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Potter

(10) **Patent No.: US 7,280,014 B2**
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(54) **MICRO-ELECTRO-MECHANICAL SWITCH AND A METHOD OF USING AND MAKING THEREOF**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 240 days.

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(51) **Int. Cl.**
H01H 51/22 (2006.01)

(52) **U.S. Cl.** **335/78**; 200/181

(58) **Field of Classification Search** 335/78; 200/181

See application file for complete search history.

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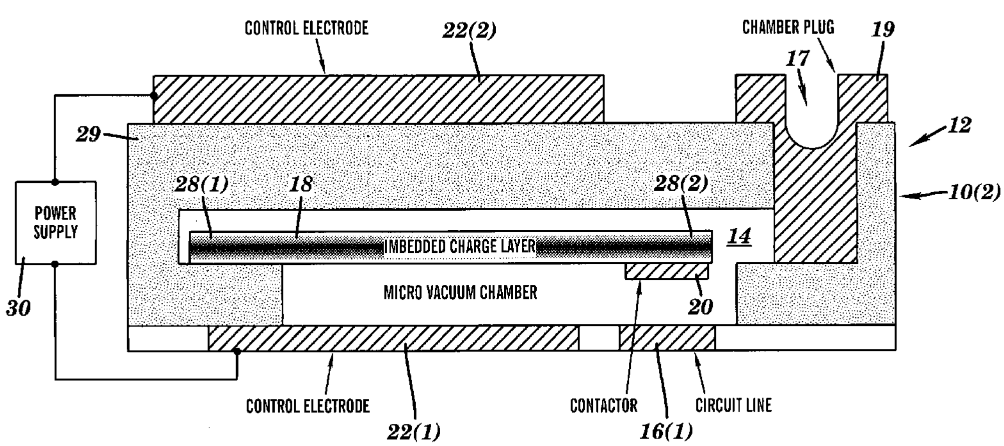
(57) **ABSTRACT**

A micro-electro-mechanical switch includes at least one portion of a conductive line in the chamber, a beam with imbedded charge, and control electrodes. The beam has a conductive section which is positioned in substantial alignment with the at least one portion of the conductive line. The conductive section of the beam has an open position spaced away from the at least one portion of the conductive line and a closed position on the at least one portion of the conductive line. Each of the control electrodes is spaced away from an opposing side of the beam to control movement of the beam.

22 Claims, 15 Drawing Sheets



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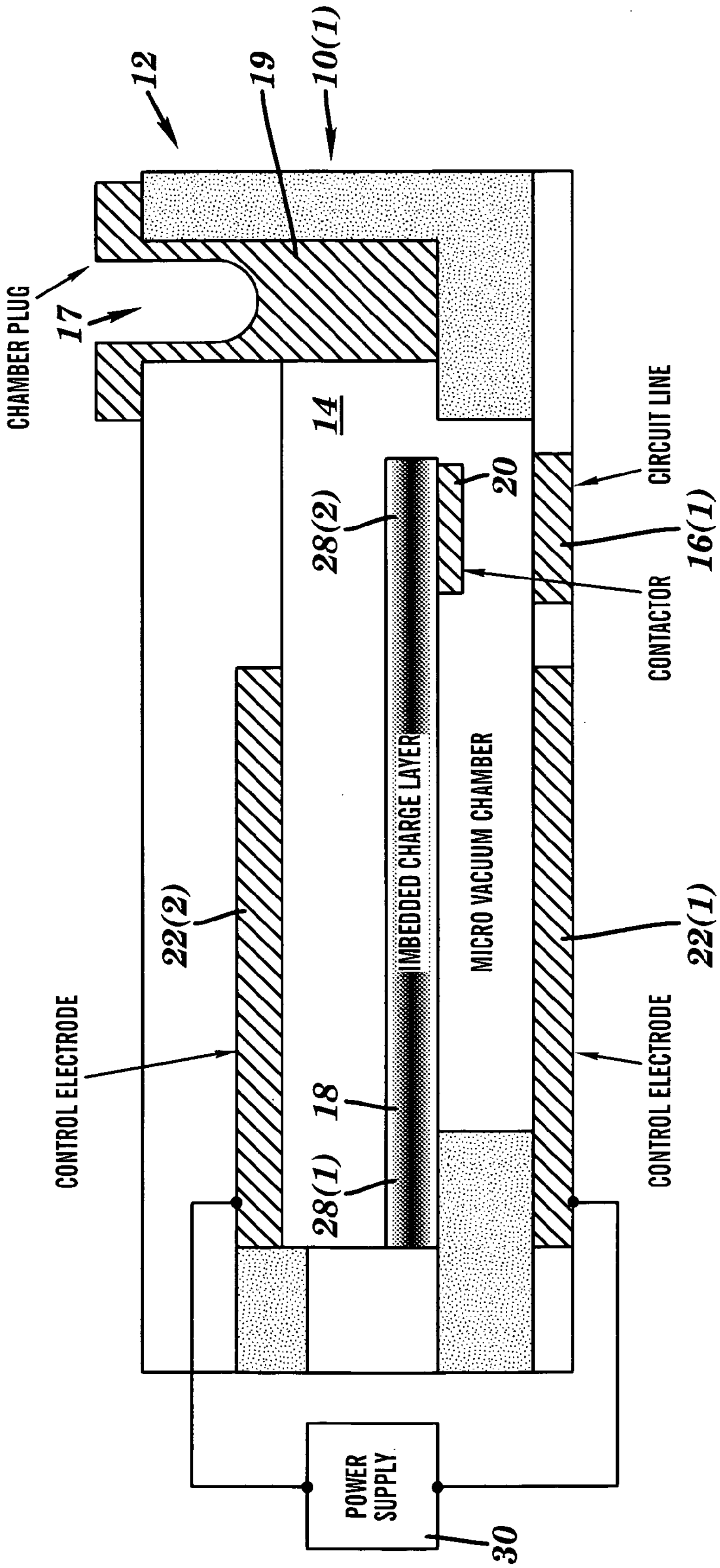
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28(2)
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CONTACTOR
IMBEDDED CHARGE LAYER
MICRO VACUUM CHAMBER
22(2)
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CONTROL ELECTRODE
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POWER SUPPLY
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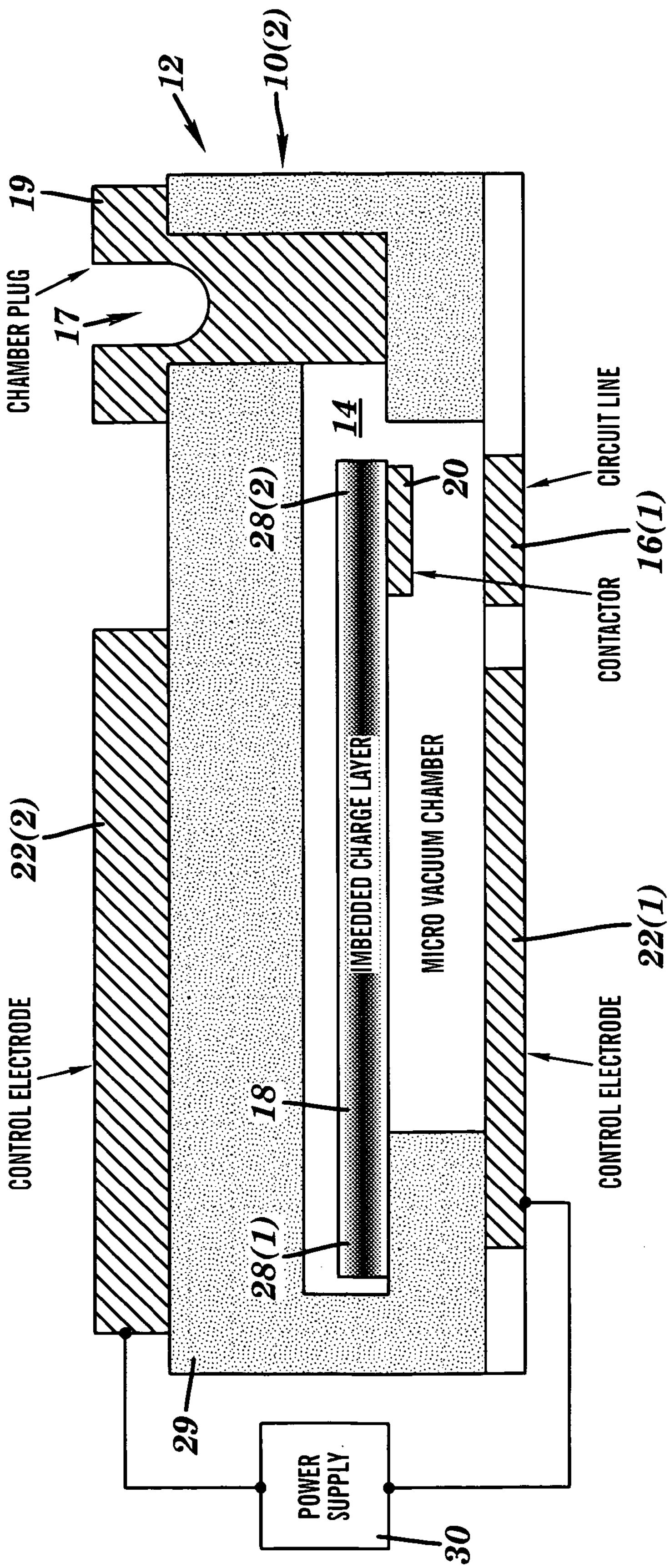
FIG. 1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MICRO VACUUM CHAMBER
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CONTROL ELECTRODE
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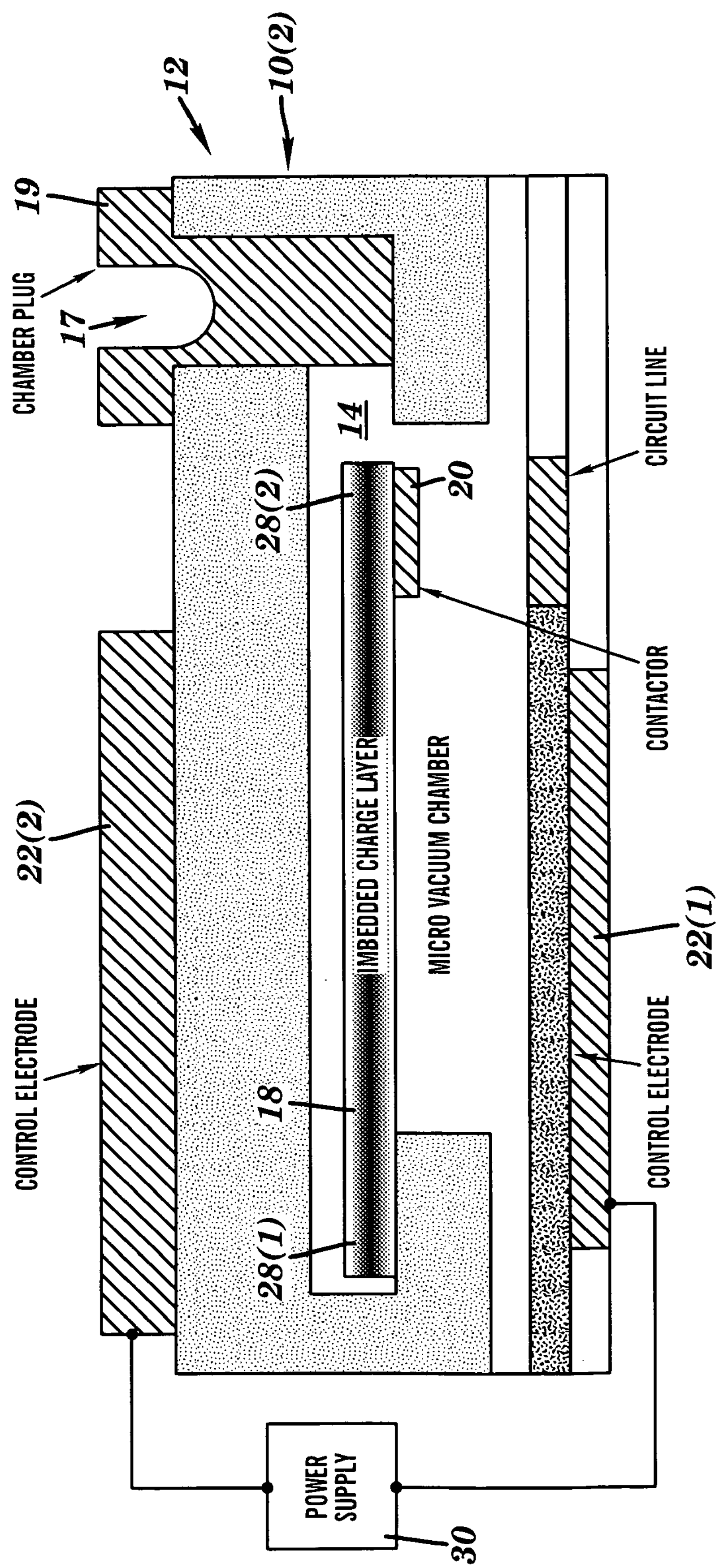
FIG. 2A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POWER SUPPLY
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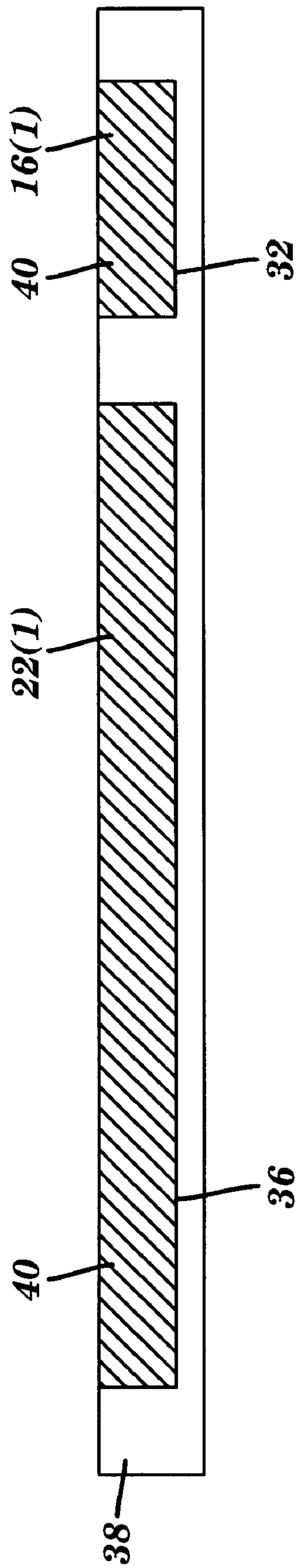
FIG. 2B



