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Oyer

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(54) **PARABOLIC VERTICAL HYBRID LIGHT EMITTING DIODE**

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(21) Appl. No.: **15/880,372**

(22) Filed: **Jan. 25, 2018**

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(51) **Int. Cl.**

H01L 33/10	(2010.01)
H01L 33/06	(2010.01)
H01L 33/14	(2010.01)
H01L 33/24	(2010.01)
H01L 33/32	(2010.01)
H01L 33/30	(2010.01)
H01L 33/40	(2010.01)
H01L 33/44	(2010.01)
H01L 33/00	(2010.01)

(52) **U.S. Cl.**

CPC ***H01L 33/105*** (2013.01); ***H01L 33/007*** (2013.01); ***H01L 33/0066*** (2013.01); ***H01L 33/0079*** (2013.01); ***H01L 33/06*** (2013.01); ***H01L 33/145*** (2013.01); ***H01L 33/24*** (2013.01); ***H01L 33/30*** (2013.01); ***H01L 33/32*** (2013.01); ***H01L 33/405*** (2013.01); ***H01L 33/44*** (2013.01); *H01L 2933/0016* (2013.01)

(58) **Field of Classification Search**

CPC . H01L 33/105; H01L 33/0066; H01L 33/007; H01L 33/0079; H01L 33/06; H01L 33/145; H01L 33/24; H01L 33/30; H01L 33/32; H01L 33/405; H01L 2933/0016

USPC 257/13

See application file for complete search history.

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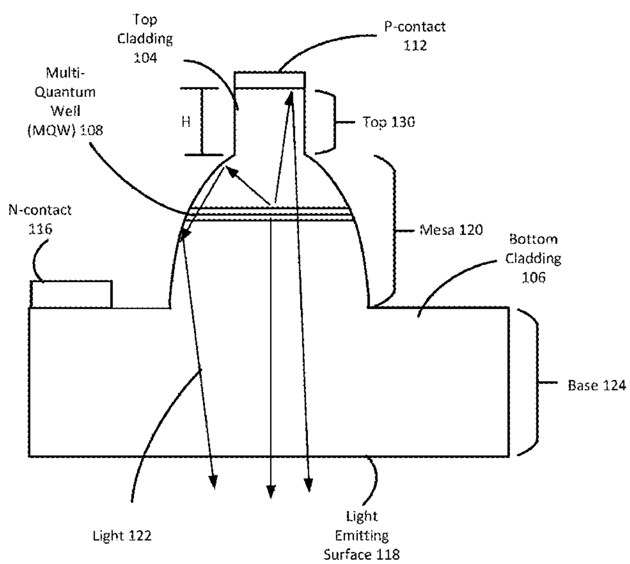
(57) **ABSTRACT**

A micro-light emitting diode (LED) includes an epitaxial structure having a mesa and a top portion on the mesa. The epitaxial structure further includes quantum wells within the mesa configured to emit light, claddings surrounding the quantum wells, and a light emitting surface on a side opposite the mesa and top portion. A reflective contact is on the top portion of the epitaxial structure. Light emitted from the quantum wells are transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward the light emitting surface. The top portion allows the quantum wells to be positioned at a parabola focal point of the mesa without limiting cladding thickness.

20 Claims, 6 Drawing Sheets



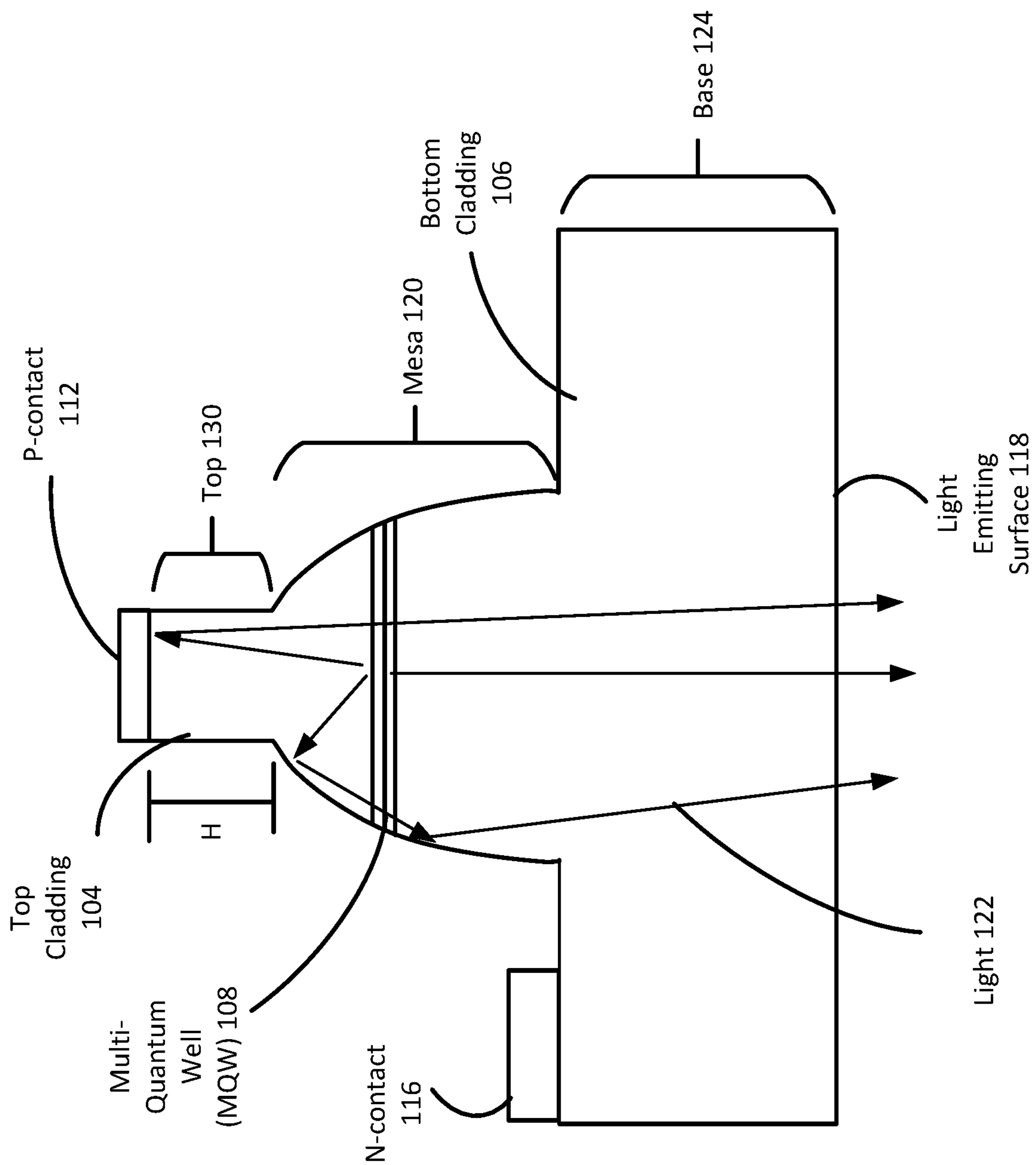

Base 124
Bottom Cladding 106
Mesa 120
P-contact 112
Top 130
Light Emitting Surface 118
H
Top Cladding 104
Multi-Quantum Well (MQW) 108
N-contact 116
Light 122

