

NOVEL 2D AND 3D M/NEMS DEVICES FOR ACCURATE ELECTROMAGNETIC MEASUREMENTS

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Abstract

A study of possible applications of 2D and 3D micro- and nano-electro-mechanical systems (M/NEMS) devices for accurate electromagnetic measurements, in particular RF and microwave (RFMW) power measurements, has recently begun at NPL. A number of novel devices have been designed and fabricated (using commercial foundries) such as 2D coplanar waveguides and RFMW power sensors, and 3D coaxial transmission lines, four terminal-pair capacitors and calculable capacitors. An outline of the devices' design, simulation, their fabrication process and preliminary results will be presented at the conference.

Introduction

Micro and Nano technology is rapidly emerging as one of the key strategic areas of scientific and industrial importance. In particular, the recent advances in lithography and fabrication techniques at the micro and nano scale are enabling extension of accurate electromagnetic measurement techniques from the traditional DC and low frequency region (typically up to 10 kHz) [1] to cover a much broader frequency spectrum, up to the RFMW region, in the next five to ten years. A key application of 2D M/NEMS devices we envisage is for the accurate measurement of RF and microwave power on wafer. Existing RFMW power measurement techniques employ thermistors, thermocouples or diodes which are typically the last components in a signal chain – utilizing a power absorbing terminating device. However, some applications require an inline sensor so that most of the RFMW power is available for useful work (rather than being absorbed by a terminating device). The 3D M/NEMS devices are expected to have broader applications in electromagnetic measurements, particularly involving dielectric measurements ranging from solids, liquids and gases to biomaterials. A number of fabricated devices are currently being tested. Preliminary results will be presented at the conference.

Device Design for RFMW Power Measurements

The design of this device consists of a capacitive

membrane which is suspended above a coplanar waveguide (CPW) at a height of $2.75\text{ }\mu\text{m}$. The membrane displaces due to electrostatic force when RFMW power is applied. This displacement of the membrane is detected using capacitive sense electrodes (at 1kHz) below the membrane. In order to minimize the power reflections, which are caused by the slight mis-match introduced by the membrane, the central conductor of the CPW is tapered below the membrane. In Fig. 1 a fabricated 2D MEMS device for RFMW power measurements is shown. Although the capacitive sense electrodes (under the membrane) and the tapered central conductor are not visible in the image, several other key components of the sensor are visible, such as the CPW, membrane, contact pads for the sense electrodes and for the membrane. The lithography masks for the 2D and 3D optimized device designs were prepared using Coventor[®] software. The 2D devices were fabricated using a commercial foundry – MEMSCAP and its poly-MUMPs[®] process.

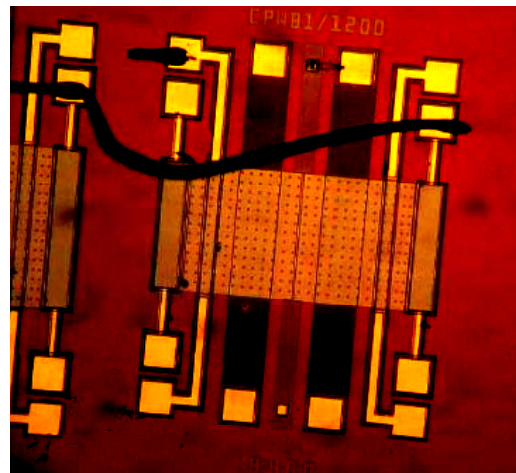


Fig. 1. 2D MEMS RFMW power sensor based on a suspended capacitive membrane above a tapered coplanar waveguide (device dimensions are $1200\text{ }\mu\text{m}$ length, $1200\text{ }\mu\text{m}$ width and $4\text{ }\mu\text{m}$ height). The image also shows wires bonded to various contact pads.

