Calibrated MEMS Switches for Near-ZERO Power RF Detector and Sensors Network

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Primary CNF Tools Used: Heidelberg DWL2000, SÜSS MA6-BA6, SC4500 odd and even hour evaporator, ASML 300C, Oxford 100, Oxford 81 and 82, AJA ion mill, CVC sputter deposition, PT720-740, Unaxis 770, Oxford Cobra

Abstract:
State-of-the-art military sensors today rely on active electronics to detect vibration, light, sound or other signals, requiring a constant consumption of power, while much of that power and time spent processing what often, unfortunately, turns out to be irrelevant data. N-ZERO program under Defense Advanced Research Projects Agency seeks to overcome such power limitations. Our research group’s approach is an implementation of a MEMS switch, calibrated through a low power CMOS controlling circuit such that the MEMS switch is kept just shy of closure, making it extremely sensitive to the incoming RF signal or sensors output, limited only by the Brownian noise. In order to demonstrate a MEMS switch that can be well calibrated digitally, we have fabricated a MEMS switch with around ten biasing electrodes of varying dimensions. We have also designed the spring constant and contact gap in accordance with operating voltage range of the CMOS control circuit. In developing so, CNF has provided crucial supports in fabricating high facility, state-of-the-art low-power Si switches.

Summary of Research:
We start our fabrication using commercial 4-inch silicon-on-insulator (SOI) substrates. The substrates are first coated with titanium (Ti, as an adhesion layer) and chrome of 3 nm and 70 nm respectively to later form a hard mask. The MEMS switch patterns are made using a Heidelberg mask writer DWL2000, while the resist coating and exposure are done through the Gamma automatic coat-develop tool. While the chrome film is highly reflective, AR60 anti-reflection coating available in the Gamma automatic coat-develop tool makes the subsequent exposure in ASML 300C DUV Stepper possible. UVN resist, a negative type, is coated on top of the AR60 film, and is post-exposure baked and developed in the Gamma system. Following the development, the CNF Oxford 82 etcher is used to remove the arc film that is not developable, before the PT720/740 RIE is used to selectively remove the titanium-chrome film. Following the chrome etch, the residual photoresist is stripped in 1165 bath, followed by a deionized water rinse and nitrogen dry.

With the sturdy chrome mask, the device layer of the SOI substrate is etched away using either the Unaxis 770 deep Si etcher or the Oxford 100 ICP. Upon confirming that the etch has gone through the entire device layer using the P-7 profilometer, the residual chrome is etched away in a chrome etchant by soaking for an hour. The patterned SOI substrate is coated with a protective photoresist for dicing (SPR220.2 is used), and is diced using the DISCO dicing saw. Each diced die is then sonicated through acetone and isopropanol, 10 minutes each, before nitrogen drying.
Finally, each die is released by etching away the box oxide using Primaxx Vapor HF system. In addition, to improve the contact resilience as well as resistance, platinum (50 nm) is coated at an angle using an SC4500 Odd hour e-beam evaporator (3 nm titanium is again used as an adhesion layer) for a sidewall coating as the MEMS switch is a lateral-motion one. Finally, ZEISS Ultra and Supra scanning electron microscopes (SEMs) are used to inspect the fabricated switches. Images can be seen in the Figures 1 and 2. For certain switches, in order to alleviate the problems posed by the high stress nature of the platinum, an AJA Ion Mill is used to remove the top platinum, while largely preserving the platinum on the side.

References: