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(54) LED ASSEMBLY WITH OMNIDIRECTIONAL LIGHT FIELD

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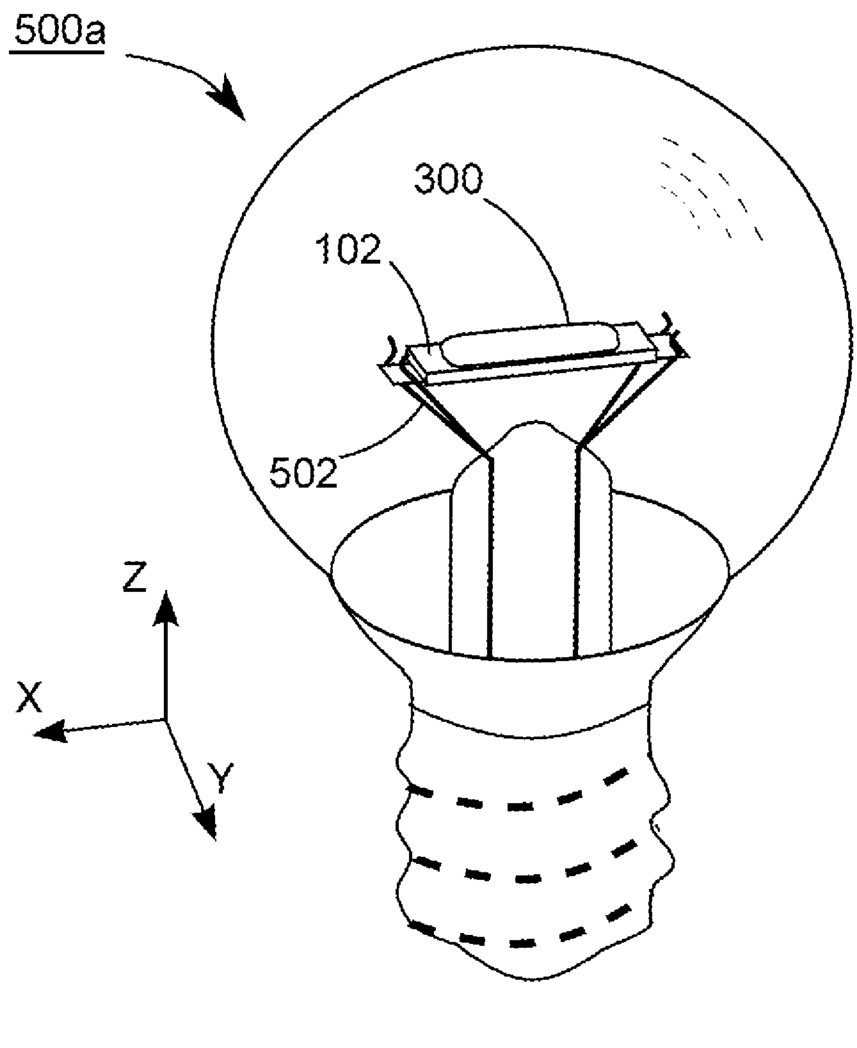
(52) **U.S. Cl.**
CPC .. ***F21K 9/56*** (2013.01); ***H01L 33/50*** (2013.01)
USPC **362/84**; 438/27

(57) **ABSTRACT**

Disclosed is an LED assembly having an omnidirectional light field. The LED assembly has a transparent substrate with first and second surfaces facing to opposite orientations respectively. LED chips are mounted on the first surface and are electrically interconnected by a circuit. A transparent capsule with a phosphor dispersed therein is formed on the first surface and substantially encloses the circuit and the LED chips. First and second electrode plates are formed on the first or second surface, and electrically connected to the LED chips.



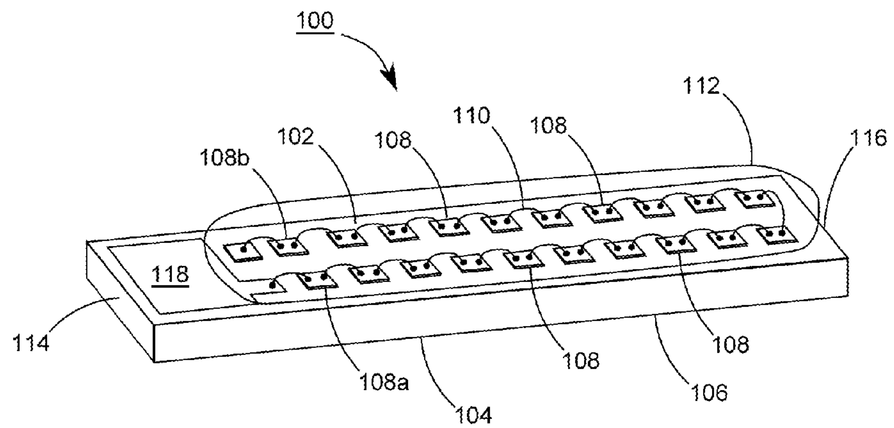


FIG. 1

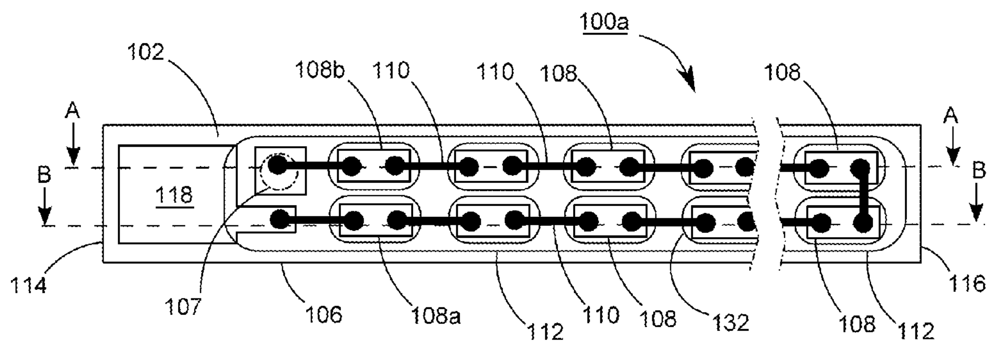


FIG. 2A

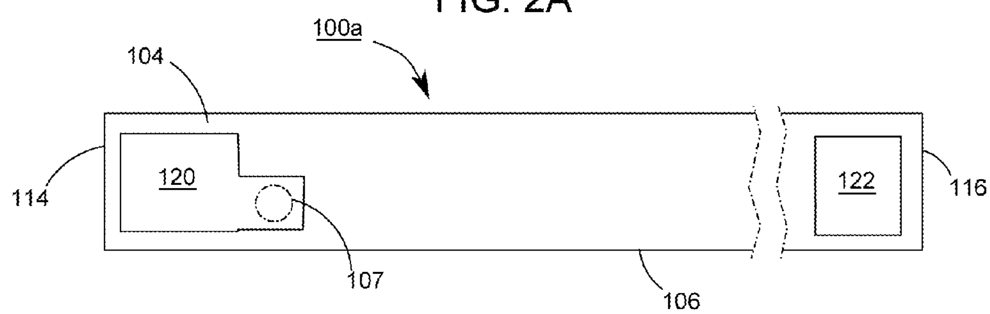


FIG. 2B

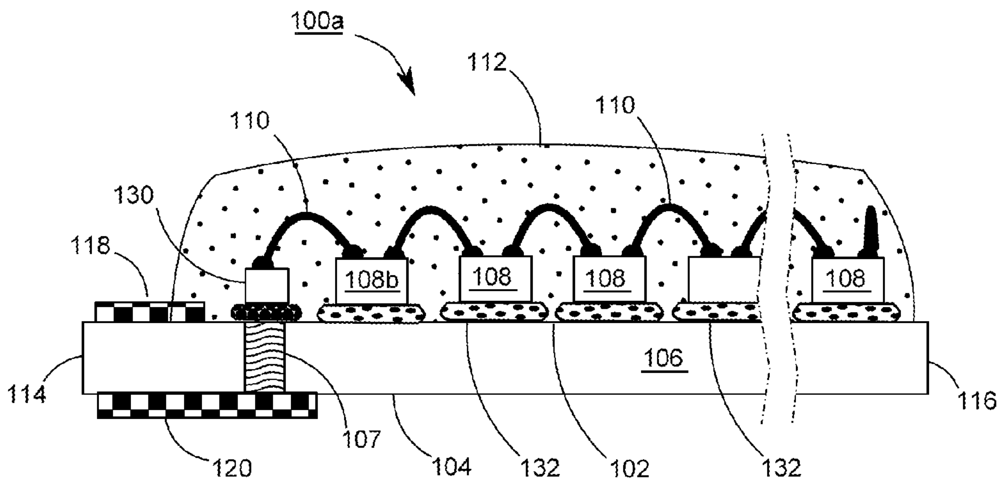
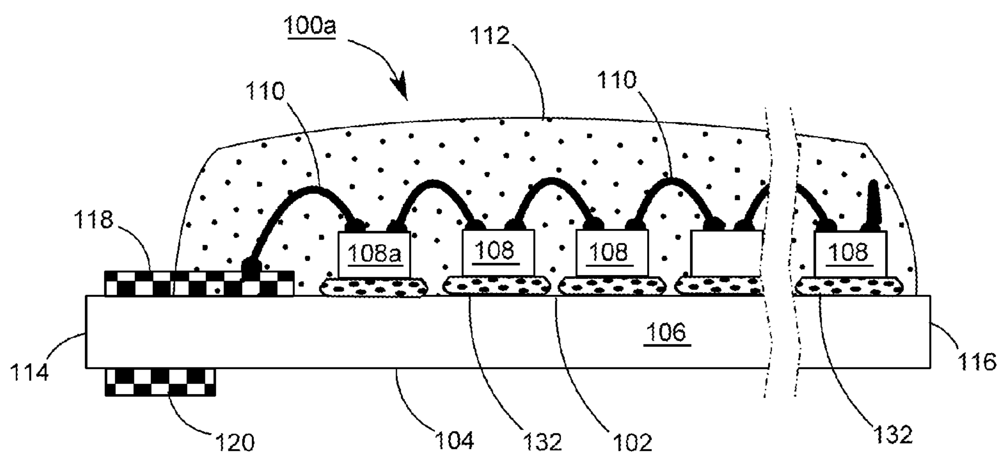

