429b Quantitative Design Approach for a Multi-Analyte Acoustic-Wave Sensor

Jane E. Valentine, Todd M. Przybycien, and Steinar Hauan

One drawback to many biochemical sensors is that they are designed to detect only one target species at a time. There are several possible approaches to detecting multiple analytes simultaneously. One is to use arrays of devices, each of which detects a single target. Another is to use a single device with multiple independent detectors. Both of these approaches are sometimes referred to as electronic noses. A third approach is to use a single detector capable of emitting characteristic responses to multiple analytes; we are working towards the design of such a sensor, and developing methods to optimize its response to a mixture where one or more of the targets are present.

Specifically, we are developing an acoustic-wave sensor using microelectromechanical systems (MEMS) membrane technology [1]. These sensors operate by detecting the frequency shifts resulting from the binding of target molecules to a functionalized resonator. Our sensor design uses membranes, for which theory and simulations [2,3] predict improved sensitivity over alternative macroscopic and MEMS-based devices [4,5]. Further increases in sensitivity arise from selectively binding mass to subregions of the membrane [6,7], which also allows single-sensor redundancy or multi-target detection.

Using matrix perturbation analysis, we have developed a first order model to determine the frequency response of our membrane sensor under spatially varied mass distributions; this further allows us to distinguish the contributions made by mass adsorbed to each subregion. Using these results, we have determined the optimal placement for a single functionalized region in terms of sensitivity [7]. We now intend to extend these results to cases where multiple subregions are functionalized simultaneously, and where sensitivity is not the only objective.

We have derived a method to determine which mass distributions are equivalent in the frequency domain. This will serve as the basis for optimization of the spatial distribution of mass for the case when multiple subregions are functionalized. Our optimization will use two different objective functions, one maximizing sensitivity to an individual analyte, and one maximizing confidence in our results. We will use these objective functions, along with physical, chemical, and operational constraints, to determine the optimal functionalization configurations for both the multiplexing and the redundancy cases for small numbers of functionalized regions. We will construct two case studies for food-borne pathogen detection, involving *Bacillus cereus* and *Escherichia coli*, and quantitatively compare our solutions to industry standards.

[1] S. Hauan, T.M. Przybycien, K.J. Gabriel, J.J. Neumann, and M.J. Bartkovsky. "A MEMS Based Biosensor" U.S. Patent Application, 2003, Filed Nov 6th; Serial No. 10/702.709.

[2] J.E. Valentine, T.M. Przybycien, and S. Hauan. "Modeling and Design of a MEMS-based Biosensor" Presented at the AIChE annual meeting, paper 197h, November 2003.

[3] M.J. Bartkovsky, T.M. Przybycien, J.J. Neumann, and S. Hauan. "A First Generation MEMS Membrane based Biosensor" Presented at the AIChE annual meeting, paper 385e, November 2003.

[4] F. Battiston et al. "A Chemical Sensor Based on a Microfabricated Resonance-Frequency and Bending Readout" Journal of Sensors and Actuators B, 2001

[5] http://www.q-sense.com

[6] M.J. Bartkovsky, S. Hauan, and T.M. Przybycien. "Photochemcial Modification of a MEMS Membrane Device for use as a Novel Gravimetric Based Biosensor" Presented at the AIChE annual meeting, paper 36g, November 2004.

[7] J.E. Valentine, T.M. Przybycien, and S. Hauan. "Response Surface Determination of a Multi-target MEMS Sensor" Presented at the AIChE annual meeting, paper 509f, November 2004.