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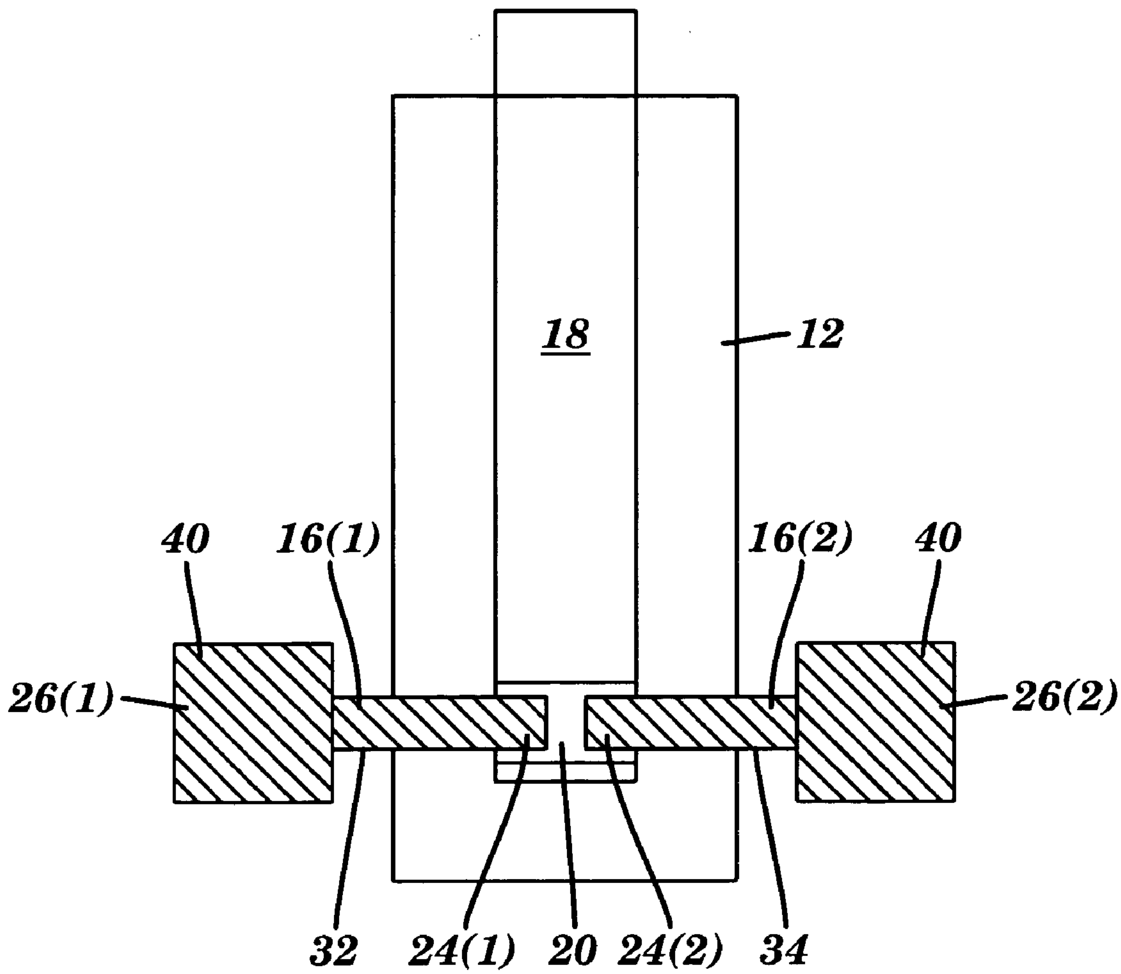

