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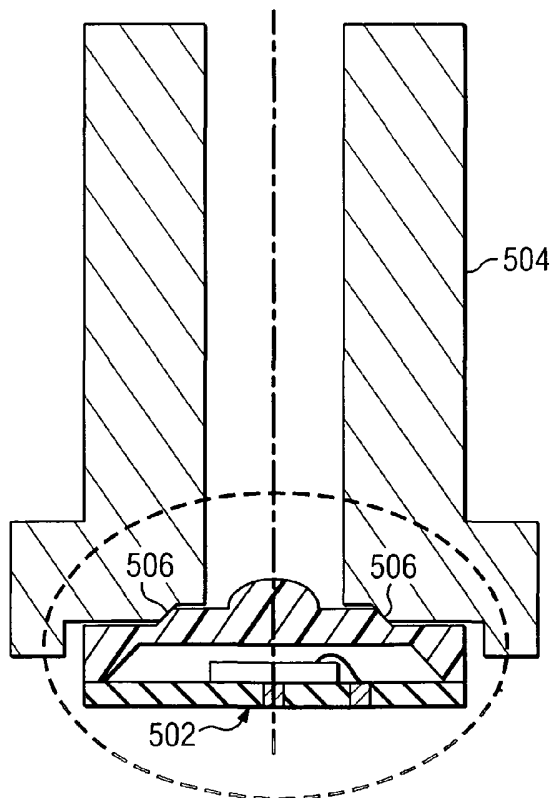
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(54) Title: PACKAGING AND PASSIVE ALIGNMENT OF MICROLENS AND MOLDED RECEPTACLE



(57) Abstract: A planar wafer-level packaging method is provided for a laser and a microlens. Light from the laser (104) is directed and shaped by the microlens (106) to couple into an external light guide. A plurality of such assemblies, each comprising a laser (104) and a microlens (106) may be assembled on a single planar substrate (102). A tapered surface (114) is formed on the microlens (106). The microlens (106) may be formed from a silicon substrate. The angle of the tapered surface (114) causes an accurate cone or pyramid shape. The tapered surface (114) is formed such that the axis of the cone or pyramid is aligned with the optical axis (410) of the lens (106). The lens (106) may then be aligned with the optical axis of the laser (104). A light guide receptacle (404) is formed with a tapered surface that matches the tapered surface (114) of the microlens (106). The tapered surface of the receptacle (404) is formed such that the axis of the cone or pyramid is aligned with the optical axis (408) of the receptacle (404). The receptacle (404) may then be passively aligned with the microlens (106) by mating the tapered surfaces.



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PACKAGING AND PASSIVE ALIGNMENT OF MICROLENS AND MOLDED RECEPTACLE

CROSS REFERENCE TO RELATED APPLICATIONS

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The present invention is related to U.S. patent application entitled "Planar and Wafer Level Packaging of Semiconductor Lasers and Photo Detectors for Transmitter Optical Sub-Assemblies," serial no. 10/283,730, filed October 30, 2002, assigned to the same assignee, and incorporated herein by reference.

10

BACKGROUND OF THE INVENTION

1. Technical Field:

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The present invention relates to lasers and, in particular, to packaging for laser assemblies. Still more particularly, the present invention provides a method and apparatus for packaging a laser with a microlens and passive alignment with a molded receptacle.

2. Description of Related Art:

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Fiber optics are used for short distance communications. A laser (Light Amplification by the Stimulated Emission of Radiation) is a device that creates a uniform and coherent light that is very different from an ordinary light bulb. Many lasers deliver light in an almost-perfectly parallel beam (collimated) that is very pure, approaching a single wavelength. Lasers create ultra-high-speed, miniscule pulses traveling in optical fibers. Light traveling in an optical fiber is impervious to external interference, which is a problem with electrical pulses in copper wire.

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An optical fiber is a thin glass strand designed for light transmission. A single hair-thin fiber is capable of transmitting trillions of bits per second. There are two primary types of fiber. Multimode fiber is very common for short distances and has a core diameter of from 50 to 100 microns. For intercity cabling and highest speed, singlemode fiber with a core diameter of less than 10 microns is used.

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A laser assembly which includes a lens and a receptacle to hold the fiber presents problems in packaging and alignment, especially for single mode fibers. The optical axes of the laser, the lens, and the receptacle must be aligned precisely to within a couple of microns for maximum coupling of light into the single mode fiber. Active alignment techniques are typically

used for this, wherein the fiber is aligned while actively monitoring the amount of light coupled into fiber. Using special algorithms and precision sub-micron stages, the fiber is moved to the optimum position and then permanently fixed in place by laser welding. Post-weld shift correction is sometimes necessitated to complete the assembly. Cycle time for this entire process may be in the order of several minutes, which is very time consuming. Coupled with the high cost of the alignment and laser weld equipment, active alignment is one of the largest contributors to the overall cost of the package.

Therefore, it would be advantageous to provide a method and apparatus for allowing passive alignment of the light source to a fiber receptacle and which is also amenable to assembly using standard automated pick-and-place equipment.

