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[54] **MULTI-COLOR SEMICONDUCTOR LAMP**

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[52] **U.S. Cl.** .... **313/501,** 250/211 J, 307/311, 313/110, 357/17, 357/73

[51] **Int. Cl.** **H03k 3/42**

[58] **Field of Search** .... 313/110, 108 D, 501; 307/311; 317/235 N; 250/211 J; 357/17, 18, 19

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[57] **ABSTRACT**

A multi-color semiconductor lamp comprising a plurality of light emitting diodes disposed close to one another and respectively emitting the light of different colors and a light scattering layer covering these light emitting diodes.

With this device, light emitted from any one of the plurality of light emitting diodes is visible as if it were emitted from one and the same position. The present invention therefore, makes it possible to obtain clear multi-color indication with a small-size lamp which has heretofore been difficult.

18 Claims, 5 Drawing Figures

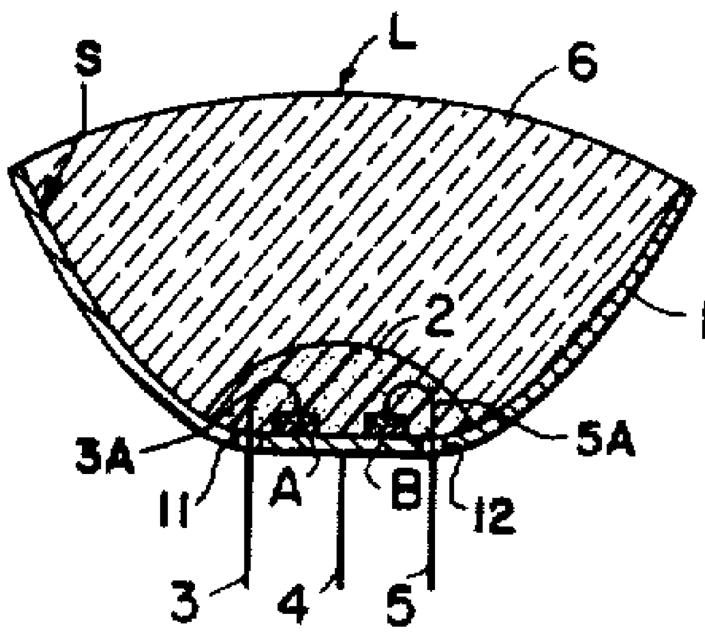


FIG. 1

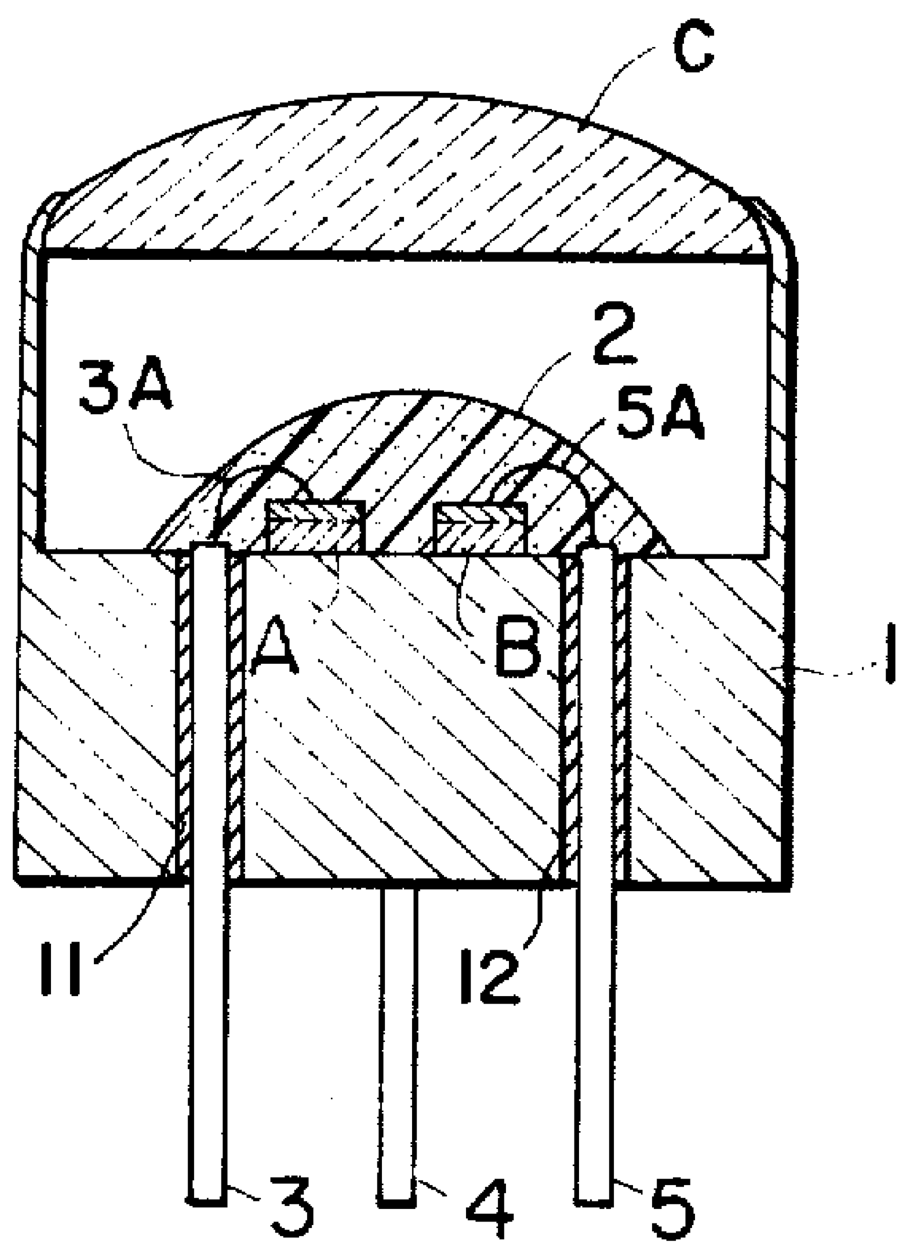


FIG. 2

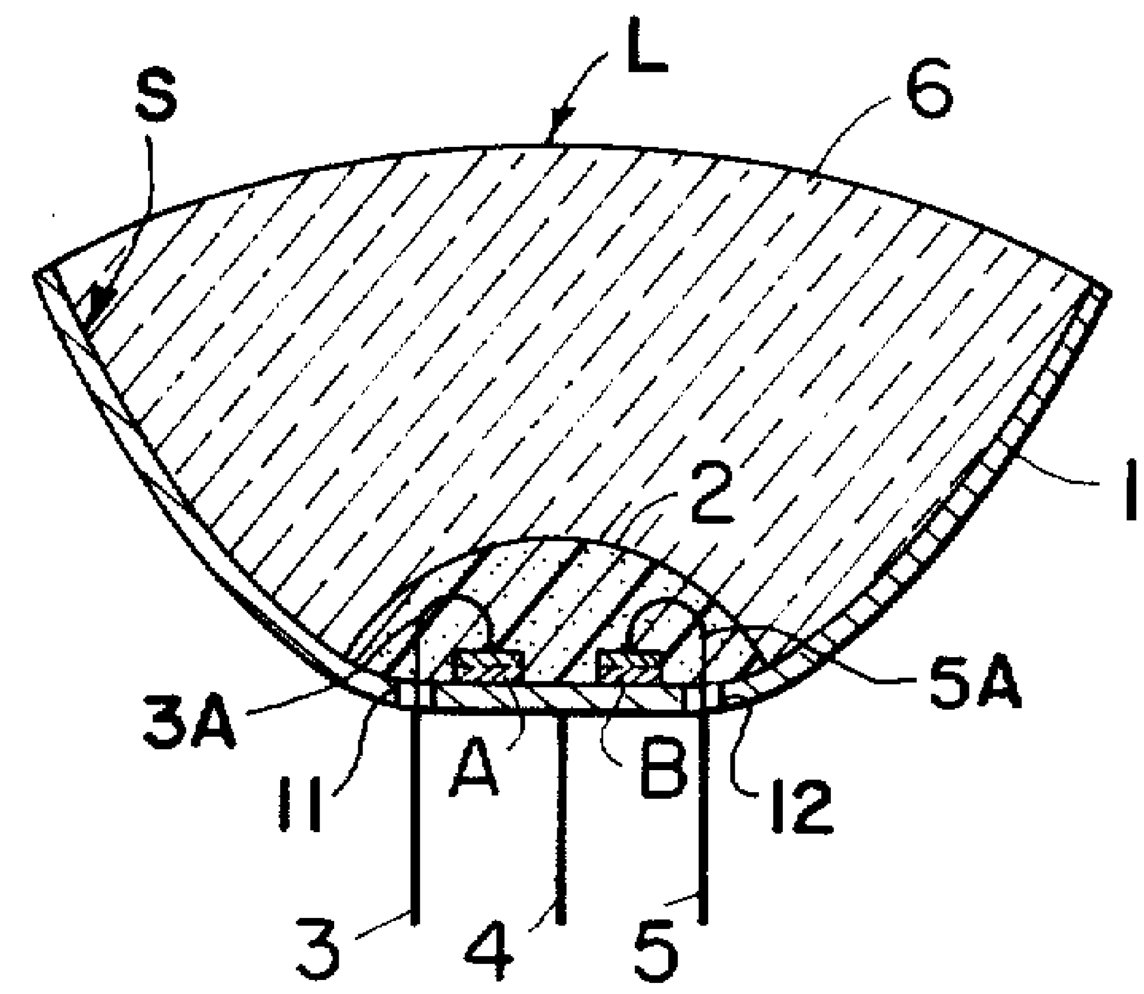


FIG. 5

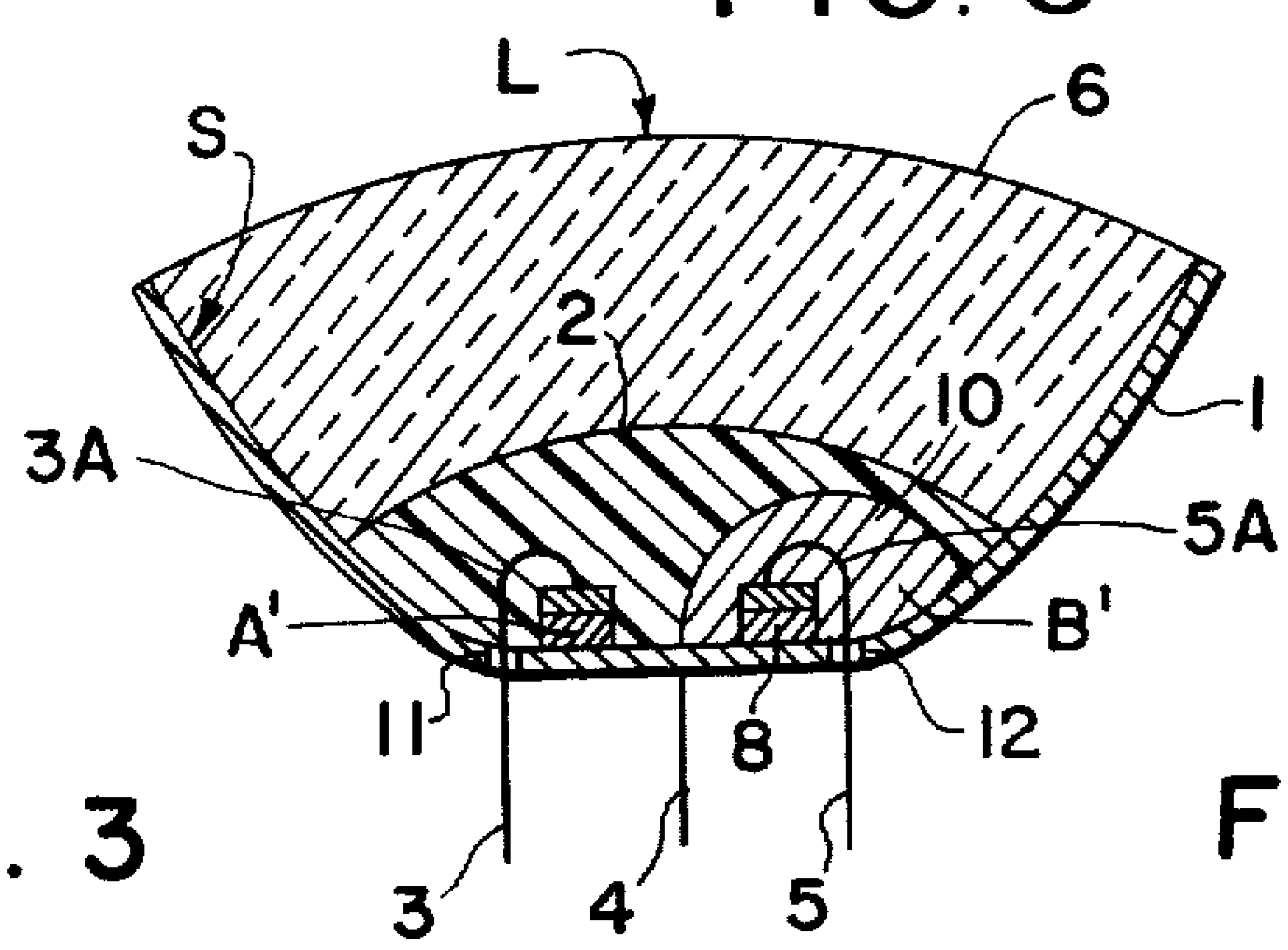


FIG. 3

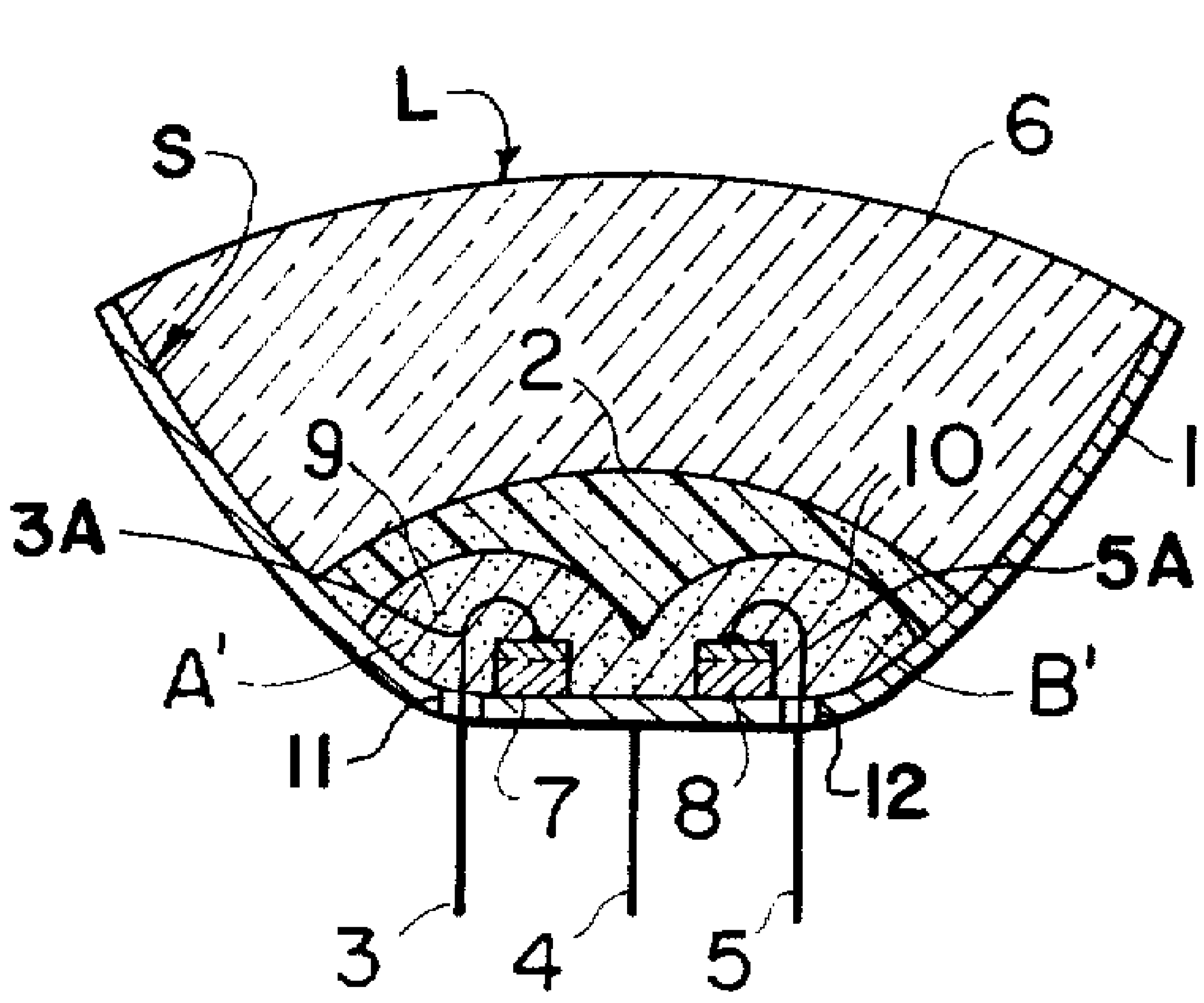
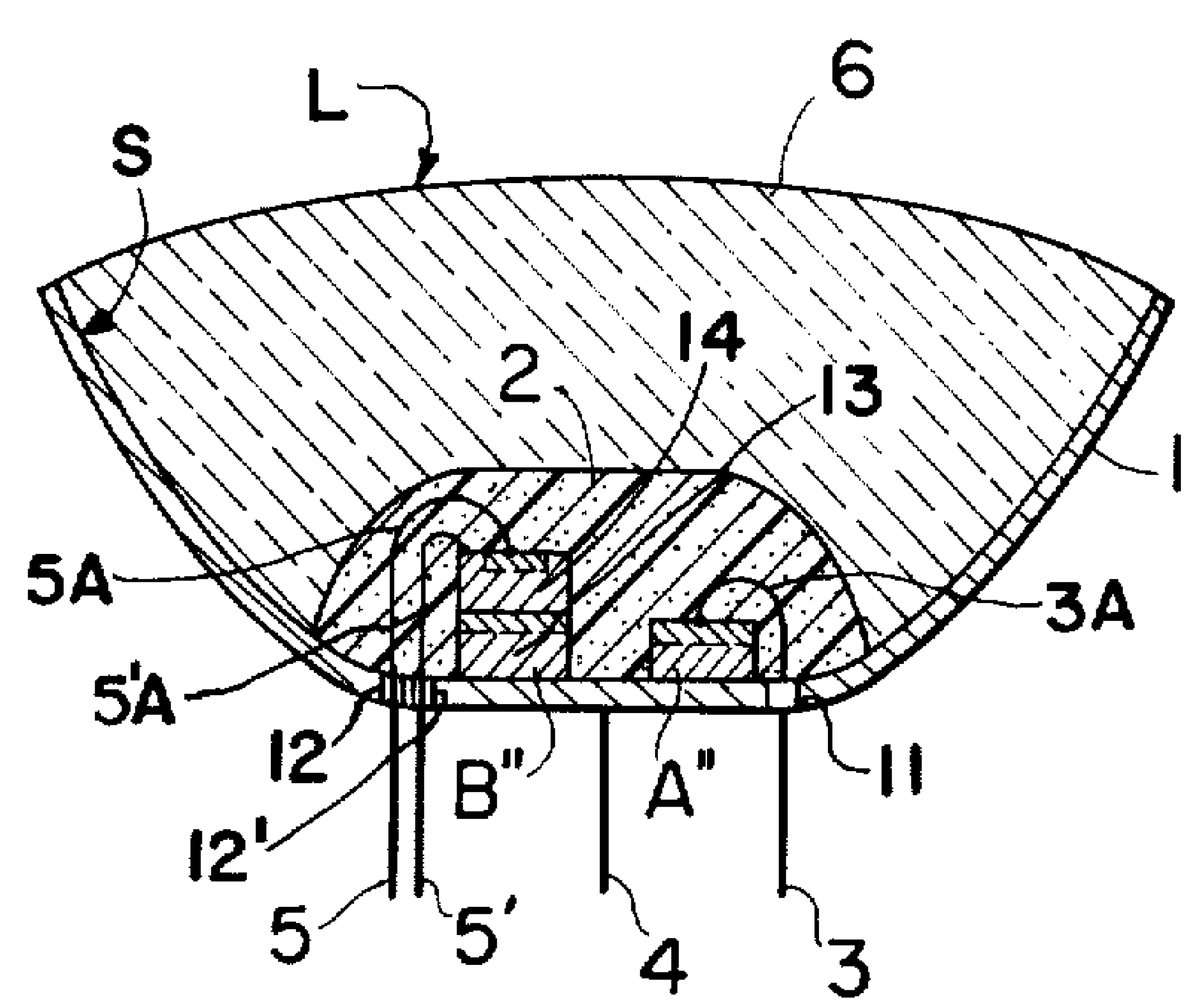


