N-Z Power NEMS Electrostatic RF Wakeup Receiver with Pt Contact

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Primary CNF Tools Used: ASML 300C DUV stepper, Heidelberg mask writer DWL2000, Gamma automatic coat-develop tool, Zeiss Ultra SEM, Zeiss Supra SEM, Oxford 81, 82 etchers, Oxford 100 etcher, AJA ion mill, Hamatech hot piranha, Primaxx Vapor HF etcher, Plasma-Therm deep Si etcher, Uniaxis 770 deep Si etcher, DISCO dicing saw, wire bonder, Aura 100, Zygo, furnaces, ResMap, Nanostrip Bath

Abstract:

This work reports a nanoelectromechanical systems (NEMS) electrostatic RF switch usable as a near-zero power wake-up receiver capable of detection sensitivity reaching -25 dBm off resonance with sub-pW passive power consumption at less than 1.5V DC operation. The switch utilizes a multielectrode design allowing for a mechanical contact gap to be held just outside thermal oscillations and the radio frequency (RF) input to physically close the switch. This allows for operation away from pull-in and improves RF sensitivity. A focused ion beam (FIB) patterned platinum-platinum contact point enables the low DC bias requirement and improves contact resistance and longevity. The potential for on-resonance operation provides a pathway forward for improved RF sensitivity in the future.

Introduction:

With the advent of RF connectivity between sensors and the subsequent proliferation of wireless sensor nodes, power consumption and battery management of distributed sensor networks has become a bottleneck for widespread implementation. With applications spanning smart cities, agricultural monitoring and military scenarios, replacing batteries for increasing size sensor arrays is becoming costly, time consuming with significant downtimes, and potentially dangerous for reaching sensors in remote locations. Beyond advancements in battery technology and power reduction of active components, asleep-yet-aware sensors provide a means for reducing power consumption and significantly extending sensor node lifetime. These sensors work by operating in a low power, or near zero power, mode (typically comparable to battery leakage) but remain triggerable by signals of interest, turning on higher power electronics (like communications or signal processing) only when this signal is perceived and only for the duration required. For sensing applications in which signals of interest are infrequent, this modality can improve sensor operational lifetime by orders of magnitude.

These schemes have been implemented in a wide variety of physical sensors including accelerometers, microphones and magnetic field sensors, among others [1,2]. Near-zero power RF wake-up sensors have been widely developed using CMOS, but state of the art has struggled to push powers lower than single digit nW at -60 to -70 dBm RF sensitivity [3,4]. MEMS based RF wake-up sensors are much less have the distinct advantage of extremely low power draw but are much less common due to complications in design and fabrication limiting their sensitivity [5,6].

In order to maintain this lower power but improve RF sensitivity, we have improved upon a near-KT lateral NEMS switch that showed 300 µV switching at 50V DC bias [7]. This is accomplished by utilizing a multielectrode design to enable device switching without pull-in. Additional fabrication changes including, but not limited to, a compliant contact and FIB post-processing device contact areas, have also been implemented to reduce the DC bias requirement and improve device longevity.

Summary of Research:

The switch is operated primarily by a set of DC bias electrodes and a single RF electrode, all of which electrostatically actuate a released shuttle and move it towards a contact electrode biased with a small voltage. The switch also contains a reset electrode that applies an electrostatic force in the opposite direction to the DC and RF electrodes, ensuring a means of un-sticking the switch if necessary. Figure 1 shows the general layout and the relevant switch components.

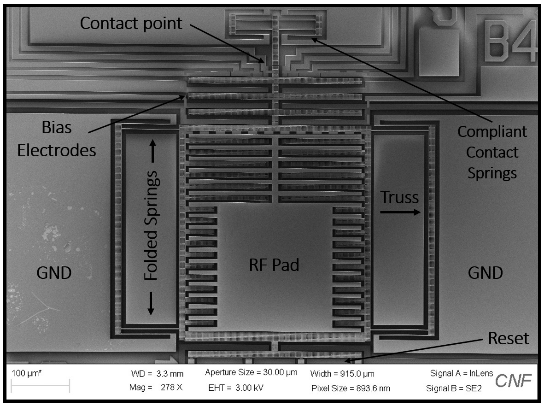

Figure 1: SEM micrograph of NEMS switch from above showing important electrical contacts and features.

