Fabrication and characterization of MEMS cantilever for power applications

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1. Introduction

A MEMS switch is a micro-machined device consisting of a membrane or strip of metal suspended over an electrode. The operation of this switch is caused by electrostatic field induced by an applied voltage. But, many of these switches are not commercialized yet. Because of the degradation phenomenon like stiction,creep,microwelding. Therefore research is further going on this and also solution has been suggested. Still,MEMS cantilever switches have superior performance compared to semiconductor devices. The main advantage of the switch is near to zero static power. In this project focus is on the design and development of MEMS cantilever interconnected switch array having higher current handling capacity. For this, current splitting in the array of switching elements is explored and utilized for high power switching applications with reduction in thermal issues. This approach allows us to configure the switch array for different power and isolation requirements

2. Micro Cantilever Switch

MEMS switches can be electrostatically actuated when voltage is applied to electrode then electrostatic force acts on electrode pulls down the canti-lever beam and making the switch 'ON and on removing the voltage it moves back to its normal position making it 'OFF'.

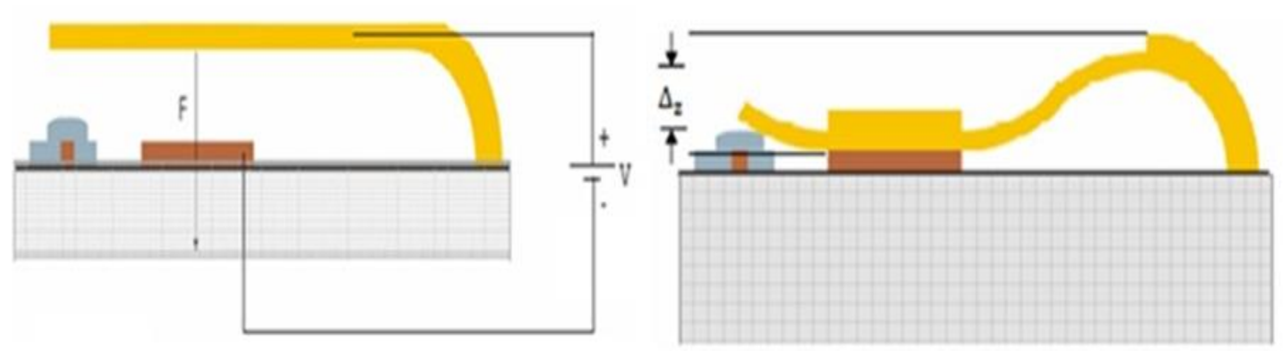

Fig. 1. Microcantilever Switch (ON and OFF state).

3. Device Design

In the design of switch, designing the physical parameters is utmost important. The dimensions of electromechanical systems affects spring constant, current , pull in voltage, resonance frequency and thermal mass, leading to drastic changes in power consumption and switching speed.
The parameters of prime importance for device performance during working of the switch are –

3.1 Current
Our objective is to design a cantilever switch for high power, hence the current carrying capacity of the transmission line plays a very important role. Therefore, lower resistive path is required as it offer high flow of current and due to this high flow causing temperature instability

$$I = A\left(\frac{\log\left(1+\frac{Tm-Ta}{234+Ta}\right)}{33s}\right)^{\frac{1}{2}}$$

3.2 Pull in Voltage
It is the voltage require to pull the cantilever beam down ,the formula is--

$$V_{Pin} = \sqrt{\frac{8kg_0^3}{27\varepsilon_0 S}}$$

3.3 Response time
The response time of any device must be as low as possible the formula is

$$t = 3.67\frac{V_{pin}}{V_s\omega_0}$$

4. Performance Analysis

Taking all these factors into consideration, design parameters has been chosen as in figure 2
The dimensions were adjusted and material finalised i.e. aluminum as it requires less pull in voltage and therefore we get low response time as shown from table 1.

