

TEMPORARY UNDERFILL-BASED SELECTIVE MASS TRANSFER FOR
MICROLED FABRICATION**BACKGROUND****Field**

[0001] Embodiments of the present disclosure generally relate to LED pixels and methods of fabricating LED pixels.

Description of the Related Art

[0002] A light emitting diode (LED) panel uses an array of LEDs, with individual LEDs providing the individually controllable pixel elements. Such an LED panel can be used for a computer, touch panel device, personal digital assistant (PDA), cell phone, television monitor, and the like. An LED panel that uses micron-scale LEDs based on III-V semiconductor technology (also called micro-LEDs) would have a variety of advantages as compared to organic light emitting diodes (OLEDs), e.g., higher energy efficiency, brightness, and lifetime, as well as fewer material layers in the display stack which can simplify manufacturing. However, there are challenges to fabrication of micro-LED panels. Accordingly, what is needed in the art are LED pixels and methods of fabricating LED pixels.

SUMMARY

[0003] In one embodiment, a device is provided. The device, includes micro-LEDs, micro-LED isolation structures, a transparent material, and an isolation substrate. The micro-LEDs are disposed over a backplane. Each micro-LED is coupled to at least one backplane electrode of the backplane. The micro-LED isolation structures are disposed over the backplane. Each micro-LED isolation structure is disposed between the at least one backplane electrode of adjacent micro-LEDs. The transparent material is disposed over the backplane between backplane electrodes, between the micro-LEDs, and over an emitting surface of each of the micro-LEDs. The isolation substrate has subpixel isolation (SI) structures disposed therein. The SI structures define wells of subpixels. The subpixels have a color conversion material disposed in wells and on the isolation substrate. The transparent material is between the color conversion materials.

[0004] In another embodiment, a device is provided. The device, includes micro-LEDs, micro-LED isolation material, a transparent material, and an isolation substrate.

The micro-LEDs are disposed over a backplane. Each micro-LED is coupled to at least one backplane electrode of the backplane. The micro-LED isolation material is disposed over the backplane, between each backplane electrode of the pairs of backplane electrodes, and between adjacent pairs of backplane electrodes of respective micro-LEDs. The transparent material is disposed over the backplane and the micro-LED isolation material, between the micro-LEDs, and over an emitting surface of each of the micro-LEDs. The isolation substrate has subpixel isolation (SI) structures disposed therein. The SI structures define wells of subpixels. The subpixels have a color conversion material disposed in wells and on the isolation substrate. The transparent material is between the color conversion materials.

[0005] In another embodiment, a method is provided. The method includes bonding target micro-LEDs to a backplane, disposing an adhesive material, vaporizing a bond, and removing the carrier substrate. Bonding target micro-LEDs includes the target micro-LEDs are bonded to the backplane via a carrier substrate. The carrier substrate has target micro-LEDs and surplus micro-LEDs between the target micro-LEDs. Disposing the adhesive material includes the adhesive material being disposed between the target micro-LEDs, the surplus micro-LEDs, and underside surface of the carrier substrate. The vaporizing a bond includes vaporizing a bond between the carrier substrate and the emitting surface of the target micro-LEDs. Removing the carrier substrate includes removing the carrier substrate with the surplus micro-LEDs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee. So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments of the present disclosure and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0007] Figure 1A is cross-sectional view of a pixel having a first isolation arrangement according to some embodiments.

[0008] Figure 1B is cross-sectional view of a pixel having a second isolation arrangement according to some embodiments.

[0009] Figure 1C is cross-sectional view of a pixel having a third isolation arrangement according to some embodiments.

[0010] Figure 1D is cross-sectional view of a pixel having a fourth isolation arrangement according to some embodiments.

[0011] Figure 2 is a flow diagram of a method of fabricating a pixel according to some embodiments.

[0012] Figures 3A-3H are schematic, cross-sectional views of a backplane during a method according to some embodiments.

