



(51) International Patent Classification:

H01L 33/48 (2010.01) *H01L 33/50* (2010.01)
H01L 33/46 (2010.01)

(21) International Application Number:

PCT/US2016/045736

(22) International Filing Date:

5 August 2016 (05.08.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/233,301 25 September 2015 (25.09.2015) US

(71) Applicant: **KONINKLIJKE PHILIPS N.V.** [NL/NL];
High Tech Campus 5, 5656AE Eindhoven (NL).

(72) Inventors; and

(71) Applicants : **BASIN, Grigoriy** [US/US]; 370 W. Trimble
Road, San Jose, California 95131 (US). **MAI, Kevin K.**
[US/US]; 370 W. Trimble Road, San Jose, California
95131 (US). **KAGEYAMA, Hideo** [JP/US]; 370 W.
Trimble Road, San Jose, California 95131 (US). **MORAN,**

Brendan J. [US/US]; 370 W. Trimble Road, San Jose,
California 95131 (US).

(74) Agent: **HSIA, David C.**; Patent Law Group LLP, P.O. Box
61839, Sunnyvale, CA 94088 (US).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
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SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,

[Continued on next page]

(54) Title: SURFACE EMITTER WITH LIGHT-EMITTING AREA EQUAL TO THE LED TOP SURFACE AND ITS FABRICATION

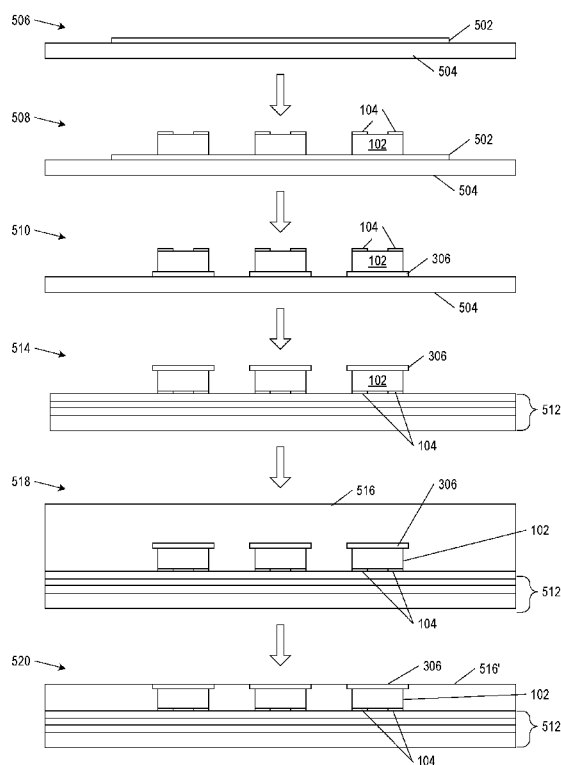


FIG. 5-1

(57) Abstract: A method includes forming a wavelength converting layer on a first support, placing light-emitting diodes (LEDs), with their top-emitting surfaces facing down, on the wavelength converting layer, curing the wavelength converting layer so the top-emitting surfaces of the LEDs adhere to the wavelength converting layer, singulating the LEDs by cutting the cured wavelength converting layer between the LEDs, wherein after said singulating each LED has a wavelength converter that exactly overlaps or slightly extends beyond a top-emitting surface of the LED, forming a reflective layer over and in-between the LEDs, curing the reflective layer, wherein the cured reflective layer has a hardness and an abrasion rate greater than the cured wavelength converting layer, and removing a top portion of the cured reflective layer to expose the LEDs.



LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, **Published:**
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, — *with international search report (Art. 21(3))*
GW, KM, ML, MR, NE, SN, TD, TG).

SURFACE EMITTER WITH LIGHT-EMITTING AREA EQUAL TO THE LED TOP SURFACE AND ITS FABRICATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of priority to co-pending U.S. Provisional Patent Application No. 62/233,301 titled, "SURFACE EMITTER WITH LIGHT-EMITTING AREA EQUAL TO THE LED TOP SURFACE", filed September 25, 2015, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present disclosure relates to semiconductor light-emitting diodes (LEDs), and more particular to top-emitting LED packages.

BACKGROUND

[0003] Small LED packages offer greater design flexibility in many applications, including camera flash and automotive lighting. For top-emitting LED packages, it is desirable to minimize the size of the top-emitting area and the overall height of the package.

SUMMARY

[0004] In one or more examples of the present disclosure, a method includes forming a wavelength converting layer on a support, placing light-emitting diodes (LEDs), with their top-emitting surfaces facing down, on the wavelength converting layer, curing the wavelength converting layer so the top-emitting surfaces of the LEDs adhere to the wavelength converting layer, singulating the LEDs by cutting the cured wavelength converting layer between the LEDs, wherein after said singulating each LED has a wavelength converter that exactly overlaps or slightly extends beyond a top-emitting surface of the LED, forming a reflective layer over and in-between the LEDs, curing the reflective layer, wherein the cured reflective layer has a hardness and an abrasion rate greater than the cured wavelength converting layer, and removing a top portion of the cured reflective layer to expose the LEDs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] In the drawings:

- [0006] FIG. 1 is a side cross-sectional view of a top-emitting LED unit or package with a wavelength converter that extends to the edge of the unit in examples of the present disclosure;
- [0007] FIG. 2 is a side cross-sectional view of a top-emitting LED unit or package with a protective glass plate over a wavelength converter in examples of the present disclosure;
- [0008] FIG. 3 is a side cross-sectional view of a top-emitting LED unit or package with a light-emitting area equal to an LED top surface in examples of the present disclosure;
- [0009] Fig. 4 is a flowchart of a method to make LED units of Fig. 3 in examples of the present disclosure;
- [0010] Figs. 5-1 and 5-2 illustrate side cross-sectional views of a process for making the LED units of Fig. 3 using the method of Fig. 4 in examples of the present disclosure;
- [0011] Fig. 6 is a flowchart of a method to make LED units of Fig. 3 in examples of the present disclosure; and
- [0012] Fig. 7 illustrates side cross-sectional views of a process for making the LED units of Fig. 3 using the method of Fig. 6 in examples of the present disclosure.
- [0013] Use of the same reference numbers in different figures indicates similar or identical elements.

