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(54) **WHITE LIGHT EMITTING DEVICE AND DIFFUSING LAYER**

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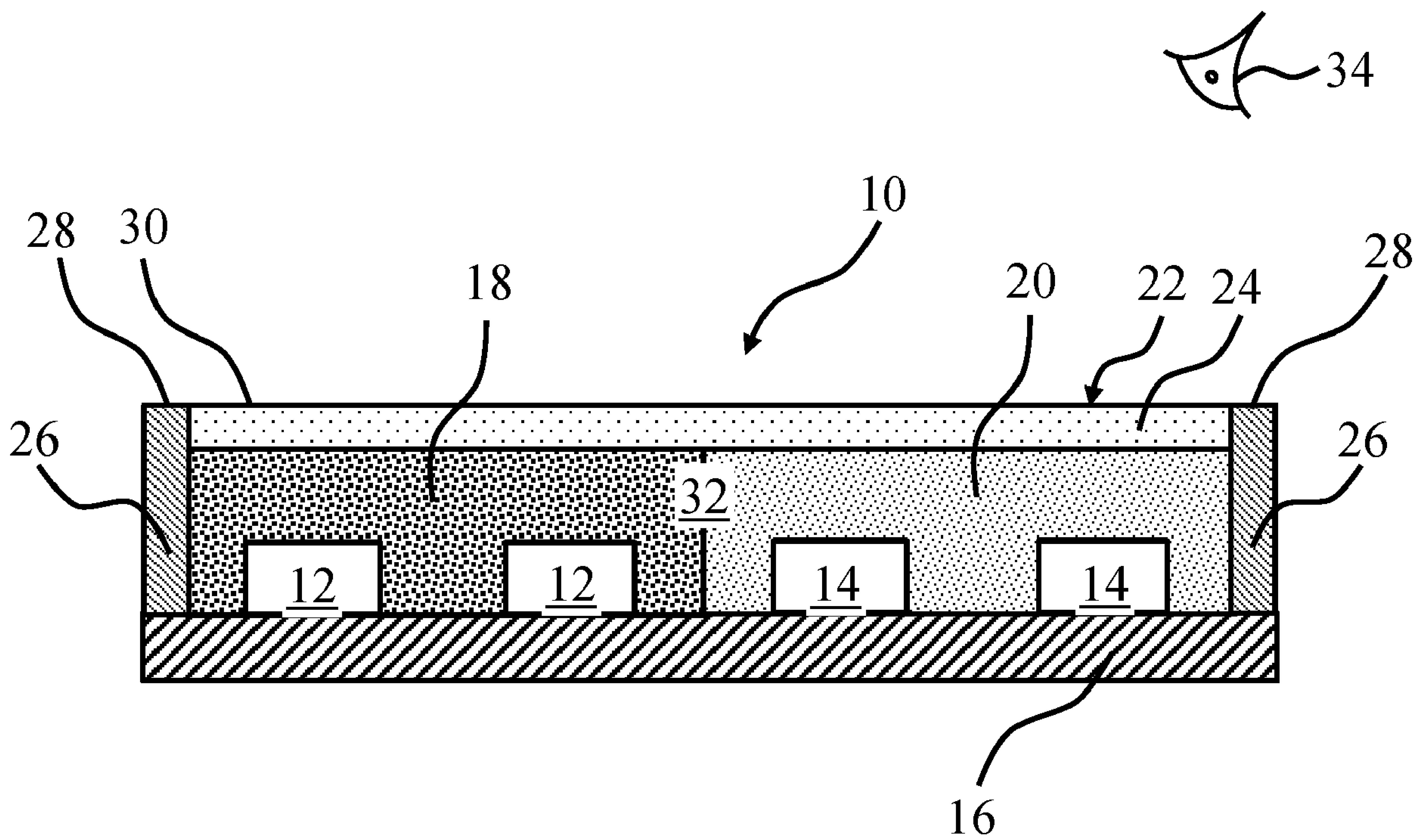
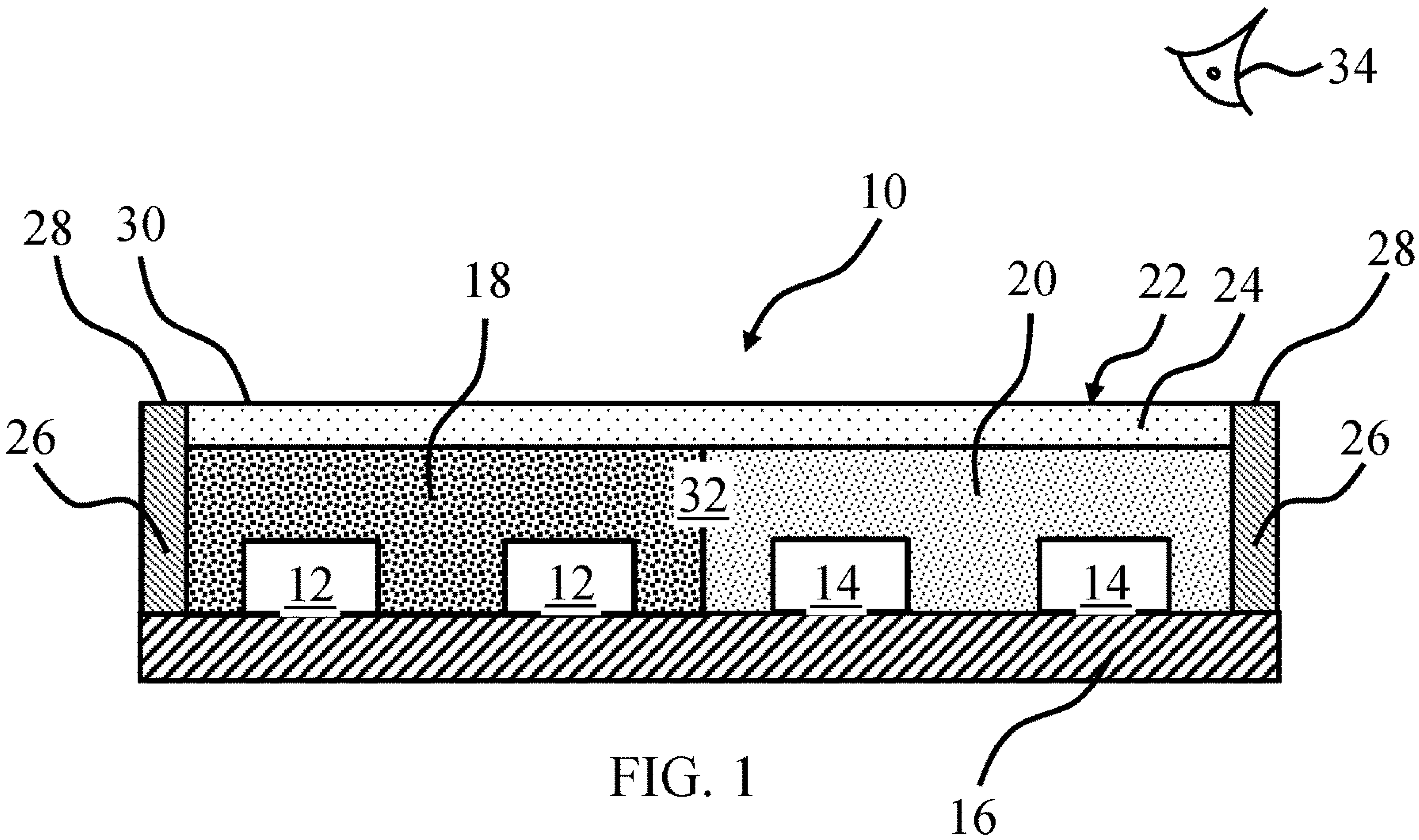
(57) **ABSTRACT**

There is provided a white light emitting device comprising a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED, and a diffusing layer disposed over said first and second photoluminescence layers, said diffusing layer comprising light scattering particles. A method and component are also provided.

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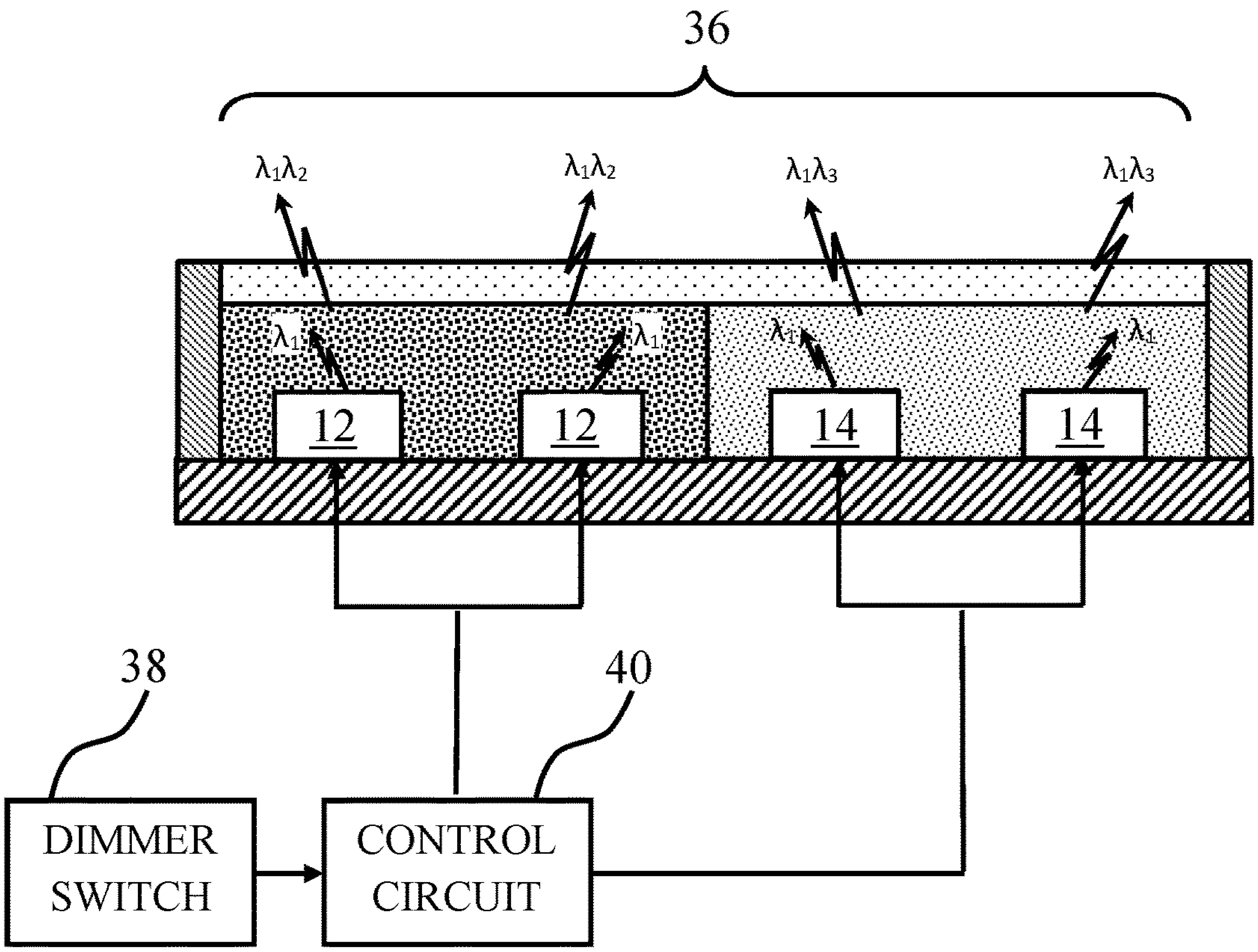
16

