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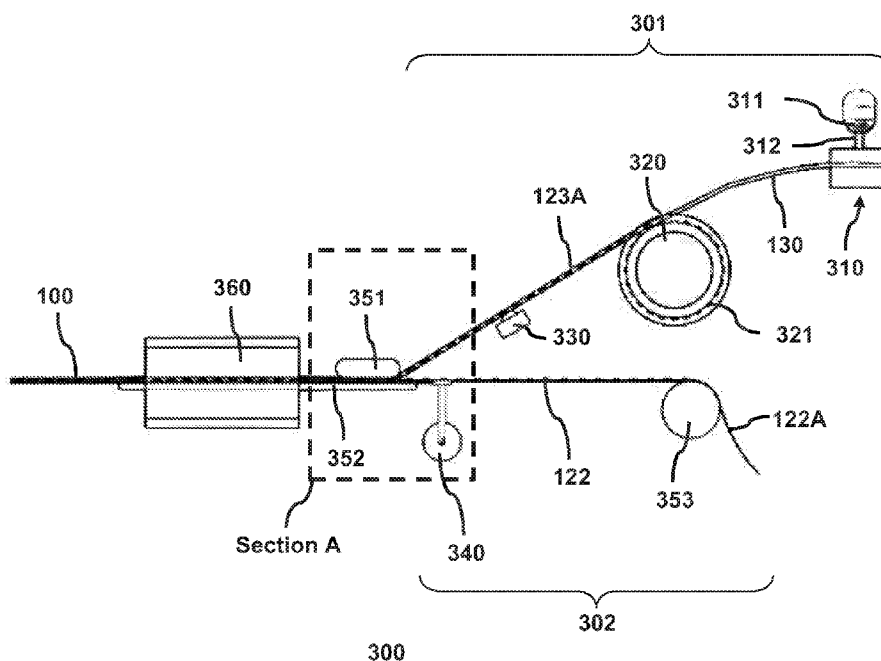


FIG. 4

(57) **Abstract:** A light-emitting diode (LED) lighting strip (100) having partial potting and the manufacturing system (300) of the LED lighting strip (100) are provided. The LED lighting strip (100) has a flexible printed circuit board (FPCB) (122) with a plurality of LED modules (120) thereon. Each individual LED module (120) comprises one or more LED chips (121). The LED lighting strip (100) is protected by an encapsulant (123) disposed above the LED chips (121). The system (300) includes an upper cover processing subsystem (301), a circuit board processing subsystem (302), and a baking oven (360). The upper cover processing subsystem (301) includes a first extrusion machine (310) for making the thermoplastic glue (130), a pit forming tool (320) to obtain an upper cover (123A), and an adhesive application tool (330). The pit forming tool (320) is configured to form slots (124A) on the bottom side of the thermoplastic glue (130), thereby the upper cover (123A) covers the FPCB (122) with air gaps (124) arranged above the LED chips



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LED LIGHTING STRIP AND THE MANUFACTURING SYSTEM THEREOF

FIELD OF THE INVENTION

[0001] The present disclosure generally relates to an LED lighting strip. In particular, the present disclosure relates to a waterproof LED lighting strip having partial potting and the manufacturing system of the LED lighting strip.

BACKGROUND OF THE INVENTION

[0002] LED lighting strip is widely used as general lighting and decorative lighting in both indoor and outdoor environments. The LED lighting strip may be creatively used in residential for interior decoration, or wrap around buildings and infrastructures to create some stunning visual effects. Generally, most colors across the visible light spectrum are available in the market and may include multiple color channels, such as the three primary colors (red, green, and blue). The brightness and colors of the light emission may be controllable to achieve different lighting effects and purposes.

[0003] The LED lighting strip typically has a flexible printed circuit board (FPCB) with a plurality of LED chips mounted thereon. The strip can be cut to a desirable length to fit a particular application, and includes an adhesive surface on the bottom side for mounting the LED lighting strip on a wall or a surface. Because the FPCB is designed to be flexible, the LED lighting strip may be mounted on curved or uneven surfaces.

[0004] In order to allow the LED lighting strip to be used in an outdoor environment or an indoor environment with high humidity, such as kitchen, bathroom, and indoor swimming pool, waterproofing and dust-proofing performance are important considerations. The industry generally uses various sealing measures to fully encapsulate the FPCB for improving ingress

protection. Materials, such as polyurethane (PU), polyvinyl chloride (PVC), and silicone glue, are used to fully encapsulate the LED lighting strip to meet the rating of IP67 or IP68.

[0005] There are two encapsulation methods conventionally used for sealing the LED lighting strip. The first method is known as a dropping glue method, as shown in FIG. 1A. The LED lighting strip is essentially a long and narrow strip of FPCB 22 having a number of LED chips 21 evenly distributed along the length of the FPCB 22. After mounting the LED chips 21 on the top side of the FPCB 22, a glue discharging device 11 is used to perform glue encapsulation. Either the glue discharging device 11 or the FPCB 22 is arranged to move from one side to another side, preferably using a conveyer belt, while the glue discharging device 11 drops the glue continuously to the FPCB 22 to encapsulate both the FPCB 22 and the LED chips 21. The glue is then solidified to form a protective layer 23.

[0006] The second encapsulation method is known as an injecting glue method, as shown in FIG. 1B. With a similar LED lighting strip as discussed above, a FPCB 22 mounted with LED chips 21 is placed within a bar-shaped substrate 23A with a cavity 23C. The glue discharging device 11 is placed at one side and injects the glue from an injection hole 23B into the substrate 23A to fully fill up the cavity 23C. When the glue is solidified, a protective layer 23 is formed on top of the LED lighting strip.

[0007] Both LED encapsulation methods can seal the LED chips 21 and the top side of the FPCB 22 from water and dust, and achieve good ingress protection. The LED lighting strip sealed by these two LED encapsulation methods is shown in FIG. 2. The LED chips 21 are in direct contact with the protective layer 23, which is the PU, PVC, or silicone. However, such an LED lighting strip is not preferred and has a disadvantage on the optical performance deviation and impacts the decorative effects. The perceptual performance on the chromaticity coordinates of the light emitted from the LED chips 21 after passing through the PU, PVC, or silicone has significantly deviated. In particular, the protective layer 23 is closely contacted with the surface of the LED chips 21, resulting in alternations to the blue and the yellow light proportions emitted from the LED chips 21.

[0008] Further, when the LED lighting strip is used for some time, the heat from the LED chips 21 or other electrical components on the FPCB 22 will cause deformation of the protective layer 23 and may result in air gaps randomly found on the protective layer 23 with irregular

shapes. The air gaps will also change the perceptual performance on the chromaticity coordinates when the light passes through the PU, PVC, or silicone. The light may also be deflected by the unevenly arranged air gaps across the LED lighting strip.