DETAILED DESCRIPTION

- [0014] Fig. 1 is a side cross-sectional view of a top-emitting light-emitting diode (LED) unit or package 100 in examples of the present disclosure. LED unit 100 includes an LED 102 with contacts 104 on a bottom surface, a reflector 106 on lateral surfaces of the LED, and a wavelength converter 108 over the top of the LED and the reflector. Note that the use of the term “over” includes one element being directly atop another element. LED 102 is a five-sided emitter. Reflector 106 contains the primary light emitted by the sidewalls of LED 102 and redirects it to the top surface of the LED. Wavelength converter 108 converts part of the primary light into a secondary light of a different wavelength, which combines with the remainder of the primary light to generate a desired color. Typically reflector 106 is molded around LED 102 and then the top surface is coated with wavelength converter 108. Wavelength converter 108 may be a laminate with a first layer of phosphor in silicone followed by a second layer of titanium oxide (TiOx) in silicone.
- [0015] LED unit 100 is inefficient because part of the light (e.g., 10%) is channeled horizontally along wavelength converter 108. LED unit 100 is also large because wavelength

converter 108 extends to cover reflector 106, which makes the top-emitting area of the LED unit much larger than the top surface of LED 102.

[0016] Fig. 2 is a side cross-sectional view of a top-emitting LED unit or package 200 in examples of the present disclosure. LED unit 200 includes LED 102 with contacts 104 on the bottom surface, a wavelength converter 206 over the LED, a protective glass plate 208 over the wavelength converter, and a reflector 210 on lateral surfaces of the LED, the wavelength converter, and the glass plate. Wavelength converter 206 converts part of the primary light emitted by LED 102 into a secondary light of a different wavelength, which combines with the remainder of the primary light to generate a desired color. Reflector 210 contains light emitted by the sidewalls of LED 102 and redirects it to the top surface of the LED. Typically wavelength converter 206 is formed on glass plate 208 and this sandwich is attached to LED 102. Wavelength converter 206 may be a phosphor ceramic plate or a laminate with a first layer of phosphor in silicone followed by a second layer of TiOx in silicone. Reflector 210 is then molded over the whole area and excess material is removed to open the surface of wavelength converter 206, which is protected by glass plate 208 during the removal of the excess material.

[0017] LED unit 200 is tall because glass plate 208 is used as a protective layer to prevent damage to wavelength converter 206 during package fabrication.

[0018] Fig. 3 is a side cross-sectional view of an LED unit or package 300 in examples of the present disclosure. LED unit 300 includes LED 102 with contacts 104 on the bottom surface, a wavelength converter 306 over the LED, and a reflector 308 on lateral surfaces of the LED and the wavelength converter.

[0019] LED 102 may be a surface mount device (SMD). LED 102 may have a height of 50 to 400 microns (μm).

[0020] Wavelength converter 306 forms the light-emitting area of LED unit 300. Wavelength converter 306 may exactly overlap or extend slightly beyond the top surface of LED 102, thereby making the top-emitting area of LED unit 300 smaller than the top-emitting area of LED unit 100 (Fig. 1). The overhang of wavelength converter 306 beyond the top surface of LED 102 depends on the precision of the singulation machine used to separate adjacent LEDs 102 as described later. In some examples, the overhang ranges from 0 to 50 μm . The lateral surfaces of wavelength converter 306 is covered by reflector 308 so light cannot exit horizontally through the wavelength converter, thereby making LED unit 300 more efficient than LED unit 100.

[0021] Wavelength converter 306 may be a laminate having a first layer of phosphor in silicone followed by a second layer of TiO_x (e.g., TiO₂) in silicone where the silicone may be an elastomer or a resin. The first layer may comprise by weight 1 to 80% of phosphor, and the second layer may comprise by weight 0.05 to 10% of TiO_x. The first layer of phosphor in silicone may be 35 to 150 (e.g., 87) μm thick and the second layer of TiO_x in silicone may be about 30 to 90 (e.g., 50) μm thick. Instead of TiO_x, the second layer may be zirconium oxide (ZrO_x) in silicone.

[0022] Reflector 308 is formed by laying down a thick layer of reflective material over wavelength converter 306 on LED 102 and removing excess material from the top surface to expose the wavelength converter. The reflective material has a hardness greater than the wavelength converting material so the reflective material also has a greater abrasion rate than the wavelength converting material. By taking advantage of difference in hardness and abrasion rate, the excess reflective material can be removed through a blasting process without damaging the wavelength converting material, thereby eliminating the need for a protective glass plate and making LED unit 300 shorter than LED unit 200 (Fig. 2).

[0023] The reflective material may have a reflectivity over 90%. The reflective material may have a hardness 100 times greater than that of the wavelength converting material, and the reflective material may have an abrasion rate 10 times greater than that of the wavelength converting material. For example, the reflective material may be a silicone molding compound (SMC) having a hardness of 7 gigapascal (GPa) while the wavelength converting material may be a laminate (described above) having a hardness of 60 megapascal (MPa), and the reflective material may have an abrasion rate of 60 μm per pass at 30 pounds per square inch (psi) while the wavelength converting material may have an abrasion rate of 0.05 μm per pass at 30 psi. SMC may include about 82% to 87% silicon oxide (SiO_x) and 13 to 18% TiO_x. Alternatively the SMC may be SiO_x and ZrO.

