

**MICRO-ELECTROMECHANICAL SWITCH HAVING A
DEFORMABLE ELASTOMERIC CONDUCTIVE ELEMENT**

5 **TECHNICAL FIELD**

This invention is generally related to micro-electromechanical switches (MEMS), and more particularly, to a MEMS structure and method of fabrication to improve its reliability and make it less susceptible to material fatigue and mechanical failure.

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BACKGROUND ART

A wide variety of communications systems, such as mobile phone handsets, require switches to direct signal flow within the systems. An example is the need to switch a mobile phone antenna between the transmit and receive blocks of the phone. Suitable switches must
15 allow radio frequency (RF) signals to pass through with low loss in the on-state (low insertion loss) while providing good isolation between terminals in the off-state.

Micro-electromechanical switches have become an increasingly attractive option for RF switching because of their potential for low insertion loss and high isolation. In one class
20 of MEM switches, a contact consisting of a conducting film is caused to move or deflect so as to come into contact with another, closing the circuit. The contacts are then separated again to open the switch.

A significant challenge in the present art micro-electromechanical contact switches is
25 the high reliability that is required, typically a lifetime greater than 1 billion cycles. When subjected to alternating stresses, most materials degrade, e.g., suffer premature failure, due to a phenomenon known as In addition, when two surfaces are pressed into contact, there is stored energy in the material that tends to separate the contacts naturally. However, the

existence of this natural separation force also implies that a large force must be generated to initially deflect the contact and close the switch. In switches where the deflection is electrostatic, these large forces generally imply the need for high control voltages, typically beyond the 6V maximum available, for example, in mobile phone handsets. The present invention describes a device that is switchable via a low control voltage and which is capable of reliable switching over billions of cycles without mechanical failure.

The prior art describes various MEM switch configurations using deformable materials. By way of example, and referring to Fig. 1, in U.S. Patent No 6,020,564, an electrostatic lateral displacement of a metallic beam (116 towards 123) causes a longitudinal displacement of the beam moving it into contact with RF-in and RF-out electrodes (111 bridging 106 and 109). A problem with this kind of MEM switch is that the force pushing the lateral beam 111 into the RF lines 106 and 109 is limited by the metallic beam material properties and will, therefore, fail after repeated operation of millions or billions cycles. The failure mode may manifest itself as plastic deformation, wherein the metallic structure will no longer elastically deform upon removal of the DC voltage (and therefore fail to restore the switch back to the off-state), or as a crack propagation through the material that ultimately produces a mechanical failure in the switch.

U.S. Patent No. 5,642,015 describes an electromechanical transducer having a substrate with a plurality of elastomeric microstructures. The microstructures are provided with microelectrodes deposited thereon within elastomeric ridges. An electrostatic force is applied between the elastomeric microstructures or between the microstructures and a macrostructure, allowing bending of the microstructures or a relative movement of the microstructure closer to the macrostructure. The net result of the movement is compression of a gas that resides between the elastomeric ridges or improving heat transfer through a membrane. U.S. Patent No. 5,642,015 uses the elastomeric material for compressing a gas, which improves the heat transfer, but not for controlling the flow of electrical signals.

OBJECTS OF THE INVENTION

Accordingly, it is an object of the invention to provide a micro-electromechanical (MEM) switch having a deformable elastomeric element which exhibits a large change in conductivity with a small amount of displacement.

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It is another object of invention to provide a MEM switch, wherein the deformable elastomeric element is displaced by an electrostatic force that is applied laterally resulting in a small vertical displacement, and wherein the vertical displacement, in turn, creates a contact between two signal lines, allowing the passage of electrical signals.

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It is yet another object to provide a MEM switch having a deformable element provided with embedded metallic elements (such as an elastomer with impregnated metallic rods) and having a contact electrode on the side of the deformable element that is vertically displaced, the embedded metallic elements creating an electrostatic attractive force to compress the deformable element and create a vertical displacement.

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It is a further object to provide a MEM switch capable of generating a change in conductivity of the deformable elastomeric element achieved by a conductive polymer.

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It is still an object to have the MEM switch change the conductivity of the elastomeric element by way of embedded metal particles embedded alongside the perimeter of the deformable elastomeric material or by embedding elastomer conductive paste.