[0013] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0014] Embodiments of the present disclosure generally relate to LED pixels and methods of fabricating LED pixels. Specifically, embodiments include a device that includes a backplane, at least three micro-LEDs disposed on the backplane, subpixel isolation (SI) structures defining wells of at least three subpixels. The at least three of the subpixels have a color conversion material disposed in the wells. Additionally, embodiments include a method. The method includes bonding target micro-LEDs to a backplane, disposing an adhesive material, vaporizing a bond, and removing the carrier substrate. The target micro-LEDs are bonded to the backplane via a carrier substrate. The carrier substrate has target micro-LEDs and surplus micro-LEDs between the target micro-LEDs. The adhesive material is then disposed between the target micro-LEDs, the surplus micro-LEDs, and underside surface of the carrier substrate. The bond between the carrier substrate and the emitting surface of the

target micro-LEDs is then vaporized and the carrier substrate with the surplus micro-LEDs is removed.

[0015] Figure 1A is a schematic, cross-sectional view of a pixel 100 having a first isolation arrangement 100a. Figure 1B is a schematic, cross-sectional view of a pixel 100 having a second isolation arrangement 100b. Figure 1C is a schematic, cross-sectional view of a pixel 100 having a third isolation arrangement 100c. Figure 1D is a schematic, cross-sectional view of a pixel 100 having a fourth isolation arrangement 100d.

[0016] The backplane 101 includes a backplane surface 101a. Micro-LEDs 109 are disposed over the backplane 101. The backplane 101 includes backplane electrodes 103 disposed on the backplane surface 101a. Each micro-LED 109 has at least one micro-LED electrode 107 coupled to at least one backplane electrode 103 of the backplane 101. In some embodiments, pairs of micro-LED electrodes 107 to are coupled to pairs of backplane electrodes 103. The micro-LED electrodes 107 to are bonded to the backplane electrodes 103 with a first bond 170.

[0017] As shown in Figure 1A, the first isolation arrangement 100a of the pixel 100 includes subpixel isolation (SI) structures 113 disposed on the backplane surface 101a between the micro-LEDs 109. The SI structures 113 have an UV reflection greater than 90%. The optical density of the SI structures 113 provides for color isolation between each of the micro-LEDs 109. The SI structures 113 define wells 127 of the subpixels 112. The subpixels 112 have the color conversion material 115 disposed in the wells 127. The subpixels 112 include a red subpixel 112a with a red color conversion material 115a disposed in the well 127a of the red subpixel 112a, a green subpixel 112b with a green color conversion material 115b disposed in the well 127b of the green subpixel 112b, and a blue subpixel 112c with a blue color conversion material 115c disposed in the well 127c of the blue subpixel 112c. When a micro-LED 109 of the red subpixel 112a is turned on the red color conversion material will convert the light emitted from micro-LED 109 into red light. When a micro-LED 109 of the blue subpixel 112c is turned on the blue color conversion material 115c will convert the light emitted from micro-LED 109 into blue light.

[0018] A material 160 is disposed over the backplane 101 and between the backplane electrodes 103, between the micro-LEDs 109, and over an emitting surface

105 of each of the micro-LEDs 109. The material 160 includes organic encapsulation materials.

[0019] As shown in Figure 1B, the second isolation arrangement 100b of the pixel 100 includes a transparent material 117. The transparent material 117 is disposed over the emitting surface 105 of the micro-LEDs 109. In an embodiment with a top substrate 123, the transparent material 117 is further disposed between the backplane 101 and a surface of the top substrate 123. The transparent material 117 includes an adhesive material. The adhesive material includes, but is not limited to, an epoxy, an acrylic material, and combinations thereof. The acrylic material may be UV transparent material.