[0009] Accordingly, there is a need in the art to have an LED lighting strip with encapsulation that can achieve good waterproofing performance and good perceptual performance on the chromaticity coordinates. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY OF THE INVENTION

[0010] Provided herein is an LED lighting strip having partial potting and the manufacturing system of the LED lighting strip. It is the objective of the present disclosure to provide a LED lighting strip that can achieve excellent waterproofing performance and better perceptual performance on the chromaticity coordinates.

[0011] An aspect of the present disclosure is to provide a system for manufacturing a LED lighting strip. The LED lighting strip has a flexible printed circuit board (FPCB) with a plurality of LED modules thereon. An individual LED module includes one or more LED chips, and the LED lighting strip is protected by an encapsulant disposed above the LED chips.

[0012] The system comprises an upper cover processing subsystem for preparing an upper cover; a circuit board processing subsystem comprising a second extrusion machine for forming a bottom thermoplastic layer; and a baking oven for solidifying the upper cover and the bottom thermoplastic layer to obtain the encapsulant. The upper cover processing subsystem comprises a first extrusion machine for making the thermoplastic glue, a pit forming tool, and an adhesive application tool. The pit forming tool is configured to form slots on the bottom side of the thermoplastic glue when the thermoplastic glue is passing through the pit forming tool, thereby the upper cover obtained from the pit forming tool covers the FPCB with an air gap arranged above each of the LED chips for improving a perceptual performance on chromaticity coordinates.

[0013] In certain embodiments, the pit forming tool includes a wheel having a plurality of protrusions evenly arranged circumferentially on the wheel for forming the slots on the thermoplastic glue.

[0014] In certain embodiments, the pit forming tool comprises a rotating blade or a digging knife for excavating the thermoplastic glue.

[0015] In certain embodiments, the first extrusion machine receives a thermoplastic composition to form the thermoplastic glue continuously with a substantially constant cross-section by continuous extrusion technique.

[0016] In certain embodiments, the adhesive application tool comprises a rolling wheel and a sealing glue flume for applying an adhesive to a bottom side of the upper cover.

[0017] In certain embodiments, the circuit board processing subsystem comprises a pick-and-place machine and a solder reflow oven for attaching the LED chips to a FPCB substrate to obtain the FPCB.

[0018] In certain embodiments, the second extrusion machine is configured to continuously form the bottom thermoplastic layer on a bottom side of the FPCB by continuous extrusion technique.

[0019] In certain embodiments, the encapsulant is made of a material selected from a group consisting polyurethane (PU), polyvinyl chloride (PVC), and silicone.

[0020] The system further comprises an upper conveyor belt and a lower conveyor belt, wherein the upper and lower conveyor belts are configured to convey the upper cover and the FPCB along a direction towards the baking oven, and the upper and lower conveyor belts are arranged to align and press the upper cover and the FPCB together tightly.

[0021] In certain embodiments, the baking oven is configured to solidify the upper cover and the bottom thermoplastic layer to obtain the encapsulant, wherein the slots on the upper cover becomes the air gaps between the upper cover and the LED chips.

[0022] In certain embodiments, the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.

[0023] Another aspect of the present disclosure is to provide a LED lighting strip comprising a flexible printed circuit board (FPCB) with a plurality of LED modules thereon, an individual LED module comprising one or more LED chips; and an encapsulant disposed above the LED

chips. The encapsulant comprises an upper cover and a bottom thermoplastic layer. The upper cover covers the FPCB with an air gap arranged above each of the LED chips for improving a perceptual performance on chromaticity coordinates.

[0024] In certain embodiments, the encapsulant is made of a material selected from a group consisting polyurethane (PU), polyvinyl chloride (PVC), and silicone.

[0025] In certain embodiments, the LED lighting strip further comprises a cutline and solder pads between two LED modules.

[0026] In certain embodiments, the FPCB comprises one or more conductive layers and a flexible substrate with both high flexibility and folding resistance. Optionally, the flexible substrate comprises a polyamide (PI), a polyester (PET), a polyetherimide (PEI), or a polyetheretherketone (PEEK).

[0027] In certain embodiments, the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.

[0028] Another aspect of the present disclosure is to provide a method for manufacturing a LED lighting strip. The LED lighting strip has a flexible printed circuit board (FPCB) with a plurality of LED modules thereon. An individual LED module comprises one or more LED chips, and the LED lighting strip is protected by an encapsulant disposed above the LED chips. The method includes continuously forming a thermoplastic glue by continuous extrusion technique; forming slots on a bottom side of the thermoplastic glue to obtain an upper cover; applying an adhesive to the bottom side of the thermoplastic glue; attaching the LED chips to a FPCB substrate to obtain the FPCB; continuously forming a bottom thermoplastic layer on a bottom side of the FPCB by continuous extrusion technique; aligning and pressing the upper cover and the FPCB together tightly; and applying heat to the upper cover and the FPCB to solidify the upper cover and the bottom thermoplastic layer to obtain the encapsulant, wherein the slots in the upper cover are aligned with the LED chips on the FPCB and become air gaps disposed above the LED chips for improving a perceptual performance on chromaticity coordinates.

[0029] In certain embodiments, the step of forming slots on a bottom side of the thermoplastic glue comprises removing a portion of the thermoplastic glue.

[0030] In certain embodiments, the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.

[0031] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. Other aspects and advantages of the present invention are disclosed as illustrated by the embodiments hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The appended drawings contain figures to further illustrate and clarify the above and other aspects, advantages, and features of the present disclosure. It will be appreciated that these drawings depict only certain embodiments of the present disclosure and are not intended to limit its scope. It will also be appreciated that these drawings are illustrated for simplicity and clarity and have not necessarily been depicted to scale. The present disclosure will now be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0033] FIG. 1A depicts a conventional LED encapsulation method using the dropping glue technology;

[0034] FIG. 1B depicts a conventional LED encapsulation method using the injection glue technology;

[0035] FIG. 2 depicts a cross-sectional side view of a conventional LED lighting strip sealed by the LED encapsulation method of FIG. 1A or FIG. 1B;

[0036] FIG. 3 depicts a cross-sectional side view of the LED lighting strip having partial potting in accordance with certain embodiments of the present disclosure;

[0037] FIG. 4 is a side view of the system for manufacturing the LED lighting strip of FIG. 3;

[0038] FIG. 5 shows section A of FIG. 4 in details; and

[0039] FIG. 6 depicts the cross-sectional side views illustrating the manufacturing method of the LED lighting strip of FIG. 3.