SUMMARY OF THE INVENTION

The present invention provides a planar wafer-level packaging method for a laser and a microlens. Light from the laser is directed and shaped by the microlens to couple into an external light guide. A plurality of such assemblies, each comprising a laser and a microlens, may be assembled on a single planar substrate. A tapered surface is formed on the microlens. The microlens may be formed from a silicon substrate. The crystalline structure of the silicon causes the tapered surface to be formed accurately along the $\langle 111 \rangle$ plane. The angle of the tapered surface causes an accurate cone or pyramid shape. The tapered surface is formed such that the axis of the cone or pyramid is aligned with the optical axis of the lens. The lens may then be aligned with the optical axis of the laser. A light guide receptacle is formed with a tapered surface that matches the tapered surface of the microlens. The tapered surface of the receptacle is formed such that the axis of the cone or pyramid is aligned with the optical axis of the receptacle. The receptacle may then be passively aligned with the microlens by mating the tapered surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a diagram depicting an example laser assembly in accordance with a preferred embodiment of the present invention;

Figure 2 illustrates a top view of a substrate populated with an array of laser assemblies in accordance with a preferred embodiment of the present invention;

Figures 3A-3C are diagrams illustrating active microlens alignment in accordance with a preferred embodiment of the present invention;

Figure 4A illustrates a laser assembly with a tapered surface in accordance with a preferred embodiment of the present invention;

Figure 4B illustrates a wave guide receptacle with a tapered surface in accordance with a preferred embodiment of the present invention;

Figures 5A and 5B illustrate a laser assembly with a microlens passively aligning with a wave guide receptacle in accordance with a preferred embodiment of the present invention;

Figures 6A-6C depict example transmitter optical sub assemblies in accordance with a preferred embodiment of the present invention; and

Figure 7 is a flowchart illustrating the operation of a process for providing a passively aligning microlens and wave guide receptacle assembly in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The description of the preferred embodiment of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

With reference now to the figures and in particular with reference to **Figure 1**, a diagram depicting an example laser assembly is shown in accordance with a preferred embodiment of the present invention. The laser assembly may be a planar assembly with laser **104** affixed to substrate **102**. Laser **104** may be a grating-outcoupled surface emitting (GSE) laser. Further details for the GSE laser may be found in copending patent application 09/844,484 (Attorney Docket No. PDGM-4) to Evans et al., entitled "Grating Outcoupled Surface Emitting Lasers," filed on April 27, 2001, and herein incorporated by reference.

Microlens **106** is affixed to substrate **102** to form a hermetically sealed cavity over the laser. The microlens may be affixed to the substrate using a eutectic attach **108**. A conductor pattern **110** is formed on the underneath side of the substrate for printed circuit board (PCB) mounting. Laser **104** and bus lines **120** are connected to the conductor pattern through via **112**. The microlens has a lens formed therein. The lens must be aligned with the optical axis of the laser.

In accordance with a preferred embodiment of the present invention, microlens **106** has formed therein a tapered surface **114**. The tapered surface surrounds the lens to form a cone or pyramid shape. The microlens may be formed from a silicon substrate. The crystalline structure of the silicon causes the tapered surface to be formed accurately along the $\langle 111 \rangle$ plane. The angle of the tapered surface causes an accurate cone or pyramid shape. The tapered surface **114** is formed such that the axis of the cone or pyramid is coincident with the optical axis of the lens. In a silicon substrate this can be achieved to a high degree of accuracy by defining the microlens and tapered surface using the same photolithographic mask.

Figure 2 illustrates a top view of a substrate populated with an array of laser assemblies in accordance with a preferred embodiment of the present invention. A ceramic substrate has formed thereon an array of laser assemblies, such as laser assembly **210**. Bus lines **220** enable

powering up of the array to allow vision-assisted placement of the microlens with respect to the laser output field. In **Figure 2**, the laser assemblies are shown with the microlenses attached.

With reference to **Figures 3A-3C**, diagrams illustrating vision-assisted microlens alignment are shown in accordance with a preferred embodiment of the present invention. More particularly, with reference to **Figure 3A**, a substrate is shown with laser **304** attached. Stationary camera **330** is positioned to receive light from laser **304** and is mounted orthogonal to the laser die. Camera view **350** illustrates the light received from laser **304**. The substrate is positioned to center the camera view on the maximum intensity spot of the laser output field. Since the camera **330** is orthogonal to laser **304**, the camera axis is now coincident with the laser optical axis.

Turning now to **Figure 3B**, microlens **306** is placed over the laser using pick-and-place tool **340**. Camera view **360** illustrates the light received from the laser. As shown in **Figure 3B**, microlens **306** laterally inverts the light received from the laser. The microlens also displaces the light unless the optical axis of the lens is precisely aligned with the optical axis of the laser.

Next, with reference to **Figure 3C**, the microlens is moved with the pick-and-place tool so that the laser output field is again centered in the camera view. Camera view **370** illustrates the light received from the laser through the microlens with the optical axes aligned. In this state, the microlens is then attached to the substrate. Solder is reflowed to complete the attach.

With reference now to **Figure 4A**, a laser assembly with a tapered surface is shown in accordance with a preferred embodiment of the present invention. Laser assembly **402** includes a microlens with tapered surface **420**. Preferably, the tapered surface surrounds the lens in a rectangle or circle to form a cone or pyramid shape. The axis of the cone or pyramid shape aligns with the optical axis **410** of the lens. The tapered surface may also surround the lens in another shape, such as a pentagon, hexagon, or the like, as long as the tapered surface may be mated with a wave guide receptacle to align the optical axes of the lens and the receptacle.

