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(54) **METHOD AND APPARATUS FOR AN INTEGRATED LASER BEAM SCANNER USING A CARRIER SUBSTRATE**

(75) Inventors: **Philip D. Floyd**, Sunnyvale, CA (US); **Decai Sun**, Los Altos, CA (US); **Joel A. Kubby**, Rochester, NY (US)

(73) Assignee: **Xerox Corporation**, Stamford, CT (US)

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(52) **U.S. Cl.** **359/201**; 359/224; 359/850
(58) **Field of Search** 359/201, 202, 359/212, 213, 214, 220, 221, 223, 224, 225, 850

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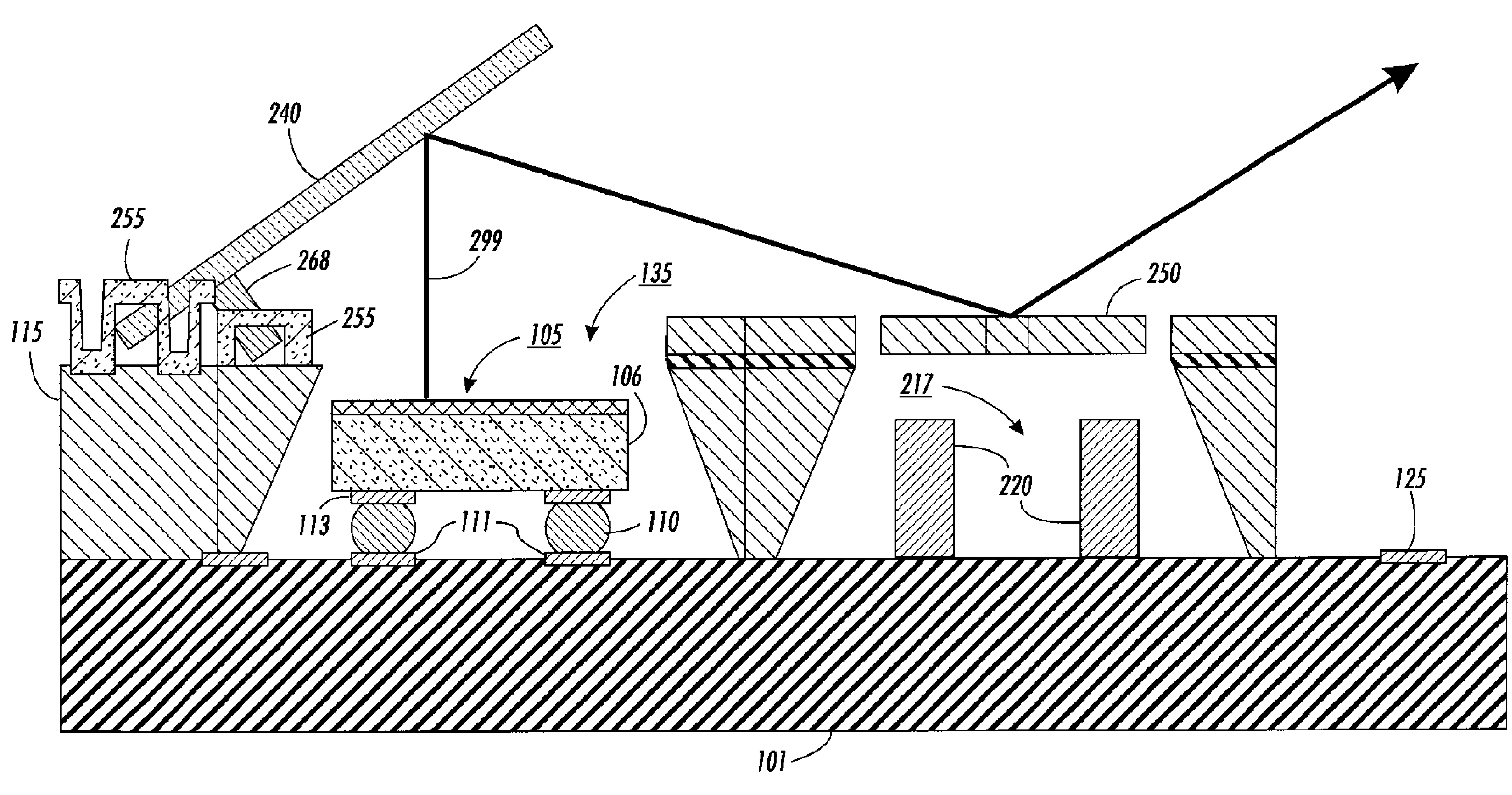
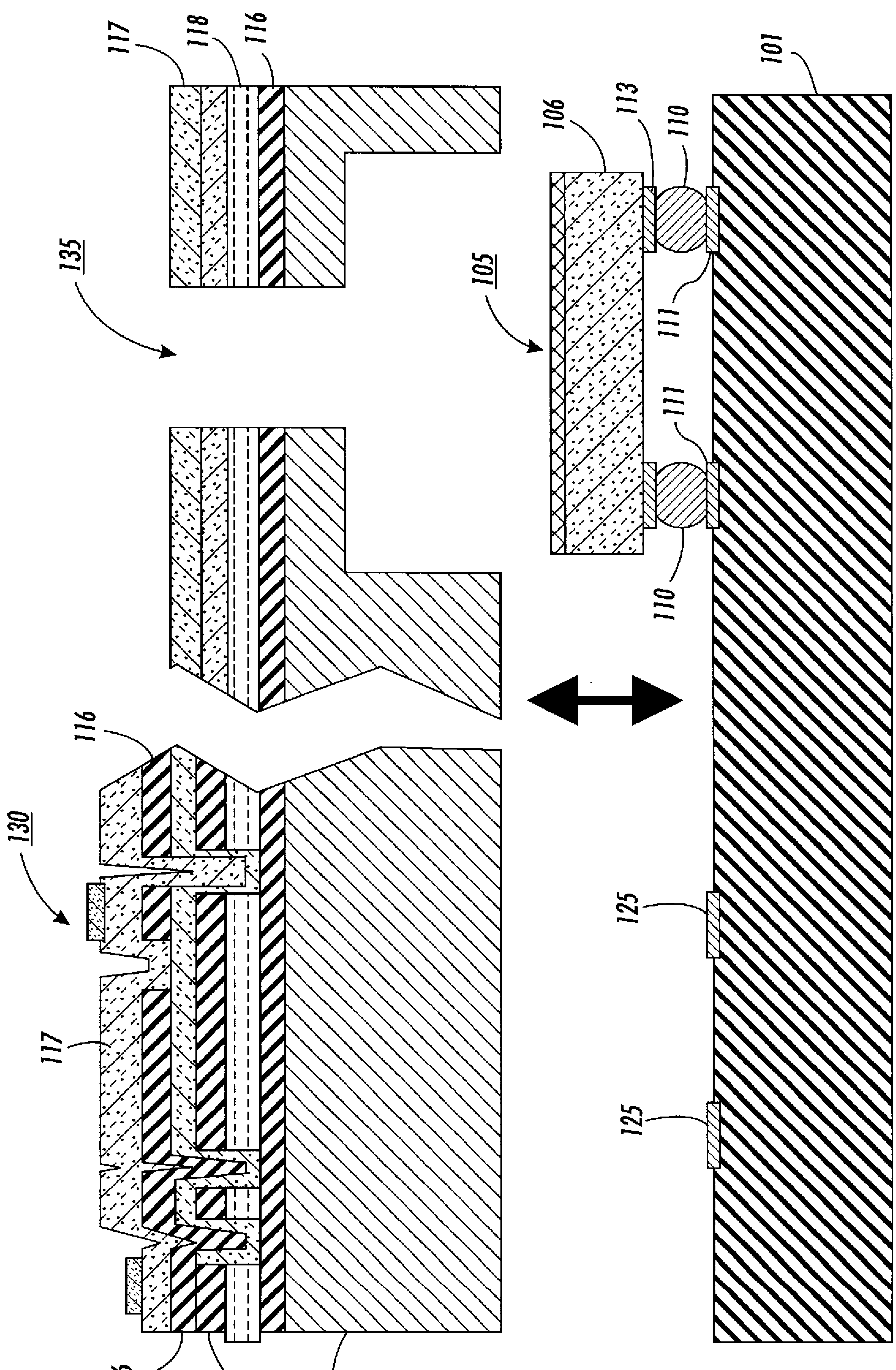
Primary Examiner—John Juba
Assistant Examiner—Leo Boutsikaris
(74) *Attorney, Agent, or Firm*—David E. Henn

(57) **ABSTRACT**

An solid state scanning system having a single crystal silicon deflection mirror and scanning mirror is integrated with a light source. Separation of the micro-electro-mechanical systems and light emitters on separate substrates allows the use of flip-chip and solder bump bonding techniques for mounting of the light sources. The separate substrates are subsequently full wafer bonded together to create an integrated solid state scanning system.

