405 nm, the illumination light E2 that is emitted from the light-emitting part **10** may contain only the fluorescence excited by the light-emitting part **10**.

[0055] Also, the white light as the illumination light E2 does not have to be emitted from the light-emitting part **10**. That is, the oscillation wavelength range of the laser element **11**, and the kinds of the first phosphor and the second phosphor are appropriately selected so that the illumination light E2 of a color that is required for a light-emitting device can be emitted.

[0056] Also, particles of the first YAG phosphor **3** are preferably bound to one another, particles of the second YAG phosphor **2** are preferably bound to one another, and the second YAG phosphor **2** and the substrate **1** are preferably bound to one another by a binding material (binder). That is, the first YAG phosphor **3** and the second YAG phosphor **2** are preferably coated with the binding material. Accordingly, adhesion between the particles of the first YAG phosphor **3**, adhesion between the particles of the second YAG phosphor **2**, and adhesion between the second YAG phosphor **2** and the substrate **1** are increased.

[0057] The binding material is preferably made of an inorganic transparent material with high heat resistance. For example, the material of the binding material may be SiO_2 (silicon dioxide) or TiO_2 (titanium dioxide). If an inorganic material is used for the binding material, the first phosphor layer La**1** and the second phosphor layer La**2** can be fabricated so as not to contain an organic substance. The characteristics of the light-emitting part **10** can be prevented from being deteriorated due to the irradiation with the excitation light E**1**.

[0058] In this embodiment, because of the coating with the binding material, the particles of the first YAG phosphor **3** do not directly contact one another, the particles of the second YAG phosphor **2** do not directly contact one another, and the second YAG phosphor **2** and the substrate **1** do not contact one another. However, the configuration is not limited thereto. For example, the substrate **1** and the second YAG phosphor **2** may directly contact one another, and the first YAG phosphor **3** and the second YAG phosphor **2** may directly contact one another.

[0059] Further, in this embodiment, after the coating with the binding material, a gap is formed between the particles of the first YAG phosphor **3**, a gap is formed between the particles of the second YAG phosphor **2**, and a gap is formed between the second YAG phosphor **2** and the substrate **1**. In the case of this configuration, the excitation light E1 and the fluorescence are likely scattered due to a difference in refractive index between the phosphor and the air in the gap. However, if this point is not considered, the gap may be completely filled with the binding material.

[0060] Also, in this embodiment, as illustrated in FIG. **1**, the particle size of the first YAG phosphor **3** arranged on the incidence side of the excitation light E**1** is smaller than the particle size of the second YAG phosphor **2** arranged on the side near the substrate **1**. The particle size of the first YAG phosphor **3** having a relatively small particle size is, for example, preferably in a range from 1 μm to 10 μm. If the particle size of the first YAG phosphor **3** is smaller than 1 μm, luminous efficiency tends to be decreased. In contrast, particularly if the particle size of the first YAG phosphor **3** is equal to or smaller than 10 μm, the incident excitation light E**1** and the illumination light E2 to be emitted can be efficiently scattered.

[0061] In this case, the particle size in this application indicates a median size (d50). The median size is a particle size when phosphors are divided into two groups on the basis of the particle size (particle diameter) and when the group with large particle sizes and the group with small particle sizes have equivalent amounts of the phosphors. The particle size of the first YAG phosphor **3** and the particle size of the second YAG phosphor **2** can be discriminated from one another by observing cross sections of the phosphors perpendicular to the substrate **1** by using an electronic microscope or the like. In particular, the particle size of the first YAG phosphor **3** arranged on the side far from the substrate **1** can be discriminated by observing the phosphors in a direction perpendicular to the substrate **1** by using an electronic microscope or the like.

[0062] The substrate **1** is supported by the first phosphor layer La**1** and the second phosphor layer La**2**. The substrate **1** is preferably made of, for example, metal or ceramics. In this case, the heat generated from, the first phosphor layer La**1** and the second phosphor layer La**2** can be efficiently released. Also, the substrate **1** is preferably made of, for example, aluminum or silver, having high reflectivity of light among metal. In this case, the excitation light E**1** that is not absorbed by the first phosphor layer La**1** and the second, phosphor layer La**2** can be efficiently emitted toward the first phosphor layer La**1** and second phosphor layer La**2** again, in addition to the heat release effect. Hence, efficiency of using the excitation light E**1** by the light-emitting part **10** can be increased.

[0063] If the second YAG phosphor **3** directly contacts the substrate **1**, the heat generated from the first phosphor-layer La**1** and the second phosphor layer La**2** can be more efficiently released to the substrate **1**. If the first YAG phosphor **2** directly contacts the second YAG phosphor **3**, the heat generated from the first phosphor layer La**1** can be further efficiently released to the substrate **1**.

[0064] Also, the size of the substrate **1** when viewed from the incidence side of the excitation light E**1** is equal to the size of the first phosphor layer La**1** and the second phosphor layer La**2**, or larger than the size of the first phosphor layer La**1** and the second phosphor layer La**2**.

[0065] In the light-emitting part **10** according to this embodiment, the blue light serving as the excitation light E**1** is emitted on the first phosphor layer La**1** containing the first YAG phosphor **3** having a relatively small particle size. In the first phosphor layer La**1**, the first YAG phosphor **3** absorbs the excitation light E**1**, and emits yellow-fluorescence serving as first fluorescence. Then, in the second phosphor layer La**2** containing the second YAG phosphor **2** having a relatively large particle size, the second YAG phosphor **2** absorbs the excitation light E**1** not absorbed by the first YAG phosphor **3** and the excitation light E**1** reflected by the substrate **1**, and emits yellow fluorescence serving as second fluorescence. (1) The excitation light E**1** not absorbed by the first YAG phosphor **3** and the second YAG phosphor **2**, and (2) the yellow fluorescence serving as the first fluorescence and the second fluorescence are mixed and the illumination light E**2** serving as quasi white light is emitted from the first phosphor layer La**1**.

[0066] When the excitation light E**1** is incident on the light-emitting part **10**, and when the illumination light E**2** is emitted from the light-emitting part **10**, the excitation light E**1** and the illumination light E**2** are emitted on the first YAG phosphor **3** contained in the first phosphor layer La**1** and having a relatively small particle size. Also, since the particle size of the first YAG phosphor **3** is smaller than the particle size of the second YAG phosphor **2**, the gap between the particles of the first YAG phosphor **3** in the first phosphor layer La**1** is smaller than the gap between the particles of the second YAG phosphor **2** in the second phosphor layer La**2**. Hence, the above-described excitation light E**1** and illumination light E**2** can be efficiently scattered. Accordingly, occurrence of color unevenness can be efficiently reduced in the illumination light E**2** that is emitted from the light-emitting part **10**.

[0067] Also, if the kinds of the first phosphor and the second phosphor constituting the light-emitting part **10** are the same kind and only the fluorescence excited by the excitation light E**1** is emitted from the light-emitting part **10**, occurrence of luminance unevenness can be efficiently reduced in the illumination light E**2** emitted from the light-emitting part **10** and containing only the fluorescence.

<Method for Producing Light-emitting Part **10**>

[0068] Next, a method for producing the light-emitting part **10** is described. The light-emitting part **10** is produced by, for example, sedimentation.

[0069] In the sedimentation, the first YAG phosphor **3** and the second YAG phosphor **2** are charged into a solvent (for example, ethanol), the resultant is stirred, and hence slurry is prepared. At this time, a dispersant and a binder may be added and mixed. Then, the substrate **1** is dipped in the slurry in which the first YAG phosphor **2** and the second YAG phosphor **3** are dispersed, and hence the first YAG phosphor **2** and the second YAG phosphor **3** are deposited on the substrate **1**. By adding and mixing the dispersant, the sedimentation speed of the first YAG phosphor **2** and the second YAG phosphor **3** can be decreased, and the thicknesses of the first phosphor layer La**1** and the second phosphor layer La**2** can be easily controlled. Also, by adding and mixing the binder, the adhesion between the first phosphor layer La**1** and the second phosphor layer La**2** is increased. Then, the substrate **1** on which the first YAG phosphor **2** and the second YAG phosphor **3** are deposited is taken out from the slurry, and dried. Then, to increase the adhesion between the particles of the first YAG phosphor **2**, the adhesion between the particles of the second YAG phosphor **3**, and the adhesion between the second YAG phosphor **2** and the substrate **1**, the first YAG phosphor **2** and the second YAG phosphor **3** are coated with the above-described binding material.

[0070] In general, the sedimentation speed depends on the density and particle size of a phosphor contained in a light-emitting part. In the case of a phosphor of the same kind, the density of the phosphor in the light-emitting part is substantially uniform, and hence particles of the phosphor with a larger particle size are more likely deposited on the side near the substrate.