FIG. 1


36
λ1λ2
λ1λ2
λ1λ3
λ1λ3
λ1
λ1
λ1
λ1
12
12
14
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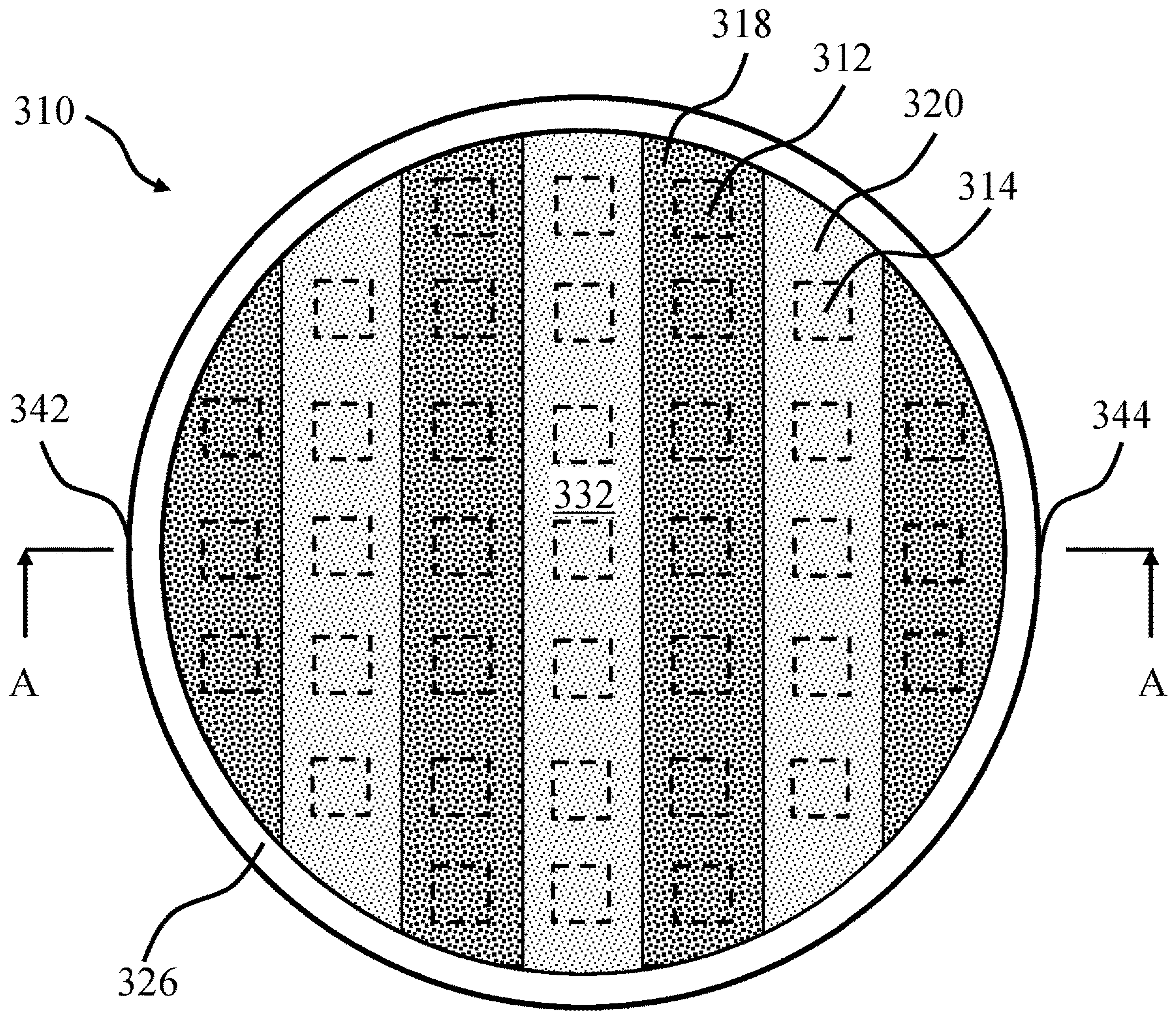
38
40
DIMMER SWITCH
CONTROL CIRCUIT

FIG. 2


310
318
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320
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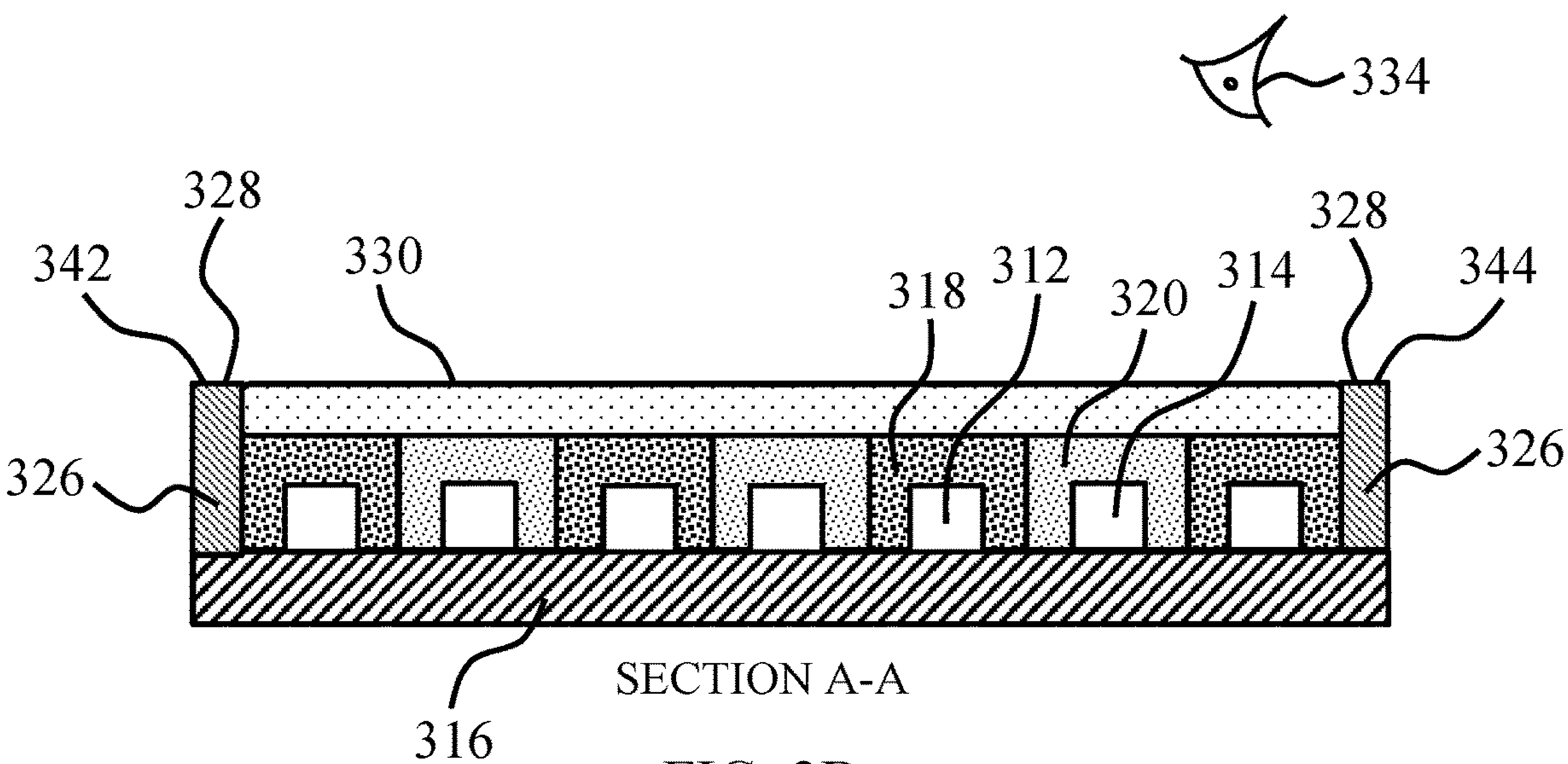
344
332
A
A
326

FIG. 3A


334
328
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344
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326
316
SECTION A-A