Turning to **Figure 4B**, a wave guide receptacle with a tapered surface is shown in accordance with a preferred embodiment of the present invention. Wave guide receptacle **404** has formed therein a tapered surface **406** along the molded receptacle bottom. Preferably, the tapered surface surrounds the wave guide cavity in a square or circle to form a cone or pyramid shape. The receptacle may be formed using precision plastic molding technology. The angle of the tapered surface causes an accurate cone or pyramid shape. The axis of the cone or pyramid shape aligns with the optical axis **408** of the wave guide receptacle. The tapered surface may also surround the wave guide cavity in another shape, such as a pentagon, hexagon, or the like, as

long as the tapered surface may be mated with the microlens to align the optical axes of the lens and the receptacle. The wave guide receptacle includes a wave guide cavity in which a connection ferule may be inserted. The connection ferule holds a wave or light guide for the laser. In a preferred embodiment of the present invention, the light guide is a single mode fiber.

5 **Figures 5A and 5B** illustrate a laser assembly with a microlens passively aligning with a wave guide receptacle in accordance with a preferred embodiment of the present invention. With passive alignment, there is no need for the laser to be powered on. Instead, the components are naturally self-aligned based upon their shapes, contours, or other physical attributes. While passive alignment of a microlens with a wave guide receptacle is described herein, the passive
10 alignment packaging technique of the present invention need not be used to the exclusion of other alignment techniques. For example, in an alternative embodiment, the passive alignment of the present invention may be reinforced with active alignment techniques, such as that shown in **Figures 3A-3C**.

More particularly, with reference to **Figure 5A**, laser assembly **502** is placed in molded
15 receptacle **504**. The optical axes of the microlens and the receptacle are automatically, passively aligned because of the tapered surfaces. Preferably, the optical design of the laser, lens, and wave guide are insensitive to the vertical location of the laser assembly in the receptacle.

As seen in the zoomed-in view in **Figure 5B**, the microlens and receptacle are mated to passively align the optical axes of the lens and the receptacle. Clearance is provided, shown at
20 **508**, between the other surfaces of the microlens and the molded receptacle. Since the optical design is insensitive to the vertical direction but very sensitive to the other two directions, it is important that the positioning of the receptacle relative to the microlens is determined by the precisely molded tapered surfaces. Therefore, the microlens and receptacle come into contact only at the tapered surfaces.

25 With reference to **Figures 6A-6C**, example transmitter optical sub assemblies (TOSA) are shown in accordance with a preferred embodiment of the present invention. **Figure 6A** illustrates a leadless package for high speed modulation. The laser assembly is affixed to the molded receptacle with epoxy **612**. The epoxy is dispensed and cured in-situ or offline. Shrinkage of epoxy forces the tapers to mate with a controlled force. **Figure 6B** depicts a laser assembly surface mounted to PCB
30 **624** which has an attached flex tape. Again, the laser assembly is affixed to the molded receptacle with epoxy **622**.

Turning to **Figure 6C**, an assembly similar to a TO-can package is shown. The laser assembly is affixed to the molded receptacle with epoxy **632** and epoxy **634**. Wirebond **363**

provides an electrical connection from the laser to leads 638. The leads are molded into the body like a leadframe. More assembly steps are required, including trimming and forming the leads.

With reference to **Figure 7**, a flowchart is shown illustrating the operation of a process for providing a passively aligning microlens and wave guide receptacle assembly in accordance with a preferred embodiment of the present invention. The process begins and forms a microlens with a tapered surface (step 702). Then, the process aligns the microlens with the laser (step 704). The process forms a wave guide assembly with a tapered surface (step 706). Next, the process passively aligns the wave guide assembly with the microlens using the tapered surfaces (step 708) and ends.

Thus, the present invention solves the disadvantages of the prior art by providing a laser assembly including a microlens and a wave guide receptacle that may be passively aligned. A tapered surface is formed on the microlens. The microlens may be formed from a silicon substrate. The crystalline structure of the silicon causes the tapered surface to be formed accurately along the $\langle 111 \rangle$ plane. The angle of the tapered surface causes an accurate cone or pyramid shape. The tapered surface is formed such that the axis of the cone or pyramid is aligned with the optical axis of the lens. The lens may then be aligned with the optical axis of the laser. A light guide receptacle is formed with a tapered surface that matches the tapered surface of the microlens. The tapered surface of the receptacle is formed such that the axis of the cone or pyramid is aligned with the optical axis of the receptacle. The receptacle may then be passively aligned with the microlens by mating the tapered surfaces.

CLAIMS

What is claimed is:

1. A method for passively aligning a laser assembly with a wave guide receptacle, the
5 method comprising:

forming a microlens with a first tapered surface and a lens element;

aligning the lens element of the microlens with a laser, wherein the laser is affixed to a
substrate;

affixing the microlens to the substrate to form a laser subassembly;

10 forming a wave guide receptacle with a second tapered surface and a wave guide cavity;
and

passively aligning the microlens with the wave guide receptacle using the first tapered
surface and the second tapered surface.

15 2. The method of claim 1, wherein the first tapered surface surrounds the lens element in a
cone or pyramid shape.

3. The method of claim 2, wherein the axis of the cone or pyramid shape is coincident with
the optical axis of the laser.

20 4. The method of claim 1, wherein the second tapered surface surrounds the wave guide
cavity in a cone or pyramid shape.

5. The method of claim 4, wherein the axis of the cone or pyramid shape is coincident with
25 the optical axis of the wave guide cavity.

6. The method of claim 1, wherein the step of passively aligning the microlens with the
wave guide receptacle includes aligning the microlens with the wave guide receptacle such that
only the first tapered surface and the second tapered surface touch.

30 7. The method of claim 1, wherein the first tapered surface and the second tapered surface
are formed using the same photolithographic mask.

8. The method of claim 1, further comprising:
affixing the wave guide receptacle to the laser subassembly to form a laser assembly.

