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(54) **FLEXIBLE LED ASSEMBLIES AND LED LIGHT BULBS**

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(51) **Int. Cl.**

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| ***H01L 25/075*** | (2006.01) |
| ***F21K 99/00*** | (2016.01) |
| ***F21V 3/00*** | (2015.01) |
| ***F21K 9/232*** | (2016.01) |
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(58) **Field of Classification Search**

CPC ........... H01L 33/504; H01L 2924/0002; H01L 25/0753; H01L 33/62; F21K 9/232; F21Y 2115/10; F21Y 2107/70; F21Y 2109/00; F21V 3/00

See application file for complete search history.

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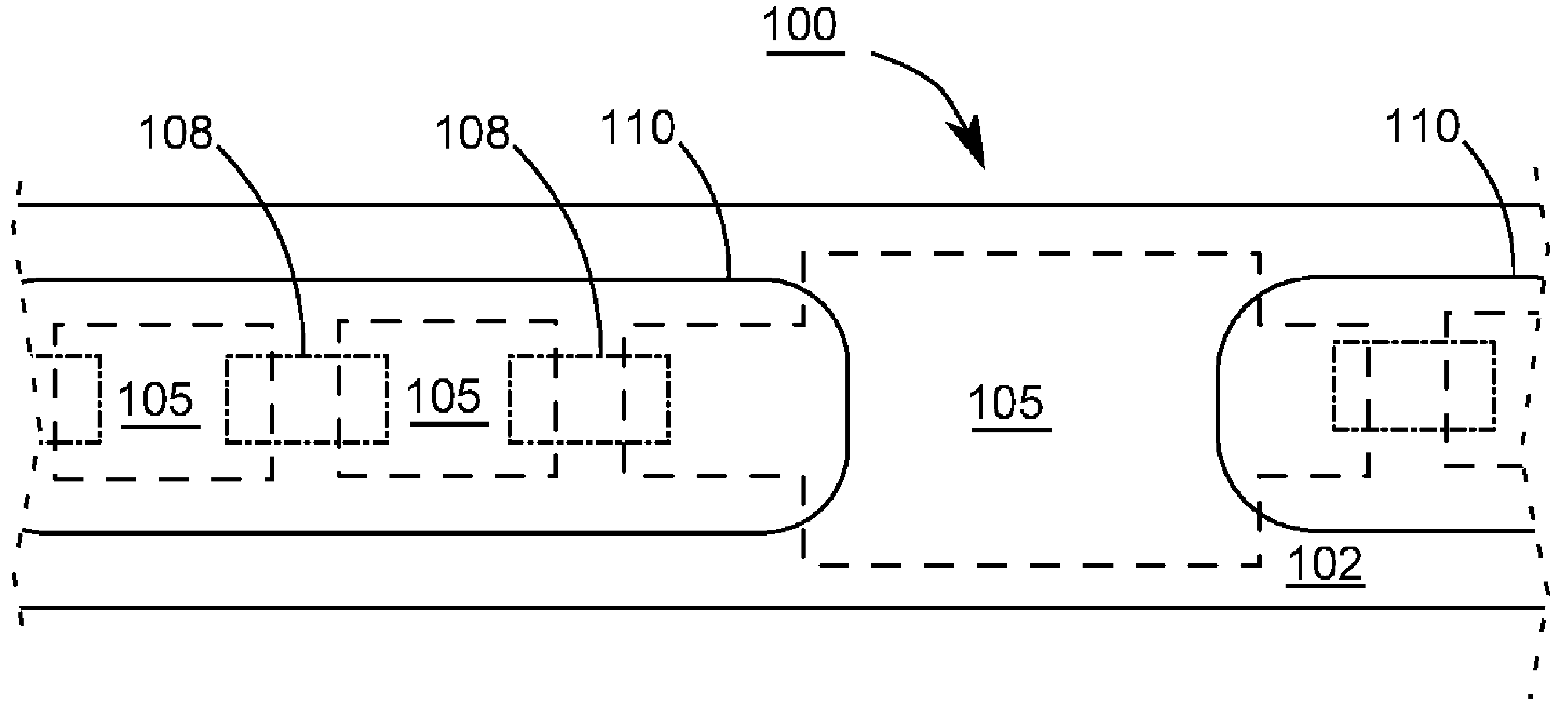
(57) **ABSTRACT**

LED assemblies and related LED light bulbs. An LED assembly has a flexible, transparent substrate, an LED chip on the first surface and electrically connected to two adjacent conductive sections, a first wavelength conversion layer, formed on the first surface to substantially cover the LED chip, and a second wavelength conversion layer formed on the second surface. The flexible, transparent substrate has first and second surfaces opposite to each other, and several conductive sections, which are separately formed on the first surface.

**12 Claims, 4 Drawing Sheets**



(51) **Int. Cl.**

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| *F21Y 115/10* | (2016.01) |
| *F21Y 107/70* | (2016.01) |

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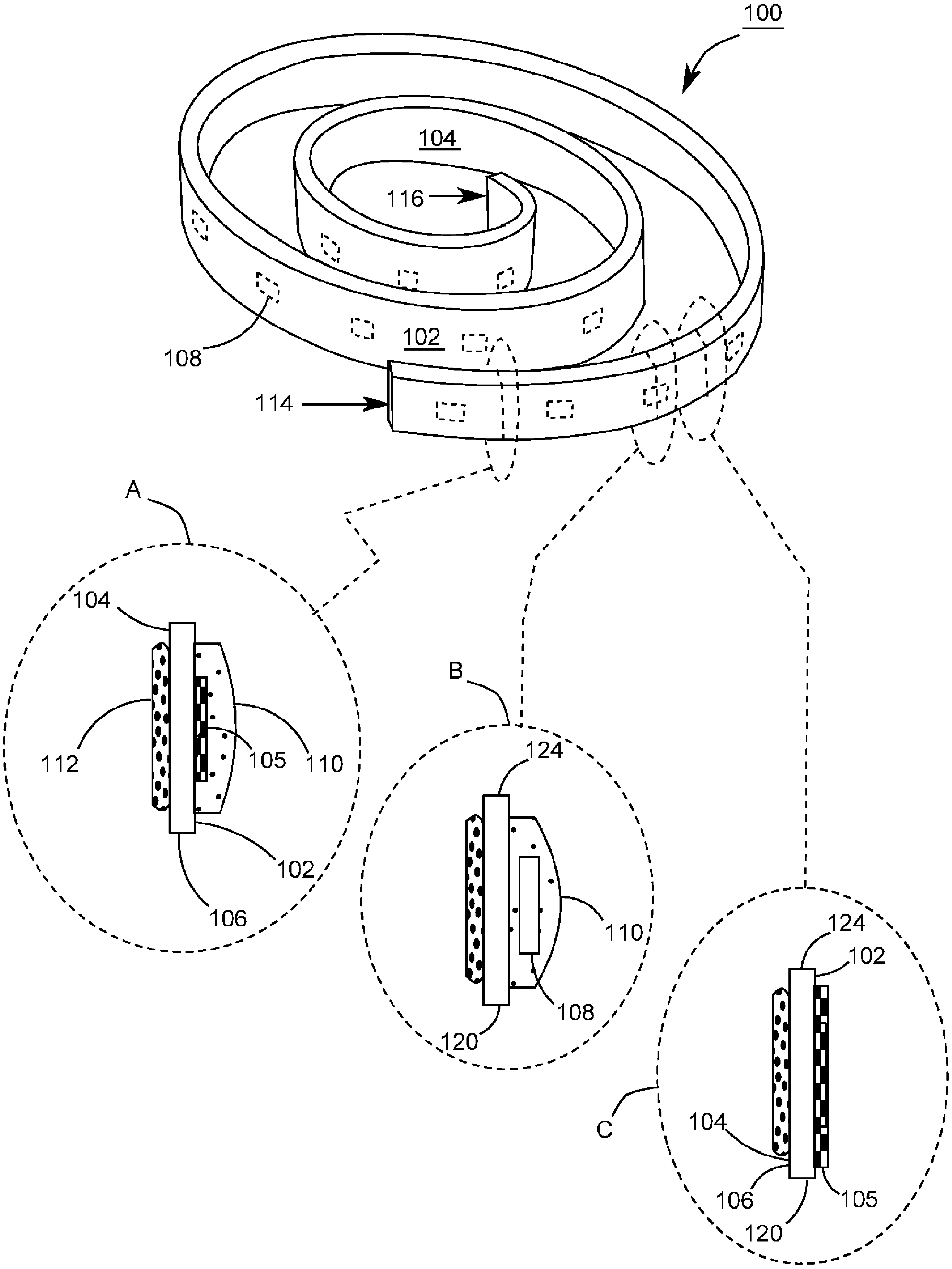
100
104
116
108
102
114
A
104
112
105
110
102
106
B
124
110
108
120
C
124
102
104
106
105
120