FIG. 1

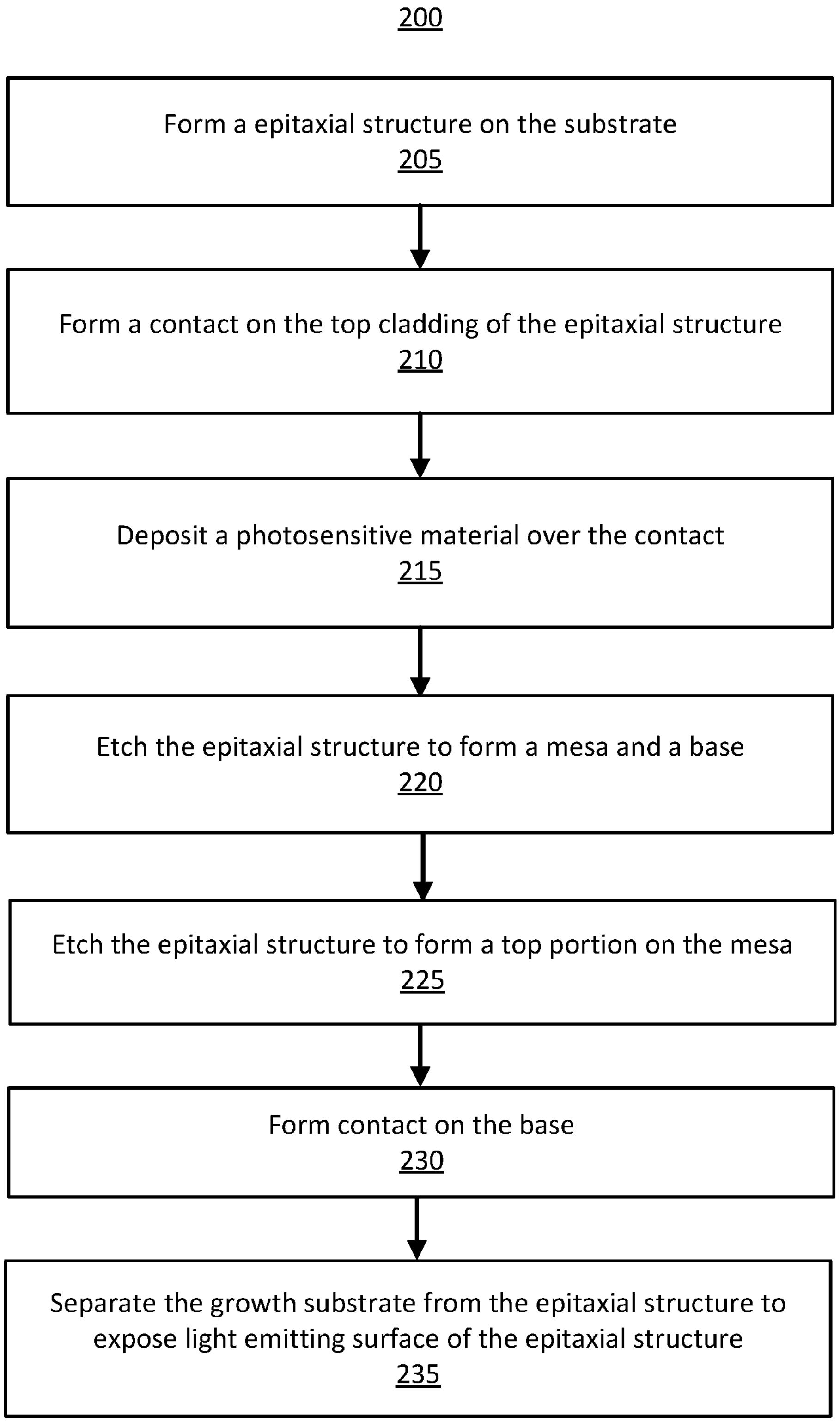
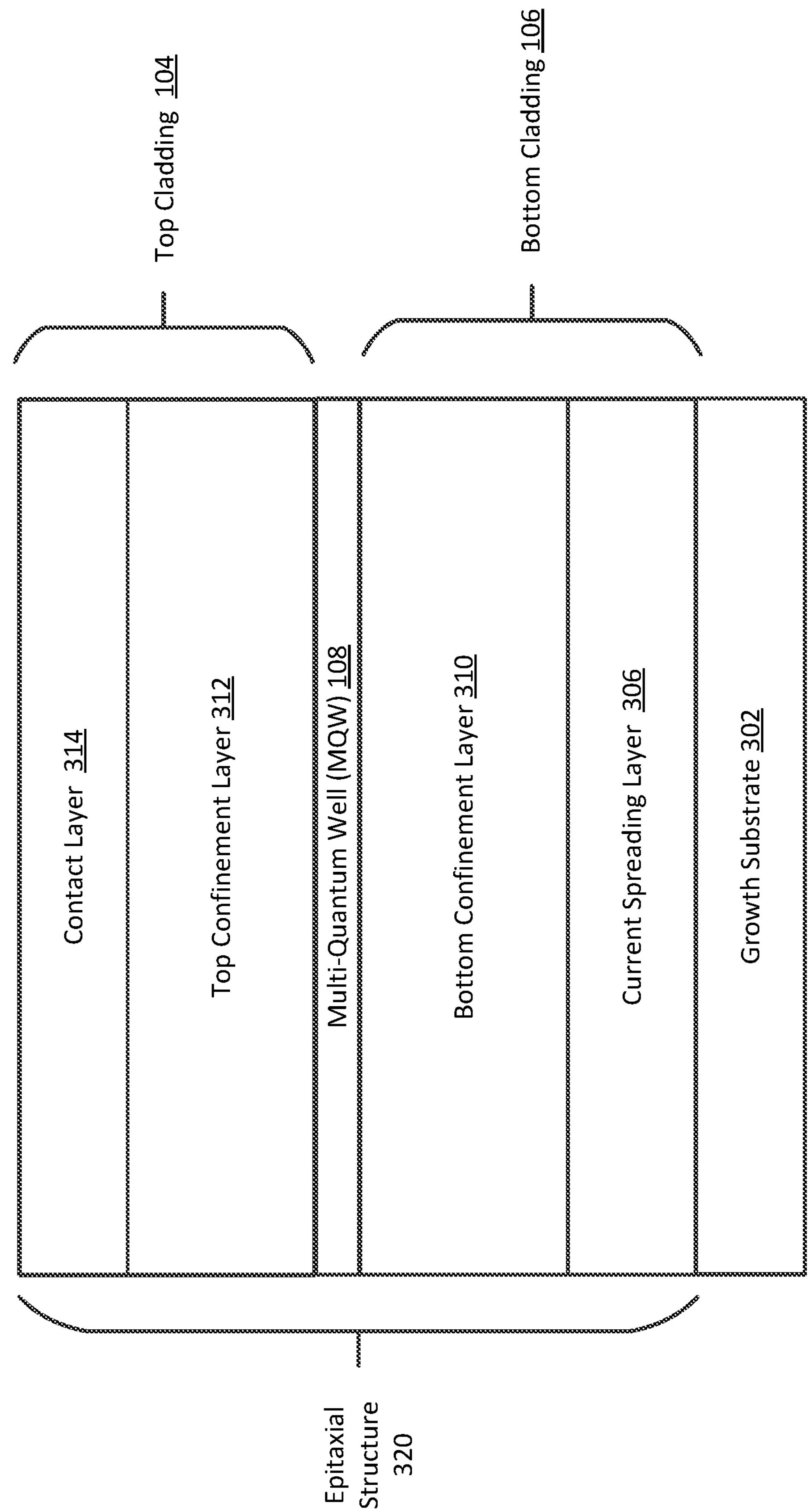

