Simulation of a Polyimide Based Micromirror

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Abstract

Our work presents the simulation of a micromirror using polyimide as the structural material. In the past two decades polyimide, SU-8 and other polymeric materials have been widely used as a structural material for MEMS devices such as: antennas [1], gyroscopes & accelerometers, sensors & actuators [2], amongst others [3-8]. In our work we designed a micro-mirror which is composed by a central beam anchored at both ends, with two plates (like wings) to at each side of the beam as shown in Figure 1. Two pair of electrodes are located on the bottom of the structure in each side of the wing like plates, two left electrodes (80 µm X 30 µm) and two right electrodes (125 µm X 40 µm), see Figure 2. The micro-mirror and electrodes are separated by 2 µm from the substrate, which acts as a common ground for the entire device, while the top electrodes are set to a different potential for the device actuation. The device has an overall size of 550 µm in width, 300 µm in length and a total of 8 µm in height.

COMSOL Multiphysics® software was used to verify the initial design parameters and to explore the different characteristics of the electromechanical device. For simulation simplicity the electrodes are integrated as part of the structural layer.The device thickness is 6 µm while the electrodes are 300 nm thick. For the actuation of the device the Bottom Left (BL) electrode and Bottom Right (BR) electrode have the same potential. Due to the difference in electrode area the mirro will have a torsion and deflect to the largest electrode side. Using this principle, we could control the tilt of the micro-mirror depending on the input voltage. Figure 3 shows the first results from our electrostatic simulations of the micro-mirrors.

As part of the results we expect to find an accurate pull-in voltage for such structures and verify the model with our fabricated chips. Figure 4 shows an SEM image of the fabricated device. We are contamplating the application of our devices toward MEMS switches and logic electromechanical operator [9-15].

Reference

1. L. Marnat, A. A. A. Carreno et al.,"New Movable Plate For Efficient Millimeter Wave Vertical On-Chip Antenna," IEEE Transactions on Antennas & Propagation, vol. Submission: AP1206-0881.R2.

2. Lee S W et al, 2005 MEMS mechanical logic units: design and fabrication with micragem and polymumps Proc. Canadian Conf. on Electrical and Computer Engineering (Saskatoon, Canada, 1 –4 May 2005) pp 1513–6.

3. Ahmed Alfadhel, Armando Arpys Arevalo Carreno et al.,"Three-axis Magnetic Field Induction Sensor Realized on Buckled Cantilever Plate," IEEE Transactions on Magnetics - Conferences, pp. Submission:MAGCON-12-11-1619.

4. Arpys Arevalo and Ian G. Foulds, "Parametric Study of Polyimide-Lead Zirconate Titanate Thin Film Cantilevers for Transducer Applications", 2013 COMSOL Conference, Rotterdam, Holland, 2013.

5. A. A. Arévalo Carreño et al., "Simulation of a Low Frequency Z-axis SU-8 Accelerometer in CoventorWare and MEMS+", UKSIM2013.

6. D. Conchouso, A. A. Arévalo Carreño et al., "Simulation of SU-8 Frequency-Driven Scratch Drive Actuators", UKSIM2013.

7. A. A. A. Carreno et al., "Optimized Cantilever-to-Anchor Configurations of Buckled Cantilever Plate Structures for Transducer Applications", COMSOL Conference, Milan, Italy, 2012.

8. A. A. A. Carreno et al., "UHeater on a Buckled Cantilever Plate for Gas Sensor Applications", COMSOL Conference, Milan, Italy, 2012.

9. J. Jeon et al., "Seesaw Relay Logic and Memory Circuits," IEEE/ASME J.Microelectromech. Syst. Lett., vol. 31, no. 4, pp. 1012-1014, 2010.

10. Tsai C-Y et al., T-L 2008 Design and fabrication of MEMS logic gates J. Micromech. Microeng. 18 045001.

11. Hirata A et al., 2000 A electrostatic micromechanical switch for logic operation in multichip modules on Si Sensors Actuators A 80 119–25.

12. R. Nathanael et al., "4-terminal relay technology for complementary logic," in IEEE IEDM Tech. Dig., 2009, pp. 223-226.

13. S. Hanson et al., "Ultralowvoltage, minimum-energy CMOS," IBM J. Res. & Dev., vol. 50, no. 4/5, pp. 469-490, 2006.

14. F. Chen et al. "Integrated circuit design with NEM relays," in Proc. IEEE/ACM Int'l Conf. Comput.-Aided Des., 2008, pp. 750-757.