FIG. 1

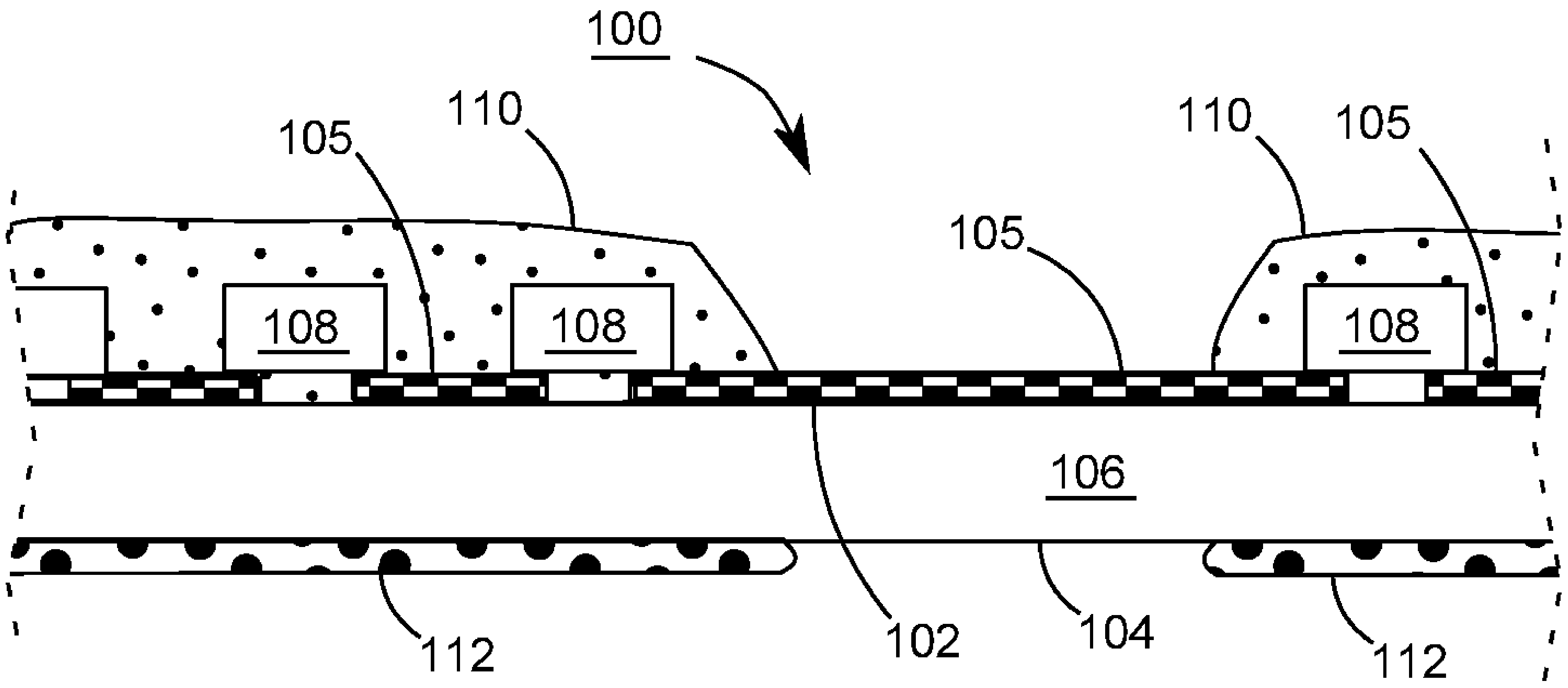

FIG. 2

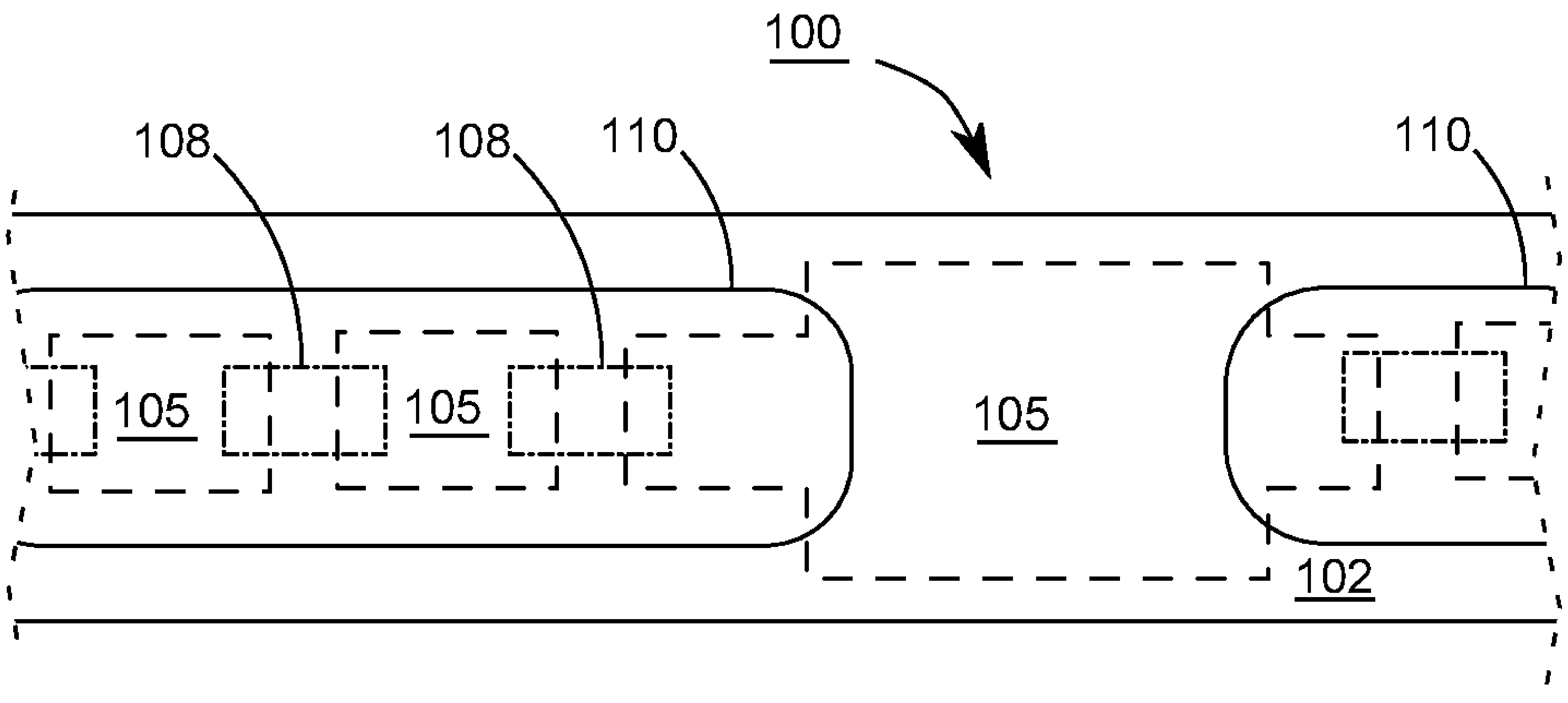

FIG. 3A

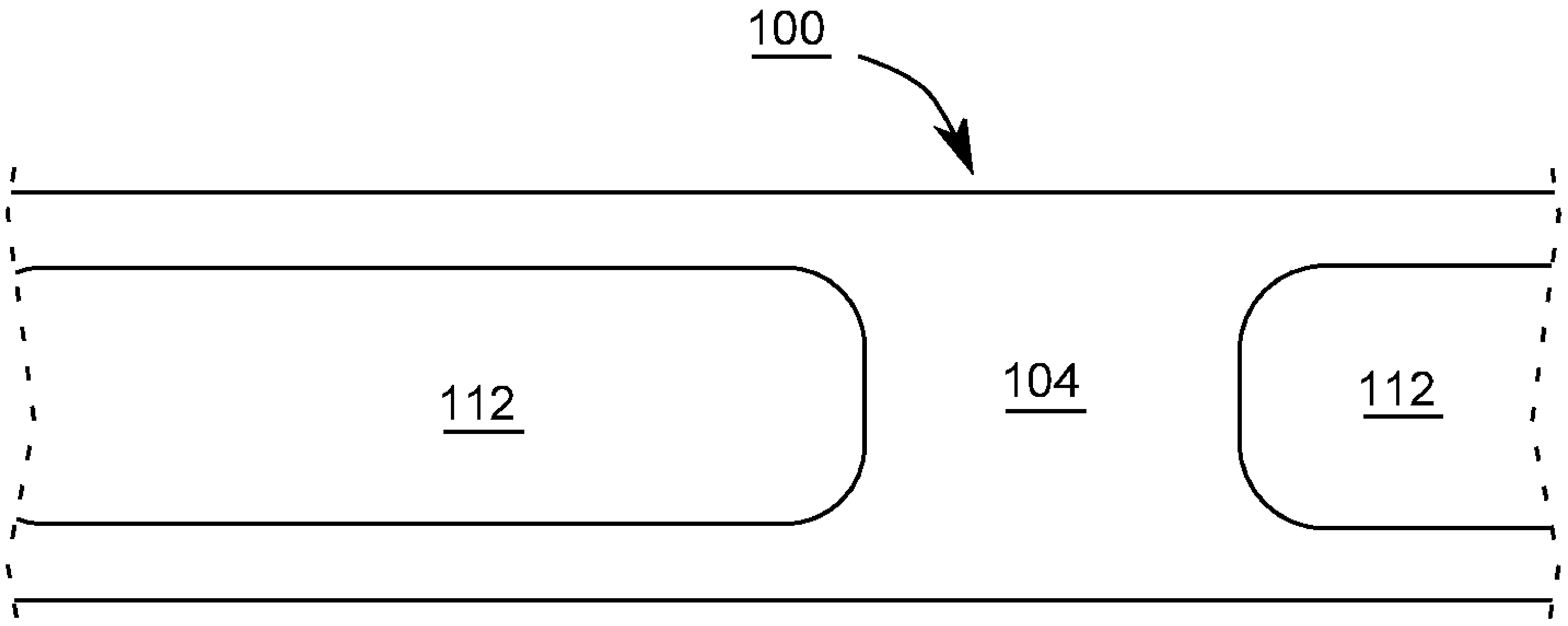

FIG. 3B

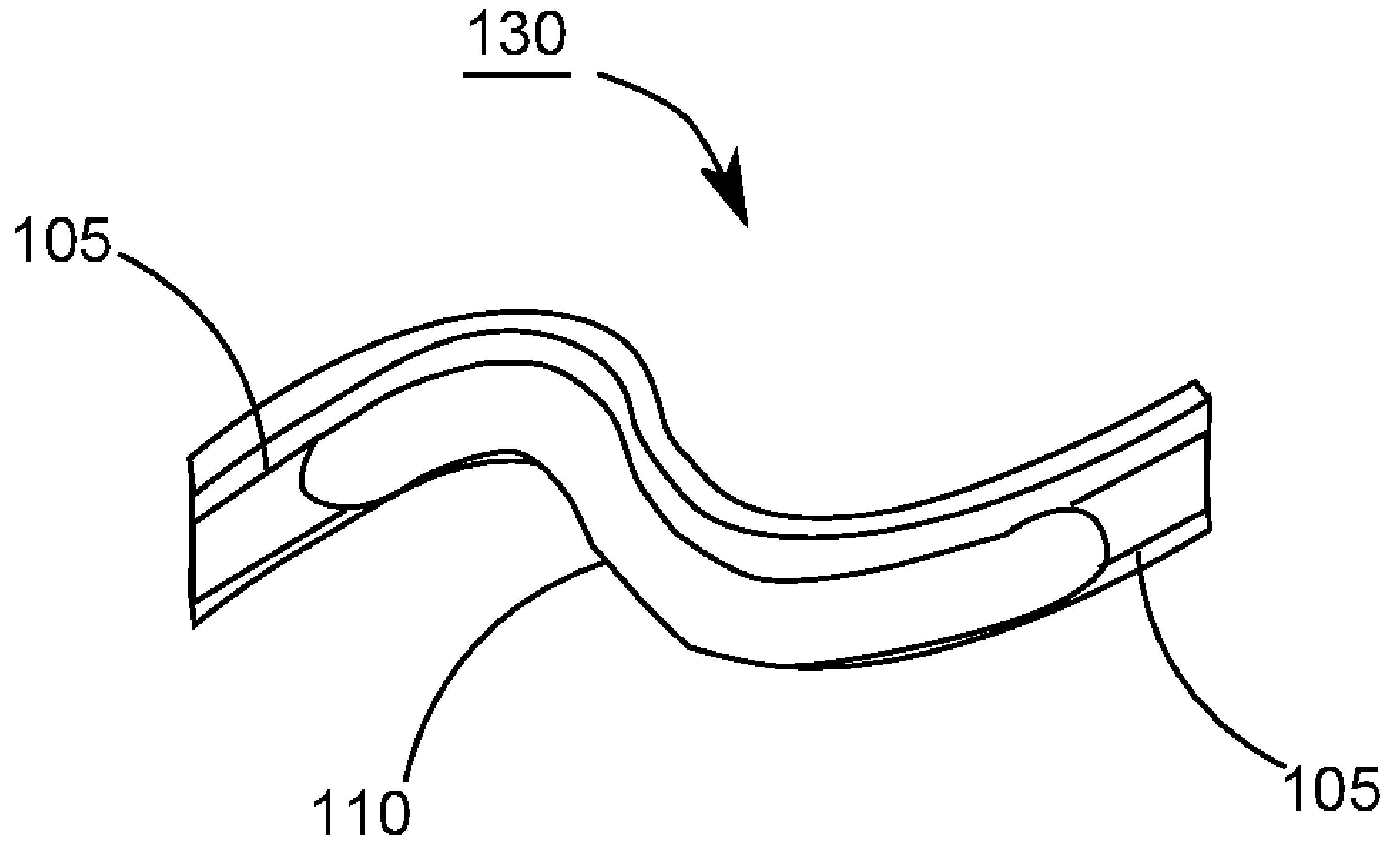

FIG. 4