[0040] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale.

DETAILED DESCRIPTION OF THE INVENTION

[0041] The present disclosure generally relates to a light-emitting diode (LED) lighting strip. More specifically, but without limitation, the present disclosure provides a waterproof LED lighting strip having partial potting for achieving excellent waterproofing performance and better perceptual performance on the chromaticity coordinates. Furthermore, the encapsulation method of the LED lighting strip and the corresponding production system are also provided.

[0042] The term “light-emitting diode” or “LED”, as used herein, includes LEDs of all types, such as light-emitting polymers, semiconductor dies that produce light in response to current, organic LEDs, electro-luminescent strips, silicon-based structures that emit light, etc.

[0043] The object of the present disclosure is to develop a longitudinal LED lighting strip that is flexible for a variety of lighting applications. For example, the LED lighting strip may be used for accent lighting, indirect lighting, furniture lighting, decorative lighting, outdoor lighting, architecture and infrastructure lightings, etc. As it is intended to use in an outdoor or humid environment, it is crucial to have excellent ingress protection. One aspect of the present disclosure is to provide an LED lighting strip that can meet the IPx8 rating. As used herein, the “IP code” is the ingress protection code based on the IEC standard 60529. The LED lighting strip rated as IPx8 means that it can be immersed in 1.5 meters of fresh water for up to 30 minutes. It is appreciated that the method and the structure described in the present disclosure can be employed to produce an LED lighting strip that can meet a lower or a higher ingress protection standard without departing from the scope and spirit of the present disclosure.

[0044] The LED lighting strip, as used herein, refers to a long flexible strip with a plurality of LEDs thereon. Although LED lighting strip is referred to, a person skilled in the art will appreciate that the strip may include other light sources known in the art. The typical longitudinal length of the LED lighting strip is ranged from 5 meters to 10 meters, and above. Cutting options are available for customizing the LED lighting strip to the desired length to meet the demand and application. A plurality of LED chips are connected in series and can be operated with a direct current (DC) supply voltage of 12 volts or 24 volts, or other input voltages.

[0045] As shown in FIG. 3, a cross-sectional side view of an LED lighting strip **100** is depicted. The LED lighting strip **100** has a flexible printed circuit board (FPCB) **122** with a plurality of

LED modules **120** thereon. The FPCB **122** may be a one-sided, a double-sided, or a multiple-layer flexible printed circuit board comprising one or more conductive layers and a flexible substrate with both high flexibility and folding resistance. The flexible substrate may comprise, for example, a polyamide (PI), a polyester (PET), a polyetherimide (PEI), a polyetheretherketone (PEEK), or the like, or any combinations thereof. The conductive layers on the flexible substrate are generally conductive paths with excellent electrical conductivity, such as copper or other conductive metals.

[0046] Each individual LED module **120** may comprise one or more LED chips **121** and other electrical components **125**, wherein the electrical components **125** may include a resistor, a capacitor, a diode, an integrated circuit configured to maintain a constant luminous flux, or the like, or any combinations thereof. The LED chips **121** are the optical device placed on the top side of the FPCB **122** for generating light. Cutline and solder pads (not shown in the drawings) may be provided between two LED modules **120**. The LED chips **121** and the electrical components **125** are bonded to the bonding pads on the FPCB **122** that electrically connect with the conductive layers of the FPCB **122**. After the LED lighting strip **100** is cut along the cutline to the desired length, the solder pads are used to solder wires or connectors for connecting the LED lighting strip **100** to a DC power supply. In the illustrated embodiment, six LED modules **120** having six LED chips **121** are disposed on the FPCB **122**, it is obvious that the number of LED chips **121** can be any number, and the LED modules **120** may be disposed on the FPCB **122** evenly, randomly, or according to certain pattern along the longitudinal length of the LED lighting strip **100**. The LED density along the LED lighting strip **100** may be optimized, and a trade-off between the light output uniformity, cost, and power consumption is used to determine the distance between the LED chips **121**. In certain embodiments, but without limitation, the LED lighting strip **100** comprises 30 to 200 LED chips **121** per meter. The electrical components **125** are shown only on the top side of the FPCB **122** in the illustrated embodiment, and in certain cases, the electrical components **125** may be bonded to the bottom side of the FPCB **122**, or on both top and bottom sides.

[0047] The LED lighting strip **100** is protected by a light permissible encapsulant **123**, which is substantially covering the FPCB **122**, in particular, the encapsulant **123** is disposed above the LED chips **121**, other electrical components **125** and circuitry on the FPCB **122**, wherein the

encapsulant **123** has a thickness in a range between 0.1mm to 5mm, and more preferably, in a range between 0.3mm to 3mm. The encapsulant **123** comprises an upper cover **123A** and a bottom thermoplastic layer **123B**. In the illustrated embodiment, the encapsulant **123** is rectangular in shape and covering the entire FPCB **122**. However, it is apparent that the encapsulant **123** may be in round-shape, dome-shape, or other shapes with less regularity and may only cover part of the FPCB **122**. More preciously, the encapsulant **123** is a light permissible encapsulation layer made of materials, such as polyurethane (PU), polyvinyl chloride (PVC), silicone glue, soft epoxy resin, or the like, or any combinations thereof. The encapsulant **123** is a uniform, clear, and transparent layer of coating with high transparency in the UV to visible wavelength region and excellent heat resistance. Therefore, by covering the LED chips **121**, other electrical components **125** and circuitry, an enclosure is formed against intrusion, accidental contact, and liquid or solid particles ingress.

[0048] On the top side of the LED lighting strip **100**, although the upper cover **123A** is substantially covering the FPCB **122**, the upper cover **123A** is not entirely covering the LED chips **121**. The LED lighting strip **100** features a partial potting, and there is provided an air gap **124** between the upper cover **123A** and the LED chip **121**, wherein the air gap **124** between the upper cover **123A** and the LED chip **121** is not less than 0.1mm, and more preferably, in a range between 0.1mm to 5mm. In certain embodiments, the air gap **124** may also cover some or all of the other electrical components **125** on the FPCB **122**. In the illustrated embodiment, the air gap **124** has a cube shape or a cuboid shape, and it is apparent that the air gap **124** may have a hemisphere shape, an elliptic shape, or other shapes. The perceptual performance on the chromaticity coordinates of the light emitted from the LED chips **121** after passing through the encapsulant **123** are significantly deviated. In particular, when the encapsulant **123** is closely contacted with the surface of the LED chips **121**, there are alternations to the blue and the yellow light proportions emitted from the LED chips **121**. The partial potting in the LED lighting strip **100** having the air gap **124** disposed above the LED chips **121** advantageously provides a separation between the LED chip **121** and the encapsulant **123**, thereby the light emitted from the LED chips **121** is arranged to travel across the air gap **124** first, and entered into the encapsulant **123**.

