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# Experimental Investigation on the Exploitation of an Active Mechanism to Restore the Operability of Malfunctioning RF-MEMS Switches

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**Abstract**

RF-MEMS (MicroElectroMechanical-Systems for Radio Frequency applications) switches and components can enable the realization of high-performance and highly-reconfigurable blocks for a variety of applications in the field of telecommunications, spanning from mobile phones to scanning radar systems and satellite communications. Nevertheless, the exploitation of MEMS technology in the RF field is still limited by the relatively poor reliability of RF-MEMS devices and networks. In this work, we discuss the exploitation of an active mechanism that was recently presented by the authors, and capable of improving the robustness of RF-MEMS switches against stiction. The mechanism exploits the heat generated by an electric current driven through a high-resistivity PolySilicon serpentine, embedded within the switch structure, to recover the normal operability of the RF-MEMS relay, and is effective both against charge entrapped in the insulating layer as well as micro-welded spots due to large RF signals. The mechanism can be added with only minimal changes to a wide variety of already existing RF-MEMS switches and components topologies. In this paper we report the first experimental results showing a successful release of a stuck switch after the heater is activated. Moreover, we discuss proper activation methods of the proposed mechanism by performing FEM simulations in order to maximize the benefits of the PolySilicon heater operation without impairing the mechanical characteristic of the MEMS switch. 

*Keywords*: RE-MEMS switches; reliability; active restoring mechanism; sticion; micro-welding; entrapped charge; FEM simulations

## 1. Introduction

MEMS (MicroElectroMechanical-Systems) technology for RF (Radio Frequency) applications has emerged in the past decade as an enabling solution to realize low-cost and high-performance lumped components, like high Q-Factor and widely reconfigurable variable capacitors and inductors [1,2], high-isolation and low-loss ohmic/capacitive switches [3]. The availability of such components speeds-up both the MEMS hybridization with

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standard semiconductor technology [4] as well as the synthesis of functional sub-blocks entirely based on microsystems, like reconfigurable phase-shifters [5], power attenuators [6] and switching matrices [7].

In spite of the significant advantages that a large-scale exploitation of RF-MEMS components and networks would bring in terms of performance and reconfigurability, their penetration into the market is still very limited, mainly because of their sensitivity to several impairing factors (both mechanical and electrical) that reduce significantly the reliability of MEMS-based implementations if compared with standard ones. Given the multi-physical behavior of MEMS (electromechanical), potential sources of malfunctioning and fatal failure are both the ones typical of standard semiconductors devices, like for instance electromigration and ESD (ElectroStatic Discharge), as well as additional causes linked to the materials and mechanical properties, e.g. plastic deformations, wearing, fatigue and fractures [8,9].

Among the most important failure modes affecting RF-MEMS devices, we focus on two that typically already start to show up in the short/medium-term operation of MEMS-based switches, namely, the charge entrapment within the insulating layer [10] and the occurrence of micro-welding [11]. To this purpose, we already presented and discussed an active solution to counteract stiction (i.e. the failed release of a MEMS switch due to one or both the above mentioned failure mechanisms), based on embedding an high-resistivity PolySilicon heater within a standard RF-MEMS ohmic switch design [12]. The heat generated by an electric current driven into the serpentine induces, on one side, deformations of the MEMS membrane and, thus, an additional contribution of shear and restoring force (useful to counteract stiction due to micro-welding). On the other hand, the heat speeds-up the dispersion of charge entrapped in the insulating layer [13].

In this paper we report the first experimental results showing the effective release of a stuck RF-MEMS switch by activating the heater, as well as an investigation, based on FEM (Finite Element Method) simulations, aimed at defining efficient operation methods of the PolySilicon serpentine, that maximize the switch restoring capabilities and minimize, at the same time, the impact of the heat on the mechanical properties of the MEMS device.

## 2. The Embedded Heating Mechanism: Experimental Measurements

The RF-MEMS series switch topology we presented in [12] is schematically reported in Fig. 1. In particular, Fig. 1-left shows the complete structure, featuring the MEMS ohmic switch, the CPW (CoPlanar Waveguide) and the DC pads for the biasing of the central plate (actuated/not-actuated positions) and for activating the PolySilicon heaters, embedded underneath the gold anchoring areas.

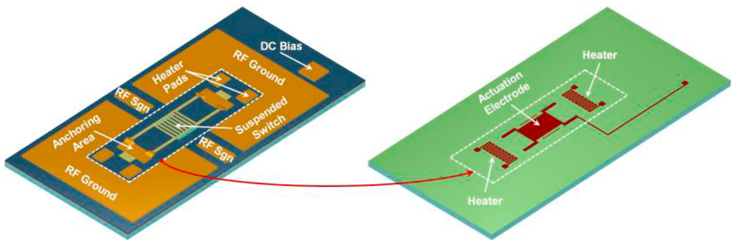


Fig. 1. (Left) 3D complete schematic of the RF-MEMS series ohmic switch featuring the heater-based active restoring mechanism. (Right) Schematic of the same switch where only the buried PolySilicon layer is visible. The central actuation electrode as well as the two serpentine heaters are visible, being the latter ones placed underneath the gold anchoring areas, where the membrane is hinged.

Fig. 1-right shows only the PolySilicon layer, highlighting the central actuation electrode for the biasing of the MEMS suspended membrane and the two serpentine heaters. Samples of the RF-MEMS switch discussed in this work are fabricated in the surface micromachining process, based on Gold, available at FBK in Italy [14].

Experimental testing is performed on a few available samples. The S11 parameter monitored at 6 GHz when the applied bias is swept between ±70 V (triangular zero mean value signal) shows the pull-in/pull-out (PI/PO) characteristic, and is reported in Fig. 2-left. The S-parameter characteristic exhibits an unusual behavior compared to a standard series ohmic switch. This is because a low-impedance path to ground for the RF signal was included by mistake in the layout when the MEMS switch is actuated (ON state). Nonetheless, the observation of S-parameters