200
Form a epitaxial structure on the substrate
205
Form a contact on the top cladding of the epitaxial structure
210
Deposit a photosensitive material over the contact
215
Etch the epitaxial structure to form a mesa and a base
220
Etch the epitaxial structure to form a top portion on the mesa
225
Form contact on the base
230
Separate the growth substrate from the epitaxial structure to expose light emitting surface of the epitaxial structure
235

FIG. 2



Top Cladding 104
Bottom Cladding 106
Contact Layer 314
Top Confinement Layer 312
Multi-Quantum Well (MQW) 108
Bottom Confinement Layer 310
Current Spreading Layer 306
Growth Substrate 302
Epitaxial Structure 320

Fig. 3A

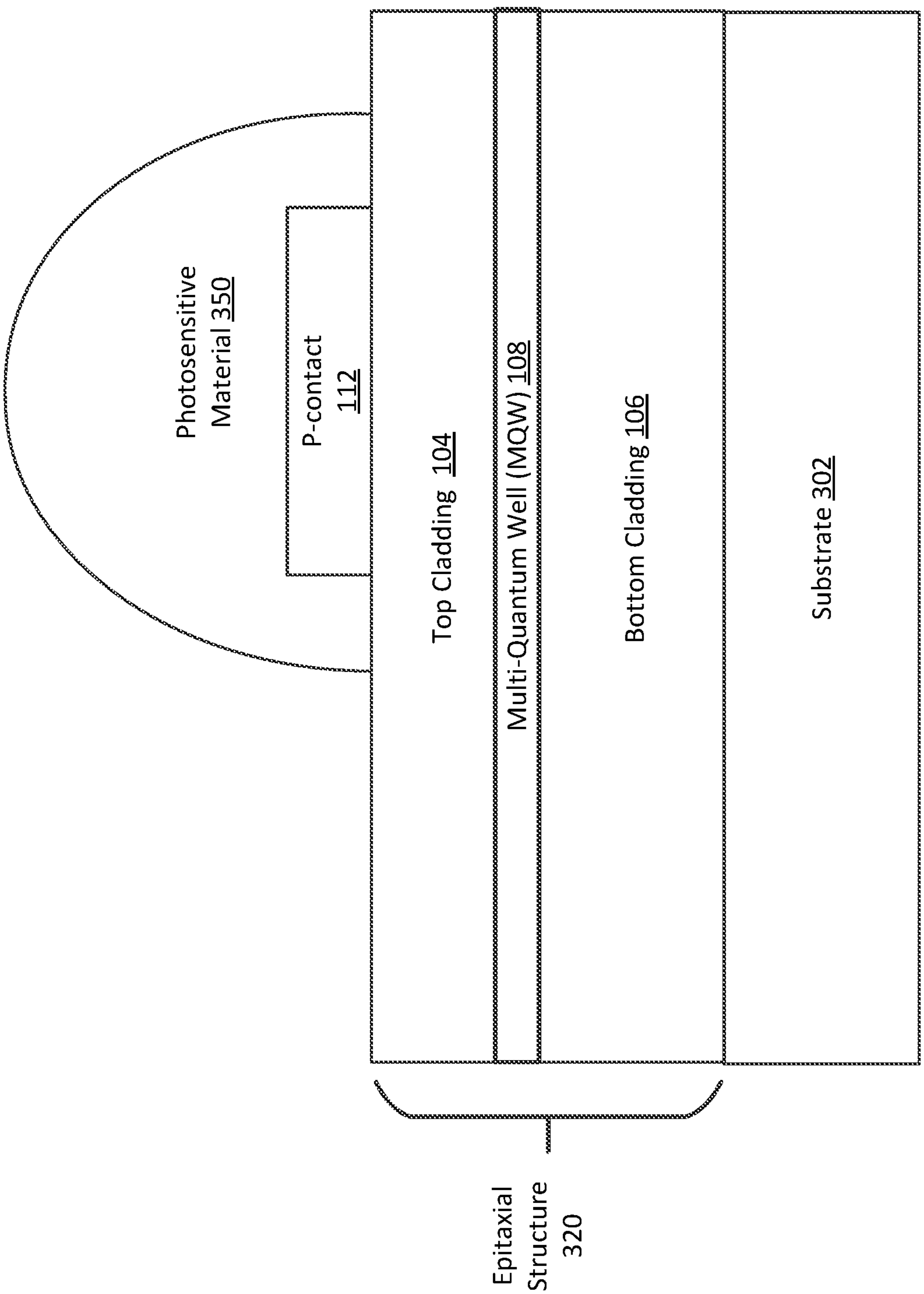

Photosensitive
Material 350
P-contact
112
Top Cladding 104
Multi-Quantum Well (MQW) 108
Bottom Cladding 106
Substrate 302
Epitaxial
Structure
320