100a
112
110
110
130
118
108b
108
108
108
106
114
116
120
107
104
132
102
132

FIG. 3A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102
132

FIG. 3B

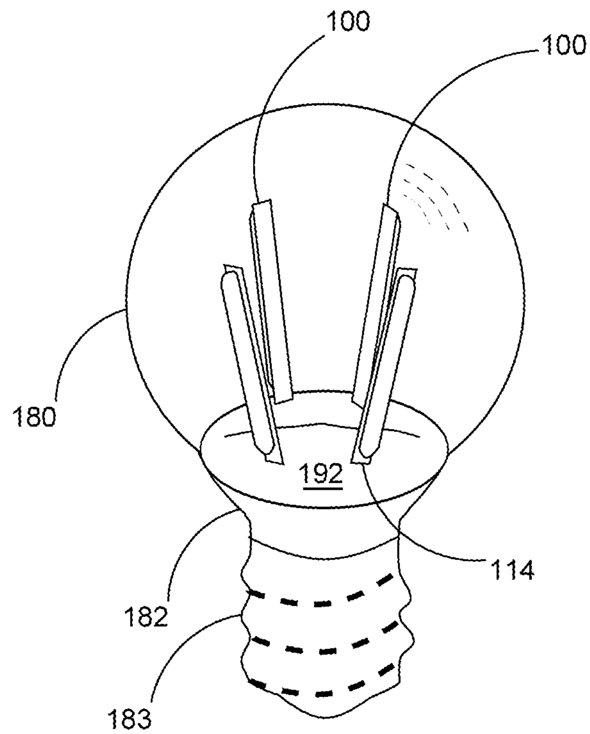


FIG. 4

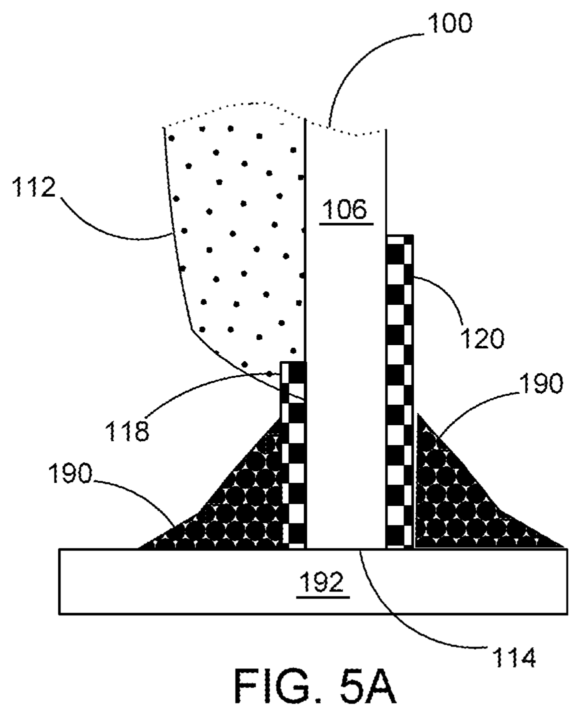


FIG. 5A

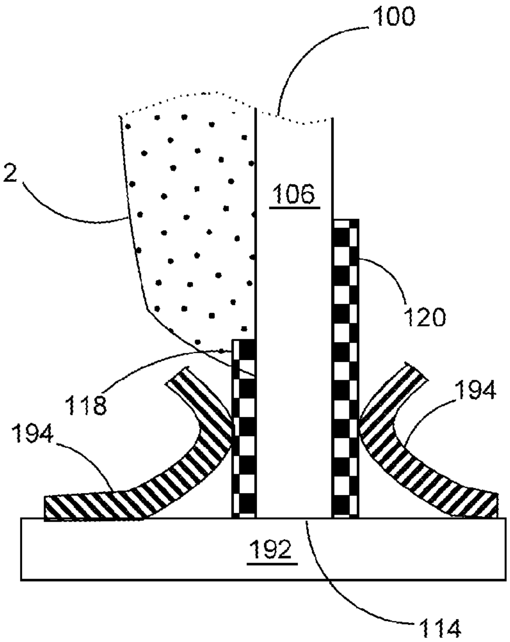

100
112
106
120
118
194
194
192
114

FIG. 5B

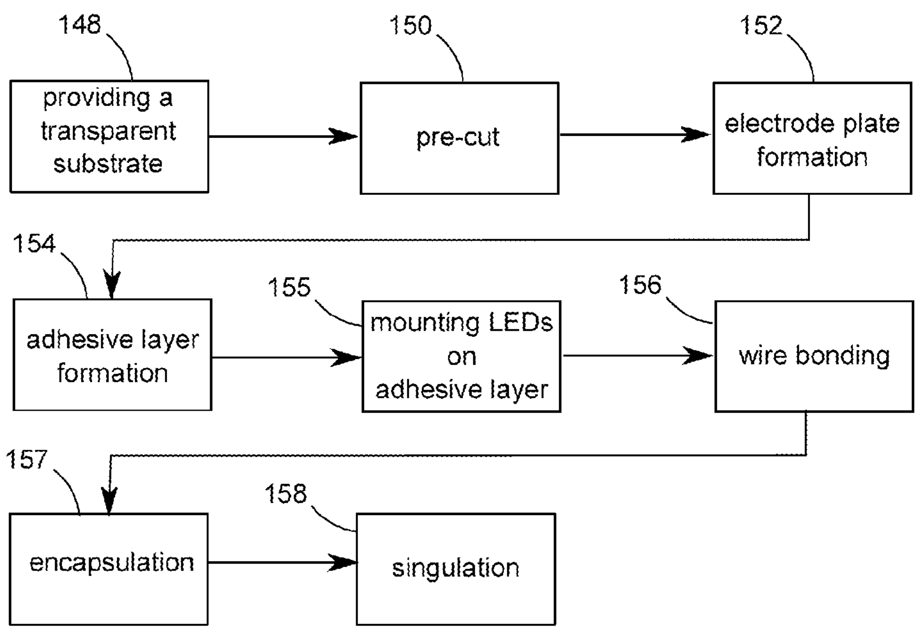

148
providing a transparent substrate
150
pre-cut
152
electrode plate formation
154
adhesive layer formation
155
mounting LEDs on adhesive layer
156
wire bonding
157
encapsulation
158
singulation

FIG. 6

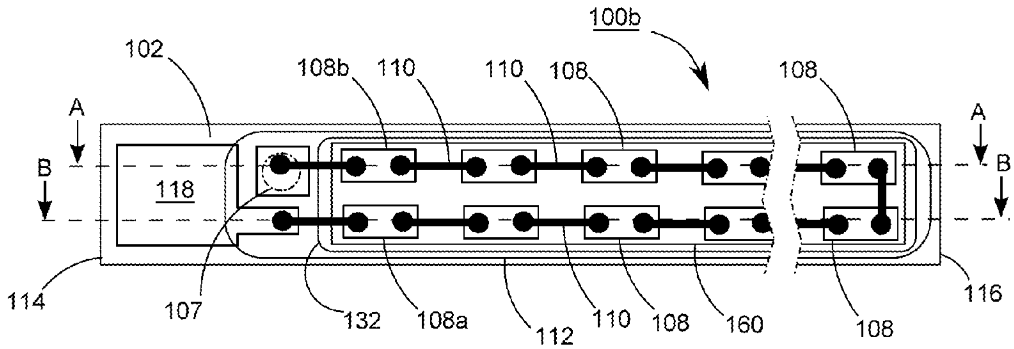


FIG. 7A

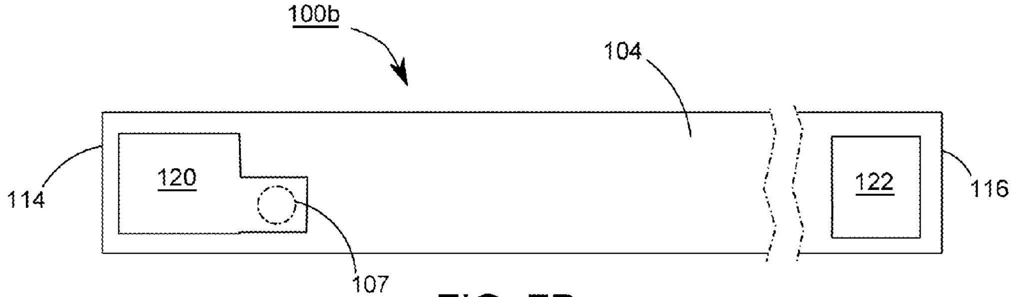


FIG. 7B

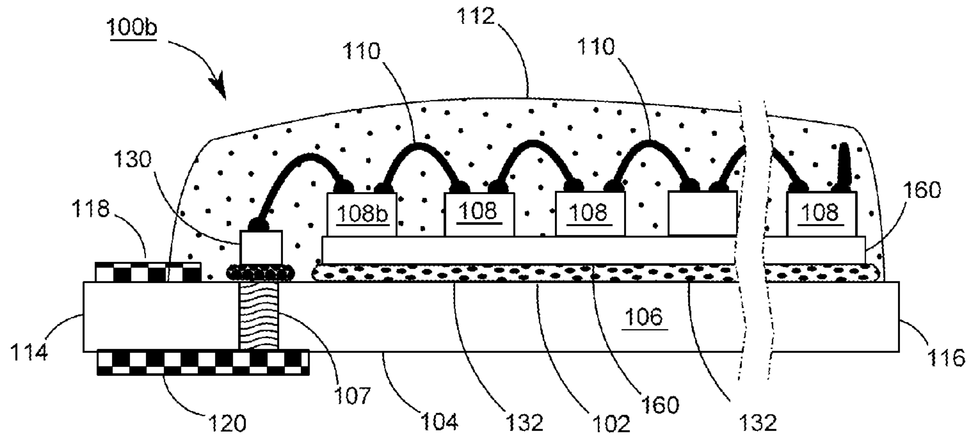
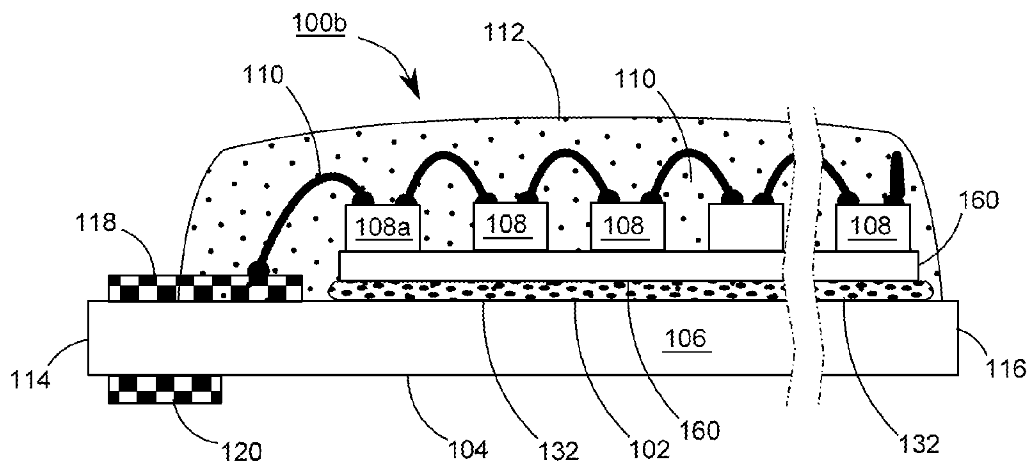


FIG. 8A


100b
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110
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118
108a
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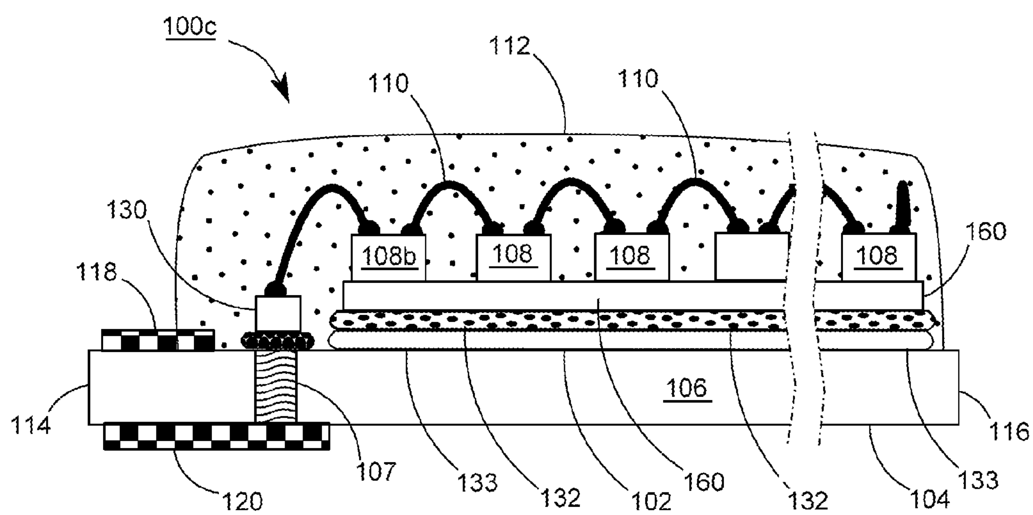
108
108
160
106
114
116
120
104
132
102
160
132

FIG. 8B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108b
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160
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102
160
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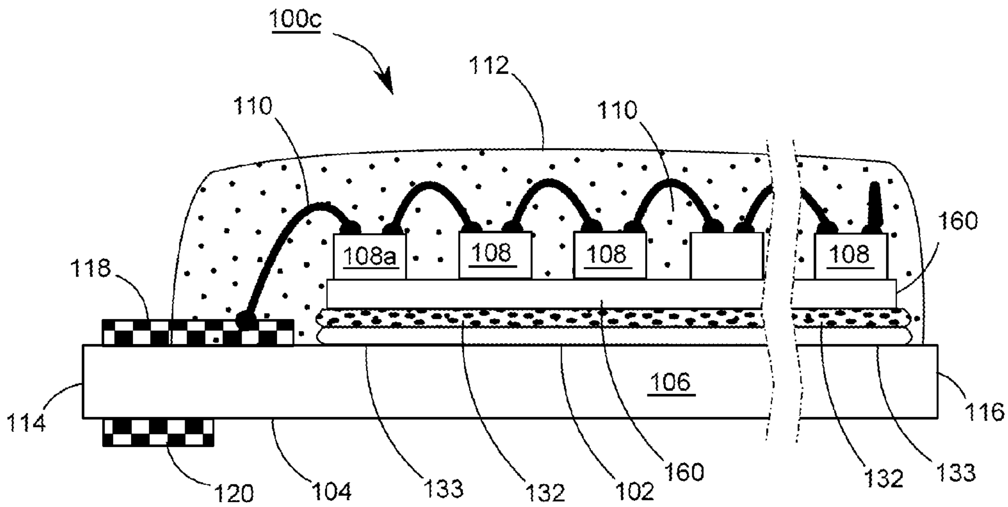
104
133

FIG. 8C


100c
112
110
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108a
108
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108
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114
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102
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FIG. 8D

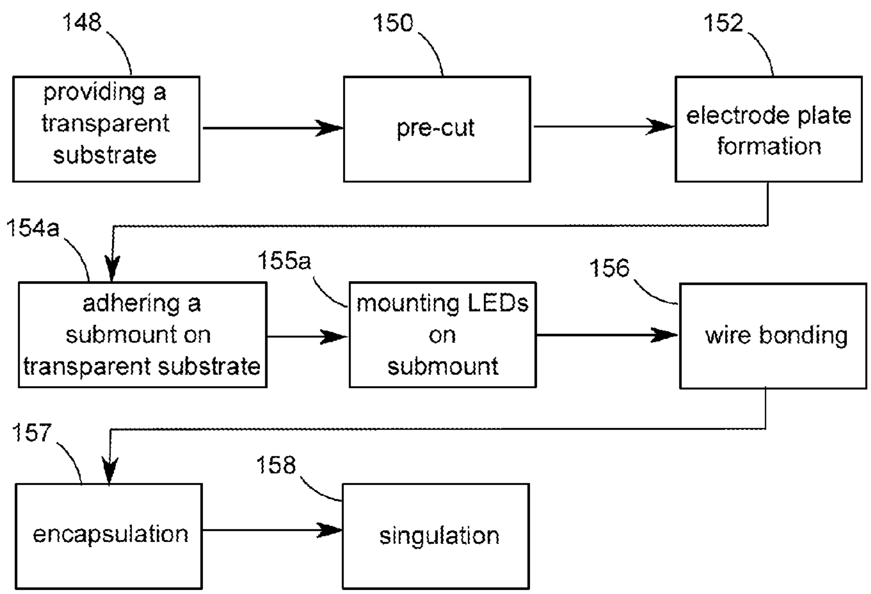

148
providing a transparent substrate
150
pre-cut
152
electrode plate formation
154a
adhering a submount on transparent substrate
155a
mounting LEDs on submount
156
wire bonding
157
encapsulation
158
singulation