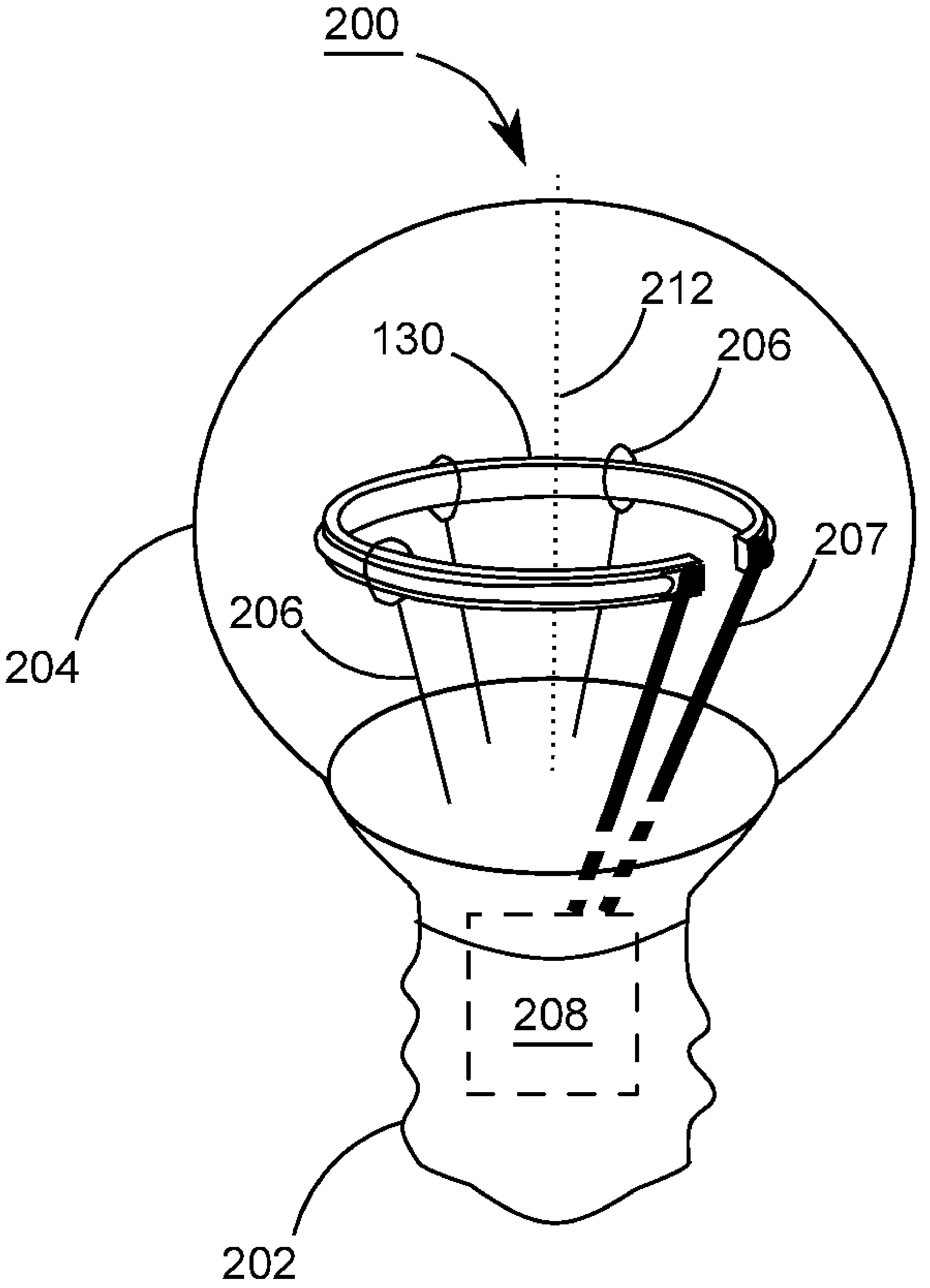

FIG. 5

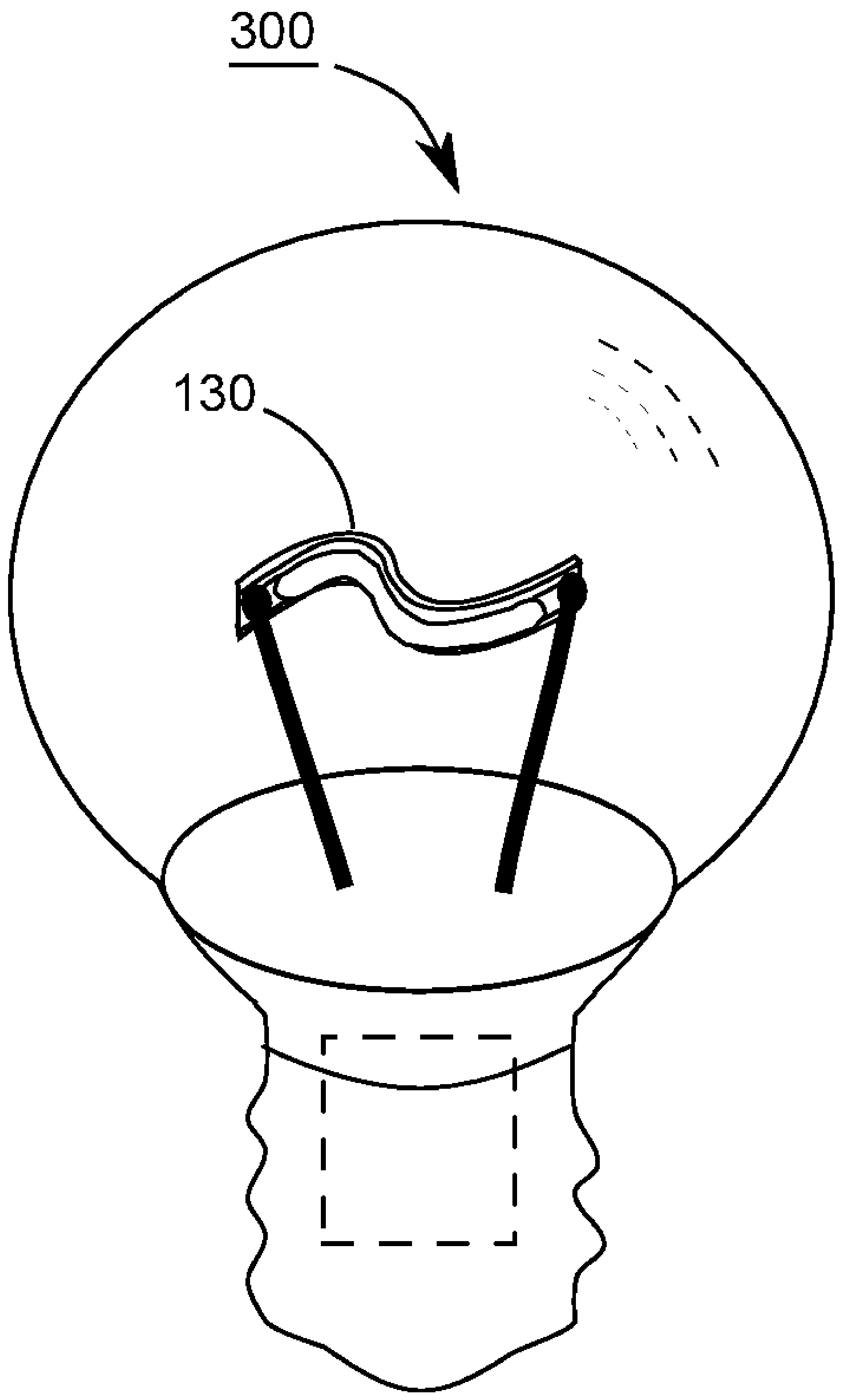

FIG. 6

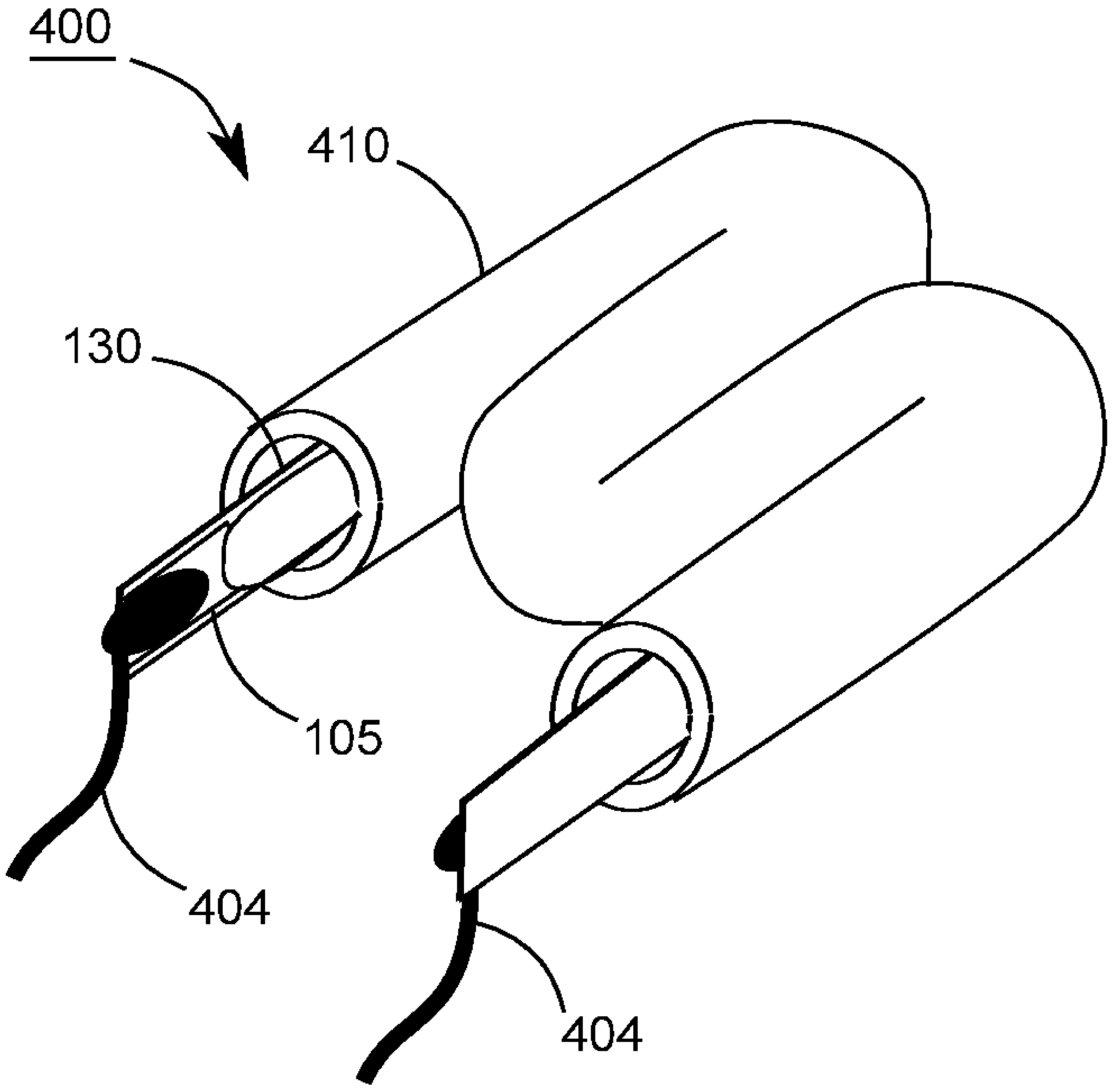

FIG. 7

# FLEXIBLE LED ASSEMBLIES AND LED LIGHT BULBS

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.**

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Taiwan Application Serial Number 102132806 filed on Sep. 11, 2013, which is incorporated by reference in its entirety.

## BACKGROUND

The present disclosure relates generally to flexible light emitting diode (LED) assemblies and their applications, more specifically to the LED assemblies suitable for omnidirectional light appliances.