[0049] Further, the heat generated from the LED chips **121** is not transferred to the encapsulant **123** directly. The encapsulant **123** can maintain a lower temperature and has a lower risk of material deformation and air bubbles formation even when the LED lighting strip **100** is operating continuously in an outdoor environment or under extreme conditions. The deficiencies found in the conventional encapsulated LED lighting strips can be improved, and the LED lighting strip **100** in accordance with the present disclosure can achieve improved perceptual performance on the chromaticity coordinates.

[0050] The bottom thermoplastic layer **123B** can also protect the bottom side of the FPCB **122**, and avoids ingress or contact to the circuitry. The LED lighting strip **100** further comprises an adhesive tape **126** at the bottom side for mounting the LED lighting strip **100** on a wall or a surface. Because the FPCB **122** is flexible, the LED lighting strip **100** may be mounted on curved or uneven surfaces.

[0051] As shown in FIG. 4, the system for manufacturing the aforementioned LED lighting strip **100** with partial potting is described. In certain embodiments, the manufacturing system **300** comprises an upper cover processing subsystem **301**, a circuit board processing subsystem **302**, an upper conveyor belt **351**, a lower conveyor belt **352**, and a baking oven **360**. The conveyor belts **351**, **352** are endless belts that configured to convey the upper cover **123A** and the FPCB **122** along the same direction towards the baking oven **360** smoothly as the rotating movement thereof. The conveyor belts **351**, **352** are placed to allow the upper cover **123A** and the FPCB **122** to pass between them, thereby the upper cover **123A** and the FPCB **122** are correctly aligned and pressed together tightly.

[0052] The upper cover processing subsystem **301** comprises a first extrusion machine **310**, a pit forming tool **320**, and an adhesive application tool **330**, which collectively used to prepare the upper cover **123A** for solidification.

[0053] The first extrusion machine **310** receives a thermoplastic composition **311** for making the thermoplastic glue **130**. The first extrusion machine **310** is a thermoplastic extrusion machine having a hopper for receiving the thermoplastic composition **311**, a heater, and a nozzle **312**, thereby the thermoplastic glue **130** can be formed continuously with a substantially constant cross-section by continuous extrusion technique. In certain embodiments, the thermoplastic composition **311** may be PU, PVC, silicone, or other suitable material in the form of granules,

pellets, or other particles. The thermoplastic glue 130 produced is accurately positioned and driven by the upper conveyor belt 351 to direct the thermoplastic glue 130 to the pit forming tool 320, the adhesive application tool 330, and finally to the baking oven 360.

[0054] The pit forming tool 320 is configured to form slots 124A on the bottom side of the thermoplastic glue 130 from the first extrusion machine 310. The purpose of the pit forming tool 320 is to remove a portion of the thermoplastic glue 130 from the bottom side accurately and evenly when the thermoplastic glue 130 is passing through the pit forming tool 320, thereby the upper cover 123A obtained can cover the FPCB 122 with an air gap 124 arranged above each of the LED chips 121. The dimension of the slot 124A depends on the size of the LED chip 121. The minimum size is 0.1mm bigger than the LED chip 121, and the maximum size is 5mm bigger than the LED chip 121. Each slot 124A may have a cube shape, a cuboid shape, a hemisphere shape, an elliptic shape, or other shapes. In the illustrated embodiment, a wheel 320 having a plurality of protrusions 321 evenly arranged circumferentially on the wheel 320 is used to form the slots 124A on the thermoplastic glue 130 to obtain an upper cover 123A. It is apparent that other digging means for forming the slots 124A on the thermoplastic glue 130 may be applied without departing from the scope and spirit of the present disclosure. For example, a rotating blade, digging knife, or other cutting tools may be used for excavating the thermoplastic glue 130.

[0055] To improve the adhesiveness of the upper cover 123A to the FPCB 122, an adhesive 127, such as sealing glue, is applied to the bottom side of the upper cover 123A using an adhesive application tool 330, which is arranged to be placed above the FPCB 122 for sealing the LED lighting strip 100. The adhesive application tool 330 comprises a rolling wheel and a sealing glue flume thereon. When the upper cover 123A passes through the rolling wheel of the adhesive application tool 330, the sealing glue flume is arranged to apply the adhesive 127 to the bottom side of the upper cover 123A.

[0056] On the bottom side, the circuit board processing subsystem 302 is configured to prepare the FPCB 122. The circuit board processing subsystem 302 comprises one or more rollers 353 and a second extrusion machine 340. Although other equipment, such as a pick-and-place machine and a solder reflow oven, are not depicted in the drawings for clarity and simplicity, it is apparent that such equipment may also be provided in the circuit board processing subsystem

302 for preparing the FPCB **122**. The FPCB substrate **122A** is accurately positioned and aligned correctly into the circuit board processing subsystem **302**, and conveyed by the lower conveyor belt **352** and the one or more rollers **353** to feed the FPCB **122** towards the baking oven **360**. A pick-and-place machine is used to mount the LED chips **121** and other electrical components **125** precisely on the FPCB substrate **122A**. In a solder reflow oven, the solder is first melted and then allowed to cool such that the LED chips **121** and other electrical components **125** are correctly attached to the FPCB substrate **122A** to obtain the FPCB **122** of the present disclosure.

[0057] The second extrusion machine **340** is configured to attach a bottom thermoplastic layer **123B** on the bottom side of the FPCB **122**. FIG. 5 shows the structure of the second extrusion machine **340** in detail. The second extrusion machine **340** is a thermoplastic extrusion machine having a hopper **341** for receiving the thermoplastic composition, a heating barrel **343**, and a nozzle **342**. The nozzle **342** is arranged to extrude the molten thermoplastic composition to the bottom side of the FPCB **122**. Therefore, the bottom thermoplastic layer **123B**, which may be PU, PVC, silicone, or other suitable material, can be formed continuously on the bottom side by continuous extrusion technique.

[0058] After the upper cover **123A** and the FPCB **122** are correctly aligned and pressed together tightly by the conveyor belts **351**, **352**, the adhesive **127** on the bottom side of the upper cover **123A** can hold the upper cover **123A** and the FPCB **122**, while the lower conveyor belt **352** can convey the combined device to the baking oven **360**. The baking oven **360** is configured to solidify the upper cover **123A** and the bottom thermoplastic layer **123B** when conveying. The temperature of the baking oven **360** is determined in accordance with the type of thermoplastic used. In certain embodiments, the temperature of the baking oven **360** is ranged between 150 degrees to 250 degrees. After baking, the encapsulant **123**, which is a light permissible protective layer, is solidified and the LED lighting strip **100** is obtained. The encapsulant **123** has an excellent waterproofing and dust-proofing performance, and the LED lighting strip **100** can meet the IPx7 or IPx8 waterproofing grade. The apparatus needed for forming an encapsulant **123** with the air gaps is mature and can be designed accordingly without complicated reengineering or changing of the production process.