FIG. 9

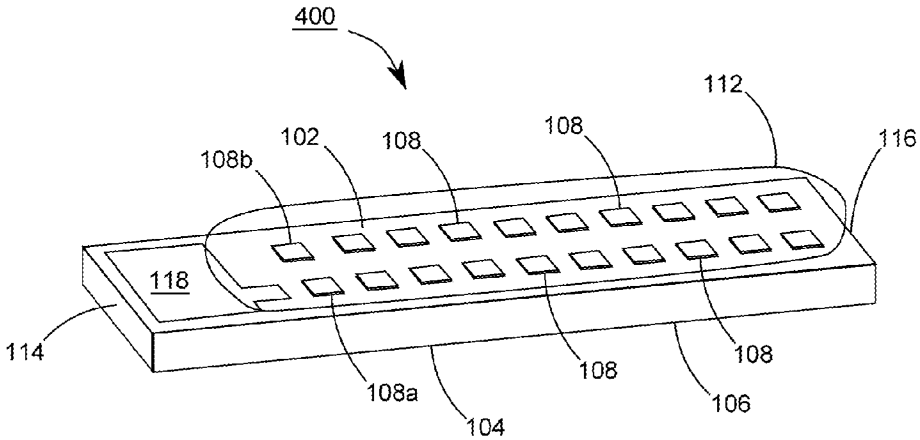


FIG. 10

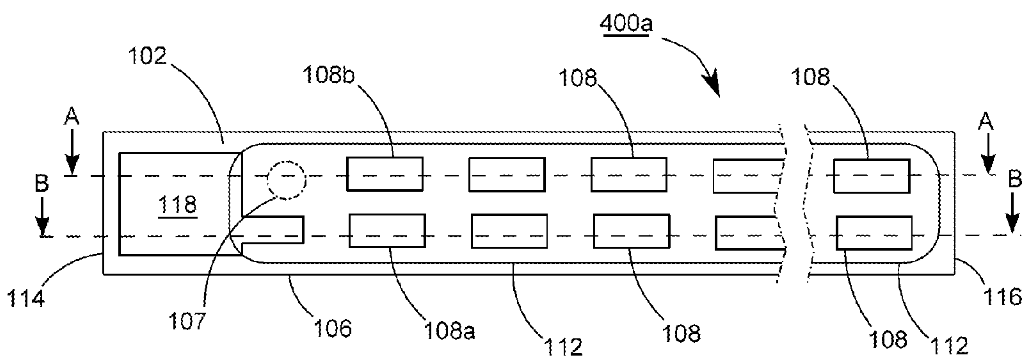


FIG. 11A

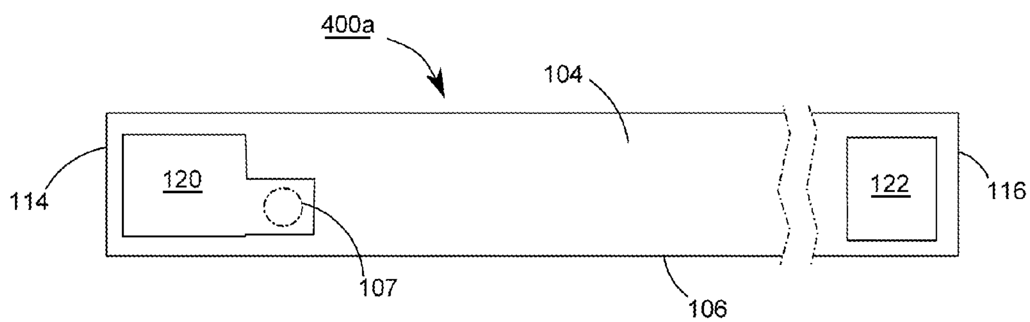


FIG. 11B

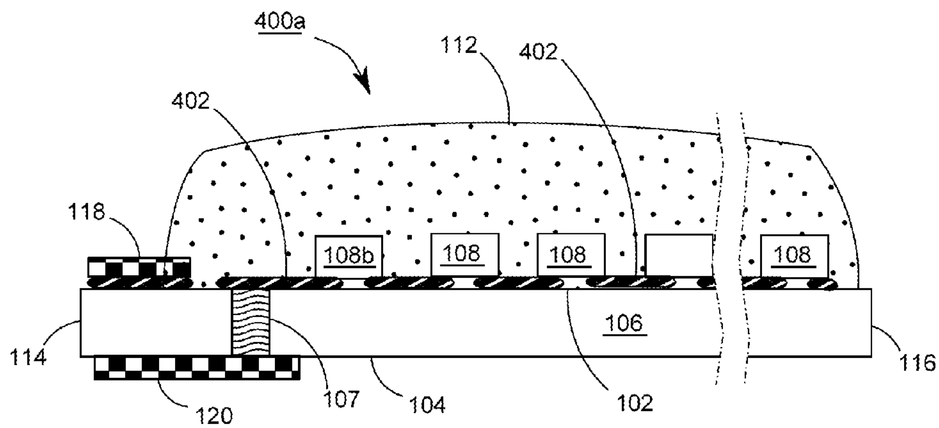


FIG. 12A

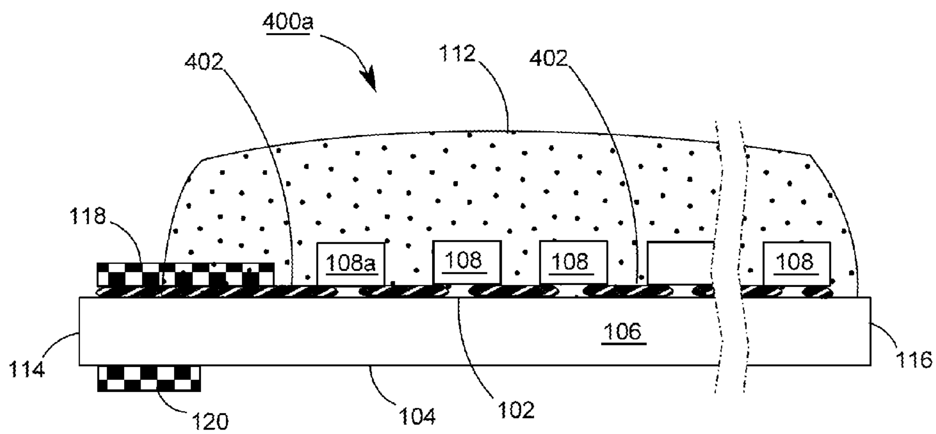


FIG. 12B

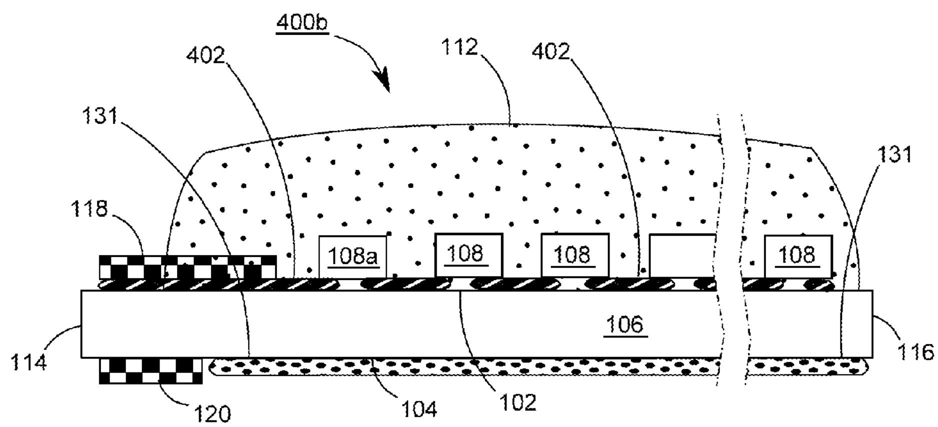


FIG. 12C

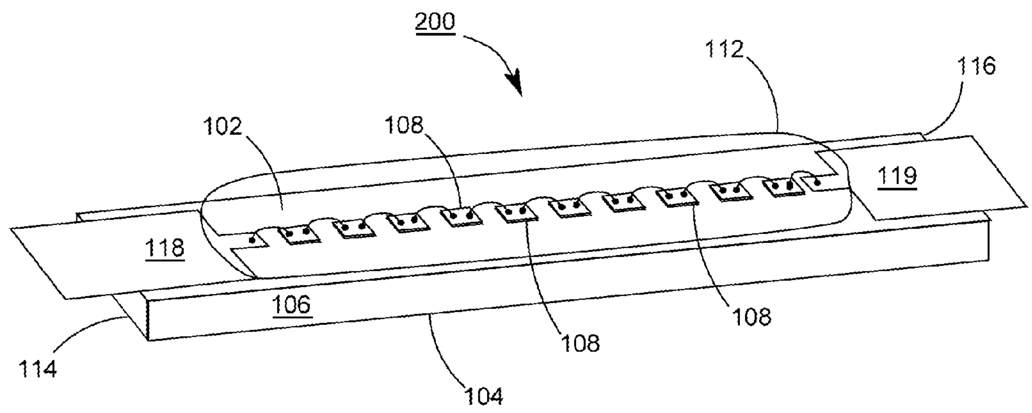


FIG. 13

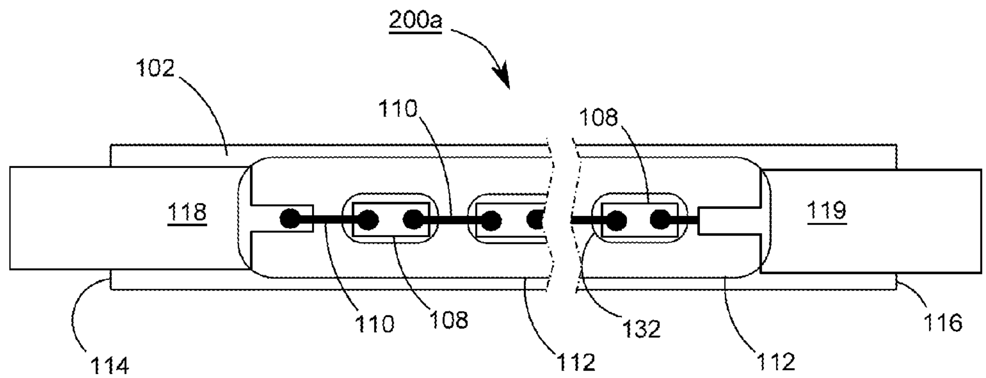


FIG. 14

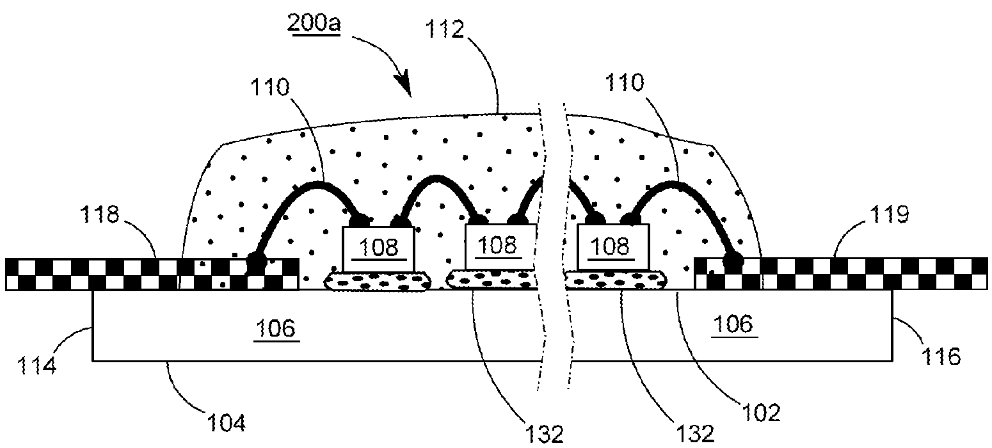
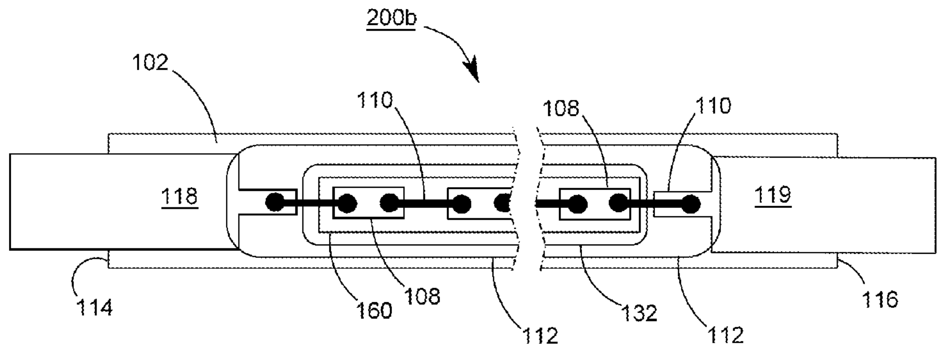