LED has been used in different kinds of appliances in our life, such as traffic lights, car headlights, street lamps, computer indicators, flashlights, LCD backlight modules, and so on. LED chips as light sources for appliances are produced by wafer manufacturing process in the front end, and then undergo LED packaging in the back end to result in LED assemblies or apparatuses.

LED packaging mainly provides mechanical, electrical, thermal, and optical supports to LED chips. LED chips, which are kind of semiconductor products, are prone to performance degradation, or aging, if exposed for a long time in an atmosphere of humidity or chemical. To isolate the LED chips from the unfriendly atmosphere, epoxy resins are commonly used to cover and seal them. Heat dissipation and light extraction should be also considered for LED packaging, such that LED products could have long lifespan, high brightness and power conservation. For example, the heat generated by an LED chip, if not well dissipated, could deteriorate the LED chip, shorten its lifespan, and downgrade its reliability. Optical design, such as the way to extract and direct the light into a preferable angle or distribution, also plays an important role for LED packaging.

Design for packaged white LEDs is more complicated and needs further consideration of color temperature, color rendering index, phosphor, etc. A white LED could be provided by using phosphor to convert a portion of the 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 emit outward directly without its intensity being attenuated by phosphor. In other words, the blue light should be kind of “sealed” or “capsulated” by phosphor inside a white LED package so as to prevent blue light from leakage to human eyes.

## SUMMARY

An LED assembly comprises a flexible, transparent substrate, an LED chip on the first surface and electrically connected to two adjacent conductive sections, a first wavelength conversion layer, formed on the first surface to substantially cover the LED chip, and a second wavelength conversion layer formed on the second surface. The flexible, transparent substrate comprises first and second surfaces opposite to each other, and several conductive sections, which are separately formed on the first surface.

## BRIEF DESCRIPTION OF THE DRAWINGS

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.

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

FIG. **1** shows an LED assembly according to an embodiment of the disclosure;

FIG. **2** is a cross sectional view of the LED assembly along a longitudinal line;

FIGS. **3**A and **3**B show two opposite surfaces of the LED assembly in FIG. **1**;

FIG. **4** demonstrates an LED filament produced from cutting the LED assembly in FIG. **1**;

FIG. **5** demonstrates an LED light bulb with the LED filament in FIG. **4**;

FIG. **6** is an LED light bulb disclosed in the disclosure; and

FIG. **7** demonstrates an LED bulb disclosed in the disclosure.

## DETAILED DESCRIPTION

An LED assembly **100** according to an embodiment of the disclosure is described in detail with reference to FIG. **1**, which shows perspective and cross sectional views of the LED assembly **100**. As shown in FIG. **1**, the LED assembly **100** is flexible, and is capable of being curved to be a tape on a reel. Depending on actual applications, the LED assembly **100** could be cut into pieces with proper lengths, each capable of being a light source in a lighting apparatus such as a light bulb. The cross sectional views A, B and C are derived from different locations of the LED assembly **100** in FIG. **1**.

The LED assembly **100** has a flexible, transparent substrate **106**, which is, in one embodiment, composed of a non-conductive material such as glass or resin. The transparent substrate **106** has surfaces **102** and **104** opposite to each other, and facing the opposite directions respectively and sidewalls **120** and **124** on the surfaces **102** and **104**. As demonstrated in FIG. **1**, the transparent substrate **106** is a thin, longitudinal strip, having two opposite ends **114** and **116**. In this specification, “transparent” means having the property of transmitting rays of light, and could refer to as transparent, translucent or semitransparent. The bodies situated beyond or behind the transparent substrate **106** could be distinctly or obscurely seen. Thickness of the transparent substrate **106**, or the distance between the surfaces **102** and **104**, could be 150 micrometer or less.

FIG. **2** is a cross sectional view of the LED assembly **100** along a longitudinal line passing through ends **114** and **116**. FIGS. **3**A and **3**B show two opposite surfaces of the LED assembly **100**.

On the surface **102** of the flexible, transparent substrate **106** has conductive sections **105**, which are formed by printing for example. Another method of forming the conductive sections **105** includes forming designed conductive patterns through masks, comprising steps of coating a conductive film on the surface **102**, and patterning the conductive film by lithography and etching to form conductive patterns on the surface **102**, wherein the conductive sections **105** can be further divided into different conductive sections **105**. The conductive sections **105** could be composed of transparent material, such as indium tin oxide (ITO) or silver thin film, and the thickness of the thin film should be well controlled to be transparent to the light emitted from the blue LED chips **108**.

The embodiment in FIGS. **1**, **2**, **3**A and **3**B has blue LED chips **108** on the surface **102**, each connecting between two adjacent conductive sections **105**. In one embodiment, a blue LED chip **108** might have only one single LED cell, having a forward voltage of about 2 to 3 volts, and this kind of LED chip is referred to as a low-voltage LED chip hereinafter. Comparatively, a blue LED chip **108** in another embodiment might include several LED cells connected in series, and is referred to as a high-voltage LED chip hereinafter, because the forward voltage of the LED chip 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 in an LED chip has a light-emitting layer, and the LED cell might be formed on an epitaxial or non-epitaxial substrate. More specifically, the LED cells without individual substrate in a high-voltage LED chip are electrically connected to each other on a common substrate by semiconductor processes.

According to some embodiments of the disclosure, on the surface **102** of the LED assembly **100** are not only blue LED chips **108** but also LED chips (not shown) that emit light different than blue. For example, the LED assembly **100** could include red, green, and/or yellow LED chips to have light mixture with a desired spectrum or an appropriate color temperature. Some or all of the LED chips in the LED assembly **100**, whether it is blue or not, could be correspondingly replaced by LED packages with one or more LED chips in some embodiments.

The blue LED chips **108** in FIGS. **1**, **2** and **3**A are positioned on the surface **102** and arranged as a row along a longitudinal line connecting the ends **114** and **116**. The cathode and anode of one blue LED chip **108** contact with two adjacent conductive sections **105** respectively, in such a way that all the blue LED chips **108** are electrically connected in series and perform as an LED with a forward voltage higher than that of the individual LED chip **108**, where the forward voltage is the summation of the forward voltages of the individual blue LED chips **108**. This disclosure is not limited to, however. In some embodiments, the blue LED chips **108** and any other kinds of LED chips on the surface **102** could be connected in many different configurations, including series, parallel, and the combination thereof.

In one embodiment, solder paste joints are used to mount the blue LED chips **108** on the conductive sections **105**, with a flip chip technique, to provide both electric interconnection and mechanical adhesion. Even though solder paste is opaque, the joints hardly block or diminish the light emitted from the LED assembly **100** because they are tiny in size and could be ignored in view of the overall light intensity. In another embodiment, an anisotropic conductive film (ACF) is used to mount the blue LED chips **108** on the conductive sections **105**. For example, the conductive sections **105** are first coated with an ACF, and the blue LED chips **108** are then mounted on the conductive sections **105** through ACF, which provides adhesion and electric connection between the blue LED chips and the conductive sections **105**. Alternatively, eutectic alloy or silver paste could be employed to mount the blue LED chips **108** on the conductive sections **105**.