[0059] Referring to FIG. 6, the method for manufacturing the LED lighting strip **100** having partial potting is illustrated. The manufacturing method is first separated into an upper cover

preparation method and a FPCB preparation method, then perform a solidification method to complete the encapsulation. For preparing the upper cover **123A**, in the first step **S101**, a thermoplastic glue **130** is formed continuously by continuous extrusion technique using a thermoplastic composition **311**. In the second step **S102**, slots **124A** are formed on the bottom side of the thermoplastic glue **130** by removing a portion of the thermoplastic glue **130** to obtain an upper cover **123A**. Each slot **124A** may have a cube shape, a cuboid shape, a hemisphere shape, an elliptic shape, or other shapes. In the third step **S103**, an adhesive **127**, such as sealing glue, is applied to the bottom side of the upper cover **123A** using an adhesive application tool **330**.

[0060] For preparing the FPCB **122**, in the first step **S201**, LED chips **121** and other electrical components **125** are accurately positioned and aligned with an FPCB substrate **122A**. In the second step **S202**, the LED chips **121** and other electrical components **125** are attached to the FPCB substrate **122A** to obtain the FPCB **122**. In the third step **S203**, a bottom thermoplastic layer **123B** is formed continuously on the bottom side of the FPCB **122** by continuous extrusion technique.

[0061] For the solidification method, the purpose is to prepare the LED lighting strip **100** with an encapsulant **123** disposed above the LED chips **121**. When the upper cover **123A** and the FPCB **122** are prepared, in the fourth step **S304**, the upper cover **123A** and the FPCB **122** are correctly aligned and pressed together tightly. In the fifth step **S305**, the upper cover **123A** and the bottom thermoplastic layer **123B** are solidified by applying heat thereto to form the encapsulant **123**. As the slots **124A** in the upper cover **123A** are aligned with the LED chips **121** on the FPCB **122**, the slots **124A** become the air gaps **124** disposed above the LED chips **121** for improving the perceptual performance on the chromaticity coordinates of the light emitted from the LED chips **121**, while the LED lighting strip **100** obtained can meet the IPx7 or IPx8 rating.

[0062] This illustrates the fundamental structure of a LED lighting strip having partial potting, and the manufacturing system and method thereof in accordance with the present disclosure. It will be apparent that variants of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different methods or apparatuses. The present embodiment is, therefore, to be considered in all respects as illustrative and not restrictive. The scope of the disclosure is indicated by the appended claims rather than by the

preceding description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A system for manufacturing a light-emitting diode (LED) lighting strip, the LED lighting strip having a flexible printed circuit board (FPCB) with a plurality of LED modules thereon, an individual LED module comprising one or more LED chips, the LED lighting strip being protected by an encapsulant disposed above the LED chips, the system comprising:

an upper cover processing subsystem for preparing an upper cover, wherein the upper cover processing subsystem comprises a first extrusion machine for making the thermoplastic glue, a pit forming tool, and an adhesive application tool;

a circuit board processing subsystem comprising a second extrusion machine for forming a bottom thermoplastic layer; and

a baking oven for solidifying the upper cover and the bottom thermoplastic layer to obtain the encapsulant,

wherein:

the pit forming tool is configured to form slots on the bottom side of the thermoplastic glue when the thermoplastic glue is passing through the pit forming tool, thereby the upper cover obtained from the pit forming tool covers the FPCB with an air gap arranged above each of the LED chips for improving a perceptual performance on chromaticity coordinates.

2. The system of claim 1, wherein the pit forming tool comprises a wheel having a plurality of protrusions evenly arranged circumferentially on the wheel for forming the slots on the thermoplastic glue.

3. The system of claim 1, wherein the pit forming tool comprises a rotating blade or a digging knife for excavating the thermoplastic glue.

4. The system of claim 1, wherein the first extrusion machine receives a thermoplastic composition to form the thermoplastic glue continuously with a substantially constant cross-section by continuous extrusion technique.
5. The system of claim 1, wherein the adhesive application tool comprises a rolling wheel and a sealing glue flume for applying an adhesive to a bottom side of the upper cover.
6. The system of claim 1, wherein the circuit board processing subsystem comprises a pick-and-place machine and a solder reflow oven for attaching the LED chips to a FPCB substrate to obtain the FPCB.
7. The system of claim 1, wherein the second extrusion machine is configured to continuously form the bottom thermoplastic layer on a bottom side of the FPCB by continuous extrusion technique.
8. The system of claim 1, wherein the encapsulant is made of a material selected from a group consisting polyurethane (PU), polyvinyl chloride (PVC), and silicone.
9. The system of claim 1 further comprising an upper conveyor belt and a lower conveyor belt, wherein the upper and lower conveyor belts are configured to convey the upper cover and the FPCB along a direction towards the baking oven, and the upper and lower conveyor belts are arranged to align and press the upper cover and the FPCB together tightly.
10. The system of claim 1, wherein the baking oven is configured to solidify the upper cover and the bottom thermoplastic layer to obtain the encapsulant, wherein the slots on the upper cover becomes the air gaps between the upper cover and the LED chips.
11. The system of claim 1, wherein the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.

12. A light-emitting diode (LED) lighting strip comprising:
- a flexible printed circuit board (FPCB) with a plurality of LED modules thereon, an individual LED module comprising one or more LED chips; and
- an encapsulant disposed above the LED chips, wherein the encapsulant comprises an upper cover and a bottom thermoplastic layer,
- wherein:
- the upper cover covers the FPCB with an air gap arranged above each of the LED chips for improving a perceptual performance on chromaticity coordinates.
13. The LED lighting strip of claim 12, wherein the encapsulant is made of a material selected from a group consisting polyurethane (PU), polyvinyl chloride (PVC), and silicone.
14. The LED lighting strip of claim 12 further comprising a cutline and solder pads between two LED modules.
15. The LED lighting strip of claim 12, wherein the FPCB comprises one or more conductive layers and a flexible substrate with both high flexibility and folding resistance.
16. The LED lighting strip of claim 15, wherein the flexible substrate comprises a polyamide (PI), a polyester (PET), a polyetherimide (PEI), or a polyetheretherketone (PEEK).
17. The LED lighting strip of claim 12, wherein the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.
18. A method for manufacturing a light-emitting diode (LED) lighting strip, the LED lighting strip having a flexible printed circuit board (FPCB) with a plurality of LED modules thereon, an individual LED module comprising one or more LED chips, the LED lighting strip being protected by an encapsulant disposed above the LED chips, the method comprising:
- continuously forming a thermoplastic glue by continuous extrusion technique;