[0071] In this embodiment, the first YAG phosphor **2** and the second YAG phosphor **3** of the same kind are used. Hence, the second YAG phosphor **2** having a relatively large particle size is stacked on the substrate **1**, and then the first YAG phosphor **3** having a relatively small particle size is stacked on the second YAG phosphor **2**. Accordingly, as illustrated in FIG. **1**, the second phosphor layer La**2** containing the second YAG phosphor **2** is formed on the side near the substrate **1**, and the first phosphor layer La**1** containing the first YAG phosphor **3** is formed on the side far from the substrate **1** (that is, the incidence side of the excitation light E**1**).

[0072] In the above-described sedimentation, the first YAG phosphor **3** and the second YAG phosphor **2** having different particle-size distributions are mixed in the slurry in advance; however, it is not limited thereto.

[0073] For example, the second YAG phosphor **2** having a relatively large particle size is dispersed in slurry. Then, the substrate **1** is clipped in the slurry in which the second YAG phosphor **2** is dispersed, and hence the second YAG phosphor **2** is deposited on the substrate **1**. Thereafter, the substrate **1** on which the second YAG phosphor **2** is deposited is taken out from the slurry, and dried.

[0074] Then, the first YAG phosphor **3** having a relatively small particle size is dispersed in slurry. Then, the substrate **1** on which the second YAG phosphor **2** is deposited is dipped in the slurry in which the first YAG phosphor **3** is dispersed, and hence the first YAG phosphor **3** is deposited on the second YAG phosphor **2**. Then, the substrate **1** on which the first YAG phosphor **3** and the second YAG phosphor **2** are deposited is taken out from the slurry, and dried.

[0075] Like the above-described process, the first YAG phosphor **3** and the second YAG phosphor **2** are coated with the binding material. The coating using the binding material may be performed as follows. For example, after the second YAG phosphor **2** is deposited and hence the second phosphor layer La**2** (first phosphor layer) is formed, the second YAG phosphor **2** is coated with the binding material. Then, after the first YAG phosphor **3** is deposited on the second phosphor layer La**2** and hence the first phosphor layer La**1** (second phosphor layer) is formed, the first YAG phosphor **3** is coated with the binding material.

[0076] In electrophoresis, the first YAG phosphor **3**, the second YAG phosphor **2**, and a dispersant are charged into a solvent, and hence slurry is prepared. At this time, a binder may be added and mixed. By adding and mixing the binder, the adhesion between the first phosphor layer La**1** and the second phosphor layer La**2** is increased. First, two electrodes are arranged at upper and lower positions in the slurry, and the substrate **1** is arranged as the lower electrode. Then, a voltage is applied in such a way that the first YAG phosphor **3** and the second YAG phosphor **2** are deposited on the substrate **1**. At this time, the substrate **1** is preferably made of metal because the substrate **1** needs to be conductive. The first YAG phosphor **3** and the second YAG phosphor **2** are settled simultaneously when moved due to an electric field. Hence, the second phosphor layer La**2** containing the second YAG phosphor **2** is formed on the side near the substrate **1**, and the first phosphor layer La**1** containing the first YAG phosphor **3** is formed on the side far from the substrate **1** (that is, the incidence side of the excitation light E**1**).

[0077] In the above-described electrophoresis, the first YAG phosphor **3** and the second YAG phosphor **2** having different particle-size distributions are mixed in the slurry in advance; however, it is not limited thereto. The first YAG phosphor **3** and the second YAG phosphor **2** may be prepared in different slurry, and deposited at different timing like the sedimentation. Alternatively, the method for producing the light-emitting part **10** may be provided by screen printing, application using a dispenser, or another method, without limiting to the sedimentation and the electrophoresis.

[0078] In the screen printing, first, a screen mask having a mesh made of synthetic fiber or metal fiber is arranged on the substrate **1**, ink containing the second YAG phosphor **2** is discharged by a squeegee via the mesh, and hence the second phosphor layer La**2** is formed on the substrate **1**. Then, a screen mask is arranged on the second phosphor layer La**2**, ink containing the first YAG phosphor **3** is discharged via the mesh, and hence the first phosphor layer La**1** is formed on the second phosphor layer La**2**. Also, a metal mask without a mesh may be used as a screen mask. This case is more preferable because a mark of the mesh does not remain on the first phosphor layer La**1** and the second phosphor layer La**2**. The ink contains phosphor particles including the first YAG phosphor **3** and the second YAG phosphor **2**, an organic solvent serving as a dispersion medium, a resin for increasing viscosity, and a dispersing material. Organic components other than the phosphor particles are eliminated by firing at high temperature after the application by printing. By coating the first phosphor layer La**1** and the second phosphor layer La**2** with a binding material after the firing, the adhesion between the first phosphor layer La**1** and the second phosphor layer La**2** is increased. The binding material may be added to the ink in advance, and the resultant may be applied by printing.

[0079] In the application method using the dispenser, first, an organic solvent in which the second YAG phosphor **2** is dispersed is discharged from, the dispenser, and hence the second phosphor layer La**2** is formed on the substrate **1**. Then, a solvent in which the first YAG phosphor **3** is dispersed is discharged from, the dispenser, and hence the first phosphor layer La**1** is formed on the second phosphor layer La**2**. Then, the resultant is fired at high temperature, and hence organic components are eliminated. By coating the first phosphor layer La**1** and the second phosphor layer La**2** with a binding material after the firing, the adhesion between the first phosphor layer La**1** and the second phosphor layer La**2** is increased.

[0080] In particular, when the light-emitting part **10** is produced by using the sedimentation or the electrophoresis, such a method is desirable because the first phosphor layer La**1** and the second phosphor layer La**2** can be simultaneously deposited.

<Advantageous Effects of Light-Emitting Part **10**>

[0081] In the light-emitting part **10** according to this embodiment, the first phosphor layer La**1** containing the first YAG phosphor **3** having a smaller particle size than the particle size of the second YAG phosphor **2** is arranged on the side far from the substrate **1**. The excitation light E**1** is incident on the first phosphor layer La**1**. Accordingly, as described above, occurrence of luminance unevenness or color unevenness can be efficiently reduced in the illumination light E**2** that is emitted from the light-emitting part **10**.

[0082] Also, with the light-emitting part **10** according to this embodiment, the problems that arise in the conventional light-emitting device can be addressed. This point is described with reference to FIG. **3**(*a*) to FIG. **3**(*c*). FIG. **3**(*a*) illustrates an outline configuration of a light-emitting part **10***a* according to a comparative example of this embodiment, in which only the second phosphor layer La**2** is arranged on the substrate **1**. That is, in the light-emitting part **10***a*, only the second YAG phosphor **2** having a relatively large particle size is stacked on the substrate **1**. FIG. **3**(*b*) illustrates an outline configuration of a light-emitting part **10***b* according to a comparative example of this embodiment, in which only the first phosphor layer La**1** is arranged on the substrate **1**. That is, only the first YAG phosphor **3** having a relatively small particle size is stacked. FIG. **3**(*c*) illustrates an outline configuration of the light-emitting part **10** according to this embodiment.

[0083] As illustrated in FIG. **3**(*a*), since the light-emitting part **10***a* uses only the second YAG phosphor **2** having a relatively large particle size, the absorption index of the excitation light E**1** being incident on the second YAG phosphor **2** is higher than that of the light-emitting part **10***b*. Hence, luminous efficiency with respect to the excitation light E**1** is higher than that of the light-emitting part **10***b*. However, when the excitation light E**1** is incident on the light-emitting part **10**, and when the illumination light E**2** is emitted from the light-emitting part **10**, the excitation light E**1** and the illumination light E**2** are less likely scattered.

[0084] Also, in general, if the absorption index of excitation light is high, it is required to decrease the density of fluorescence contained in a light-emitting part in order to obtain a desirable color for illumination light. Since the light-emitting part **10***a* has high absorption index of the excitation light E**1**, it is required to decrease the density of the second YAG phosphor: **2** contained in the second phosphor layer La**2**. Hence, the gap between the second phosphor layers La**2** is increased, the excitation light E**1** and the yellow fluorescence are less likely mixed, and color unevenness in the illumination light E**2** becomes noticeable.

[0085] Further, since the gap is increased, the surface of the substrate **1** is exposed, and the surface may be viewed from the incidence side of the excitation light E**1** (that is, the emission side of the illumination light E**2**). In this case, the excitation light E**1** directly emitted on the substrate **1** and reflected by the substrate **1** is not emitted on the second YAG phosphor **2**, is likely added to the illumination light E**2**, and is emitted.