[0020] An isolation substrate 119 has SI structures 113 disposed on an isolation surface 119a. The isolation substrate 119 is disposed over the backplane 101. The SI structures 113 define wells 127 of subpixels 112. The subpixels 112 have the color conversion material 115 disposed in the wells 127 and on the isolation surface 119a of the isolation substrate 119. The subpixels 112 have color filters 125 disposed on the top substrate surface 119b. The subpixels 112 include a red subpixel 112a with a red color conversion material 115a disposed in the well 127a of the red subpixel 112a, and a red color filter 125a disposed above the red color conversion material 115a. The subpixels 112 include a green subpixel 112b with a green color conversion material 115b disposed in the well 127b of the green subpixel 112b, and a green color filter 125b disposed above the green color conversion material 115b. The subpixels 112 include a blue subpixel 112c with a blue color conversion material 115c disposed in the well 127c of the blue subpixel 112c, and a blue color filter 125c disposed above the blue color conversion material 115c. When a micro-LED 109 of the red subpixel 112a is turned on the red color conversion material will convert the light emitted from micro-LED 109 into red light. When a micro-LED 109 of the blue subpixel 112c is turned on the blue color conversion material 115c will convert the light emitted from micro-LED 109 into blue light.

[0021] In some embodiments, the second isolation arrangement 100b includes a top substrate 123. The top substrate 123 includes isolation matrix structures 121 disposed between the top substrate 123 and the isolation substrate 119. The color filters 125 are disposed between the top substrate 123 and the isolation substrate

119. The color filters 125 include a photo resist with colorant. The isolation matrix structures 121 are aligned with the SI structures 113. The color filters 125 are aligned with the color conversion material 115.

[0022] The isolation matrix structures 121 and the color filters 125 are disposed between the isolation substrate 119 and the top substrate 123. The color filters 125 are defined by the isolation matrix structures 121, the isolation substrate 119, and the top substrate 123. The top substrate 123, the isolation substrate 119, and the SI structures 113 are surrounded by and coupled to the transparent material 117. The isolation matrix structures 121 include, but are not limited to, black matrix materials.

[0023] As shown in Figure 1C, the third isolation arrangement 100c includes micro-LED isolation structures 150a. The micro-LED isolation structures 150a are disposed over the backplane 101. Each micro-LED isolation structure 150a is disposed between adjacent micro-LEDs 109. The transparent material 117 is disposed between micro-LED isolation structures 150a and at least one backplane electrode 103 of adjacent micro-LEDs 109. The transparent material 117 is disposed over the backplane between backplane electrodes 103, between the micro-LEDs, and over an emitting surface of each of the micro-LEDs. In some embodiments, the transparent material 117 surrounds each micro-LED isolation structure 150a. In some embodiments, the SI structures 113 are aligned with the micro-LED isolation structures 150a. In some embodiments, the micro-LED isolation structures 150a are disposed between the wells 127. In some embodiments, the micro-LED isolation structures 150a are disposed between the micro-LEDs 109 and the backplane 101. In some embodiments, the micro-LED isolation structures 150a are disposed between the emitting surface 105 of the micro-LEDs 109 and the backplane 101.

[0024] As shown in Figure 1D, the fourth isolation arrangement 100d includes micro-LED isolation material 150b. The micro-LED isolation material 150b is disposed over the backplane 101, between each backplane electrode 103. In some embodiments, the micro-LED isolation material 150b is disposed over the backplane 101, between each backplane electrode 103 of pairs of backplane electrodes 103 and between adjacent pairs of backplane electrodes 103 of respective target micro-LEDs 109x. The transparent material 117 is disposed on the micro-LED isolation material 150b. In some embodiments, the micro-LED isolation material 150b is disposed

between the emitting surface 105 of the micro-LEDs 109 and the backplane 101. In some embodiments, the micro-LED isolation material 150b is disposed between and in contact with the pairs of backplane electrodes 103. In some embodiments, the micro-LED isolation material 150b is disposed between the color conversion material 115 of the wells 127 and the backplane 101.

[0025] Figure 2 is a flow diagram of a method 200 of forming a pixel 100 according to some embodiments. Figures 3A-3H are schematic cross-sectional views of the backplane 101 during the method 200. At operation 201, as shown in Figure 3A, the micro-LEDs 109 are bonded to the backplane 101 by the first bond 170. The backplane 101 has backplane electrodes 103 disposed on the surface 101a of the backplane 101. The carrier substrate 301 has an underside surface 303. A plurality of micro-LEDs 109 are coupled to the carrier substrate 301. The plurality of micro-LEDs 109 are bonded to the underside surface 303 of the carrier substrate 301 by a second bond 315. The plurality of micro-LEDs 109 include target micro-LEDs 109x and surplus micro-LEDs 109y. The target micro-LEDs 109x are bonded to the backplane 101 by the first bond 170. The surplus micro-LEDs 109y are not bonded to the backplane 101. Utilizing a carrier substrate 301 with surplus micro-LEDs 109y will decrease the cost of production, thereby reducing the overall cost of micro-LED fabrication.