forming slots on a bottom side of the thermoplastic glue to obtain an upper cover;
applying an adhesive to the bottom side of the thermoplastic glue;
attaching the LED chips to a FPCB substrate to obtain the FPCB;
continuously forming a bottom thermoplastic layer on a bottom side of the FPCB by continuous extrusion technique;
aligning and pressing the upper cover and the FPCB together tightly; and
applying heat to the upper cover and the FPCB to solidify the upper cover and the bottom thermoplastic layer to obtain the encapsulant, wherein the slots in the upper cover are aligned with the LED chips on the FPCB and become air gaps disposed above the LED chips for improving a perceptual performance on chromaticity coordinates.

19. The method of claim 18, wherein the step of forming slots on a bottom side of the thermoplastic glue comprises removing a portion of the thermoplastic glue.

20. The method of claim 18, wherein the air gap has a cube shape, a cuboid shape, a hemisphere shape, or an elliptic shape.

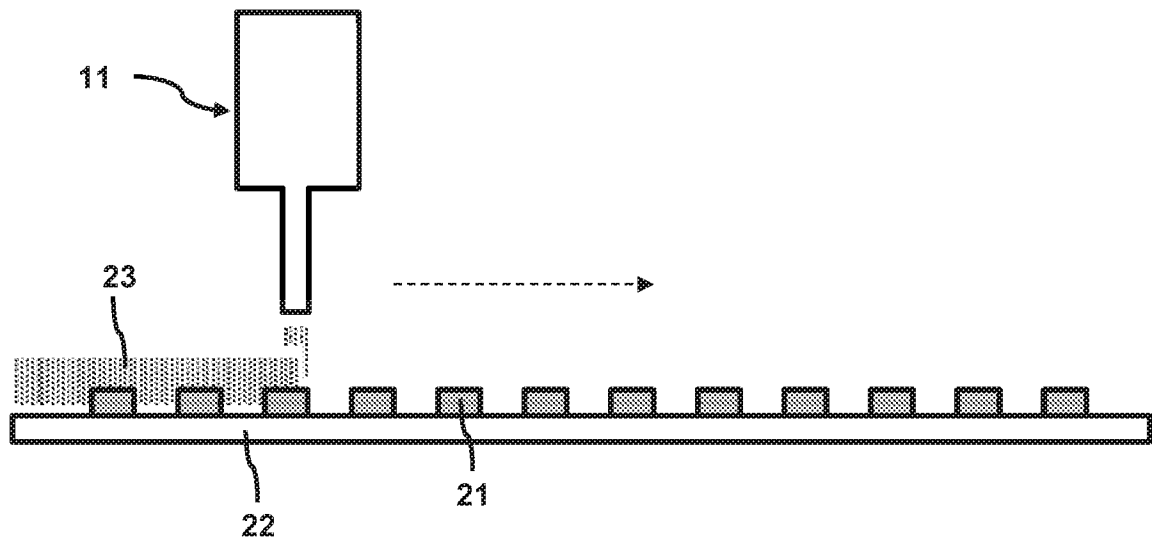


FIG. 1A (Prior Art)

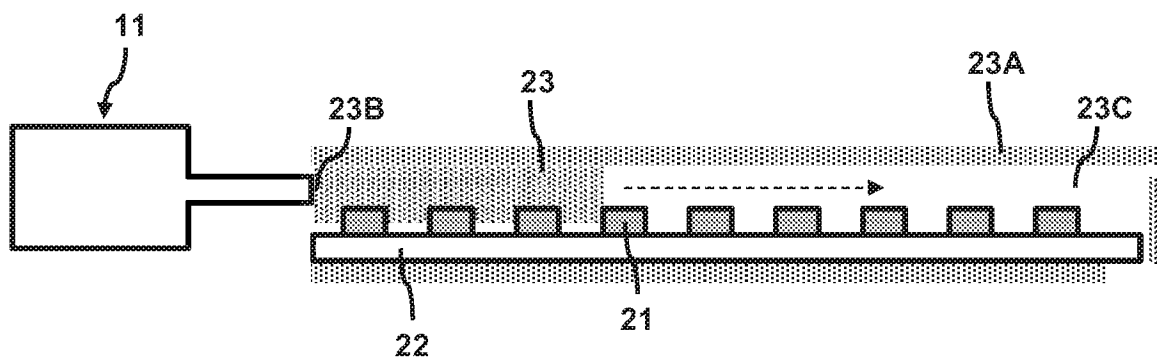


FIG. 1B (Prior Art)

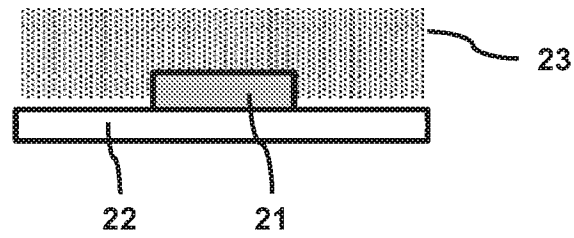


FIG. 2 (Prior Art)

