# Real-Time Biomolecular Sensing with Porous Silicon Microcavity Films


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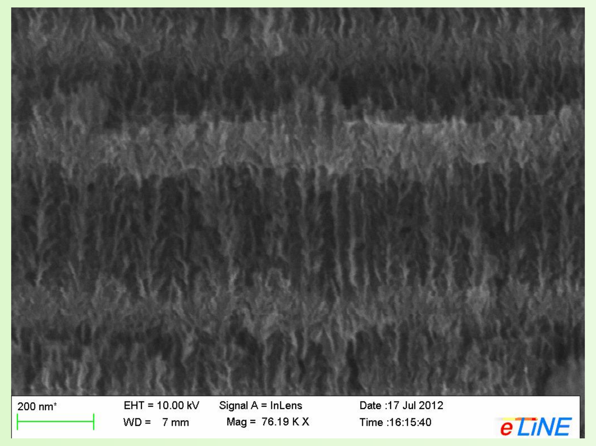
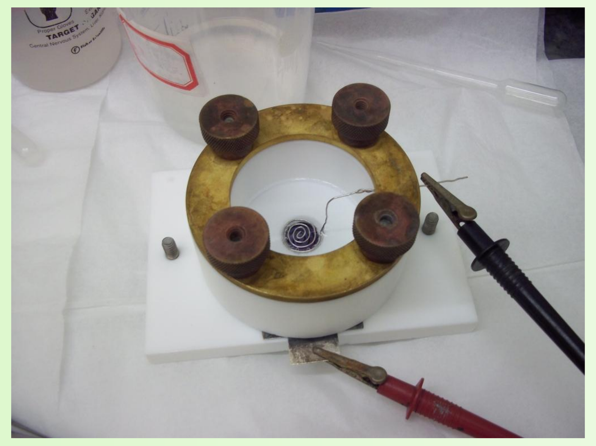
## Introduction

Strong demand exists for biodetection technologies that are fast, economical, and can be implemented outside the confines of a laboratory. Porous silicon has become a very promising material in the quest for next generation real-time biosensing devices due to:

- Large internal surface area (200-700 $m^2/cm^3$)
- Tunable optical properties
- Cheap, rapid fabrication
- Simple integration with microfluidic devices



SEM image of porous SI layered film



Etching Setup

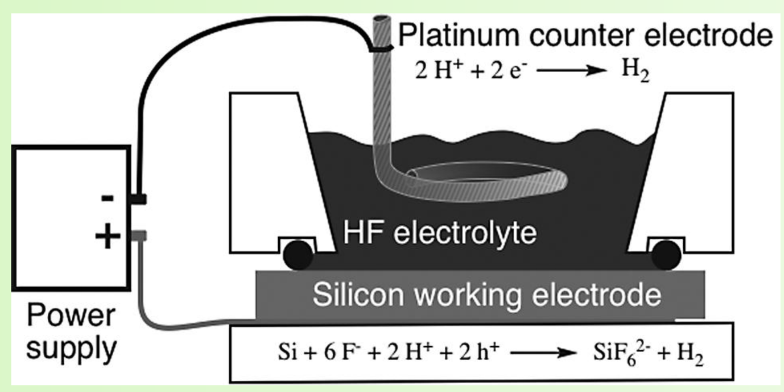
## Research Objectives

- Determine response time and molecule size-dependent sensitivity of optically resonant porous silicon microcavity structure with buried active layer
- Investigate sensitivity and speed of sensor to large and small molecules

## Methods

Porous Silicon Fabrication

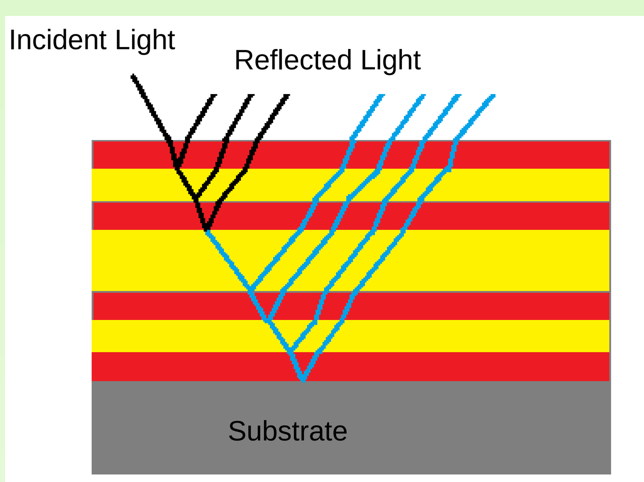
- Electrochemical etch creates nanoscale pores
- Adjustment of current density for period of time controls thickness and porosity of layers
- Porous material can be modeled as an effective medium creating 1-dimensional photonic crystals