9. The method of claim 8, further comprising:
5 mounting the laser subassembly to a printed circuit board.

10. The method of claim 8, further comprising:
attaching leads to the laser assembly; and
electronically connecting the leads to the laser subassembly with wirebond.

10 11. A passively aligned laser assembly with a wave guide receptacle, the laser assembly comprising:

a subassembly including:

15 a microlens, wherein the microlens has formed therein a first tapered surface and a lens element;

a substrate having affixed thereto a laser, wherein the microlens is affixed to the substrate such that the lens element of the microlens is aligned with a laser;

a wave guide receptacle, wherein the wave guide receptacle has formed therein a second tapered surface and a wave guide cavity,

20 wherein the microlens is passively aligned with the wave guide receptacle using the first tapered surface and the second tapered surface.

12. The laser assembly of claim 11, wherein the first tapered surface surrounds the lens element in a cone or pyramid shape.

25 13. The laser assembly of claim 12, wherein the axis of the cone or pyramid shape is coincident with the optical axis of the laser.

14. The laser assembly of claim 11, wherein the second tapered surface surrounds the wave 30 guide cavity in a cone or pyramid shape.

15. The laser assembly of claim 14, wherein the axis of the cone or pyramid shape is coincident with the optical axis of the wave guide cavity.

16. The laser assembly of claim 11, wherein the microlens is passively aligned with the wave guide receptacle such that only the first tapered surface and the second tapered surface touch.

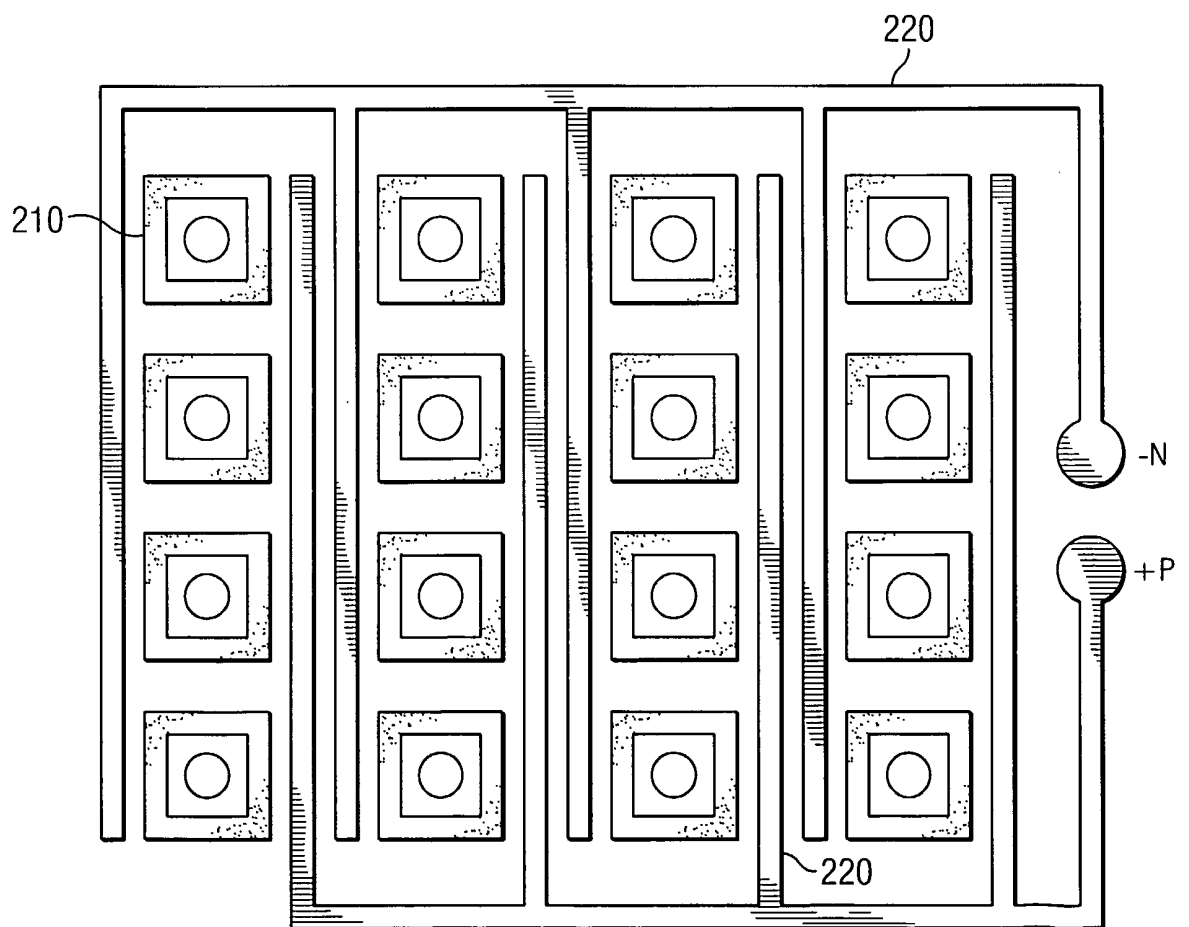
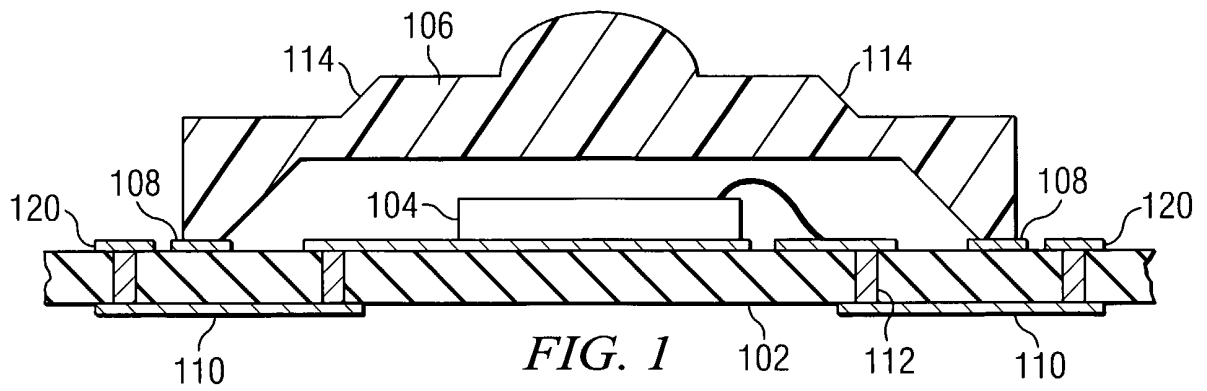
17. The laser assembly of claim 11, wherein the first tapered surface and the second tapered surface are formed using the same photolithographic mask.