DISCLOSURE OF INVENTION

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In one aspect of the invention, there is described a MEM switch and a fabrication method thereof. The switch controls the flow of electrical signals by selectively allowing an electrical RF signal pass through a signal line by making an ohmic contact between two signal lines or by interrupting the flow of a signal to ground, based on the relative position of a conductive pad. The movement and relative position of the conductive pad are controlled by

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the movement of an elastomeric material that has either impregnated metallic particles or is a elastomeric conductive polymer, or an elastomer with impregnated metallic rods (or sheets of metal) and a solid metallic element as a contact. An electrostatic force is used to compress the elastomer laterally on both sides, creating a small vertical movement of the conductive pad area in order to pass or interrupt the signal. A vertical movement of less than 0.5 micrometers is required to perform a switching operation.

The elastomeric element creates a movement of the RF switch contact and prolongs the switch lifetime (e.g., the number of switching cycles) by extending fatigue life of the deformable switch element. The metallic element used by most switches to create a displacement is replaced by a deformable polymer elastomer. Typical lifetime requirement for RF switches is 10^6 - 10^{10} cycles. Most materials fail after repeated dynamic load because of the high stress involved in creating bending. The switch release to off-state is facilitated by the elastic properties of the deformable elastomeric polymer material and is not totally dependent on the restoring force of a metallic membrane beam that typically relies only on the mechanical stiffness of a beam to return to the relaxed off-state. Therefore, the tendency for the MEMs switch of the present invention to stick will be less than when metals under stress are used to perform the same function. Furthermore, the MEM switch fabrication process is compatible with semiconductor state-of-the-art CMOS and BiCMOS chip-wiring process, which makes the device fully integratable on a semiconductor chip.

The DC control voltages and the RF signals routed by the MEM switch are entirely decoupled due to the insulating elastomeric material between them. PIN diodes that are typically used as RF switches have shown losses in RF signal transmission due to coupling effects between the RF signals and the DC control voltage. Typically, these two signals need to be subsequently decoupled in the circuit exterior to the switch itself. The RF switch described herein solves this problem by decoupling the signals before they enter the micro-mechanical portion of the switch.

Finally, the MEM switch of the present invention can be designed as a Single-Pole-Double-Throw (SPDT) or Single-Pole-Multi-Throw (SPMT) by connecting a number of MEMS switches in series.

5 To achieve these and other objects of the invention, the invention provides a micro-electromechanical (MEM) switch that includes:

10 **BRIEF DESCRIPTION OF DRAWINGS**

These and other objects, aspects and advantages of the present invention will be better understood by a detailed description of several preferred embodiments to be described hereinafter when taken in conjunction with the accompanying drawings.

15 Fig. 1 shows a prior art MEM RF switch provided with a deformable conductive element, wherein an electrostatic displacement of the beam causes a longitudinal displacement of the beam moving it into contact with the electrodes.

Figs. 2a-2b show a cross-sectional schematic view of a first preferred embodiment of the invention, illustrating the MEM switch in the off-state (Fig. 2a) and in the on-state (Fig. 2b).

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Fig. 3 illustrates the relationship between lateral and vertical displacements of the elastomeric material under lateral compression due to the application of a control voltage to actuate the electrodes.

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Fig. 4a-4b is a schematic cross-section of a second embodiment of the present invention, with the MEM switch in the on-state (Fig. 4a) and in the off-state (Fig. 4b).

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Fig. 5 shows a schematic diagram of a single-pole-double throw MEM RF switch, where MEM switch 1 is in the on-state and switch 2 is off.

Fig. 6 is a schematic illustration of a third embodiment of the invention, showing metallic particles embedded on the lateral sides of the deformable elastomeric material and their effect on the MEM switch when a voltage is applied to the electrodes.

Figs. 7a-7b are schematic illustrations showing metallic particles embedded on the lateral sides of the deformable elastomeric material for a MEM switch in the on-state (Fig. 7a) and in the off-state (Fig. 7b).

Figs. 8a-8b are schematic illustrations of yet another embodiment of the invention, showing the MEMS structure constructed using fabrication techniques that are easily integrated in a CMOS or BiCMOS semiconductor manufacturing facility.

Figs. 9a-9s illustrate the fabrication steps for a MEM switch integrated in a CMOS or BiCMOS semiconductor fabrication facility.