[0026] The micro-LED electrodes 107 are bonded to the backplane electrodes 103 via the first bond 170. The first bond 170 may be a melting process. The melting process forms an alloy. The alloy may be the first bond 170, between the micro-LED electrodes 107 and the backplane electrodes 103. The carrier substrate 301 may be made of a ceramic material. The ceramic material may include sapphire, SiN, AlN, Si, SiO₂, GaN, or combinations thereof.

[0027] As shown in Figure 3B, the micro-LED isolation structures 150a are disposed over the backplane 101. The micro-LED isolation structures 150a are disposed prior to bonding the micro-LEDs 109 to the backplane 101. The isolation structures 150a are disposed between the at least one backplane electrode 103 of adjacent micro-LEDs 109. When the micro-LEDs 109 are being bonded, the target micro-LEDs 109x are disposed over the backplane electrodes 103. When the when

the micro-LEDs 109 are being bonded, the surplus micro-LEDs 109y are disposed over the micro-LED isolation structures 150a.

[0028] As shown in Figure 3C the micro-LED isolation material 150b is disposed over the backplane 101. The micro-LED isolation material 150b is disposed prior to bonding the micro-LEDs 109 to the backplane 101. The micro-LED isolation material 150b is disposed between the at least one backplane electrode 103 of adjacent micro-LEDs 109. When the micro-LEDs 109 are being bonded, the target micro-LEDs 109x are disposed over the backplane electrodes 103. When the micro-LEDs 109 are being bonded, the surplus micro-LEDs 109y are disposed over the micro-LED isolation material 150b.

[0029] At operation 203, as shown in Figure 3D, adhesive material 307 is disposed between the micro-LEDs 109 on an underside surface 303 of the carrier substrate 301. In some embodiments, the adhesive material is disposed between the micro-LEDs 109, the carrier substrate 301, and the backplane 101. The adhesive material 307 is also disposed between the backplane surface 101a and the underside surface 303 of the carrier substrate 301. In some embodiments the adhesive material 307 is disposed by flowing the adhesive material 307 between the backplane surface 101a, the underside surface 303, gaps between the pairs of micro-LED electrodes 107, gaps between pairs of backplane electrodes 103, and the gaps between the micro-LEDs 109. The adhesive material 307 may be disposed from a corner of the pixel 100. In some embodiments, the adhesive material 307 is disposed in the corner with a syringe or a dispenser. The adhesive material 307 may be disposed in a vacuum environment. The adhesive material 307 is cured after operation 203. In some embodiments the adhesive material 307 is cured with light. In some embodiments, the adhesive material 307 is cured thermally. The adhesive material 307 may be a thermal-curable organic adhesive materials or photo-curable organic adhesive materials, such as an acrylic adhesive or an epoxy adhesive.

[0030] At operation 205, as shown in Figure 3E, the second bond 315 between the emitting surface 105 of the target micro-LEDs 109x and the underside surface 303 of the carrier substrate 301 is vaporized. In some embodiments, the second bond 315 between the emitting surface 105 of the surplus micro-LEDs 109y is not vaporized. In some embodiments, the second bond 315 between the emitting surface 105 of the

target micro-LEDs 109x and the underside surface 303 of the carrier substrate 301 is vaporized. The surplus micro-LEDs 109y remain coupled to the carrier substrate 301. Vaporizing the second bond 315 may be done through the use of a light 309. For example, the light 309, may be a laser. A laser wavelength may be chosen based on the carrier substrate 301 and the absorbance of the carrier substrate 301. The laser wavelength may be between 190 nm and 250 nm. In one embodiment, the laser wavelength may be 248 nm. The laser fluence may be between 0.6 J/cm² and 1.1 J/cm². Additionally, the scanning frequency of the laser may range from 5 Hz to 40 Hz.