18. The laser assembly of claim 11, wherein the wave guide receptacle is affixed to the laser subassembly with an epoxy.

19. The laser assembly of claim 18, further comprising:
a printed circuit board, wherein the printed circuit board is mounted to the subassembly.

20. The laser assembly of claim 18, further comprising:
leads attached to the laser assembly; and
wirebond, wherein the wirebond electronically connects the leads to the laser subassembly.

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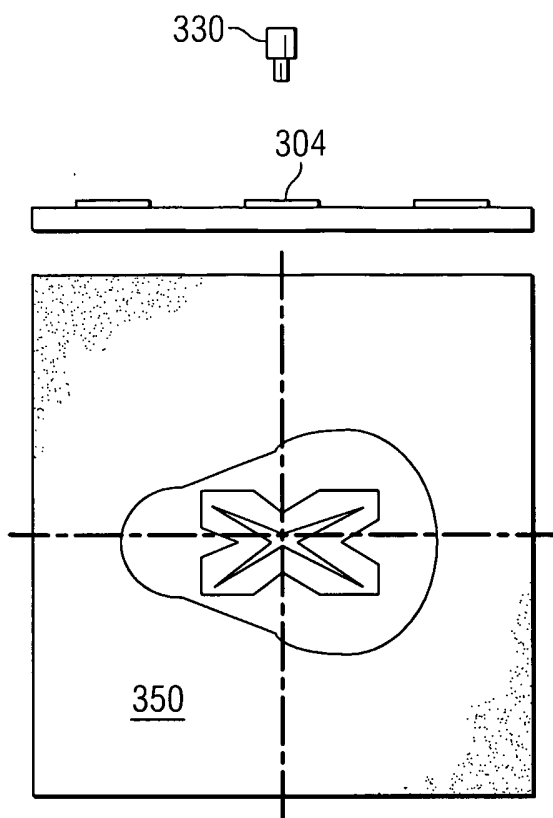