FIG. 4



MULTI-COLOR SEMICONDUCTOR LAMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to semiconductor lamps and more particularly, to multi-color semiconductor lamps capable of emitting light of many different colors from what appears to be a single light source.

2. Description of the Prior Art

A typical example of a multi-color indicating device is a traffic signal lamp device. It consists of three different light sources arranged side by side respectively emitting the lights of red, orange and green colors, these light sources being selectively and individually switched, on and off electrically, and the colors of these sources respectively indicating the condition of danger, caution and safety. Since the multi-color indicating device of this type has the excellent function of permitting an observer to recognize various conditions instinctively, there are extensive applications for these devices such as for indicating the working state of apparatus, for indicating the occupancy of roads and seats, for indicating positive or negative signs of various values, for indicating whether some value is greater or less than a reference value and for indicating whether an input signal is correct or not.

However, prior-art multi-color indicating devices such as the afore-mentioned traffic signal lamp device usually use a separate light sources for each different color, and the individual light sources are located at different positions. Therefore, an undesirably large space is required for the whole device. Also, unless the device is located in a dark place, the light sources which are not emitting light are likely to be mistaken for those emitting light since they can reflect ambient light.

Due to the above drawbacks it has heretofore been very difficult to achieve clear multi-color indication with a small light emitting device or lamp.

In order to overcome the afore-mentioned drawbacks it has been proposed to dispose a plurality of filters individually transmitting the lights of respectively different particular wavelengths in front of a single white light source and switch or position these filters by a suitable means or provide light sources disposed at the focuses of lenses or curved mirrors mounted in a panel such that these light sources may be not seen from the back of the panel and suitably switch these light sources on and off by an appropriate means. All of such systems, however require very complicated mechanism, so they are not in popular use yet.

An ideal multi-color indicating device or lamp would be one from which light of two or more colors can be emitted from an apparently single light source with the color selected by simple electric control. Such a light source, which would thereby occupy an optimally minimum amount of space, has not been practically available prior to the present invention.

An object of the present invention is to provide a novel and improved multi-color semiconductor lamp.

Another object of the invention is to provide a multi-color semiconductor lamp, which can emit light of different colors apparently from a single light source.

A further object of the invention is to provide a multi-color semiconductor lamp, which is capable of emitting light of different colors, but occupies smaller space and nevertheless permits to emit light in clear and distinct colors.

SUMMARY OF THE INVENTION

According to the invention, a plurality of light-emitting diodes individually capable of emitting the light of respectively different colors are disposed close to one another, and these light-emitting diodes are covered with a light scattering layer such that light from any one of this plurality of light sources corresponding to a respective color is seen as if emitted apparently from the same source or position, whereby multicolor indication with the respectively different colors of the individual light emitting diodes as well as blends of these colors may be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section of a first embodiment of the invention including multiple color light sources in a casing and lens module;

FIG. **2** is a cross-section of a second embodiment of the invention including an integrally formed modular casing and lens structure for multiple sources of visible light;

FIG. **3** is a cross-section of a modification of FIG. **2** in which multiple sources of invisible light and visible light producing layers of material are respectively associated with said sources in the integrally formed module of FIG. **2**;

FIG. **4** is a cross-section of another modification of FIGS. **2** and **3** including at least one compound light source and another light source cooperating with a common light scattering layer in the modular structure of FIGS. **2** and **3**; and

FIG. **5** is a cross-section of a further modification of FIGS. **2** and **3** in which the common light scattering layer for a plurality of light sources in the modular structure includes fluorescent materials.