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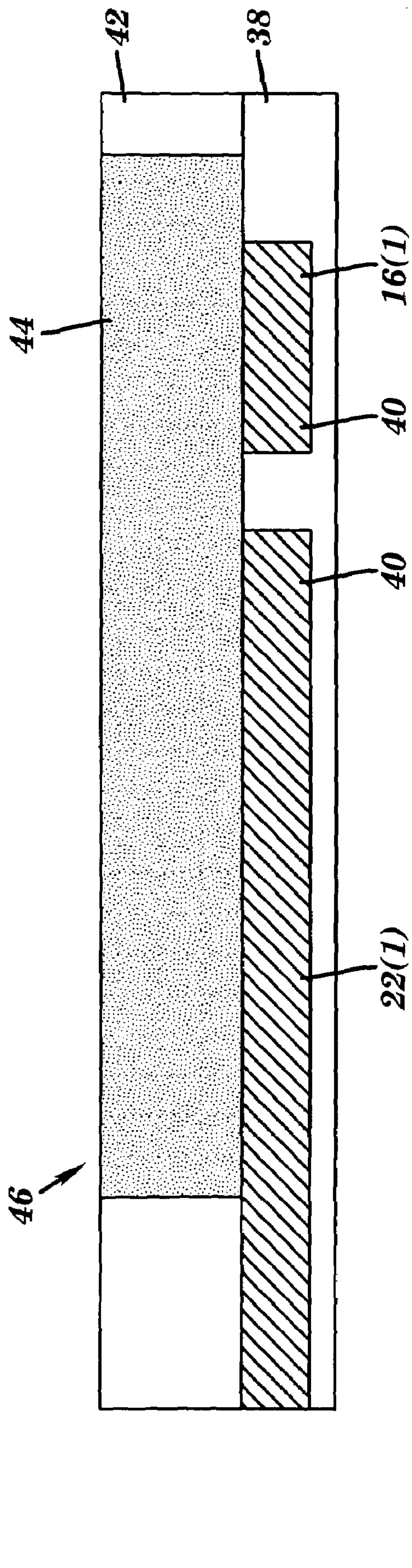

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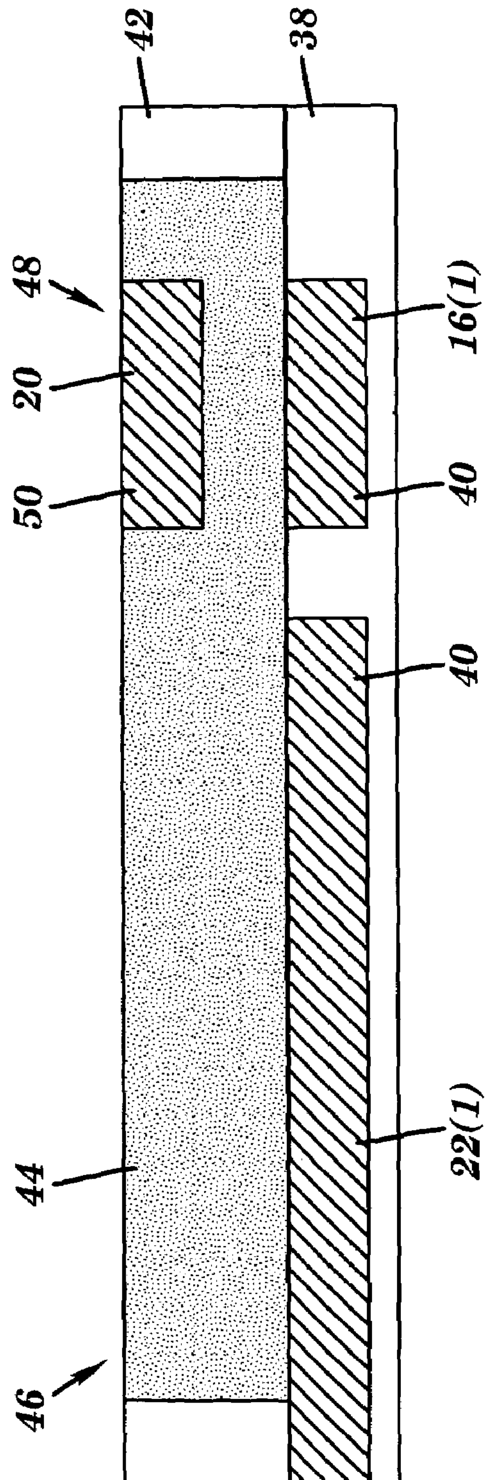

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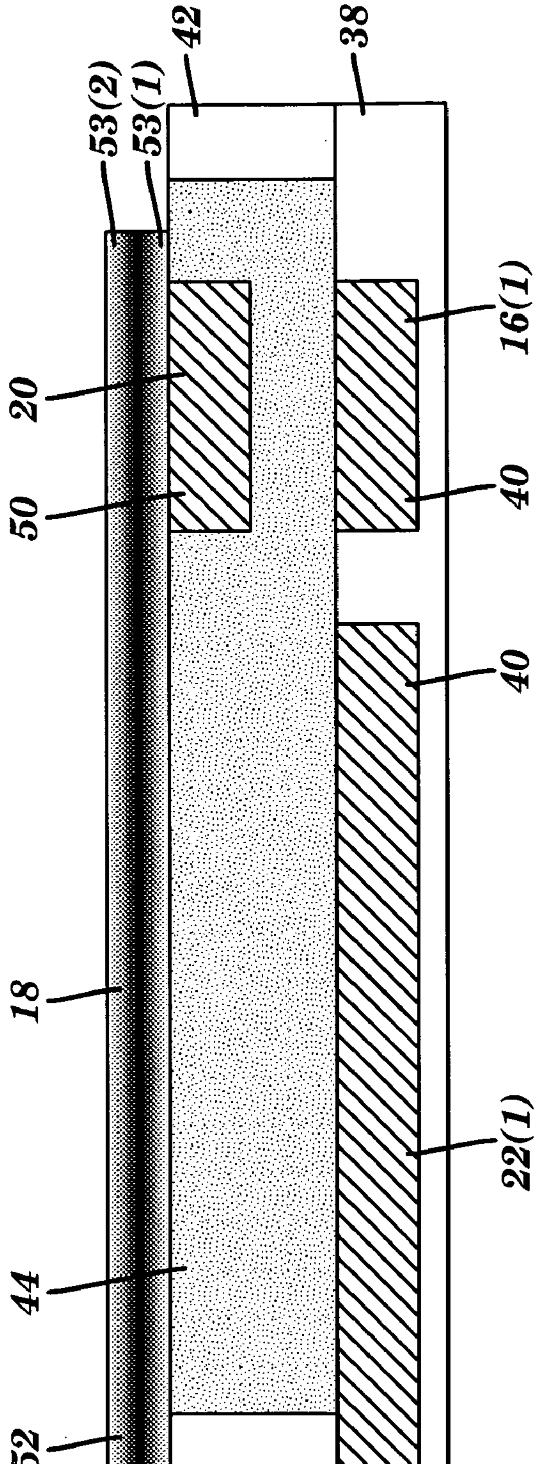

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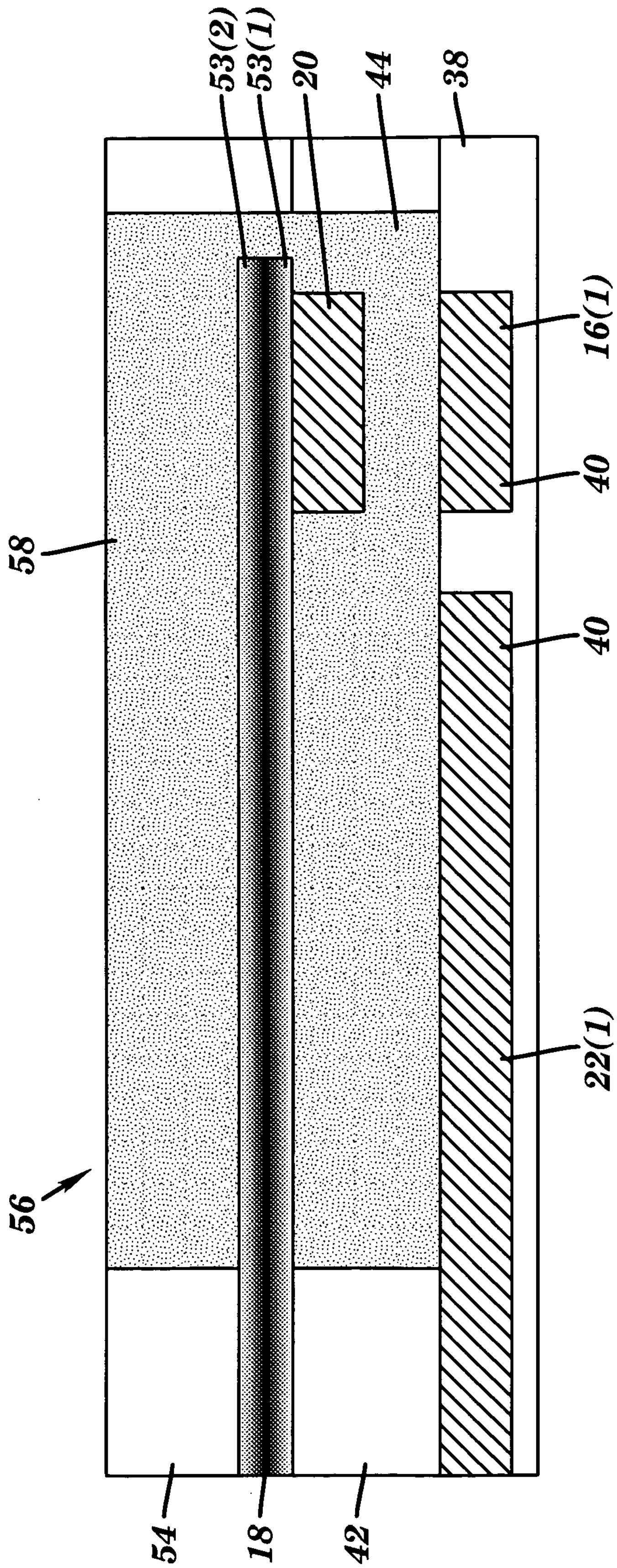