FIG. 3B

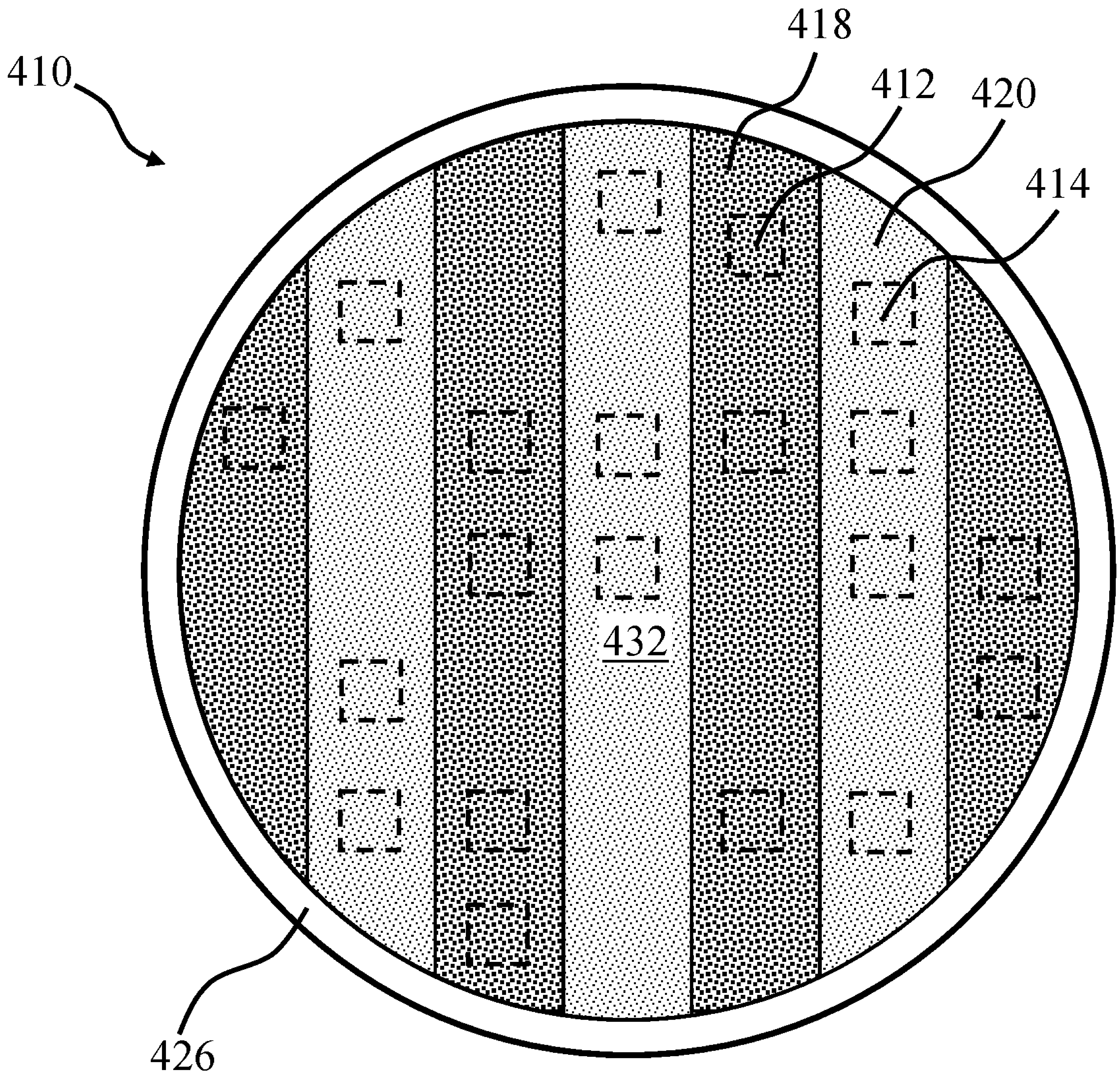

FIG. 4

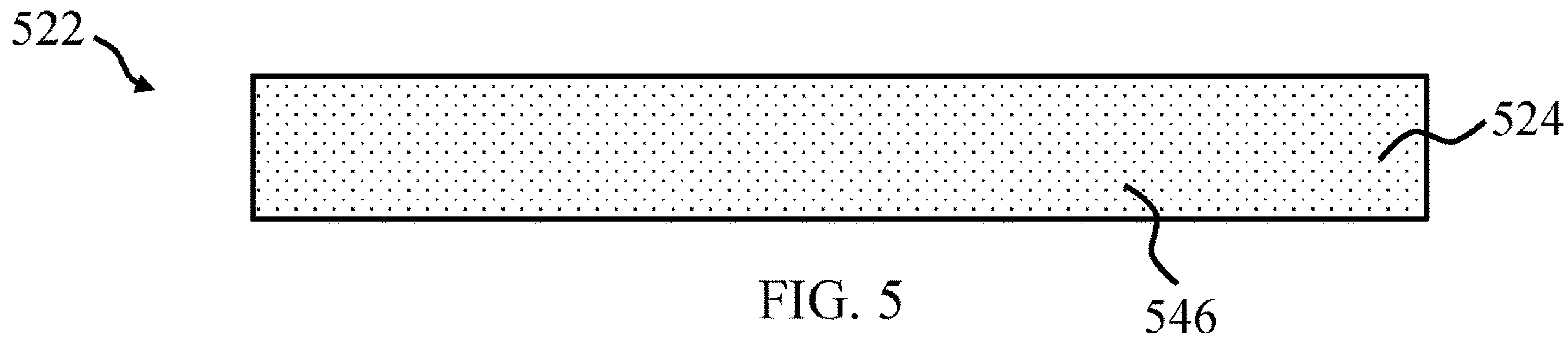

FIG. 5

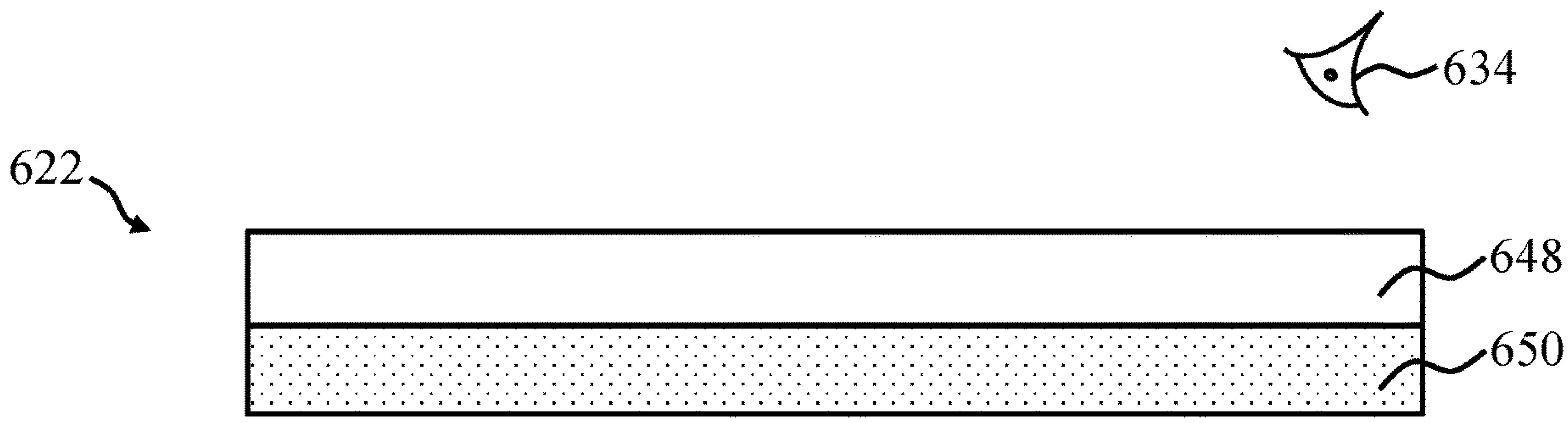

FIG. 6

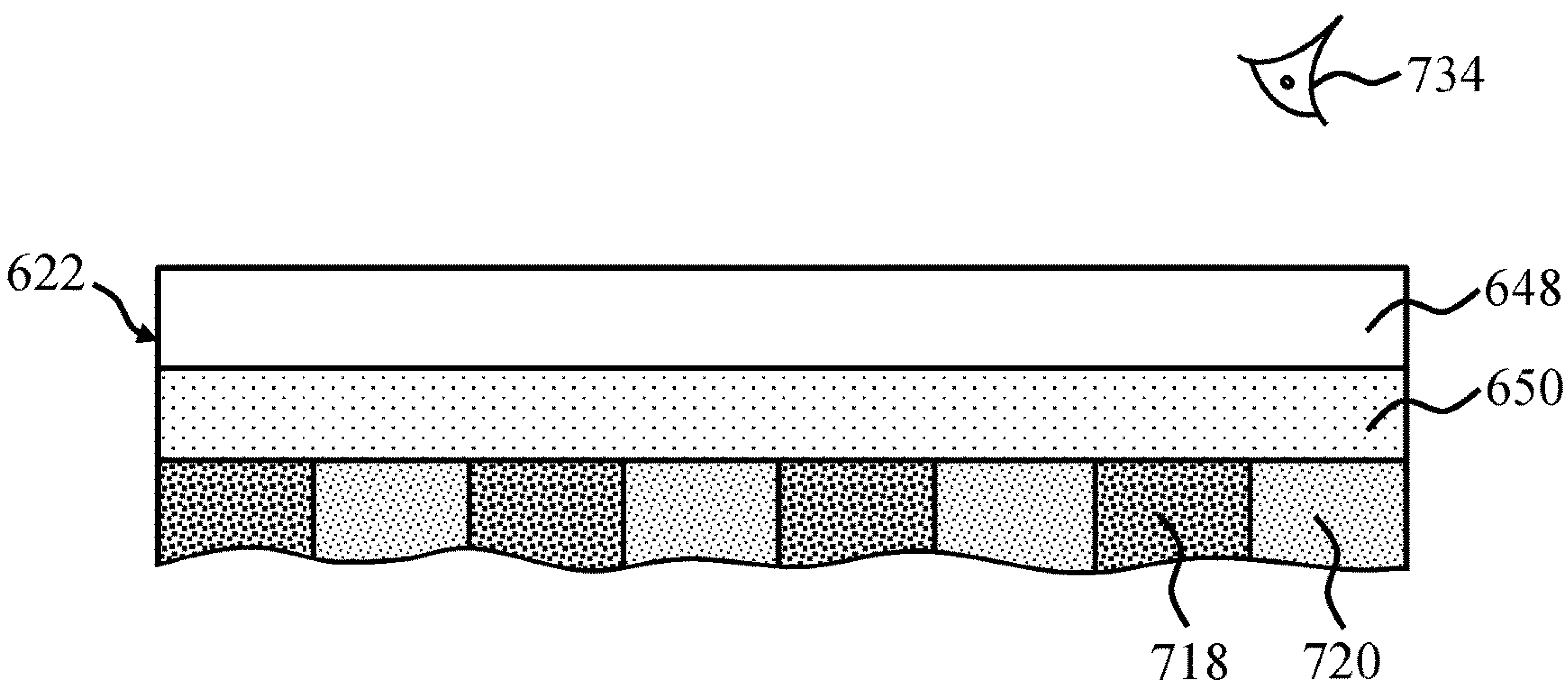

FIG. 7

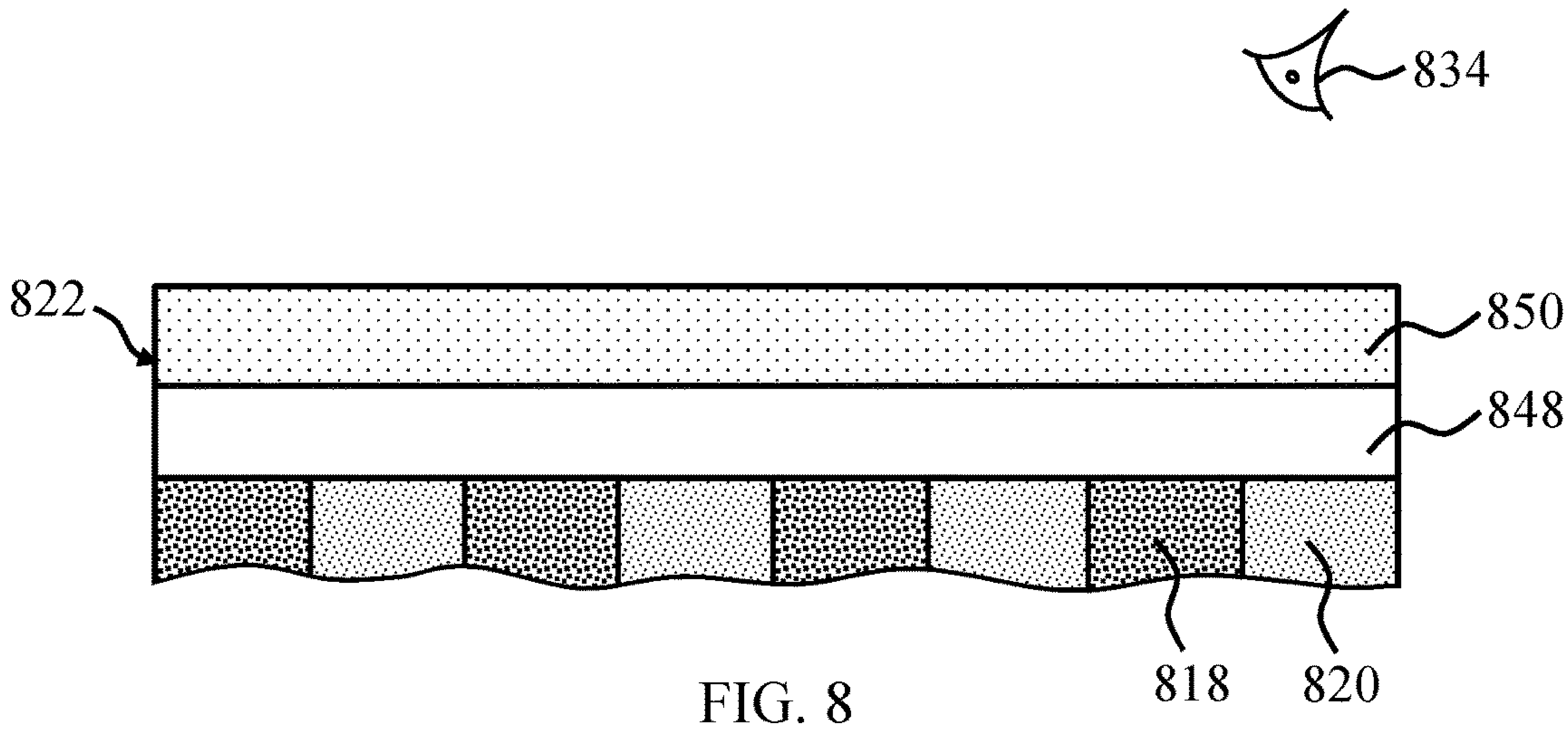

FIG. 8

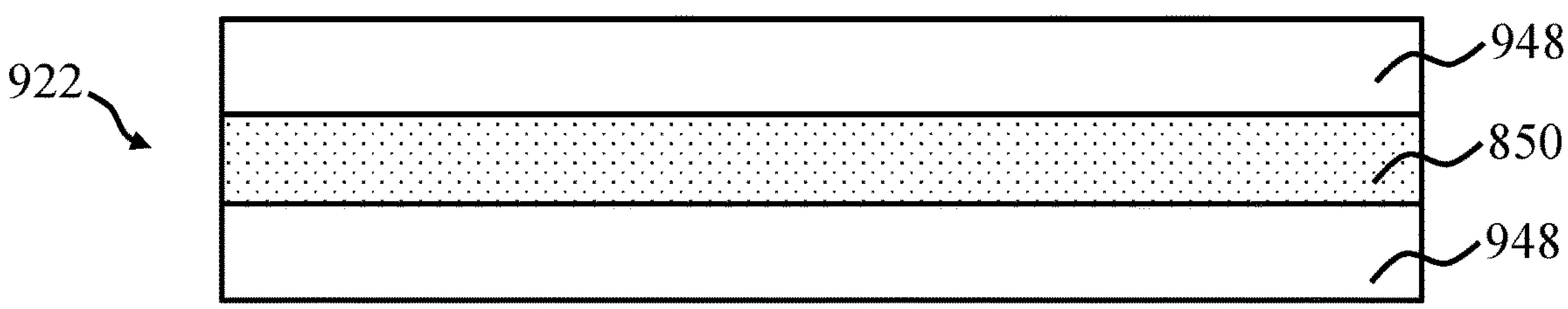

FIG. 9

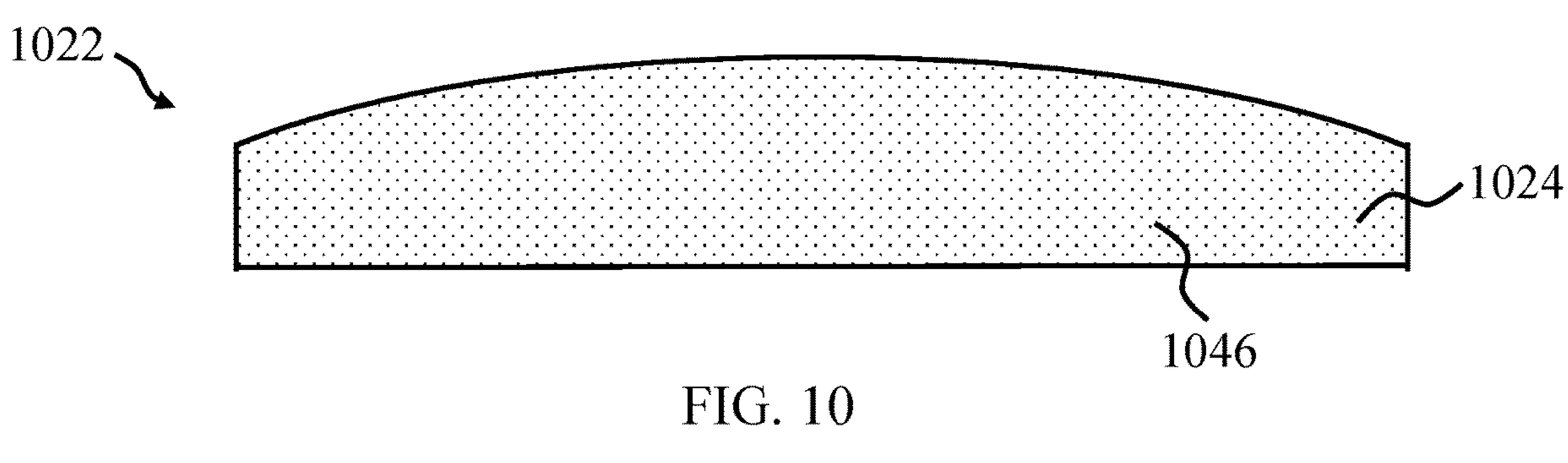

FIG. 10

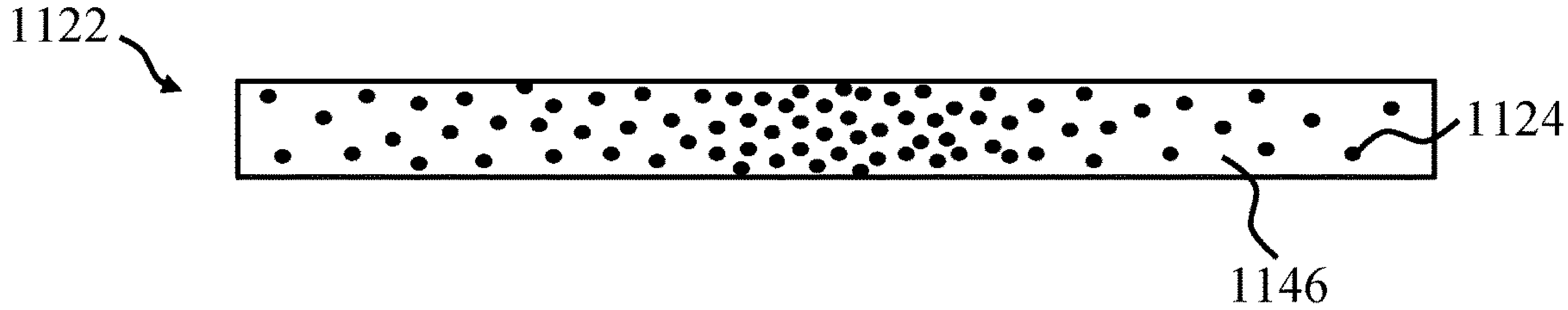

FIG. 11

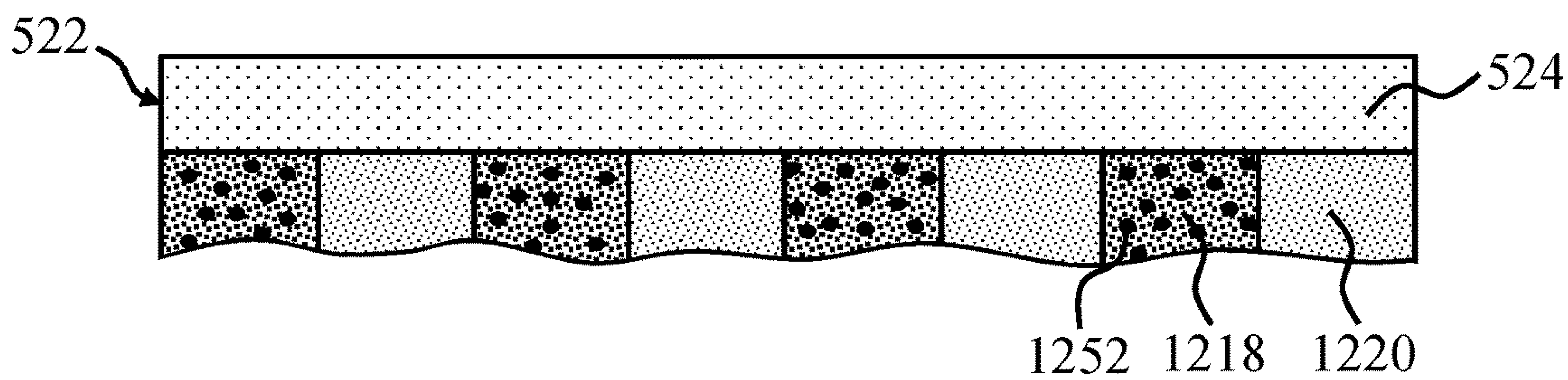

FIG. 12

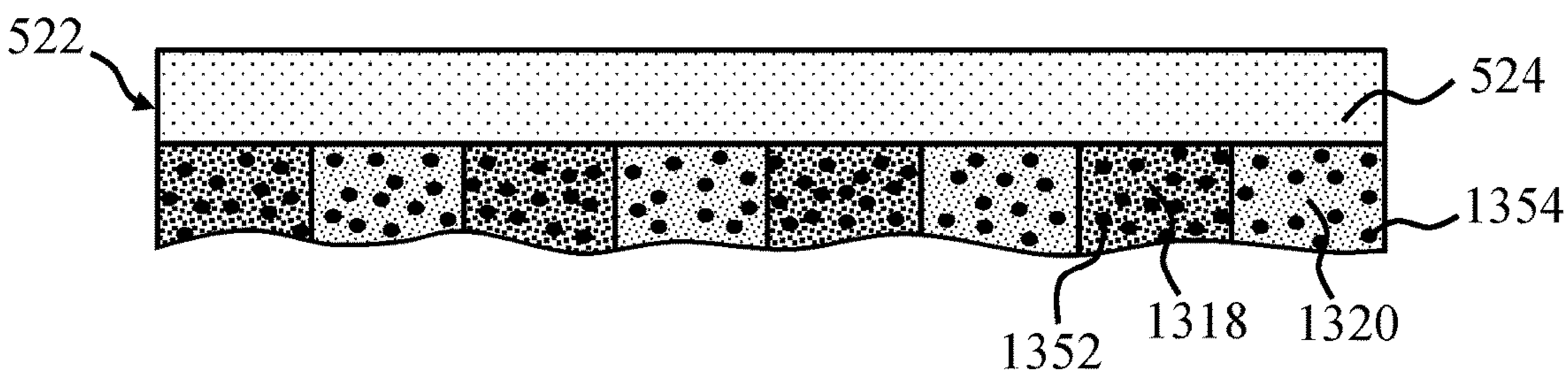