[0024] Fig. 4 is a flowchart of a method 400 to make LED units 300 in examples of the present disclosure. Method 400 may begin in block 402.

[0025] In block 402, as shown in view 506 of Fig. 5-1, a wavelength converting layer 502 is formed on a support 504. Wavelength converting layer 502 may be a laminate with a first layer of TiO_x in silicone followed by a second layer of phosphor in silicone over the first layer. Support 504 may be a tacky tape supported by a metal rim. Referring back to Fig. 4, block 402 may be followed by block 404.

[0026] In block 404, as shown in view 508 of Fig. 5-1, LEDs 102 (only one is labeled) are picked and placed, with their top-emitting surfaces facing down and bottom contact surfaces facing up, on wavelength converting layer 502. LEDs 102 may be heated up to adhere to wavelength converting layer 502 or the LEDs may be at room temperature during attachment and the wavelength converting layer 502 may be heated up. Referring back to Fig. 4, block 404 may be followed by block 406.

[0027] In block 406, wavelength converting layer 502 is cured to adhere the top-emitting surfaces of LEDs 102 to the wavelength converting layer. Block 406 may be followed by block 408.

[0028] In block 408, as shown in view 510 of Fig. 5-1, LEDs 102 are singulated by cutting the cured wavelength converting layer 502 (view 508 in Fig. 5-1) between the LEDs. After being singulated, each LED 102 has a wavelength converter 306 over its top-emitting surface. As can be seen, wavelength converter 306 makes up the light-emitting area of LED unit 300, which is substantially the same size as the top-emitting surface of LED 102. Referring back to Fig. 4, block 408 may be followed by optional block 410.

[0029] In optional block 410, as shown in view 514 of Fig. 5-1, LEDs 102 are picked and placed, with their bottom contact surfaces facing down and top-emitting surfaces facing up, onto an adhesive side of a support 512. LEDs 102 may be transferred from support 504 to support 512. Support 512 may be a tacky tape on a metal frame. Referring back to Fig. 4, optional block 410 may be followed by block 412.

[0030] In block 412, as shown in view 518 of Fig. 5-1, an optically reflective layer 516 is formed over and in-between LEDs 102. Referring back to Fig. 4, block 412 may be followed by block 414.

[0031] In block 414, reflectively layer 516 is cured to adhere LEDs 102 to the reflective layer. The cured reflective material has a hardness and an abrasion rate greater than the cured wavelength converting material. Block 414 may be followed by block 416.

[0032] In block 416, as shown in view 520 of Fig. 5-1, a top portion of reflective layer 516 (view 518 in Fig. 5-1) is removed to expose LEDs 102. For example, the top portion of reflective layer 516 is removed down to the top of wavelength converters 306 (only one is labeled). The top portion of reflective layer 516 may be removed by blasting. As can be seen, LED units 300 are without any protective glass plates that would otherwise increase the height of the units. Referring back to Fig. 4, block 416 may be followed by block 418.

[0033] In block 418, as shown in view 522 of Fig. 5-2, LEDs 102 are singulated into LED units 300 with reflectors 308 by cutting the cured reflective layer 516' (view 520 in Fig. 5-1) between the LEDs. As can be seen, reflectors 308 cover the lateral surfaces of wavelength converters 306 to prevent any light from escaping laterally along the wavelength converter. Referring back to Fig. 4, block 418 may be followed by block 420.

[0034] In block 420, as shown in view 524 of Fig. 5-2, LED units 300 (only one is labeled) are released from support 512 (view 522 in Fig. 5-2). For example, LED units 300 are thermally released from support 512.

[0035] Fig. 6 is a flowchart of a method 600 to make LED units 300 in examples of the present disclosure. Method 600 may begin in block 602.

[0036] In block 602, as shown in view 708 of Fig. 7, wavelength converting layer 502 is formed on support 512. Referring back to Fig. 6, block 602 may be followed by block 604.

[0037] In block 604, as shown in view 708 of Fig. 7, LEDs 102 (only one is labeled) are picked and placed, with their top-emitting surfaces facing down and bottom contact surfaces facing up, on wavelength converting layer 502. LEDs 102 may be heated up to adhere to wavelength converting layer 502 or the LEDs may be at room temperature during attachment and the wavelength converting layer 502 may be heated up. Referring back to Fig. 6, block 604 may be followed by block 606.

[0038] In block 606, wavelength converting layer 502 is cured to adhere the top-emitting surfaces of LEDs 102 to the wavelength converting layer. Block 606 may be followed by block 608.

[0039] In block 608, as shown in view 710 of Fig. 7, LEDs 102 are singulated by cutting the cured wavelength converting layer 502 (view 708 in Fig. 7) between the LEDs. After being singulated, each LED 102 has a wavelength converter 306 (only one is labeled) over its top-emitting surface. As can be seen, wavelength converter 306 makes up the light-emitting area of LED unit 300, which is substantially the same size as the top-emitting surface of LED 102. Referring back to Fig. 6, block 608 may be followed by optional block 612.

[0040] In block 612, as shown in view 718 of Fig. 7, optically reflective layer 516 is formed over and in-between LEDs 102. Referring back to Fig. 6, block 612 may be followed by block 614.