FIG. 15


200b
102
110
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116

FIG. 16

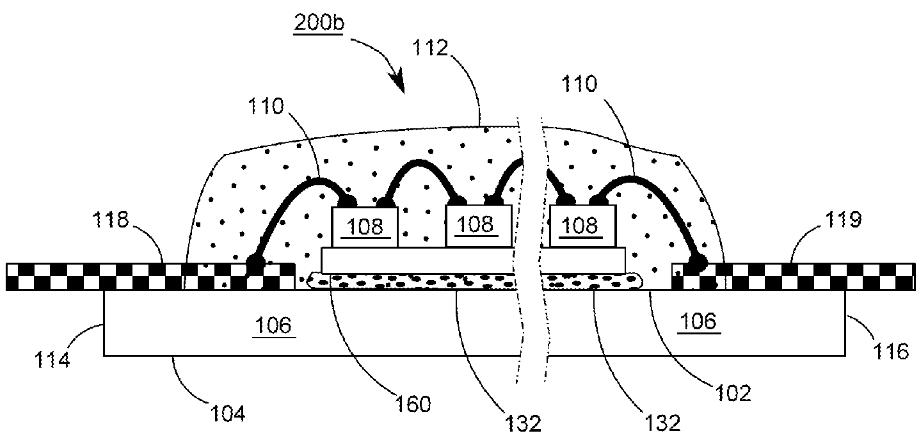
200b
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FIG. 17

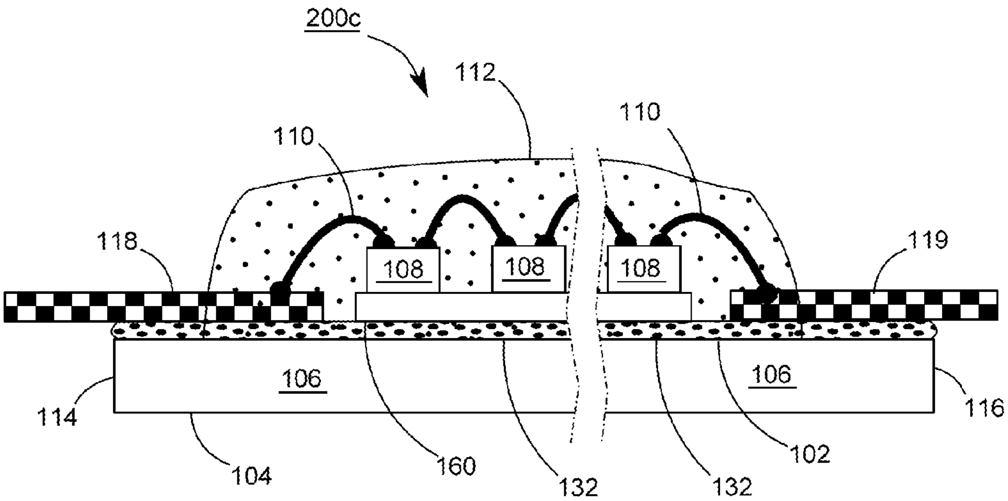
200c
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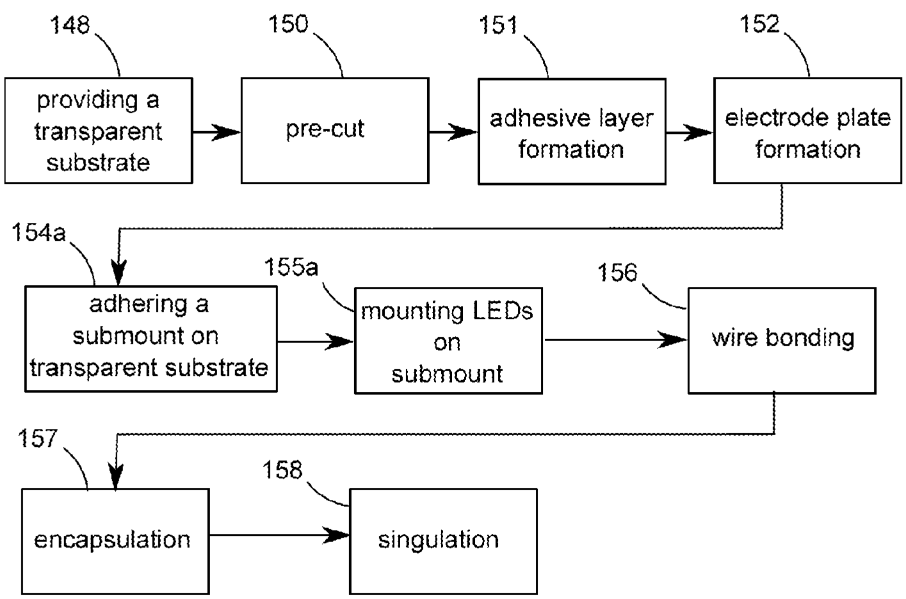
FIG. 18


148
providing a transparent substrate
150
pre-cut
151
adhesive layer formation
152
electrode plate formation
154a
adhering a submount on transparent substrate
155a
mounting LEDs on submount
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wire bonding
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encapsulation
158
singulation

FIG. 19

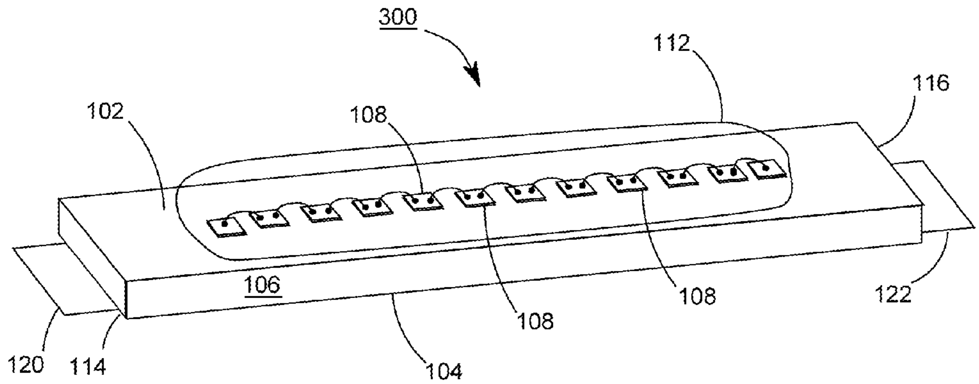


FIG. 20

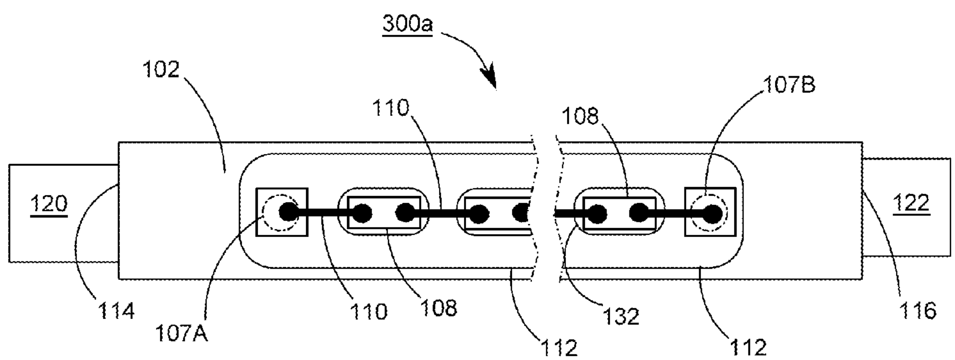


FIG. 21A

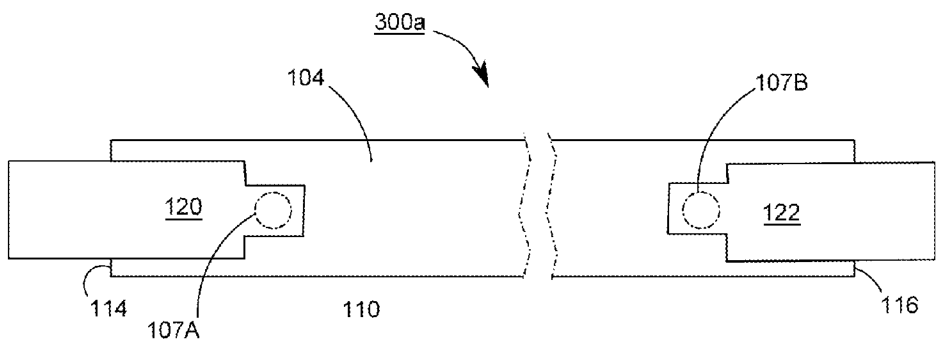
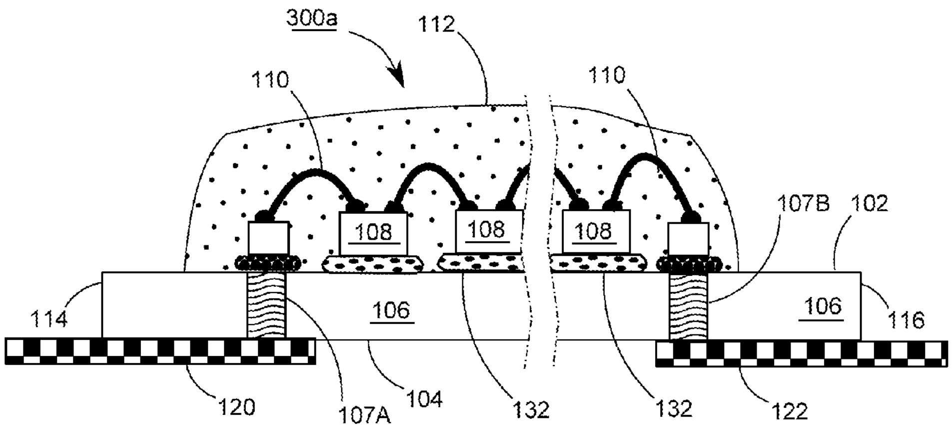


FIG. 21B


300a
112
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107B
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114
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107A
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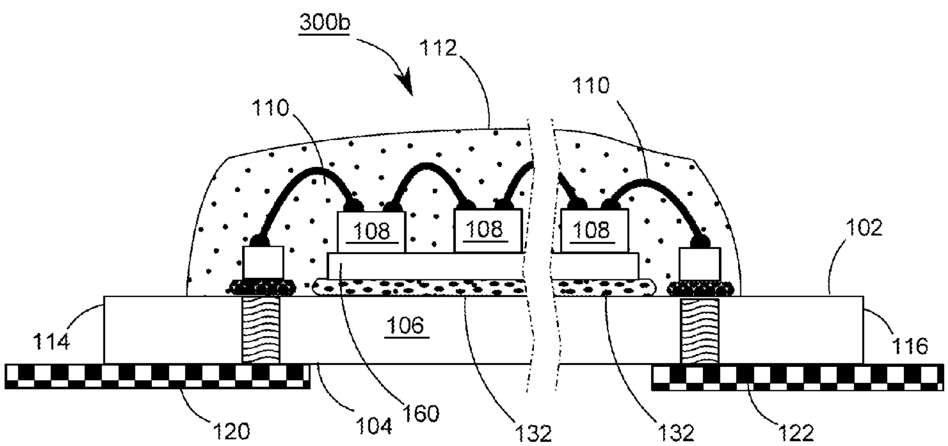
122

FIG. 22


300b
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102
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114
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160
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122