[0031] At operation 207, the carrier substrate 301 is removed. In some embodiments, as shown in Figure 3F, the adhesive material 307 remains on the backplane 101 after removal of the carrier substrate 301. In embodiments where the adhesive material 307 remains after removal of the carrier substrate 301, the adhesive material 307 is subsequently removed as shown in Figure 3G. The adhesive material 307 may be removed by a solvent.

[0032] In some embodiments, as shown in Figure 3H, the adhesive material 307 is removed before operation 207. As shown, the adhesive material 307 after the second bond 315 has been vaporized, but before the carrier substrate 301 has been removed. In those embodiments, the target micro-LEDs 109x are no longer bonded to the carrier substrate 301.

[0033] To form the first isolation arrangement 100a of the pixel 100, the SI structures 113 are disposed on the backplane 101. The SI structures 113 and the emitting surface 105 form the wells 127. Subsequently, the color conversion material 115 of the subpixels 112 is disposed in the wells 127 as shown in Figure 1A.

[0034] To form the second isolation arrangement 100b of the pixel 100, the top substrate 123 is disposed above the backplane 101. The top substrate 123 is positioned such that the SI structures 113 and micro-LEDs 109 are aligned. The top substrate 123 includes the isolation matrix structures 121 and the color filters 125 disposed thereon. The isolation substrate 119 is coupled to the isolation matrix structures 121 and the color filters 125. The isolation substrate 119 is disposed between the top substrate 123 and the backplane 101. The SI structures 113 are disposed on the isolation surface 119a of the isolation substrate 119. The color

conversion materials 115 are disposed on the isolation surface 119a of the isolation substrate 119. As shown in Figure 1B, after the SI structures 113 and micro-LEDs 109 are aligned, the transparent material 117 is disposed.

[0035] To form the third isolation arrangement 100c of the pixel 100, the top substrate 123 is disposed above the backplane 101. The backplane 101 includes the micro-LED isolation structures 150a disposed over the backplane. The top substrate 123 is positioned such that the SI structures 113 and micro-LEDs 109 are aligned. The top substrate 123 includes the isolation matrix structures 121 and the color filters 125 disposed thereon. The isolation substrate 119 is coupled to the isolation matrix structures 121 and the color filters 125. The isolation substrate 119 is disposed between the top substrate 123 and the backplane 101. The SI structures 113 are disposed on the isolation surface 119a of the isolation substrate 119. The color conversion materials 115 are disposed on the isolation surface 119a of the isolation substrate 119. As shown in Figure 1C, after the SI structures 113 and micro-LEDs 109 are aligned, the transparent material 117 is disposed.

[0036] To form the fourth isolation arrangement 100d of the pixel 100, the top substrate 123 is disposed above the backplane 101. The backplane 101 includes the micro-LED isolation material 150b disposed over the backplane. The top substrate 123 is positioned such that the SI structures 113 and micro-LEDs 109 are aligned. The top substrate 123 includes the isolation matrix structures 121 and the color filters 125 disposed thereon. The isolation substrate 119 is coupled to the isolation matrix structures 121 and the color filters 125. The isolation substrate 119 is disposed between the top substrate 123 and the backplane 101. The SI structures 113 are disposed on the isolation surface 119a of the isolation substrate 119. The color conversion materials 115 are disposed on the isolation surface 119a of the isolation substrate 119. As shown in Figure 1C, after the SI structures 113 and micro-LEDs 109 are aligned, the transparent material 117 is disposed.