In one embodiment, each of the blue LED chips **108** is mounted on a portion of the surface **102** where no conductive sections **105** are formed, and interconnection means, such as bonding wires, are then formed to connect the blue LED chips **108** to the conductive sections **105**. In practice, material with excellent thermal conductivity but poor electric conductivity is employed first to adhere the blue LED chips **108** to the surface **102** or the LED chips **108** are directly connected to the surface **102**, and then bonding wires are provided to electrically connect blue LED chips **108** and conductive sections **105**.

Over the blue LED chips **108** in FIGS. **2** and **3**A is a phosphor layer **110**, a wavelength conversion layer. The phosphor layer **110** comprises epoxy or plastic and wavelength conversion material dispersed therein, such as phosphor or dye powder, that is capable of being stimulated by some light emitted from the blue LED chips (with a dominant wavelength ranging from 430 nm to 480 nm) to produce green or yellow light (with a dominant wavelength ranging from 540 nm to 590 nm), so that the mixture of the lights is perceived as white light by human eyes. FIG. **1** is illustrative to show the blue LED chips **108** is under the phosphor layer **110**, but in some embodiments the blue LED chips **108** could not be seen because of the phosphor in the phosphor layer **110**. The phosphor layer **110** could comprise thermosetting resin, thermoplastic resin, light-cured resin, acrylic resin, epoxy, or silicone, for example.

FIGS. **2** and **3**A show that the blue LED chips **108** are covered by the phosphor layer **110**, which does not cover all conductive sections **105**. The cross sectional view C in FIG. **1** also demonstrates a portion of a conductive section **105** is not covered by the phosphor layer **110**. The phosphor layer **110** shown in FIGS. **2** and **3**A could form segments with different sizes, and the segments are arranged in a row aligned with a longitudinal line connecting ends **114** and **116**. The gap between two adjacent segments exposes a portion of a conductive section **105**.

Dispensing or screen printing could form the phosphor layer **110** on the blue LED chips **108**. Each segment of the phosphor layer **110** could cover one or more blue LED chips **108**. Possibly, one segment of the phosphor layer only covers one blue LED chip **108**, while another segment covers several blue LED chips **108**. The phosphor layer **110** could be epoxy or silicone, for example, dispersed therein with one kind or several kinds of phosphor, and the phosphor includes, but is not limited to, yttrium aluminum garnet (YAG), terbium aluminum garnet (TAG), Eu-activated alkaline earth silicate, and SiAlON. The phosphor could be green-emitting or yellow-emitting phosphor having elements selected from a group consisting of Sr, Ga, S, P, Si, O, Gd, Ce, Lu, Ba, Ca, N, Eu, Y, Cd, Zn, Se, and Al.

Thickness and coverage of the phosphor layer **110** could determine the flexibility of the LED assembly **100**. The thicker the phosphor layer **110** is, or the more the blue LED chips **108** that is covered by one segment of the phosphor layer **110**, the less flexible the LED assembly **100** is.

As demonstrated in FIGS. **2** and **3**B, on the surface **104**, which is opposite to the surface **102**, is another wavelength conversion layer, the phosphor layer **112**, composition and manufacturing of which could be the same or similar with those of the phosphor layer **110**. Similar with the phosphor layer **110**, the phosphor layer **112** is formed to have segments and gaps alternatively arranged in a row. Basically, segments of phosphor layer **112** are formed on the positions of the surface **104** corresponding to the blue LED chips **108**. Moreover, one segment of the phosphor layer **112** is corresponding to one blue LED chip **108**, to multiple blue LED chips **108**, or to a segment of phosphor layer **110**. In other words, each blue LED chip **108** is substantially sandwiched by one segment of the phosphor layer **112** and one segment of the phosphor layer **110**. One segment of the phosphor layer **112**, nevertheless, could be used for, in association with the phosphor layer **110**, sandwiching only one blue LED chip **108** in one embodiment, or several blue LED chips **108** in another embodiment. The phosphor layer **112** on the surface **104** might be absent in some embodiments while the phosphor layer **110** still presents. The phosphor layer **112** and the phosphor layer **110** could differ in materials in the phosphor or in the lights emitted by the phosphors having same chemical elements.

There on the surface **102** in one embodiment are red LED chips (not shown), and they could be sandwiched between the phosphor layers **110** and **112**. In one embodiment, covering on the red LED chips is not the phosphor layer **110**, but a transparent resin or epoxy layer that has no or little phosphor; and there is no phosphor layer **112** on the locations of the surface **104** corresponding to the red LED chips.

As demonstrated in FIG. **1**, sidewalls **120** and **124** connect between surfaces **102** and **104**, and are not covered or partially covered by the phosphor layer **110** or **112**.

For assembling a lighting apparatus, a cutting instrument, such as a pair of scissors, a slitter, a film slitter or a cutting machine, could be used to cut the LED assembly **100** at the locations where the conductive sections **105** located without being covered by the phosphor layer **110** to result in several flexible LED filaments. An LED filament **130** produced by the cutting is shown in FIG. **4**, where the LED filament **130** has, at its two ends, two conductive sections **105** uncovered by the phosphor layer **110** to be its cathode and anode respectively, from which the LED chips in the LED filament **130** might be driven by a power supply.

FIG. **5** demonstrates an LED light bulb **200** with the LED filament **130** in FIG. **4**. The light bulb **200** further includes a bulb base **202**, a transparent or semitransparent lamp cover **204**, supports **206**, conductive wires **207** and an LED filament **130**. The bulb base **202** could be an Edison screw base capable of screwing into a matching socket and could be equipped with an LED driving circuit **208** therein. The lamp cover **204** is fixed on the bulb base **202**, and the space enclosed by the lamp cover **204** and the bulb base **202** is referred to as an inner space. Inside the inner space, the LED filament **130** is fixed on the supports **206**, which in one embodiment are substantially transparent in regard to the light emitted from the LED filament **130**. The LED filament **130** is curved to form a circle with a notch, and the circle is on a plane perpendicular to the screw axis **212** of the bulb base **202** and the lamp cover **204**. In other words, the screw axis **212** passes the center of the circle. The conductive wires **207** could be used to mechanically support the LED filament **130**. The conductive wires **207** also electrically connect the two conductive sections **105** at two ends of the LED filament **130** electrically and the LED driving circuit **208** in the bulb base **202**, so that the LED filament **130** can be driven to illuminate.

Advantages of the LED assembly **100** are below.

1. Blue light leakage could be decreased or eliminated. The light that the blue LED chips **108** emit in all the directions confronts either the phosphor layer **112** or the phosphor layer **110**, except the directions to the sidewall **120** or **124**. It implies that blue light leakage resulted from the blue light emitted from the blue LED chips leaves while the light passing through the sidewalls **120** and **124**. Experiment results demonstrate that when the sidewalls **120** and **124** are small enough (or the substrate **106** is thin enough), for example smaller than 150 micrometer in height or in thickness, the blue light leakage through the sidewalls **120** and **124** is hardly detectable and could be ignored.