FIG. 23

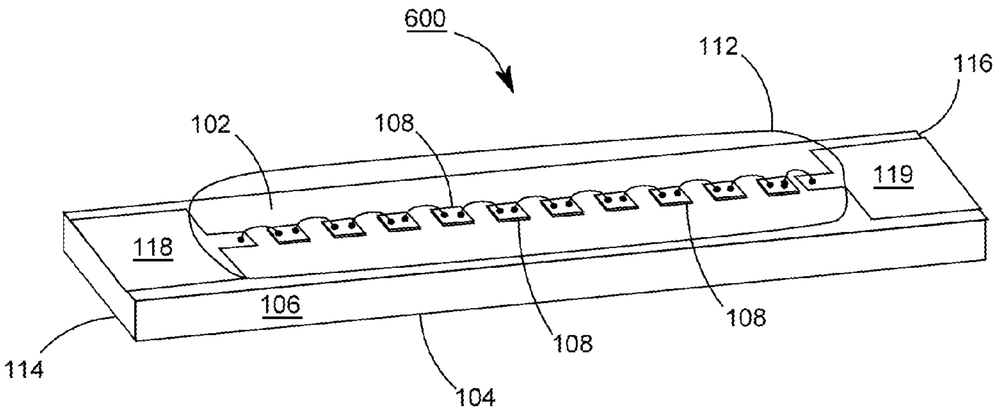

FIG. 24

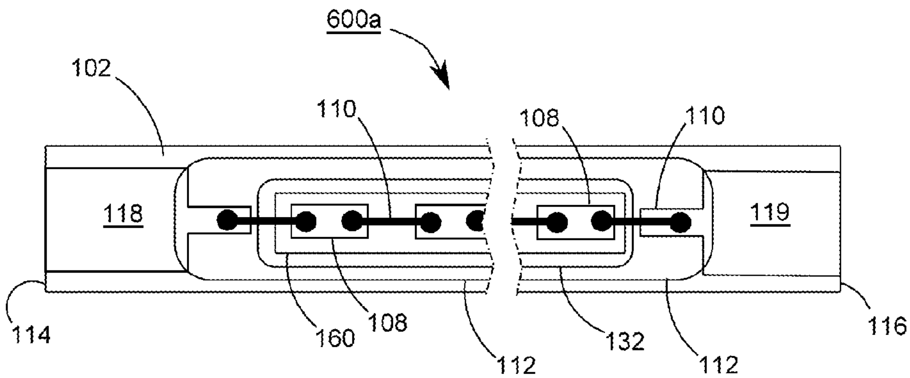

FIG. 25A

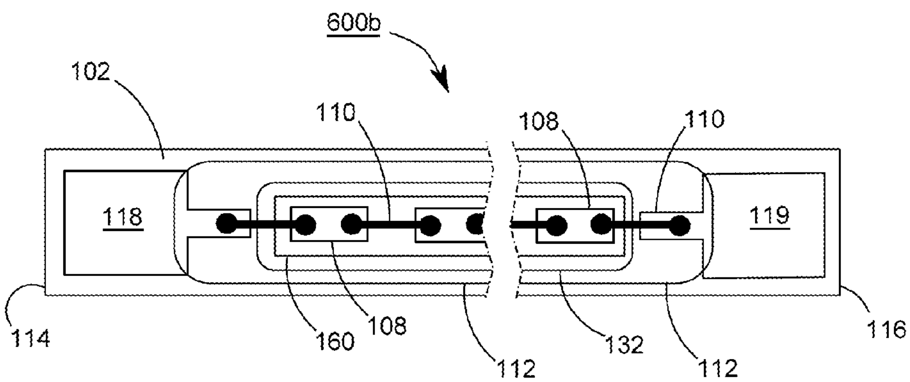

FIG. 25B

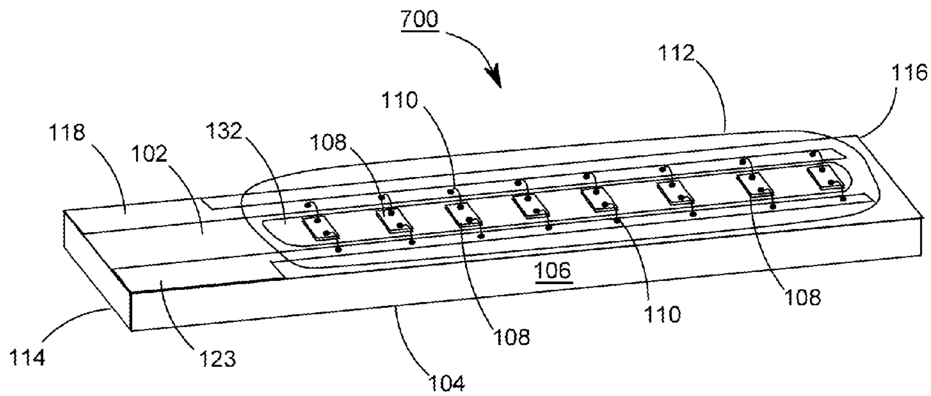

FIG. 26A

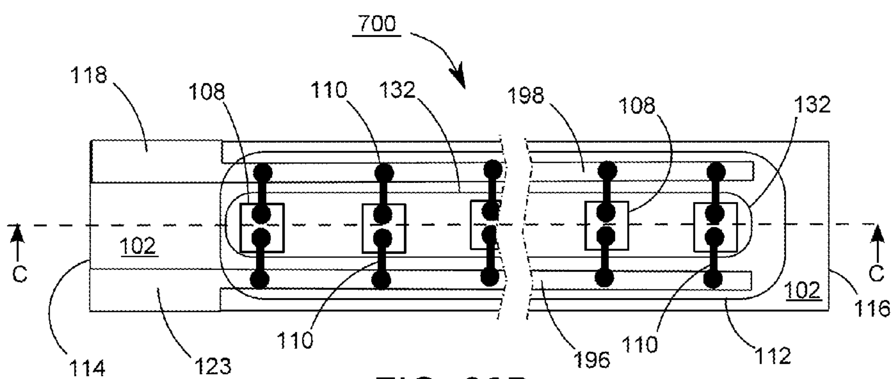

FIG. 26B

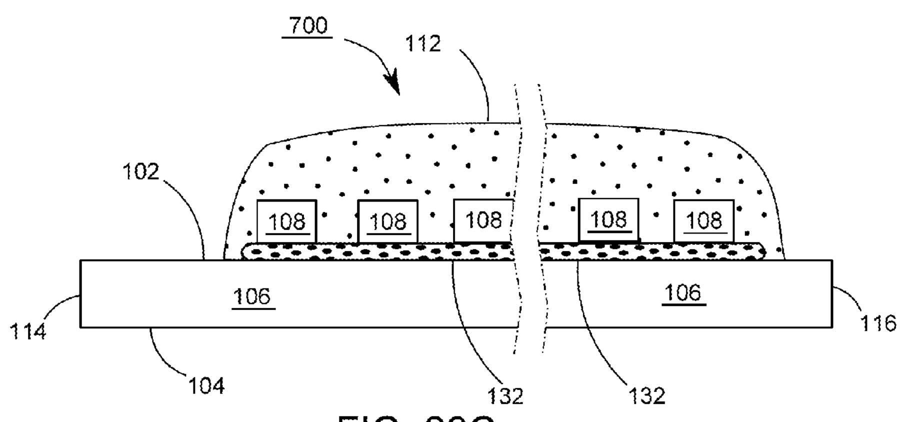

FIG. 26C

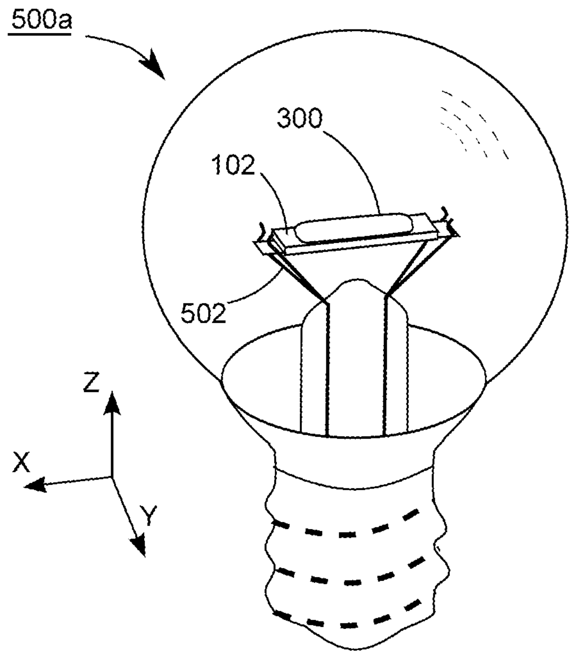

FIG. 27A

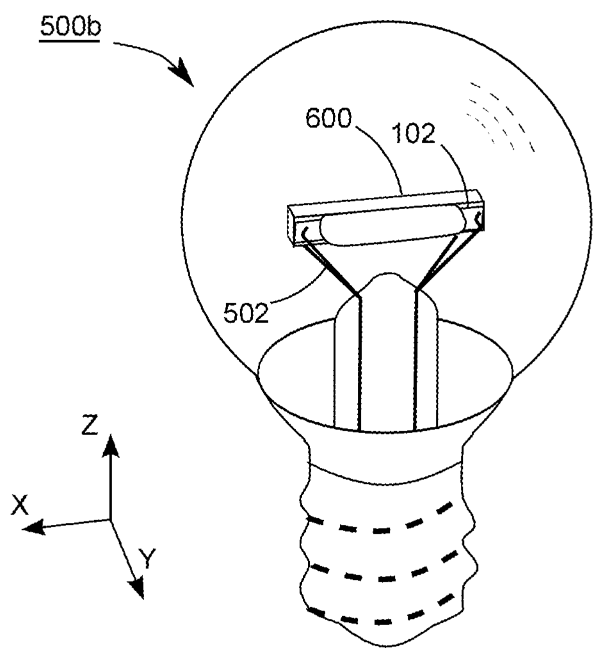

FIG. 27B

LED ASSEMBLY WITH OMNIDIRECTIONAL LIGHT FIELD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Taiwan Application Series Number 102122873 filed on Jun. 27, 2013 and Taiwan Application Series Number 103111887 filed on Mar. 27, 2014, which are incorporated by reference in their entirety.

BACKGROUND

[0002] The present disclosure relates generally to light emitting diode (LED) assemblies, and more specifically, to LED assembly that has an omnidirectional light field.

[0003] LED has been used in different kinds of appliances in our daily life, such as traffic lights, car headlights, street lamps, computer indicators, flashlights, LCD backlight modules, and so on. Beside the semiconductor manufacturing process in the front end, the LED chips used in these appliances should go through LED packaging in the back end.

[0004] LED packaging mainly provides mechanical, electrical, thermal, and optical supports to LED chips. LED chips, which are a kind of semiconductor products, are prone to performance degradation, or aging, if exposed for a long time in an atmosphere full of humidity or chemical. Epoxy resin is commonly used in LED packaging to cover or seal LED chips, such that LED chips are effectively isolated from detrimental atmosphere. Furthermore, LED packaging should take heat dissipation and luminance extraction into consideration, in order to make LED assembly more power-saving and reliable. Heat generated in an LED chip must be dissipated efficiently. Otherwise, heat accumulated in the PN junction of an LED chip will damage or degrade its performance, shortening its lifespan. Optical design is also a key factor when designing of LED packaging. Light emitted from an LED chip must be transmitted in a way that results in certain luminance distribution with certain intensity.

[0005] The design for packaging a white LED further needs to consider color temperature, color rendering index, phosphor, etc. The white LED could be provided by phosphor converting a portion of blue light from a blue LED chip into green/yellow light such that the mixture of the lights is perceived as white light by human eyes. Because human eyes are vulnerable to high-intensity blue light, the blue light from a blue LED chip in a white LED package should not go outside directly without its intensity being attenuated. In other words, the blue light should be kind of "sealed" or "capsulated" so as to prevent blue light leakage to human eyes.

[0006] In order to make products more competitive in the market, LED package manufactures constantly pursue packaging processes which are reliable, low-cost, and high-yield.

SUMMARY OF THE DISCLOSURE

[0007] The present disclosure provides a light emitting diode assembly.

[0008] The light emitting diode assembly comprises a transparent substrate, comprising first and second surfaces facing to opposite orientations respectively; light emitting diode chips, mounted on the first surface; a circuit electrically connecting the light emitting diode chips; a transparent capsule with a phosphor dispersed therein, formed on the first surface and substantially enclosing the circuit and the light emitting diode chips; and first and second electrode plates, formed on the first or second surface, and electrically connected to the light emitting diode chips.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Non-limiting and non-exhaustive embodiments of the present disclosure are described with reference to the following drawings. In the drawings, like reference numerals refer to like parts throughout the various figures unless otherwise specified. These drawings are not necessarily drawn to scale. Likewise, the relative sizes of elements illustrated by the drawings may differ from the relative sizes depicted.

[0010] The disclosure can be more fully understood by the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

[0011] FIG. **1** illustrates an LED assembly according to embodiments of the disclosure;

[0012] FIG. **2**A demonstrates a top view of the LED assembly in FIG. **1**;

[0013] FIG. **2**B demonstrates a bottom view of the LED assembly in FIG. **1**;

[0014] FIG. **3**A demonstrates a cross-sectional view of the LED assembly in FIG. **2**A along line AA, and FIG. **3**B demonstrates that along line BB;

[0015] FIG. **4** shows a light bulb using several LED assemblies assembled therein as its lighting sources;

[0016] FIG. **5**A demonstrates that the LED assembly is fixed on a circuit board by solder joints;

[0017] FIG. **5**B demonstrates a clamp with two metal jaws to grasp and hold one LED assembly vertically on a circuit board;

[0018] FIG. **6** illustrates a manufacturing process for producing the LED assembly of FIGS. **3**A and **3**B;

[0019] FIGS. **7**A and **7**B demonstrate top and bottom views of an LED assembly respectively, according to embodiments of the disclosure;

[0020] FIGS. **8**A and **8**B show two cross-sectional views of the LED assembly in FIG. **7**A along line AA and line BB;

[0021] FIGS. **8**C and **8**D show two cross-sectional views of an LED assembly

[0022] FIG. **9** exemplifies a manufacturing method to produce an LED assembly;

[0023] FIG. **10** is a drawing of LED assembly in one embodiment of the disclosure;

[0024] FIGS. **11**A and **11**B are top and bottom views of an LED assembly respectively;

[0025] FIG. **12**A demonstrates a cross-sectional view of the LED assembly along line AA in FIG. **11**A;

[0026] FIG. **12**B demonstrates a cross-sectional view of the LED assembly along line BB in FIG. **11**A;

[0027] FIG. **12**C shows another LED assembly **400***b;*

[0028] FIG. **13** is a drawing of an LED assembly in one embodiment of the disclosure;

[0029] FIGS. **14** and **15** are a top view and a cross-sectional view of an LED assembly, respectively;

[0030] FIGS. **16** and **17** are a top view and a cross-sectional view of an LED assembly, respectively;

[0031] FIG. **18** is a cross-sectional view of an LED assembly and FIG. **19** demonstrates a method for manufacturing it;

[0032] FIG. **20** is a pictorial drawing of an LED assembly;

[0033] FIGS. **21**A and **21**B are a top view and a cross-sectional view of an LED assembly, respectively;

[0034] FIG. **22** demonstrates a cross-sectional view of an LED assembly;

[0035] FIG. **23** demonstrates a cross-sectional view of LED assembly;

[0036] FIG. **24** is a drawing of an LED assembly;

[0037] FIG. **25**A shows a top view of the LED assembly;

[0038] FIG. **25**B shows a top view of the LED assembly;

[0039] FIG. **26**A is a pictorial drawing of an LED assembly in one embodiment of the disclosure;

[0040] FIGS. **26**B and **26**C are a top view and a cross-sectional view of the LED assembly in FIG. **26**A, respectively;

[0041] FIG. **27**A illustrates an LED lamp using LED assembly as its filament; and

[0042] FIG. **27**B illustrates an LED lamp using LED assembly as its filament.