[0086] In contrast, as illustrated in FIG. **3**(*b*), since the light-emitting part **10***b* uses only the first YAG phosphor **3** having a relatively small particle size, the absorption index (that is, luminous efficiency) of the excitation light E**1** is lower than that of the light-emitting part **10***a*. Accordingly, to compensate for the decrease in absorption index, it is required to increase the amount of the first YAG phosphor **3**. Consequently, as illustrated in FIG. **3**(*b*), the film thickness of the first phosphor layer La**1** is increased. Since the film thickness is increased, heat release effect is decreased.

[0087] In contrast, since the light-emitting part **10***b* uses the first YAG phosphor **3** having a relatively small particle size, the excitation light E**1** and the illumination light E**2** can be efficiently scattered at the surface of the first YAG phosphor **3** when the excitation light E**1** is incident and the illumination light E**2** is emitted, as compared with the light-emitting part **10***a*. Accordingly, occurrence of color unevenness can be efficiently reduced in the illumination light E**2**. Also, it is not required to decrease the density of the first YAG phosphor **3** contained in the first phosphor-layer La**1** in order to obtain a desirable color for the illumination light E**2**.

[0088] In the light-emitting part **10** according to this embodiment illustrated in FIG. **3**(*c*), the first phosphor layer La**1** containing the first YAG phosphor **3** having a relatively small particle size is arranged on the side far from the substrate **1**, as described above. The excitation light E**1** is incident on the first phosphor layer La**1**.

[0089] Since the first YAG phosphor **3** having a relatively small particle size is arranged on the side which is irradiated with the excitation light E**1** first, the excitation light E**1** can be efficiently scattered like the light-emitting part **10***b*. Also, the excitation light E**1** can be efficiently scattered when the illumination light E**2** is emitted like the light-emitting part **10***b*. Further, since the excitation light E**1** can be efficiently scattered, the excitation light E**1** and the yellow fluorescence are likely mixed. Accordingly, occurrence of color unevenness can be efficiently reduced in the illumination light E**2**.

[0090] If the first YAG phosphor **3** having a relatively small particle size is used, luminous efficiency with respect to the excitation light E**1** is decreased as described above. However, in the light-emitting part **10**, the second phosphor layer La**2** containing the second YAG phosphor **2** having a relatively large particle size is arranged on the side near the substrate **1**. Hence, even when the first YAG phosphor **3** having a relatively small particle size is used, the luminous efficiency can be prevented from being decreased. Also, by arranging the second phosphor layer La**2**, the film thickness of the light-emitting part **10** can be decreased. Hence, since the distance to the uppermost surface of the light-emitting part **10** (that is, the emission surface of the illumination light E**2**, and the upper surface of the first phosphor layer La**1**) is decreased, heat release effect can be increased.

[0091] Also, even when the second YAG phosphor **2** having a relatively large particle size is used, since the first YAG phosphor **3** having a relatively small particle size is stacked, an exposed portion is not present in the surface of the substrate **1**. Hence, the excitation light E**1** reflected by the substrate **1** is not directly emitted to the outside, and safety can be increased.

(Difference from PTL 1)

[0092] The semiconductor light-emitting device in PTL 1 includes a so-called transmissive-type light-emitting part (resin layer) ("transmissive-type" light-emitting part will be described in Embodiment 5). If the light-emitting part is used for a so-called reflective-type light-emitting part, excitation light passes through a scattering material (light scattering layer) contained in a resin layer before the excitation light is incident on a phosphor. Hence, light-beams of illumination light may be decreased due to multiple scattering, and the excitation light not absorbed by the phosphor and reflected by the phosphor may be increased. Also, when a phosphor having a relatively small particle size is dispersed in the resin layer, since the phosphor is separated from a light-emitting element (that is, element substrate), the temperature of the resin layer rises. As a result, the resin layer may be deteriorated, and luminous efficiency may be decreased.

[0093] In contrast, in the light-emitting part **10** according to this embodiment, the excitation light E**1** is incident on the first YAG phosphor **3** having a relatively small particle size, and the illumination light E**2** is emitted from the first YAG phosphor **3**. Accordingly, occurrence; of color unevenness can be efficiently reduced without the scattering material. Since the scattering material is not provided, the decrease in light beams and the occurrence of reflected excitation light as described above can be reduced. Also, since the scattering material is not provided, the first YAG phosphor **3** and the second YAG phosphor **2** can efficiently absorb the excitation light E**1**.

[0094] Further, since the first YAG phosphor **3** and the second YAG phosphor **2** are stacked on the substrate (not dispersed in the resin layer), the neat generated from the first YAG phosphor **3** and the second YAG phosphor **2** can be efficiently released. Hence, occurrence of the deterioration in the light-emitting part **10** and the decrease in luminous efficiency as described above can be reduced.

Example

[0095] FIG. **4** provides illustrations for explaining a difference in projection pattern of illumination light E**2** due to a difference in particle size of phosphors stacked on a substrate **1**. FIG. **4**(*a*) illustrates an experimental result of a light-emitting part **10** according to this example. FIG. **4**(*b*) illustrates an experimental result of a light-emitting part **10***a* according to a comparative example.

[0096] In FIG. **4**, a laser element **11** that emits excitation light E**1** having a peak wavelength of 445 nm was used as an excitation light source. A first YAG phosphor **3** having a particle size (d50) of 9 μm was used. A second YAG phosphor **2** having a particle size (d50) of 13 μm was used. Illumination light E**2** emitted from the light-emitting part **10** and the light-emitting part **10***a* were projected on a white wall surface from a projecting lens **17**. The projection patterns formed by the illumination light E**2** projected on the wall surface were captured. FIG. **4**(*a*) illustrates the result of capturing the projection pattern formed by the illumination light E**2** emitted from, the light-emitting part **10**. FIG. **4**(*b*) illustrates the result of capturing the projection pattern formed by the illumination light E**2** emitted from the light-emitting part **10***a*.

[0097] Comparing FIG. **4**(*a*) with FIG. **4**(*b*), in FIG. **4**(*b*), a near field, pattern of a phosphor layer of the light-emitting part **10***b* substantially directly appears, in which phosphor particles are yellow, gaps between the phosphor particles are blue, and the yellow color and the blue color are separated from one another. In contrast, in FIG. **4**(*a*), gaps between phosphor particles are almost not present, the yellow color and the blue color are mixed and appear white, and hence color unevenness is reduced by a certain degree that does not cause a problem in practical use. That is, the color unevenness of the projection pattern (FIG. **4**(*a*)) obtained from the light-emitting part **10** according to this example is more reduced, compared with the color unevenness of the projection pattern (FIG. **4**(*b*)) obtained from the light-emitting part **10***a* according to the comparative example.

Embodiment 2

[0098] Another embodiment of the present invention is described as follows with reference to FIG. **5**. For the convenience of description, the same reference sign is applied to a member having the same function as that of the member described in the aforementioned embodiment, and the description thereof is omitted.

[0099] FIG. **5** illustrates an outline configuration of a light-emitting part **20** (light-emitting body) according to this embodiment. The light-emitting part **20** of reflective type uses a green luminescent phosphor **5** as a first phosphor-contained in a first phosphor layer La**1**, and uses a red luminescent phosphor **4** as a second phosphor contained in a second phosphor layer La**2**. The light-emitting part **20** differs from, the light-emitting part **10** according to Embodiment 1 for this point. That is, the light-emitting part **20**

according to this embodiment has a structure in which a first phosphor and a second phosphor of two kinds (i.e., different kinds) having mutually different emission wavelengths are stacked.

[0100] As illustrated in FIG. **5**, the green luminescent phosphor **5** having a relatively small particle size and contained in the first phosphor layer La**1** arranged on the incidence side of excitation light E**1** (that is, the emission side of illumination light E**2**, and the side far from the substrate **1**) emits, for example, green fluorescence (first-fluorescence) with a peak wavelength (emission peak wavelength) of about 530 nm. For the green luminescent phosphor **5**, for example, a β-SiAlON phosphor may be used.

[0101] Also, the red luminescent phosphor **4** having a relatively large particle size and contained in the second phosphor layer La**2** arranged on the side near the substrate **1** emits, for example, red fluorescence (second fluorescence) with a peak wavelength of about 630 nm. For the red luminescent phosphor **4**, for example, a $CaAlSiN_3$:Eu phosphor (CASN phosphor), or (Sr, Ca) $AlSiN_3$:Eu phosphor (SCASN phosphor) may be used.

[0102] In this embodiment, the light-emitting part **20** emits illumination light E**2** serving as white light in which blue light serving as excitation light E**1**, green fluorescence emitted from the green luminescent phosphor **5**, and red fluorescence emitted from the red luminescent phosphor **4** are mixed.