FIG. 13

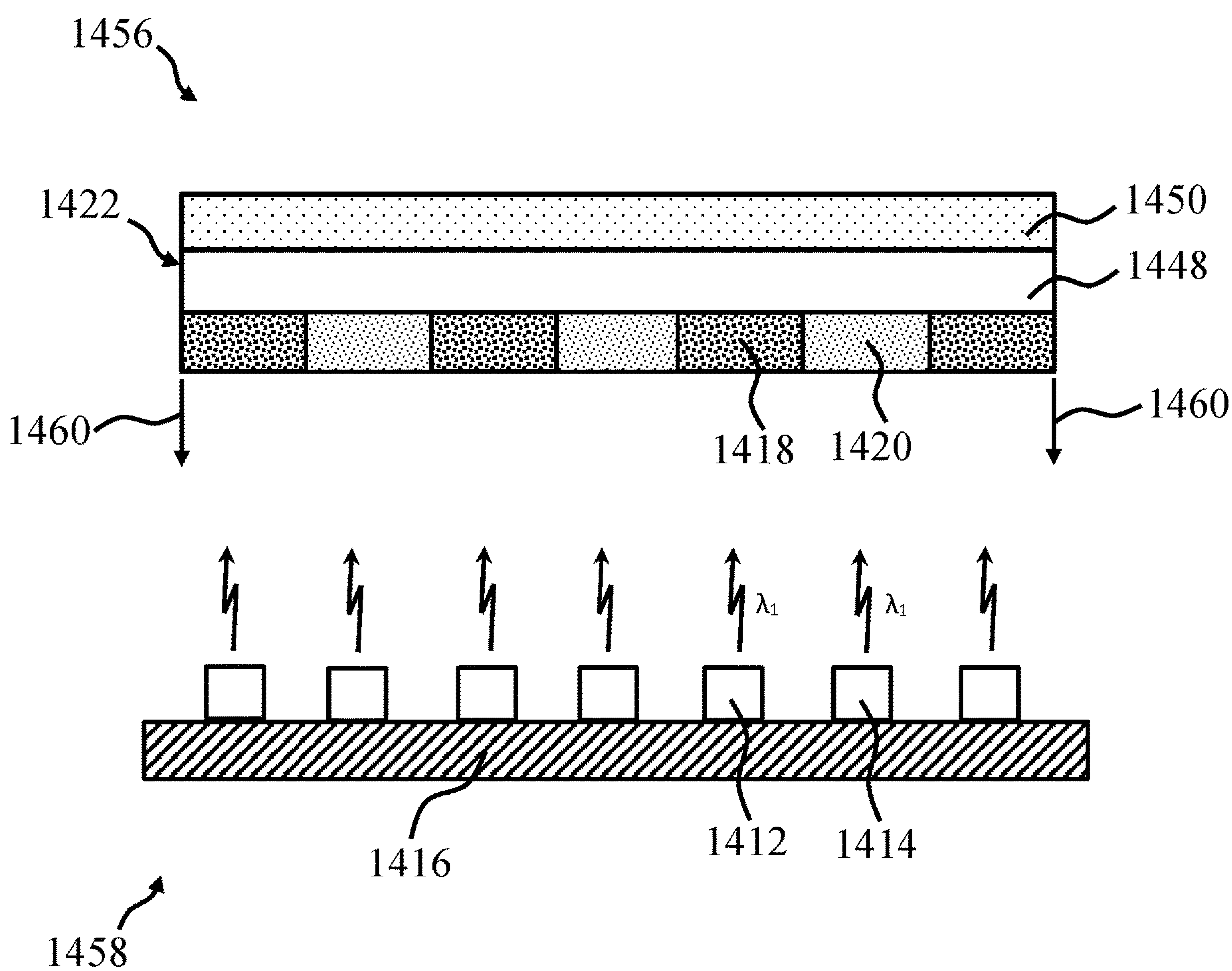
1456
1422
1450
1448
1460
1460
1418
1420
λ1
λ1
1416
1412
1414
1458

FIG. 14

WHITE LIGHT EMITTING DEVICE AND DIFFUSING LAYER

FIELD OF THE INVENTION

[0001] Embodiments of the present invention are directed to white light emitting devices; in particular, although not exclusively, to color tunable white light emitting devices. More particularly, although not exclusively, embodiments concern white light emitting devices comprising a diffusing layer.