Fig. 3B

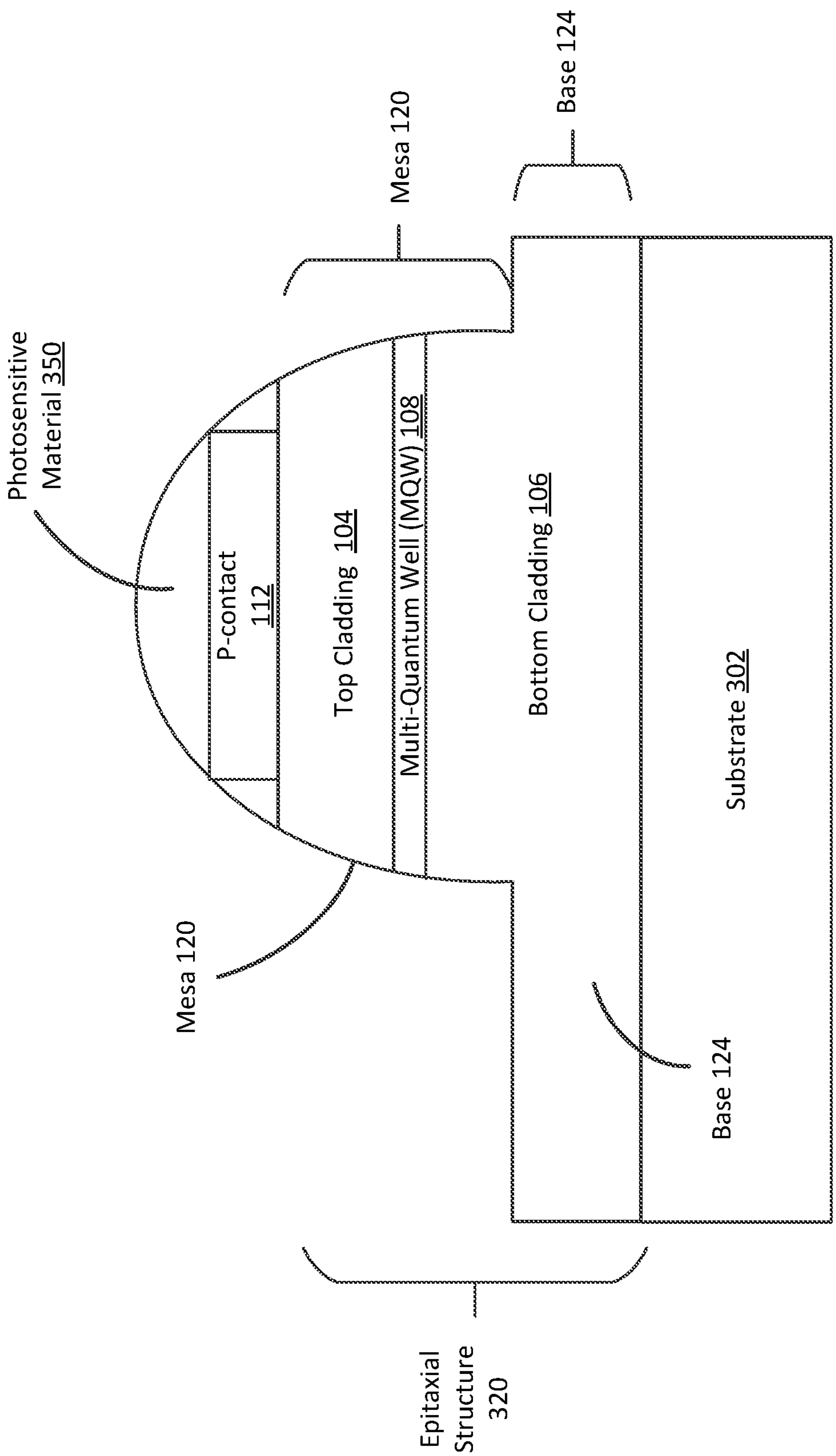

Photosensitive Material 350
P-contact 112
Top Cladding 104
Multi-Quantum Well (MQW) 108
Bottom Cladding 106
Substrate 302
Mesa 120
Base 124
Mesa 120
Base 124
Epitaxial Structure 320

