RF MEMS FOR HIGH-FREQUENCY APPLICATIONS

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ABSTRACT

RF micromachining and MEMS technology promise to provide an innovative approach in the development of effective and low-cost circuits and systems, and is expected to have significant application in the development of low-cost antenna arrays and re-configurable apertures. This paper presents a brief history and the state of the art in the development of RF MEMS devices, with primary emphases on switches, and of Si micromachined circuit components for use in high-performance, high-density, on-wafer packaged circuits.

SUMMARY

RF Micro Electrical Mechanical Structures (MEMS) has been identified as a technology, that has the potential to provide a major impact on existing RF architectures in sensors(radar) and communications by reducing weight, cost and size, and power dissipation. The impact of this technology to communication system cost, size and volume is expected to be a few orders of magnitude. Key MEMS devices for current RF architectures are switches in radar systems and filters in communications systems. From a system's standpoint, RF MEMS is enabling new RF System architectures. Future communications require increasing functionality and performance endurance requirements that can be addressed by the successful insertion of new highly integrated MEMS sensors and instruments.

In the last ten years, MEMS as applied to microwave and millimeter wave circuits have experienced an exponential growth. In 1991, Larson et al. described rotary MEMS switches with good performance at RF frequencies [1, 2]. C.T. Nguyen demonstrated the successful development of MEMS HF filters in 1993-1994 [3] and Yao et al. demonstrated a surface micromachined series switch for telecommunications applications in 1995 [4]. Recently, shunt microwave switches have been developed in the X to K/Ka band [5], [6] and [8]. These switches are usually electrostatic in nature and commonly driven by bias voltages in the 30-80 V range. Most recently, low actuation voltage switches requiring 9 Volts of DC actuation have been demonstrated [7], [9], [10] and have opened new directions in system implementation and development of communication systems architectures. These MEMS devices are primarily designed for low-loss applications that do not require fast rates such as airborne and/or deep space communication. The advantage of MEMS switches over their solid state counterparts such as FETs or PIN diodes is their extremely low series resistance and low drive power requirements.

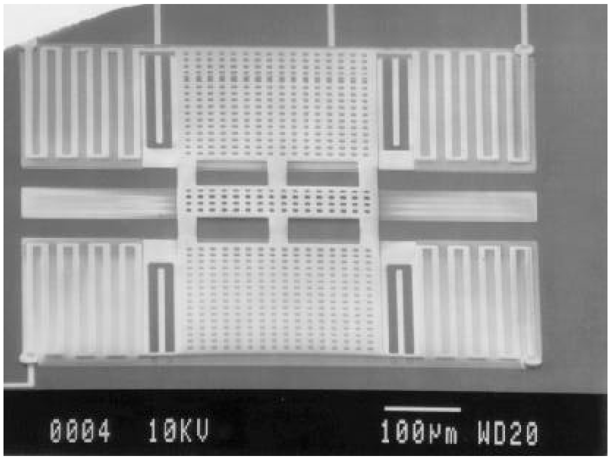

Figure 1: Low-Activation Voltage Switch Designed and Fabricated at the University of Michigan

For MEMS switches to become appropriate for wireless hand-held communications systems, actuation voltages less than 6 Volts are required. The primary goal of this section is to demonstrate the design, fabrication and DC as well as RF characterization of low-actuation-voltage electrostatic shunt microwave switches. Ultra low-loss, low actuation voltage RF MEMS switches have been successfully fabricated at the University of Michigan as shown in Figures 1