[0103] Also, in this embodiment, the peak wavelength of the red luminescent phosphor **4** contained in the second phosphor layer La**2** arranged on the side near the substrate **1** is longer than the peak wavelength of the green luminescent phosphor **5** contained in the first phosphor layer La**1** arranged on the incidence side of the excitation light E**1**. The fluorescence from the second phosphor layer La**2** is incident on the first phosphor layer La**1**. However, if a phosphor with a peak wavelength longer than that of the phosphor contained in the second phosphor layer La**2** is contained in the first phosphor layer La**1**, the fluorescence from the second phosphor layer La**2** may excite again the phosphor contained in the first phosphor layer La**1**. Hence, by arranging the green luminescent phosphor **5** having a short wavelength in the first phosphor layer La**1**, and arranging the red luminescent phosphor **4** having a long wavelength in the second phosphor layer La**2**, fluorescence from the second phosphor layer La**2** can be prevented from, being absorbed again by the first phosphor layer La**1**.

[0104] However, if this point is not considered, the red luminescent phosphor **4** having a relatively small particle size may be contained in the first phosphor layer La**1**, and the green luminescent phosphor **5** having a relatively large particle size may be contained in the second phosphor layer La**2**. Also, the first phosphor and the second phosphor having the mutually different peak wavelengths are not limited to the red luminescent phosphor **4** and the green luminescent phosphor **5**. A phosphor that emits other light may be appropriately selected in accordance with the oscillation wavelength range of the excitation light E**1**.

<Advantageous Effects of Light-Emitting Part **20**>

[0105] In the light-emitting part **20**, the green luminescent phosphor **5** having a relatively small particle size is arranged on the incidence side of the excitation light E**1** (the emission side of the illumination light E**2**), and hence occurrence of color unevenness and luminance unevenness can be efficiently reduced like Embodiment 1.

[0106] Since the green luminescent phosphor **5** and the red luminescent phosphor **4** are phosphors of mutually different kinds, the variety of colors of the illumination light E**2** can be increased. For example, a red component may be added to white light serving as the illumination light E**2**. In this case, color rendering properties of the illumination light E**2** can be improved.

[0107] Also, since the kinds of the phosphors are mutually different, even if the illumination light E**2** does not include the excitation light E**1**, the light-emitting part **20** can emit illumination light E**2** with a color similar to the color in the case where the illumination light E**2** includes the excitation light E**1**. For example, the blue luminescent phosphor, the green luminescent phosphor, and the red luminescent phosphor are contained in either of the first phosphor and the second phosphor. Then the phosphors are irradiated with excitation light E**1** of 405 nm. Thus, white light (illumination light E**2**) can be generated only with the fluorescence.

Embodiment 3

[0108] Still another embodiment of the present invention is described as follows with reference to FIG. **6**. For the convenience of description, the same reference sign is applied to a member having the same function as that of the member described in the aforementioned embodiment, and the description thereof is omitted.

[0109] FIG. **6** illustrates an outline configuration of a light-emitting part **30** (light-emitting body) according to this embodiment. The light-emitting part **30** of reflective type uses a green luminescent phosphor **7** as a first phosphor contained in a first phosphor layer La**1**, and uses a red luminescent phosphor **6** as a second phosphor contained in a second phosphor layer La**2**. The light-emitting part **30** differs from, the light-emitting part **10** according to Embodiment 1 for this point. That is, the light-emitting part **30** according to this embodiment has a structure in which the first phosphor and the second phosphor of the two kinds (i.e., different kinds) having mutually different emission wavelengths are stacked.

[0110] As illustrated in FIG. **6**, the green luminescent phosphor **7** having a relatively small particle size and contained in the first phosphor layer La**1** arranged on the incidence side of excitation light E**1** (that is, the emission side of illumination light E**2**, and the side far from the substrate **1**) emits, for example, green fluorescence (first fluorescence) with a peak wavelength (emission peak wavelength) of about 530 nm. For the green luminescent-phosphor **7**, for example, a β-SiAlON phosphor like Embodiment 2 may be used. Also, the green luminescent phosphor **7** has smaller thermal quenching than that of the red luminescent phosphor **6**.

[0111] Also, the red luminescent phosphor **6** having a relatively large particle size and contained in the second phosphor layer La**2** arranged on the side near the substrate **1** with respect to the first phosphor layer La**1** emits, for example, red fluorescence (second fluorescence) with a peak wavelength of about 630 nm. For the red luminescent phosphor **6**, for example, a CASN phosphor or a SCASN phosphor like Embodiment 2 may be used. Also, the red luminescent phosphor **6** has larger thermal quenching than that of the green luminescent phosphor **7**.

[0112] That is, in the light-emitting part **30**, the green luminescent phosphor **7** having a relatively small particle size and having relatively small thermal quenching is arranged on the incidence side of the excitation light E**1**, and the red luminescent phosphor **6** having a relatively large particle size and having relatively large thermal quenching is arranged on the side near the substrate **1**.

[0113] The thermal quenching represents that the luminous efficiency of a phosphor decreases as the temperature rises. The state in which the thermal quenching is large (or small) represents that the degree of decrease in luminous efficiency of a phosphor with respect to the rate of temperature rise is large (or small).

[0114] The light-emitting part **30** emits illumination light E**2** serving as white light in which blue light serving as excitation light E**1**, green fluorescence emitted from the green luminescent phosphor **7**, and red fluorescence emitted from, the red luminescent phosphor **6** are mixed.

[0115] The first phosphor and the second phosphor having the mutually different peak, wavelengths are not limited to the red luminescent phosphor **6** and the green luminescent phosphor **7**. That is, a phosphor having relatively small thermal quenching may be selected as the first phosphor, and a phosphor having relatively large thermal quenching may be selected as the second, phosphor. Also, for the first phosphor and the second phosphor, a phosphor that emits other light may be appropriately selected in accordance with the oscillation wavelength range of the excitation light E**1**.

<Advantageous Effects of Light-Emitting Part **30**>

[0116] The configuration in which the first phosphor and the second phosphor of the mutually different kinds are stacked is similar to the configuration of Embodiment 2; however, this embodiment focuses on the difference in degree of the thermal quenching depending on the kind.

[0117] For example, it is known that a silicate-based phosphor exhibits a large decrease in luminous efficiency with respect to the rate of temperature rise, and a SiAlON phosphor or a YAG phosphor exhibits a small decrease in luminous efficiency with respect to the rate of temperature rise.

[0118] The heat generated from the reel luminescent phosphor **6** and the heat generated from the green luminescent phosphor **7** are released via the substrate **1**. Hence, in the light-emitting part **30**, the temperature is lower as the position is closer to the substrate **1**, and the temperature is higher as the position is farther from the substrate **1**. Hence, in this embodiment, the reel luminescent phosphor **6** having large thermal quenching is deposited on the side near the substrate **1** the temperature of which less likely rises, and the green luminescent phosphor **7** having small thermal quenching is deposited thereon. In other words, the red luminescent phosphor **6** containing a CASN phosphor or a SCASN phosphor having relatively large thermal quenching is arranged at a position closer to the substrate **1** as compared with the green luminescent phosphor **7** containing a β-SiAlON phosphor having relatively small thermal quenching. Hence, the temperature rise of the red luminescent phosphor **6** having a greater degree of decrease in luminous efficiency along with the temperature rise can be reduced with higher priority. Accordingly, the decrease in luminous efficiency of the light-emitting part **30** during excitation by the excitation light E**1** (in particular, strong excitation) can be reduced.

[0119] Further, in the light-emitting part **30**, the green luminescent phosphor **7** having a relatively small particle size is arranged on the incidence side of the excitation light E**1** (the emission side of illumination light E**2**), and hence occurrence of color unevenness and luminance unevenness can be efficiently reduced like Embodiment 1.

Embodiment 4

[0120] Yet another embodiment of the present invention is described as follows with reference to FIG. **7**. For the convenience of description, the same reference sign is applied to a member having the same function as that of the member described in the aforementioned embodiment, and the description thereof is omitted.

[0121] FIG. **7**(*a*) illustrates an outline configuration of a light-emitting part **40** (light-emitting body) according to this embodiment. FIG. **7**(*b*) illustrates an outline configuration of a light-emitting part **50** (light-emitting body) according to this embodiment.

[0122] As illustrated in FIG. **7**(*a*) and FIG. **7**(*b*), the reflective-type light-emitting parts **40** and **50** each have a configuration in which a first phosphor layer La**1** and a second phosphor layer La**2** are entirely or partly covered with a sealing material **8**.