FIG. 3A

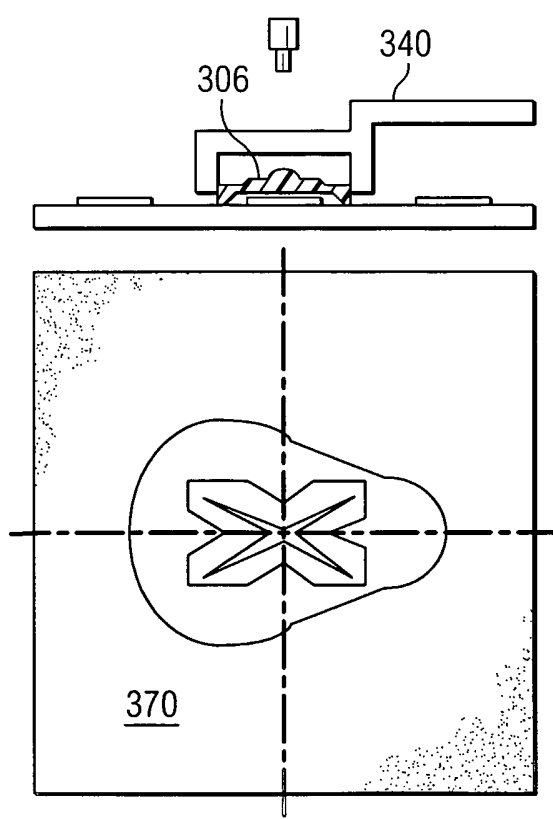


FIG. 3C

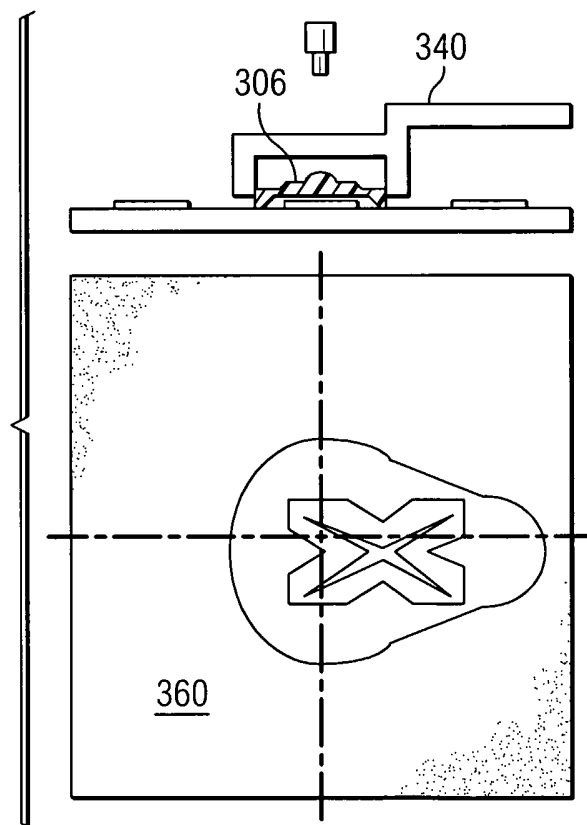


FIG. 3B

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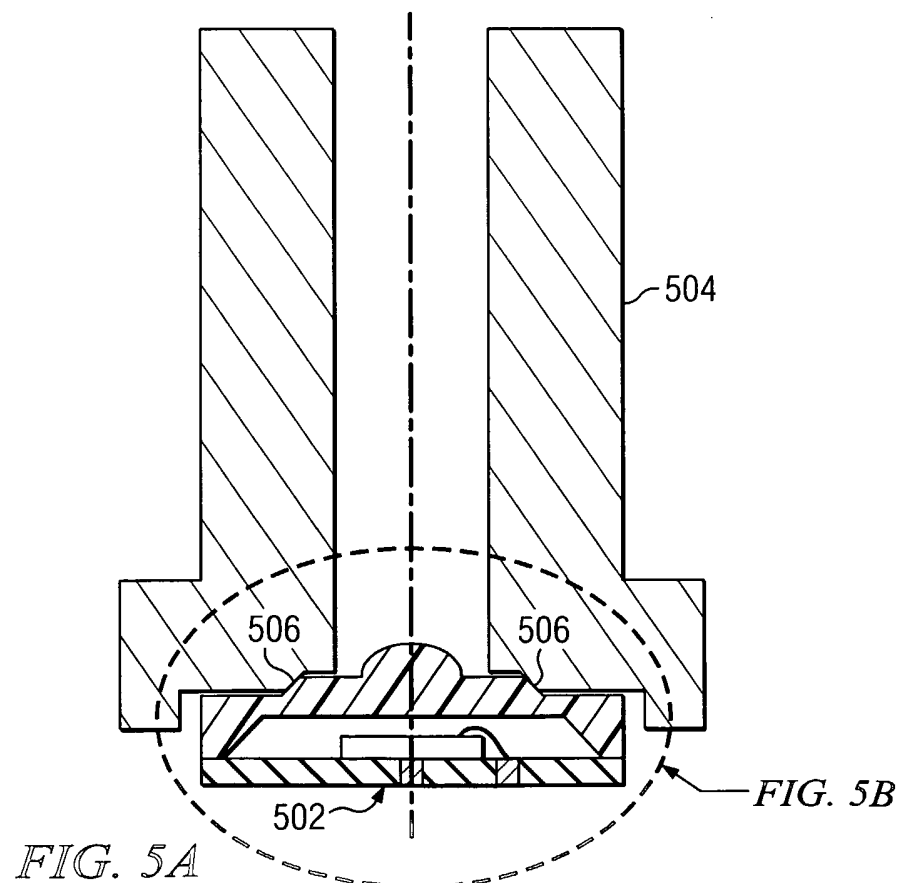
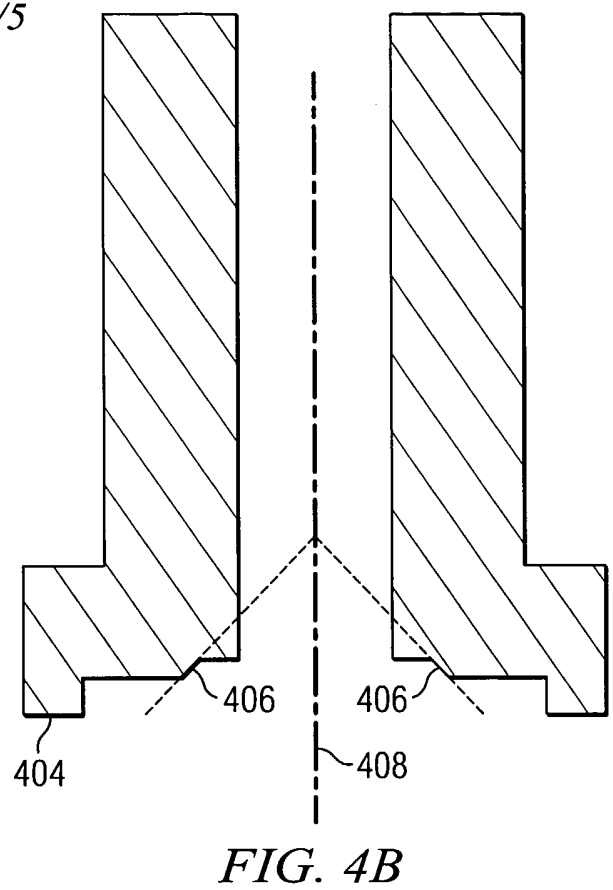
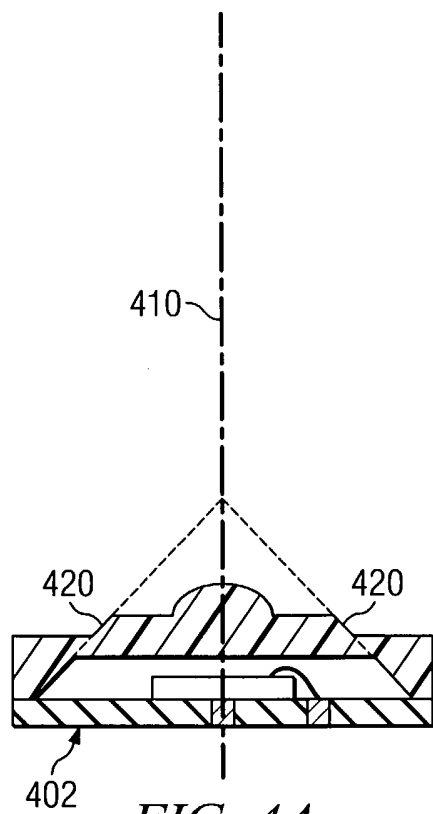