FIG. 8

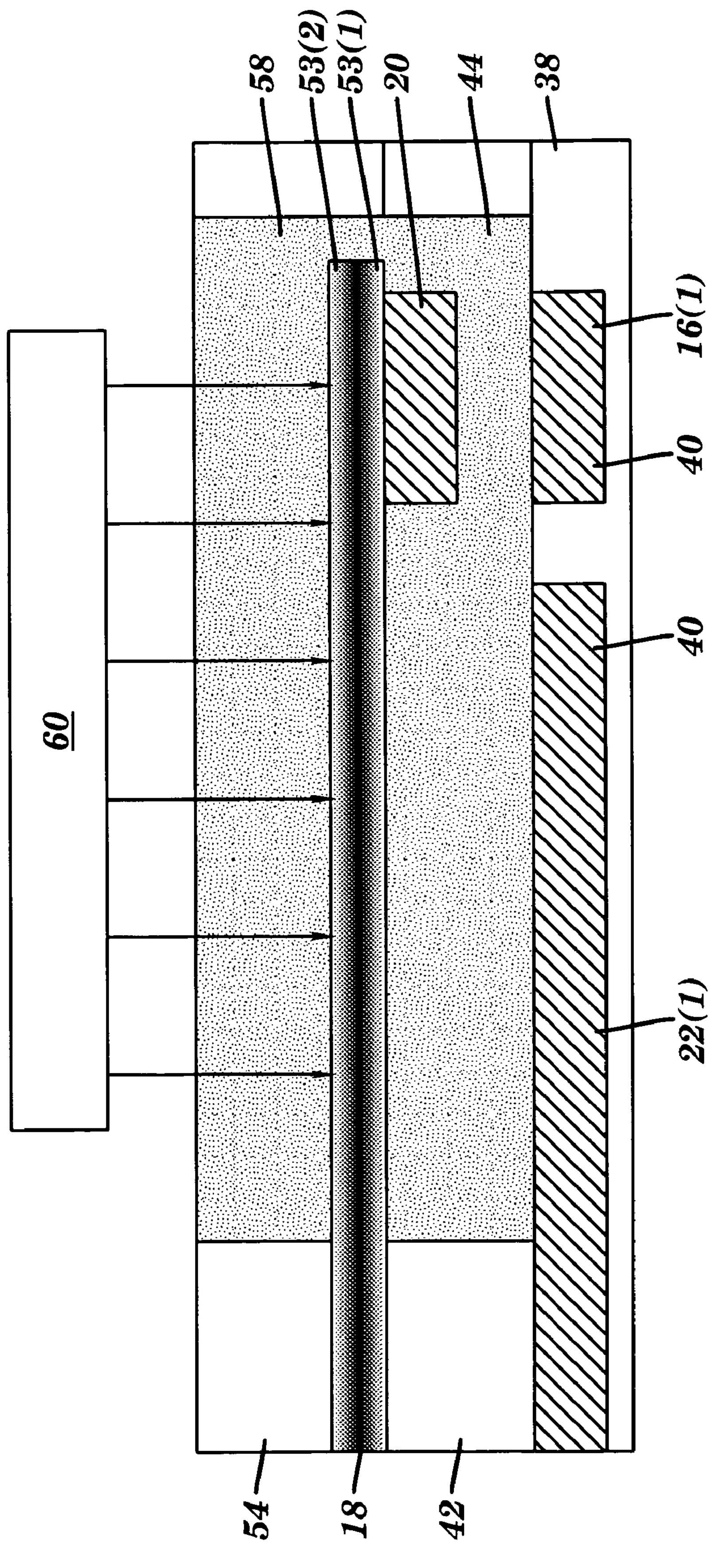
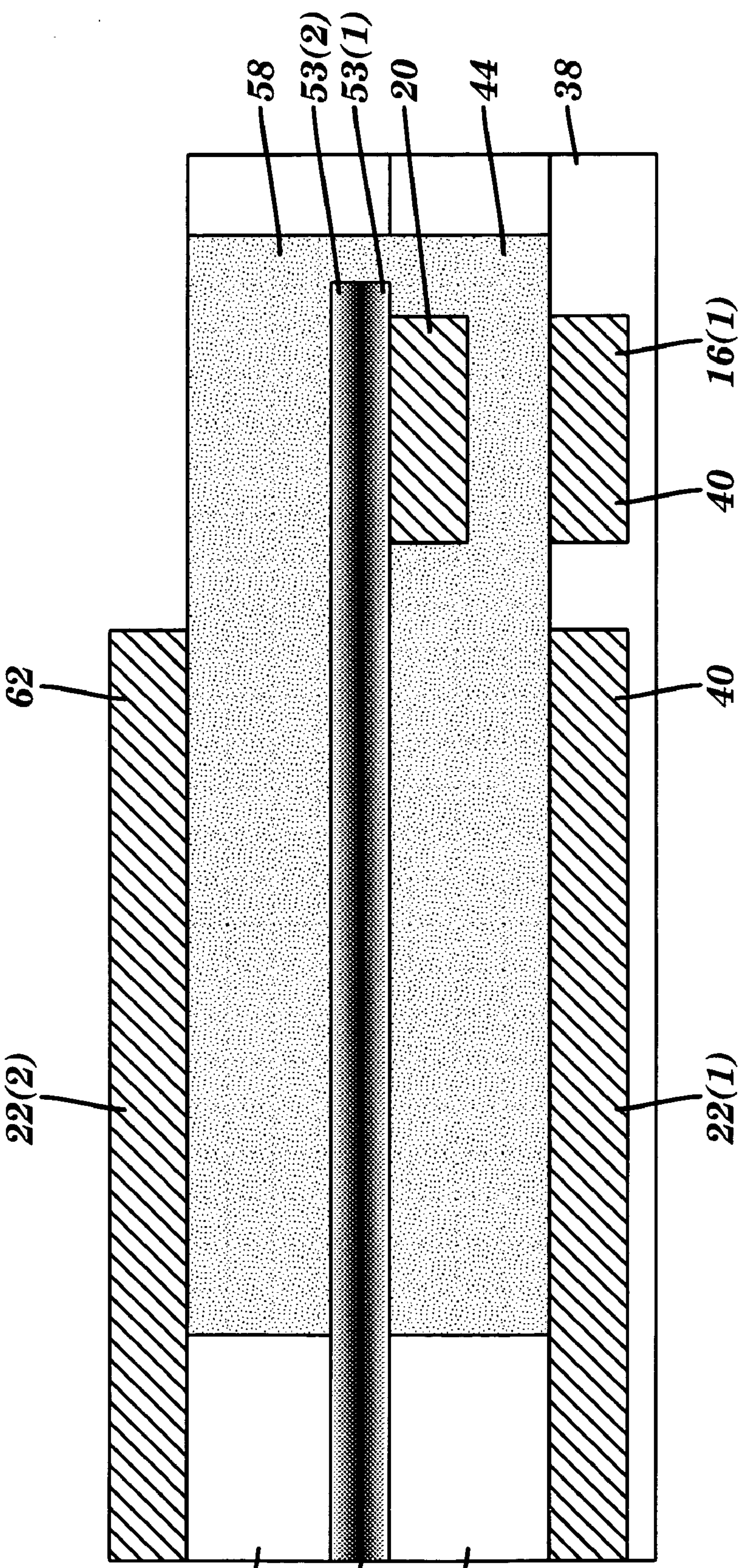


