A Novel Bi-Stable MEMS Switch

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***Abstract*: This paper proposes a novel MEMS based switch which can be used to make an electrical contact without continuous supply of energy. The proposed structure is bi-stable and can be toggled with just a pulse of energy. The bi-stable state generates its own pressure to result in a low contact resistance. The simulations were done using ANSYS 14.**

Keywords: switch; bi-stable; MEMS

I INTRODUCTION

Switches are used in our everyday life. The size of the mechanical switches is usually large. Despite having large contact area, they carry relatively less amount of current. This is somehow inefficient and space consuming in this era of miniaturization. Furthermore, the switches must occupy less space, actuate very fast, consume less energy to operate them, have less contact resistance and hence carry large currents with more efficiently.

We need switches that require less amount of actuation energy and even if the actuating force is withdrawn, it should still be able to maintain a very low resistance contact.

Also the question of reliability arises. We often encounter many catastrophic failure cases when these switches cause overheating of the contacts leading to fire hazard which in turn causes severe damage. So there is a need for a switch design that is more reliable.

Micro Electro Mechanical Systems (MEMS) is already an established technology for making micro-switches [1,2]. In this paper we propose a novel toggle-type MEMS micro-switch which will have the above mentioned qualities.

II PROPOSED DEVICE

The proposed MEMS switch has the dimension 100µm x 100µm x 1µm. This single unit would carry 10mA of current. Therefore 500 such units will be integrated in a single device of 2.5mm x 2.5mm that will be able to carry 5A of current. Putting many units in parallel provide redundancy which tremendously improve reliability. The device current of 5A is sufficiently large compared to the area of the device.

A Bi-Stable bending element is the key novel idea to achieve the most important property of low contact resistance of the switch. The bending element has been planned to have two different engineering materials that have dissimilar linear coefficient of thermal expansion. Usually the MEMS fabrication processes are done at higher temperatures like 350˚C-700˚C. The sequence and the temperatures of deposition give us the inherent possibility that when the device is brought down to room temperature they will be having uneven contraction leading to a bi-stable element.

The device structures is shown in Fig-1a (isometric view) and Fig. 1b (plan view).

The outside D-part is of one material and the reed-like part sitting on is made of another material and has a electrically conducting tip. While the processes make a stress free structure at elevated temperatures, when it is used at a much lower temperature, say close to room temperature, the reed part contracts more and pulls at the D-part. This pulling action has 2 possible results, either the structure can bend upward or bend downward. The reed part is initially bent in one of its 2 stable states as shown in Fig. 2. When force is applied in upward direction, the switch will bend in opposite direction, make contact and develop pressure on contact so as to reduce contact resistance.

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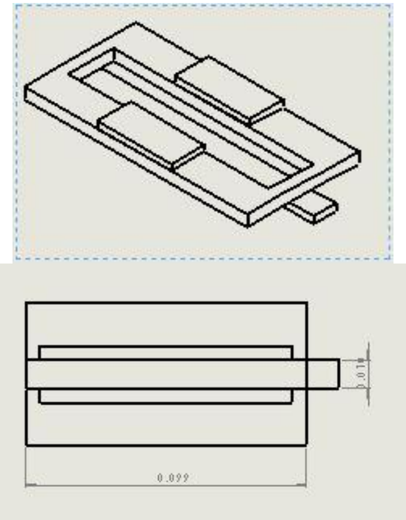

Fig. 1 (a) Isometric view of the bi-element structure (b) plan of bi-element structure

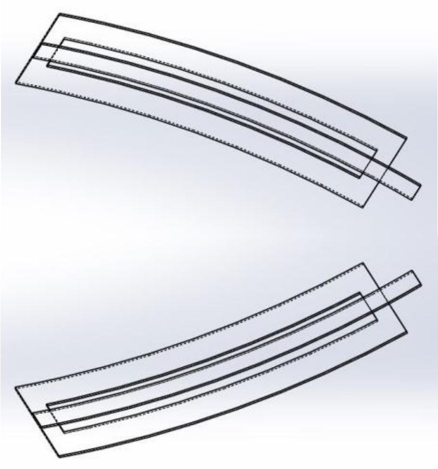

Fig. 2 The switch is initially bent down and on application of force bends up to make contact

The proposed switch has two stable states. The switch can toggle from one stable state to another by application of an external force as shown in Fig. 3. It can create enough external pressure on the contact area by itself even if the external force is removed.

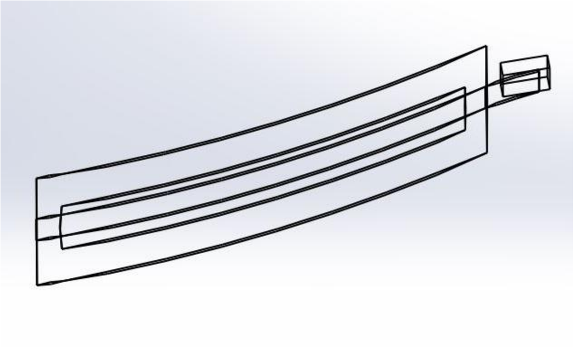

Fig. 3 An electrical contact is made when switch bends up

III SIMULATIONS AND RESULTS

TABLE 1. Data used for simulations using ANSYS 14.5.