BEST MODE FOR CARRYING OUT THE INVENTION

The basic concept of the MEM RF switch of the invention is illustrated in Figs. 2a and 2b showing a cross-sectional view of the MEM switch in the off-state (Fig. 2a) and in the on-state (Fig. 2b).

The switch consists of a deformable elastomeric material 1 which is distorted laterally by electrostatic actuation by applying a voltage difference between metallic element 8 and 10 placed at the side 4 of elastomeric material 1. Similarly, a voltage difference is applied between metallic element 18 and 9 placed at the side 3 of elastomeric material 1. More specifically, if metallic elements 9 and 10 are kept at ground and a positive DC voltage is applied on conductive element 8 and 18, then elements 9 and 10 will move laterally toward 8

and 18, laterally squeezing the elastomeric polymer. The voltage difference between element 8 and 10, and 9 and 18, creates an attractive electrostatic force and a compression of the elastomeric material 1 in the lateral direction. The compression in the lateral direction creates an elongation in the vertical direction and, as a result, contact 7 shorts the disconnected signal lines 5 and 6. The initial air gap 17 between contact 7 and signal lines 5 and 6 becomes extremely small (effectively zero) when the elastomeric material is compressed and contact is achieved. To keep actuation voltages below 10V, the initial gap 17 is preferably 0.5 μm or less.

In the preferred embodiment, silicone rubber, polyimide, low dielectric constant material such as SiLK (manufactured by DuPont) may be used as the elastomeric material. SiLK is a semiconductor dielectric in the form of a polymer resin consisting of gamma-butyrolactone, B-staged polymer and mesitylene.

Contact 7 is a metallic element, preferably, a noble metal that does not oxidize during the removal of the sacrificial material. Noble metals that are hard and which have properties similar to refractory metals are best used as contact materials. These include W, Pt, Pd, Ir, Ru, Re, Rh, Au and their alloys. SiLK and an amorphous hydrogenated carbon, also known as diamond-like-carbon (DLC), are advantageously used as organic sacrificial materials. DLC is an amorphous carbon containing coating wherein a proportion of the carbon atoms are bonded in a manner that is similar and which resembles in many ways to diamond. DLC is produced when carbon is deposited under energetic bombardment. The instantaneous localized high temperature and pressure induce a proportion of the carbon atoms to be bonded as diamond. These conditions are obtained during plasma assisted chemical vapor deposition (PACVD). The deposition is performed with a carbon containing gas, such as acetylene, which is introduced to provide the energetic carbon ions. Polymers can typically be spun or laminated and then planarized, using, for instance, chemical-mechanical polish (CMP). Generally, any number of organic compounds may be used as sacrificial material, such as photoresist, polyimides, and PECVD materials, such as SiCOH and SiCH, silicon-containing organics, carbon-containing glasses, DLC, SiLK, and the like.

Referring now to Fig. 3, there is shown a schematic diagram illustrating the relationship between the lateral (W) and vertical (L) displacements of the elastomeric material 1 upon compression. The MEMS is shown in the on state with contact 7 shorted against signal lines 3 due to the application of a control voltage to actuating electrodes (not shown).

An example of a typical displacement and stress that the elastomer sees during the MEMS switch operation is shown with reference to Fig. 3:

$$H_1 + H_2 = (W - 2S_1) / 2 \tan(\theta/4) \quad (1)$$

wherein

H_1 is the vertical displacement of the polymer, e.g., 0.5 μm ;
 H_2 is the thickness of the contact pad, e.g., 0.5 μm ;
 S_1 is the lateral displacement of the elastomeric polymer, e.g., 2.0 μm ;
 W is the width of elastomeric material, e.g., 20 μm ; and
 θ is the angle by which the elastomer is compressed.

Equation 1 represents the relationship between lateral compression of the elastomer and vertical displacement. Due to the fact that a small vertical displacement is needed to achieve contact of the MEM switch, a very low activation voltage below 10V is adequate to achieve small movements in the elastomeric polymer.