Fig. 3C

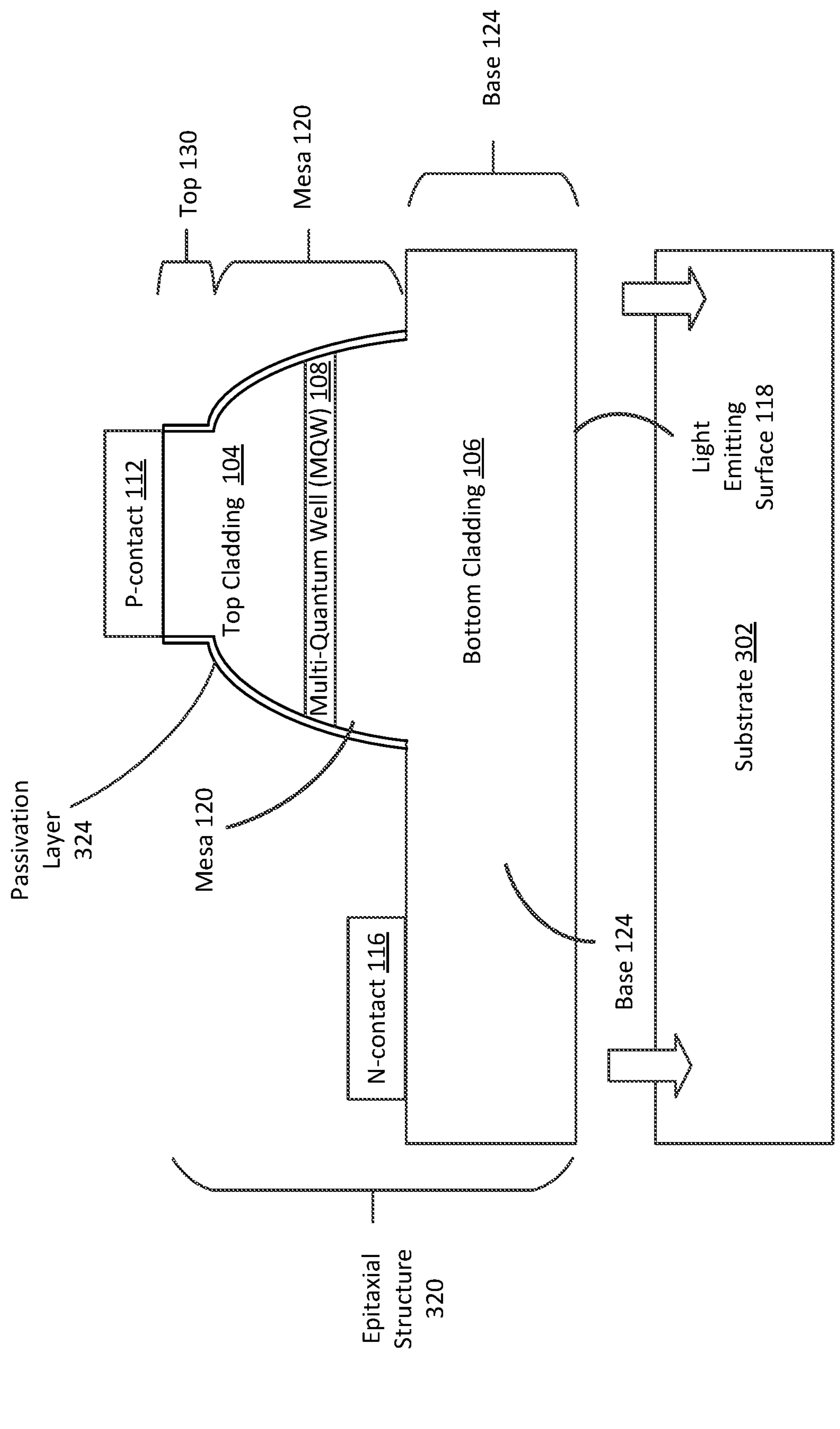

Base 124
Mesa 120
Top 130
P-contact 112
Top Cladding 104
Multi-Quantum Well (MQW) 108
Bottom Cladding 106
Light Emitting Surface 118
Substrate 302
Passivation Layer 324
Mesa 120
Base 124
N-contact 116
Epitaxial Structure 320

Fig. 3D

PARABOLIC VERTICAL HYBRID LIGHT EMITTING DIODE

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 62/542,672, titled "Parabolic Vertical Hybrid Light Emitting Diode," filed Aug. 8, 2017, which is incorporated by reference in its entirety.

BACKGROUND

Light emitting diodes (LEDs) can be used as individual pixel elements in electronic displays. To improve the pixel density of displays, it is desirable to decrease the size of the LEDs and to improve their electrical and optical performance. For example, the light extraction efficiency of a LED can be improved using structures that reflect and collimate light generated within the LED. However, effective collimation of the light can constrain the types and sizes of structures in the LED, resulting in performance tradeoffs.

SUMMARY

Embodiments relate to a light emitting diode (LED) including an epitaxial structure and a reflective contact on the epitaxial structure. The epitaxial structure includes a mesa having a truncated top at a first side of the epitaxial structure, one or more quantum wells within the mesa to emit light, a top portion on the truncated top of the mesa, and a light emitting surface at a second side of the epitaxial structure opposite the first side. At least a portion of the light emitted from the one or more quantum wells are transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward the light emitting surface.

In some embodiments, the mesa includes a parabolic shape and the one or more quantum wells are positioned at a parabolic focal point of the mesa. A top portion of the mesa includes a cylindrical structure.

Some embodiments include a method of manufacturing a LED. The method includes: forming an epitaxial structure including one or more quantum wells; forming a contact on the epitaxial structure; depositing photosensitive material on the contact; and etching the epitaxial structure with the contact and the photosensitive material as masks form a mesa having a truncated top and a top portion over the truncated top.

In some embodiments, etching the epitaxial structure causes the mesa to have a parabolic shape and the one or more quantum wells to be positioned at a parabola focal point of the mesa.

In some embodiments, etching the epitaxial structure includes performing a first etch using the photosensitive material as a first mask to form the mesa; and performing a second etch using the contact as a second mask to form the top portion on the mesa.

In some embodiments, the method further includes applying a reflow process to the photosensitive material to form a shape. The shape is transferred to the mesa by the etching of the epitaxial structure with the photosensitive material as a mask.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional diagram of a micro-LED (μLED), in accordance with one embodiment.

FIG. **2** is flowchart of a process for manufacturing a μLED, in accordance with one embodiment.

FIGS. **3**A through **3**D show an epitaxial structure and a μLED manufactured from the epitaxial structure, in accordance with one embodiment.

DETAILED DESCRIPTION

Embodiments relate to a LED including a mesa having a truncated top and a top portion on the truncated top of the mesa, and the manufacturing of the LED. The top portion is an elongated region of the epitaxial structure extending from the truncated top of the mesa. The epitaxial structure includes a top cladding, quantum wells that emit light, and bottom cladding. A reflective contact is on the top portion to reflect light emitted from the quantum wells and transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward a light emitting surface. The top portion allows the quantum wells to be positioned at a focal point of the (e.g., parabolic) mesa without limiting the thickness epitaxial layers, such as the top cladding.

The micro-LED, or "μLED" as described herein, refers to a particular type of light emitting diode having a small active light emitting area, such as between 0.2 to 100 um in diameter or width.

Overview of Example μLED

FIG. **1** is a schematic diagram of a cross section of a micro-LED **100** (hereinafter referred to as "μLED"), in accordance with one embodiment. The μLED **100** may include, among other components, an epitaxial structure including a top cladding **104**, a bottom cladding **106**, and a multi-quantum well ("MQW") **108** between the top cladding **104** and the bottom cladding **106**. In some embodiments, the μLED **100** may include a single quantum. The μLED **100** further includes a p-contact **112** on the top portion **130** of the epitaxial structure **320**, and an n-contact **116** on the bottom cladding **104**. The semiconductor structure is shaped, such as via an etch process, into a mesa **120**, a base **124** of the mesa **120**, and a top portion **130** on the mesa **120**. The top cladding **104** defines the top of the mesa **120** and the top portion **130**, and the bottom cladding **106** defines a bottom portion of the mesa **120** and the base **124**. The top cladding **104** may be a p-type cladding and the bottom cladding **106** may be an n-type cladding. In some embodiments, the top cladding **104** is an n-type cladding and the bottom cladding **106** is a p-type cladding. Here, the p-contact **112** is an n-contact and the n-contact **116** is a p-contact.