BACKGROUND OF THE INVENTION

[0002] White light emitting LEDs ("white LEDs") include one or more photoluminescence materials (typically inorganic phosphor materials), which absorb a portion of the excitation light (typically blue) emitted by the LED and re-emit light of a different color (wavelength). The portion of the blue light generated by the LED that is not absorbed by the photoluminescence material combined with the light emitted by the photoluminescence material provides light which appears to the eye as being white in color. Due to their long operating life expectancy (>50,000 hours) and high luminous efficacy (100 lumens per watt and higher), white LEDs are rapidly replacing conventional fluorescent, compact fluorescent and incandescent lamps.

[0003] A color tunable white light emitting device typically comprises multiple LEDs. There are various forms of color tunable LEDs. One form is Chip Scale Packaging (CSP) in which each LED Chip (Die) is individually coated with the photoluminescence material. Typically, multiple CSP LEDs are then packaged to form the color tunable white light emitting device. While this form of LED generates white light having good color uniformity, it is relatively expensive to manufacture since each LED Chip requires an individual uniform thickness coating of photoluminescence material. Since the manufacturing process takes more time due to the intricacies involved in individually coating each LED Chip, this process is expensive. Moreover, CSP can require the use of more photoluminescence material, thereby further increasing costs. The luminous efficacy of CSP LEDs can be relatively lower compared with other LED forms.

[0004] Another form of color tunable white light emitting devices is Chip on Board (COB) in which multiple LED Chips (Dies) are located on a substrate before one or more photoluminescence materials is disposed thereon. The luminous efficacy of white light emitting devices in the form of COB is generally superior to the luminous efficacy of white light emitting devices in the form of CSP. However, COB LEDs can suffer from generation of white light having low color uniformity compared with other forms.

[0005] The present invention intends to address and/or overcome the limitations discussed above by presenting new designs and method not hitherto contemplated nor possible by known constructions. More particularly, there is a need for a cost-effective white light emitting device that generates light with improved color uniformity.

SUMMARY OF THE INVENTION

[0006] According to an aspect of the present invention, there is provided a white light emitting device comprising a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED, and a diffusing layer disposed over said first and second photoluminescence layers, said diffusing layer comprising light scattering particles.

[0007] The white light emitting device formed according to an embodiment of the present invention exhibits enhanced color uniformity of generated white light due to the combination of the first/second photoluminescence material layers and the diffusing layer disposed thereover. Enhanced color uniformity is particularly advantageous when the device is used in large beam optics. Moreover, compared with CSP LEDs, for example, the amount of photoluminescence material used may also be reduced thereby providing a more cost-effective manner of manufacturing the white light emitting device. This is because the diffusing layer comprising light scattering particles increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the first or second photoluminescence layers. Thus, the amount of photoluminescence material required to generate a given color temperature of light can be reduced since more of the first/second LED light is converted to photoluminescence light owing to the diffusing layer.

[0008] Further, COB LEDs provided with a diffusing layer thereon are able to generate white light having a luminous efficacy that is comparable or greater than white light generated by CSP LEDs.

[0009] Hence, the present invention is the provision of a white light emitting device that does not suffer from the disadvantages discussed above such as high cost of manufacture and low color uniformity of white light generated.

[0010] It may be that the first photoluminescence material layer comprises a first phosphor material and/or the second photoluminescence material layer comprises a second phosphor material. The first and second phosphor materials may be different. It may be that the first photoluminescence material layer comprises a first quantum dot material (QD) and/or the second photoluminescence material layer comprises a second quantum dot (QD) material.

[0011] The first phosphor material may be excitable to generate white light having a correlated color temperature of 2700K to 3500K.

[0012] The second phosphor material may be excitable to generate white light having a correlated color temperature of 5000K to 6500K.

[0013] In this way, the white light emitting device may be a color temperature tunable white light emitting device.

[0014] The white light emitting device may comprise alternating arrays of first LEDs and second LEDs. Such a white light emitting device lends itself to a tunable configuration in which the arrays of the first and second LEDs can be arranged according to the desired requirements of light to be generated.

[0015] More particularly, the white light emitting device may comprise alternating strips of the first and second photoluminescence material layers associated with the alternating arrays of first LEDs and second LEDs. Such an arrangement is particularly advantageous because it simplifies the manufacturing process thereby reducing costs. For example, compared to CSP LEDs which are individually coated with a photoluminescence material, the inventors have discovered that disposing the first and second photoluminescence materials as "layers" in the form of alternating strips over the first and second LEDs is significantly more time-efficient and cost-effective. That is a plurality of first/

second LEDs can be covered/disposed with a first/second photoluminescence material rather that coating each LED individually.

[0016] The diffusing layer may be in direct contact with the first and/or second photoluminescence material layer. This may improve the amount of light being scattered by the light scattering particles.

[0017] The diffusing layer may comprise a light transmissive material and light scattering particles. The light transmissive material may allow the light scattering material to be suspended therein.

[0018] It may be that the light scattering particles are incorporated in the light transmissive material. This may simplify the manufacturing process of the diffusing layer and improve its robustness and reliability.

[0019] The light scattering particles may be substantially uniformly distributed through the light transmissive material. Having uniformly distributed light scattering particles within the light transmissive material may enhance the uniformity of light generated by the white light emitting device.

[0020] The diffusing layer may comprise a layer of the light transmissive material and a layer of the light scattering particles. The layer of light scattering particles can be deposited directly onto the light layer of light transmissive material by for example screen printing. Alternatively, the layer of light scattering particles can be manufactured separately. This alternative configuration may provide more flexibility in the way the diffusing layer is manufactured, since the light transmissive layer and the layer of light scattering particles may be separately manufactured before assembly, which could be more cost-effective is some instances.

[0021] It may be that the layer of the light transmissive material is disposed between the layer of the light scattering particles and the first and/or second photoluminescence material layers. Such a configuration may provide greater distance between the light scattering particles and the first and/or second photoluminescence material layers and this can improve color uniformity since color mixing of light can occur within the layer of light transmissive material.

[0022] The layer of the light scattering particles may be disposed between the layer of the light transmissive material and the first and/or second photoluminescence material layers. In such a configuration, the layer of light transmissive material may act as a protective layer to the layers of the light scattering particles and the first and/or second photoluminescence material layers. It may be that the layer of light transmissive is the outermost layer or faces outwardly.

[0023] The diffusing layer may comprise two layers of the light transmissive material and a layer of the light scattering particles disposed therebetween. This configuration may provide a greater distance between the light scattering particles and the first and/or second photoluminescence material layers, as well as the layer of light transmissive material may acting as a protective layer.

[0024] It may be that at least one of the first photoluminescence material layer, the second photoluminescence material layer, or the diffusing layer comprises light scattering particles. Thus, light scattering particles may be contained in the first photoluminescence material layer and the diffusing layer; in the second photoluminescence material layer and the diffusing layer; or in the first photoluminescence material layer, the second photoluminescence material layer and the diffusing layer. The inclusion of light scattering particles in the first and/or second photoluminescence material layers increases the probability that a photon will result in the generation of photoluminescence light thereby reducing the amount of photoluminescence material required. Further, this inclusion of light scattering particles in the photoluminescence layer(s) may improve the uniformity of the white light generated by the light emitting device generated still further.

[0025] The first photoluminescence material layer and/or the second photoluminescence material layer may comprise light scattering particles incorporated in a light transmissive material. The light transmissive material may allow the light scattering particles to be distributed more uniformly by suspension therein, for instance.

[0026] The white light emitting device of claim **1**, wherein the substrate is light transmissive. The substrate can comprise a circuit board such as a metal core printed circuit board (MCPCB).

[0027] The light scattering particles may have an average particle size selected such that they scatter excitation light generated by the first and second LEDs relatively more than they scatter light generated by the first and second photoluminescence material layers, optionally the average particle size may be in a range from about 100 nm to about 200 nm.

[0028] One benefit of this approach, especially within the diffuser layer, is that by selecting an appropriate particle size and concentration per unit area of the light scattering particles, an improvement is obtained in the white color appearance of an LED device in its OFF state. Another benefit is an improvement to the color uniformity of emitted light from the white light emitting device for emission angles over a ±60° range from the emission axis. Moreover, the use of a diffusing layer having an appropriate particle size and concentration per unit area of the light scattering particles can substantially reduce the quantity of photoluminescence material required to generate a selected color of emitted light, since the diffusing layer increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the photoluminescence layer(s). It may be that inclusion of a diffusing layer in direct contact with the photoluminescence layer(s) can reduce the quantity of phosphor material required to generate a given color emission product, e.g. by up to 40%. As used herein, "direct contact" means that there are no intervening layers or air gaps.

[0029] The light transmissive medium may be disposed between the diffusing layer and the first and/or second photoluminescence layers.

[0030] The amount of light scattering particles may vary across the diffusing layer. For instance, there may be more light scattering particles towards the center of the light emitting device than its edges. The center of the light emitting device may be considered the center of the substrate, for instance.

[0031] The thickness of the diffusing layer may vary.

[0032] The concentration of light scattering particles within the diffusing layer may vary.

[0033] By varying the thickness of the light diffusing layer and/or the concentration of light scattering particles within the diffusing layer, the light scattering properties can be appropriately selected depending on the desired output of the white light emitting device.

[0034] The light scattering particles may comprise titanium dioxide (TiO_2), barium sulfate ($BaSO_4$), magnesium oxide (MgO), silicon dioxide (SiO_2) or aluminum oxide (Al_2O_3), for example.

[0035] The light transmissive material may comprise a curable liquid polymer such as a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone or a fluorinated polymer.

[0036] The substrate may comprise a circuit board such as a metal core printed circuit board (MCPCB).

[0037] In another aspect, the present invention encompasses a method of manufacturing a white light emitting device, comprising the steps of: providing an array of first LEDs; dispensing a first photoluminescence material layer at least over said array of first LEDs; providing an array of second LEDs; dispensing a second photoluminescence material layer at least over said array of second LEDs; and dispensing a diffusing layer over said first and second photoluminescence material layers.

[0038] To reduce the variation in emitted light color with emission angle, the weight loading of light scattering particles to light transmissive material may be in a range from 0.1 to 50% wt or 5 to 10% wt.

[0039] In another aspect, the present invention envisages a white light emitting device comprising alternating arrays of first LEDs and second LEDs disposed on a substrate, a first photoluminescence material layer disposed over at least said array of first LEDs, a second photoluminescence material layer disposed over at least said array of second LEDs, and a diffusing layer disposed over said first and second photoluminescence material layers, the diffusing layer comprising light scattering particles, wherein the first photoluminescence material layer comprises a first phosphor material excitable to generate white light having a first correlated color temperature, the second photoluminescence material layer comprises a second phosphor material excitable to generate white light having a second correlated color temperature.

[0040] It may be that the first phosphor material is excitable to generate white light having a correlated color temperature of 2700K to 3500K and/or the second phosphor material is excitable to generate white light having a correlated color temperature of 5000K to 6500K.

[0041] According to another aspect of the present invention, there is provided a component for a white light emitting device, comprising alternating strips of first and second photoluminescence material layers disposed on a substrate, and a diffusing layer disposed over said alternating strips of first and second photoluminescence material layers, the diffusing layer comprising light scattering particles, wherein the first photoluminescence material layer comprises a first phosphor material excitable to generate white light having a first correlated color temperature, and the second photoluminescence material layer comprises a second phosphor material excitable to generate light having a second correlated color temperature.