The distance between the signal line and the contact is kept to about 0.5 μm for improved isolation. The strain ϵ_{zz} on the elastomer is given by Equations 2 and 3:

$$\epsilon_{zz} = H_r - H_1 / H_1 = 0.0625 \quad (2)$$

$$\epsilon_{zz} = 2 \sigma_{xx} \nu / E_{\text{polymer}} \quad (3)$$

wherein $E_{\text{polymer}} = 3.9$ GPa is the Young Modulus for a typical polymer, and ν , Poisson's ratio for the polymer, typically, around 0.2. Solving Equation 3 for the stress σ_{xx} , one finds $\sigma_{xx} = 400$ MPa, which is reasonable for this type of material. The lower the stress that the material experiences during the cycling of the MEMS, the longer the MEMS switch fatigue life will be.

Fig. 4 illustrates an alternate embodiment of the present invention, wherein a shunt switch in the off-state is built around elastomeric polymer 1. The elastomer is connected to ground via electrodes 9 and 10. A DC voltage is applied with respect to ground on electrodes 8 and 18. The electrostatic force creates a lateral elongation of the deformable elastomer 1 resulting from a compression of the elastomer in the vertical direction. As a result of this compression, the elastomeric conductive polymer 1 contacts RF transmission line 2, shunting it to ground and interrupting the passage of the electrical signals. When the DC voltage is not applied to electrodes 8 and 18, then the conductive polymer returns to its previous state, and the RF signal then flows through line 2. Line 2 is typically made of a low resistivity metal such as Al, Cu and the like. The loss of a shunt MEM switch is determined primarily by the loss of the signal as it flows through signal line 2 when the switch is on. The isolation of the shunt switch is determined by the ability of the conductive polymer to interrupt the RF signal. Fig. 4a shows the MEMS switch in the on-state while Fig. 4b shows the signal in the off-state when the signal going through line 2 is shunt to ground.

In addition to describing switches capable of simply connecting or disconnecting a signal, the present invention also routes a signal between two or more contacts (multiple throw) or to simultaneously connect or disconnect multiple signals (multiple pole). By way of example, Fig. 5 illustrates how two MEM switches are interconnected to achieve a single-pole-multi-throw switch (single input and signal multiple outputs). To conserve space, it is possible to orient the MEM switches circularly around a single signal input incoming at the center of

a circle. Fig. 5 shows switch 1 on and switch 2 off. In switch 1, control electrodes 8 and 18 attract conductive elements 9 and 10, causing the horizontal part of elastomer 1 to lift metal electrode 7 and short signal line 5 to 6. This action closes the switch, shunting Signal In to Signal 1 Out. Switch 2 remains inactive, inhibiting Signal In from passing through to Signal 2 Out. The method shown in this figure can be readily extended to any number of switches, allowing signal in to be routed to any number of Signal Out lines (either individually or in any arbitrary combination).

Fig. 6 shows a second embodiment of the invention, for the switch previously shown in Fig. 2. The MEM switch illustrated is shown in the on state. It consists of an elastomeric element 1 with dispersed conductive particles embedded therein. Conductive particles or paste are used to actuate the elastomeric element. The metallic particles provide a conductive path at the surface of the elastomeric material. The metallic particles 9 and 10 dispersed at the sides of the elastomeric material 1, are connected to ground, while a DC bias voltage is applied to embedded metallic element 8 and 18. The voltage difference between element 8, 18 and 9, 10 creates an attractive electrostatic force and a compression of the elastomeric material 1 in the lateral direction. The compression in the lateral direction creates an elongation in the vertical direction and, as a result, contact 7 shorts the disconnected signal lines 5 and 6.

Fig. 7 is a more detailed version of the MEM switch shown in Fig. 6. Therein is illustrated how the peripherally conductive, deformable elastomeric material is created for the second embodiment of the invention with the MEMS in the on-state (Fig. 7a) and in the off-state (Fig. 7b). The switch is formed by a deformable elastomeric material 1 with embedded metallic particles 9, 7 and 10. The metallic particles provide a conductive path around the perimeter of the elastomeric material. The string of metallic particles 9, 7 and 10 are connected to ground. A metallic transmission line 2 allows the transfer of the electrical signal. Line 2 is embedded within the deformable elastomeric material 1 and is electrically isolated from the conductive path of the metallic particles. Fig. 7b shows the MEM switch in the shunted state. A DC voltage with respect to ground is applied to electrodes 8 and 18. The electrostatic force creates a lateral elongation of the deformable elastomer 1, resulting in the

compression of the elastomer in the vertical direction. As a result of the compression in the vertical direction, the metallic particles 7 contact the RF transmission line and shunt it to ground, interrupting the signal. The same effect can be achieved by metallic thin films embedded in the deformable element 1 in lieu of the string of metallic particles as shown in