DETAILED DESCRIPTION OF THE INVENTION

Referring in detail to the drawings and with specific reference to FIG. **1**, a first preferred embodiment of the present invention is shown as including first and second conventional light-emitting diodes A and B, each containing a p-n junction capable of emitting light of a desired color. The two diodes A and B are disposed closely adjacent one another on an internal surface of a common metal casing **1** such that ohmic contact is made between one side of each of the diodes A and B and the said casing **1**. Both diodes are encased in a common light scattering layer **2** on the casing **1**.

The diodes A and B are respectively connected to external terminal leads **3** and **5** which extend through the casing **1** within respective insulating sleeves **11** and **12**. The internal ends of the terminal leads **3** and **5** are respectively connected through metal wires **3A** and **5A** to the other sides of the said diodes A and B, namely, those not in ohmic contact with the casing **1**. A common terminal lead **4** for both diodes is conductively connected to the underside of the metal casing **1**.

A lens C is positioned over the light scattering layer **2** to confine the said layer and the diodes A and B within the said casing **1**.

The light emitting diode A is energized to emit light of its chosen color by impressing an appropriate voltage between the input terminal leads **3** and **4** and the light emitting diode B is energized to emit light of its chosen color by impressing an appropriate voltage between the input terminal leads **4** and **5**. When these diodes are so energized, either one at a time or concurrently, the resulting light emitted thereby is scattered in passing through the light scattering layer **2** so that all such emissions transmitted to the exterior of the casing **1** through the lens C appear to come from one and the same source.

FIG. **2** shows a modified construction in which like elements to FIG. **1** bear like numerals. In this case, the casing **1** has an inner reflecting surfaces, and the light scattering layer **2** is covered with a transparent resin layer **6** having a lens-shaped outer surface L.

FIG. **3** shows another embodiment in which like elements to FIGS. **1** and **2** bear like numerals. In this case, light emitting diodes A' and B' for converting infrared rays to visible light respectively consisting of infrared luminescent diodes **7** and **8** covered with respective resin layers **9** and **10** each containing different phosphorescent powder are used in place of the conventional light emitting diodes A and B described in reference to FIG. **2**. These diodes and their respective resin layers **9** and **10** are covered with the light scattering layer **2** and transparent resin layer **6** as previously described with reference to FIG. **2**.

While the constructions shown in FIGS. **1** to **3** have used two light-emitting diodes for emitting respectively different visible lights, similar effects may of course be obtained if three or more different light-emitting diodes are used.

Also, colored light resulting from the blending of the individual colors from the respective light emitting diodes may be obtained by causing two or more of the said light-emitting diodes to simultaneously emit light.

The light-emitting diodes may be visible light-emitting diodes, or a combination of an infrared luminescent diode with a fluorescent material for emitting visual light in response to the infrared emissions.

The light scattering layer **2** of the several embodiments of the invention may comprise a ground glass body disposed in the position of the lens C of FIG. **1** or located between the light-emitting diodes A and B and the lens C.

Alternatively, the light scattering layer **2** may comprise fine alumina powder bonded with resin.

For infrared to visual conversion, the light scattering layer **2** may comprise powdered phosphors (the fluorescent material responsive to infrared emissions) bonded with resin.

As has been described, according to the invention a variety of combinations may be incorporated into the device; for instance it is possible to provide a device where a plurality of visible light-emitting diodes capable of emitting respectively different colored light are covered with a light-scattering layer, a device where a plurality of infrared luminescent diodes in combination with respective fluorescent powders capable of converting infrared rays into visible light of different colors are wholly covered with a light scattering layer, or a device where a visible light emitting diode and an infrared luminescent diode are covered with a fluorescent material for visualizing the infrared and scattering the visible light.

Also, by using not only the ordinary light emitting diodes having only one p-n junction but also one or more multi-color emitting diodes each having two or more p-n junctions defined between successively laminated

layers of semiconductor crystal presenting different band gaps, three or more colors of luminescence may be very readily obtained.

EXAMPLE 1

In the multi-color semiconductor lamp of FIGS. **1** and **2**, a green light-emitting gallium phosphide diode is used as light-emitting diode A, a red light-emitting gallium phosphide diode is used as light-emitting diode B, and an epoxy resin body containing fine powder of alumina is used as light scattering layer **2**. Green light is emitted from the light-emitting diode A by impressing between the input terminal leads **3** and **4** an electric input of 3.5 volts and 10 milliamperes, and red light is emitted from the light emitting diode B by impressing between the input terminal leads **4** and **5** the same electric input. These emitted lights are projected through the lens C or the transparent resin layer **6** as the case may be.