[0123] Specifically, as illustrated in FIG. **7**(*a*), the light-emitting part **40** has a configuration in which a first YAG phosphor **3** serving as a first phosphor, and a second YAG phosphor **2** serving as a second phosphor are completely covered with the sealing material **8**. In contrast, as illustrated in FIG. **7**(*b*), the light-emitting part **50** has a configuration in which a first YAG phosphor **3** and a second YAG phosphor **2** are covered with the sealing material **8** so that a portion of the surface of the first YAG phosphor **3** is exposed. More specifically, in the light-emitting part **50**, an upper surface of the first phosphor layer La**1** (a surface on which excitation light E**1** is incident) is not sealed with the sealing material **8** and is exposed. The surface has protrusions and depressions due to the first YAG phosphor **3** covered with a binding material.

[0124] In other words, the sealing material **8** entirely or partly seals the first phosphor layer La**1** and the second phosphor layer La**2**, and hence fills a gap between particles of the first YAG phosphor **3** serving as the first phosphor, a gap between particles of the second YAG phosphor **2** serving as the second phosphor, and a gap between the first YAG phosphor **3** and the second YAG phosphor **2**. The sealing material **8** is preferably an inorganic compound having high heat resistance and high thermal conductivity, and may be, for example, silica such as SiO_2, or TiO_2. Alternatively, resin or the like may be employed as the sealing material **8**.

[0125] The major configuration of each of the light-emitting parts **40** and **50** other than the sealing material **8** is similar to the configuration of the light-emitting part **10** according to Embodiment 1 illustrated in FIG. **2**. Also, the sealing material **8** may be used for the light-emitting part **20** according to Embodiment 2, and the light-emitting part **30** according to Embodiment 3.

<Advantageous Effects of Light-Emitting Parts **40** and **50**>

[0126] In each of the light-emitting parts **40** and **50**, the first YAG phosphor **3** having a relatively small particle size is arranged on the incidence side of the excitation light E**1** (the emission side of illumination light E**2**), and hence occurrence of color unevenness and luminance unevenness can be efficiently reduced like Embodiment 1.

[0127] Also, in each of the light-emitting parts **40** and **50**, the first phosphor layer La**1** and the second phosphor layer La**2** are entirely or partly sealed with the sealing material **8** to fill the aforementioned gaps. Hence, the thermal conductivity of the entirety of the light-emitting parts **40** and **50** can be increased. Accordingly, the heat generated from, the light-emitting parts **40** and **50** can be further efficiently released.

[0128] Also, as illustrated in FIG. **7**(*b*), in the light-emitting part **50**, the upper surface of the first phosphor layer La**1** is exposed, and the protrusions and depressions are formed at the surface. Hence, the difference in refractive index with respect to the air can be increased at the surface, and the excitation light E**1** can be likely diffused and reflected by the projections and depressions at the surface. Hence, as compared with the light-emitting part **40** in which the upper surface of the first phosphor layer La**1** is completely sealed with the sealing material **8** illustrated in FIG. **7**(*a*), the excitation light E**1** and the illumination light E**2** can be further efficiently scattered. Consequently, since the excitation light E**1** is likely mixed with fluorescence, occurrence of color unevenness can be reduced in the illumination light E**2**. Similar advantageous effects can be attained in any of the light-emitting parts **10** to **30** according to Embodiments 1 to 3.

Embodiment 5

[0129] A further embodiment of the present invention is described as follows with reference to FIGS. **8** and **9**. For the convenience of description, the same reference sign is applied to a member having the same function as that of the member described in the aforementioned embodiment, and the description thereof is omitted. Unlike Embodiments 1 to 4, in this embodiment, an illuminator **200** including a transmissive-type light-emitting part **60** (light-emitting body) is described.

<Outline Configuration of Illuminator **200**>

[0130] FIG. **8** illustrates an outline configuration of the illuminator **200** according to this embodiment. As illustrated in FIG. **8**, the illuminator **200** includes a laser element **11**, a first lens **12**, an optical fiber **13**, the light-emitting part **60**, a fixing jig **62**, a ferrule **103**, a ferrule fixing part **104**, a projecting lens **105** (projecting part), a lens fixing part **106**, and a heat release fin **107**. The light-emitting part **60** and the laser element **11** form a basic configuration of a light-emitting device. Also, the light-emitting part **60**, the laser element **11**, and the projecting lens **105** form a basic configuration of an illuminator.

[0131] The illuminator **200** projects illumination light E**2** including at least fluorescence that is emitted from the light-emitting part **60** when excited by excitation light E**1** emitted from the laser element **11**, in a specific direction by the projecting lens **105**. While this embodiment is described such that the illumination light E**2** includes the excitation light E**1** and the fluorescence, only the fluorescence may be projected as the illumination light E**2**.

[0132] Also, in this embodiment, the illuminator **200** includes a plurality of laser elements **11**. The number of laser elements **11** can be appropriately changed depending on the required output. The first lens **12** is arranged to face corresponding one of the laser elements **11**. The optical fiber **13** has a certain number of incidence ends **13***a* on which the excitation light E**1** is incident and the number of which corresponds to the number of the laser elements **11**, and a single emission end **13***b* from which the excitation light E**1** is emitted to the light-emitting part **60**. The optical fiber **13** may be a fiber bundle in which a certain number of optical fibers corresponding to the number of laser elements **11** are bundled.

[0133] The fixing jig **62** is a member to which the light-emitting part **60** is fixed. The fixing jig **62** has a cylindrical shape. The light-emitting part **60** is thermally bonded to one end of the cylindrical fixing jig **62** by using silicon grease.

[0134] A specific example of the material constituting the fixing jig **62** may be metal, such as aluminum, copper, iron, or silver. The surface of aluminum may be black anodized. In this embodiment, black anodized aluminum is used as the material of the fixing jig **62**.

[0135] The ferrule **103** holds the optical fiber **13**. Specifically, the ferrule **103** holds the periphery of the optical fiber **13** at a position near the emission end **13***b*.

[0136] The ferrule fixing part **104** is a member for fixing the ferrule **103** to the illuminator **200**. The ferrule fixing part **104** is provided at an end portion of the fixing jig **62** on a side opposite to one end to which the light-emitting part **60** is fixed. Since the ferrule **103** is fixed to the ferrule fixing part **104**, the emission end **13***b* of the optical fiber **13** held by the ferrule **103** is fixed at a position facing the light-emitting part **60**.

[0137] The projecting lens **105** is a projecting member (projection optical system) that projects the illumination light E**2** including at least the fluorescence emitted from the light-emitting part **60** to the outside, like the projecting lens **17**.

[0138] The lens fixing part **106** is a member that fixes the relative positions of the light-emitting part **60** and the projecting lens **105**. The lens fixing part **106** is a cylindrical member surrounding the peripheries of the fixing jig **62** and the projecting lens **105**. The material of the lens fixing part **106** is preferably one having high heat release effect. For example, anodized aluminum may be suitably used as the material of the lens fixing part **106**.

[0139] The heat release fin **107** is a member that increases heat release efficiency of the fixing jig **62**. The heat release fin **107** is provided on the side of the fixing jig **62** on which the ferrule fixing part **104** is provided. The shape, size, and number of the heat release fin **107** are determined depending on the output of the laser element **11** and the specifications of the light-emitting part **60**. Hence, the neat release performance of the fixing jig **62** can be increased. Accordingly, the decrease in luminous efficiency of the light-emitting part **60** along with the temperature rise can be reduced.

<Specific Configuration of Light-emitting Part **60**>

[0140] Next, a specific configuration of the light-emitting part **60** is described with reference to FIG. **9**. FIG. **9** illustrates an outline configuration of the light-emitting part **60** of transmissive type. As illustrated in FIG. **9**, the light-emitting part **60** includes a transmissive substrate **61** (substrate), and a phosphor film including a first phosphor layer La**1** and a second phosphor layer La**2**.

[0141] The first phosphor layer La**1** is a layer containing a particulate first phosphor that receives excitation light E**1** and emits first fluorescence. The second phosphor layer La**2**

is a layer containing a particulate second phosphor that receives the excitation light E**1** and emits second fluorescence. The first phosphor layer La**1** and the second phosphor layer La**2** are stacked on the substrate **1**. That is, the light-emitting part **60** has a double-layer structure.