DETAILED DESCRIPTION

[0043] An LED assembly **100** according to an embodiment of the disclosure is described in detail with reference to FIG. **1**. The LED assembly **100** has a transparent substrate **106**, which is for example an electrically non-conductive glass. The transparent substrate **106** has a top surface **102** and a bottom surface **104** facing to opposite orientations respectively. As shown in FIG. **1**, the transparent substrate **106** is substantially in the form of a thin and longitudinal strip with two ends **114** and **116**. In this specification, the term, transparent, only means admitting the passage of light and could also be referred to as translucent or semitransparent. Objects situated behind a transparent material in this specification might be distinctly or indistinctly seen. In other embodiments, the transparent substrate **106** is sapphire, ceramic material (ex. Al_2O_3 or AlN), silicon carbide (SiC), or diamond-like carbon (DLC). It is noted that the transparent substrate **106** can contain a plurality of thermal-conduction particles or other components for reducing process temperature during its manufacturing process.

[0044] FIG. **2**A demonstrates a top view of an LED assembly **100***a*, which exemplifies the LED assembly **100** in one embodiment. Mounted on the top surface **102** are several blue LED chips **108** electrically connected to each other through a circuit mainly composed of bonding wires **110**, which provide interconnection to the blue LED chips **108**. Each blue LED chip **108** could have only one single LED cell, whose forward voltage is about 2 to 3 volts, and this kind of LED chip is referred to as a low-voltage LED chip hereinafter. Comparatively, each blue LED chip **108** might include several LED cells connected in series, and is referred to as a high-voltage LED chip hereinafter, because its forward voltage could be as high as 12V, 24V, or 48V, much higher than that of a low-voltage LED chip. In one embodiment, each LED cell has a light-emitting layer in a diode formed on a substrate, which could be an epitaxial or non-epitaxial substrate. More specifically, the LED cells in a high-voltage LED chip are electrically connected to each other on a common substrate, not by wire bonding but by some patterned conductive strips produced by semiconductor processes, such as metallization or lithography that processes all the LED cells at the same time. In FIG. **1** and FIG. **2**A, the blue LED chips **108** are arranged in two rows beside a longitudinal line that links two ends **114** and **116** of the transparent substrate **106**. The bonding wires **110** electrically connect the blue LED chips **108** in series, generating an equivalent LED device with a high forward voltage. The blue LED chips **108** are not limited to connect in series and arrange in two rows though. In some other embodiments, the blue LED chips **108** might be arranged to any kind of patterns and could be electrically connected in series, in parallel, in series-parallel, in bridge or in the combination thereof.

[0045] As shown in FIG. **2**A, the transparent substrate **106** has a conductive via **107** close to the end **114**. The conductive via **107** has a via hole tunneling through the transparent substrate **106** and the via hole is formed with electrically-conductive material filled therein or coated on its sidewall, so as that the conductive via **107** is capable of coupling or connecting an electric component on the top surface **102** to another on the bottom surface **104**. Nearby the end **114** has a conductive electrode plate **118** on the top surface **102**. The conductive electrode plate **118** locates between the end **114** and the conductive via **107**. The conductive electrode plate **118** does not directly contact with conductive via **107**. One of the blue LED chips **108**, specifically labeled as **108***a* in FIG. **2**A, is close to the end **114** and has a bonding wire **110** thereon to electrically connect to the electrode plate **118**. Another blue LED chip **108***b*, which is close to the end **114**, is electrically connected to the conductive via **107** by another bonding wire **110**.

[0046] All the blue LED chips **108** and all the bonding wires **110** on the top surface **102** are covered by a transparent body **112** to prevent moisture or chemical in atmosphere from damaging or aging the blue LED chips **108** or the bonding wires **110**. The transparent body **112** is epoxy resin or silicone, for example. Dispersed in the transparent body **112** is at least one kind of phosphor that is capable of converting portion of the blue light from blue LED chips **108** (having a peak wavelength about 430 nm to 480 nm) into yellow light (having a peak wavelength from about 570 nm to 590 nm) or yellowish green light (having a peak wavelength about 540 nm to 570 nm), such that human eyes perceive white light from the mixture. In one embodiment, the transparent body **112** comprises two kinds of phosphors dispersed therein. One of the phosphors is capable of converting portion of the blue light from blue LED chips **108** into yellow light or yellowish green light or green (having a peak wavelength from about 520 nm to 590 nm) and the other of the phosphors is capable of converting portion of the blue light from blue LED chips **108** into red light (having a peak wavelength from about 610 nm to 680 nm). FIG. **1** is illustrative to show blue LED chips **108** and bonding wires **110** clearly visible under transparent body **112**. In one embodiment, as aforementioned, the term, transparent, only means admitting the passage of light and could also be referred to as translucent or semitransparent. Therefore, the transparent body **112** can be translucent or semitransparent such that the LED chips **108** and the bonding wires **110** could be distinctly or indistinctly seen behind the transparent body **112**. In another embodiment, the LED chips **108** and the bonding wires **110** could be invisible because of the phosphor dispersed inside the transparent body **112** and the transparent body **112** appears the color of the phosphor dispersed therein.

[0047] FIG. **2**B demonstrates a bottom view of the LED assembly **100***a*. As shown in FIG. **2**B, no blue LED chips are mounted on the bottom surface **104**. Formed on the bottom surface **104** nearby the end **114** is another electrode plate **120**, which electrically connects to the conductive via **107**. In one embodiment, the electrode plate **120** geometrically overlaps and physically contacts with the conductive via **107**. In another embodiment, the conductive via **107** and the electrode plate **120** do not overlap, and a conductive device, such as a bonding wire or a metal strip, is located therebetween to electrically connect them to each other. FIG. **2**B also shows an optional electrode plate **122** formed on the bottom surface **104** nearby the end **116**. This kind of design could have the electrode plates **122** and **120** coplanar, and therefore the LED assembly **100***a*, during handling or transportation, could be steadier to avoid flipping or falling. The electrode plate **122** electrically floats in this embodiment. In other words, the electrode plate **122** does not electrically couple or connect to any electric devices or elements in the LED assembly **100***a*. When the LED assembly **100***a* is laid on a planar surface, the electrode plate **122** helps stabilize the LED assembly **100***a*.

[0048] The embodiment shown in FIGS. **2**A and **2**B has the electrode plates **120** and **118** located completely within the top surface **102** or the bottom surface **104** as the electrode plates **120** and **118** do not extend across the edges of the top surface **102** and the bottom surface **104**. The electrode plates **120** and **118** are not required to be rectangular or to have the same size. For example, one of the electrode plates **120** and **118** could be about rectangular, indicating a cathode of the LED assembly **100***a*, while the other is about spherical, indicating an anode of the LED assembly **100***a*.

[0049] In view of electric connection, the blue LED chips **108** and the conductive via **107** are connected in series between the electrode plates **120** and **118**, which are two power input nodes for powering the LED assembly **100***a*. A conventional power supply (not shown) would have two power output terminals respectively contacting the electrode plates **120** and **118** to drive and illuminate the blue LED chips **108**.

[0050] FIG. **3**A demonstrates a cross-sectional view of the LED assembly **100***a* in FIG. **2**A along line AA, and FIG. **3**B demonstrates that along line BB.

[0051] Shown in FIG. **3**A, a bonding wire **110** connects the blue LED chip **108***b* to the conductive via **107**, which in turn connects to the electrode plate **120** on the bottom surface **104**. In FIG. **3**B, another bonding wire **110** connects the blue LED chip **108***a* to the electrode plate **118**. FIG. **4** shows a light bulb using several LED assemblies **100** as its lighting sources. The light bulb in FIG. **4** includes a lamp shell **180**, the LED assemblies **100**, a circuit board **192**, a heat dissipation apparatus **182** and an electrical connection structure **183**. The end **114** of each LED assembly **100** fixes on the circuit board **192**, which firmly mounts on the heat dissipation apparatus **182** such that the heat generated by the LED assembly **100** could be dissipated efficiently. The heat dissipation apparatus **182** stays firmly on the electrical connection structure **183**, which is for example an Edison screw base capable of screwing into a matching socket. As both electrode plates **120** and **118** are nearby a common end **114** of the transparent substrate **106** in one LED assembly **100** but locate on opposite surfaces, electrically-conductive blocks, such as solder joints **190**, can electrically connect the electrode plates **120** and **118** to two different terminals on the circuit board **192**, respectively, as shown in FIG. **5**A. Beside the electrical connection, the solder joints **190** also provide mechanical support to the end **114**, to hold the LED assembly **100** up straight on the circuit board **192**, so the LED assembly **100**, if illuminating, could generate an omnidirectional light field to its surrounding. In FIG. **5**A, one LED assembly **100** stands, but is not limited to stand, almost vertically, only by way of the mechanical support provided by the solder joints **190**, which also transmit any necessary electric power from the circuit board **192** to the LED assembly **100**. FIG. **5**B demonstrates a clamp with two metal jaws **194** to grasp and hold one LED assembly **100** vertically on the circuit board **192**. The metal jaws **194** provide both electrical connection and mechanical support to one LED assembly **100**, simplifying the manufacture processes required to secure the LED assembly **100** on the circuit board **192**. In some embodiments, an LED assembly **100** stands on the circuit board **192** with a sloping position.

[0052] Exemplified in FIG. **3**A is a vertically-conducting device **130** placed on the top surface **102** above the conductive via **107**. The vertically-conductive device **130** conducts current vertically, and is by way of examples a PN junction diode (such as a vertical-type light-emitting diode, a schottky diode or a zener diode), a resistor, or simply a metal ingot, adhering on the conductive via **107** via a conductive silver paste. In another embodiment, the vertically-conducting device **130** and the conductive silver paste demonstrated in FIG. **3**A could be omitted and a bonding wire **110** bonding on both the conductive via **107** and the blue LED chip **108***b* provides necessary electric connection.

[0053] In both non-limiting FIGS. **3**A and **3**B, each blue LED chip **108** has a transparent adhesive layer **132** thereunder, each adhering only one corresponding blue LED chip **108** on the top surface **102** of the transparent substrate **106**. In another embodiment, there are several transparent adhesive layers **132** on the top surface **102**, and at least one of the adhesive layers carries several blue LED chips **108**. In another embodiment, there is only one single transparent adhesive layer **132** to adhere all blue LED chips **108** to the top surface **102**. Tradeoff occurs to the area size of one transparent adhesive layer **132**. The larger the area of a transparent adhesive layer **132**, the more effective the heat dissipation that the transparent adhesive layer **132** provides to the blue LED chips **108** thereabove, in expense of the more shear stress due to the difference in thermal expansion coefficients of the transparent adhesive layer **132** and the transparent substrate **106**. Accordingly, the design of both the area size of one transparent adhesive layer **132** and the number of the blue LED chips **132** carried on by one transparent adhesive layer **132** depends on actual applications and might vary. In some embodiments, some particles with excellent thermal conductivity, such as alumina powder, diamond-like carbon, or silicon carbide, whose thermal conductivity is more than 20 W/mK, are dispersed in one transparent adhesive layer **132**. These particles help not only dissipate heat, but also scatter the light from the blue LED chips **108**.

[0054] The transparent adhesive layers **132** could be epoxy resin or silicone, and mix with phosphor similar with or different from that of the transparent body **112**. The phosphor is, for example, yttrium aluminum garnet (YAG) or terbium aluminum garnet (TAG). As mentioned, the transparent body **112** with phosphor covers above and surrounds each blue LED chip **108** while the transparent adhesive layers **132** locates under each blue LED chips **108**. The transparent body **112** and the transparent adhesive layers **132** sandwich blue LED chips **108**. In other words, the transparent body **112** and the transparent adhesive layers **132** together as a whole become a kind of transparent capsule that encloses all blue LED chips **108**, but leaves a portion of electrode plate **118** exposed for external electric connection. The blue or UV light from any blue LED chip **108** inevitably experiences conversion, so that human eyes could avoid damage or stress caused by over high intensity of the blue or UV light.

