SAND2007-6142C

MEMS Ohmic Latching Relay

We have developed a Microelectromechanical System (MEMS) latching relay that operates at low voltage (< 5V), operates during shock events (>7000 g), and operates during extreme radiation doses (100 Mrad/s). A wide variety of applications, including, medical, automotive, and RADAR systems use relays [1]. These applications use circuits operating from DC to RF frequencies. MEMS relays operate with significant improvements in size and performance over macro-relays. Specifically, MEMS relays have smaller physical dimensions than conventional relays; therefore, they achieve higher switch densities. With respect to performance, RF MEMS ohmic switches demonstrate lower insertion loss, higher isolation, greater linearity, and lower static power dissipation than solid state switches [2, 3]. Systems of relays realize single-pole single-throw to multiple-pole and multiple-throw switching capabilities.

Our MEMS latching relay is composed of three distinct components, 2 thermal actuators and a fully compliant bi-stable micromechanism (FCBM) (Figs. 1a & 1b). The components are fabricated from multiple planarized polysilicon layers using Sandia's SUMMiT V™ process. A polysilicon layer (Fig. 1(b)) is fabricated above the thermal actuators and FCBM to shadow these components during metal deposition. This prevents shorting the components to ground. The "unlatch" and "latch" thermal actuators are located on the top and bottom of the design (Fig. 1a), respectively. The FCBM is located in between them. The FCBM has two stable positions, open and closed, with an unstable equilibrium point in between the two positions. Applying power to the thermal actuators toggles the FCBM between stable positions, opening and closing the relay.

The latching relay has been tested in two extreme environments: high shock and high radiation dose. To test the sensitivity of the latching relays to shock, the latching relay were assembled in a gun-fired penetrator (Fig. 2a) and shot into a cement target (Fig 2b) at the Army Waterways Experiment Station in Vicksburg, Mississippi. This test resulted in a peak acceleration of 7191 g's for a duration of 5.5 ms. The MEMS devices were instrumented using the MEMS Diagnostic Extraction System (MDES), which is capable of driving the devices and recording the device output data during the high-g event, providing in-flight data to assess the device performance. All relays functioned properly before, during, and after the high-g test without a single failure (Fig. 2c). To test the sensitivity of the relays to high radiation dose, the devices were instrumented and connected to recording equipment through 50' of cabling. The relays were lowered into the ACRR (Fig 3a) at SNL and operated remotely. The data was recorded continuously through all experiments. The reactor produced a pulse of 100 Mrad(Si)/s and total dose of 16.5 Mrad(Si) with a mix of neutrons and high energy photons, with a maximum neutron fluence of 1 x 10^{16} n/cm^2. The relays opened and closed through these events without fail (Fig. 3).

We have developed, fabricated, and tested a latching relay that is shock and radiation hard. The relay operated through a shock event of 7191 g without an error opening or closing. The relay also operated through a peak radiation dose of 100 Mrad(Si)/s with a total dose of 16.5 Mrad(Si) without a failure opening or closing. The relay has a 3 dB bandwidth of 1 GHz with isolation of 60 dB at 1 GHz. The majority of the insertion loss is capacitive coupling to the substrate. We are currently redesigning the relay to improve RF performance. The switch has not failed mechanically to > 100M cycles. We are incorporating a metallurgy into the relay that has demonstrated stable contact resistance to 1 B cycles in a different switching platform.

[1] K. E. Petersen, "Membrane switches on silicon," IBM J. Res. Develop., vol. 23, pp. 376–385, 1979.

[2] S. Lucyszyn, "Review of radio frequency microelectromechanical systems technology", IEE Proc.-Sci. Meas. Technol. Vol. 151, No. 2, pp. 93-103, March 2004.

[3] G. M. Rebeiz, *RF MEMS Theory, Design, and Technology,* John Wiley & Sons, New York, NY, 2003.