[0142] As illustrated in FIG. **9**, in the light-emitting part **60**, the first phosphor layer La**1** and the second phosphor layer La**2** are stacked on the transmissive substrate **1** in that order from the incidence side of the excitation light E**1**. That is, in the light-emitting part **60**, the first phosphor layer La**1** is arranged on a side near the transmissive substrate **61**, and the excitation light E**1** is incident on a surface of the first phosphor layer La**1** facing the transmissive substrate **61** (that is, a surface of the first phosphor layer La**1** on a side opposite to a surface thereof facing the second phosphor layer La**2**) via the transmissive substrate **61**. Illumination light E**2** including the first fluorescence and the second fluorescence is emitted from a surface of the second phosphor layer La**2** arranged on a side far from the substrate **1** opposite to a surface thereof facing the first phosphor layer La**1** (an upper surface of the second phosphor layer La**2**). That is, in the light-emitting part **60**, the surface on which, the excitation light E**1** is mainly incident and the surface from which the fluorescence is mainly emitted to the outside are opposite to one another. In this application, such, a light-emitting part is called a "transmissive-type" light-emitting part.

[0143] In this embodiment, the first phosphor is a first YAG phosphor **3**, and the second phosphor is a second YAG phosphor **2**, In this embodiment, by irradiating the light-emitting part **60** with excitation light E**1** of 450 nm (blue) (or excitation light E**1** of near blue), white light (so-called quasi white light) serving as the illumination light E**2** can be obtained.

[0144] As described in Embodiment 1, the first phosphor and the second phosphor may be of mutually different kinds, only fluorescence may be emitted as the illumination light E**2**, and light other than white light may be emitted as the illumination light E**2**. That is, the oscillation wavelength range of the laser element **11**, and the kinds of the first phosphor and the second phosphor are appropriately selected so that the illumination light E**2** of a color that is required for a light-emitting device can be emitted.

[0145] Also, like Embodiment 1, particles of the first YAG phosphor **3** are preferably bound to one another, particles of the second YAG phosphor **2** are preferably bound to one another, and the second YAG phosphor **2** and the transmissive substrate **61** are preferably bound to one another by a binding material (binder).

[0146] Also, In this embodiment, as illustrated in FIG. **9**, the particle size of the first YAG phosphor **3** arranged on the incidence side of the excitation light E**1** is smaller than the particle size of the second YAG phosphor **2** arranged on the side far from the transmissive substrate **61**. That is, unlike Embodiment 1, only the first YAG phosphor **3** having a relatively small particle size is arranged on the side near the transmissive substrate **61**.

[0147] The transmissive substrate **61** supports the first phosphor layer La**1** and the second phosphor layer La**2**. The first phosphor layer La**1** and the second phosphor layer La**2** are formed on a surface of the transmissive substrate **61** on the side opposite to the surface thereof on which the excitation light E**1** is incident. For the material of the transmissive substrate **61**, for example, glass or sapphire may be used. The size of the transmissive substrate **61** when viewed from the incidence side of the excitation light E**1** is equal to the size of the first phosphor layer La**1** and the second phosphor layer La**2**, or larger than the size of the first phosphor layer La**1** and the second phosphor layer La**2**.

[0148] In the light-emitting part **60** according to this embodiment, the blue light serving as the excitation light E**1** is transmitted through the transmissive substrate **61** and then is emitted on the first phosphor layer La**1** containing the first YAG phosphor **3** having a relatively small particle size. In the first phosphor layer La**1**, the first YAG phosphor **3** absorbs the excitation light E**1**, and emits yellow fluorescence serving as the first fluorescence. Then, in the second phosphor layer La**2** containing the second YAG phosphor **2** having a relatively large particle size, the second YAG phosphor **2** absorbs the excitation light E**1** not absorbed by the first YAG phosphor **3**, and emits yellow fluorescence serving as the second fluorescence. (1) The excitation light E**1** not absorbed by the first YAG phosphor **3** and the second YAG phosphor **2**, and (2) the yellow fluorescence serving as the first fluorescence and the second fluorescence are mixed, and the illumination light E**2** serving as quasi white light is emitted from, the second phosphor layer La**2**.

[0149] Also, in the light-emitting part **60**, a dielectric, multilayer film that transmits the excitation light E**1** and reflects the fluorescence may be formed between the phosphor film including the first phosphor layer La**1** and the second phosphor layer La**2**, and the transmissive substrate **61**. For the transmissive substrate **61**, sapphire having high thermal conductivity is suitable to release the heat generated from the phosphor film. Also, it is desirable that the transmissive substrate **61** contacts the heat sink.

[0150] The fluorescence generated from the phosphor film is emitted in all directions from, the second phosphor layer La**2**. However, if the dielectric multilayer film is formed, the fluorescence emitted, in a direction, toward the ferrule **103** is reflected in a direction toward the projecting lens **105**. Accordingly, light extraction efficiency from the light-emitting part **60** is increased, and the illuminator **200** having higher luminance can be provided.

[0151] Also, in the light-emitting part **60**, a surface of the transmissive substrate **61** on a side near the ferrule **103** may be provided with AR (Anti-Reflection) coating. In this case, the reflectivity of the excitation light E**1** at the surface of the transmissive substrate **61** is decreased, and the ratio of the excitation, light E**1** to be incident on the phosphor film, is increased. Accordingly, the light extraction efficiency from the light-emitting part **60** is increased, and the illuminator **200** having higher luminance can be provided.

<Method for Producing Light-Emitting Part **60**>

[0152] Next, a method for producing the light-emitting part **60** is described. The light-emitting part **60** is produced by, for example, sedimentation.

[0153] In sedimentation, for example, the first YAG phosphor **3** having a relatively small particle size is dispersed in slurry. Then, the transmissive substrate **61** is dipped in the slurry in which the first YAG phosphor **3** is dispersed, and hence the first YAG phosphor **3** is deposited on the transmissive substrate **61**. Then, the transmissive substrate **61** on which the first YAG phosphor **3** is deposited is taken out from the slurry, and dried.

[0154] Then, the second YAG phosphor **2** having a relatively large particle size is dispersed in slurry. Then, the transmissive substrate **61** on which the first YAG phosphor

3 is deposited is dipped in the slurry in which the second YAG phosphor **2** is dispersed, and hence the second YAG phosphor **2** is deposited on the first YAG phosphor **3**. Then, the transmissive substrate **61** on which the first YAG phosphor **3** and the second YAG phosphor **2** are deposited is taken out from the slurry, and dried.

[0155] The first YAG phosphor **3** and the second YAG phosphor **2** are coated with a binding material. The first YAG phosphor **3** and the second YAG phosphor **2** may be collectively coated after being dried, or may be coated as follows. That is, after the first phosphor layer La**1** (first phosphor layer) is formed, the first YAG phosphor **3** is coated with the binding material. Then, after the second phosphor layer La**2** (second phosphor layer) is formed, the second YAG phosphor **2** is coated with the binding material.

[0156] Also, the method for producing the light-emitting part **60** may be provided by screen printing, application using a dispenser, electrophoresis, or another method, without limiting to the sedimentation. The method for producing the light-emitting part **60** using these methods is substantially similar to the content described in Embodiment 1 except for the following points. That is, in this embodiment, the first phosphor layer La**1** containing the first YAG phosphor **3** is formed on the transmissive substrate **61**, and then the second phosphor layer La**2** containing the second YAG phosphor **2** is formed on the first phosphor layer La**1**.

<Advantageous Effects of Light-Emitting Part **60**>

[0157] In the light-emitting part **60** according to this embodiment, the excitation light E**1** is emitted on the first YAG phosphor **3** contained in the first phosphor layer La**1** and having a relatively small particle size. Hence, since the excitation light E**1** can be efficiently scattered, the excitation light E**1** and the yellow fluorescence are likely mixed. Accordingly, occurrence of color unevenness can be efficiently reduced in the illumination light E**2** that is emitted from the light-emitting part **60**. Also, if the kinds of the first phosphor and the second phosphor constituting the light-emitting part **60** are the same kind and only the fluorescence excited by the excitation light E**1** is emitted from the light-emitting part **60**, occurrence of luminance unevenness can be efficiently reduced in the illumination light E**2** emitted from the light-emitting part **60** and containing only the fluorescence.

[0158] Also, like Embodiment 1, the light-emitting part **60** includes the second phosphor layer La**2** containing the second YAG phosphor **2** having a relatively large particle size. Hence, the decrease in luminous efficiency which may be generated when the first YAG phosphor **3** having a relatively small particle size is used can be prevented. Also, by arranging the second phosphor layer La**2**, as compared with a case where only the first phosphor layer La**1** is stacked on the transmissive substrate **61**, the film thickness of the light-emitting part **60** can be decreased. Hence, since the distance to the uppermost surface of the light-emitting part **60** (that is, the emission surface of the illumination light E**2**, and the upper surface of the second phosphor layer La**2**) is decreased, heat release effect can be increased.