37 Claims, 12 Drawing Sheets

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118
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135
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101
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110
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125

FIG. 1

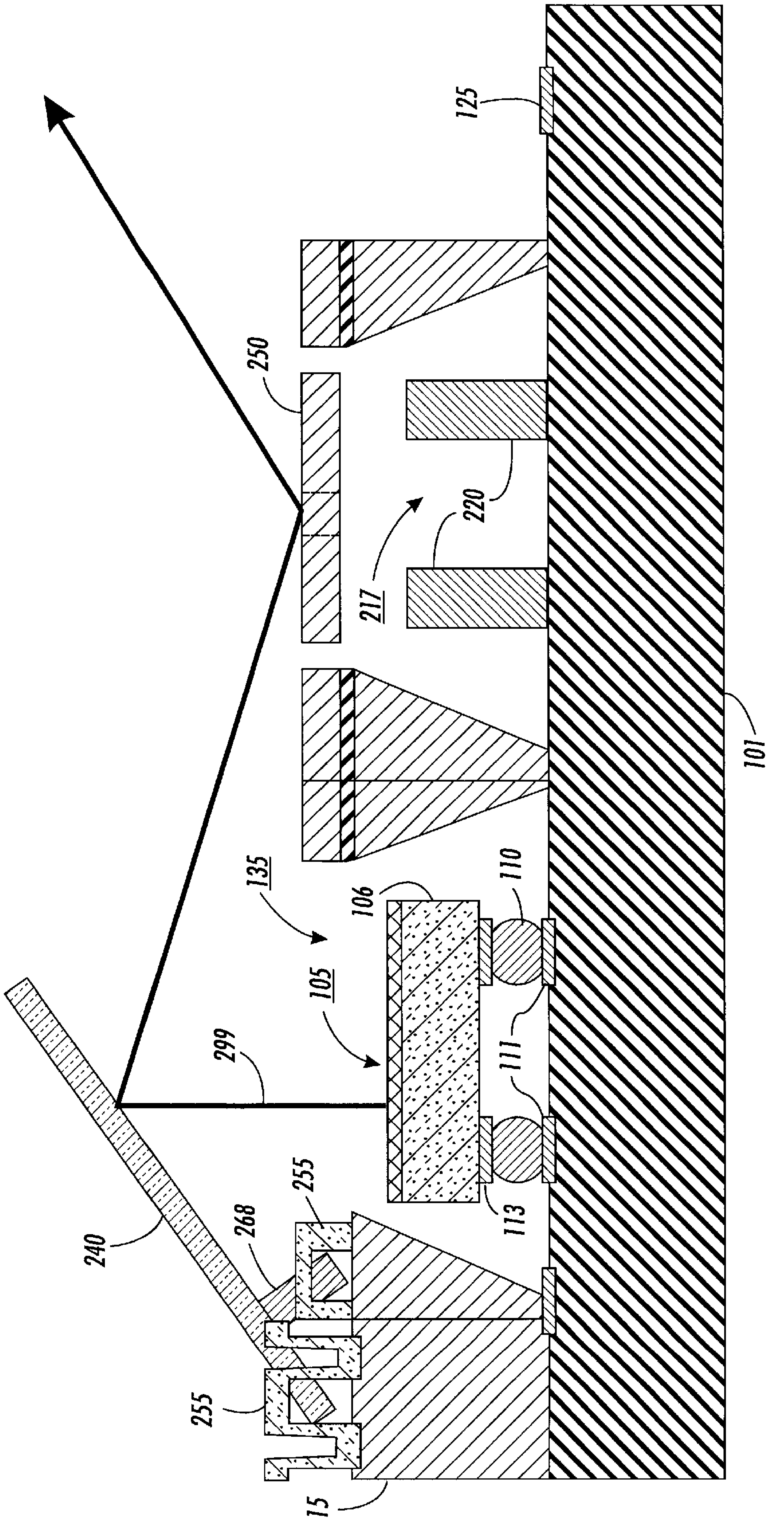


FIG. 2A

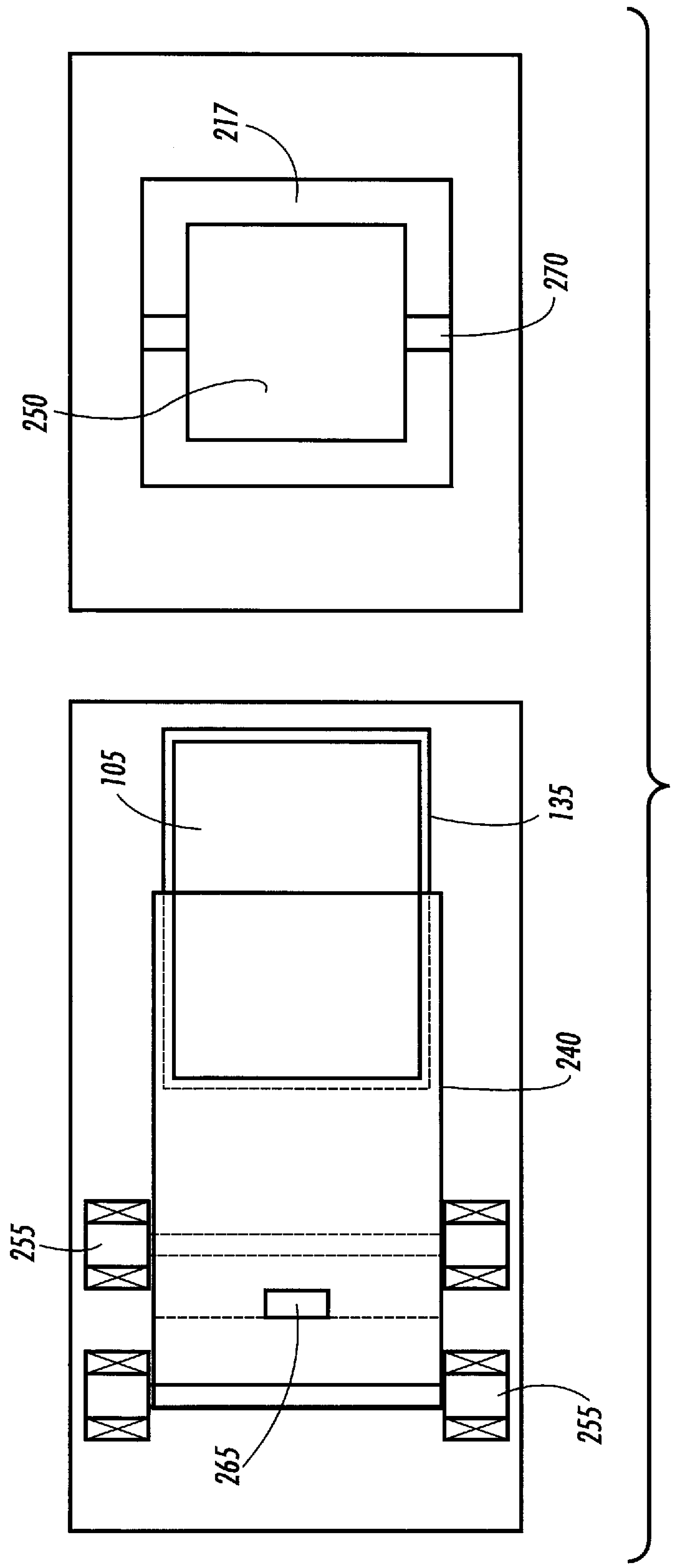
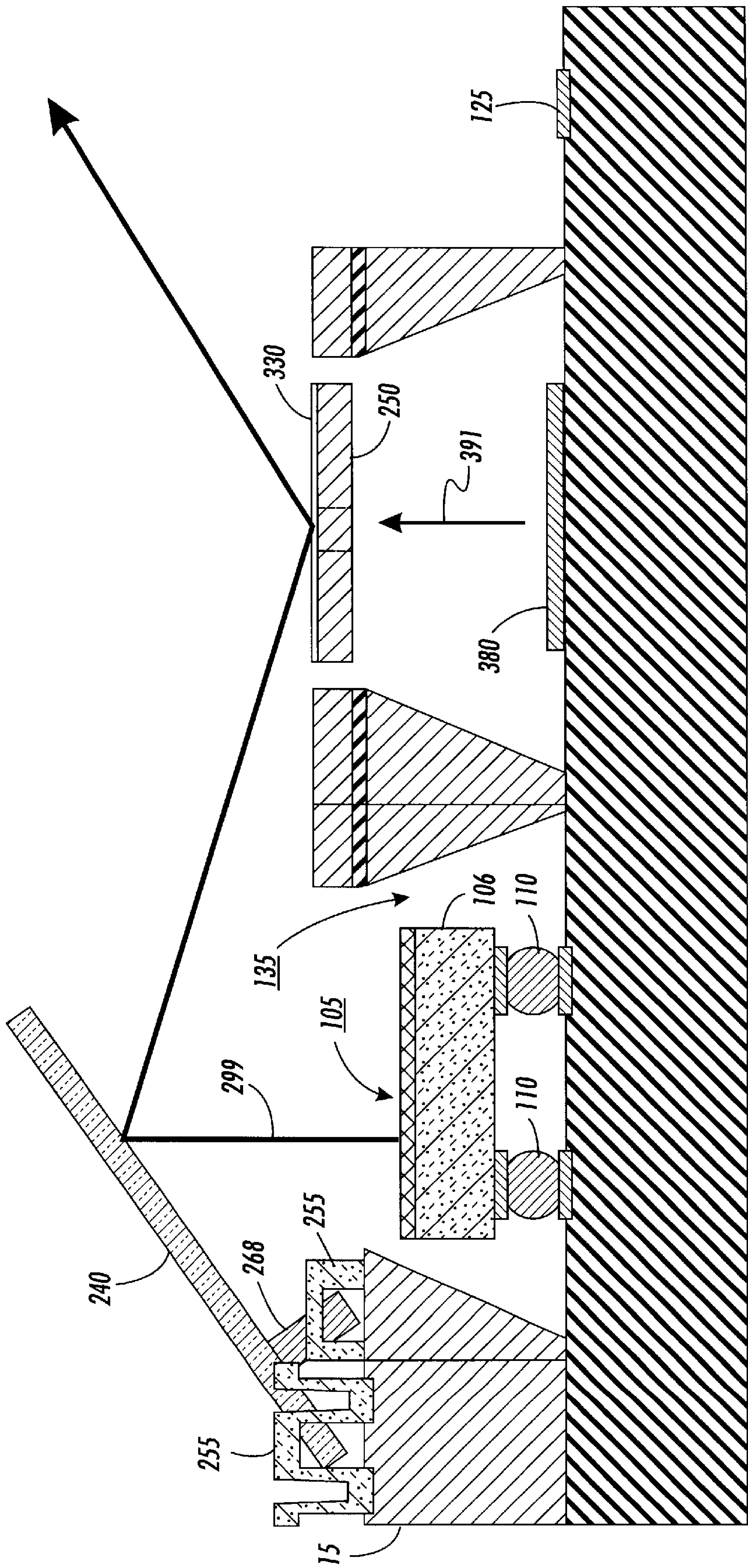


