423e A Mems Based Acoustic-Wave Gravimetric Biosensor: Device Characterization and Performance

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We have designed and fabricated a novel MEMS biosensing device that consists of resonant composite mesh structures capable of detecting target analyte molecules. The computer-aided design of our MEMS microchip involves the layout of each mechanical mesh sensing structure along with the integrated electronic instrumentation and control elements. Each suspended mesh structure can be electrostatically driven at resonance by applied a voltage between the composite metal mesh and the underlying silicon substrate. Specific target analyte detection can be monitored through the resultant frequency shifts which occur from the selective binding of molecules to the resonating membrane structure. Recently, macroscopic quartz crystal resonators and microcantilevers have been used to detect various proteins, antibodies, cells and DNA molecules by similar principles [1,5]. However, our MEMS sensor should be several orders of magnitude more sensitive due to its larger surface area to mass ratio.

The fabrication of the suspended composite membrane structures is based on processing existing complementary metal oxide semiconductor (CMOS) layers using a variant of the CMOS-based micromachining technique developed at Carnegie Mellon University [4]. Each MEMS microchip consists of a 4x4 array of mesh structures. Electrostatic actuation, integrated piezoresistive sensing, and the ability to operate at higher harmonic modes are some of the chip design key features. Adaptation from MEMS microchip to a biosensing device has focused on: (a) modification of the metal oxide mesh with a conformal coating of polystyrene, (b) the photochemical functionalization of the polymer surface with immobilized biotin moieties capable of exploiting ligand-ligate specificity [3], (c) the incorporation of a reservoir for introduction of liquid phase samples to the membrane surface [2], and (d) the locatization of binding patches on the membrane surface via computer-aided modeling to optimize device sensitivity and flexibility [6].

We are testing our MEMS based biosensor to evaluate its performance. MEMS structural release is followed by electrical validation of both the actuation and sensing circuitry. The membranes will then be actuated in air to study their harmonic frequencies with comparisons being made between two different structural designs and their corresponding resonant frequencies. To allow for operation in a liquid environment, we have the ability to deposit a conformal polystyrene coating. Actuation and detection of the composite structure's motion will allow for the investigation of the effect of damping within the system. Specific binding experiments are performed through the photochemical modification of the polystyrene structure using photobiotin (PHB). This photoactive molecule allows us to uniformly and covalently functionalize the resonant surface and enables the detection of specific target analyte molecules. Using a lithographic mask, this immobilization scheme provides a straightforward method to selectively and spatial deposit receptor molecules on the polymeric surface. We currently have the ability to creature feature sizes on the order of 25 microns. This spatially selective functionalization scheme will increase device sensitivity and ultimately allow for simultaneous detection of multiple targets. Using this developed photochemical functionalization scheme, we will validate the operation of our device using the immobilized biotin chemistry and the detection of fluorophore-labeled avidin and avidin coated microspheres. We will also demonstrate practical sensitivity limits with comparisons made to other micro and macro-based gravimetric sensors.

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