[0041] In block 614, reflectively layer 516 is cured to adhere LEDs 102 to the reflective layer. The cured reflective material has a hardness and an abrasion rate greater than the cured wavelength converting material. Block 614 may be followed by block 616.

[0042] In block 616, as shown in view 720 of Fig. 7, a top portion of reflective layer 516 (view 718 in Fig. 7) is removed to expose LEDs 102. For example, the top portion of reflective layer 516 is removed down to contacts 104 (only two are labeled) on the bottom contact surfaces of LEDs 102. The top portion of reflective layer 516 may be removed by blasting or polishing. As can be seen, LED units 300 are without any protective glass plates that would otherwise increase the height of the units. Referring back to Fig. 6, block 616 may be followed by block 618.

[0043] In block 618, as shown in view 722 of Fig. 7, LEDs 102 are singulated into LED units 300 with reflectors 308 by cutting the cured reflective layer 516' (view 720 in Fig. 7) between the LEDs. As can be seen, reflectors 308 cover the lateral surfaces of wavelength converters 306 to prevent any light from escaping laterally along the wavelength converter. Referring back to Fig. 6, block 618 may be followed by block 620.

[0044] In block 620, LED units 300 are released from support 512. For example, LED units 300 are thermally released from support 512.

[0045] Various other adaptations and combinations of features of the embodiments disclosed are within the scope of the invention. Numerous embodiments are encompassed by the following claims.

CLAIMS:

Claim 1: A method, comprising:
forming a wavelength converting layer on a support;
placing light-emitting diodes (LEDs), with their top-emitting surfaces facing down and bottom contact surfaces facing up, on the wavelength converting layer;
curing the wavelength converting layer to adhere it to the top-emitting surfaces of the LEDs;
singulating the LEDs by cutting the cured wavelength converting layer between the LEDs, wherein after said singulating each LED has a wavelength converter that exactly overlaps or extend slightly beyond a top-emitting surface of the LED;
forming an optically reflective layer over and in-between the LEDs;
curing the reflective layer; and
removing a top portion of the cured reflective layer to expose the LEDs.

Claim 2: The method of claim 1, further comprising, after singulating the LEDs and before forming the optically reflective layer:

placing the LEDs, with the bottom contact surfaces facing down, onto another support, wherein removing the top portion of the cured reflective layer comprises removing the cured reflective layer down to wavelength converters on the top-emitting surfaces.

Claim 3: The method of claim 1, wherein removing the top portion of the cured reflective layer comprises removing the cured reflective layer down to contacts on the bottom contact surfaces.

Claim 4: The method of claim 2 or 3, further comprising, after said removing the top portion of the cured reflective layer:

singulating the LEDs into LED units by cutting the cured reflective layer between the LEDs, wherein each LED unit has a reflector on lateral surfaces of its wavelength converter and LED.

Claim 5: The method of claim 4, further comprising, after said singulating the LEDs into LED units, releasing the LED units from the second support.

Claim 6: The method of claim 2 or 3, wherein the cured reflective layer has a hardness and an abrasion rate greater than the cured wavelength converting layer.

Claim 7: The method of claim 6, wherein removing the top portion of the cured reflective layer comprises blasting or polishing the reflective layer.

Claim 8: The method of claim 1, wherein the wavelength converting layer comprises a laminate including a first layer of phosphor in silicone and a second layer of titanium oxide in silicone.

Claim 9: The method of claim 1, wherein the reflective layer comprises titanium oxide in silicone.

Claim 10: The method of claim 1, wherein the wavelength converter overhangs the top-emitting surface of LED from 0 to 50 microns.

Claim 11: A light-emitting diode (LED) unit, comprising:

an LED with a top-emitting surface;

a wavelength converter that exactly overlaps or extends slightly beyond the top-emitting surface; and

a reflector surrounding lateral surfaces of the wavelength converter and the LED, wherein the reflector comprises a hardness and an abrasion rate higher than the wavelength converter.

Claim 12: The LED unit of claim 11, wherein the wavelength converting layer comprises a laminate including a first layer of phosphor in silicone and a second layer of titanium oxide in silicone over the first layer.

Claim 13: The LED unit of claim 11, wherein the reflector comprises titanium oxide in silicone.

Claim 14: The LED unit of claim 11, wherein the wavelength converter overhangs the top-emitting surface of the LED from 0 to 50 microns.