FIG. 2B


125
330
250
391
380
101
106
110
135
105
299
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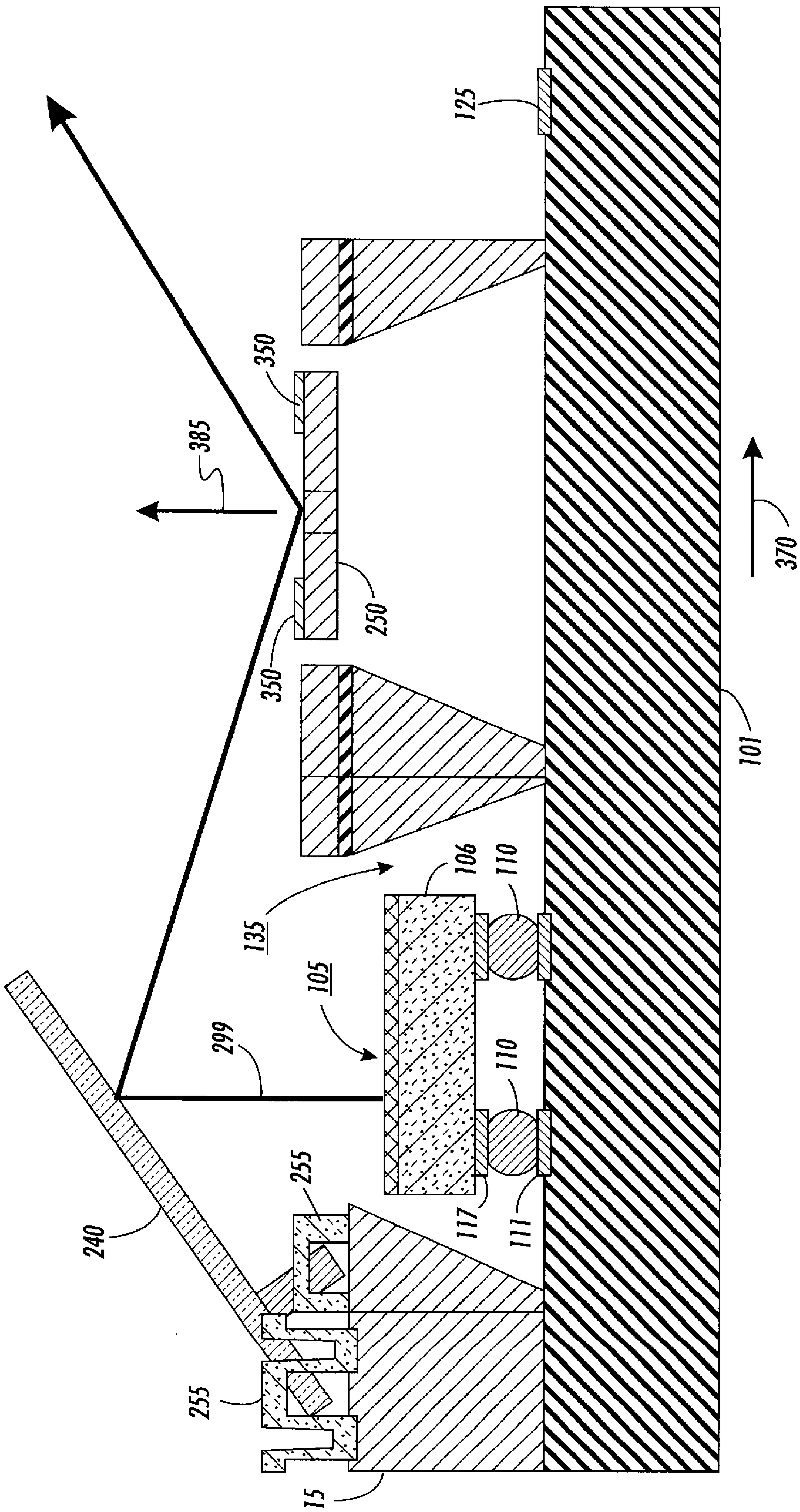
255
268
240
255
115

FIG. 3A


125
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135
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299
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240
117
111
255
115