5 Figure 4

A great value of the present invention is its ability to be easily integrated into existing CMOS and BiCMOS processes. Figure 8 illustrates yet another embodiment of the present invention specifically designed to be easily integrated into a conventional CMOS or BiCMOS semiconductor manufacturing facility. The present embodiment features the additional advantage of not requiring the deformable elastomeric material to be conductive or to contain embedded metallic particles. The switch is shown in the off-state (Fig. 8a) and in the on-state (Fig. 8b). A control voltage applied between electrodes 8 and 10 and between electrodes 9 and 18 causes a deflection of electrodes 8 and 18 toward electrodes 9 and 10. This action compresses deformable elastomeric material 1, causing elongation of 1 in the vertical direction and pushing contact 7 against signal lines 5 and 6, connecting RF- in to RF- out.

Figs. 9a-9r describe process steps that are fully compatible with CMOS and BiCMOS for fabricating the MEM switch.

The process to be described hereinafter is shown in Fig. 9a starting with a substrate, e.g., a silicon wafer (not shown), a high resistivity wafer such as silicon-on-insulator (SOI), or a GaAs wafer, and the like. A dielectric layer such as SiO₂ is deposited on top of the substrate, preferably, by PECVD (Plasma Enhanced Chemical Vapor Deposition) and a standard Damascene single level photolithography with reactive-ion etching (RIE) used to pattern and etch holes in insulator 12. Subsequent to the blanket barrier layer deposition (not shown), copper electroplating the etched holes in the insulator 12 and planarization of copper and barrier films yield metallic in-laid structures 22 within insulator 12. A thin barrier layer such as PECVD silicon nitride layer 33 is deposited next on top of the in-laid metal. The

copper in-laid structure 22 serves as the base upon which the metallic electrodes will be subsequently build thereon. Another thicker layer of dielectric insulator 20 is then deposited on top of the barrier silicon nitride layer. The thickness of the SiO₂ 20 layer determines the height of the switch movable element. A typical thickness ranges between 2-6 micrometers.

5 Fig. 9a shows the process after completion of the series of aforementioned steps.

Fig. 9b shows the formation of pattern 25 on insulator 20. The insulating layer 20 is patterned by photolithography and etched to create holes 25 in the insulator by fluorine or chlorine based RIE. A conductive barrier film, such as W, Ta, TaN, is followed by a copper
10 seed layer deposited by physical vapor deposition on top and within pattern 25. Pattern 25 is then filled with copper 30 by electroplating. The metal and barrier films are both planarized by chemical-mechanical polishing resulting in in-laid electrically isolated metallic structures 30. Fig. 9c shows the process after completing the aforementioned steps.

15 Next, a cavity is patterned and etched within the insulator over an area larger than the one containing the metal deposited to a depth that is less than the height of the metal. The Si₃N₄ layer 33 acts as a RIE stop. This step produces free standing, parallel metal plates within air cavity 35, with the bottoms of the plates anchored in the insulator. Fig. 9d shows insulator
20 20 and metal electrodes 30 after cavity 35 pattern transfer. The pattern is established by way of a conventional photolithography stencil and fluorine or chlorine based reactive ion etch.

Referring next to Fig. 9e, the cavity is filled by deposition of sacrificial insulating material 40, such as SiLK or DLC or polyimide, with the property that is easily etched by an etchant such as oxygen plasma that will not also etch the original deposited insulator 20. The
25 sacrificial material 40 filling the cavity 35 is planarized by chemical-mechanical polishing.

In the following step, shown in Fig. 9f, another layer of insulator 50, typically consisting of the same material as 20 is deposited on top of the existing structure.

30 Referring next to Fig. 9g, dielectric 50 is patterned and opened over metal electrodes

30. A pattern transfer is accomplished by way of a conventional photolithography stencil and fluorine or chlorine based RIE.

5 At the step shown in Fig. 9h, cavity 60 is patterned and etched within material 40. This cavity is smaller than, but as deep as the original cavity 35, leaving material 40 along the cavity walls but not along the cavity bottom. The etch that removes the sacrificial material 40 from between metal electrodes 30 uses an oxygen based RIE.