[0055] A manufacturing process for producing the LED assembly **100***a* of FIGS. **3**A and **3**B is described in detail with reference to FIG. **6**. In Step **148**, a transparent substrate **106** is provided with a conductive via **107** formed in advance. For example, a laser beam could be used to melt a small area of the transparent substrate **106** so as to form a via hole on the transparent substrate **106**. An electrically-conductive material could fill in the via hole or be coated on the via hole to form the conductive via **107**. In Step **150**, the transparent substrate **106** is pre-cut, forming some trenches or grooves thereon, which geometrically partition LED assemblies **100** that are formed and separated in the end. In Step **152**, electrode plates **118** and **120** are attached respectively on top and bottom surfaces (**102**, **104**) of the transparent substrate **106**, both nearby the end **114**. Incase that an electrode plate **112** is expected, it is formed nearby the end **116** in step **152**. For example, electrode plates would be formed by screen printing and/or lift-off process, to generate specific conductive patterns on the top and bottom surfaces (**102**, **104**) of the transparent substrate **106**. In Step **154**, one or more transparent adhesive layers **132** with phosphor is formed on the top surface **102** by gluing, printing, spraying, dispensing, or coating, for example.

[0056] In Step **155**, blue LED chips **108** are mounted on the transparent adhesive layers **132**. A vacuum nuzzle, for example, picks up blue LED chips **108** one by one and then put them to adhere onto specific locations of the transparent adhesive layers **132**. In reference to a top view of an LED assembly, preferably each blue LED chip **108** is completely surrounded by the periphery of one transparent adhesive layer **132**, so as to form a phosphor capsule in the end to totally seal a blue LED chip **108** therein. In other words, the transparent adhesive layer **132** has a flat area larger than the total area of all blue LED chips **108**, so as to completely cover the backsides of all blue LED chips **108**. Meanwhile, a silver paste can be used to attach a vertically-conductive device **130** on the top surface **102** and adhere it to the conductive via **107**. Bonding wires **110** are formed in step **156**, to provide an electric connection between every two blue LED chips **108**, between the blue LED chip **108***a* and the electrode plate **118**, and between the blue LED chip **108***b* and the vertically-conductive device **130**. In Step **157**, a transparent body **112** with phosphor is formed on the top surface **102**, to encapsulate the bonding wires **110** and the blue LED chips **108**, by way of dispensing or screen printing. In Step **158**, a singulation process is performed, where the transparent substrate **106** is cut to form a plurality of individual LED assemblies **100**, by way of saw cutting along the previously-formed trenches or grooves for example.

[0057] It can be derived from FIG. **6** that, in step **152**, the electrode plates **120** or **122** are formed on the bottom surface **104**. However, in step **154-157**, all the transparent adhesive layer **132**, the LED chips **108**, the bonding wires **110** and the transparent body **112** are formed on the top surface **102**. Therefore, only large patterns like the electrode plates **120** and **122** are formed on the bottom surface **104**, which are immune from casual tiny scratches. In addition, holders, carriers, or robot arms for transporting or holding the transparent substrate **106** could physically contact the bottom surface **104** to avoid any damage to the fine patterned structures on the top surface **102**, such that yield improvement is foreseeable.

[0058] Embodiments exemplified in FIGS. **3**A, **3**B, and **6** do not restrain the direction where the light from a blue LED chip **108** goes. The light from a blue LED chip **108** could go downward through the transparent adhesive layer **132** and the transparent substrate **106** to provide light that appears white. The light from a blue LED chip **108** could go upward or vertically through the transparent body **112** to provide white light as well. Therefore, the LED assembly **100***a* is a lighting device that has an omnidirectional white light field. As the lamp in FIG. **4** uses the LED assemblies **100** as its light resources, it could be an omnidirectional white lighting apparatus, which is possible to replace a traditional incandescent lamp.

[0059] In FIGS. **2**A, **2**B, **3**A and **3**B, the blue LED chips **108** mounted directly on the transparent substrate **106** only through the transparent adhesive layers **132**, but this disclosure is not limited to. FIGS. **7**A and **7**B demonstrate top and bottom views of an LED assembly **100***b* respectively, according to one embodiment of the disclosure. Two cross-sectional views of the LED assembly **100***b* are shown in FIGS. **8**A and **8**B, and a manufacturing method to produce the LED assembly **100***b* is exemplified in FIG. **9**. FIGS. **7**A, **7**B, **8**A, **8**B and **9** correspond to FIGS. **2**A, **2**B, **3**A, **3**B, and **6**, where devices, elements or steps with similar or the same symbols represent those with the same or similar functions and could be omitted in the following explanation for brevity.

[0060] Different from FIG. **2**A, FIG. **7**A additionally includes a submount **160** positioning inside the periphery of a transparent adhesive layer **132** (from the perspective of a top view) and sandwiched between the transparent adhesive layer **132** and the blue LED chips **108**. Submount **160** could be glass, sapphire, SiC, or diamond-like carbon. Unlike FIGS. **3**A and **3**B, all or a portion of blue LED chips in FIGS. **8**A and **8**B are mounted on the submount **160**, which is adhered onto the transparent substrate **106** through the transparent adhesive layer **132**.

[0061] FIG. **9** uses steps **154***a* and **155***a* to replace steps **154** and **155** in FIG. **6**. In Step **154***a*, the submount **160** is fixed on the transparent substrate **106** using the transparent adhesive layer **132** with phosphor. In one embodiment, the transparent adhesive layer **132** first adheres to the backside of the submount **160**, followed by attaching the submount **160** on the transparent substrate **106**. In another embodiment, the transparent adhesive layer **132** first adheres to the top surface **102** of the transparent substrate **106** and the submount **160** is then attached over the transparent adhesive layer **132**. In Step **155***a*, the blue LED chips **108** are mounted on the submount **160**.

[0062] The blue LED chips **108** in FIGS. **7**A, **7**B, **8**A, **8**B, and **9** could be mounted on the submount **160** using the material the same or similar with that of the transparent adhesive layer **132**, but the disclosure is not limited to. Eutectic alloy or transparent glue without phosphor could be used to attach the blue LED chips **108** onto the submount **160**. In one embodiment, the top surface of the submount **160** has patterned conductive strips, over which the blue LED chips **108** are mounted by way of flip chip technique. As known in the art, flip chip technique, which has semiconductor chips facing downward on interconnection metal strips for example, needs no bonding wires shown in step **156** in FIG. **9** might be skipped. Nevertheless, the bonding wires **100** or the silver paste might be used in some embodiments for electrically connecting the blue LED chip **108***b* to the conductive via **107**, or the blue LED chip **108***a* to the electrode plate **118**. In one embodiment, an anisotropic conductive polymer (ACP) or an anisotropic conductive film (ACF) is used to mount the blue LED chips **108** on the submount **160**.

[0063] The LED assembly **100***b* in FIGS. **7**A, **7**B, **8**A, **813**, and **9** could enjoy the same advantages as the LED assembly **100***a* in FIGS. **2**A, **2**B, **3**A, **313**, and **6** does. For instance, the solder joints **190** alone can fix the end **114** of the LED assembly **100***b* onto a printed circuit board and also deliver electric power from the printed circuit board to the LED assembly **100***b*. The bottom surface **104** of the LED assembly **100***b* has only large patterns and could be immune from scratch damage, resulting in considerable yield improvement. The blue LED chips **108** in the LED assembly **100***b* are enclosed by a transparent material with phosphor, so as to prevent blue light leakage. An omnidirectional lighting apparatus using the LED assembly **100***b* as its lighting sources could replace a conventional incandescent lamp.

[0064] FIGS. **8**C and **8**D are two cross-sectional views of a LED assembly **100***c*, alternatives to FIGS. **8**A and **8**B respectively. Unlike the LED assembly **100***b* in FIGS. **8**A and **8**B, where a single transparent adhesive layer **132** mounts the submount **160** on the transparent substrate **106**, the LED assembly **100***c* in FIGS. **8**C and **8**D uses two transparent adhesive layers **132** and **133** for mounting the submount **160** on the transparent substrate **106**, and at least one of the transparent adhesive layers **132** and **133** has phosphor. In FIGS. **8**C and **8**D, the transparent adhesive layer **132** has phosphor, and the transparent adhesive layer **133** does not. The transparent adhesive layer **133** could be epoxy resin or silicone. As the transparent adhesive layer **133** has no phosphor, it could provide better adhesion to stick on the transparent substrate **106**. The transparent adhesive layers **132** and **133** might have the same or different major substance. In one embodiment, another transparent adhesive layer **133** could be formed between the submount **160** and the transparent adhesive layer **132** to improve the adhesion therebetween.

[0065] The blue LED chips in FIG. **1** employs bonding wires **110** for electric interconnection, but the disclosure is not limited to. FIG. **10** is a drawing of a LED assembly **400** in one embodiment of the disclosure, where blue LED chips **108** are mounted on the top surface **102** using a flip chip technique. FIGS. **11**A and **11**B are top and bottom views of the LED assembly **400***a* respectively, FIG. **12**A demonstrates a cross-sectional view of the LED assembly **400***a* along line AA in FIG. **11**A, and FIG. **12**B demonstrates a cross-sectional view of the LED assembly **400***a* along line BB in FIG. **11**A. FIGS. **10**, **11**A, **11**B, **12**A, and **12**B correspond to FIGS. **1**, **2**A, **2**B, **3**A, and **3**B, respectively, where devices or elements with similar or the same symbols refer to those with the same or similar functions and could be omitted in the following explanation for brevity.

[0066] Unlike FIGS. **3**A and **3**B, which use bonding wires **110** for interconnection, FIGS. **12**A and **12**B have electrically-conductive strips **402** printed on the top surface **102** of the transparent substrate **106** and these strips **402** connects blue LED chips **108** to each other. As the blue LED chips **108** in FIGS. **12**A and **12**B have omnidirectional light fields, the LED assembly **400***b* could be used as a light source for an omnidirectional lighting apparatus. FIG. **12**C shows another LED assembly **400***b*, which has an additional phosphor layer **131** coated or attached on the bottom surface **104** of the transparent substrate **106**. Phosphor layer **131** can convert the blue light from blue LED chips **108** into light with a different color, so as to reduce the possibility of blue light leakage from the bottom surface **104**. In one embodiment, all blue LED chips **108** in the LED assembly **400***a* are replaced by white LED chips, each substantially being a blue LED chip coated with a phosphor layer, and accordingly blue light leakage problem might be avoided.

[0067] Even though each of the LED assemblies **100***a*, **100***b*, **100***c*, and **400***a* has a conductive via **107**, which is a part of a circuit and makes it possible that the electrode plates **120** and **118** over the top and bottom surfaces (**102** and **104**) act as two power input terminals for driving, but this disclosure is not limited to.

[0068] FIG. **13** is a drawing of a LED assembly **200** in one embodiment of the disclosure. FIGS. **14** and **15** are a top view and a cross-sectional view of the LED assembly **200***a*, respectively. Different from the LED assemblies **100***a* and **100***b*, which have no electrode plate nearby the end **116** on the top surface **102**, the LED assembly **200***a* in FIGS. **14** and **15** has an electrode plate **119** at the end **116**. The electrode plates **118** and **119** extend across the ends **114** and **116**, respectively. What should be noted is that the LED assembly **200***a* has no conductive via **107**. The way to produce the LED assemblies **200** or **200***a* in FIGS. **13**, **14** and **15** can be derived from the aforementioned teaching and therefore is omitted herein for brevity.

[0069] In the LED assembly **200***a*, the blue LED chips **108** are one-on-one mounted on the transparent adhesive layers **132**, but this disclosure is not limited to. In some other embodiments, some blue LED chips **108** could share one of several transparent adhesive layers **132** to mount on the transparent substrate **106**. Alternatively, all blue LED chips **108** might have only one single transparent adhesive layers **132** to mount on the transparent substrate **106** in another embodiment.

[0070] FIGS. **16** and **17**, similar with FIGS. **14** and **15**, are a top view and a cross-sectional view of the LED assembly **200***b*, respectively. FIGS. **16** and **17** have nevertheless a submount **160**, which carries the blue LED chips **108** mounted thereabove and fix on to the transparent substrate **106** via the transparent adhesive layer **132**. Detail of the LED assembly **200***b* is omitted herein and could be derived from the teaching in reference to the LED assembly **100***b* in FIGS. **8**A and **8**B.

[0071] FIG. **18** is a cross-sectional view of a LED assembly **200***c* and FIG. **19** demonstrates a method for manufacturing it. The top view of the LED assembly **200***c* could be similar with FIG. **16**, while FIGS. **18** and **19** are similar to FIGS. **17** and **9**, respectively. Different from FIG. **17**, where the electrode plates **118** and **119** directly attach on the transparent substrate **106**, FIG. **18** has the transparent adhesive layer **132** to provide adhesion between the transparent substrate **106** and each of the electrode plates **118** and **119**. In FIG. **19**, in step **151**, the transparent adhesive layer **132** forming on the transparent substrate **106** is inserted between steps **150** and **152**. In other words, formation of the transparent adhesive layer **132** could be prior to attaching the electrode plates **118** and **119** on to the transparent substrate **106**. The transparent adhesive layer **132** is epoxy resin or silicone, for example, in which phosphor is dispersed. The phosphor in the transparent adhesive layer **132** could be the same with or similar to that in the transparent body **112**. For example, the phosphor is YAG or TAG.