FIG. 3B

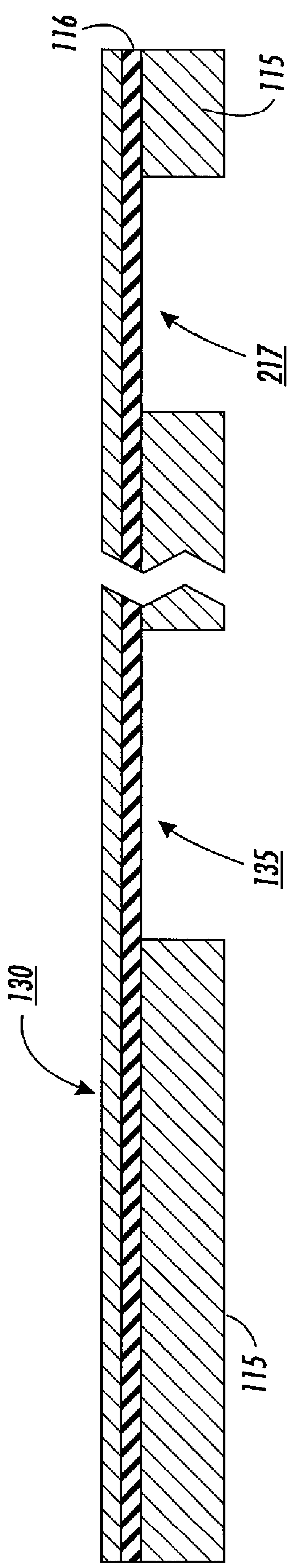

FIG. 4A

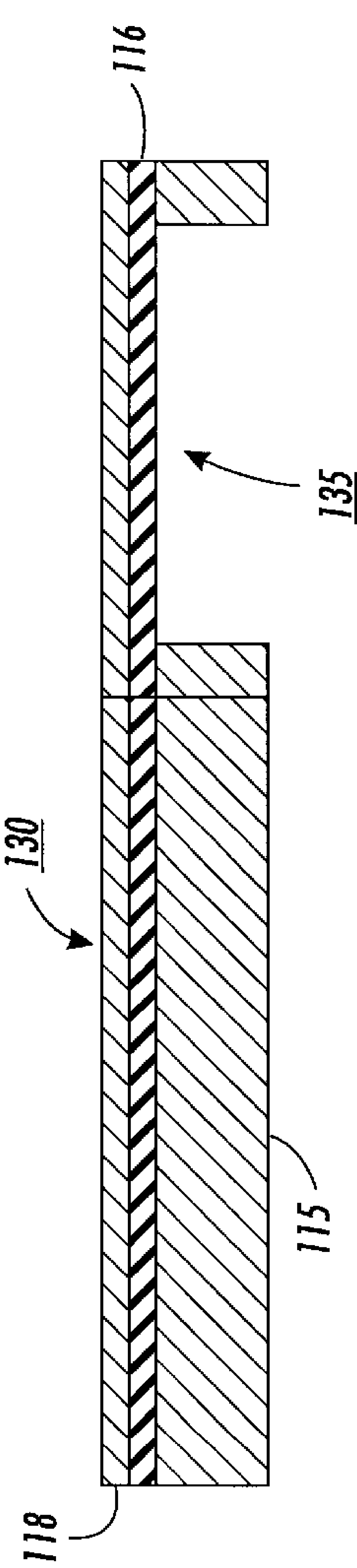

FIG. 4B

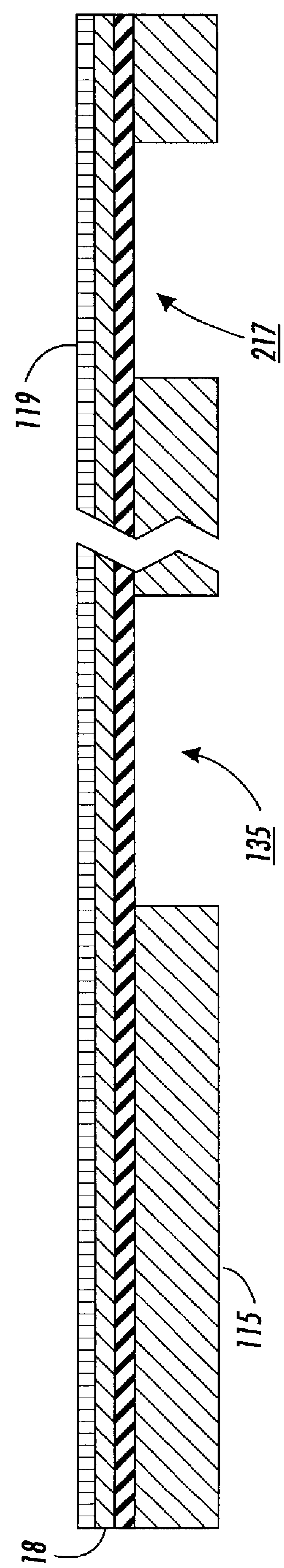

FIG. 4C

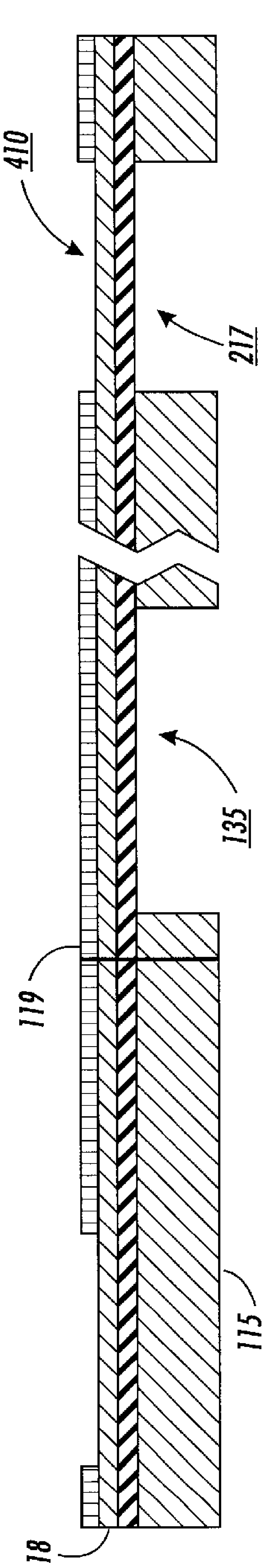

FIG. 4D

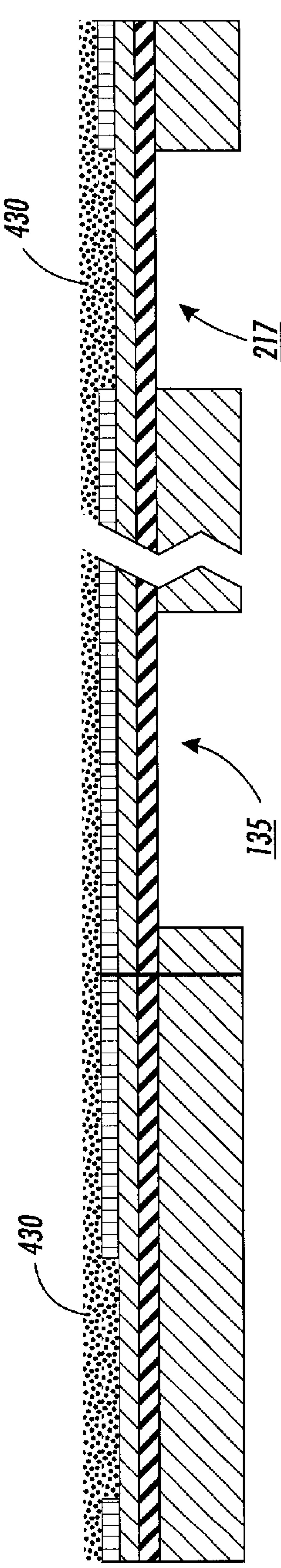

FIG. 4E

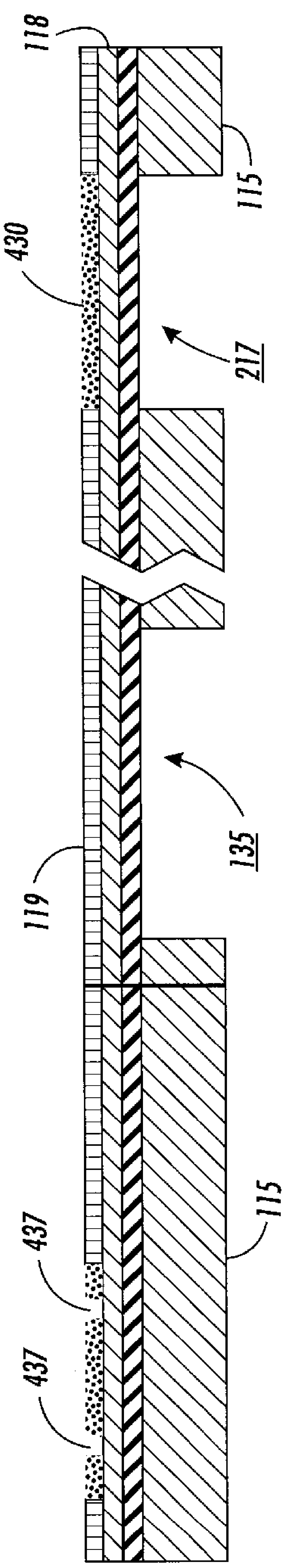

FIG. 4F

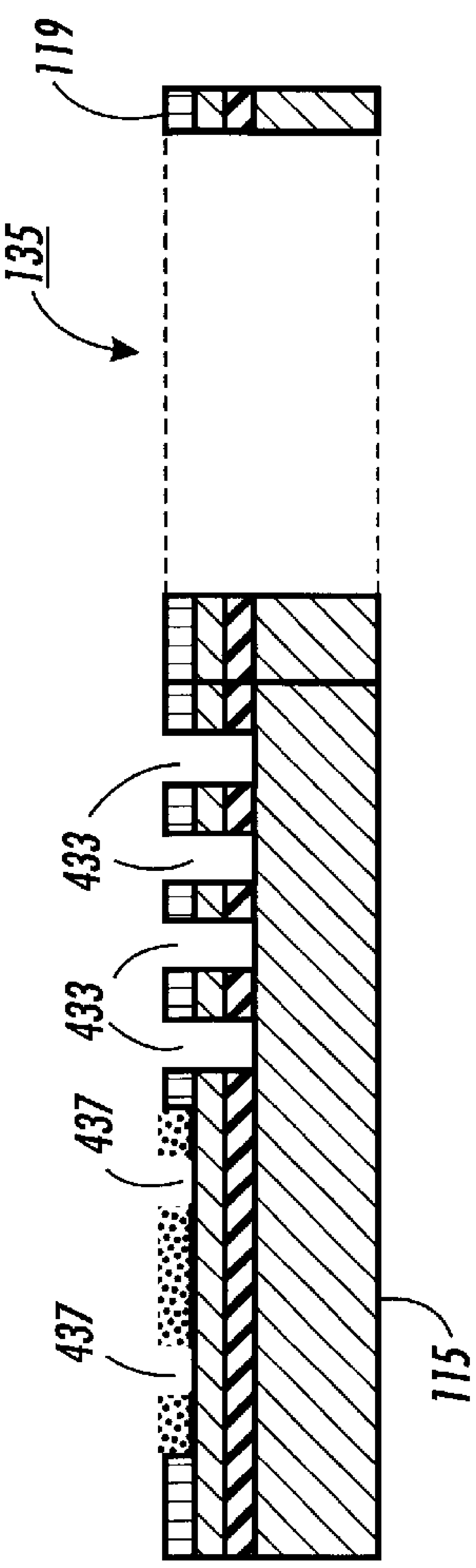

FIG. 4G

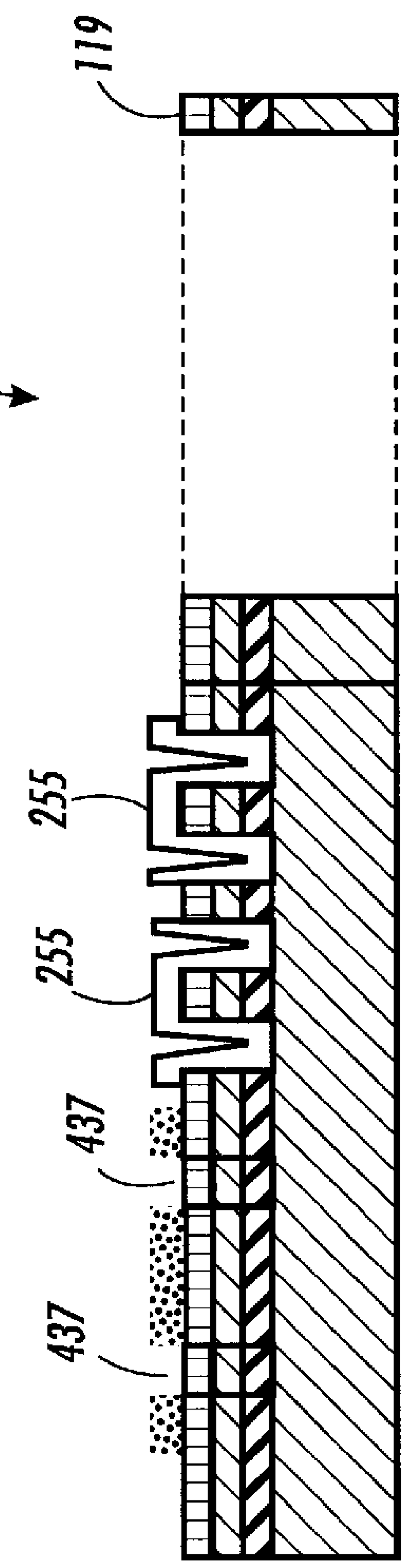

FIG. 4H

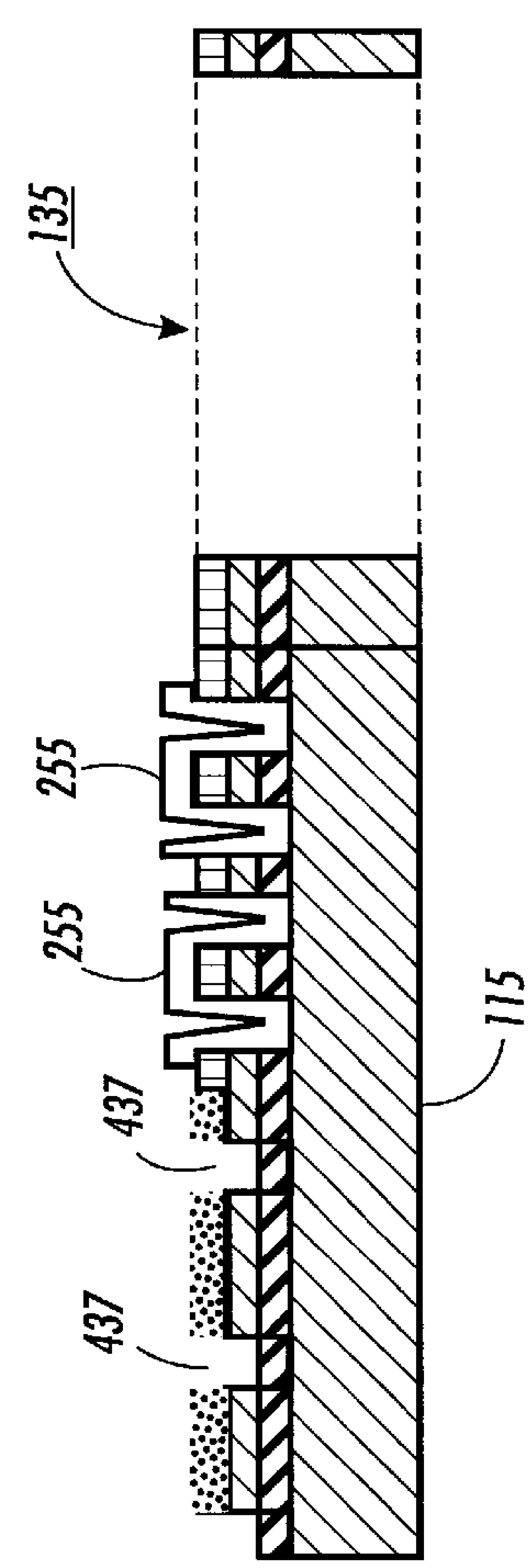

FIG. 4I

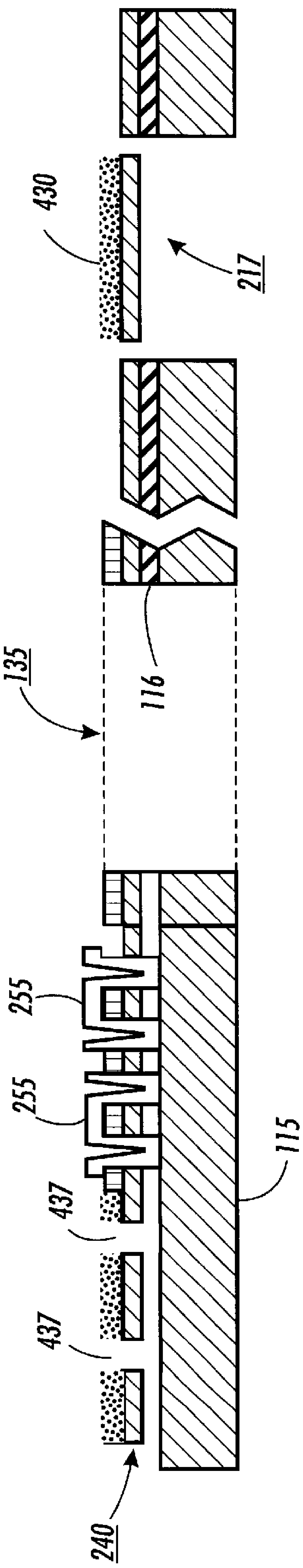

FIG. 4J

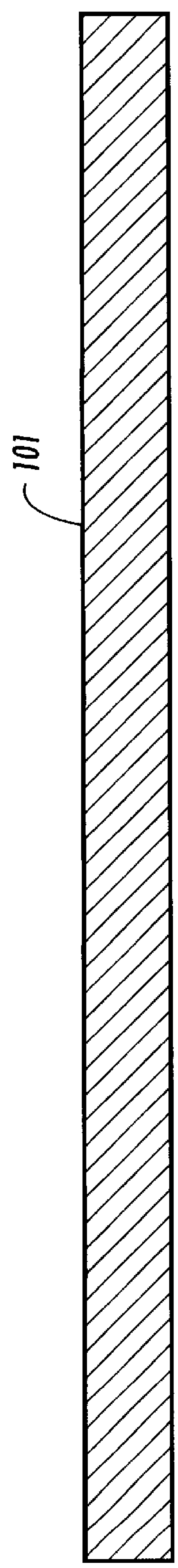

FIG. 5A

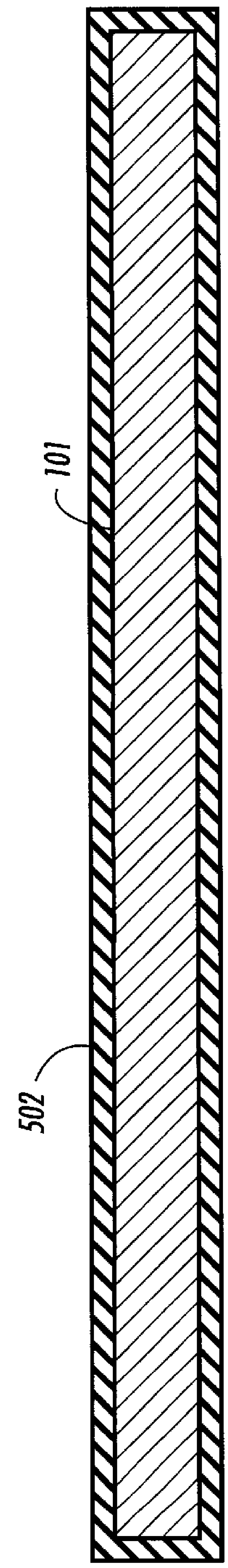

FIG. 5B

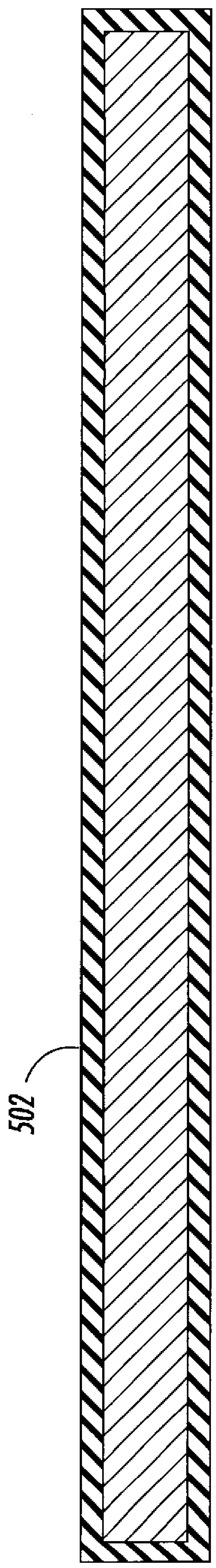

FIG. 5C

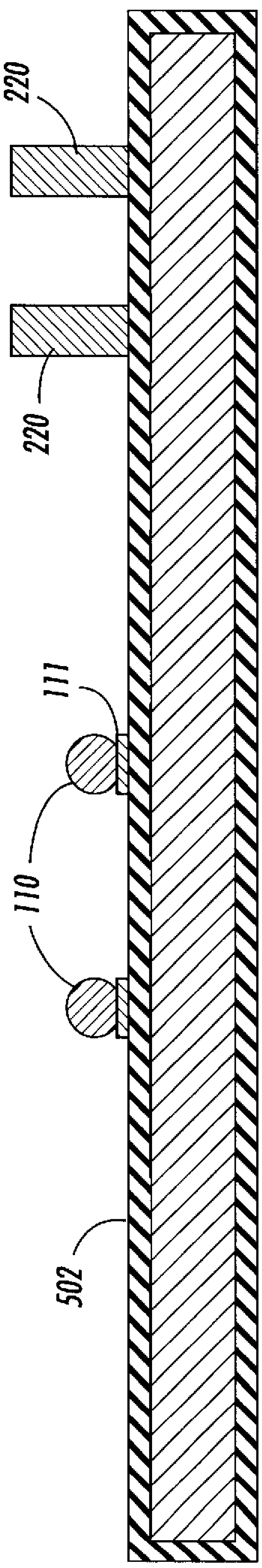

FIG. 5D

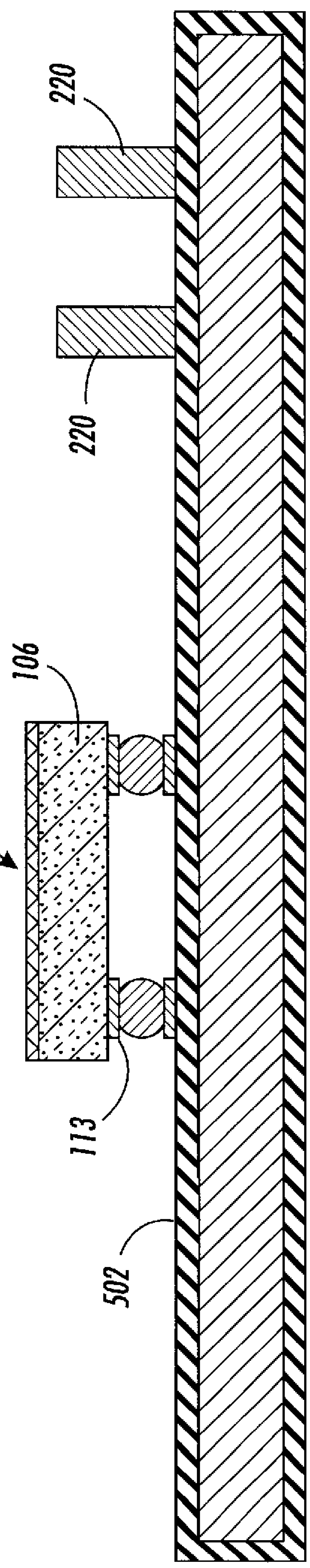

FIG. 5E

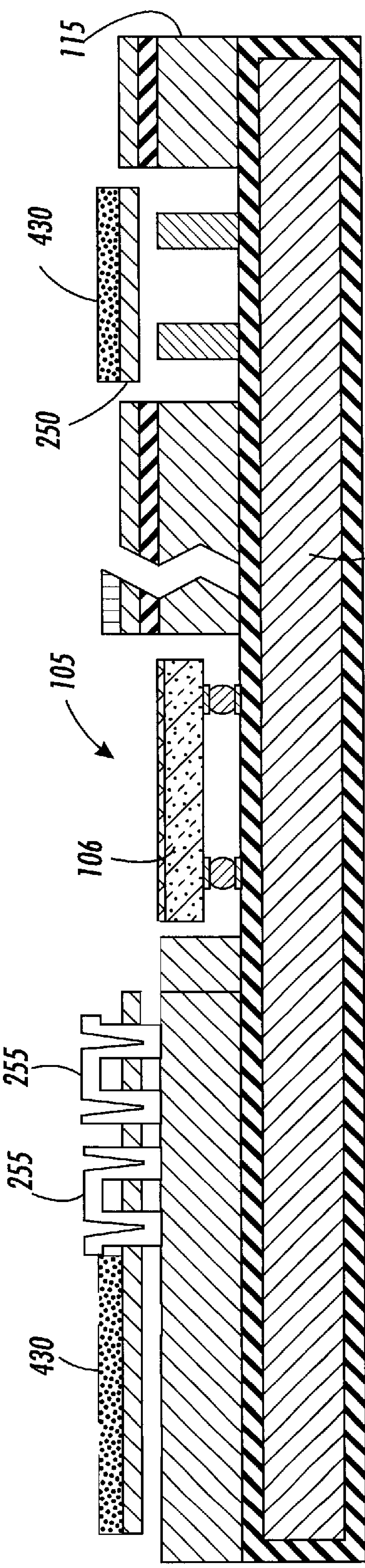

FIG. 6A

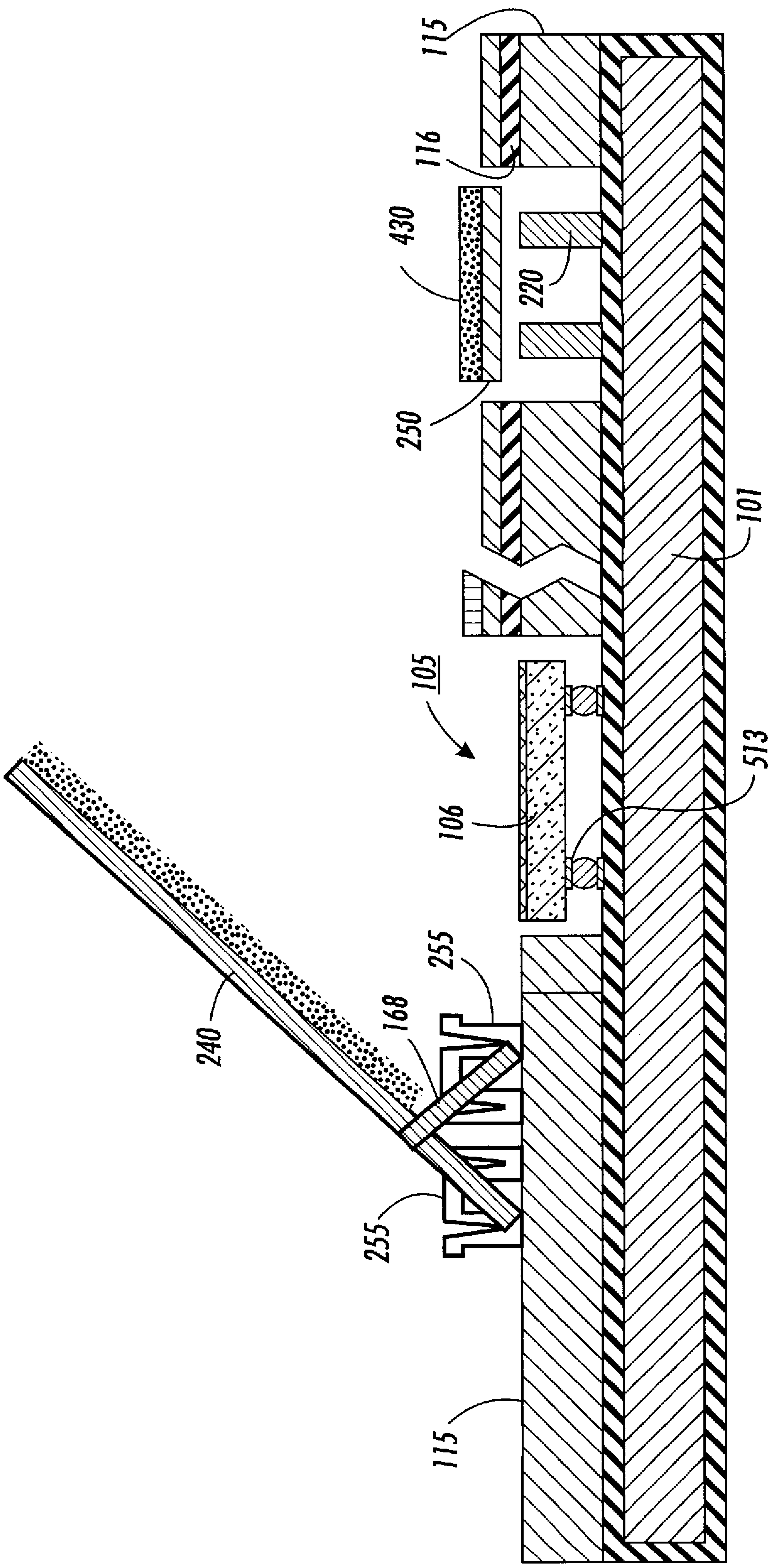

FIG. 6B

METHOD AND APPARATUS FOR AN INTEGRATED LASER BEAM SCANNER USING A CARRIER SUBSTRATE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is related to "METHOD AND APPARATUS FOR AN INTEGRATED LASER BEAM SCANNER" by Floyd, Sun and Kubby (Attorney Docket No. D/98706). Ser. No. 09/201738, filed on the same day and assigned to the same assignee which is hereby incorporated by reference in its entirety.

BACKGROUND AND SUMMARY OF INVENTION

The present invention relates generally to the field of laser beam scanning systems, and more particularly to micro-electro-mechanical systems (MEMS) for laser beam scanning. Miniature laser beam scanning systems are important for applications such as barcode scanning, machine vision and, most importantly, xerographic printing. The use of MEMS to replace standard raster output scanning (ROS) in xerographic print engines allows simplification of printing systems by eliminating macroscopic mechanical components and replacing them with large arrays of scanning elements. Advanced computation and control algorithms are used in managing the large arrays of scanning elements. Such MEMS based printing systems are entirely solid state, reducing complexity, and allowing increased functionality, including compensation of errors or failures in the scanner elements.