Device Simulations

A number designs for the MEMS RFMW power measurement device were simulated, using Microwave Studio[®], to achieve minimum power

reflection by the membrane yet also result in maximum power sensitivity. The final design which met this criteria was a device with a tapered central conductor located directly below the capacitive membrane. Fig. 2. shows a graph of the simulated scattering parameter S_{11} for the optimized device design at frequencies up to 50 GHz. The simulation shows that the design potentially has reasonably good impedance matching (better than -25 dB) up to 50 GHz.

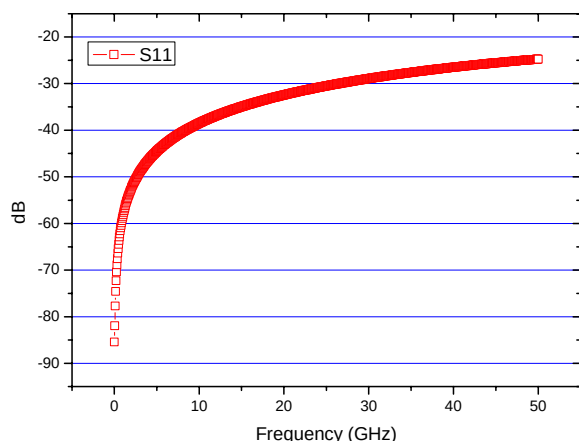


Fig. 2. Microwave Studio simulation of the prototype MEMS RFMW Power device design with tapered central conductor of the CPW

The Fabrication Process

A three layer polysilicon surface micromachining process was used to fabricate a number of different 2D RFMW power measurement devices and coplanar waveguides. The latter are necessary for evaluating the losses in the transmission lines. The multi project wafer devices are fabricated on a 100 mm n-type (100) silicon substrate with 1-2 Ωcm resistivity. The fabrication process then involves deposition of structural material (Polysilicon), its lithographic patterning and etching. This process is repeated for the three layers of structural material with a final metal layer deposition (usually gold) for contact pads. In contrast, the 3D devices are fabricated by patterning layer deposition, blanket layer desposition and planarisation of 20 layers of structural (nickel) and sacrificial (copper) material.

3D M/NEMS Coaxial Devices

In Fig. 2 an outline design is shown for a 3D MEMS Calculable Capacitor. There are number of applications that could emerge for such a device; on-chip reference standard or enabling accurate dielectric measurements including bio-materials

measurements [2]. In addition, 3D M/NEMS coaxial transmission lines, shielded transformers, four terminal-pair coaxial capacitors and inductors have also been designed. These devices are fundamental building blocks for developing accurate electromagnetic measurement systems for use over a broad range of frequencies. Some of these devices are currently under fabrication using Microfabrica's 20 layer EFAB™ process. The fabricated devices are expected in September and the results of their test and evaluation will also be reported at the conference.

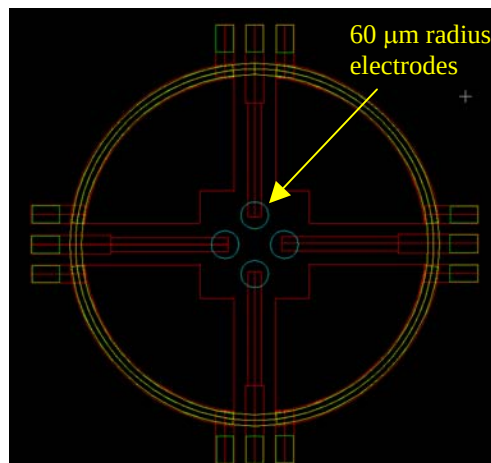


Fig. 2. 3D MEMS Calculable Capacitor for possible use as an on-chip reference or for accurate dielectric measurements up to RFMW frequencies (device height is 140 μm and shield radius is 785 μm).

Acknowledgements

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References

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- [2] Awan S. A., Miall J., Lees K. and Clarke R. N. "Accurate dielectric measurements at frequencies up to 10 GHz based on novel M/NEMS devices", BioNano3, University of Sussex, Sept 2005.