The multi-quantum well **108** defines an active light emitting area that is included in the structure of the mesa **120**. The mesa **120** may include a truncated top defined on a side opposed to a light emitting surface **118** of the μLED **100**. In some embodiments, the epitaxial structure including the top cladding **104**, MQW **108**, and bottom cladding **106** are grown on a growth substrate.

The mesa **120** may include various shapes, such as a parabolic shape with a truncated top, to form a reflective enclosure for light **122** generated within the μLED **100**. In other embodiments, the mesa **120** may include a cylindrical shape with a truncated top, or a conic shape with a truncated top, or some other light-collimating shape. The top portion **130** is formed on the truncated top of the mesa **120** to improve the extraction efficiency of light for the μLED **100**, and to enhance electrical performance. The top portion **130** has a cylindrical shape. In some embodiments, the top portion **130** may be some other elongated shape that extends from the truncated top of the mesa **120**. For example, the top portion **130** may be cube shaped, or some other shape.

The arrows show how the light **122** emitted from the MQW **108** is reflected off the p-contact **112** and internal walls of the mesa **120** and top portion **130** toward the light emitting surface **118** at an angle sufficient for the light to escape the μLED device **100** (i.e., within a critical angle of total internal reflection). The p-contact **112** and the n-contact **116** electrically connect the μLED **100**, such as to a display substrate including a control circuit for the μLED **100**. The n-contact **116** is formed at the base **124**, which is defined by a surface of the bottom cladding **106** opposite the light emitting surface **118**. The n-contact **116** may include a conductive material to support the placement of the μLED **100** on the display substrate with the p-contact **112** and the n-contact **116** bonded to the display substrate.

The μLED **100** may include an active light emitting area defined by the MQW **108**. The μLED **100** directionalizes the light output from the MQW **108** and increases the brightness level of the light output. In particular, the p-contact **112** may be reflective for the light **122** emitted from the MQW **108**. The mesa **120**, top portion **130**, and p-contact **112** cause reflection of the light **122** from the MQW **108** to form a collimated or quasi-collimated light beam emerging from the light emitting surface **118**.

The mesa **120** and top portion **130** may be formed by etching into a semiconductor structure, including the top cladding **104**, the MQW **108**, and the bottom cladding **106**, during wafer processing steps. The etching results in the MQW **108** being in the structure of the mesa **120**, and at a particular distance to the p-contact **112** to facilitate the collimation of the light **122**. For example, the MQW **108** may be located at the parabola focal point of the mesa **120**. A portion of the generated light **122** is reflected at the mesa **120** and top portion **130** to form the quasi-collimated light beam emitted from the light emitting surface **118**.

One or many advantages of the top portion **130** being formed in the top cladding **104** is that a thicker top cladding **104** may be used. In some embodiments, the top cladding **104** may have a height of 10 um (or more), and the top portion **130** may have a height H of between 0.1 and 5 um. Without the top portion **130** and having only a mesa, the top cladding **104** must be thinner in order for the MQW **108** to be at a parabola focal point with respect to the mesa structure. Thus, the top portion **130** provides for thicker top cladding **104** while keeping the MQW **108** at the parabola focal point of the mesa **120**. A thin top cladding **104** is challenging to produce and presents poor electrical performance, and also can reduce Internal Quantum Efficiency (IQE). With the parabolic mesa **120** and cylindrical top portion **130**, the top cladding **104** can be as thick as needed to achieve desirable electrical properties. Furthermore, the thickness of an electron blocking layer (EBL) in the top cladding **104** can be increased to improve the optical performance.

Furthermore, the top portion **130** allows for size reduction of LEDs. With the truncated parabolic mesa shape without the cylindrical top portion **130**, LED size diminution is limited by the thickness requirements of the top cladding **104**. For example, if the top cladding **104** is too thick (e.g., 100 nm), having the MQW **108** at the focal point while being able to process the p-contact **112** may not be possible. With the parabolic mesa shape and cylindrical top portion **130**, the thickness of the top cladding **104** can be varied.

Furthermore, different types of epitaxial layers and structures may be used with the top portion **130**. Red color light, for example, has longer wavelengths than blue or green color light, and thus a larger top cladding **104** including top portion **130** may be used for LEDs that emit red color light in order to keep the MQW **108** at the parabola focal point. In some embodiments, a red color LED epitaxial structure may include a top cladding **104** including P-GaAs, and having a top portion **130** with a height H of 0.1 to 5 um. In another example, a red LED epitaxial structure may include a top cladding **104** including P-GaP, and having top portion **130** with a height H of 3 to 5 um.

In some embodiments, the mesa **120** has a height between 0.2 to 10 um, the MQW **108** has a height between a few nanometers to 10 um, the top cladding **104** has a height between 0.1 to 0.5 um, and the bottom cladding **106** has a height between 0 um (e.g., if the growth substrate is transparent and conductive) and more than 20 um.

Example Process of Manufacturing μLED

FIG. **2** is a flowchart of a process **200** for manufacturing a μLED, in accordance with one embodiment. The process **200** may be performed to manufacture a μLED **100** having a top portion **130** over a mesa **120**. The process **200** is discussed with reference to FIGS. **3**A through **3**D which show manufacturing of the μLED **100**, in accordance with one embodiment. In some embodiments, the process **200** may include different and/or additional steps, or some steps may be in different orders.

An epitaxial structure of a LED, such as the μLED **100**, is formed **205** on a growth substrate. FIG. **3**A shows a cross section of an epitaxial structure **320** and a growth substrate **302**, in accordance with one embodiment. The epitaxial structure **320** is etched to form the mesa **120** and top portion **130** of the μLED **100**.

The epitaxial structure **320** may include semiconductor layers grown on the growth substrate **302**. The semiconductor layers include the bottom cladding **106** on the growth substrate **302**, the MQW **108** on the bottom cladding **106**, and the top cladding **104**. The epitaxial structure **320** may be grown using techniques such as Molecular Beam Epitaxy (MBE) or Metalorganic Chemical Vapor Deposition (MOCVD).