An important step in constructing solid state scanning systems is integration of the semiconductor light emitter directly with MEMS actuators to gain the desired optical system simplification. Integrated scanners, which have lasers and scanning mirrors in the same structure, have been demonstrated using manual placement of laser chips onto MEMS wafers with micromachined alignment parts and adhesives by L. Y. Lin et al in Applied Physics Letters, 66, p. 2946, 1995 and by M. J. Daneman et al in Photonics Technology Letters, 8(3), p. 396, 1996. However, current techniques do not allow for wafer-scale integration of the light-emitter and MEMS device.

In accordance with the present invention a laser beam scanner consisting of a single crystal silicon deflection mirror and a torsional mirror is integrated with a laser diode in the same structure. Details of creating a torsional mirror and actuating it magnetically or electrostatically are detailed in U.S. Pat. No. 5,629,790 by Neukermans and Slater which is incorporated herein by reference in its entirety.

Using solder bump bonding methods, completed and tested laser diodes are bonded to a glass or a silicon carrier substrate. The carrier substrate is aligned and bonded to a Si or SOI wafer containing the MEMS layers. Bonding of the lasers to a carrier substrate completely partitions the bonding process from the MEMS. This complete partition eliminates possible conflicts between the conditions needed for solder bump bonding, such as the use of solder flux, and preserves the integrity of the MEMS layers.

The substrates are heated in a non-oxidizing environment to join the two substrates. High surface tension of the solder aligns the wettable metal bonding pads on each substrate with each other. The ability of the reflowed solder to self-align the substrates because of surface tension simplifies assembly.