[0042] It may be that the first correlated color temperature is from 2700K to 3500K and/or the second correlated color temperature is from 5000K to 6500K.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] These and other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures, wherein:

[0044] FIG. **1** is a sectional view of a white light emitting device in accordance with an embodiment of the invention;

[0045] FIG. **2** is a sectional view of the white light emitting device of FIG. **1** with color tunable control;

[0046] FIG. **3**A is a plan view of a white light emitting device in accordance with an embodiment of the invention;

[0047] FIG. **3**B is cross sectional side view through A-A;

[0048] FIG. **4** is a plan view of a white light emitting device in accordance with an embodiment of the invention;

[0049] FIG. **5** is a sectional view of a diffusing layer in accordance with an embodiment of the invention;

[0050] FIG. **6** is a sectional view of a diffusing layer in accordance with another embodiment of the invention;

[0051] FIG. **7** is a sectional view of a diffusing layer in contact with photoluminescence material layers in accordance with an embodiment of the invention;

[0052] FIG. **8** is a sectional view of a diffusing layer in contact with photoluminescence material layers in accordance with another embodiment of the invention;

[0053] FIG. **9** is a sectional view of a diffusing layer in accordance with another embodiment of the invention;

[0054] FIG. **10** is a sectional view of a diffusing layer in accordance with another embodiment of the invention;

[0055] FIG. **11** is a sectional view of a diffusing layer in accordance with another embodiment of the invention;

[0056] FIG. **12** is a sectional view of a diffusing layer in contact with photoluminescence material layers in accordance with another embodiment of the invention;

[0057] FIG. **13** is a sectional view of a diffusing layer in contact with photoluminescence material layers in accordance with another embodiment of the invention; and

[0058] FIG. **14** is a sectional view of a component and a separate LED array for a white light emitting device in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0059] Embodiments of the present invention will now be described in detail with reference to the drawings, which are provided as illustrative examples of the invention so as to enable those skilled in the art to practice the invention. Notably, the figures and examples below are not meant to limit the scope of the present invention to a single embodiment, but other embodiments are possible by way of interchange of some or all of the described or illustrated elements. Moreover, where certain elements of the present invention can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present invention will be described, and detailed descriptions of other portions of such known components will be omitted so as not to obscure the invention. In the present specification, an embodiment showing a singular component should not be considered limiting; rather, the invention is intended to encompass other embodiments including a plurality of the same component, and vice-versa, unless explicitly stated otherwise herein. Moreover, applicants do not intend for any term in the specification or claims to be ascribed an uncommon or special meaning unless explicitly set forth as such. Further, the present invention encompasses present and future known equivalents to the known components referred to herein by way of illustration. Throughout this specification like reference numerals are used to denote like parts.

[0060] A white light emitting device **10** in accordance with an embodiment of the invention will now be described with reference to FIG. **1** which show a sectional side view of the device.

[0061] The device **10** comprises first LEDs **12** and second LEDs **14** disposed on a substrate **16** (e.g. MCPCB); a first photoluminescence material layer **18** disposed over at least said first LEDs **12**; a second photoluminescence material layer **20** disposed over at least said second LEDs **14**; and a diffusing layer **22** disposed over said first and second photoluminescence layers **18**, **20**; said diffusing layer **22** comprising light scattering particles **24**.

[0062] More particularly, FIG. **1** shows a sectional view of two rows of first LEDs **12** adjacent two rows of second LEDs **14** in a chip on board (COB) type arrangement. Only one LED of each row is shown in FIGS. **1** and **2**; there being a total of four rows (two for first LEDs **12** and two rows for second LEDs **14**). In this embodiment, the first and second LEDs **12**, **14** are InGaN (indium gallium nitride) blue LEDs which are operable to generate blue light having a peak wavelength in a wavelength range 400 to 480 nm (typically 450 to 470 nm). The two rows of first LEDs **12** and two rows of second LEDs **14** are deposited on a planar substrate **16**. Towards the edges of the planar substrate **16** is located a peripheral wall **26** which surrounds (encloses) the two rows of first LEDs **12** and two rows of second LEDs **14**. Typically, the wall **26** surrounds the two rows of first LEDs **12** and two rows of second LEDs **14**. In other embodiments, the wall may delineate one or more sides of the substrate.

[0063] A first photoluminescence material layer **18** comprising a first phosphor material (typically green and red emitting phosphor materials) is deposited onto the planar substrate **16** and, in this embodiment, completely covers the two rows of first LEDs **12**. The first phosphor material is excitable to generate white light having a correlated color temperature of about 2700K to 3500K (warm white light). Similarly, the second photoluminescence material layer **20** comprising a second phosphor material (Typically a green phosphor material) is deposited onto the planar substrate **16** and, in this embodiment, completely covers the two rows of second LEDs **14**. The second phosphor material is excitable to generate white light having a correlated color temperature of 5000K to 6500K (cool white light). In this way, the first and second photoluminescence material layers **18**, **20** are located adjacent one another and also contained within the wall **26**.

[0064] A planar diffusing layer **22**, having similar dimensions to those of the planar substrate **16**, is disposed over and on top of both the first photoluminescence material layer **18** and second photoluminescence material layer **20**, and is also contained inside the wall **26**. The upper surfaces **28** of the upright walls **26** together with the upper surface **30** of the planar diffusing layer **22** define a flush surface. The planar diffusing layer **22**, the planar substrate **16**, and wall **26** define an interior volume **32** which houses and encloses the first and second photoluminescence material layers **18**, **20** and the two rows of first LEDs **12** and the two rows of second LEDs **14**.

[0065] The white light emitting device **10**, to an observer **34**, exhibits enhanced color uniformity of generated white light due to the combination of the first and second photoluminescence material layers **18**, **20** and the diffusing layer **22** disposed thereover. Compared with CSP LEDs, for example, the amount of photoluminescence material used may also be reduced thereby providing a more cost-effective manner of manufacturing the white light emitting device **10**. This is because the diffusing layer **22** comprising light scattering particles **24** increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the first or second photoluminescence layers. Thus, the amount of photoluminescence material required to generate a given color temperature of light can be reduced since more of the first/second LED **12**, **14** light is converted to photoluminescence light owing to the diffusing layer **22**.

[0066] Referring now to FIG. **2**, there is shown the white light emitting device of FIG. **1** with dimming control. The first and second photoluminescence material layers **18**, **20** are operable to absorb a proportion of the blue light λ_1 generated by the two rows of first LEDs **12** and the two rows of second LEDs **14** and convert it to light of a different wavelength by a process of photoluminescence. In this embodiment, the first photoluminescence material layer **18** converts the blue light λ_1 to λ_2, and the second photoluminescence material layer **18** converts the blue light λ_1 to λ_3. Not all of the blue light λ_1 generated by the two rows of first LEDs **12** and the two rows of second LEDs **14** is absorbed by the first and second photoluminescence material layers **18**, **20** and some of it is emitted through the diffusing layer **22**. The emission product **36** of the white light emitting device **10** thus comprises the combined light of wavelengths λ_1, λ_2, λ_3 generated by the by the two rows of first LEDs **12** and the two rows of second LEDs **14** and the first and second photoluminescence material layers **18**, **20**. The CCT of the emission product **36** is thus a combination of the CCT of light (λ_1) generated by the two rows of first LEDs **12** and the two rows of second LEDs **14**, the CCT of light (λ_2) generated by the first photoluminescence material layer **18**, and the CCT of light (λ_3) generated by the second photoluminescence material layer **20**.

[0067] In this embodiment, the combination of light (λ_1) generated by the two rows of first LEDs **12** and light (λ_2) generated by the first photoluminescence material layer **18** generates light having a CCT corresponding to a warm yellowish white (a correlated color temperature of about 2700K to 3500K). Similarly, the combination of light (λ_1) generated by the two rows of second LEDs **14** and light (λ_3) generated by the second photoluminescence material layer **20** generates light having a CCT corresponding to a cool blueish white (a correlated color temperature of about 5000K to 6500K). Therefore, the emission product **34** of the white light emitting device **10** in this example would be a combination of the warm yellowish white light deriving from (λ_1)/(λ_2), the cool blueish white light deriving from (λ_1)/(λ_3).

[0068] A dimmer switch **38** may be operably connected to a control circuit **40** which is operably connected to the two rows of first LEDs **12** and the two rows of second LEDs **14**. The dimmer switch **38** is configured to generate a continuous range of output powers to be used for controlling (tuning) the color temperature and dimming level of the white light emitting device **10**. The control circuit **40** is configured to translate the generated output power into an on/off arrangement and/or adjustable power arrangement for the two rows of first LEDs **12** and the two rows of second LEDs **14**.

[0069] While the variation in color temperature of an incandescent light bulb is directly related to the output power of the dimmer switch, the CCT of the emission product **36** of the light emitting device **10** is not directly related to the output power of the dimmer switch **38**. As such, the control circuit **40** must translate the output power of the dimmer switch **38** into a control arrangement for the two rows of first LEDs **12** and the two rows of second LEDs **14** such that the white light emitting device **10** dimming behavior resembles that of a dimmable incandescent light bulb—that is on dimming its color temperature changes from cool white at full power to warm white when dimmed.

[0070] Because the emission product **36** of the white light emitting device **10** is a combination of light (λ_1) generated by the two rows of first LEDs **12** and the two rows of second LEDs **14** and light (λ_2, λ_3) generated by the first and second photoluminescence material layers **18**, **20**, the CCT of the emission product **36** can be changed by modifying the combination of light. In this way, a CCT corresponding to a warm yellowish white color may be generated by having a larger portion of the emission product **36** originate from the first photoluminescence material layer **18** (e.g., region generating light with a CCT corresponding to a warm yellowish white) and a smaller portion of the emission product **36** originate from the second photoluminescence material layer **20** (e.g., region generating light with a CCT corresponding to a cool blueish white). A CCT corresponding to a cool bluish white color may be generated by having a smaller portion of the emission product **36** originate from the first photoluminescence material layer **18** and a larger portion of the emission product **36** originate emanate from the second photoluminescence material layer **20**.

[0071] The emission product **36** may be modified, for example, by altering the on/off configuration of the two rows of first LEDs **12** and the two rows of second LEDs **14**. Thus, the CCT of the emission product **36** may grow closer to a warm yellowish color as some or all of the second LEDs **14** corresponding to the second photoluminescence material layer **20** are turned off while the two rows of first LEDs **12** corresponding to the first photoluminescence material layer **18** remain on. Conversely, if a emission product **36** having a CCT with a cool blueish is color is desired, some or all of the first LEDs **12** corresponding to the first photoluminescence material layer **18** may be turned off while the two rows of second LEDs **14** corresponding to the second photoluminescence material layer **20** remain on.

[0072] Thus, by configuring the control circuit **40** of the white light emitting device **10** to translate output power of the dimmer switch **38** into a corresponding on/off configuration of the two rows of first LEDs **12** and the two rows of second LEDs **14**, the white light emitting device **10** may be tuned like a typical incandescent light bulb.

[0073] Alternatively, in another embodiment, instead of an on/off control, individual power levels (typically current) are adjusted by the control circuit **40** to the two rows of first LEDs **12** and the two rows of second LEDs **14**, so that a selected ratio of the emissions λ_2, λ_3 from the first and second photoluminescence material layers **18**, **20** is obtained to generate a desired CCT of the emission product **36**. In this approach, the CCT of the emission product **36** corresponds to a cool blueish white color or a warm yellowish white color depending upon the relative amounts of power that are provided to the two rows of first LEDs **12** and the two rows of second LEDs **14**.

[0074] With reference to FIGS. **3**A and **3**B, there is shown a plan view of a white light emitting device **310** in accordance with an embodiment of the invention, and a cross section side view through A-A (of FIG. **3**A). The white light emitting device **310** is similar to the white light emitting device **10** of FIG. **1**. Therefore, like reference numerals are used in FIG. **3** to denote like features.