FIG. 9



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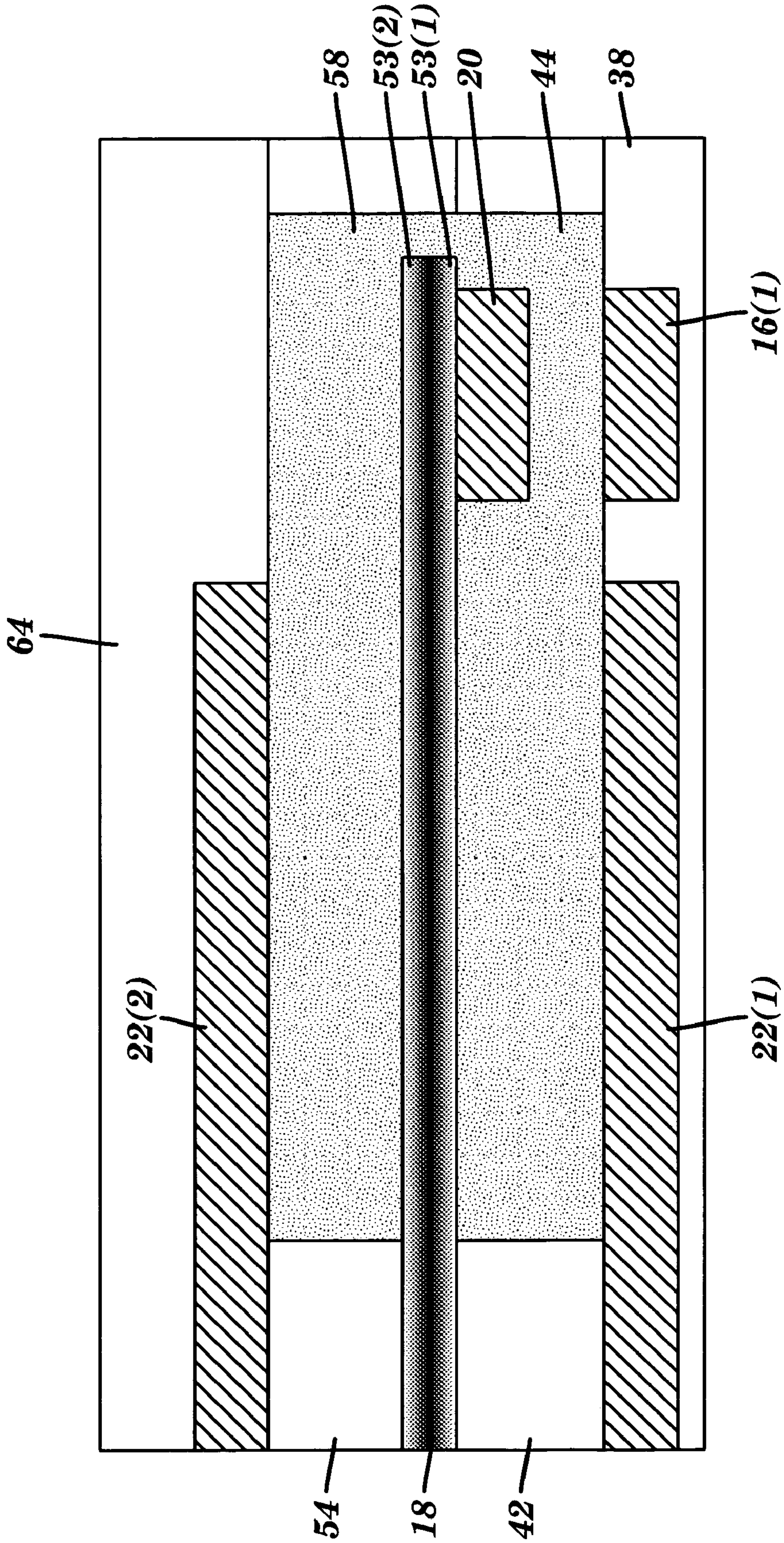