15. R. Parsa et al., "Nanoelectromechanical relays with decoupled electrode and suspension," in IEEE MEMS Cancun, Mexico, 2011.

16. S. Chowdhury et al. “Pull-In Voltage Calculations for MEMS Sensors with Cantilevered Beams”, IEEE NEWCAS Conference (2005).

Figures used in the abstract

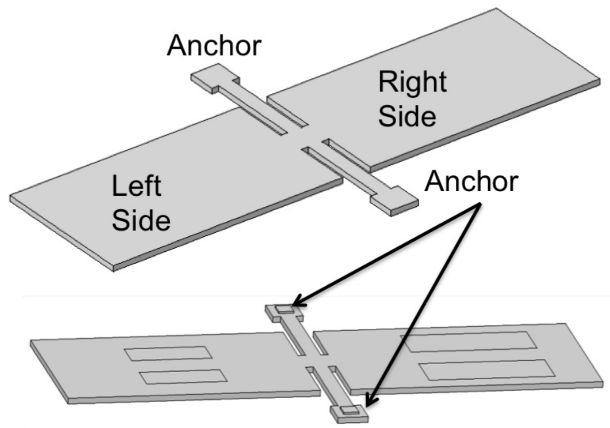

Figure 1: Top Perspective view of the micromirror, also bottom showing anchors and electrodes.

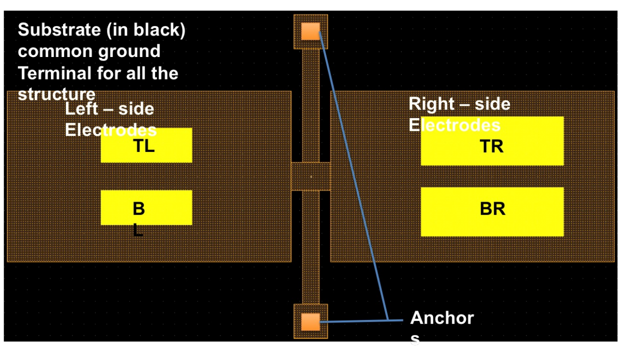

Figure 2: Layout design view of the micro-mirror, highlighting the electrodes configuration.

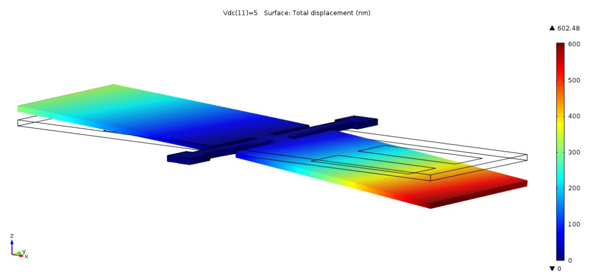

Figure 3: Micromirror simualted with a bias voltage of 5 Volts. Just before pull-in at a displacement of 602nm.

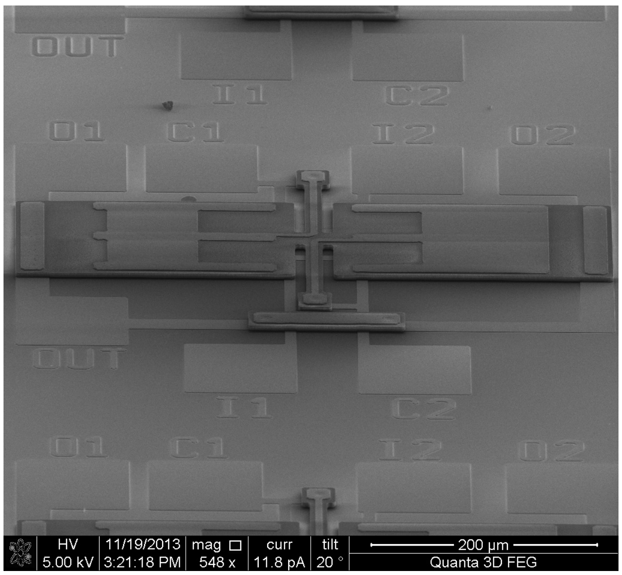

Figure 4: SEM image of fabricated micro-mirrors using Polyimide as the structural material.