EXAMPLE 2

In the light-emitting semiconductor lamp of FIG. **3**, the light-emitting diode A' comprises a light emitting diode in which an infrared luminescent gallium arsenide diode **7** is covered with a layer **9** consisting of sodium yttrium fluoride fluorescent powder activated with ytterbium and erbium and a resin bonded therewith; and the lightemitting diode B' comprises a light emitting diode in which an infrared luminescent gallium arsenide diode **8** is covered with a layer **10** consisting of yttrium oxyfluoride phosphor powder activated with ytterbium and erbium and a resin bonded therewith. Over these fluorescent powder layers **9** and **10**, the light scattering layer **2** is provided comprising a fine alumina powder bonded with resin and the fluorescent powder layers **9** and **10** together with the alumina powder layer **2** are covered with the epoxy resin layer **6**. Green light is emitted through the epoxy resin layer **6** by impressing an electric input of 1.2 volts and 50 milliamperes between the input terminal leads **3** and **4** for the light-emitting diode A', and red light is emitted through the same layer by impressing an electric input of 1.2 volts and 100 millivolts between the input terminal leads **4** and **5** for the light emitting diode B'.

EXAMPLE 3

A light emitting semiconductor lamp having a function similar to that of Example **2** is obtained by utilizing, in the fluorescent layer **10**, yttrium oxychloride fluorescent powder activated with ytterbium and erbium in place of yttrium oxyfluoride activated with ytterbium and erbium of Example **2**.

EXAMPLE 4 milliamperes

This example is one modification of the lamp of FIG. **2** or FIG. **3**, and is shown in FIG. **5**, wherein the light emitting diode A' is replaced by a red light-emitting gallium arsenide diode and the light-emitting diode B' is replaced by a light emitting diode in which an infrared luminescent gallium arsenide diode is combined with the fluorescent layer **10** consisting of sodium yttrium fluoride fluorescent powder activated with ytterbium and erbium. These light-emitting elements A' and B' are covered with a light scattering layer **2** of sodium-yttrium fluoride fluorescent powder activated with ytterbium and erbium, which is fixed with a polystyrene layer **6** covering it. Red light is emitted through the polystyrene layer **6** by impressing an electric input of 1.7 volts and 20 milliamperes between the input terminal leads **3** and **4** for the light-emitting element A', and green light is emitted through the same layer by impressing an electric input of 1.2 volts and 60 milliamperes between the input terminal leads **4** and **5** for the light-emitting element B'. In this case, the light scattering layer **2** and a fluorescent layer **10** which contain the fluorescent powders serve the dual roles of both converting the wavelengths of light and scattering light.

This lamp is a modification of that of Example **2** in that a red light emitting diode A' and an infrared emitting diode **8** are covered directly with a light scattering layer **2** containing powdered fluorescent material.

EXAMPLE 5

A light emitting semiconductor lamp having a function similar to that of Example 4 is obtained by using, in the fluorescent layer **10**, yttrium fluoride fluorscent powder activated with ytterbium and erbium in place of sodium yttrium fluoride fluorescent powder activated with ytterbium and erbium.

EXAMPLE 6

A yellow light-emitting gallium phosphide diode is used as a third light-emitting diode (not shown) in addition to the two light-emitting diode A' and B' of Example 4. Red light is emitted by impressing an electric input of 1.7 volts and 20 milliamperes between the input terminal leads **3** and **4** for the light-emitting diode A', while green light is emitted by impressing an electric input of 1.2 volts and 60 milliamperes between the input terminal terminal leads **4** and **5** for the light-emitting diode B', and yellow light is emitted by impressing an electric input of 3.5 volts and 10 milliamperess between the input terminal lead **4** and a similar additional input lead (not shown) extending through the casing **1** like the leads **3** and **5**, for the said third light-emitting element.

EXAMPLE 7

In the lamp of Example 2, green light is emitted by impressing an electric input of 1.2 volts and 50 milliamperes between the input leads **3** and **4** for the light-emitting diode A', while red light is emitted by impressing an electric input of 1.2 volts and 100 milliamperes between the input leads **4** and **5** for the light emitting diode B', and yellow light is emitted by simultaneously impressing an electric input of 1.2 volts and 40 milliamperes between the input leads **3** and **4** for the light-emitting diode A' and an electric input of 1.2 volts and 80 milliamperes between the input leads **4** and **5** for the light emitting diode B'. It will thus be seen that light of three different colors can be emitted in employing only two different light-emitting diodes.

EXAMPLE 8

This example is realized by using the construction as shown in FIG. **2**, but a light-emitting diode having two p-n junctions is used as one of the two light-emitting elements for three-color emission, as will be described with reference to FIG. **4**.

Referring to the diagrams, light emitting-diode A'' is constituted by a conventional light emitting gallium phosphide diode, and light emitting diode B'' is composed of a GaAs crystal doped with Si and a $GaAs_{0.6}P_{0.4}$ crystal, each said crystal containing a p-n junction. Light-scattering layer **2** is formed by hardening a coating of epoxy resin containing yttrium fluoride fluorescent powder activated with ytterbium and erbium.