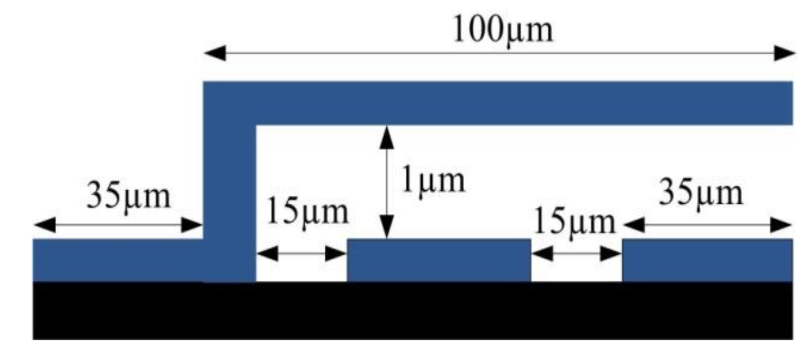

Fig. 2. Microcantilever Switch

Parameters	Materials			
	Aluminium	Nickel	Copper	Silicon
Density (kg-m³)	2700	8908	8900	2350
Young's Modulus (GPa)	71	200	110	130
k_t(N/m)	0.077	0.21	0.12	0.14
m (p kg)	4.725	15.5	15.4	4.112
V_p(V)	1.44	2.6	1.9	2

Table 1. Material Comparison for cantilever having dimensions 100µm x 35µm x 0.5 µm

4.1 Array –
Based on the power splitting approach, the current splitting approach is chosen for the increasing the current handling capacity of the MEMS cantilever switch using an array of switching elements. By current splitting concept, an increase in the number of rows of the switch matrix can effectively increase the current handling of the system of switches.