Length of D-base part	100µm	Initial temperature of structure	22^{o}C
Length of the reed strip	110 µm	Temperature at which simulation is done	300^{o}C
Width of the base	50µm	Young's modulus	71 & 200 GPa
Width of the reed strip	10µm	Thermal expansion co-efficient	2.3e-5 & 1.2e-5/K
Separation	15µm	Thickness of the structures	0.5µm

The simulations were done using ANSYS 14.5 to demonstrate the bi-stability of the structure and also to find out the 2 stable states (bent-up and bent-down) and the unstable position. Another simulation result shows the force that is required to flip from one stable state to another.

The switch was held fixed at the rear end and was given different displacements in vertical direction at the tip. The strain energies at those different positions were noted and plotted, as shown in Fig. 4. The sudden change in strain energy at a certain deflection demonstrates the bi-stability. The inherent asymmetry in the structure causes the difference in strain energies in two sides of deflection. The side with the higher energy would be used to make a firm electrical contact.

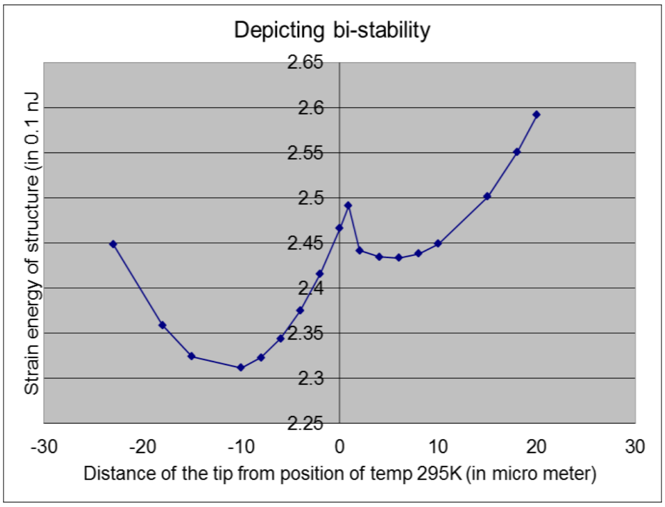

Fig. 4 Plot of Strain energy Vs tip deflection for the switch

We found the reaction force that will be generated if a contact is placed to prevent complete deformation. Reaction force generated at different deflections is shown in Fig-3. The reaction force varies linearly as the distance from the maximum deflection at the stable state 1.

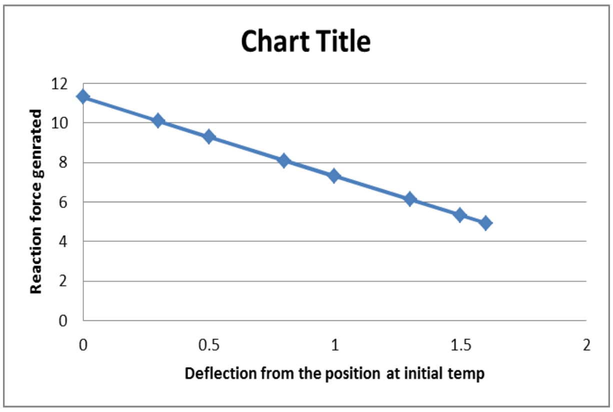

Fig. 5. Reaction force provided by the switch for a fixed deflection

To determine the force needed to flip from stable state 1 to state 2, simulations were done for steps of force applied in increasing steps to tip. The bent structure slowly straightens and but simulation halts when the structure goes through the point of singularity. Therefore the force required to flip the switch is calculated as the force at which the static simulation halts. This fig. 6 shows the structure passing through the point of instability.

The force required to flip from more stable state 1 to less stable state 2 was found to be 4.33 µN.

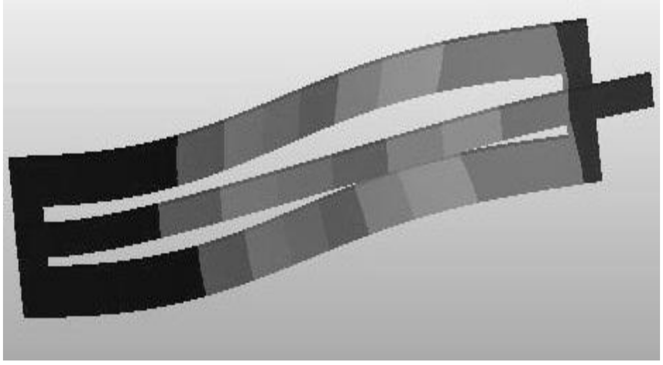

Fig. 6 The structure passing through the point of singularity (unstable point)

IV CONCLUSION

The proposed switch has two unsymmetrical stable states. This can be used to make contact and remove it also by actuating through thermal or electrostatic forces. There is no need to keep the force continuously. Once actuated, it can provide enough pressure to maintain the contact with low contact resistance.

REFERENCES

1. Marc Madou, Fundamentals of Microfabrication : the science of miniaturization, CRC press, 2002.
2. Mohamed Gad-el-Hak (Eds.), MEMS Introduction and Fundamentals, CRC press, 2006