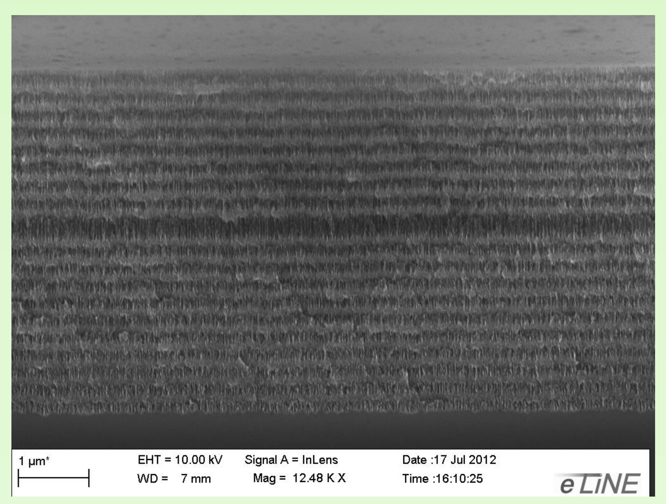

Etching half-reactions and diagram. Process involves the electrochemically assisted corrosion of the silicon sample [1]

Microcavity Structure

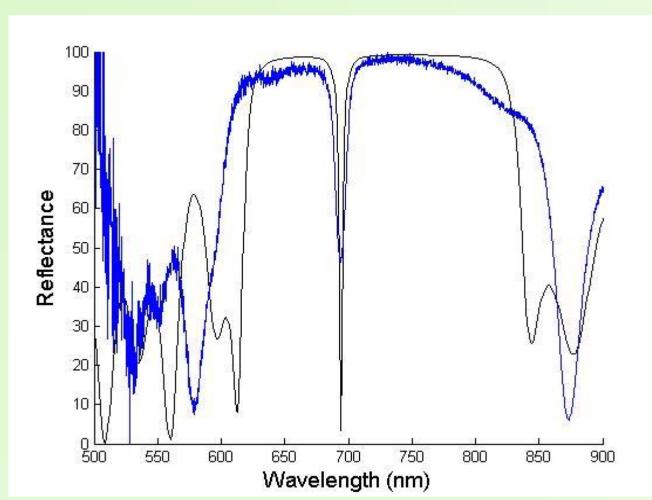
- Two Bragg mirrors separated by a cavity layer
- Cavity introduces allowed mode creating dip in reflectance spectrum
- Structures modeled with MATLAB using transfer-matrix based code




Cross section of microcavity with rays to show optical path. Reflections constructively interfere.



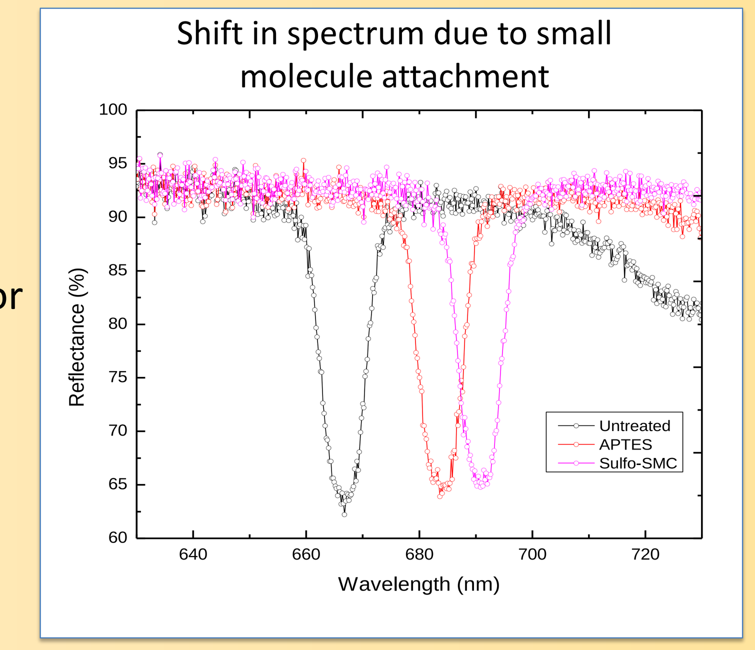
SEM image of microcavity film cross section

