613d Computer-Aided Design and Fabrication of a Mems Based Acoustic-Wave Biosensor

Michael J. Bartkovsky, Anna Liao, Steinar Hauan, Todd M. Przybycien, and Gary K. Fedder

We are currently developing a MEMS based acoustic-wave biosensing device which promises to be highly sensitive due to its high surface area to mass to ratio. Our resonant membrane structures can be operated in a liquid environment for biological applications such as studying protein adsorption and measuring specific ligand-ligate binding events, DNA hybridization, and antibody-antigen interactions. The design and fabrication of our composite membrane structures differ from that of commonly used microcantilever sensing devices [2,3]. As opposed to using bulk-micromachined silicon nitride cantilevers, our metal-oxide mesh structure is based on the design and fabrication of an integrated complementary metal oxide semiconductor (CMOS) chip and post-processing these existing layers with compatible micromachining techniques developed at Carnegie Mellon University [4]. Chip design and fabrication is subsequently followed by surface modification of each mesh structure. This consists of the deposition of a conformal polymer coating and the photochemical surface functionalization which enables the specific detection of target analyte molecules [1].

We will present the computer-aided design and fabrication of our MEMS microchip. The CAD chip layout consists of mesh structures integrated with electronic instrumentation and logic control. The MEMS chip contains a 4x4 array of mesh structures which are approximately 150 microns in length. The mesh can be electrostatically actuated by applying a voltage between the metal mesh and the underlying silicon substrate. Membrane oscillations are sensed via piezoresistors embedded in the mesh which respond to changes in stress within the resonating structure. Other key design features include: the ability to operate at higher harmonic frequencies, embedded multiplexer circuitry elements used for the electrical logic control of the output signals, and reference membranes which will be used to monitor the occurrence of non-specific molecular adsorption. The electrical coupling of a sensing membrane with a reference structure will enable a self-calibrating differential measurement to be performed. We will demonstrate the step-wise progression from computer-aided design of the MEMS chip with the associated mechanical and electrical validation steps to the post-processing release of the mechanical structure. The mesh structure will be released using two reactive ion etching (RIE) steps to remove the oxide and underlying silicon to created the suspended membrane structure. Following the release, electrical tests will be performed to validation proper electrical connectivity of the sensing circuitry, actuation electrodes, and output logic control elements. Membrane deflection will then be measured both optically and piezoresisitvely to determine each structure's resonant frequency and quality factor.

[1] Bartkovsky, M.J. and Przybycien, T.M. and Hauan, S. Photochemical modification of a MEMS membrane device for use as a novel gravimetric based biosensor. AIChE annual meeting, Austin, TX, Advances in Biosensors I, paper 36g, 2004.

[2] Ilic, B. and Czaplewski, D. and Zalalutdinov, M. and Craighead, G. Single Cell Detection with Micromechanical Oscillators. Journal of Vacuum Science Technology B, 19(6), 2825-2828, 2001.

[3] Kovacs, G.T.A. and Maluf, N.I. and Petersen, K.E.. Bulk Micromachining of Silicon. Proceedings of the IEEE, 86(8), 1536-1551, 1998.

[4] Neumann, J. and Gabriel, K. CMOS-MEMS Membrane for Audio-Frequency Acoustic Actuation. Sensors and Actuators A, 95, 175-182, 2003.