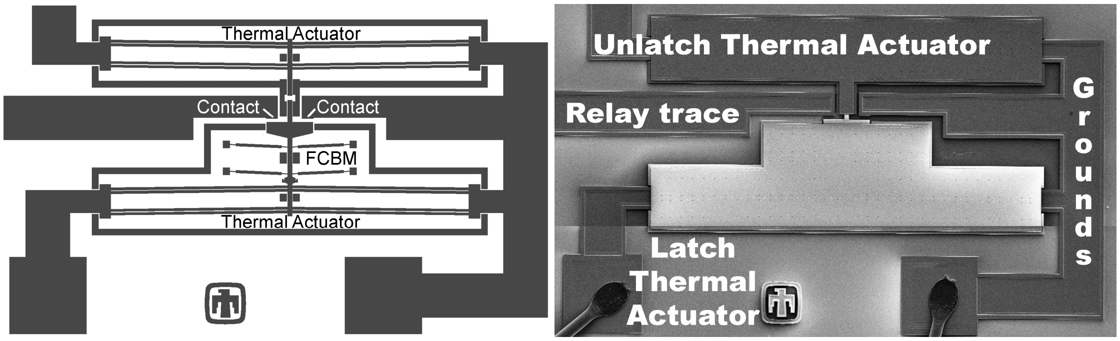

Figure 1 a) Schematic of the latching relay showing the two thermal actuators that are used to toggle the FCBM between positions where it is separated from the traces by 8 μm (relay is open) and where it is in contact with both traces (relay is closed). b) Scanning electron micrograph of the latching relay. The area of the SEM encompasses the entire schematic in 1a. For testing purposes, the ground for the thermal actuators and trace are connected on the right. The actuation signals for the thermal actuators are the upper and lower traces on the left. The relay trace is the center trace on the left.

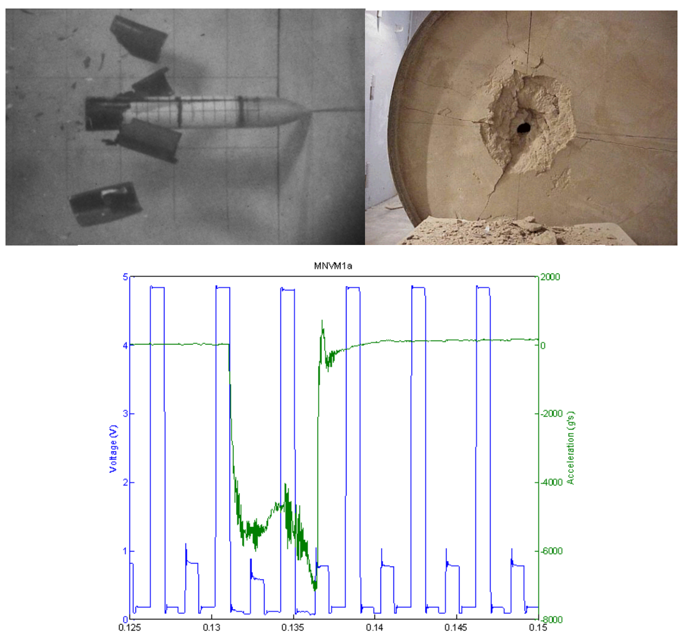

Figure 2 a) The assembled penetrator, encapsulating the MEMS relay, was shot into a concrete block. b) The front of the concrete block after the penetrator was imbedded into the concrete. c) Data showing the relay open (high voltage signal ~ 4.8 V) and close (low voltage signal ~ .75 V) during the shock event.

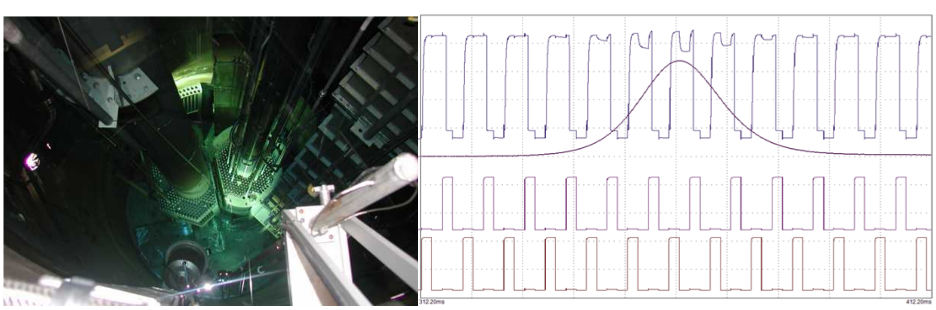

Figure 3 a) The reactor at Sandia National Laboratories, used to generate the high radiation doses. B) Data showing the relay open and close during the radiation event (Gaussian-shaped curve). Below the actuation data is shown the drive signals used to operate the relay.