10 The resulting cavity 60 is filled with deformable elastomeric material 1 in the next step, Fig. 9i. A subsequent polishing step is required to planarize the surface down to the level of the insulating material. Next, an additional insulating layer 81 such as Si_3N_4 and a SiO_2 layer is deposited on top of the deformable element 40, as shown in Fig. 9j.

15 Referring now to Fig. 9k, a pattern transfer contact metal is formed into insulating layer 80 using a lithography stencil and RIE. In the latter case, the RIE stop layer 81 need not be removed. Subsequently, the pattern is metallized by depositing by CVD, PVD, electroplating a blanket noble metal such as Ru, Rh, Pt, Au or Pd. The metal is deposited over pattern 82 and within the field area thereon, and patterned by chemical mechanical planarization to form
20 the isolated noble metal contact 7, as shown in Figure 9l.

 After the formation of contact 7, as shown in Fig. 9m, the pattern is transferred, and dielectric layers 50 and 80 local to cavity 35 are removed. The RIE chemistry is chosen to be selective to RIE stop layers within the dielectric layers. RIE stop 81 is removed from 50 and
25 80 simultaneously after removing the primary dielectric. Optionally, two photolithography stencils can be used.

 The next step consists of filling the cavity and planarizing the surface with additional sacrificial material 40, such as DLC or SiLK, as shown in Fig. 9n and depositing a hard mask

72 such as tungsten, tantalum or tantalum nitride or titanium nitride for patterning the sacrificial layer. The hard mask acts as an RIE stop and results in creating a flat upper contact surface with minimal roughness.

5 The next two steps are used to pattern the upper contacts and are shown in Figs 9p and 9q. In Fig. 9p, the pattern is transferred to remove sacrificial material from outside of cavity 35. In Fig. 9q, a dielectric 75 is deposited to form the upper switch contacts. The insulator 75 is then planarized.

10 Upper contacts 5 and 6 are formed in a similar manner as the lower contact 7. A pattern is formed in the insulator 75 by photolithography and reactive-ion etching. The etching stops on hardmask 72. The pattern is metallized by CVD, PVD or electroplating of a noble metal such as Au, Pt, Pd, Ru, Rh. The noble metal may be the same as metal 7 or different than the metal used for contact 7. Finally, the metal deposited on the upper contacts is
15 planarized to give structures 5 and 6, as shown in Fig. 9r.

 To conclude the process, the structure is patterned and etched to remove the insulting material in region 79 exposing the sacrificial material in cavity 35. This is followed by an etch step to remove all the contiguous sacrificial material creating an air cavity 90. The completed
20 MEM switch is shown in Fig. 9s.

 Although only certain embodiments of the invention have been described herein, it will be apparent to those skilled in the art that changes and modifications may be made thereto without departing from the spirit and the scope of the invention as claimed.

25

INDUSTRIAL APPLICABILITY

 This invention is used in the field of wireless communications; namely, in cell phones and base stations.

CLAIMS

1 1. A micro-electromechanical switch (MEMS) for opening and closing a conductive
2 path comprising:

3
4 an elastomeric deformable element (1) having two opposing conductive sides
5 (9,10);

6
7 a conductor (7) positioned on a further surface of said elastomeric deformable
8 element (1); and

9 at least two actuation electrodes (18, 8) substantially parallel to said opposing
10 conductive sides of said elastomeric deformable element (1) , wherein a voltage applied
11 between each of said opposing conductive sides (9,10) and a corresponding one of said two
12 actuation electrodes (18, 8) electrostatically attracts said opposing conductive sides (9,10)
13 towards corresponding ones of said actuation electrodes (18, 8), creating an elongation of
14 said elastomeric deformable element (1) which displaces said conductor (7) in a direction
15 away from said elastomeric deformable element (1), thereby closing the MEMS.

1 2. The MEMS as recited in claim 1, wherein said actuation electrodes (18, 8) are
2 positioned within said elastomeric deformable element (1).

1 3. The MEMS as recited in claim 1, wherein deactivating said voltage applied between
2 each of said opposing conductive sides and a corresponding one of said two actuation
3 electrodes (18, 8) reduces the elongation of said elastomeric deformable element (1) and
4 opens said conductive path.