FIG. 11

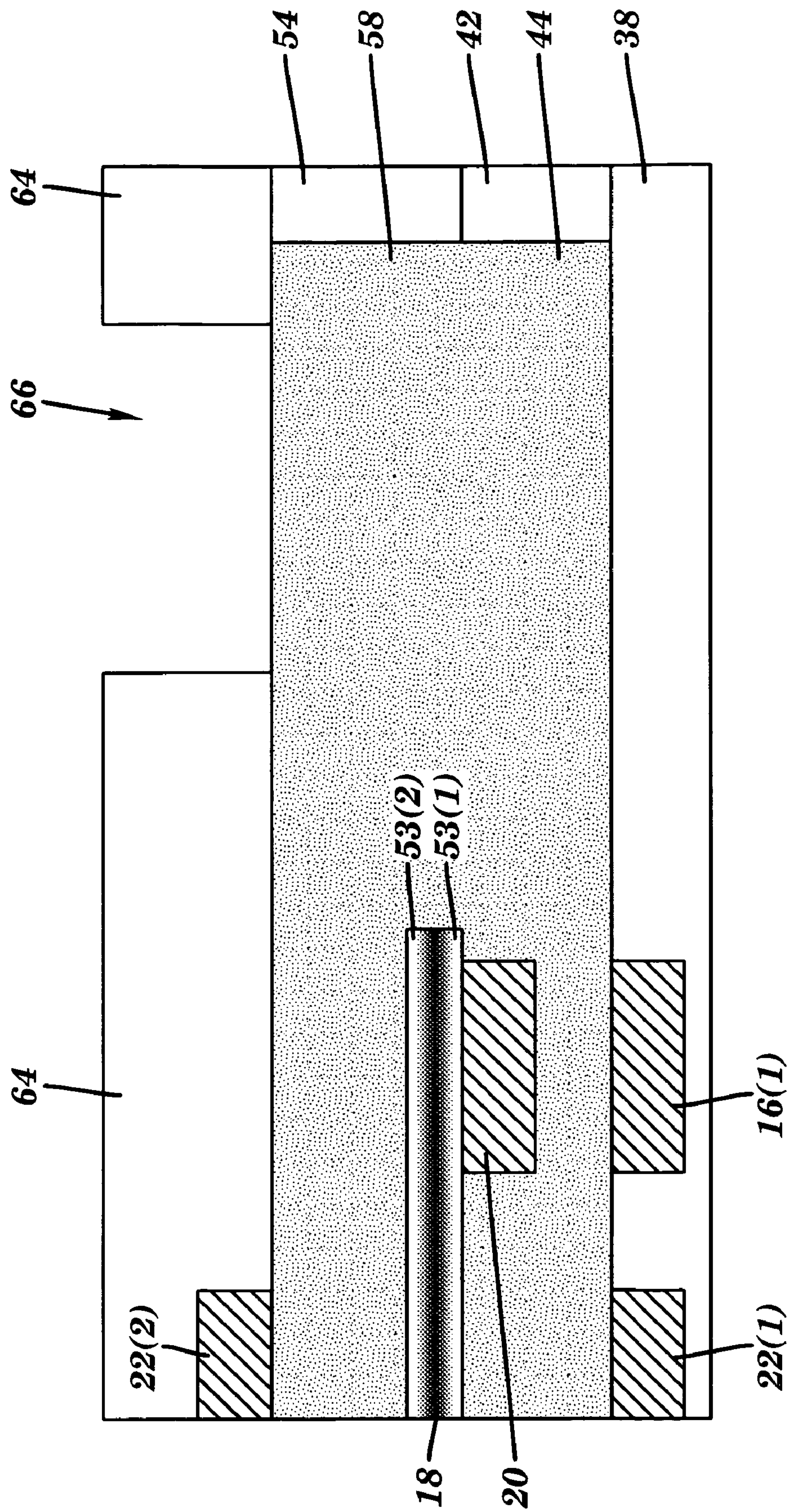

FIG. 12

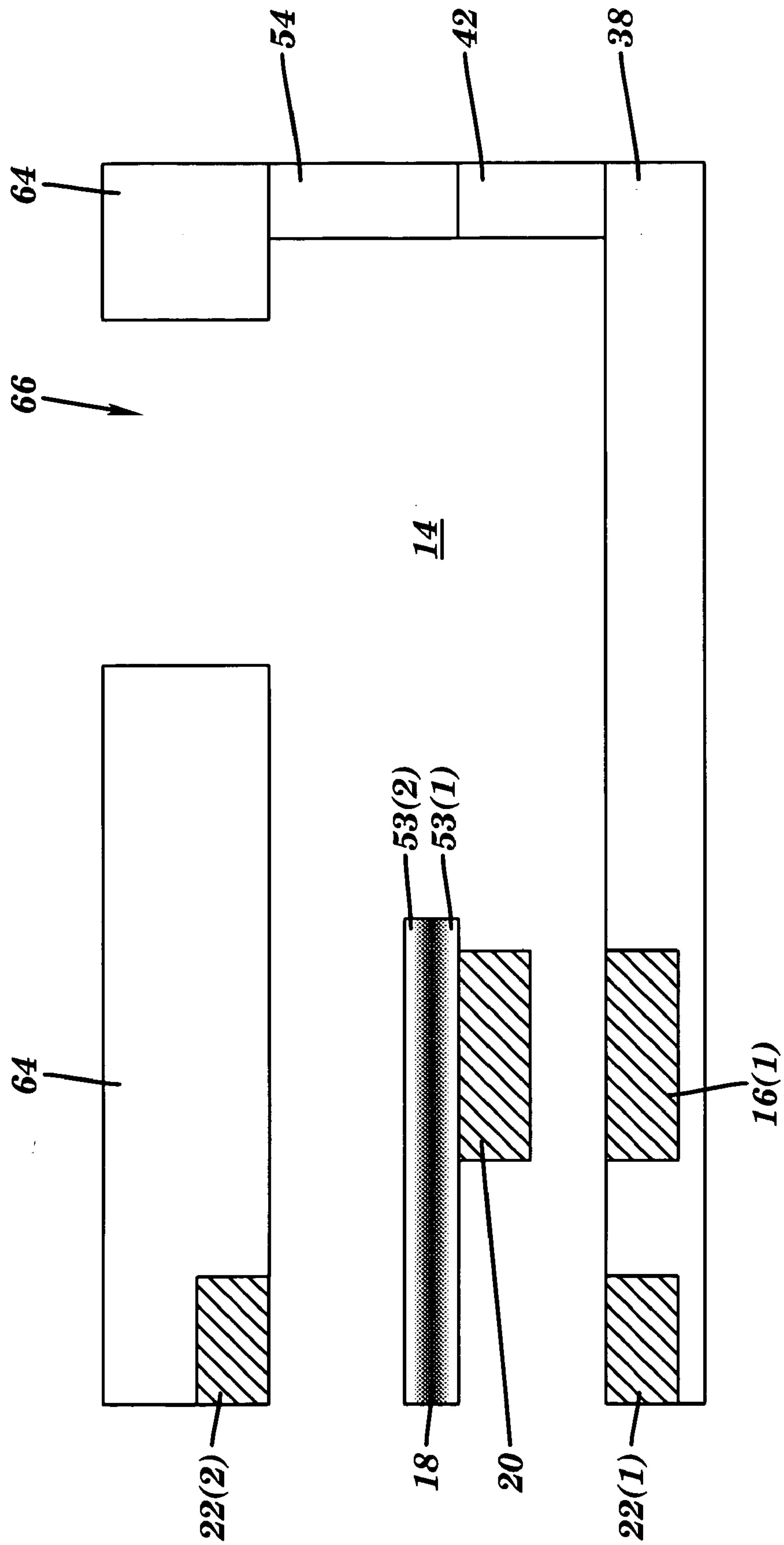

FIG. 13

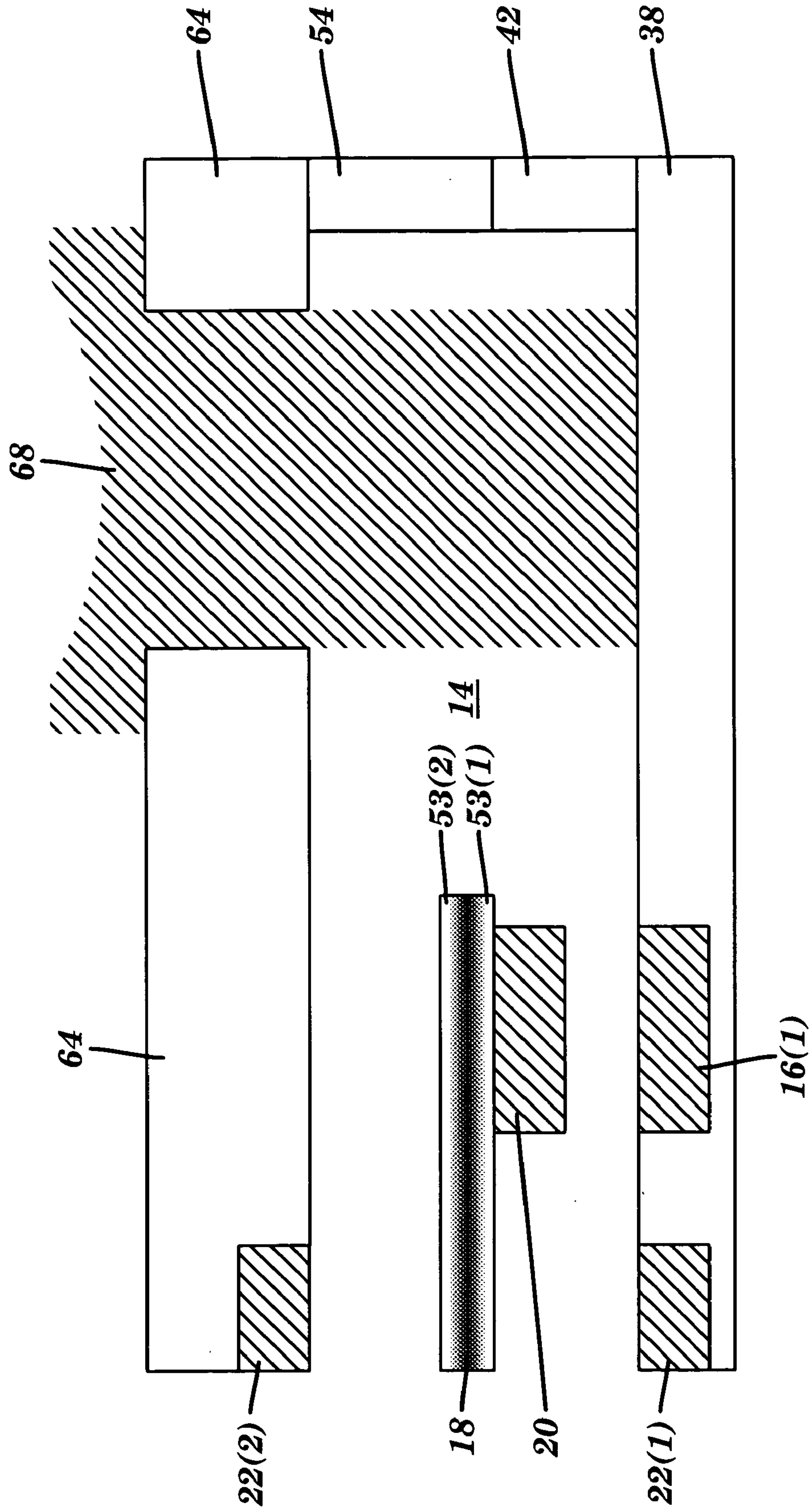

FIG. 14

MICRO-ELECTRO-MECHANICAL SWITCH AND A METHOD OF USING AND MAKING THEREOF

The present invention claims the benefit of U.S. Provisional Patent Application Ser. No. 60/275,386, filed Mar. 13, 2001, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

This invention relates generally to switches and, more particularly, to a micro-electro-mechanical switch (MEMS) and a method of using and making thereof.

BACKGROUND OF THE INVENTION

Micro-electro-mechanical switches are operated by an electrostatic charge, thermal, piezoelectric or other actuation mechanism. Application of an electrostatic charge to a control electrode in the MEMS causes the switch to close, while removal of the electrostatic charge on the control electrode, allowing the mechanical spring restoration force of the armature to open the switch. Although these MEMS switches work problems have prevented their more widespread use.

For example, one problem with cantilever type MEMS is that they often freeze into a closed position due to a phenomenon known as stiction. These cantilever type MEMS may be actuated by electrostatic forces, however there is no convenient way to apply a force in the opposite direction to release the MEMS to the open position.

One solution to this problem is a design which uses electrostatic repulsive forces to force apart MEMS contacts, such as the one disclosed in U.S. Pat. No. 6,127,744 to R. Streeter et al. which is herein incorporated by reference. In this design, the improved switch includes an insulating substrate, a conductive contact, a cantilever support, a first conductive surface and a cantilever beam. Additionally, a first control surface is provided on the lower surface of and is insulated from the beam by a layer of insulation. A second control surface is disposed over and is separated from the first conductive surface by a layer of insulative material. A variable capacitor is formed by the two control surfaces and the dielectric between them. This capacitor must be considered in addition to the capacitors formed by the first control surface, the layer of insulation and the beam and by the second control surface, the layer of insulation and the first conductive surface.

Unfortunately, there are drawbacks to this design. As discussed above, the additional layers used for attraction or repulsion charge form capacitors which require additional power for operation and thus impose a serious limitation on this type of design. These additional layers also add mass that limits the response time of the switch. Further, this design results in a variable parasitic capacitor between the cantilever beam and contact post.

SUMMARY OF THE INVENTION

A switch in accordance with one embodiment of the present invention includes at least one portion of a conductive line in the chamber, a beam with imbedded charge, and control electrodes. The beam has a conductive section which is positioned in substantial alignment with the at least one portion of the conductive line. The conductive section of the beam has an open position spaced away from the conductive

line and a closed position on the conductive line. Each of the control electrodes is spaced away from an opposing side of the beam to control movement of the beam.

A method for making a switch in accordance with another embodiment of the present invention includes forming a chamber in a switch housing, forming separated portions of a conductive line in the chamber, forming a beam with imbedded charge which extends into the chamber, and forming a pair of control electrodes spaced away from opposing sides of the beam. The beam has a conductive section located at or adjacent an edge of the beam and which is positioned in substantial alignment with the separated portions of the conductive line. The conductive section of the beam has an open position spaced away from the separated portions of the conductive line and a closed position on a part of each of the separated portions of the conductive line to couple the separated portions of the conductive line together.

A method of using a switch in accordance with another embodiment of the present invention includes applying a first potential to control electrodes and moving a conductive section on a beam to one of an open position spaced away from at least one portion of a conductive line or a closed position on the at least one portion of the conductive line in response to the applied first potential. The beam has imbedded charge and a conductive section that is located at or adjacent an edge of the beam and is positioned in substantial alignment with the at least one portion of a conductive line. Each of the control electrodes is spaced away from an opposing side of the beam to control movement of the beam.

A method for making a switch in accordance with another embodiment of the present invention includes forming at least one portion of a conductive line, forming a beam with imbedded charge, and forming control electrodes. The beam has a conductive section which is positioned in substantial alignment with the at least one portion of the conductive line. The conductive section of the beam has an open position spaced away from the at least one portion of the conductive line and a closed position on the at least one portion of the conductive line. Each of the control electrodes is spaced away from an opposing side of the beam to control movement of the beam.

A method for making a switch in accordance with another embodiment of the present invention includes filling at least three trenches in a base material with a first conductive material. The first conductive material in two of the trenches forms separated portions of a conductive line and the first conductive material in the other trench forms a first control electrode. A first insulating layer is deposited on at least a portion of the first conductive material and the base material. A trench is formed in a portion of the first insulating layer which extends to at least a portion of the first conductive material in the trenches in the base material. The trench in the portion of the first insulating layer is filled with a first sacrificial material. A trench is formed in the first sacrificial material which is at least partially in alignment with at least a portion of the first conductive material in the trenches in the base material that form the separated portions of the conductive line. The trench in the first sacrificial material is filled with a second conductive material to form a contactor. A charge holding beam is formed over at least a portion of the first insulating layer, the first sacrificial material, and the second conductive material in the trench in the first sacrificial material. The beam is connected to the beam. A second insulating layer is deposited over at least a portion of the beam, the first sacrificial material, and the first insulating layer. A trench is formed in the second insulating layer which extends to at least a portion of the beam and the first sacrificial material. The trench in the second insulating layer is filled with a second sacrificial material. A charge is inbedded on the beam. A third conductive material is deposited over at least a portion of the second insulating layer and the second sacrificial material. A second control electrode is formed from the third conductive material over at least a portion of the second insulating layer and the second sacrificial material. A third insulating layer is deposited over at least a portion of the second control electrode, the second sacrificial material, and the second insulating layer. At least one access hole is formed to the first and second sacrificial materials. The first and second sacrificial materials are removed to form a chamber and sealing the access hole to form a vacuum or a gas filled chamber.