The use of the SCS layer of a SOI wafer, rather than a polysilicon film provides for the introduction of very flat and smooth mirrors and high reliability torsion bars. The device is scalable to arrays of lasers and scanning mirrors.

Integration of the scanner and light source eliminates the need for external, manual alignment of light sources and scanning mirrors. Simplified post-processing steps such as interconnect metallization can be realized because the use of an etched recess results in nearly planar surfaces. In addition, pick and place technologies used for multi-chip module assembly can be adapted for wafer scale assembly and bonding of light sources to the carrier substrate.

Thus, the present invention allows the integration of lasers, electrical interconnects, and electrodes on a single glass or Si wafer for actuation of MEMS devices. The glass or Si wafer is aligned and bonded to the MEMS wafer, forming an integrated, three dimensional structure.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained and understood by referring to the following detailed description and the accompanying drawings in which like reference numerals denote like elements as between the various drawings. The drawings, briefly described below, are not to scale.

FIG. **1** is shows MEMS layers and VCSEL for a laser beam scanner in accordance with an embodiment of this invention.

FIG. **2**a shows a laser beam scanner with optical path having an electrostatically actuated torsion mirror in accordance with an embodiment of this invention.

FIG. **2**b shows a top view a laser beam scanner in accordance with an embodiment of this invention.

FIG. **3**a shows a laser beam scanner with optical path having a magnetically actuated torsion mirror in accordance with an embodiment of this invention.

FIG. **3**b shows a laser beam scanner with optical path having a magnetically actuated torsion mirror using an external magnetic field in accordance with an embodiment of this invention.

FIGS. **4**a–**4**j show process steps for fabricating MEMS components in accordance with an embodiment of this invention.