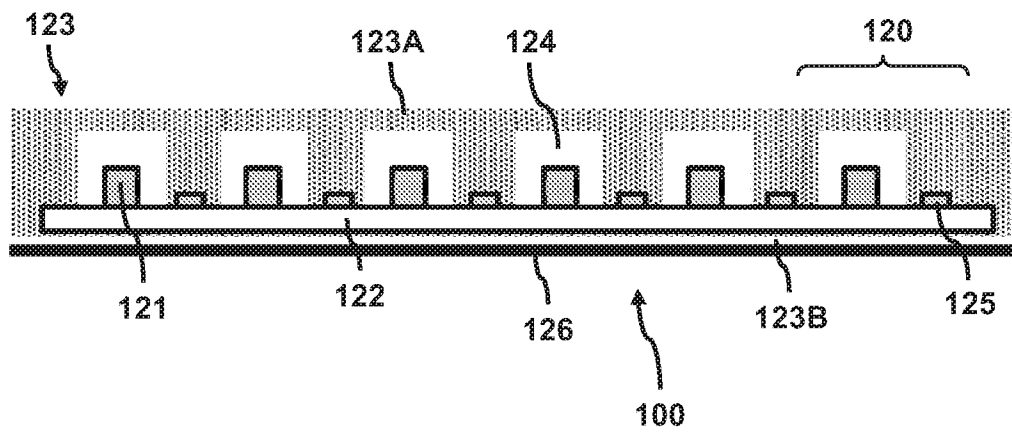


FIG. 3

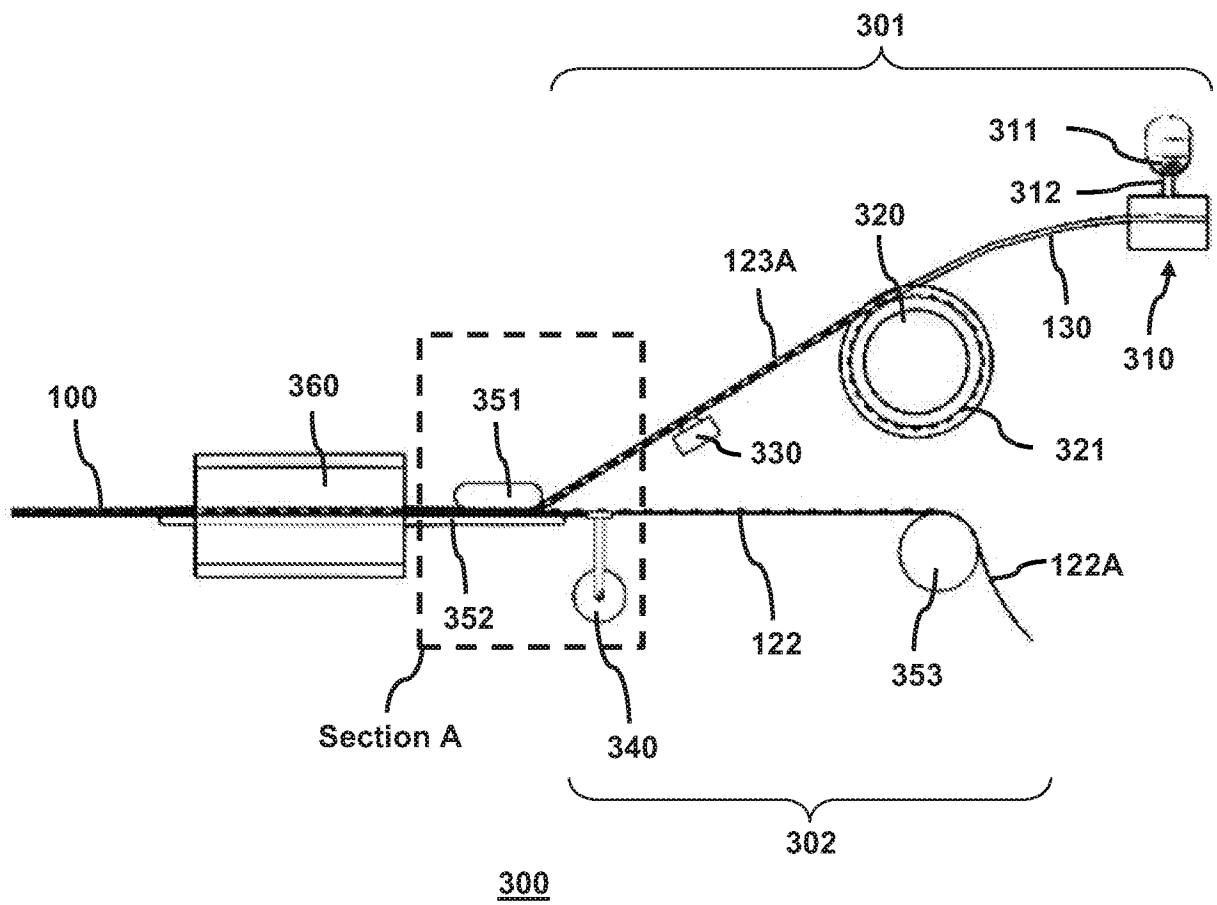


FIG. 4

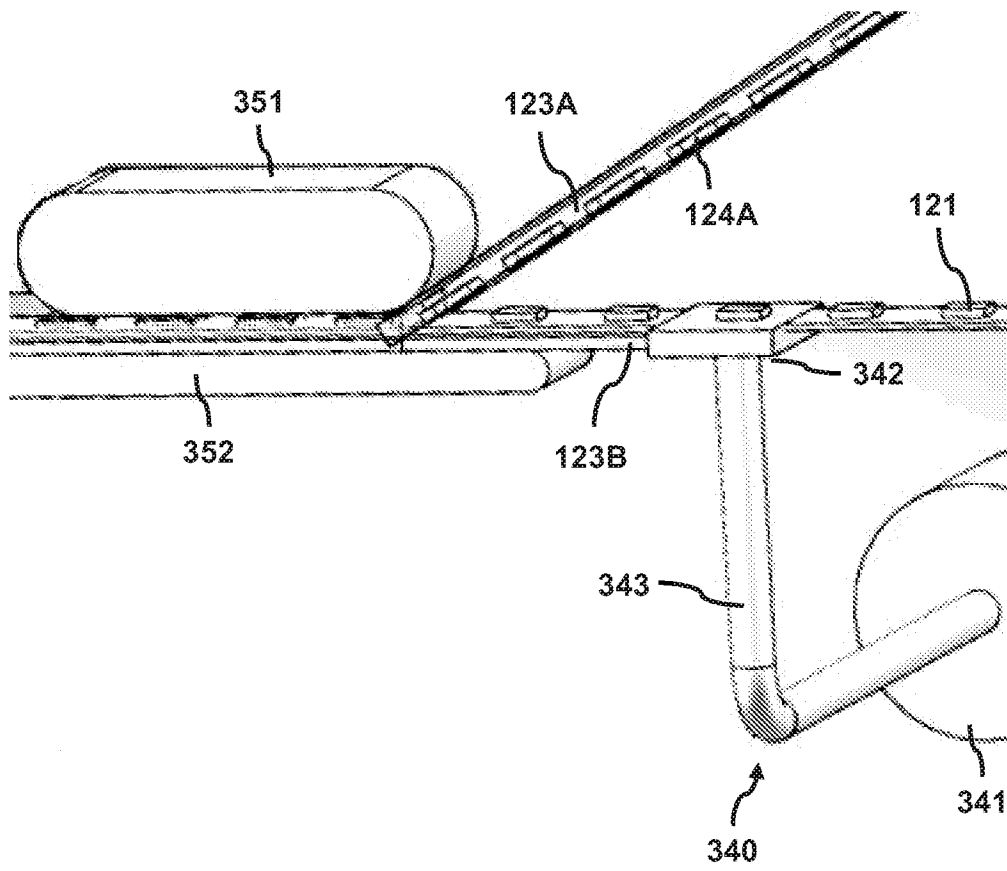


FIG. 5

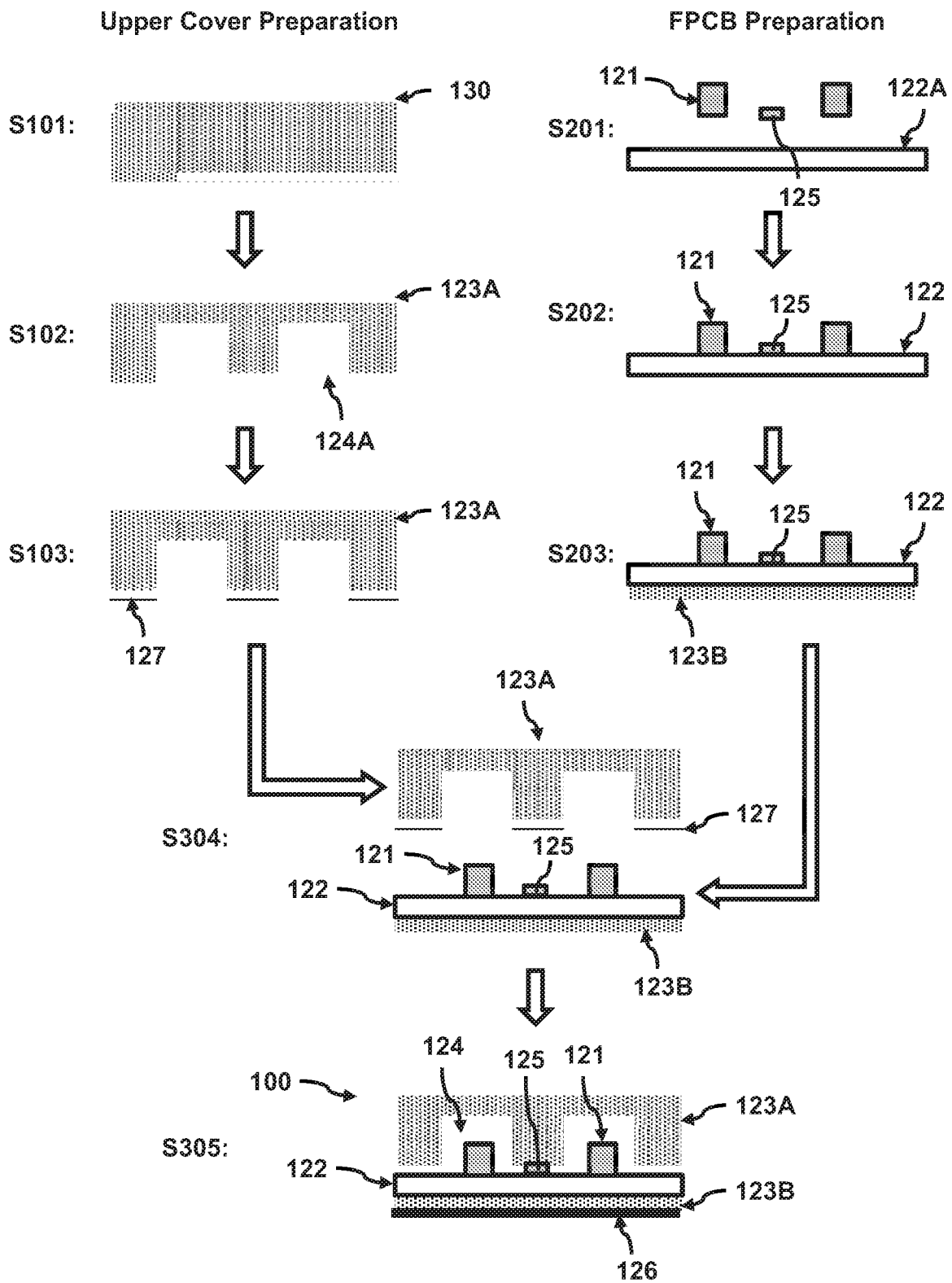


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/094528

A. CLASSIFICATION OF SUBJECT MATTER

H01L 33/52(2010.01)i; F21V 31/00(2006.01)i; F21S 4/22(2016.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L:F21

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT,CNABS,CNKI,WPI,EPODOC: TRIDONIC GMBH, lamp?, LED, strip?, strap?, ribbon?, gap?, mold+, hollow, cavum, cavity, air, thermoplastic+, glue, chip?, cup?, tube?, FPCB, waterproof, dustproof, protect+, encapsulat+, encapsulant, adhesive, elastic+, flexibl+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017114692 A1 (PHILIPS LIGHTING HOLDING B.V.) 06 July 2017 (2017-07-06) description, page 4, line 27 - page 7, line 19, figures 1-6	12-17
A	CN 107850274 A (HAUSER ELEKTRONIK G.M.B.H.) 27 March 2018 (2018-03-27) description, paragraphs [0059]-[0073], figures 1-13	1-20
A	CN 104051603 A (SUZHOU DONGSHAN PRECISION MANUFACTURING CO., LTD.) 17 September 2014 (2014-09-17) the whole document	1-20
A	CN 202209571 U (SHENZHEN RISHANG OPTOELECTRONICS CO., LTD.) 02 May 2012 (2012-05-02) the whole document	1-20