The growth substrate **302** may include a variety of suitable materials for forming an epitaxial layers. The type of growth substrate and epitaxial structure **320** may vary based on the type of LED (e.g., emission color). For example, the top cladding **104** and bottom cladding **106** may be GaN-based heterostructure or a GaAs-based heterostructure. A GaAs-based heterostructure may be grown on a GaAs substrate, a AlInGaP (red LED) may be grown on a GaP substrate, and a GaN-based heterostructure may be grown on a GaAs, GaP, sapphire, Si, or GaN substrate, or some other type of substrate. The top cladding **104** includes the p-type layers of the epitaxial structure **320**. The top cladding **104** may include, among other things, a top confinement layer **312** facing the MQW **108**, and a contact layer **314** on the top confinement layer **312**. The MQW **108** may include a multiple quantum wells, or in some embodiments, a single quantum well is used instead of multiple quantum wells. The bottom cladding **106** includes the n-type layers of the epitaxial structure **320**. The bottom cladding **106** may include a current spreading layer **306** on the growth substrate **302**, and a bottom confinement layer **310**. The confinement layers **310** and **312** provide electron blocking layers including a barrier material to confine electrons in the MQW **108**. As discussed above, the top portion **130** of the LED **100** provides for variable heights for the top cladding **104** while keeping the MQW **108** in the parabola focal point of the mesa **120**, which allows for a thicker top confinement layer **312**. The contact layer provides an interface to the p-contact **112** for the epitaxial structure **320**.

Additional details regarding formation of a semiconductor structure (or "material structure") that may be applicable to some embodiments are discussed in U.S. Patent Application Publication No. 2006/0110839, filed Feb. 2, 2004, which is incorporated by reference in its entirety.

A contact (e.g., p-contact **112**) is formed **210** on the top cladding **104** of the epitaxial structure **320**. With reference to FIG. 3B, the p-contact **112** may be a metallic material deposited on the top cladding **104** to define the location of the mesa **120** and top portion **130**. In some embodiments, a dielectric layer may be formed on top cladding **104**, and the p-contact **112** is formed on the dielectric layer, with a portion of the p-contact **112** extending through the dielectric layer to contact the top cladding **104**. As discussed in greater detail below, the p-contact **112** provides a hard mask for etching the epitaxial structure **320** to form the top portion **130**. Furthermore, the contact may be a reflective contact that reflects light emitted from the MQW **108**.

A photosensitive material is deposited **215** over the contact. With reference to FIG. 3B, the photosensitive material **350** is formed over the p-contact **112**. The photosensitive material **350** may cover the p-contact **112**. The photosensitive material **350** provides a photoresist mask for etching the epitaxial structure **320** to from the mesa **120**. The surface of the top cladding **104** is patterned using the photosensitive material **350** to define a region of the epitaxial structure **320** to be formed into the mesa **120**. The photosensitive material **350** may be a negative photoresist or a positive photoresist.

In some embodiments, a reflow process is applied to the photosensitive material **350**. The reflow process includes applying a thermal treatment to the photosensitive material **350** and results in the photosensitive material **350** having a parabolic, lens, or ellipse shape. The type of shape may vary, and complicated shapes (e.g., half donut) may be formed using reflow. As discussed in greater detail below, the shape of the reflown photosensitive material **350** may be transferred to the epitaxial structure **320** to form the mesa **120** via etching with a controlled selectivity.

The epitaxial structure **320** is etched **220** to form a mesa **120** and a base **124**. With reference to FIG. 3C, the mesa **120** and base **124** are formed in the epitaxial structure **320** using the photosensitive material **350** as a mask for the etching process. The photosensitive material **350** may be a sacrificial layer that is fully or at least partially removed in connection with the etching of the epitaxial structure **320** to form the mesa **120**. The p-contact **116** may also serve as a hard mask for the etching.

In some embodiments, a dry etching processes, such as an inductively coupled plasma (ICP) etch, may be used to form the mesa **120** and the base **124** in the epitaxial structure **320**. The ICP etch may be used to provide controllable isotropic or anisotropic etching by varying parameters to form the shape of the mesa **120** and the base **124**, such as the parabolic, cylindrical, or conic shapes with truncated top. The ICP etch may include a combination of physical and chemical etching. The physical etching may provide an anisotropic, non-selective etch while the chemical etching may provide an isotropic etch that is selective to etch reactive materials (e.g., the epitaxial structure **320**, but not the photosensitive material **350**). By tweaking the ICP recipe, the etch process is controlled to etch sloped side walls for the mesa **120** that define the shape of the mesa **120**. For regions of the epitaxial structure **320** to be formed into the base **124**, which are not protected by the photosensitive material **350** and p-contact **112**, the epitaxial structure **320** is etched from the top cladding **104**, through the MQW **108**, and through a portion of the bottom cladding **106**. After the etching, the mesa **120** includes the top cladding **104** at the top of the mesa, the MQW **108**, and a portion of the bottom cladding **106**. The base **124** located below the mesa **120** includes another (e.g., un-etched) portion of the bottom cladding **106**.

In some embodiments, the photosensitive material **350** is reflown into a shape, and the reflown resist shape is replicated to the epitaxial structure **320** to form the mesa **120** via an etching with a controlled selectivity. For example, the photosensitive material **350** may be formed into a parabolic shape to result in the mesa **120** having the parabolic shape with truncated top. Additional details regarding using an etching process to form a mesa in a semiconductor structure are discussed in U.S. Pat. No. 7,598,148, titled "Microleds," issued Oct. 6, 2009, which is incorporated by reference herein in its entirety.

The epitaxial structure **320** is further etched **225** to form a top portion **130** on the mesa **120**. With reference to FIG. 3D, the epitaxial structure **320** may be etched using the p-contact **112** as a hard mask to form the top portion **130** over the mesa **120**. In some embodiments, the top portion **130** is formed using a separate etching from the etching of step **220** used to form the mesa **120**. The etching to form the top portion **130** may also be an ICP etch, except that the ICP etch to form the top portion **130** may be more anisotropic. For example, the etching to form the top portion **130** may use an anisotropic physical etch, or by varying selectivity between the photosensitive material **350** and the material of the epitaxial structure **320** for the ICP etch. This results in etching away portions of the mesa **120** to form the top portion **130** above the mesa **120** and under the p-contact **112**. In other embodiments, a single (e.g., ICP) etch may be performed to form the mesa **120** and the top portion **130**. Here, the epitaxial structure **320** may be over etched after formation of the mesa **120** to from the top portion **130**. The etching steps discussed herein are not limited to ICP etching, and other types of etching may be used to form the mesa **120** and the top portion **130** including dry etching, wet etching, or combinations of dry and wet etching.