FIGS. **5**a–**5**e show steps for fabricating substrate containing laser die and mirror actuation electrodes in accordance with an embodiment of this invention

FIG. **6**a shows a completed laser beam scanner before release of deflecting mirror in accordance with an embodiment of this invention.

FIG. **6**b shows a completed integrated solid state scanner after release of deflecting mirror in accordance with an embodiment of this invention.

DETAILED DESCRIPTION

An embodiment in accordance with the present invention is shown in FIG. **1** and FIG. **2**a. A laser beam scanner consisting of single crystal silicon (SCS) deflecting mirror **240** and torsional mirror **250** is integrated with laser diode or light emitting diode **105**. Using solder bump bonding methods, completed and tested laser diodes **105** are bonded to glass or silicon carrier substrate **101**. Carrier substrate **101** is aligned and bonded to MEMS substrate **130** containing the MEMS layers. Bonding of laser diode **105** to carrier substrate **101** completely partitions the bonding process from the MEMS layers. This complete partition eliminates possible conflicts between the conditions needed for solder bump bonding, such as the use of solder flux, and preserves the integrity of the MEMS layers. Typically, solders such as Pb/Sn, Au/Sn, or In/Sn are evaporated selectively onto wettable metal bonding pads **111** onto substrate **101** and reflowed to form hemispherical solder bumps **110**. Solder bumps **110** are contacted to wettable metal bonding pads **113** on laser substrate **106**.

Laser substrate **106** and carrier substrate **101** are heated in a non-oxidizing environment to join the respective substrates together. High surface tension of the solder aligns wettable metal bonding pads **11 1** with wettable metal bonding pads **113** on laser substrate **106**. The ability of the reflowed solder to self-align laser substrate **106** with carrier substrate **101** because of surface tension simplifies the assembly process. Additionally, very little pressure is required during the process of bonding laser substrate **106** to carrier substrate **101**.

Micromechanical elements (MEMS) are formed on MEMS substrate **130**, typically about 500 μm thick using conventional photolithography and the patterning of single crystal silicon (SCS) layer **118**, polysilicon layers **117** and insulating oxide layers **116**, which are typically PSG or thermal oxide, is performed using both dry and wet etching techniques. MEMS substrate **130** embodies SCS layer **118**, insulating oxide layer **116** and silicon substrate **115**. Typical thickness for each of layers **116**, **117**, and **118** is on the order of several μm. VCSEL (vertical cavity surface emitting laser) **105** is solder bump **110** bonded to glass or dielectric-coated (typically SiO_2 or Si_3N_4 coated) Si substrate **101**, typically about 500 μm thick. Additionally, two actuation electrodes **220** and two interconnects **125** are formed on glass or dielectric-coated Si substrate **101**. Interconnects **125** provide current to substrate **101** to power VCSEL **105** and to electrodes **220** for control of torsional mirror **250**. After solder bonding of VCSEL **105** to glass or dielectric-coated Si substrate **101**, substrate **101** is aligned and bonded to MEMS substrate **130**.

MEMS substrate **130** has deep reactive ion etching (RIE) and/or wet etched hole **135**, typically 3 mm in diameter, for emitted light **299** (see FIG. **2**a) to pass through MEMS substrate **130** and onto deflecting mirror **240**. Deflecting mirror **240** reflects emitted light **299** onto torsional mirror **250**. As shown in FIG. **2**a, polysilicon hinge **255** attaches deflecting mirror **240** to MEMS substrate **130**. Deflecting mirror **240** is etched from SCS layer **118**. Polysilicon hinge **255** allows deflecting mirror **240** to rotate clockwise about an axis perpendicular to the plane of FIG. **2**a, out of MEMS substrate **130** to the position above via **135** as shown in FIG. **2**a. Deflecting mirror **240** is supported by support latch **268** controlled by a spring and latch assembly (not shown) in the manner described in the paper by Lin et al. in Photonics Technology Letters, 6(12), p. 1445, 1994 which is incorporated herein in its entirety by reference. Controlling the position and length of support latch **268** allows the angle of deflecting mirror **240** to be precisely fixed. Deflection of torsional mirror **250** in both directions is accomplished by charging alternately one of two actuator electrodes **220**. Torsional mirror **250** is electrically grounded and attracted to charged one of two actuator electrodes **220**.

FIG. **2**b shows a top view of one combination deflection mirror/torsional mirror solid state element. Polysilicon hinges **255** and deflecting mirror **240** are shown along with hole **265** to receive the tab (not shown) on support latch **268**. The layout of torsional mirror **250** supported by torsion bar **270** with respect to hole **217** is also shown.

MEMS components such as deflecting mirror **240** and torsional mirror **250** can be formed in MEMS substrate **130** by using a combination of well-known surface and bulk micro-machining techniques. Polysilicon hinges **255** may be formed as described by M. C. Wu, "Micromachining for Optical and Optoelectronic Systems," Proceedings of IEEE, Vol. 85, p. 1833, 1997 and by Pister et al., "Microfabricated Hinges," Sensors and Actuators, A: Physical v. 33 n. 3 pp. 249–256, June 1992 which are hereby incorporated by reference in their entirety.

As seen in FIG. **1**, bonding of VCSEL **105** to glass or SiO_2 coated Si substrate **101** completely separates the bonding process from the MEMS components. The separation eliminates possible conflicts between conditions needed for solder bump bonding, such as the use of solder flux and the integrity of the MEMS layers. Full wafer bonding of glass or dielectric-coated Si substrate **101** to MEMS substrate **130** is done at low temperature to avoid damage to VCSEL **105**. Metallization on glass or dielectric-coated Si substrate **101** is achieved by use of adhesive bonding techniques requiring temperatures of between 20° C.–100° C.

Another embodiment in accordance with the present invention is shown in FIG. **3**A. VCSEL (vertical cavity surface emitting laser) **105** is solder bump **110** bonded to glass or dielectric-coated Si substrate **101**. Glass or dielectric-coated Si substrate **101** is aligned and bonded to MEMS substrate **130**. MEMS substrate **130** has deep RIE and/or wet etched via **135** for emitted light **199** to pass through the surface of MEMS substrate **130** and onto deflecting mirror **240** which reflects emitted light **299** onto torsional mirror **250**. Torsional mirror **250** contains ferromagnetic thin film **330** with magnetization in the plane of torsional mirror **250**. Coil **380** on glass or dielectric-coated Si substrate **101** generates magnetic field **391** perpendicular to the magnetic field created by ferromagnetic thin film **330** contained on torsional mirror **250**. Hence, actuation of coil **380** turns torsional mirror **250**. Polysilicon hinge **255** attaches deflecting mirror **240** to MEMS substrate **130**. Polysilicon hinge **255** allows deflecting mirror **240** to rotate clockwise about an axis perpendicular to the plane of FIG. **3**a, out of MEMS substrate **130** to a position above via **135** as shown in FIG. **3**a. Deflecting mirror **240** can be supported by support latch **268** controlled by a spring and latch assembly (not shown) in the manner shown by Lin et al. in Photonics Technology Letters, 6(12), p. 1445, 1994 and incorporated herein in its entirety by reference. Fixing the position and length of support latch **268** allows the angle of deflecting mirror **240** to be precisely fixed.

FIG. **3**b shows an embodiment in accordance with this invention wherein torsional mirror **250** contains microfabricated coil **350** generating magnetic field **385** perpendicular to torsional mirror **250** but is otherwise similar to FIG. **3**a. Coil **350** is a conductive loop which may be formed by vapor depositing conductive material onto torsional mirror **250** and patterning into coil **350**. External magnetic field **370** is applied parallel to the plane of torsional mirror **250** to turn torsional mirror **250**. Application of current to coil **350** results in an angular deflection of torsional mirror **250** proportional to the current introduced into coil **350**. Hence, coil **350** behaves like a galvanometer coil. Direction of current flow in coil **350** determines the direction of the angular deflection of torsional mirror **250**.

Steps for fabricating deflecting mirror, supporting latch and VCSEL in accordance with this invention are shown in

FIGS. **4**a–**4**j and FIGS. **5**a–**5**e. The starting material is MEMS substrate **130** which comprises a silicon on insulator material (SOI). MEMS substrate **130** includes silicon substrate **115**, thermally-grown SiO_2 layer **116** bonded to wafer **113**. MEMS substrate **130** is then thinned to the required thickness. MEMS substrates **130** are commercially available from, for example, Bondtronix, Inc. of Alamo, Calif. or Ibis Technology Corporation of Danvers, Mass. Typical thickness of SCS layer **118** is 2–20 μm depending on the required stiffness of the torsional spring elements and mirror surfaces to be constructed. Other MEMS layers are deposited on top of MEMS substrate **130** by well-known methods such as low pressure chemical vapor deposition (LPCVD). These MEMS layers include mechanical layers of polycrystalline silicon (polysilicon) **117** (not shown in FIGS. **4**) and sacrificial oxide layer **119** that is phosphorus-doped glass (PSG). The embodiment in FIG. **[4a]** *4c* has PSG layer **119** deposited directly on top of SCS layer **[114]** *118*. Polysilicon layer **117** (see FIG. **1**) is subsequently deposited on PSG layer **119**. Typical thicknesses for polysilicon layer **117** and PSG layer **119** are 1–2 μm.

Formation of MEMS elements occurs by conventional photolithography and patterning of SCS layer **[114]** *118*, polysilicon layer **117**, and PSG layer **119** is performed using both wet and dry etching. In accordance with an embodiment of this invention, deflecting mirror **240** and deep recess **135** are required.

FIGS. **4**a–**4**j show steps for fabricating deflecting mirror **240**, torsional mirror **250**, supporting latch **268**, and deep recesses **135** and **217**. Latch **268** has a tab (not shown) which inserts into corresponding hole **165** in the bottom of deflecting mirror **240**. The final configuration of deflecting mirror **240** and latch **255** are shown in FIG. **6**b. Typical sizes for deflecting mirror **240** are between 0.5 mm^2 to 1 mm^2.

