Development of a Micro Ultrasonic Transducer

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Abstract

Capacitive Micromachined Ultrasound Transducer (CMUT) structures are attractive sensors/actuators due to is CMOS compatible production that uses the already mature methods of integrated circuit industry in Silicon. Basically, a CMUT structure comprises a capacitor where one electrode is a suspended membrane. Electrostatic forces act when a voltage is applied inducing a bending of the membrane. On the other hand, if the membrane is subjected to a pressure variation, an electric current is generated by the capacitance change when under a bias voltage. This dual action of actuation and sensing is important in highly integrated transducer design for future ultrasonic proximity sensors and imaging devices.

We model our CMUT in an axisymmetric system as represented in Figure 1. The layers in blue are conductors, where an alternating voltage difference is applied. This generates the driving force to oscillate the membrane while the stiffness of the materials provides the restoring force. To model the dynamics in COMSOL Multiphysics® software we combine the Electrostatics and Solid Mechanics physics interfaces. Additionally we use the Moving Mesh physics interface. It is important to have the mesh deforming with the objects because the position of the membrane will sensibly affect the electrostatic force between the membrane and the substrate. The ability to couple several physical systems is one of the characteristics of COMSOL that we used in this model.

A time dependent analysis of the structure was carried out. COMSOL evaluates the potential distribution from which the polarization, surface charge and forces can be inferred. These forces, acting on the boundaries, deform the device. The stress, deformations and velocities are also evaluated. Figure 2(a) shows the electric potential distribution for a particular time. The red regions indicate higher voltage. Note how the deformation between the membrane and the substrate are noticeable. This variation changes the electric capacitance and the whole electric potential distribution is reevaluated accordingly in each time step. In Figure 2(b) the norm of the stress is shown. In the white regions the solution is either null or disinteresting, so it is not shown. The whole model is highly nonlinear as variables evaluated in one of the physics are inserted as parameters in the others. The time evolution allows us to observe if the simulation is performing as expected. We spanned 3 periods to certify that the membrane was not collapsing on the substrate. Figure 3 shows the time evolution of the spacing between membrane and substrate for several frequencies. As the frequency approaches the resonance the amplitude increases until the gap eventually collapses. The time evolution presents some modulation due to the difference between the natural frequency of the device (5.3 MHz) and the excitation frequency.

We managed to obtain all the electric and structural characteristics of the device via simulation. Now we are prepared to step forward and study the configuration of maximum efficiency by analyzing the acoustic power transferred to the surrounding medium and to test several different geometries.

Figures used in the abstract

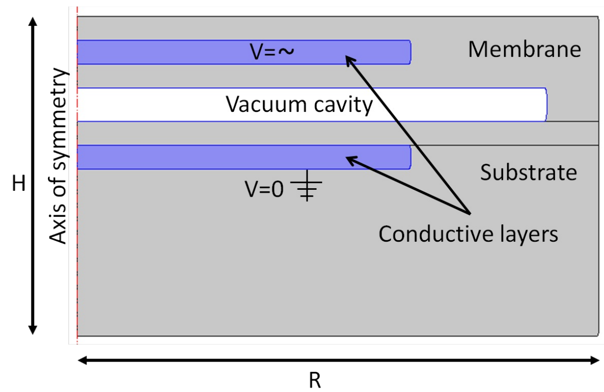

Figure 1: Main features of the simulated acoustic transducer. Typically R>>H.

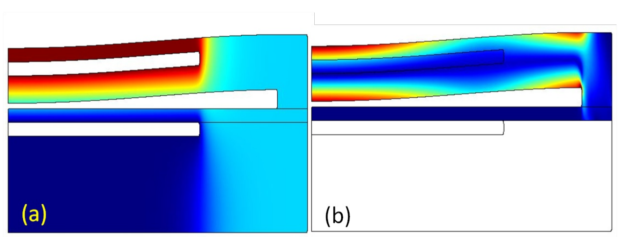

Figure 2: Solution of the CMUT in a particular time: In (a) the electric potential distribution and in (b) the stress distribution.

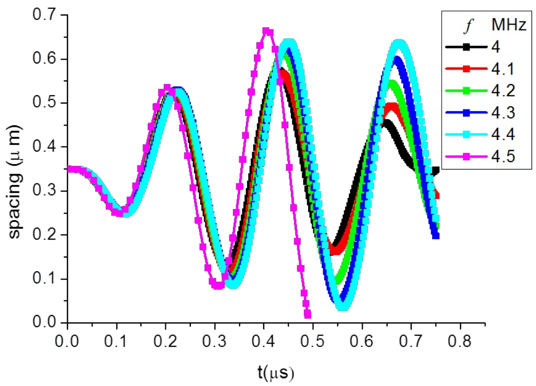

Figure 3: Time evolution of the CMUT in the first three periods near the resonance.