[0037] While the foregoing is directed to implementations of the present disclosure, other and further implementations of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A device, comprising:
 - micro-LEDs disposed over a backplane, each micro-LED is coupled to at least one backplane electrode of the backplane;
 - micro-LED isolation structures disposed over the backplane, each micro-LED isolation structure is disposed between the at least one backplane electrode of adjacent micro-LEDs;
 - a transparent material disposed over the backplane between backplane electrodes, between the micro-LEDs, and over an emitting surface of each of the micro-LEDs; and
 - an isolation substrate having subpixel isolation (SI) structures disposed therein, the SI structures defining wells of subpixels, the subpixels having a color conversion material disposed in wells and on the isolation substrate, the transparent material is between the color conversion material of the wells.
2. The device of claim 1, wherein the transparent material is disposed between the micro-LED isolation structures and backplane electrodes of the micro-LEDs.
3. The device of claim 1, further comprising a top substrate, that top substrate having matrix structures and color filters disposed between the top substrate and the isolation substrate, the matrix structures aligned with the SI structures and the micro-LED isolation structures, and the color filters aligned with the color conversion material.
4. The device of claim 1, wherein the SI structures are aligned with the micro-LED isolation structures.
5. The device of claim 1, wherein the micro-LED isolation structures are disposed between the wells.
6. The device of claim 1, wherein the micro-LED isolation structures are disposed between the micro-LEDs and the backplane.

7. The device of claim 1, wherein the micro-LED isolation structures are disposed between the emitting surface of the micro-LEDs and the backplane.
8. The device of claim 1, wherein each micro-LEDs comprises at least one micro-LED electrode coupled to the at least one backplane electrode.
9. A device, comprising:
micro-LEDs disposed over a backplane, each micro-LED is coupled to pairs of backplane electrode of the backplane;
micro-LED isolation material disposed over the backplane, between each backplane electrode of the pairs of backplane electrodes, and between adjacent pairs of backplane electrodes of respective micro-LEDs;
a transparent material disposed over the backplane and the micro-LED isolation material, between the micro-LEDs, and over an emitting surface of each of the micro-LEDs; and
an isolation substrate having subpixel isolation (SI) structures disposed therein, the SI structures defining wells of subpixels, the subpixels having a color conversion material disposed in wells and on the isolation substrate, the transparent material is between the color conversion material of the wells.
10. The device of claim 9, wherein the micro-LED isolation material is disposed between the transparent material and the backplane.
11. The device of claim 9, further comprising a top substrate, that top substrate having matrix structures and color filters disposed between the top substrate and the isolation substrate, the matrix structures aligned with the SI structures, and the color filters aligned with the color conversion material.
12. The device of claim 9, wherein each micro-LEDs comprises at least one micro-LED electrode coupled to the at least one backplane electrode.
13. The device of claim 9, wherein the micro-LED isolation material is disposed between the emitting surface of the micro-LEDs and the backplane.

14. The device of claim 9, wherein the micro-LED isolation material is disposed between and in contact with the pairs of backplane electrodes.

15. The device of claim 9, wherein the micro-LED isolation material is disposed between the color conversion material of the wells and the backplane.

16. A method, comprising:

bonding target micro-LEDs to a backplane, the target micro-LEDs are bonded to the backplane via a carrier substrate, the carrier substrate has target micro-LEDs and surplus micro-LEDs between the target micro-LEDs;;

disposing an adhesive material, the adhesive material is disposed between the target micro-LEDs, the surplus micro-LEDs, and underside surface of the carrier substrate;

vaporizing a bond between the carrier substrate and the emitting surface of the target micro-LEDs; and

removing the carrier substrate with the surplus micro-LEDs.

17. The method of claim 16, further comprising removing the adhesive material before removing the carrier substrate, wherein the adhesive material is disposed between micro-LED isolation structures of the target micro-LEDs and at least one backplane electrode of adjacent target micro-LEDs.

18. The method of claim 16, further comprising removing the adhesive material after removing the carrier substrate, wherein the adhesive material is disposed between micro-LED isolation structures of the target micro-LEDs and at least one backplane electrode of adjacent target micro-LEDs.

19. The method of claim 16, further comprising removing the adhesive material after removing the carrier substrate, wherein the adhesive material is disposed over a micro-LED isolation material, the micro-LED isolation material disposed over the backplane and between the target micro-LEDs and at least one backplane electrode of adjacent target micro-LEDs.

20. The method of claim 16, further comprising removing the adhesive material before removing the carrier substrate, wherein the adhesive material is disposed over a micro-LED isolation material, the micro-LED isolation material disposed over the backplane and between the target micro-LEDs and at least one backplane electrode of adjacent target micro-LEDs.