[0159] Also, when only the second YAG phosphor **2** having a relatively large particle size is used for the light-emitting part, as described in Embodiment 1, the gap between the particles of the second YAG phosphor **2** is increased. The surface of the transmissive substrate **61** is exposed, and the surface may be viewed from the emission side of the illumination light E**2**. In this case, the excitation light E**1** emitted from the exposed potion may not be emitted on the second YAG phosphor **2**, and may be directly emitted to the outside of the light-emitting part. In this embodiment, the first YAG phosphor **3** having a relatively small particle size, together with the second YAG phosphor **2**, is stacked on the transmissive substrate **61**. Hence, the excitation light E**1** emitted from the exposed portion is emitted on the first YAG phosphor **3** before the excitation light E**1** is transmitted through the gap. Accordingly, the excitation light E**1** is not directly emitted to the outside, and safety can be increased.

[0160] In general, a phosphor having a relatively small particle size more likely generates heat due to lower internal quantum efficiency as compared with a phosphor having a relatively large particle size. Hence, if the phosphor having a relatively small particle size is arranged on the incidence side of the excitation light, the light-emitting part entirely more likely generates heat.

[0161] In this embodiment, while the first phosphor layer La**1** containing the first YAG phosphor **3** having a relatively small particle size is provided on the incidence side of excitation light E**1**, the first phosphor layer La**1** is arranged on the transmissive substrate **61**. Hence, the heat generated from the first phosphor layer La**1** can be efficiently released to the transmissive substrate **61**. Accordingly, even when the excitation light E**1** is incident on the first phosphor layer La**1**, the heat generated from the light-emitting part **60** can be efficiently released.

<Modification 1>

[0162] In the transmissive-type light-emitting part **60**, the kind of the first phosphor and the kind of the second phosphor may differ from one another. That is, the peak wavelength (emission peak wavelength) of the first phosphor and the peak wavelength of the second phosphor may differ from one another. For example, a red luminescent phosphor that emits red fluorescence (first fluorescence) may be used as the first phosphor having a relatively small particle size, and a green luminescent phosphor that emits green fluorescence (second fluorescence) may be used as the second phosphor having a relatively large particle size.

[0163] In this case, the peak wavelength of the reel luminescent phosphor contained in the first phosphor layer La**1** arranged on the side near the substrate **1** (that is, the incidence side of the excitation light E**1**) is longer than the peak wavelength of the green luminescent phosphor contained in the second phosphor layer La**2** arranged on the first phosphor layer La**1**. In this case, the fluorescence from the first phosphor layer La**1** excites again the phosphor of the second phosphor layer La**2**, and can prevent the luminous efficiency from being decreased.

[0164] Also, since the kind of the first phosphor differs from the kind of the second phosphor as described in Embodiment 2, the variety of colors of the illumination light E**2** can be increased. Also, even if the illumination light E**2** does not include the excitation light E**1**, the light-emitting part **60** can emit illumination light E**2** with a color similar to the case where the illumination light E**2** includes the excitation light E**1**.

[0165] However, if this point is not considered, the green luminescent phosphor having a relatively small particle size may be contained in the first phosphor layer La**1**, and the red luminescent phosphor having a relatively large particle size may be contained in the second phosphor layer La**2**. Also, the first phosphor and the second phosphor having the mutually different peak wavelengths are not limited to the red luminescent phosphor and the green luminescent phosphor. A phosphor that emits other light may be appropriately selected in accordance with the oscillation wavelength range of the excitation light E**1**.

<Modification 2>

[0166] In the transmissive-type light-emitting part **60**, the first phosphor having a relatively small particle size and relatively large thermal quenching may be arranged on the incidence side of the excitation light E**1** (that is, on the side near the transmissive substrate **61**), and the second phosphor having a relatively large particle size and relatively small thermal quenching may be arranged on the emission side of the illumination light E**2**. That is, the thermal quenching of the first phosphor arranged on the side near the transmissive substrate **61** is larger than the thermal quenching of the second phosphor. In this case, like Modification 1, the red luminescent phosphor may be used as the first phosphor, and the green luminescent phosphor may be used as the second phosphor.

[0167] Since the first phosphor having relatively large thermal quenching is arranged on the side near the transmissive substrate **61**, the decrease in luminous efficiency of the light-emitting part **60** during excitation by the excitation light E**1** (in particular, strong excitation) can be reduced like Embodiment 3.

[0168] The first phosphor and the second phosphor having the mutually different peak wavelengths are not limited to the red luminescent phosphor and the green luminescent phosphor. That is, a phosphor having relatively large thermal quenching may be selected as the first phosphor, and a phosphor having relatively small thermal quenching may be selected as the second phosphor. Also, for the first phosphor and the second phosphor, a phosphor that emits other light may be appropriately selected in accordance with the oscillation wavelength range of the excitation light E**1**.

<Modification 3>

[0169] Like Embodiment 4, the transmissive-type light-emitting part **60** may be sealed with the sealing material **8**. In this case, thermal conductivity can be increased for the entire light-emitting part **60**.

[Appendix]

[0170] A light-emitting body (light-emitting part **10**, **20**, **30**, **40**, **50**) according to a first aspect of the invention includes

[0171] a first phosphor layer (La**1**) containing a first phosphor (first YAG phosphor **3**, green luminescent phosphor **5**, **7**) that receives excitation light (E**1**) and emits first fluorescence; and

[0172] a second phosphor layer (La**2**) containing a second phosphor (second YAG phosphor **2**, red luminescent phosphor **4**, **6**) that receives the excitation light and emits second fluorescence, in which

[0173] the first and second phosphor layers are stacked on a substrate (**1**),

[0174] a particle size of the first phosphor is smaller than a particle size of the second phosphor, and

[0175] the first phosphor layer is arranged on a side far from the substrate, and the excitation light is incident on the first phosphor layer,

[0176] With the above-described configuration, the first phosphor layer is arranged on the side far from the substrate, and the excitation light is incident on the first phosphor layer. In this case, when the first fluorescence; and the second fluorescence are emitted from the light-emitting body, the first fluorescence and the second fluorescence are emitted on the first phosphor contained in the first phosphor layer and having a relatively small particle size, the first fluorescence and the second fluorescence can be efficiently scattered. Accordingly, occurrence of luminance unevenness or color unevenness can be efficiently reduced in light that is emitted from the light-emitting body.

[0177] Furthermore, a light-emitting body (light-emitting part **60**) according to a second aspect of the invention includes

[0178] a first phosphor layer (La**1**) containing a first phosphor (first YAG phosphor **3**, red luminescent phosphor) that receives excitation light (E**1**) and emits first fluorescence; and

[0179] a second phosphor: layer (La**2**) containing a second phosphor (second YAG phosphor **2**, green luminescent phosphor) that receives the excitation light and emits second fluorescence, in which

[0180] the first and second phosphor layers are stacked on a substrate (transmissive substrate **61**),

[0181] a particle size of the first phosphor is smaller than a particle size of the second phosphor, and

[0182] the first phosphor layer is arranged on the substrate, and the excitation light is incident on the first phosphor layer.

[0183] In general, a phosphor having a relatively small particle size more likely generates heat due to lower internal quantum, efficiency as compared with a phosphor having a relatively large particle size. Hence, if the phosphor having a relatively small particle size is arranged on the incidence side of the excitation light, the light-emitting body entirely likely generates heat.

[0184] With the above-described configuration, the first phosphor layer is arranged on the substrate, and the excitation light is incident on the first phosphor layer. Hence, even if the first phosphor layer containing the first phosphor having a relatively small particle size is provided on the incidence side of the excitation light, since the first phosphor layer is arranged on the substrate, the heat generated from the first phosphor layer can be efficiently released. Accordingly, even when the excitation light is incident on the first phosphor layer, the heat generated from the light-emitting body can be efficiently released.

[0185] Preferably, in a light-emitting body according to a third aspect of the invention, based on the first or second aspect,

[0186] a kind of the first phosphor differs from a kind of the second phosphor.

[0187] With the above-described configuration, the variety of colors of the light that is emitted by the light-emitting body can be increased. Also, even if the light that is emitted by the light-emitting body does not include the excitation light, the light-emitting body can emit light with a color similar to the color in the case where the light includes the excitation light.

[0188] Preferably, in a light-emitting body according to a fourth aspect of the invention, based on the first aspect, an emission peak wavelength of the second phosphor is longer than an emission peak wavelength of the first phosphor.

[0189] With the above-described configuration, the first phosphor can be prevented from, being excited again by the fluorescence from the second phosphor.

[0190] Preferably, in a light-emitting body according to a fifth aspect of the invention, based on the second aspect,

[0191] an emission peak wavelength of the first phosphor is longer than an emission peak wavelength of the second phosphor.