The present invention provides a switch that utilizes fixed static charge to apply attractive and repulsive forces for activation. With the present invention, the parasitic capacitance is minimal, while the switching speed or response is high. The switch does not add extra mass and only requires one power supply. The present invention can be used in a variety of different applications, such as wireless communications, cell phones, robotics, micro-robotics, and/or autonomous sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross sectional, side view of a switch in accordance with one embodiment of the present invention;

FIG. **2**A is a cross sectional, side view of a switch in accordance with another embodiment of the present invention;

FIG. **2**B is a cross sectional, side view of a switch in accordance with yet another embodiment of the present invention;

FIGS. **3** and **5-11** are cross sectional, side views of steps in a method of making a switch in accordance with another embodiment of the present invention; and

FIG. **4** is a partial, cross sectional, top-view of a step in the method of making the switch; and

FIGS. **12-14** are partial, cross sectional, top-view of additional steps in the method of making the switch.

DETAILED DESCRIPTION

A switch **10**(**1**) in accordance with at least one embodiment of the present invention is illustrated in FIG. **1**. The switch **10**(**1**) includes a switch housing **12** with a chamber **14**, separated portions of a conductive line **16**(**1**) and **16**(**2**), a beam **18** with imbedded charge and a contactor **20**, and control electrodes **22**(**1**) and **22**(**2**). The present invention provides a switch **10**(**1**) that utilizes fixed static charge to apply attractive and repulsive forces for activation of the switch and to overcome stiction. This switch **10**(**1**) has lower power requirements to operate, less parasitic capacitance, less mass, and faster switching speed or response than prior designs.

Referring more specifically to FIG. **1**, the switch housing **12** defines a chamber **14** in which the switch **10**(**1**) is located. The switch housing **12** is made of several layers of an insulating material, such as silicon dioxide, although other types of materials can be used and the switch housing **12** could comprise a single layer of material in which the chamber **14** is formed. The chamber **14** has a size which is sufficiently large to hold the components of the switch **10**(**1**), although the chamber **14** can have other dimensions. By way of example only, the control electrodes **22**(**1**) and **22**(**2**) in the switch housing **12** may be separated from each other by a distance of about one micron with each of the control electrodes **22**(**1**) and **22**(**2**) spaced from the beam **18** by about 0.5 microns, although these dimensions can vary based on the particular application. The chamber **14** has an access hole **17** used in removing sacrificial material from the chamber **14** although the chamber **14** can have other numbers of access holes. A plug **19** seals the access hole **17**. In this embodiment, the chamber **14** is vacuum sealed, although it is not required. The switch housing **12** is vacuum sealed which helps to protect the switch **10**(**1**) from contaminates which, for example, might be attracted and adhere to the beam **18** with the imbedded charge.

Referring to FIGS. **1** and **4**, each of the separated portions **16**(**1**) and **16**(**2**) of the conductive line or conductor has an end **24**(**1**) and **24**(**2**) which is adjacent to and spaced from the other end **24**(**1**) and **24**(**2**) in the chamber **14** to form an open circuit along the conductive line. The other end **26**(**1**) and **26**(**2**) of each of the separated portions of the conductive line extends out from the chamber to form a contact pad. The separated portions **16**(**1**) and **16**(**2**) of the conductive line are made of a conductive material, such as copper, although another material or materials could be used.

Referring back to FIG. **1**, the beam **18** has one end **28**(**1**) which is secured to the switch housing **12** and the other end **28**(**2**) of the beam **18** extends into the chamber **14** and is spaced from the other side of the chamber **14**, although other configurations for the beam **18** can be used. For example, both ends **28**(**1**) and **28**(**2**) of the beam **18** could be secured to the switch housing **12**, although this embodiment would provide less flexibility than having the beam **18** secured at just one end **28**(**1**) to the switch housing **12** as shown in FIGS. **1** and **2**. The beam **18** is made of a material which can hold an imbedded charge. In this particular embodiment, the beam **18** is made of a composite of silicon oxide and silicon nitride, although the beam **18** could be made of another material or materials. By way of example, the beam **18** could be a composite of a plurality of layers of different materials.

Referring to FIGS. **1** and **4**, the contactor **20** is located at or adjacent one end **28**(**2**) of the beam **18**, although the contactor **20** could be located in other locations or could be part of the end **28**(**1**) or another section of the beam **18** that was made conductive. The contactor **20** is positioned on the beam **18** to be in substantial alignment with the ends **24**(**1**) and **24**(**2**) of the separated portions **16**(**1**) and **16**(**2**) of the conductive line. In this particular embodiment, the contactor **20** is made of a conductive material, such as copper, although another material or materials could be used. In an open position, the contactor **20** is spaced away from the ends **24**(**1**) and **24**(**2**) of the separated portions **16**(**1**) and **16**(**2**) of the conductive line and in a closed position the contractor **20** is located on the ends **24**(**1**) and **24**(**2**) of each of the separated portions **16**(**1**) and **16**(**2**) of the conductive line to couple the separated portions **16**(**1**) and **16**(**2**) of the conductive line together.

Referring back to FIG. **1**, the control electrodes **22**(**1**) and **22**(**2**) are located in the chamber **14** of the switch housing **12** and are spaced away from opposing sides of the beam **18**, although other configurations are possible. For example, one of the control electrodes **22**(**1**) could be located outside of the chamber **14**, as shown in the switch **10**(**2**) in FIG. **2** or both of the control electrodes **22**(**1**) and **22**(**2**) could be located outside of the chamber **14**. Each of the control electrodes **22**(**1**) and **22**(**2**) is made of a conductive material, such as chrome, although another material or materials could be used. A power supply **30** is coupled to each of the control electrodes **22(1)** and **22(2)** and is used to apply the potential to the control electrodes **22(1)** and **22(2)** to open and close the switch **10(1)**.

The operation of the switch **10(1)** will now be described with reference to FIG. **1**. The switch **10(1)** is operated by applying a potential across the control electrodes **22(1)** and **22(2)**. When a potential is applied across the control electrodes **22(1)** and **22(2)**, the beam **18** with the imbedded charge is drawn towards one of the control electrodes **22(1)** or **22(2)** depending on the polarity of the applied potential. This movement of the beam **18** towards one of the control electrodes **22(1)** or **22(2)** moves the contactor **20** to a closed position resting on ends **24(1)** and **24(2)** of each of the separated portions **16(1)** and **16(2)** of the conductive line to couple them together. When the polarity of the applied potential is reversed, the beam **18** is repelled away from the control electrode **22(1)** or **22(2)** moving the contactor **20** to an open position spaced from the ends **24(1)** and **24(2)** of each of the separated portions **16(1)** and **16(2)** of the conductive line to open the connection along the conductive line. Accordingly, the switch **10(1)** is controlled by electrostatic forces that can be applied to both close and to open the switch **10(1)**. No extraneous current path exists, the energy used to open and close the switch is limited to capacitively coupled displacement current, and the dual force directionality overcomes stiction.

The components and operation of the switches **10(2)** **10(3)**, and **10(4)** shown in FIGS. **2**A and **2**B are identical to those for the switch **10(1)** shown and described with reference FIG. **1**, except as described and illustrated herein. Components in FIGS. **2**A and **2**B which are identical to components in FIG. **1** have the same reference numeral as those in FIG. **1**. In FIG. **2**A, control electrode **22(2)** is located outside of the chamber **14**. A portion **29** of the switch housing **12** separates the control electrode **22(2)** from the chamber **14**. In this embodiment, portion **29** is made of an insulating material although another material or materials could be used. In an alternative embodiment, control electrode **22(1)** could be outside of chamber **14** and control electrode **22(2)** could be inside chamber **14**. In FIG. **2**B, control electrodes **22(1)** and **22(2)** are located outside of the chamber **14**. Portions **29** and **31** of the switch housing **12** separate the control electrodes **22(1)** and **22(2)** from the chamber **14**. In this embodiment, portions **29** and **31** of the switch housing **12** are each made of an insulating material, although another material or materials could be used.

Referring to FIGS. **3-14**, a method for making a switch **10(1)** in accordance with at least one embodiment will be described. Referring more specifically to FIGS. **3** and **4**, three trenches **32**, **34**, and **36** are etched into a base material **38**. Two of the etched trenches **32** and **34** have ends located adjacent and spaced from each other and are used in the forming the separated portions **16(1)** and **16(2)** of the conductive line. The other trench **36** is used to form one of the control electrodes **22(1)**. Although etching is used in this particular embodiment to form the trenches **32**, **34**, and **36**, other techniques for forming the trenches or opening can also be used.