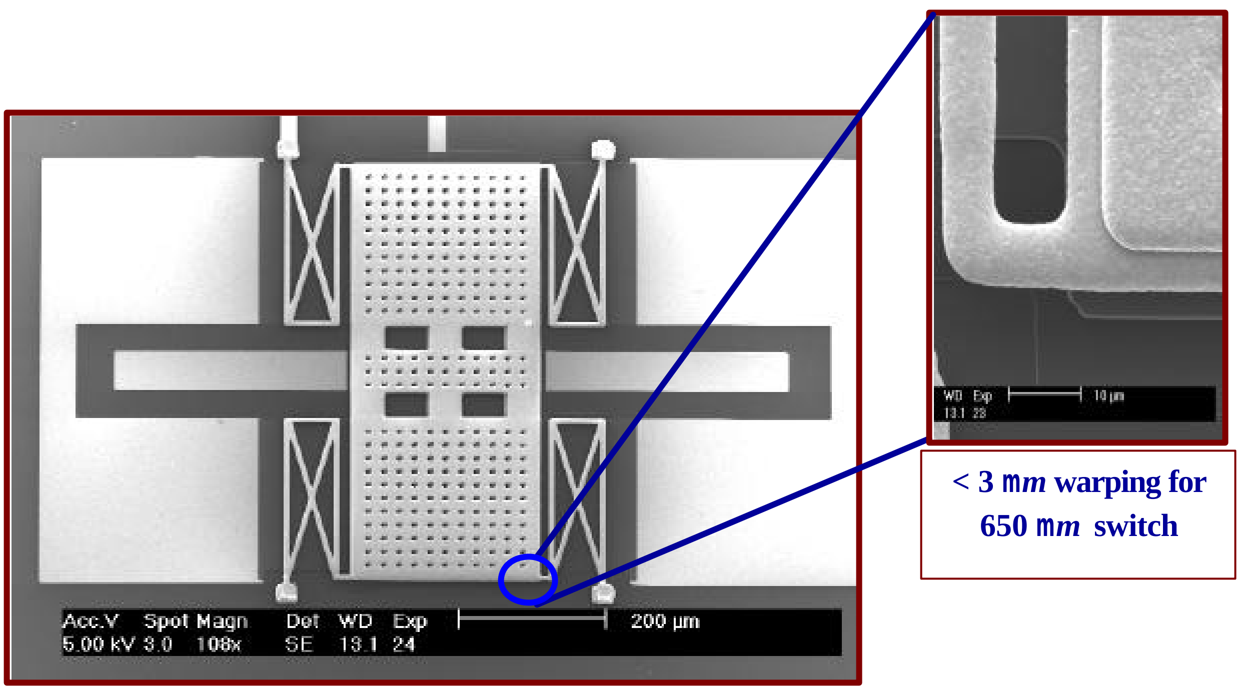

Figure 2: Fabrication of an RF MEMS Switch with Reduced Warping

and 2. These switches are designed for use with finite ground coplanar waveguide, but the design methodology and fabrication approach are very general and can be utilized towards the development of any low-actuation voltage switch architectures. In order to lower the pull-in voltage of the structure, three different design goals may be pursued: (1) increasing the area of actuation, (2) diminishing the gap between the switch and bottom electrode, and (3) designing a structure with low spring constant. In the first case, the area can only be increased by so much before compactness becomes a prevailing issue. In the second case, the return loss associated with the RF signal restricts the gap. The third design goal is the one with the most flexibility, since the design of the springs does not considerably impact the size, weight, and/or RF performance of the circuit. Figure 1 shows a scanning electron micrograph (SEM) of a shunt switch design appropriate for operation with a Finite Ground CPW (FGCPW) interconnect. The development of RF MEMS devices continues at present in government laboratories, industry and academia with substantial emphasis on packaging and reliability.

CONCLUSIONS

The micromechanical switch is without doubt the paradigm RF MEMS device. Within the last decade the RF community has experienced a growing plethora of MEMS switch designs. These designs have achieved a high level of RF performance, while maintaining ultra-low-power dissipation and large-scale integration. Due to the above characteristics, such RF MEMS devices should enable a wide variety of new system capabilities. With the ability to support any combination of electrical and micromechanical devices on a single chip, RF MEMS open an endless horizon of tantalizing possibilities for future designs and systems. In addition, the continual research on new design tools and methodologies, ensures that MEMS holds a tremendous promise in contributing heavily to the next generation of RF-based applications.

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