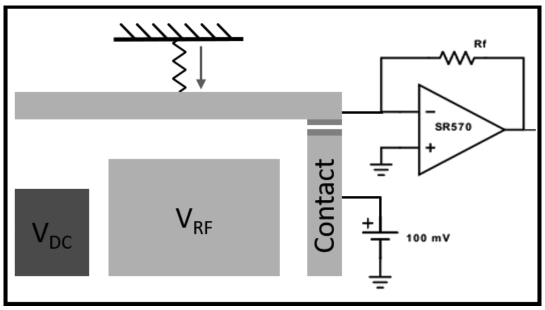

Figure 3: Simplified schematic of switch components showing biasing electrodes and TIA for detection.

Device fabrication follows a typical one mask SOI micromachining process with a vapor HF release. A full description of the device fabrication is available in last year's CNF technical report or [8]. Figure 2 shows an SEM image of the device contact area modified with Pt from a FIB process.

For operation, the switch is first pre-biased using the DC electrodes to bring the shuttle nearly into contact. The device is designed such that pull-in is not reached during this step. After pre-biasing, the RF wake-up signal is then applied to the RF electrode, which closes the switch the rest of the way. A TIA is used to read out a voltage when the switch closes. Figure 3 depicts a simplified schematic of the switch after DC pre-biasing and awaiting an RF input.

Testing is accomplished with a custom vacuum probe station with Python code managing a control loop running a MAXIM 5318 18-bit DAC, SR570 TIA and R&S SMC100A RF source. RF Probability of Detection (PoD) and False Alarm testing is accomplished using this automated code, described in [9]. Figure 4 shows a successful PoD test with -25 dBm sensitivity. Typical power consumption is 0.2 pW with a DC bias requirement of less than 1.5V. Ongoing work aims to operate the switch on resonance by modulating the RF signal at the device resonance.

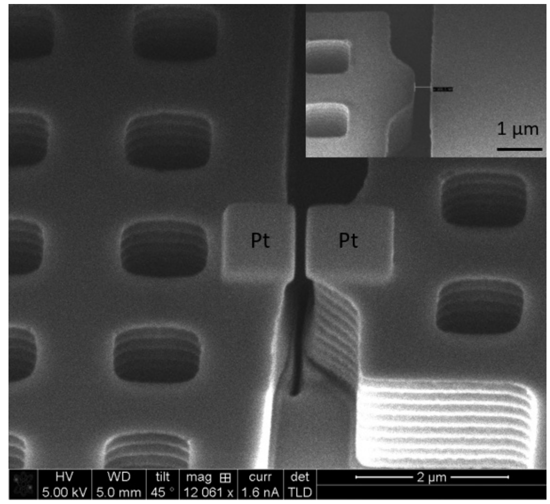

Figure 2: SEM micrograph of switch contact after Pt deposition using FIB.

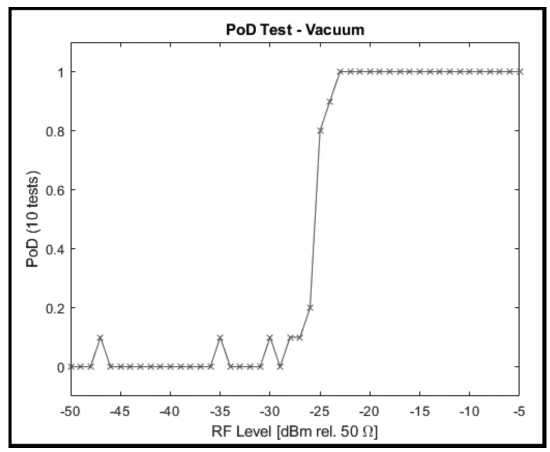

Figure 4: Probability of detection test showing 100% detection (out of 10 tests) for RF amplitudes of -25 dBm and greater.

References:

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