[0072] One single transparent adhesive layer **132** is used to mount the submount **160** on the transparent substrate **106** in the LED assemblies **200***b* and **200***c* of FIGS. **17** and **18**, but this disclosure is not limited to. Alteration could be introduced to the LED assemblies **200***b* and **200***c*, to have both the transparent adhesive layers **132** and **133** (of FIGS. **8**C and **8**D) between the submount **160** and the transparent substrate **106**. In another embodiment, the transparent adhesive layer **133**

without phosphor could be positioned between the submount **160** and transparent adhesive layer **132** to enhance adhesion therebetween.

[0073] The LED assembly **200***a*, **200***b*, or **200***c* has no patterns on the bottom surface **104**, which accordingly does not care any scratches thereon. The LED assemblies **200***a*, **200***b*, and **200***c* all are suitable for omnidirectional lighting applications and possibly free from blue light leakage. For instance, a bulb according to an embodiment of the disclosure can use solder joints or electrically-conductive clamps to fix and power the electrode plates **118** and **119** respectively nearby two ends **114** and **116**.

[0074] FIG. **20** is a drawing of an LED assembly **300**, and FIGS. **21**A and **21**B are a top view and a cross-sectional view of the LED assembly **300***a*, respectively. FIG. **22** demonstrates a cross-sectional view of the LED assembly **300***a*. Formed on the bottom surface **104** of the transparent substrate **106** of the LED assembly **300***a* are two electrode plates **120** and **122**, at two ends **114** and **116** respectively. In each of FIGS. **21**A, **21**B, and **22**, the LED assembly **300***a* has two conductive vias **107**A and **107**B, respectively formed somewhere close to two ends **114** and **116**. The electrode plate **120**, as being on the bottom surface **104**, uses conductive via **107**A for electrically connecting to one blue LED chip **108** on the top surface **102**, while the electrode plate **122** uses the conductive via **107**B for electrically connecting to another blue LED chip **108**. The blue LED chips **108** are electrically connected in series between the conductive vias **107**A and **107**B, or, in other words, between the electrode plates **120** and **122**. Details of the LED assembly **300***a* and possible alternatives or variations thereto could be derived in reference to other embodiments disclosed in this specification and are omitted herein.

[0075] FIG. **23** demonstrates a cross-sectional view of an LED assembly **300***b*, where the submount **160** is placed under the blue LED chips and above the transparent adhesive layer **132**. Details of the LED assembly **300***b* and possible alternatives or variations thereto could be derived in reference to other embodiments disclosed in this specification and are omitted herein.

[0076] The LED assemblies **200** and **300** both have the electrode plates extending across the ends **114** and **116**, but this disclosure is not limited to. FIG. **24** is a drawing of a LED assembly **600**. FIG. **25**A shows the LED assembly **600***a*, which could be a top view of the LED assembly **600** and has the electrode plates **118** and **119**, each having an edge aligned with an edge of the transparent substrate **106**. FIG. **25**B shows an LED assembly **600***b*, which could be another top view of the LED assembly **600** and has the electrode plates **118** and **119** completely inside the edges of the transparent substrate **106**.

[0077] FIG. **26**A is a drawing of an LED assembly **700** in one embodiment of the disclosure. FIG. **26**B is a top view of the LED assembly **700**. FIG. **26**C is a cross-sectional view of the LED assembly **700** along line CC in FIG. **26**B. The LED assembly **700** in FIGS. **26**A and **26**B has both electrode plates **118** and **123** on the top surface **102** at the end **114**, and has nothing on the bottom surface **104** of the transparent substrate **106**. Extending from the electrode plates **118** and **123** toward the end **116** are conductive strips **198** and **196**. Blue LED chips **108** are mounted on the top surface **102** and between the conductive strips **198** and **196**. The cathode and anode of each blue LED chip **108** are electrically connected to the conductive strips **198** and **196** with bonding wires **110**. Accordingly, the blue LED chips **108** in FIGS. **26**A, **26**B and **26**C are connected in parallel between the electrode plates **118** and **123**, which therefore acts as two power input nodes for the LED assembly **700**. In one embodiment, the blue LED chips **108** can be electrically connected to the conductive strips **198** and **196** by way of flip chip technique, that is, the blue LED chips **108** are electrically connected to the conductive strips **198** and **196** without using the bonding wires **110**. As shown in FIG. **26**C, the blue LED chips **108** are substantially encapsulated by the transparent adhesive layer **132** and the transparent body **112**, both having at least one kind of phosphor dispersed therein. In one embodiment, the blue LED chips **108** are totally enclosed by the transparent adhesive layer **132** and the transparent body **112**, however, the bonding wires **110** could be still exposed from the transparent adhesive layer **132** and the transparent body **112**. In one embodiment, the transparent body **112** comprises two kinds of phosphors dispersed therein. One of the phosphors is capable of converting portion of the blue light (having a peak wavelength about 430 nm to 480 nm) from blue LED chips **108** into yellow light or yellowish green light or green light (having a peak wavelength from about 520 nm to 590 nm) and the other of the phosphors is capable of converting portion of the blue light from blue LED chips **108** into red light (having a peak wavelength from about 610 nm to 680 nm). The phosphor emitting yellow light or yellowish green light or green light comprises aluminum oxide (such as YAG or TAG), silicate, vanadate, alkaline-earth metal selenide, or metal nitride. The phosphor emitting red light comprises silicate, vanadate, alkaline-earth metal sulfide, metal nitride oxide, a mixture of tungstate and molybdate. The method to produce the LED assembly **700** in FIG. **26**A, **26**B, or **26**C can be derived from the aforementioned teaching and therefore is omitted herein for brevity.

[0078] Alteration could be made to the LED assembly **700** in light of the disclosed embodiments according to the disclosure. For example, the blue LED chips **108** could be mounted on a submount, which adheres to the transparent substrate **106** via at least one transparent adhesive layer with or without a phosphor dispersed therein.

[0079] FIG. **27**A illustrates an LED lamp **500***a* using only one LED assembly **300** as its filament. The LED lamp **500***a* has two clamps **502**, and each clamp **502** is in a shape of V or Y. In another embodiment, each clamp **502** could be substantially rectangular in shape, but has a notch in one of its edges for fixing the LED assembly **300** thereon. Two jaws of each clamps **502** vise one electrode plate at one end of the LED assembly **300**, making the top surface **102** of the transparent substrate **106** in the LED assembly **300** face upward (the direction Z shown in FIG. **27**A). Preferably, clamps **502** are made of electrically-conductive material, so as to electrically connect the electrode plates in the LED assembly **300** to the Edison screw base of the LED assembly **500***a*, which could drain electric power from an Edison socket to power the LED assembly **300**. FIG. **27**B is similar with FIG. **27**A, but the LED lamp **500***b* in FIG. **27**B uses one LED assembly **600** as its filament. Different from the LED lamp **500***a* which has the LED assembly **300** facing upward, the LED assembly **600** in the LED lamp **500***b* has its top surface **102** facing the direction Y, which is vertical to the axis (Z axis) of the LED lamp **500***b*. Any of the assemblies **300** and **600** in FIGS. **27**A and **27**B could be replaced by the LED assembly **200**, details or alternatives of which could be derived in reference to the teaching disclosed in this specification and are omitted herein.

[0080] The bottom surface **104** of the LED assembly **300***a* or **300***b* has only the electrode plates **120** and **122** occupied in a large area, which is immune to casual scratches, such that yield improvement is expectable. Each of the LED assemblies **600***a* and **600***b* has no pattern on its bottom surface **104**, and therefore scratches on the bottom surface **104** could not impact the yield of LED assemblies **600***a* and **600***b*. Each of the LED assemblies **300***a*, **300***b*, **600***a*, and **600***b* could be suitable for applications to generate an omnidirectional light field, and could prevent any blue light leakage.

[0081] The aforementioned embodiments all employ only blue LED chips as their lighting resource, but this disclosure is not limited to. In some embodiments, some or all blue LED chips are replaced with red or green LED chips, for example.

[0082] Because of the transparency provided by the transparent substrate **106** and the transparent adhesive layer **132**, the LED assemblies in some embodiments could have an omnidirectional light field and be suitable for applications to generate an omnidirectional light field. The blue LED chips **108** in some embodiments are substantially encapsulated by the transparent adhesive layer **132** and transparent body **112** with phosphor, to avoid blue light leakage. One embodiment of the disclosure has a LED assembly with only one end fixed on a circuit board to provide both electric power and mechanic support. Nevertheless, a LED assembly of another embodiment has two ends, both fixed for mechanic support and coupled for receiving electric power from a power source. An LED assembly according to some embodiments has no fine patterns on its bottom surface, immune to scratch damage and convenient for the LED assembly transportation.

[0083] While the disclosure has been described by way of example and in terms of preferred embodiment, it is to be understood that the disclosure is not limited thereto. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A light emitting diode assembly, comprising:

a transparent substrate, comprising first and second surfaces facing to opposite orientations respectively;

light emitting diode chips, mounted on the first surface;

a circuit electrically connecting the light emitting diode chips;

a transparent capsule with a phosphor dispersed therein, formed on the first surface and substantially enclosing the circuit and the light emitting diode chips; and

first and second electrode plates, formed on the first or second surface, and electrically connected to the light emitting diode chips.

2. The light emitting diode assembly as claimed in claim **1**, wherein the transparent capsule comprises a transparent adhesive layer having a first phosphor dispersed therein, and placed between at least one of the light emitting diode chips and the transparent substrate.

3. The light emitting diode assembly as claimed in claim **2**, wherein the transparent capsule comprises transparent adhesive layers, and the light emitting diode chips are mounted one-on-one on the transparent adhesive layers.

4. The light emitting diode assembly as claimed in claim **2**, wherein the transparent capsule has a single transparent adhesive layer, and all the light emitting diode chips in the light emitting diode assembly are mounted on the transparent adhesive layer.

5. The light emitting diode assembly as claimed in claim **2**, wherein the transparent capsule has a transparent body covering on and surrounding the light emitting diode chips, and the transparent body has a second phosphor dispersed therein.

6. The light emitting diode assembly as claimed in claim **2**, further comprising a submount placed under the light emitting diodes and on the transparent adhesive layer.

7. The light emitting diode assembly as claimed in claim **6**, wherein the light emitting diode chips are mounted on the submount by way of flip chip technique.

8. The light emitting diode assembly as claimed in claim **1**, wherein the circuit comprises a bonding wire electrically connecting two of the light emitting diodes.

9. The light emitting diode assembly as claimed in claim **1**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the first and second electrode plates are placed on the first and second surfaces respectively and nearby one common end of the two opposite ends.

10. The light emitting diode assembly as claimed in claim **1**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the first and second electrode plates are placed nearby the two opposite ends respectively.

11. A method for manufacturing a LED assembly, comprising:

providing a transparent substrate, having first and second surfaces facing the opposite orientations;

mounting LED chips on the first surface using at least one transparent adhesive layer, wherein the transparent adhesive layer has a phosphor dispersed therein;

forming a circuit one the first surface for interconnection between the LED chips; and

forming a transparent body covering on and surrounding the LED chips, wherein the transparent body has a first phosphor dispersed therein.

12. The method as claimed in claim **11**, wherein comprising:

mounting the LED chips on the first surface using two transparent adhesive layers;

wherein at least one of the two transparent adhesive layers has a second phosphor, the other has no phosphor, and the two transparent adhesive layers stack between one of the LED chips and the transparent substrate.

13. The method as claimed in claim **11**, further comprising:

mounting the LED chips on a submount; and

mounting the submount on the first surface of the transparent substrate.

14. The method as claimed in claim **13**, comprising:

forming the at least one transparent adhesive layer on a backside of the submount; and

fixing both the submount and the transparent adhesive layer on the first surface.

15. The method as claimed in claim **13**, wherein the LED chips are mounted on the submount by way of flip chip technique.

16. The method as claimed in claim **11**, wherein the transparent substrate comprises a via hole tunneling therethrough and the via hole is formed with conductive material therein to provide a conductive via, the method comprising:

forming a first electrode plate on the first surface; and
forming a second electrode plate on the second surface, wherein the second electrode plate contacts the conductive via;
wherein the LED chips and the conductive via are connected in series between the first and second electrode plate.

17. The method as claimed in claim **11**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the method further comprises forming first and second electrode plates on the first and second surfaces respectively and nearby one common end of the two opposite ends.

18. The method as claimed in claim **11**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the method further comprises forming first and second electrode plates nearby the two opposite ends respectively and on the first surface.

19. The method as claimed in claim **11**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the method further comprises forming first and second electrode plates nearby the two opposite ends respectively and on the second surface.

20. The method as claimed in claim **11**, wherein the transparent substrate is substantially in the form of a longitudinal strip having two opposite ends, and the method further comprises forming first and second electrode plates on the first surface and nearby one common end of the two opposite ends.

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