1 4. The MEMS as recited in claim 1, wherein said actuation electrodes (18, 8) are
2 positioned outside said elastomeric deformable element (1) and wherein said conductive
3 path (2) traverses said elastomeric deformable element (1).

1 5. The MEMS as recited in claim 4, wherein a voltage applied between said actuation
2 electrodes (18, 8) and the conductive sides (9,10) of said elastomeric deformable element
3 (1) generates an electrostatic force that creates a lateral elongation of said deformable
4 elastomer (1) resulting in said elastomeric deformable element (1) being shortened in a
5 transverse direction, allowing said elastomer make contact with said conductive path (2),
6 shunting it, and interrupting passage of an electrical signal.

1 6. The MEMS as recited in claim 5, wherein when no voltage is applied between said
2 actuation electrodes (18, 8) and the conductive sides (9,10) of said elastomeric deformable
3 element (1), then said elastomer returns to its original shape, allowing said electrical signals
4 to flow through said conductive path (5,6).

1 7. The MEMS as recited in claim 1 further comprising a plurality of parallel actuation
2 electrodes (18, 8) wherein a voltage difference between any two adjacent actuation
3 electrodes (18, 8) electrostatically attracts the free end of said actuation electrodes (18, 8),
4 further increasing the displacement of said conductor in a direction away from said
5 elastomeric deformable element (1) and closing said MEMS.

1 8. The MEMS as recited in claim 1, wherein said MEMS is configured as a single
2 pole, single throw switch.

1 9. The MEMS as recited in claim 1, wherein said MEMS is configured as a single-
2 pole-multiple throw switch.

1 10. The MEMS as recited in claim 1, wherein the elongation of said elastomeric
2 deformable element is govern by equation 1:

$$3 \quad H_1 + H_2 = (W - 2S_1)/2 \tan(\theta/4) \quad (1)$$

4 wherein

5 H_1 is the elongation of the elastomeric deformable element,

6 H_2 is the thickness of the conductor,

7 S_1 is the lateral displacement of the elastomeric deformable element,

8 W is the width of elastomeric deformable element, and

9 θ is the angle by which the elastomeric deformable element is compressed.

1 11. The MEMS as recited in claim 1, wherein said elastomeric deformable element (1)
2 is made of a material selected from the group consisting of polymer, polyimide, SiLK,
3 DLC, and silicone rubber.

1 12. The MEMS as recited in claim 11, wherein the strain on the conductive path is
2 given by Equations 2 and 3:

$$3 \quad \epsilon_{zz} = H_f - H_i / H_i \quad (2)$$

4

$$5 \quad \epsilon_{zz} = 2 \sigma_{xx} \nu / E_{\text{polymer}} \quad (3)$$

6 wherein E_{polymer} is Young Modulus for the polymer, and ν Poisson's ratio for the polymer.

1 13. The MEMS as recited in claim 1, wherein said conductor (7) is made of a material
2 selected from the group consisting of W, Pt, Pd, Ir, Ru, Re, Rh, Au and their alloys.

1 14. The MEMS as recited in claim 1, wherein said actuation electrodes (18, 8) are made
2 of a material selected from the group consisting of Al, Cu, and W.

1 15. The MEMS as recited in claim 1, wherein said each of said conductive sides (9,10)
2 are comprised of interconnected metallic particles.

1 16. The MEMS as recited in claim 1, wherein said conductive path (2) is positioned
2 within said elastomeric deformable element (1).

1 17. A method of fabricating a MEMS switch for opening and closing a conductive path
2 comprising the steps of

3 a) forming discrete metallic bases (22) on an insulated substrate;

4 b) forming a plurality of metallic beams (30) respectively on each of said bases (22);

5 c) forming a cavity (35) to free each of said metallic beams (30);

6 d) filling the cavity (35) with an elastomeric deformable material (1);

- 7 e) forming a conductor (7) on a surface of the elastomeric deformable material (1);
- 8 f) forming at least two individual conductive paths (5,6); and
- 9 g) exposing the elastomeric deformable material (1) having the embedded metallic
- 10 beams (30), the conductor (7) and the conductive paths (5,6) to make electrical contact
- 11 between the conductor (7) and the conductive paths (5,6) when activating the MEMS.