FIG. 5B

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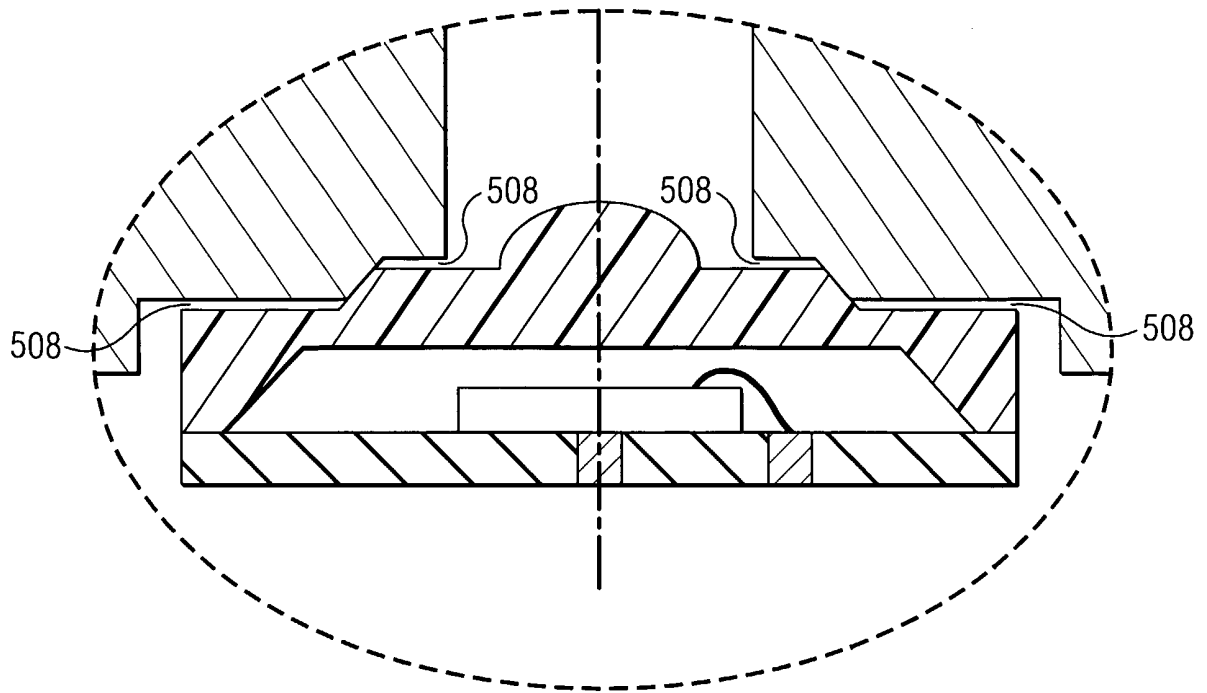