A	CN 110869664 A (SIGNIFY HOLDING B.V.) 06 March 2020 (2020-03-06) the whole document	1-20
A	CN 105179984 A (OSRAM G.M.B.H.) 23 December 2015 (2015-12-23) the whole document	1-20

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

08 February 2021

Date of mailing of the international search report

24 February 2021

Name and mailing address of the ISA/CN

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Telephone No. 86-(10)-53962635

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2020/094528

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2017114692	A1	06 July 2017	None			
CN	107850274	A	27 March 2018	EP	3344912	A1	11 July 2018
				WO	2017005234	A1	12 January 2017
				DE	112015006675	A5	19 July 2018
CN	104051603	A	17 September 2014	CN	104051603	B	09 June 2017
CN	202209571	U	02 May 2012	None			
CN	110869664	A	06 March 2020	JP	2020526891	A	31 August 2020
				WO	2019011721	A1	17 January 2019
				US	2020132263	A1	30 April 2020
				EP	3652480	A1	20 May 2020
				IN	202047004732	A	14 February 2020
CN	105179984	A	23 December 2015	EP	3158262	B1	11 July 2018
				CN	105179984	B	12 March 2019
				WO	2015193015	A2	23 December 2015
				US	10386022	B2	20 August 2019
				US	2017159893	A1	08 June 2017
				EP	3158262	A2	26 April 2017