FIG. **4**a has silicon nitride (SiN_x) deposited on substrate **130** using LPCVD. SiN_x layer (not shown) is patterned using CF_4/O_2 RIE with a photoresist mask. Potassium hydroxide (KOH) is used to etch holes from the bottom of substrate **115**, stopping on layer **116**. Size of hole **217** is similar to torsional mirror **250** to allow free rotation. Hole **135** is simultaneously etched, for fitting VCSEL **105** which typically has dimensions of 500 μm by 500 μm. Alternatively, holes **217** and **135** may be defined by deep RIE using C_4F_8 and SF_6 with a mask of SiN_x or photoresist.

FIG. **4**b shows recess **135** (200–250 μm deep) etched into MEMS substrate **130** using a combination of CF_4/O_2 RIE for etching SCS layer **[114]** *118* and insulator layer **116** and a deep RIE of recess **135** using C_4F_8 and SF_6.

FIG. **4**c shows CVD deposition of PSG layer **119**.

FIG. **4**d shows the wet etch of windows **410** into PSG layer **119** down to SCS layer **[114]** *118*.

FIG. **4**e shows deposition of aluminum film **430** (typically 0.1–0.2 μm thick) as a high reflectivity layer.

FIG. **4**f shows a wet etch (typically a mixture of phosphoric and nitric acid) of aluminum film **430** to remove aluminum in all but the mirror regions. The mirror region locations coincide with the locations of windows **410**.

FIG. **4**g shows the etch of vias **433** using CF_4/O_2 RIE with a photoresist mask. This step also serves to open laser die window **135**.

FIG. **4**h shows formation of hinges **255** for deflecting mirror **240** from polysilicon layer **117** (not shown, see FIG. **1**) that is deposited in this step.

FIG. **4**i shows etch of PSG layer **119** and SCS layer **[114]** *118* to pattern deflecting mirror **240**, hinges **255** and access holes **437**. A typical size for access holes **437** is 10 μm by 10 μm. Access holes **437** allow for the etchant used to release deflecting mirror **240** to reach insulating layer **116**. Deflecting mirror **240** size is typically from 1 mm^2–2 mm^2. Torsional mirror **250** is also defined in this step.

FIG. **4**j shows release of deflecting mirror **240**, torsional mirror **250** and hinge **255** by etching PSG layer **119** and layer **116** using an HF based etch.

FIGS. **5**a–e show the steps used to fabricate wafer **103** containing VCSEL **105** and mirror actuation electrodes **220** in accordance with an embodiment of this invention.

FIG. **5**a shows starting glass or silicon substrate **101** for fabrication of wafer **103**.

FIG. **5**b shows deposition of silicon nitride or silicon dioxide layer **502** by LPCVD or plasma-enhanced CVD process to provide electrical isolation from silicon substrate **101**.

FIG. **5**c shows deposition of electrodes **220** and solder for solder bumps **110**.

FIG. **5**d shows completed deposition of electrodes **220** for mirror actuation. Electrodes **220** are much thicker ~200–300 μm) than solder bumps **110** (typically 50–100 μm) and are electroplated.

FIG. **5**e shows alignment and solder bump bonding of VCSEL **105** to Si substrate **101** in the GaAs bonding step. Solder bumps **110** can be defined on metal bonding pads **113** of VCSEL substrate **106**. Si substrate **101** and VCSEL substrate **106** are heated to allow solder to flow and contact wettable metal bonding pads **111** on Si substrate **101**.

FIG. **6**a shows integration of substrate **101** with MEMS substrate **130** using well-known procedures of adhesive bonding while FIG. **6**b shows the finished assembly with raised deflecting mirror **240** locked into place with latch **168**.

Linear arrays of lasers can be bonded in a similar way; the extent of the array being perpendicular to the cross section shown in FIG. **6**a.

While the invention has been described in conjunction with specific embodiments, it is evident to those skilled in the art that many alternatives, modifications, and variations will be apparent in light of the foregoing description. Accordingly, the invention is intended to embrace all such alternatives, modifications, and variations that fall within the spirit and scope of the appended claims.

What is claimed is:

1. An integrated laser beam scanning structure comprising:

a first wafer having a first surface and a second surface, said wafer having a recess piercing said first surface and said second surface;

a layer having a first region and a second region, said layer being attached to said first surface;

a deflecting mirror fashioned from said first region of said layer;

a torsional mirror fashioned from said second region of said layer;

a second wafer having a first side; and

a light source mounted on said first side of said second wafer, said first side of said second wafer being attached to said second surface of said first wafer such that said light source occupies said recess

whereby a light beam emitted from said light source is deflected by said deflecting mirror onto said torsional mirror.

2. The structure of claim **1** wherein said first wafer is a silicon on oxide wafer.

3. The structure of claim **1** wherein said layer is a single crystal silicon layer.

4. The structure of claim **1** wherein said light source is a semiconductor light emitter.

5. The structure of claim **4** wherein said semiconductor light emitter is mounted on said first side of said second wafer using solder bumps.

6. The structure of claim **4** wherein said semiconductor light emitter is a VCSEL chip.

7. The structure of claim **1** wherein said recess is deep reactive ion etched.

8. The structure of claim **1** wherein said torsional mirror is actuated by a pair of electrodes.

9. The structure of claim **1** wherein said torsional mirror is actuated by a thin film coil.

10. The structure of claim **1** wherein a ferromagnetic thin film coil is attached to said torsional mirror.

11. The structure of claim **1** wherein a thin film coil is attached to said torsional mirror.

12. A method for making an integrated laser beam scanner comprising the steps of:

providing a first wafer having a first surface and a second surface, said wafer having a recess piercing said first surface and said second surface;

attaching a layer having a first region and a second region to said first surface of said first wafer;

fashioning a deflecting mirror from said first region of said layer;

fashioning a torsional mirror from said second region of said layer;

providing a second wafer having a first side, said second wafer having a light source mounted on said first side; and

attaching said first side of said second wafer to said second surface of said first wafer such that said light source occupies said recess

whereby a light beam emitted from said light source is deflected by said deflecting mirror onto said torsional mirror.

13. The method of claim **12** wherein said layer is a single crystalline silicon layer.

14. The method of claim **12** wherein said light source is a semiconductor light emitter.

15. The method of claim **14** wherein said semiconductor light emitter is a VCSEL chip.

16. The method of claim **14** wherein said semiconductor light emitter is mounted using solder bumps.

17. The method of claim **12** wherein said torsional mirror is actuated by a pair of electrodes.

18. The method of claim **12** wherein said torsional mirror is actuated by a thin film coil and an external magnetic field.

19. The method of claim **12** wherein a ferromagnetic thin film coil is attached to said torsional mirror.

20. The method of claim **12** wherein a thin film coil is attached to said torsional mirror.

21. A MEMS formation method including:

providing a single crystal silicon layer;

forming at least one first MEMS component by patterning the single crystal silicon layer;

depositing at least one layer of polysilicon on the patterned single crystal silicon; and

forming at least one second MEMS component by patterning the polysilicon.

22. The method of claim 21 wherein the single crystal silicon layer is bonded to an insulator layer in a SOI wafer and providing a single crystal silicon layer comprises providing a SOI wafer.

23. The method of claim 21 wherein the at least one second MEMS component is a hinge.

24. The method of claim 23 wherein the at least one first MEMS component is a mirror retained by the hinge.

25. The method of claim 21 wherein depositing at least one layer of polysilicon includes chemical vapor deposition.

26. The method of claim 21 wherein forming at least one first MEMS component includes forming a deflecting mirror.

27. A MEMS formation method including:

providing a single crystal silicon layer;

forming at least one first MEMS component by patterning the single crystal silicon layer;

depositing at least one layer of polysilicon on the patterned single crystal silicon; and

forming at least one second MEMS component by patterning the polysilicon, the at least one second MEMS component including a hinge retaining a deflecting mirror.

28. The method of claim 27 wherein forming at least one first MEMS component further includes forming a torsional mirror, and the method further comprises forming a recess in the single crystal silicon layer and directing a light beam through the recess at the deflecting mirror so that the deflecting mirror deflects light to the torsional mirror.

29. A MEMS device comprising:

at least one single crystal silicon component; and

a hinge derived from a layer of polysilicon applied over the at least one single crystal silicon component.

30. The MEMS device of claim 29 wherein the at least one single crystal silicon component is bonded to an insulator that rests on a handle wafer as a result of being formed from a single crystal silicon layer of a SOI wafer.

31. The MEMS device of claim 29 wherein the at least one single crystal silicon component comprises a deflecting mirror.

32. The MEMS device of claim 31 wherein the hinge retains the deflecting mirror.

33. The MEMS device of claim 29 wherein the at least one single crystal silicon component comprises a torsional mirror.

34. A MEMS device comprising:

at least one single crystal silicon component;

at least one polysilicon component derived from a layer of polysilicon applied over the at least one single crystalline silicon component; and

a semiconductor light emitter mounted on a substrate bonded to a supporting structure of the at least one single crystal silicon component and oriented to emit a light beam at the at least one single crystal silicon component.

35. The MEMS device of claim 34 wherein the at least one single crystal silicon component is bonded to an insulator as a result of having been formed from a single crystal silicon layer of an SOI wafer to which the semiconductor light emitter substrate is bonded.

36. The MEMS device of claim 35 wherein the SOI wafer includes a recess into which the semiconductor light emitter projects.

37. The MEMS device of claim 34 wherein the at least one single crystal silicon component comprises a deflecting mirror at which the light beam is directed and a torsional mirror to which the deflecting mirror deflects the light beam, and the at least one polysilicon component comprises a hinge retaining the deflecting mirror.

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