FIG. 5B

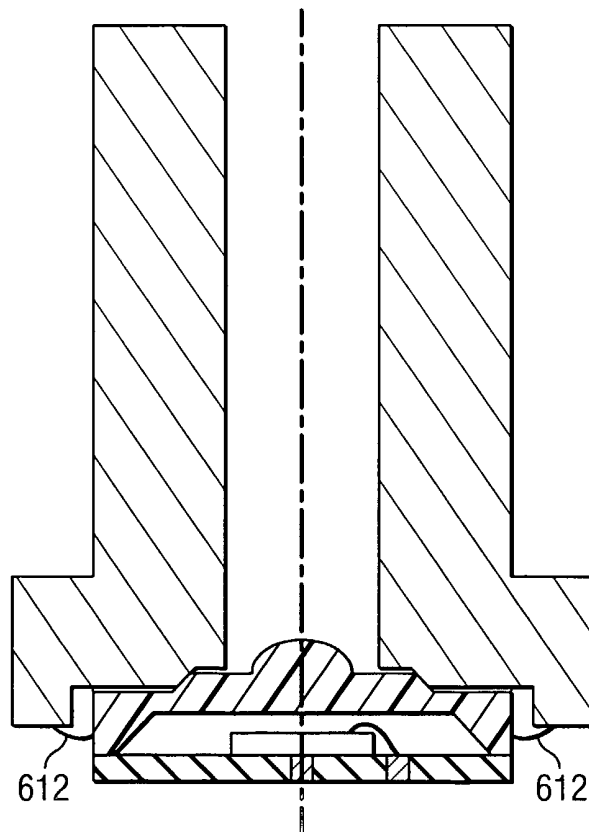


FIG. 6A

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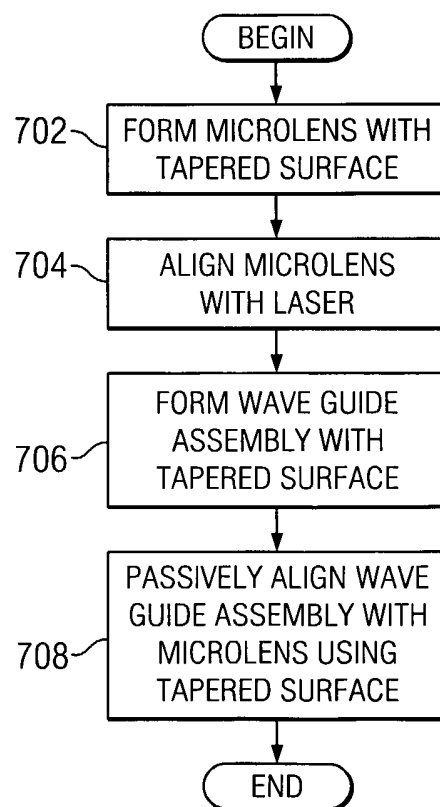
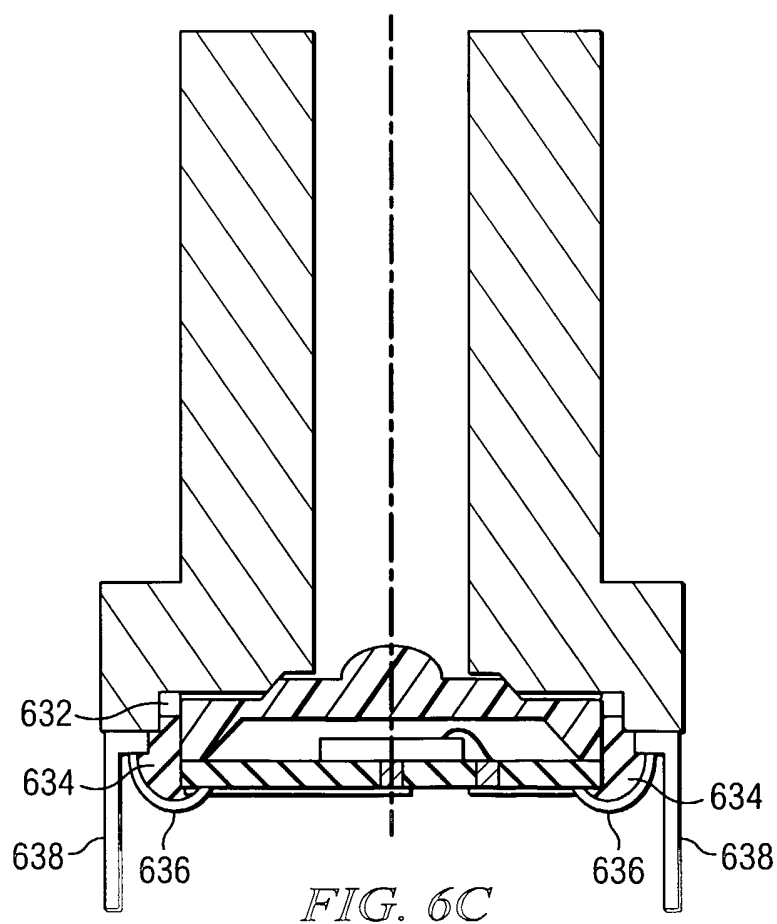
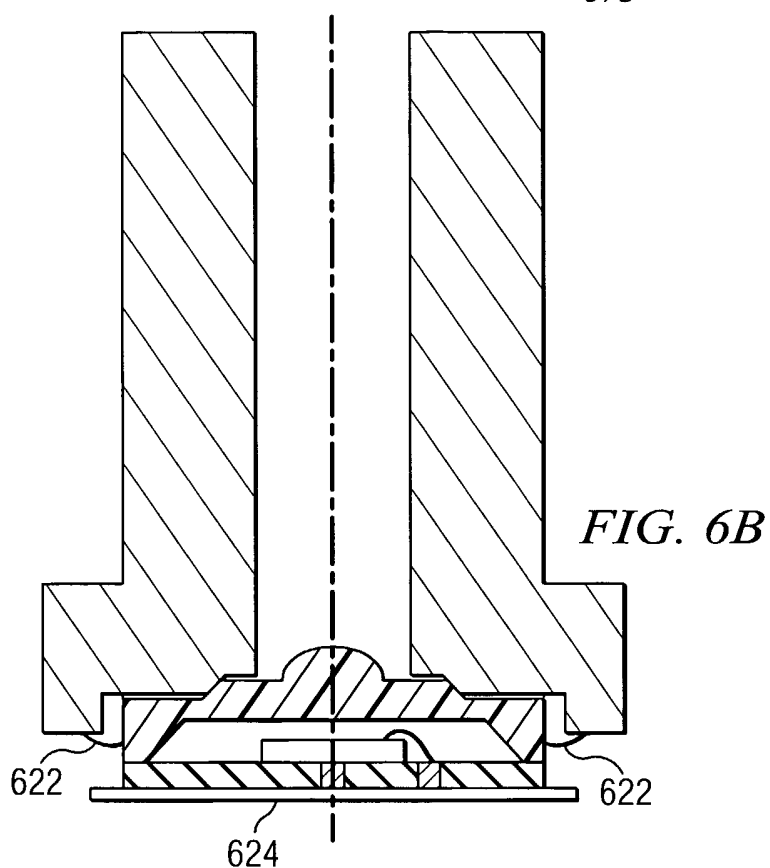


FIG. 7