Next, a conductive material **40** is deposited in the trenches in the base material **38**. The conductive material **40** in the two trenches **32** and **34** with the adjacent ends forms the separated portions **16(1)** and **16(2)** of the conductive line. The conductive material **40** in the other trench **36** forms control electrode **22(1)**. Next, the conductive material **40** deposited in these trenches **32**, **34**, and **36** may also be planarized. Again although in this embodiment, the control electrodes **22(1)** is formed in the chamber **14** of the switch housing **12**, the control electrode **22(1)** could be positioned outside of the switch housing **12**.

Referring to FIG. **5**, once the separated portions **16(1)** and **16(2)** of the conductive line and the control electrode **22(1)** are formed, an insulating material **42** is deposited over the base material **38** and the conductive material **40** in the trenches **32**, **34**, and **36**. In this particular embodiment, silicon dioxide, SiO_2, is used as the insulating material **42**, although other types of insulating materials can be used.

Once the insulating material **42** is deposited, the insulating material **42** is etched to extend down to a portion of the conductive material **40** in the trenches **32**, **34**, and **36**. Next, a sacrificial material **44** is deposited in the etched opening or trench **46** in the insulating material. In this particular embodiment, polysilicon is used as the sacrificial material **44**, although another material or materials can be used. Next, the sacrificial material **44** may be planarized. Although etching is used in this particular embodiment to form opening or trench **46**, other techniques for forming trenches or openings can be used.

Referring to FIG. **6**, once the sacrificial material **44** is deposited, a trench **48**, is etched into the sacrificial material **44** at a location which is in alignment with a portion of the conductive material **40** in the trenches that form the separated portions **16(1)** and **16(2)** of the conductive line. A conductive material **50** is deposited in the trench **48** in the sacrificial material **44** to form a contactor **20**. Next, the conductive material **50** may be planarized. Although etching is used in this particular embodiment to form opening or trench **48**, other techniques for forming trenches or openings can be used.

Referring to FIGS. **4** and **7**, once the contactor **20** is formed, an insulator **52** comprising a pair of insulating layers **53(1)** and **53(2)** are deposited over the insulating material **42**, the sacrificial material **44**, and the conductive material **44** that forms the contactor **20**. The insulator **52** is patterned to form a cantilever charge holding beam **18** which extends from the insulating layer **42** across a portion of the sacrificial layer **44** and is connected to the contactor **20**. Although in this particular embodiment the beam **18** is patterned, other techniques for forming the beam **18** can be used. Additionally, although in this embodiment insulator **52** comprises two insulating layers, insulator **52** can be made of more or fewer layers and can be made of another material or materials that can hold fixed charge.

Referring to FIG. **8**, once the beam **18** is formed, an insulating material **54** is deposited over the insulating material **42**, the beam **18**, and the sacrificial material **44**. A trench **56** is etched into the insulating material **54** which extends down to a portion of the beam **18** and the sacrificial material **44**. A sacrificial material **58** is deposited in the trench **56** in the insulating material **54**. The sacrificial material **58** can be planarized. Sacrificial material **58** can be made of the same or a different material from sacrificial layer **44** and in this embodiment is polysilicon, although another material or materials could be used. Although etching is used in this particular embodiment to form opening or trench **56**, other techniques for forming trenches or openings can be used.

Referring to FIG. **9**, electrons are injected into the beam **18** from a ballistic energy source **60** to imbed charge in the beam **18**, although other techniques for imbedding the electrons can be used, such as applying an electrical bias to the beam **18**.

Referring to FIG. **10**, a conductive material **62** is deposited over the insulating material **54** and the sacrificial material **58**. The conductive material **62** is etched to form a control electrode **22(2)** for the switch **10(1)**. Although in this particular embodiment the control electrode **22**(**2**) is formed by patterning, other techniques for forming the control electrode can be used.

Referring to FIG. **11**, once control electrode **22**(**1**) is formed, an insulating material **64** is deposited over the conductive material, the sacrificial material, and the insulating material. The base material **38** and insulating materials **42**, **54**, and **64** form the switch housing **12** with the chamber **14** which is filled with the sacrificial materials **44** and **58**, although switch housing **12** could be made from one or other numbers of layers.

Referring to FIG. **12**, an access hole **66** is drilled through the insulating layer **64** to the sacrificial material **58**. Although in this particular embodiment a single access hole **66** is etched, other numbers of access holes can be formed and the hole or holes can be formed through other materials to the sacrificial material **44** and **58**. Contact vias to separated portions **16**(**1**) and **16**(**2**) of the conductive line and control electrodes **22**(**1**) and **22**(**2**) may also be etched or otherwise formed at this time.

Referring to FIG. **13**, once the access hole **66** is formed, the sacrificial materials **44** and **58** removed using xenon difluoride (XeF_2) via the access hole **66**, although other techniques for removing sacrificial materials **44** and **58** can be used.

Referring to FIG. **14**, once the sacrificial materials **44** and **58** are removed, aluminum is deposited in the access hole **66** to form a plug **68** to seal the chamber **14**, although another material or materials can be used for the plug **68**. In this embodiment, the chamber **14** is vacuum sealed when the sacrificial materials **44** and **58** are removed and access hole **66** is sealed with a plug **68**, although the chamber **14** does not have to be vacuum sealed. Once the chamber **14** is sealed, the switch is ready for use.

Accordingly, the present invention provides a switch that utilizes fixed static charge to apply attractive and repulsive forces for activation and is easy to manufacture. Although one method for making a switch is disclosed, other steps in this method and other methods for making the switch can also be used. For example, other techniques for imbedding charge in the beam can be used, such as applying a bias to the beam to imbed charge.

Having thus described the basic concept of the invention, it will be rather apparent to those skilled in the art that the foregoing detailed disclosure is intended to be presented by way of example only, and is not limiting. Various alterations, improvements, and modifications will occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested hereby, and are within the spirit and scope of the invention. Additionally, the recited order of processing elements or sequences, or the use of numbers, letters, or other designations therefor, is not intended to limit the claimed processes to any order except as may be specified in the claims. Accordingly, the invention is limited only by the following claims and equivalents thereto.

What is claimed is:

1. A switch comprising:

at least one portion of a conductive line;

a beam comprising two or more insulating layers, wherein one of the two or more insulating layers is located directly on the other one of the two or more insulating layers and the layers hold a fixed, imbedded charge, the beam having a conductive section which is positioned in substantial alignment with the at least one portion of the conductive line, the conductive section of the beam having an open position spaced away from the at least one portion of the conductive line and a closed position on the at least one portion of the conductive line; an

control electrodes, each of the control electrodes are spaced away from an opposing side of the beam to control movement of the beam.

2. The switch as set forth in claim **1** further comprising a switch housing with a chamber, the beam extending into the chamber and the at least one portion of a conductive line is in the chamber.

3. The switch as set forth in claim **2** wherein at least one of the control electrodes is located in the chamber.

4. The switch as set forth in claim **2** wherein the control electrodes are all located outside the chamber in the switch housing.

5. The switch as set forth in claim **2** further comprising:

an opening into the chamber; and

a plug sealing the opening into the chamber.

6. The switch as set forth in claim **2** wherein the chamber is a vacuum chamber.

7. The switch as set forth in claim **2** wherein the chamber is a filled with at least one gas.

8. The switch as set forth in claim **1** wherein the conductive section is located at or adjacent an end of the beam.

9. The switch as set forth in claim **1** wherein the conductive section is a contactor connected to the beam.

10. The switch as set forth in claim **1** wherein the at least one portion of a conductive line comprises a pair of separated portions of a conductive line, the conductive section is positioned in substantial alignment with the separated portions of the conductive line.

11. The switch as set forth in claim **1** wherein each of the control electrodes are in alignment along at least one axis which extends substantially perpendicularly through the two or more insulating layers of the beam and each of the control electrodes.

12. A method of using a switch, the method comprising:

applying a potential with a first polarity to control electrodes which are spaced away from opposing side of a beam to control movement of the beam, wherein the beam comprises two or more insulating layers, wherein one of the two or more insulating layers is located directly on the other one of the two or more insulating layers and the layers hold a fixed, imbedded charge and the beam has a conductive section which is positioned in substantial alignment with a conductor; and

moving the conductive section on the beam to one of an open position spaced away from the conductor or a closed position on the conductor in response to the first polarity of the applied potential.

13. The method as set forth in claim **10** further comprising:

applying a potential with a second polarity to the control electrodes; and

moving the conductive section on to one of an open position spaced away from the at least one portion of the conductive line or a closed position on the at least one portion of the conductive line in response to the second polarity of the applied potential.

14. The method as set forth in claim **12** wherein the first polarity is opposite from the second polarity.

15. The method as set forth in claim **12** wherein the beam extends into a chamber in a switch housing and the at least one portion of a conductive line is in the chamber.

16. The method as set forth in claim **15** wherein at least one of the control electrodes is located in the chamber.

17. The method as set forth in claim **15** wherein the control electrodes are all located outside the chamber in the switch housing.

18. The method as set forth in claim **15** wherein the chamber is a vacuum chamber.

19. The method as set forth in claim **15** wherein the chamber is filled with at least one gas.

20. The method as set forth in claim **12** wherein the conductive section is located at or adjacent an end of the beam.

21. The method as set forth in claim **12** wherein the conductive section is a contactor connected to the beam.

22. The method as set forth in claim **12** wherein each of the control electrodes are in alignment along at least one axis which extends substantially perpendicularly through the two or more insulating layers of the beam and each of the control electrodes.

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