Simulation and Fabrication of Wireless Passive MEMS Pressure Sensor

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Abstract

A wireless passive pressure sensor and the measurement system were design and simulated using COMSOL Multiphysics. The sensor is based on MEMS capacitor attached to a planar inductor for wireless powering and readout. An external coil (antenna) is used for the measuring system. An electromagnetic field is produced by the antenna which couples with the sensor, inducing currents in it. The sensor has a characteristic resonance frequency given by the LC system. The pressure to be measured compresses the MEMS capacitor and changes the resonance frequency of the sensor.
The sensor was fabricated using fiber glass substrate (FR4) with a 30 um copper layer; a PDMS layer of 1000 um was used as dielectric for the capacitor with an internal air cavity of 2.5 mm x 2.5 mm, the sensor size was 5.1 mm x 5.1 mm as shown in Figure 1. All the fabrication and characterization processes were carried out at the clean room of the Universidad de los Andes. Measurements were done using a Vector Network Analyzer (VNA) Master (Anritsu, Japan). The resonance frequency was taken from the real part of the impedance magnitude of the antenna coupled with the sensor. The complete system requires an electromagnetic and a mechanical model simulation; COMSOL 4.3 was used for the analysis of the two physics interactions. The RF Module was used to simulate the antenna response and the effect of a coupled sensor in the frequency domain. Structural Mechanics Module was used for the simulation of the compression of the sensor caused by an external pressure. The model was elaborated in 3D because no symmetry planes were present on the design and non uniform changes on the sensor's geometry had to be taken into account, because they represent mayor variations on sensor sensibility and response.
Mechanical simulations are show in Figure 2. For this study, a maximum pressure of 75 torr was used. The deformation simulated on the sensor for that pressure was in average of 26 um. Figure 3 show the simulated sensor impedance and the measurement registered with the VNA. The coupling effects caused by the sensor are similar in both real and simulated data. The resonance frequency of the simulated sensor was 200.00 MHz, and the measured frequency was 199.72 MHz. The resonance frequencies were used for pressure measurement; Figure 4 shows the relation within the pressure applied and the resonance frequency. The differences were caused by the sensor's fabrication processes. Multiphysic simulations of the wireless pressure sensor and the coupling antenna system were presented. Data obtained from the fabricated sensor were consistent with the simulation results.

Figures used in the abstract

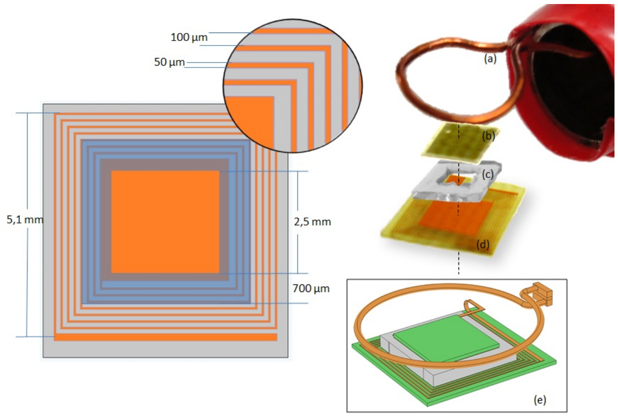

Figure 1: Wireless Passive MEMS pressure sensor system. (a) Antenna (b) Capacitor top plate (c)PDMS cavity (d) Planar inductance and Capacitor bottom plate (e) COMSOL 4.3 simulation model.

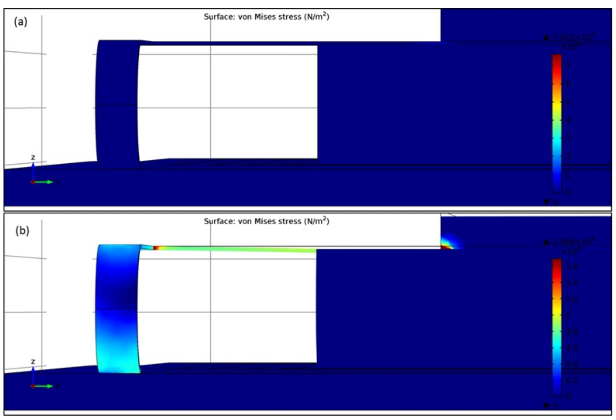

Figure 2: Deformation caused by an external pressure applied to the sensor. (a) Pressure of 3 torr applied (b) Pressure of 75 torr.

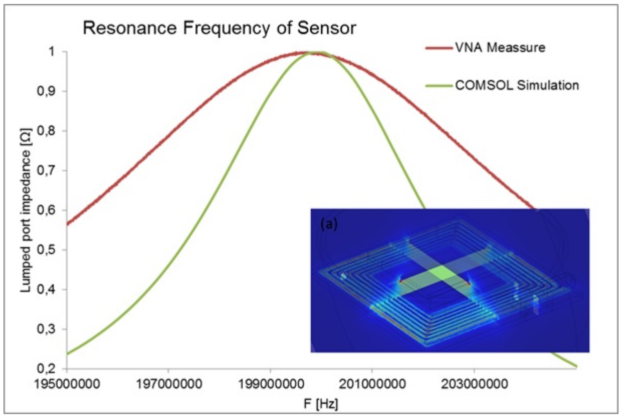

Figure 3: Normalized simulated and measured resonance frequency of the sensor. (a) Energy induced on the sensor.

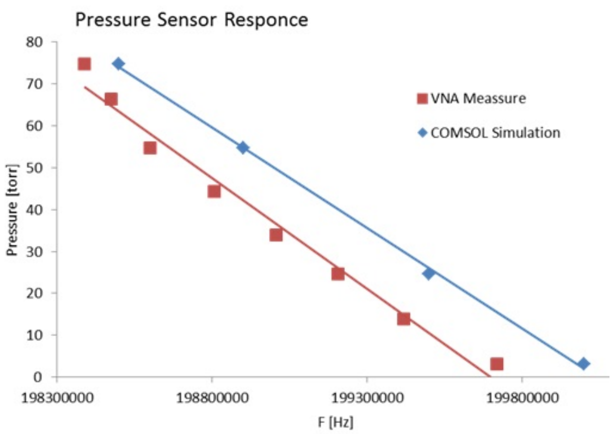

Figure 4: Resonance frequency of the sensor with different pressures. Simulated data is shown in blue and measured data in red.