Curved cantilever design for a robust and scalable microelectromechanical switch

D. Grogg, U. Drechsler, A. Knoll, Y. Pu, C. Hagleitner, M. Despont
IBM Research - Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland
dgr@zurich.ibm.com

We propose a novel concept for in-plane curved cantilever switches for logic applications that is compact and robust because of good control of the actuation gap in the closed position. The contact and actuation gap are not defined lithographically, but through the thickness of the same sacrificial layer. Hence, the fabrication process is drastically simplified and allows scaling to the nanometer size. We have demonstrated high robustness and good switching characteristics.

The design of microelectromechanical switches for logic applications needs to address many challenges, such as device size, operation voltage, operation speed, robustness, and contact resistance. In common MEM switch designs, the actuation and the contact electrodes are placed in a plane normal to the direction of motion, requiring creation of a dimple or leading to high electric fields at the edge of the actuation electrode [1, 2, 3]. Tilting the actuation electrode by an angle α with respect to the normal plane, as shown in Figure 1, reduces the closing of the actuation gap and results in a minimal electric field from gate to cantilever for α = 60° in the closed position. The motion of the curved cantilever switch can be approximated as a rotation around a softer hinge close to the anchor, and its direction of motion is given by the tangent of a circle centered on the hinge.

Figure 2 shows FEM simulations of the displacement versus actuation voltage for 29.5-µm- and 15.5-µm-long switches. The inset shows the simulation results for a 3-µm-long switch with a 100-nm-wide hinge and a gap of 10 nm, illustrating the scalability of the concept. The fabrication process (Figure 3) is based on a SOI substrate, which is patterned to form the switch and its anchor. A 30-nm-thick platinum silicide is created on the lateral sidewalls before the deposition of a sacrificial silicon dioxide layer. Care has been taken to avoid Cu on the lateral sidewalls to enable the plating of the electrode in the desired location. Finally, the switches are released with time-controlled SiO_2 etching in BHF. An SEM picture of a 29.5-µm-long device is reproduced in Figure 4.

The static I_D-V_G characteristic of the 29.5-µm-long switch is shown in Figure 5, revealing ohmic contact at low drain voltage levels and a resistance of 5 kΩ in the on-state given by the long and thin PtSi layer. The pull-in voltage is at 14.3 V and corresponds to a gap of about 75 nm. The time to electrical contact during pull-in is given in Figure 6, showing a mechanical switching time of 130 ns. Bouncing of the switch cannot be observed because of the slow discharge of the parasitic capacitance shown in the inset. Figures 7 and 8 show an SEM image and the I_D-V_G characteristic of a 15.5-µm-long switch. The pull-in voltage is 8 V, whereas the breakdown voltage of the actuation electrode is at 35.8 V, demonstrating the high robustness of the proposed design.

1. Min-Wu Kim et al., J. Micromech. Microeng. 21 (115009), 2011.
2. H.F. Dadgour et al., Proc. Design Automation Conf. 2010.
3. R. Parsa et al., Proc. IEEE MEMS 2011.

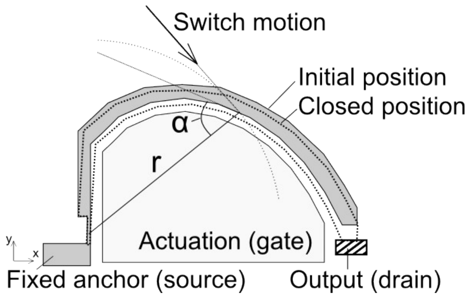

Figure 1: Layout of a curved cantilever switch.

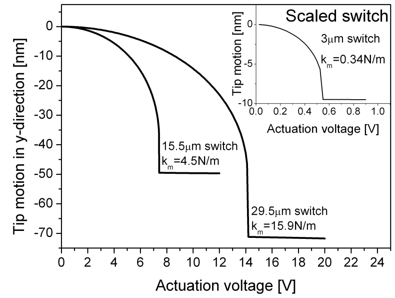

Figure 2: FEM simulation of the tip motion versus actuation voltage for different curved cantilever switches.