[0192] With the above-described configuration, the second phosphor can be prevented from being excited again by the fluorescence from the first phosphor.

[0193] Preferably, in a light-emitting body according to a sixth aspect of the invention, based on the first aspect, the second phosphor layer is arranged on a side near the substrate with respect to the first phosphor layer, and thermal quenching of the second phosphor is larger than thermal quenching of the first phosphor.

[0194] In general, when excitation light is incident on a light-emitting body, the temperature of the light-emitting body on the incidence side of the excitation light is higher than the temperature on a side near a substrate.

[0195] With the above-described configuration, the second phosphor having larger thermal quenching than that of the first phosphor is arranged on the side near the substrate. Hence, thermal quenching less likely occurs in the second phosphor as compared with the first phosphor. Accordingly, the luminous efficiency of the light-emitting body can be prevented from, being decreased.

[0196] Preferably, in a light-emitting body according to a seventh aspect of the invention, based on the second aspect,

[0197] thermal quenching of the first phosphor is larger than thermal quenching of the second phosphor.

[0198] With the above-described configuration, the first phosphor having larger thermal quenching than that of the second phosphor is arranged on the side near the substrate. Hence, thermal quenching less likely occurs in the first phosphor as compared with the second phosphor. Accordingly, the luminous efficiency of the light-emitting body can be prevented from being decreased.

[0199] Furthermore, a light-emitting device according to an eighth aspect of the invention includes

[0200] an excitation light source (laser element **11**) that emits the excitation light; and

[0201] the light-emitting body according to any one of the first to seventh aspects.

[0202] With the above-described configuration, like the first aspect, a light-emitting device capable of reducing occurrence of luminance unevenness or color unevenness in light to be emitted can be provided. Alternatively, like the second aspect, a light-emitting device capable of efficiently releasing the heat generated from a phosphor can be provided.

[0203] Preferably, in a light-emitting device according to a ninth aspect of the invention, based on the eighth aspect,

[0204] the excitation light source is a laser element (**11**).

[0205] With the above-described configuration, the luminous efficiency of the light-emitting body can be increased.

[0206] Further, an illuminator (**100**, **200**) according to a tenth aspect of the invention includes

[0207] the light-emitting device according to the eighth or ninth aspect; and

[0208] a projecting part (projecting lens **17**, **105**) that projects the first fluorescence and the second fluorescence emitted from the light-emitting device.

[0209] With the above-described configuration, like the first aspect, an illuminator capable of reducing occurrence of luminance unevenness or color unevenness in light to be emitted can be provided. Alternatively, like the second aspect, an illuminator capable of efficiently releasing the heat generated from the phosphor can be provided.

[0210] Further, a producing method according to an eleventh aspect of the invention is

[0211] a method for producing the light-emitting body according to any one of the first to seventh aspects, the method including

[0212] stacking the first phosphor and the second phosphor on the substrate by electrophoresis or sedimentation.

[0213] With the above-described configuration, the light-emitting body according to the first or second aspect can be produced. Also, the density (concentration) of the first phosphor in the first phosphor layer, and the density (concentration) of the second phosphor in the second phosphor layer can be increased. Hence, a gap between particles of the first phosphor and a gap between particles of the second phosphor can be decreased, and consequently the layer thickness of each layer can be decreased. Accordingly, the thickness of the light-emitting body in a direction in which respective layers are stacked on the substrate can be decreased.

[Other Expressions According to Aspect of the Invention]

[0214] Alternatively, an aspect of the invention can be expressed as follows.

[0215] That is, a light-emitting device according to an aspect of the invention includes a semiconductor light-emitting element that emits light; and a phosphor member containing a phosphor that converts the light from the semiconductor-light-emitting element into fluorescence of a color different from a color of the light from the semiconductor light-emitting element and provided on a substrate with a high reflectivity. The light-emitting device mixes the color of the light from the semiconductor light-emitting element and the color of the fluorescence from the phosphor-member and emits light, in which a particle size distribution of a phosphor on a side near the substrate differs from, a particle size distribution of a phosphor on an opposite side, and a particle size of the phosphor on the side near the substrate is larger than a particle size of the phosphor on the opposite side.

[0216] Also, in a light-emitting device according to an aspect of the invention, the particle size of the phosphor on the opposite side is 10 μm or smaller.

[0217] Also, in a light-emitting device according to an aspect of the invention, a kind of the phosphor on the side near the substrate differs from a kind of the phosphor on the opposite side.

[0218] Also, in a light-emitting device according to an aspect of the invention, an emission wavelength of the phosphor on the side near the substrate is longer than an emission wavelength of the phosphor on the opposite side.

[0219] Also, in a light-emitting device according to an aspect of the invention, thermal quenching of the phosphor on the side near the substrate is larger than thermal quenching of the phosphor on the opposite side.

[0220] Also, in a light-emitting device according to an aspect of the invention, the phosphor (phosphor particles) is deposited on the substrate.

[0221] Also, in a light-emitting device according to an aspect of the invention, the semiconductor light-emitting element is a semiconductor laser.

[0222] Also, a method for producing a light-emitting device according to an aspect of the invention includes depositing a phosphor having a large particle size on a side near a substrate, and depositing a phosphor having a small particle size on the phosphor having the large particle size by electrophoresis or sedimentation.

[Additional Matter]

[0223] The invention is not limited to the embodiments described above and may be modified in various manners within the scope of the claims, and an embodiment achieved by appropriately combining technical measures disclosed in different embodiments is also included in the technical scope of the invention. Further, by combining the technical measures disclosed in the embodiments, a new technical feature can be formed.

REFERENCE SIGNS LIST

[0224] **1** substrate
[0225] **2** second YAG phosphor (second phosphor)
[0226] **3** first YAG phosphor (first phosphor)
[0227] **4** red luminescent phosphor (second phosphor)
[0228] **5** green luminescent phosphor (first phosphor)
[0229] **6** reel luminescent phosphor (second phosphor)
[0230] **7** green luminescent phosphor (first phosphor)
[0231] **17** projecting lens (projecting part)
[0232] **61** transmissive substrate (substrate)
[0233] **10**, **20**, **30**, **40**, **50**, **60** light-emitting part (light-emitting body)
[0234] **100**, **200** illuminator
[0235] **105** projecting lens (projecting part)
[0236] E**1** excitation light
[0237] La**1** first phosphor layer
[0238] La**2** second phosphor layer

1. A light-emitting body comprising:
a first phosphor layer containing a first phosphor that receives excitation light and emits first fluorescence; and
a second phosphor layer containing a second phosphor that receives the excitation light and emits second fluorescence,
wherein the first and second phosphor layers are stacked on a substrate,
wherein a particle size of the first phosphor is smaller than a particle size of the second phosphor,
wherein the first phosphor layer is arranged on a side far from the substrate, and the excitation light is incident on the first phosphor layer, and
wherein a material of the first phosphor is same as a material of the second phosphor.

2. A light-emitting body comprising:
a first phosphor layer containing a first phosphor that receives excitation light and emits first fluorescence; and
a second phosphor layer containing a second phosphor that receives the excitation light and emits second fluorescence,
wherein the first and second phosphor layers are stacked on a substrate,
wherein a particle size of the first phosphor is smaller than a particle size of the second phosphor,
wherein the first phosphor layer is arranged on the substrate, and the excitation light is incident on the first phosphor layer, and
wherein a material of the first phosphor is same as a material of the second phosphor.

3. (canceled)

4. The light-emitting body according to claim **1**, wherein an emission peak wavelength of the second phosphor is longer than an emission peak wavelength of the first phosphor.

5. The light-emitting body according to claim **2**, wherein an emission peak wavelength of the first phosphor is longer than an emission peak wavelength of the second phosphor.

6. The light-emitting body according to claim **1**,
wherein the second phosphor layer is arranged on a side near the substrate with respect to the first phosphor layer, and
wherein thermal quenching of the second phosphor is larger than thermal quenching of the first phosphor.

7. The light-emitting body according to claim **2**, wherein thermal quenching of the first phosphor is larger than thermal quenching of the second phosphor.

8. A light-emitting device comprising:
an excitation light source that emits the excitation light; and
the light-emitting body according to claim **1**.

9. The light-emitting device according to claim **8**, wherein the excitation light source is a laser element.

10. An illuminator comprising:
the light-emitting device according to claim **8**; and
a projecting part that projects the first fluorescence and the second fluorescence emitted from the light-emitting device.

11. A method for producing the light-emitting body according to claim **1**, the method comprising:
stacking the first phosphor and the second phosphor on the substrate by electrophoresis or sedimentation.

12. A light-emitting device comprising:
an excitation light source that emits the excitation light; and
the light-emitting body according to claim **2**.

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