[0075] In this embodiment, the white light emitting device **310** has a circular shape. Thus, the substrate **316** is planar and disk shaped. Forming another chip on board arrangement, alternating arrays (rows) of first LEDs **312** and second LEDs **314** are configured from one circumferential point **342** to the diametrically opposing circumferential point **344**. In this embodiment, the arrays are in the form of rows. As illustrated, the circular substrate **316** comprises a total of seven rows of alternating arrays of first LEDs **312** and second LEDs **314**, wherein the first and second LEDs **312**, **314** are substantially symmetrically distributed over the entirety on the circular substrate **316**. The circular substrate **316** also comprises about its entire perimeter a wall **326** which encloses all the arrays of first LEDs **312** and second LEDs **314**. In this embodiment, the first and second LEDs **312**, **314** are InGaN (indium gallium nitride) blue LEDs which are operable to generate blue light having a peak wavelength in a wavelength range 400 to 480 nm (typically 450 to 470 nm).

[0076] A first photoluminescence material layer **318** comprising a first phosphor material (typically green and red emitting phosphor materials) is deposited onto the circular substrate **316** and, in this embodiment, completely covers the arrays of first LEDs **312**. The first phosphor material is excitable to generate white light having a correlated color temperature of about 2700K to 3500K (warm white light). Similarly, the second photoluminescence material layer **320** comprising a second phosphor material (typically a green phosphor material) is deposited onto the circular substrate **316** and, in this embodiment, completely covers the arrays of second LEDs **314**. The second phosphor material is excitable to generate white light having a correlated color temperature of 5000K to 6500K (cool white light). In this way, the first and second photoluminescence material layers **18**, **20** are located adjacent one another and also contained within the upright walls **26**. In this way, the white light emitting device **310** comprises a total of seven alternating strips of the first and second photoluminescence material layers **18**, **20** associated with the alternating arrays of first and second LEDs **312**, **314**.

[0077] A circular and planar diffusing layer **322**, having slightly smaller dimensions to those of the circular substrate **316**, is disposed over and on top of both the first photoluminescence material layer **318** and second photoluminescence material layer **320**, and is also contained inside the upright wall **26**. The upper surface **328** of the upright wall **326** together with the upper surface **330** of the circular diffusing layer **322** define a flush surface. The circular diffusing layer **322**, the circular substrate **316**, and wall **326** define an interior volume **332** which houses and encloses the first and second photoluminescence material layers **18**, **20** and the alternating arrays of first LEDs **312** and second LEDs **314**.

[0078] A method of manufacturing the white light emitting device **310**, for example, comprises the steps of: providing an array of first LEDs **312**; dispensing a first photoluminescence material layer **318** at least over said array of first LEDs

312; providing an array of second LEDs 314; dispensing a second photoluminescence material layer 320 at least over said array of second LEDs 314; and dispensing a diffusing layer 322 over said first and second photoluminescence material layers 318, 320. In this embodiment, the diffusing layer 322 is in direct contact with the first and second photoluminescence material layers 318, 320. Although, it will be appreciated that, in other embodiments, the diffusing layer may be in direct contact with only the first or second photoluminescence material layer.

[0079] The white light emitting device 310, to an observer 334, exhibits enhanced color uniformity of generated white light due to the combination of the first and second photoluminescence material layers 18, 20 and the diffusing layer 322 disposed thereover. Compared with CSP LEDs, for example, the amount of photoluminescence material used may also be reduced thereby providing a more cost-effective manner of manufacturing the white light emitting device 310. This is because the diffusing layer 322 comprising light scattering particles 324 increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the first or second photoluminescence layers. Thus, the amount of photoluminescence material required to generate a given color temperature of light can be reduced since more of the first/second LED 312, 314 light is converted to photoluminescence light owing to the diffusing layer 322.

[0080] Table 1 tabulates values for a white light emitting device without a diffusing layer. More particularly, the white light emitting device comprises a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED. The device having a nominal correlated color temperature (CCT) of 2700 K. A first batch containing six samples of the device without a diffusing layer were prepared and tested, and the parameter data including light intensity (lm), luminous efficacy LE (lm/W), chromaticity CIE x,y, CRI-Ra, and CRI-R9 for each sample is shown in Table 1 together with an average value for each parameter.

TABLE 1

White light emitting device performance without a diffusing layer

	Intensity	LE	Chromaticity		CCT	CRI	
Number	(lm)	(lm/W)	CIE x	CIE y	(K)	Ra	R9
1	1980.0	112.1	0.4631	0.4216	2740	95.0	67.3
2	1991.0	112.8	0.4632	0.4212	2735	95.1	68.0
3	2007.0	113.8	0.4636	0.4212	2729	95.2	68.4
4	1979.0	112.3	0.4628	0.4210	2740	95.0	67.4
5	1976.0	113.3	0.4626	0.4195	2731	95.5	69.5
6	1979.0	112.5	0.4618	0.4203	2747	94.7	66.4
Avg	1985.3	112.8	0.4629	0.4208	2737	95.1	67.8

[0081] Table 2 tabulates values for a white light emitting device having a 5% wt diffusing layer. More particularly, the white light emitting device comprising a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED, and a diffusing layer disposed over said first and second photoluminescence layers, said diffusing layer comprising light scattering particles. The 5% wt diffusing layer denotes a loading of 5 weight percent of scattering particles in 95 weight percent liquid silicone (e.g. light transmissive material). The device having a nominal correlated color temperature (CCT) of 2700 K. The first batch containing six samples of the device with a 5% wt diffusing layer were prepared and tested, and the parameter data including light intensity (lm), CIE x,y, CRI-Ra, and CRI-R9 for each sample is shown in Table 2 together with an average value for each parameter.

TABLE 2

White light emitting device performance without a diffusing layer

	Intensity	LE	Chromaticity		CCT	CRI	
Number	(lm)	(lm/W)	CIE x	CIE y	(K)	Ra	R9
1	1960.0	110.85	0.4668	0.4247	2712	94.4	64.7
2	1980.0	112.02	0.4669	0.4240	2705	94.6	65.3
3	1990.0	112.84	0.4674	0.4243	2701	94.6	65.7
4	1960.0	111.22	0.4665	0.4243	2713	94.4	64.4
5	1950.0	111.79	0.4664	0.4228	2703	94.9	66.5
6	1960.0	111.38	0.4656	0.4235	2720	94.2	63.6
Avg	1966.7	111.68	0.4666	0.4239	2709	94.5	65.0

[0082] Comparing the average data values of Tables 1 and 2, it can be seen that by including a 5% wt diffusing layer there is a negligible change in CIE x (0.46289 compared with 0.4666), CIE y (0.4208 compared with 0.4239), CRI-Ra (95.1 compared with 94.5), and CRI-R9 (67.8 compared with 65.0). Tables 1 and 2 also show that there is only a negligible change in light intensity (1985.3 lm compared with 1966.7 lm) and luminous efficacy (112.8 lm/W compared with 111.7 lm/W). Therefore, the data demonstrates that the performance and characteristics of the white light emitting device do not degrade with the inclusion of a 5% wt diffusing layer. However, the observer will observe a significant improvement in the color uniformity of light generated by the white light emitting device formed according to the invention, compared with a device devoid of a diffusing layer. The inventors have also found that the white light emitting device of the present invention advantageously has a superior light intensity output and luminous efficacy than an equivalent device utilizing CSP LEDs without a diffusing layer.

[0083] Table 3 tabulates values for a white light emitting device without a diffusing layer. More particularly, the white light emitting device comprises a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED. The device having a nominal correlated color temperature (CCT) of 2700 K. A second batch containing six samples of the device without a diffusing layer were prepared and tested, and the parameter data including light intensity (lm), efficacy (lm/W), CIE x,y, CRI-Ra, and CRI-R9 for each sample is shown in Table 3 together with an average value for each parameter.

TABLE 3

White light emitting device performance without a diffusing layer

	Intensity	LE	Chromaticity		CCT	CRI	
Number	(lm)	(lm/W)	CIE x	CIE y	(K)	Ra	R9
7	1958.0	111.4	0.4641	0.4217	2726	95.1	68.1
8	1991.0	113.4	0.4628	0.4214	2742	95.0	67.3

TABLE 3-continued

White light emitting device performance without a diffusing layer

Number	Intensity (lm)	LE (lm/W)	Chromaticity CIE x	CIE y	CCT (K)	CRI Ra	R9
9	1953.0	110.7	0.4631	0.4199	2726	95.5	69.4
10	1994.0	113.1	0.4630	0.4216	2741	94.9	67.3
11	2000.0	113.1	0.4647	0.4211	2714	94.8	65.5
Avg	1979.2	112.3	0.4635	0.4211	2730	95.1	67.5

[0084] Table 4 tabulates values for a white light emitting device having a 10% wt diffusing layer. More particularly, the white light emitting device comprising a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED, and a diffusing layer disposed over said first and second photoluminescence layers, said diffusing layer comprising light scattering particles. The 10% wt diffusing layer denotes a loading of 5 weight percent of scattering particles in 90 weight percent liquid silicone (e.g. light transmissive material). The device having a nominal correlated color temperature (CCT) of 2700 K. The second batch containing six samples of the device with a 10% wt diffusing layer were prepared and tested, and the parameter data including light intensity (lm), efficacy (lm/W), CIE x,y, CRI-Ra, and CRI-R9 for each sample is shown in Table 4 together with an average value for each parameter.

TABLE 4

White light emitting device performance without a diffusing layer

Number	Intensity (lm)	LE (lm/W)	Chromaticity CIE x	CIE y	CCT (K)	CRI Ra	R9
7	1920.0	109.2	0.4720	0.4260	2653	94.5	64.6
8	1940.0	110.4	0.4711	0.4258	2663	94.3	63.8
9	1910.0	108.2	0.4713	0.4243	2650	94.9	65.9
10	1950.0	110.5	0.4713	0.4259	2662	94.4	64.0
11	1960.0	110.7	0.4729	0.4253	2636	94.9	66.8
Avg	1936.0	109.8	0.4717	0.4246	2653	94.6	65.0

[0085] Comparing the average data values of Tables 3 and 4, it can be seen that by including a 10% wt diffusing layer there is only a negligible change in CIE x (0.4635 compared with 0.4717), CIE y (0.4211 compared with 0.42456), CRI-Ra (95.1 compared with 94.6), and CRI-R9 (67.5 compared with 65.0). Tables 3 and 4 also show that there is only a negligible change in light intensity (1985.3 lm compared with 1966.7 lm) and luminous efficacy (112.3 lm/W compared with 109.8 lm/W). Therefore, the data demonstrates that the performance and characteristics of the white light emitting device do not degrade with the inclusion of a 10% wt diffusing layer. However, the observer will observe a significant improvement in the color uniformity of light generated by the white light emitting device formed according to the invention, compared with a device devoid of a diffusing layer.

[0086] Referring to FIG. **4**, there is shown a white light emitting device **410** formed according to an embodiment of the invention. The white light emitting device **410** is the same as the white light emitting device **310** shown in FIG. **3**A except that it comprises fewer first and second LEDs **412**, **414**. More particularly, the first and second LEDs **412**, **414** are substantially non-symmetrically (non-uniformly) distributed. Despite, the non-symmetrical distribution, the observer **434** (not shown) exhibits enhanced color uniformity of generated white light due to the combination of the first and second photoluminescence material layers **418**, **420** and the diffusing layer **422** (not shown) disposed thereover. Compared with CSP LEDs, for example, the amount of photoluminescence material used may also be reduced thereby providing a more cost-effective manner of manufacturing the white light emitting device **410**. This is because the diffusing layer **422** (not shown) comprising light scattering particles **424** (not shown) increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the first or second photoluminescence layers **418**, **420**. Thus, the amount of photoluminescence material required to generate a given color temperature of light can be reduced since more of the first/second LED **412**, **414** light is converted to photoluminescence light owing to the diffusing layer **422** (not shown).