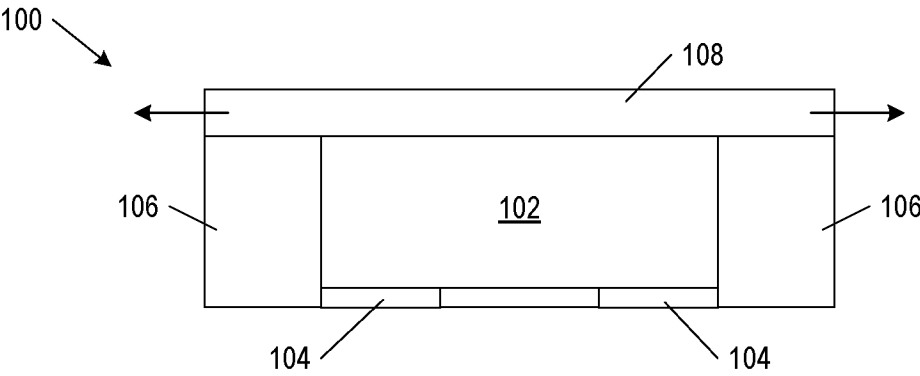


FIG. 1

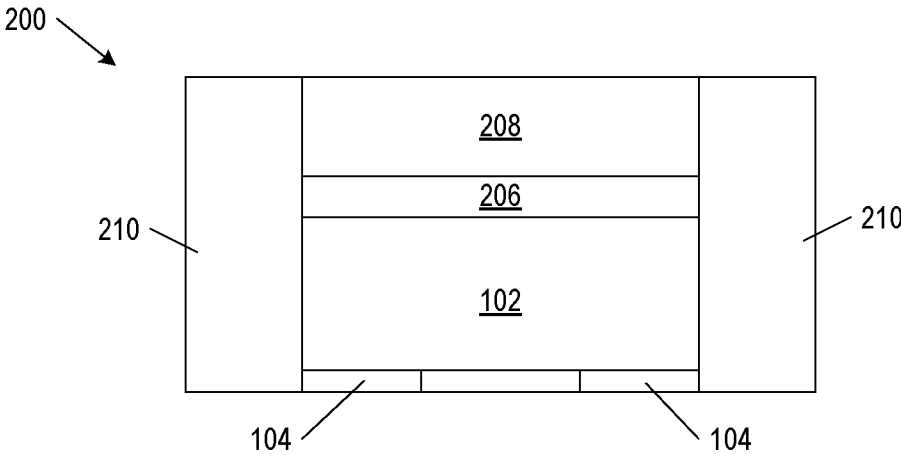


FIG. 2

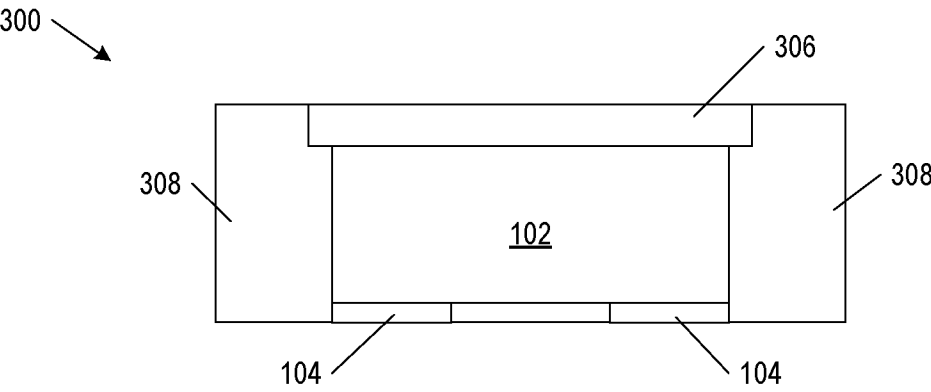


FIG. 3

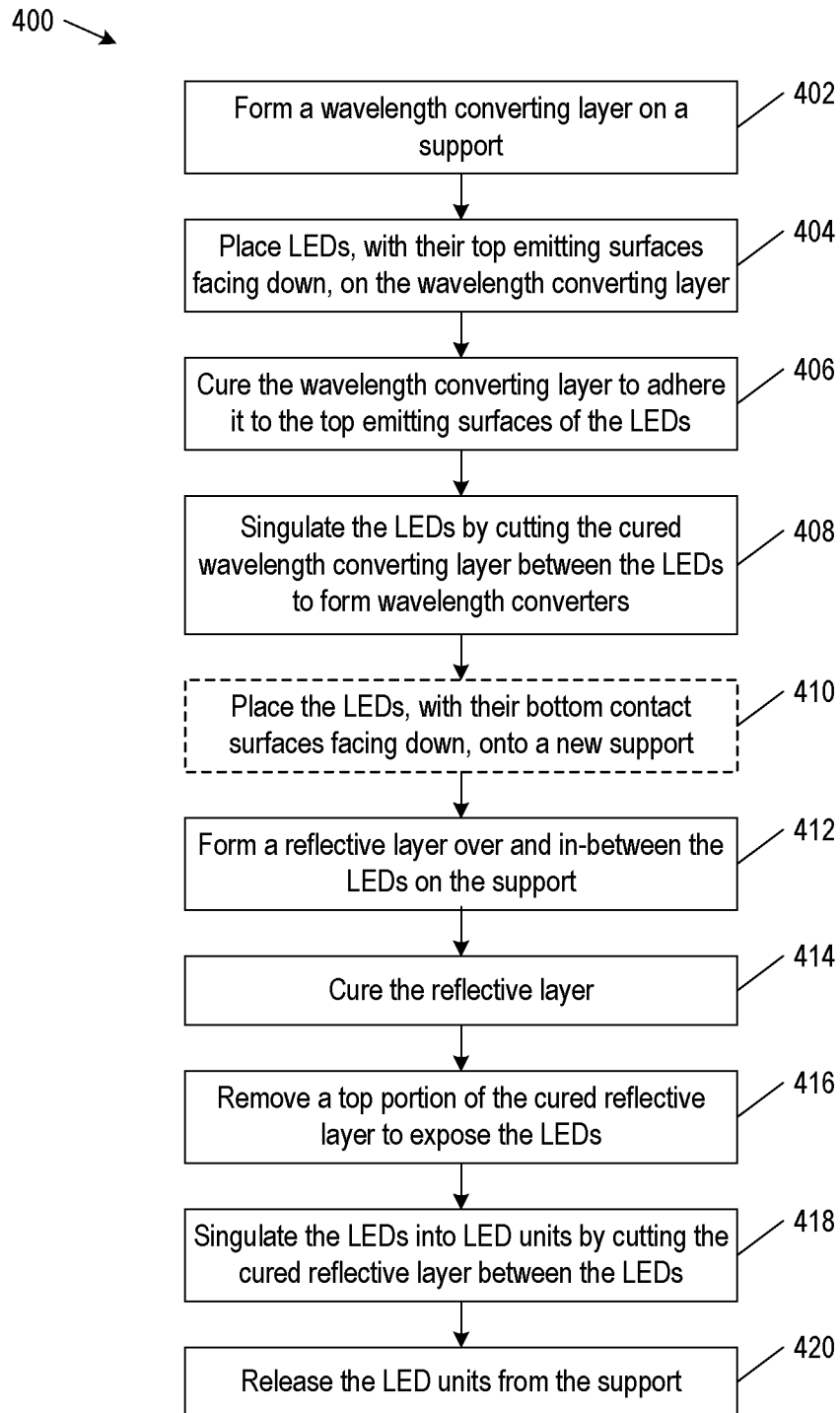


FIG. 4

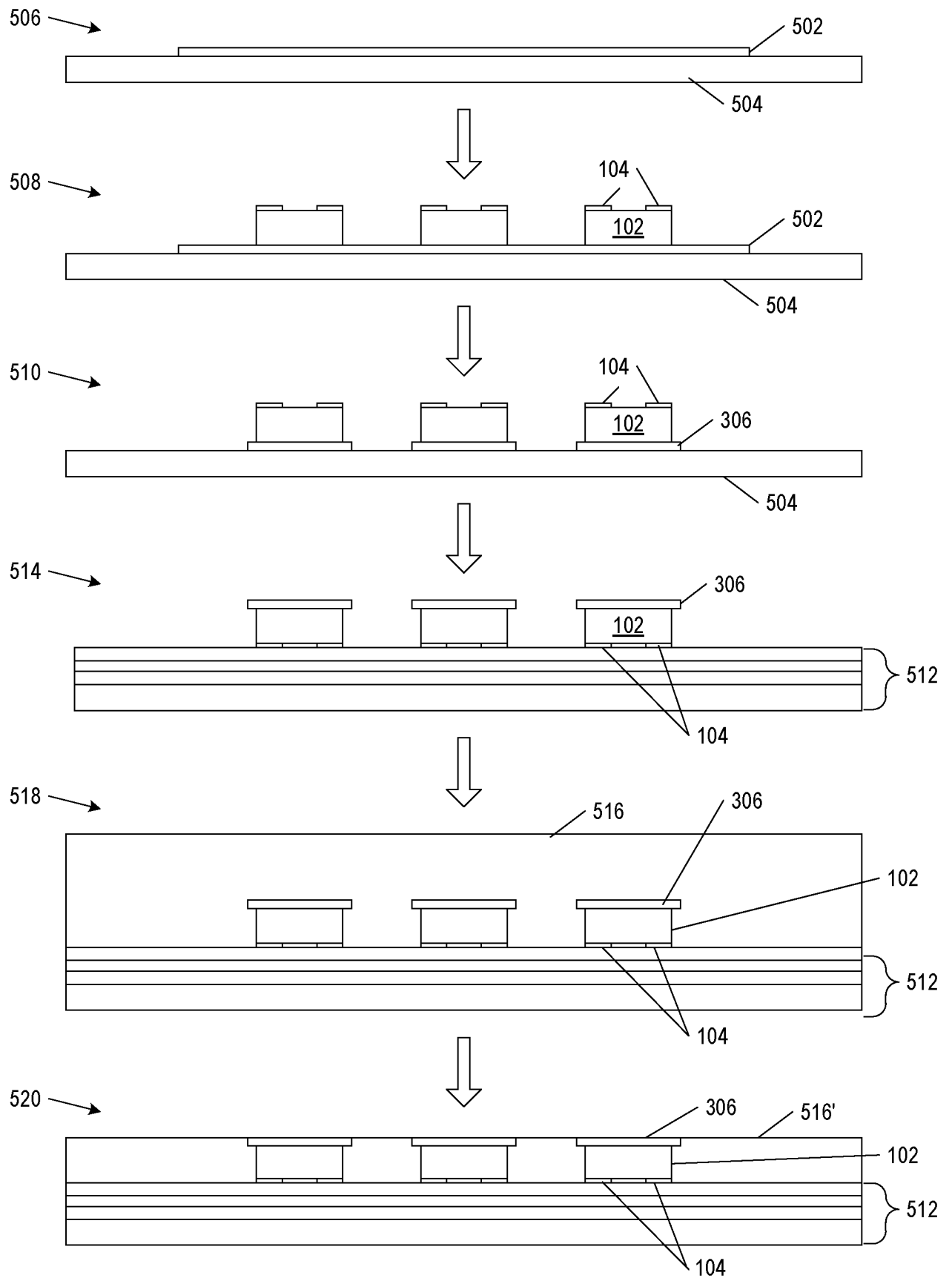


FIG. 5-1

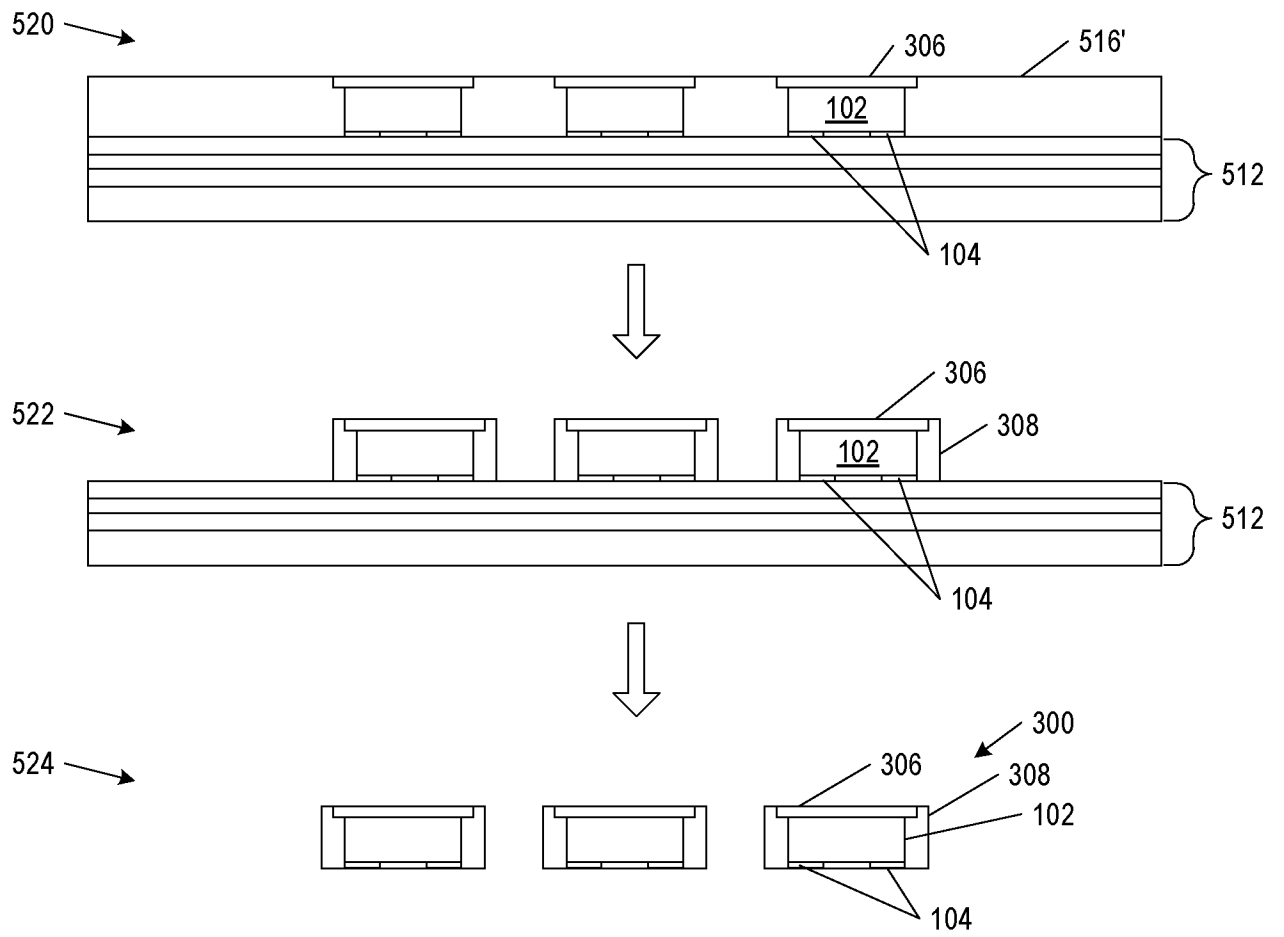


FIG. 5-2

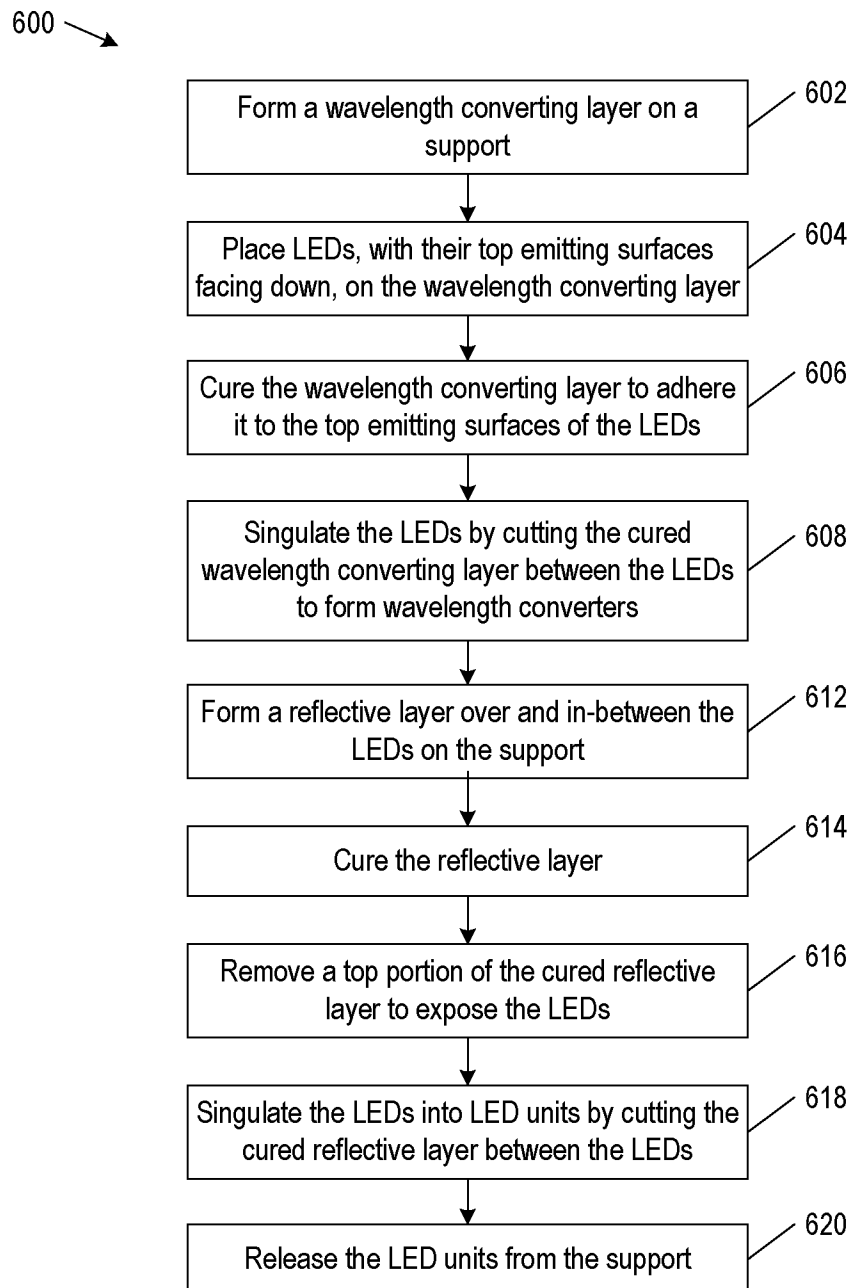