2. Each blue LED chip **108** could light in all directions as it is substantially not surrounded or encapsulated by opaque material. That is, the blue LED chip **108** is substantially surrounded or encapsulated by the phosphor layers **112** and **110**, two transparent layers with phosphor dispersed therein.

3. The LED assembly **100** is easy for storage, as it could be curved into a tape on a reel.

4. The length of an LED filament can be adjusted. For producing a filament with an expected length, it might only need a knife or a pair of scissors to cut at appropriate locations of the LED assembly **100**.

5. The forward voltage of an LED filament can be adjusted. Based upon the forward voltage required in an appliance, an assembler could cut the LED assembly **100** to have a filament with a suitable forward voltage. For example, if three blue LED chips **108** are connected in series between every two adjacent exposed conductive sections **105** in FIG. **1**, a filament with an integral multiple of three blue LED chips **108** connected in series can be easily produced by cutting the LED assembly **100**. In case that there is only one blue LED chip **108** between every two adjacent exposed conductive sections **105**, it is possible to form an LED filament having any number of the blue LED chips **108** connected in series.

6. Simple assembling for a lighting apparatus. For example, the assembling could be realized by simple conventional soldering which adjoins the conductive wires **207** and the LED filament. Supports **206** can be optionally provided to support the filament **130** within the bulb at different locations, and the power supply is connected to the conductive sections **105** at the ends of the filament **130**.

7. Suitability for an omnidirectional lighting apparatus. As exemplified by the LED bulb **200** in FIG. **5**, the filament **130** is curved to be almost a circle which is omnidirectional in respect with the screw axis **212**, while the blue LED chips **108** in the filament **130** emit light in all directions. Accordingly, the light bulb **200** could be an omnidirectional lighting apparatus while the lamp cover **204** is not opaque material.

Even though the filament **130** is almost in a shape of a circle in FIG. **5**, the invention is not limited to. An LED filament according to the disclosure is flexible and could be curved into any shape suitable for a lighting apparatus. Another LED bulb **300** according to the disclosure is demonstrated in FIG. **6**, where the LED filament **130** has an arc, or a curved line shape, and is only supported or fixed in an inner space by two conductive supports. FIG. **7** demonstrates another LED bulb **400** of the disclosure, which has a transparent or translucent serpentine tube **410**, and the LED filament **130** meanders through its channel. Two exposed conductive sections **105** at the ends of the LED filament **130** in FIG. **7** are soldered to conductive wires **404**, which connect to a power supply (not shown) or a mains voltage plug (not shown) for supplying electric power and illuminating the LED filament **130**. In another embodiment, the LED filament **130** could be adopted as a lighting source within a channel letter.

As aforementioned, the LED assembly according to embodiments of the disclosure is not limited to have only blue LED chips, and possibly has LED chips with a color other than blue. Furthermore, and not all blue LED chips are covered by a common phosphor layer. In one embodiment of the disclosure, some blue LED chips **108** are covered by the phosphor layer **110**, but some are covered by another phosphor layer with phosphor different from that in the phosphor layer **110**.

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**. [An LED assembly] *A light bulb* comprising:

a flexible[,] *and* transparent substrate[,] comprising[:] *a first surface, a second surface opposite to the first surface, and an end;*

*an LED chip, which is flipped mounted on to the first surface;*

[first and second surfaces opposite to each other; and several] *a first* conductive [sections, separately formed] *section and a second conductive section successively formed* on the first surface *and separated from each other*;

[an LED chip on the first surface and electrically connected to two adjacent conductive sections;]

a first wavelength conversion layer[,] formed on the [first surface to substantially cover] *flexible and transparent substrate and directly contacting* the LED chip, *the first conductive section, and the second conductive section*; [and]

a second wavelength conversion layer formed on the second surface*; and*

*a conductive wire, formed on the first surface, extended beyond the end, and electrically connected to the LED chip,*

*wherein, in a direction perpendicular to the first surface, the LED chip is overlapped with the first conductive section and the second conductive section,*

*wherein the second conductive section has a wider portion and a narrower portion, and the wider portion is exposed from the first wavelength conversion layer, and*

*wherein the first conductive section has a uniform width, and the second conductive section has a varying width.*

[**2**. The LED assembly as claimed in claim **1**, wherein the transparent substrate is a longitudinal strip with two opposite ends, and the LED assembly comprises LED chips arranged in a first row along a longitudinal line connecting the opposite ends.]

[**3**. The LED assembly as claimed in claim **1**, wherein the flexible, transparent substrate further comprises a sidewall connecting the first and second surfaces, and at least a portion of the sidewall is not covered by the first wavelength conversion layer.]

**4**. The [LED assembly] *light bulb* as claimed in claim **1**, wherein the *first* conductive [sections are] *section is* transparent [in view of the] *to* light emitted from the LED chip.

**5**. The [LED assembly] *light bulb* as claimed in claim **1**, wherein [at least one of] the [conductive sections has a] *wider* portion [not covered by] *is exposed from* the [first] *second* wavelength conversion layer.

[**6**. The LED assembly as claimed in claim **1**, wherein the LED chip is flipped over and mounted on the first surface.]

**7**. The [LED assembly] *light bulb* as claimed in claim **1**, wherein the first wavelength conversion layer [comprises a phosphor] *and the second wavelength conversion layer are extended along a same direction.*

**8**. The [LED assembly] *light bulb* as claimed in claim **1**, wherein the [LED assembly] *flexible and transparent substrate* is capable of being curved to be a tape on a reel.

**9**. [An LED light bulb,] *The light bulb as claimed in claim 1, further* comprising:

a base; *and*

a lamp bulb, fixed on the base to define an inner space; [and]

*wherein* the LED [assembly claimed in claim **1**] *chip is* positioned inside the inner space and electrically connected to the base.

[**10**. The LED light bulb as claimed in claim **9**, wherein the LED assembly is curved to have an arc.]

**11**. The [LED] light bulb as claimed in claim [**9**] *1*, wherein the [LED] light bulb has [a] *an imaginary* screw axis and the [LED assembly] *flexible and transparent substrate* is *substantially* curved [to be] on [a] *an imaginary* plane *which is substantially* perpendicular to the screw axis.

**12**. The [LED] light bulb as claimed in claim [**11**] *1*, wherein the [LED assembly] *flexible and transparent substrate* is *capable of being* curved [to substantially be] *in a shape of* a circle.

[**13**. The LED light bulb as claimed in claim **9**, further comprising two conductive wires respective connected to two of the conductive sections.]

*14. The light bulb as claimed in claim 1, further comprising a support supporting the flexible and transparent substrate.*

*15. The light bulb as claimed in claim 14, wherein the support is not arranged on the end of the flexible and transparent substrate.*

*16. The light bulb as claimed in claim 14, wherein the support is substantially thinner than the flexible and transparent substrate.*

*17. The light bulb as claimed in claim 14, wherein the support has a portion substantially surrounding the flexible and transparent substrate.*

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