A contact (e.g., n-contact **116**) is formed **230** on the base **124**. With reference to FIG. 3D, the n-contact **116** is formed on the base **124** of the bottom cladding **106** opposite the light emitting surface **118**. The n-contact **116** and p-contact **112** form the electrical contacts used to drive the μLED **100**. Furthermore, a passivation layer **324** may be formed on the exterior of the mesa **120** and the top portion **130**. In some embodiments, a reflective material is formed on the formed on the exterior of the mesa **120** and the top portion **130** to improve light extraction efficiency.

The growth substrate **302** is separated **235** from the epitaxial structure **320** to expose a light emitting surface **118** of the epitaxial structure **320**. In some embodiments, a laser lift-off process may be used to separate the substrate **302** from the epitaxial structure **320**. For example, the bottom cladding **106** of the epitaxial structure **320** may be a gallium-based layer or other type of layer that absorbs laser light, and the growth substrate **302** may be transparent to the laser light (e.g., sapphire substrate for ultraviolet (UV) light). The laser may be applied to the bottom cladding **106** through the substrate **302** to form a gallium material between the bottom cladding **106** and the substrate **302**. The laser light is absorbed over a thin thickness inducing a local melting of a portion of the bottom cladding **106** into gallium (Ga) metal and a gas. In an example where the bottom cladding **106** includes GaN, the portion of the bottom cladding **106** is separated into the gallium metal and nitrogen (N_2) gas. The gallium material is heated to debond the bottom cladding **106** and the substrate **302**, and the substrate **302** is then separated from the bottom cladding **106**. The separation of the substrate **302** and the epitaxial structure **320** is not limited to using a laser lift-off process, and other types of suitable processes may also be used such as wet etching. In some embodiments, if the growth substrate is transparent for the light emitted from the LED, then the growth substrate can remain attached to the epitaxial structure **320**. For example, it is not necessary to separate a GaN epitaxial structure from a sapphire growth substrate because sapphire is transparent for the blue or green light emitted from the GaN epitaxial structure.

Although the process **200** is discussed for forming a single μLED **100**, the process **200** may be used to form multiple (e.g., an array) of μLEDs on a single epitaxial structure. For example, multiple p-contacts **112** and photosensitive material **350** masks may be formed on the top cladding **104** of an epitaxial structure **320**, and then the epitaxial structure **320** may be etched to form a mesa **120** and a top portion **130** under each p-contact **112**. Multiple μLEDs **100** may share a common epitaxial structure **320**, or the μLEDs **100** may be singulated into separate dies, such as by another ICP etching or a laser dicing.

The foregoing description of the embodiments has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the patent rights to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the patent rights be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the patent rights, which is set forth in the following claims.

What is claimed is:

1. A light emitting diode (LED), comprising:
- an epitaxial structure, including:
  - a mesa including a truncated top at a first side of the epitaxial structure;
  - an active light emitting area within the mesa and configured to emit light;
  - a top portion of the epitaxial structure on the truncated top of the mesa, wherein the mesa includes a parabolic shape and a portion of the active light emitting area is positioned at a parabolic focal point of the mesa; and
  - a light emitting surface at a second side of the epitaxial structure opposite the first side; and
- a reflective contact on the top portion, at least a portion of the light emitted from the active light emitting area being transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward the light emitting surface.

2. The LED of claim **1**, wherein the active light emitting area includes one or more quantum wells.

3. The LED of claim **1**, wherein the epitaxial structure includes an electron blocking layer (EBL) on the active light emitting area.

4. The LED of claim **1**, wherein the top portion includes one of an n-type gallium nitride (GaN) layer, an n-type gallium arsenide (GaAs) layer, or an n-type gallium phosphide (GaP) layer.

5. The LED of claim **1**, wherein the top portion includes one of a p-type gallium nitride (GaN) layer, a p-type gallium arsenide (GaAs) layer, or a p-type gallium phosphide (GaP) layer.

6. The LED of claim **1**, further comprising a reflective material along a side surface of the top portion.

7. The LED of claim **1**, wherein the top portion includes a cylindrical structure.

8. The LED of claim **1**, wherein the top portion has a height of between 0.1 and 5 um.

9. The LED of claim **1**, wherein the top portion and the mesa form a cladding including an electron blocking layer and a contact layer, the cladding having a height of at least 10 um.

10. The LED of claim **1**, wherein the mesa includes one of:
- a parabolic shape with the truncated top;
- a cylindrical shape with the truncated top; or
- a conic shape with the truncated top.

11. An electronic display, comprising:
- a light emitting diode (LED), including:
  - an epitaxial structure, including:
    - a mesa including a truncated top at a first side of the epitaxial structure;
    - an active light emitting area within the mesa and configured to emit light;
    - a top portion of the epitaxial structure on the truncated top of the mesa, wherein the mesa includes a parabolic shape and a portion of the active light emitting area is positioned at a parabolic focal point of the mesa; and
    - a light emitting surface at a second side of the epitaxial structure opposite the first side; and
  - a reflective contact on the top portion, at least a portion of the light emitted from the active light emitting area being transmitted through the mesa and the top portion in first directions, and reflected by the reflective contact back through the top portion and the mesa in second directions toward the light emitting surface.

12. The electronic display of claim **11**, wherein the active light emitting area includes one or more quantum wells.

13. The electronic display of claim **11**, wherein the epitaxial structure includes an electron blocking layer (EBL) on the active light emitting area.

14. The electronic display of claim **11**, wherein the top portion includes one of an n-type gallium nitride (GaN) layer, an n-type gallium arsenide (GaAs) layer, or an n-type gallium phosphide (GaP) layer.

15. The electronic display of claim **11**, wherein the top portion includes one of a p-type gallium nitride (GaN) layer, a p-type gallium arsenide (GaAs) layer, or a p-type gallium phosphide (GaP) layer.

16. The electronic display of claim **11**, further comprising a reflective material along a side surface of the top portion.

17. The electronic display of claim **11**, wherein the top portion includes a cylindrical structure.

18. The electronic display of claim **11**, wherein the top portion has a height of between 0.1 and 5 um.

19. The electronic display of claim **11**, wherein the top portion and the mesa form a cladding including an electron blocking layer and a contact layer, the cladding having a height of at least 10 um.

20. The electronic display of claim **11**, wherein the mesa includes one of:

a parabolic shape with the truncated top;

a cylindrical shape with the truncated top; or

a conic shape with the truncated top.

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