FIG. 6

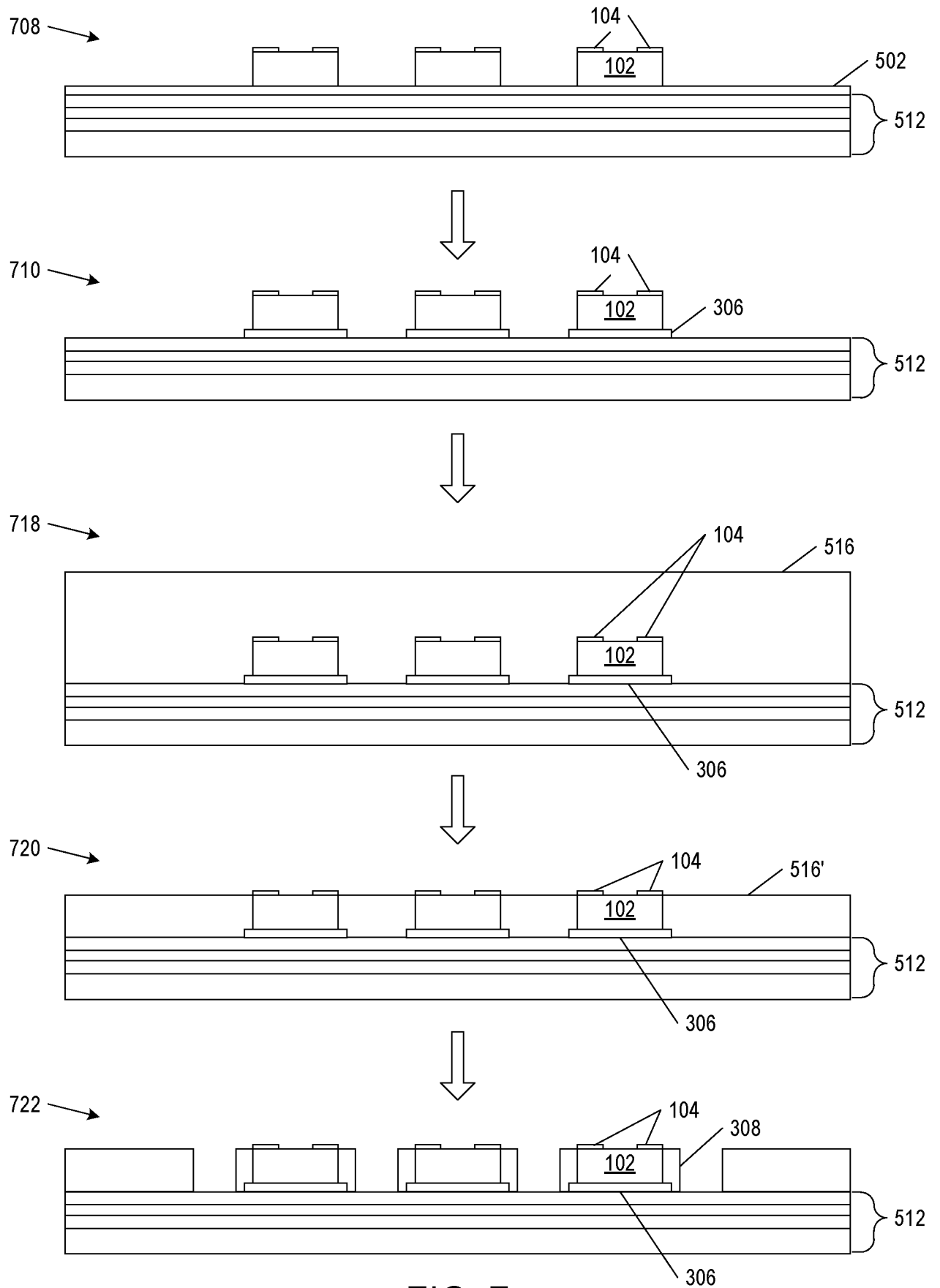


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/045736

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01L33/48

ADD. H01L33/46 H01L33/50

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

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2014/167455 A2 (KONINKL PHILIPS NV [NL]) 16 October 2014 (2014-10-16) page 5, line 29 - page 7, line 21; figure 6 -----	11,13
Y	US 2014/131753 A1 (ISHIDA MASASHI [JP] ET AL) 15 May 2014 (2014-05-15) paragraphs [0069], [0074]; figure 6 -----	1,3-10, 12,14
Y	JP 2014 110333 A (CITIZEN HOLDINGS CO LTD; CITIZEN ELECTRONICS) 12 June 2014 (2014-06-12) abstract; figures 3, 4 figure 7 -----	12,14
Y	----- -/-	1



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

30 September 2016

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10/10/2016

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/045736

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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