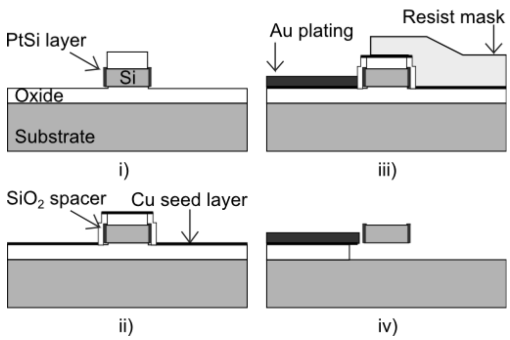

Figure 3: Fabrication process of the in-plane switches with PtSi to Au contacts.

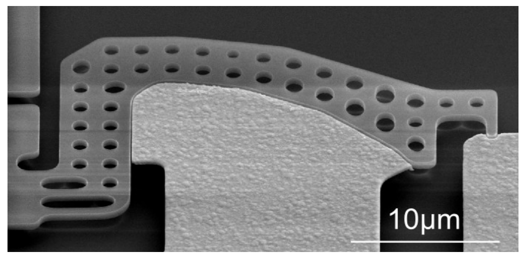

Figure 4: Tilted-view SEM image of a released 29.5-μm-long switch.

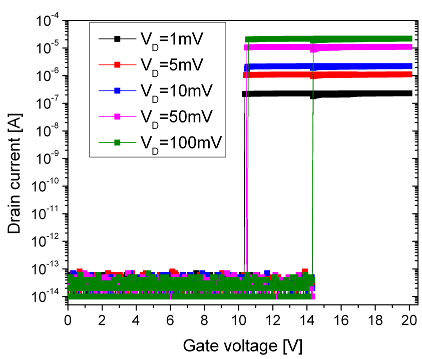

Figure 5: Static characteristics of a 29.5-μm-long curved cantilever switch.

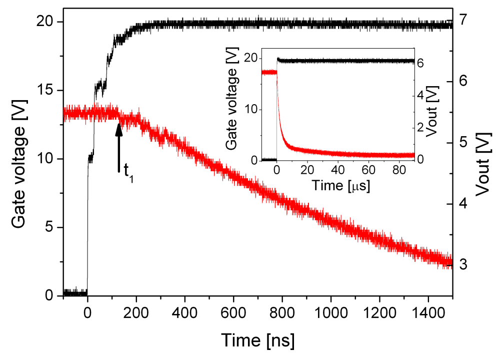

Figure 6: The switching time until electrical contact (t_1) during pull-in of a 29.5-μm-long switch is 130 ns.

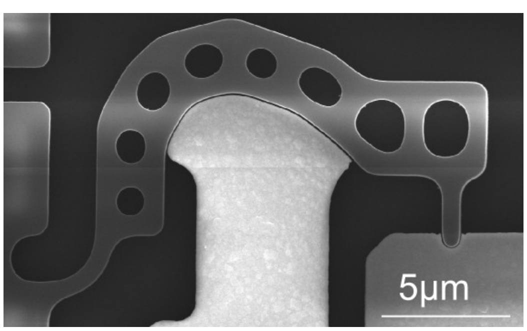

Figure 7: SEM image of a 15.5-μm-long curved cantilever switch.

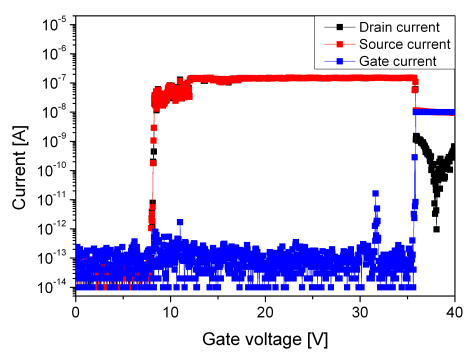

Figure 8: A pull-in and stability experiment showing $V_{pull\text{-}in}$ at 8 V and electrical breakdown at 35.8 V.