The crystal **13** makes ohmic contact with the casing **1** and its p-n junction makes ohmic contact with the crystal **14.** The p-n junction of the crystal **14** is connected with the metal wire **5A** from the input terminal lead **5** and the crystal **14** is connected with a metal wire **5'**A extending from an input terminal lead **5'** extending through the casing **1** via an insulating sleeve **12'** in the same manner as the input terminal leads **3** and **5** extend through the sleeves **11** and **12,** respectively.

With this lamp, green light having a wavelength of 5,600 A is emitted through the resin layer **6** by impressing voltage between input terminal leads **3** and **4,** while blue light having a wavelength of 4,750 A is emitted through the same layer **6** by impressing voltage between input terminal leads **5** and **5'**, and red light having a wavelength of 6,600 A is emitted through the same layer **6** by impressing voltage between input terminal leads **4** and **5'**.

While this embodiment has used a double p-n junction diode composed of $GaAs_{0.6}P_{0.4}$ crystal and GaAs crystal doped with Si, it is also possible to use various other double p-n junction diodes, for instance those composed of GaP crystal doped with Zn and O, and GaP crystal doped with Zn and N.

Also, by using not only the double junction diode but also a multiple junction diode formed by laminating a greater number of diodes, it is possible to obtain a far greater number of colors for the indication of the occurrence of a correspondingly greater number of conditions being monitored.

What is claimed is:

1. A semiconductor lamp for emitting a plurality of colors of light as if from a single source of light comprising a plurality of light-emitting semiconductor diodes disposed closely adjacent one another in distinct and separate positions on a common support means and capable of emitting light of respectively different colors, a common light scattering layer covering said light-emitting diodes acting to disperse the light from said diodes to provide the appearance of a single source of light emitting said respectively different colors from the same position therein, and input terminal means for each of said diodes extending therefrom for receiving electrical input signals to selectively energize said diodes to transmit light of various colors through said light scattering layer.

2. A multi-color semiconductor lamp according to claim **1**, wherein said light-emitting diodes include at least one light emitting diode emitting invisible light and a layer of flourescent material covering said one diode and responsive to said invisible light to emit visible light of a selective color.

3. A multi-color semiconductor lamp according to claim **1**, wherein said light emitting diodes include at least a first such diode emitting visible light and at least a second such diode emitting invisible light; and

wherein at least said second such diode is covered with a layer of fluorescent material responsive to said invisible light to emit visible light of a selective color.

4. A multi-color semiconductor lamp according to claim **1**, wherein said light-emitting diodes emit invisible light; and wherein each such diode is covered by a layer of fluorescent material responsive to said invisible light to emit visible light of a predetermined color.

5. A multi-color semiconductor lamp according to claim 1, wherein at least one of said light-emitting diodes is a multiple p-n junction light-emitting diode capable of emitting light of a different color from each said p-n junction.

6. A multi-color semiconductor lamp according to claim 1, wherein said light scattering layer contains alumina powder.

7. A multi-color semiconductor lamp according to claim 1, wherein said light scattering layer is covered with a transparent material.

8. A multi-color semiconductor lamp according to claim 1, which further comprises a lens covering said light scattering layer.

9. A multi-color semiconductor lamp according to claim 1, wherein said support means comprises a light-reflecting layer defining a casing around said lamp with a light emitting opening opposite said light scattering layer.

10. The invention defined in claim 3, wherein said layer of fluorescent material comprises said light scattering layer.

11. The invention defined in claim 3, wherein said layer of fluorescent material is positioned between said second such diode and said light scattering layer.

12. The invention defined in claim 4, wherein said layer of fluorescent material over each said diode is positioned between said diode and said light scattering layer.

13. The invention defined in claim 4, wherein, for one of said diodes said light scattering layer comprises said fluorescent layer and for the remaining said diodes the said respective fluorescent layers for same are located between said diodes and said light scattering layer.

14. The invention defined in claim 1, wherein said light scattering layer contains powdered fluorescent material.

15. The invention defined in claim 1, wherein said light scattering layer comprises a body of ground glass.

16. The invention defined in claim 1, wherein said supporting means comprises a metal casing having a light emitting opening therein opposite said light scattering layer and lens means positioned across said opening in the provision of a modular semiconductor lamp; and wherein said input terminal means are mounted on said support means adjacent said light emitting diodes.

17. The invention defined in claim 16, wherein said casing further includes a reflective internal surface and said lens means comprises a transparent layer filling said casing, covering said light scattering layer and having a lens-shaped external surface thereon.

18. A semiconductor lamp for emitting a pluralty of colors of light as if from a single source of light comprising a plurality of light-emitting semiconductor diodes disposed closely adjacent one another in distinct and separate positions on a common support means and capable of emitting light of respectively different colors, a common light scattering layer covering said light-emitting diodes acting to disperse the light from said diodes to provide the appearance of a single source of light emitting different colors from the same position therein, and input terminal means for each of said diodes extending therefrom for receiving electrical input signals to selectively simultaneously energize at least two of said diodes to transmit light of various blends of colors through said light scattering layer.

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