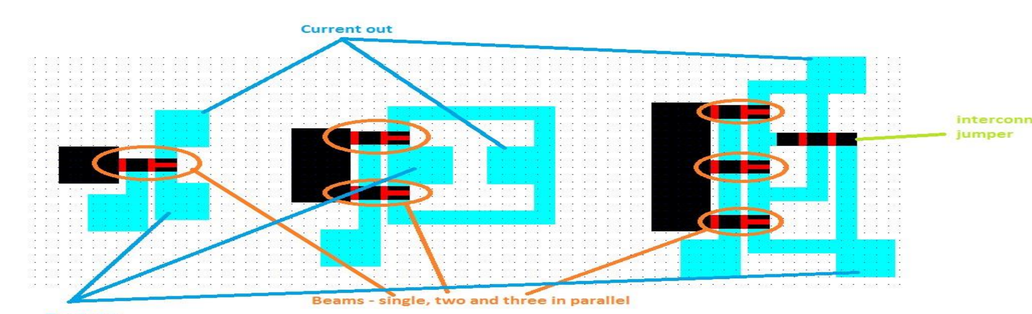

Fig.3. Current Splitting across Parallel Beams

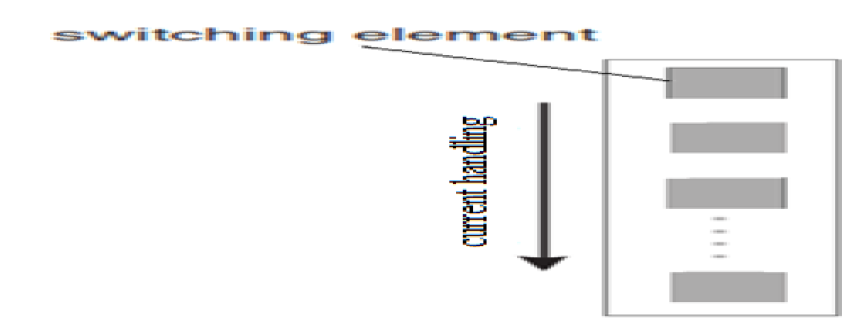

Fig.4. Array of MEMS switching elements

5. FABRICATION

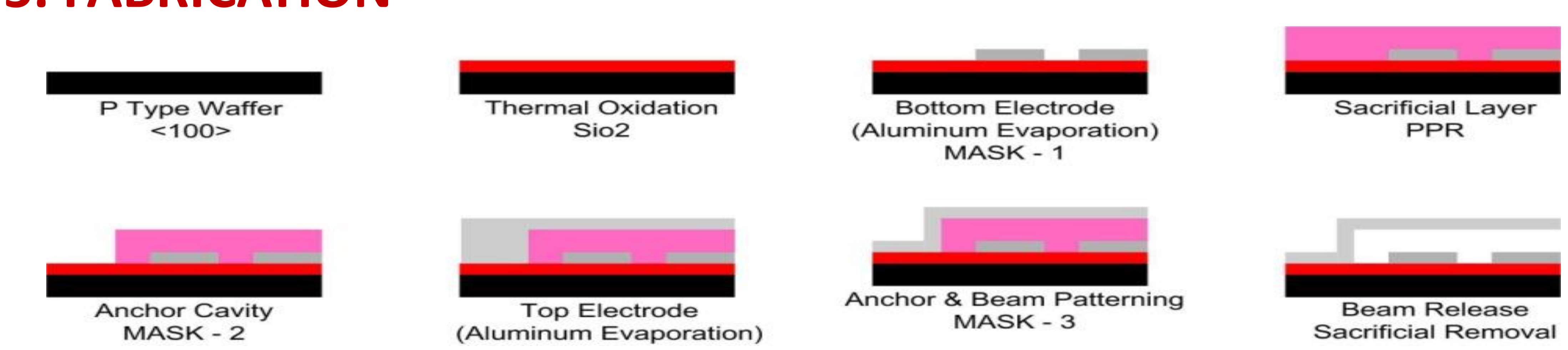

Fig .5. Fabrication Process Flow

6. ELECTRICAL CHARATERIZATION

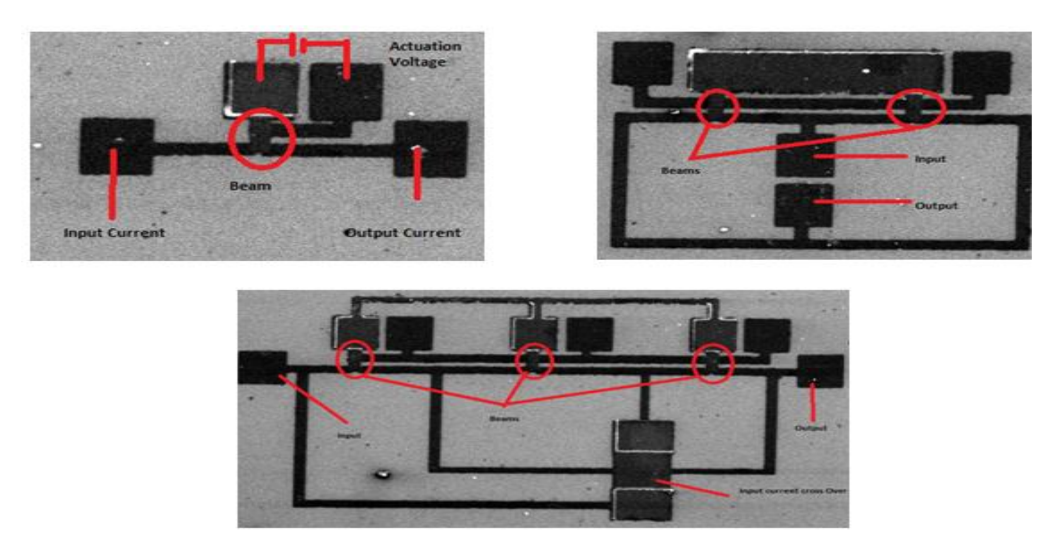

Fig.6. One, Two and three beam in parallel

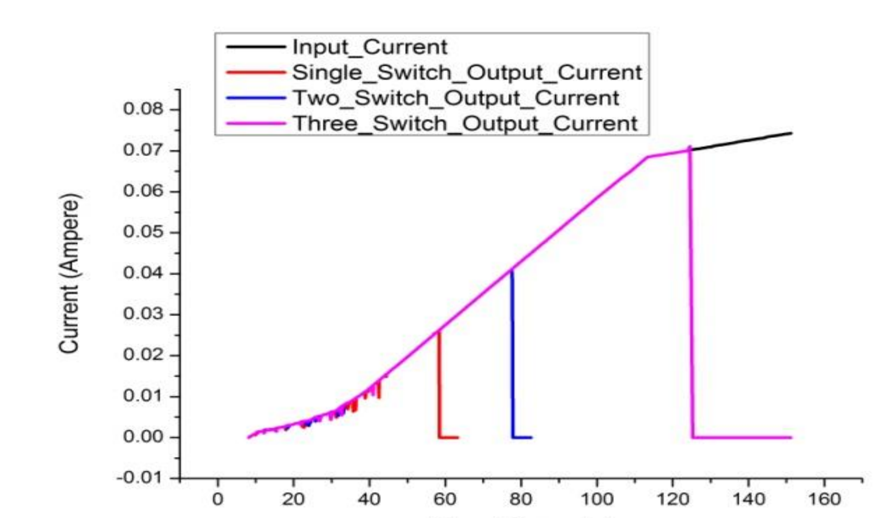

Fig.7. Current VS Time

7. CONCLUSION

MEMS cantilever switch has been fabricated and tested for its current capability. The parallel arrangement of these switches is used to increase the current capability.

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