[0087] Referring to FIG. **5**, there is shown a side sectional view of an embodiment of a diffusing layer **522**. The diffusing layer **522** has a rectangular cross section and is essentially planar in form. The diffusing layer **522** comprises a light transmissive material **546** and light scattering particles **524**. In this embodiment, the light scattering particles **524** are incorporated in the light transmissive material **546** and are substantially uniformly distributed through the light transmissive material **546**. However, it will be appreciated that in other embodiments the light scattering particles may not be uniformly distributed in a light transmissive medium/material. The light scattering particles **524** can have an average particle size selected such that they scatter excitation light generated by the first and second LEDs relatively more than they scatter light generated by the first and second photoluminescence material layers, and in this embodiment the average particle size being in a range from about 100 nm to about 200 nm. The light scattering particles **524** are formed from titanium dioxide or other materials as defined herein.

[0088] Referring to FIG. **6**, there is shown a side sectional view of another embodiment of a diffusing layer **622**. Similar to the embodiment of FIG. **5**, the diffusing layer **622** has a rectangular cross section and is essentially planar in form. However, in this embodiment the diffusing layer **622** comprises a layer of the light transmissive material **648** and a layer of the light scattering particles **650**. The layer of light scattering particles **650** may be formed in accordance with the diffusing layer **522** of FIG. **5**, for instance. As shown in FIG. **6**, the layer of the light transmissive material **648** is directly in contact with and disposed above the layer of the light scattering particles **650** so that the layer of the light transmissive material **648** appears closest to the observer **634**.

[0089] Referring to FIG. **7**, there is shown a side sectional view of the diffusing layer **622** of FIG. **6** directly in contact with and disposed above alternating strips of first and second photoluminescence material layers **718**, **720** (partially shown in FIG. **7**). In this arrangement, as seen from an observer **734**, the layer of light transmissive material **648** is the outermost layer and faces outwardly towards the observer **734**. More particularly, the layer of the light scattering particles **650** is disposed between the layer of the light transmissive material **648** and the alternating strips of first and second photoluminescence material layers **718**, **720**. In such a configuration, the layer of light transmissive material **648** may act as a protective layer to the layer of the light scattering particles **650** and the alternating strips of first and second photoluminescence material layers **718**, **720**.

[0090] Referring to FIG. **8**, there is shown a side sectional view of an alternative embodiment of a diffusing layer **822** directly in contact with and disposed above alternating strips of first and second photoluminescence material layers **818**, **820** (partially shown in FIG. **8**). The diffusing layer **822** is the same as the diffusing layer **622** of FIGS. **6** and **7**, except that the layer of the light scattering particles is transposed with the layer of the light transmissive material. Hence, in this arrangement, as seen from an observer **834**, the layer of the light scattering particles **850** is the outermost layer and faces outwardly towards the observer **834**. More particularly, the layer of the light transmissive material **848** is disposed between the layer of the light scattering particles **850** and the alternating strips of first and second photoluminescence material layers **818**, **820**. In such a configuration, provides greater distance between the layer of light scattering particles **850** and the first and second photoluminescence material layers **818**, **820**.

[0091] Referring to FIG. **9**, there is shown a side sectional view of a diffusing layer **922** in accordance with another embodiment of the invention. In this embodiment, the diffusing layer **922** comprises two layers of the light transmissive material **948** and a layer of the light scattering particles **950** disposed therebetween. This configuration provides a greater distance between the layer of light scattering particles **950** and the first and second photoluminescence material layers **918**,**920**, as well as the layers of light transmissive material **948** acting as a protective layer.

[0092] Referring to FIG. **10**, there is shown a side sectional view of a diffusing layer **1022** in accordance with another embodiment of the invention. In this embodiment, the diffusing layer **1022** is the same as the diffusing layer **522** of FIG. **5**, except the diffusing layer **1022** has a different shape (Convex shape). The diffusing layer **1022** has a shape having a cross section which is rectangular with an arch along one of its longer sides. Thus, the cross section defines a shape in which the thickness of the diffusing layer **1022** varies across its width. Of course, it will be appreciated that the thickness of the diffusing layer may vary across its length, in other embodiments. In this way, the amount of light scattering particles **1024** may vary across the diffusing layer **1022**. For instance, in this embodiment, there are more light scattering particles **1024** towards the center of the light diffusing layer **1022** than its edges. By varying the thickness of the light diffusing layer **1022**, the light scattering properties can be appropriately selected depending on the desired output of the white light emitting device with which it is utilized.

[0093] Referring to FIG. **11**, there is shown a side sectional view of a diffusing layer **1122** in accordance with another embodiment of the invention. In this embodiment, the diffusing layer **1122** is the same as the diffusing layer **522** of FIG. **5**, except the diffusing layer **1122** has a different distribution of light scattering particles **1124** within the light transmissive material **1146**. In this embodiment, the light scattering particles **1124** are incorporated in the light transmissive material **1146** and are not uniformly distributed through the light transmissive material **1146**. Instead, in this embodiment, the concentration of light scattering particles **1124** within the diffusing layer **1124** varies along its width. Of course, it will be appreciated that the concentration of light scattering particles **1124** within the diffusing layer **1124** may vary across its length, in other embodiments. In this way, the amount of light scattering particles **1124** may vary across the diffusing layer **1122**. For instance, in this embodiment, there is a higher concentration of light scattering particles **1124** towards the center of the light diffusing layer **1122** than its edges. By varying the concentration of light scattering particles **1124** in the light diffusing layer **1022**, the light scattering properties can be appropriately selected depending on the desired output of the white light emitting device with which it is utilized.

[0094] FIG. **12** is a sectional view of the diffusing layer **522** of FIG. **5** directly in contact with and disposed above alternating strips of first and second photoluminescence material layers **1218**, **1220** (partially shown in FIG. **12**). In this embodiment, while the diffusing layer **522** comprises light scattering particles **524**, the first photoluminescence material layer **1218** also comprises light scattering particles **1252**. This may improve the uniformity of the white light generated by the light emitting device generated still further.

[0095] FIG. **13** is a sectional view of the diffusing layer **522** of FIG. **5** directly in contact with and disposed above alternating strips of first and second photoluminescence material layers **1318**, **1320** (partially shown in FIG. **13**). In this embodiment, while the diffusing layer **522** comprises light scattering particles **524**, the first and second photoluminescence material layers **1318**, **1320** also comprise light scattering particles **1352**, **1354** respectively. This may improve the uniformity of the white light generated by the light emitting device generated even further.

[0096] Referring to FIG. **14**, there is shown a component **1456** and a separate LED array **1458** for a white light emitting device in accordance with an embodiment of the invention. In this embodiment, the component **1456** comprises a diffusing layer **1422** disposed over alternating strips of first and second photoluminescence material layers **1418**, **1420**. The diffusing layer **1422** comprising a layer of light scattering particles **1450** and a layer of light transmissive material **1448**. In this embodiment, the alternating strips of first and second photoluminescence material layers **1418**, **1420** are in direct contact with the layer of light transmissive material **1448** of the diffusing layer **1422**, such that the layer of light transmissive material **1448** is disposed between the layer of light scattering particles **1450** and the alternating strips of first and second photoluminescence material layers **1418**, **1420**.

[0097] The first photoluminescence material layer **1418** comprises a first phosphor material excitable to generate white light having a correlated color temperature of 2700K, and the second photoluminescence material layer **1420** comprises a second phosphor material excitable to generate light having a correlated color temperature of 5000K.

[0098] There is also shown a separate LED array **1458** having an alternating array of first and second LEDs **1412**, **1414** disposed on a substrate **1416**.

[0099] The component **1456** and LED array **1458** function in the manner described herein. The component **1456** may be assembled with the LED array **1458** in the direction indicated by arrows **1460** so that the alternating strips of the first and second photoluminescence material layers **1418**, **1420** can be associated with the alternating arrays of first LEDs and second LEDs **1412**, **1414**.

[0100] It will be appreciated that the present invention is not restricted to the specific embodiments described and that variations can be made that are within the scope of the invention.

1. A white light emitting device comprising a first LED and a second LED disposed on a substrate, a first photoluminescence material layer disposed over at least said first LED, a second photoluminescence material layer disposed over at least said second LED, and a diffusing layer disposed over said first and second photoluminescence layers, said diffusing layer comprising light scattering particles.

2. The White light emitting device of claim **1**, wherein the first photoluminescence material layer comprises a first phosphor material and/or the second photoluminescence material layer comprises a second phosphor material.

3. The white light emitting device of claim **2**, wherein the first phosphor material is excitable to generate white light having a correlated color temperature of 2700K to 3500K.

4. The white light emitting device of claim **2**, wherein the second phosphor material is excitable to generate white light having a correlated color temperature of 5000K to 6500K.

5. The white light emitting device of claim **1**, comprising alternating arrays of first LEDs and second LEDs.

6. The white light emitting device of claim **5**, comprising alternating strips of the first and second photoluminescence material layers associated with the alternating arrays of first LEDs and second LEDs.

7. (canceled)

8. The white light emitting device of claim **1**, wherein the diffusing layer comprises a light transmissive material and light scattering particles.

9. (canceled)

10. The white light emitting device of claim **8**, wherein the light scattering particles are substantially uniformly distributed through the light transmissive material.

11. The white light emitting device of claim **8**, wherein the diffusing layer comprises a layer of the light transmissive material and a layer of the light scattering particles.

12. The white light emitting device of claim **11**, wherein the layer of the light transmissive material is disposed between the layer of the light scattering particles and the first and/or second photoluminescence material layers.

13. The white light emitting device of claim **11**, wherein the layer of the light scattering particles is disposed between the layer of the light transmissive material and the first and/or second photoluminescence material layers.

14. (canceled)

15. The white light emitting device of claim **1**, wherein at least one of the first photoluminescence material layer, the second photoluminescence material layer, or the diffusing layer comprises light scattering particles.

16. (canceled)

17. The white light emitting device of claim **1**, wherein the substrate comprises a circuit board, optionally a metal core printed circuit board.

18. (canceled)

19. (canceled)

20. (canceled)

21. The white light emitting device of claim **20**, wherein the thickness or concentration of the diffusing layer varies.

22. (canceled)

23. (canceled)

24. The white light emitting device of claim **1**, wherein the weight percent loading of the light scattering particles is from 0.1 to 50% wt or from 5 to 10% wt.

25. (canceled)

26. A method of manufacturing a white light emitting device, comprising the steps of:

providing an array of first LEDs;

dispensing a first photoluminescence material layer at least over said array of first LEDs;

providing an array of second LEDs;

dispensing a second photoluminescence material layer at least over said array of second LEDs; and

dispensing a diffusing layer over said first and second photoluminescence material layers.

27. A white light emitting device comprising alternating arrays of first LEDs and second LEDs disposed on a substrate, a first photoluminescence material layer disposed over at least said array of first LEDs, a second photoluminescence material layer disposed over at least said array of second LEDs, and a diffusing layer disposed over said first and second photoluminescence material layers, the diffusing layer comprising light scattering particles,

wherein the first photoluminescence material layer comprises a first phosphor material excitable to generate white light having a first correlated color temperature, the second photoluminescence material layer comprises a second phosphor material excitable to generate white light having a second correlated color temperature.

28. The white light emitting device of claim **27**, wherein the first correlated color temperature is from 2700K to 3500K and/or the second correlated color temperature is from 5000K to 6500K.

29. A component for a white light emitting device, comprising alternating strips of first and second photoluminescence material layers disposed on a substrate, and a diffusing layer disposed over said alternating strips of first and second photoluminescence material layers, the diffusing layer comprising light scattering particles,

wherein the first photoluminescence material layer comprises a first phosphor material excitable to generate white light having a first correlated color temperature, and the second photoluminescence material layer comprises a second phosphor material excitable to generate light having a second correlated color temperature.

30. The component of claim **29**, wherein the first correlated color temperature is from 2700K to 3500K and/or the second correlated color temperature is from 5000K to 6500K.

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