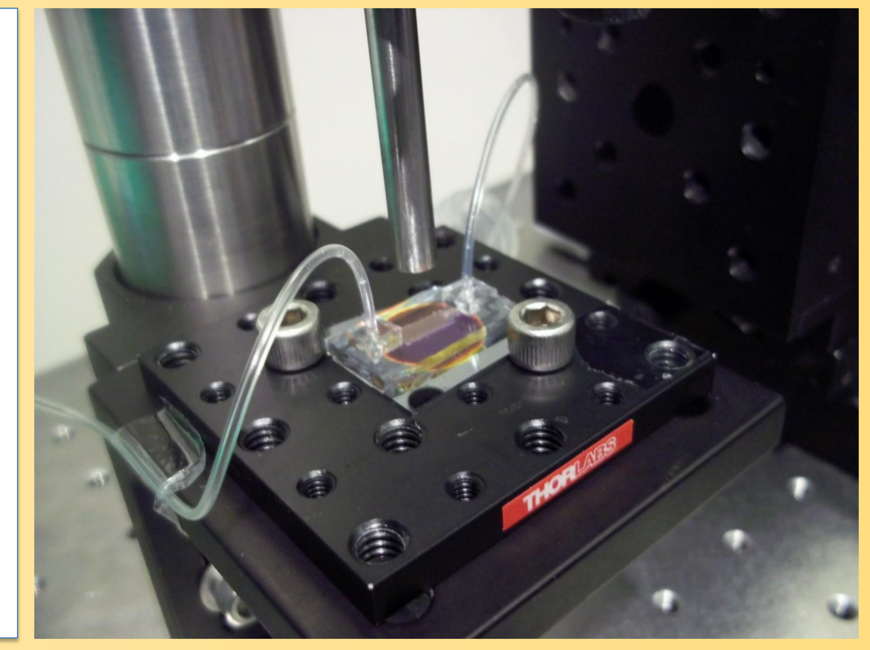



MATLAB simulation of reflectance spectrum with experimental results overlaid in blue

### Sensing Mechanism

- Molecular detection is achieved by analysis of the reflection spectrum
- Shift in reflectance spectrum quantifies the amount of analyte attached to sensor
- Shift due to change in effective refractive index of layers with analyte infiltration
- Simulations show a sensitivity of **465 nm/RIU**
- Cavity layer is most sensitive region of microcavity structure



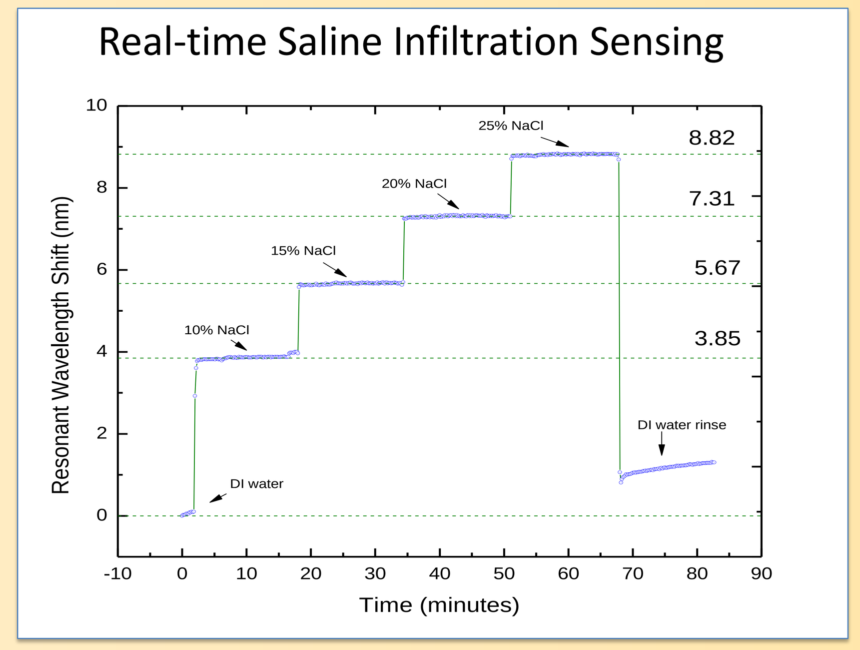
Sample positioned below spectrophotometer for reflectance measurements. Tubes attached to inject analytes.

### Flow Cells

- PDMS (polydimethylsiloxane) flow cells used extensively in microfluidics research
- Transparent, non-toxic, and chemically stable
- Enables real-time measurements

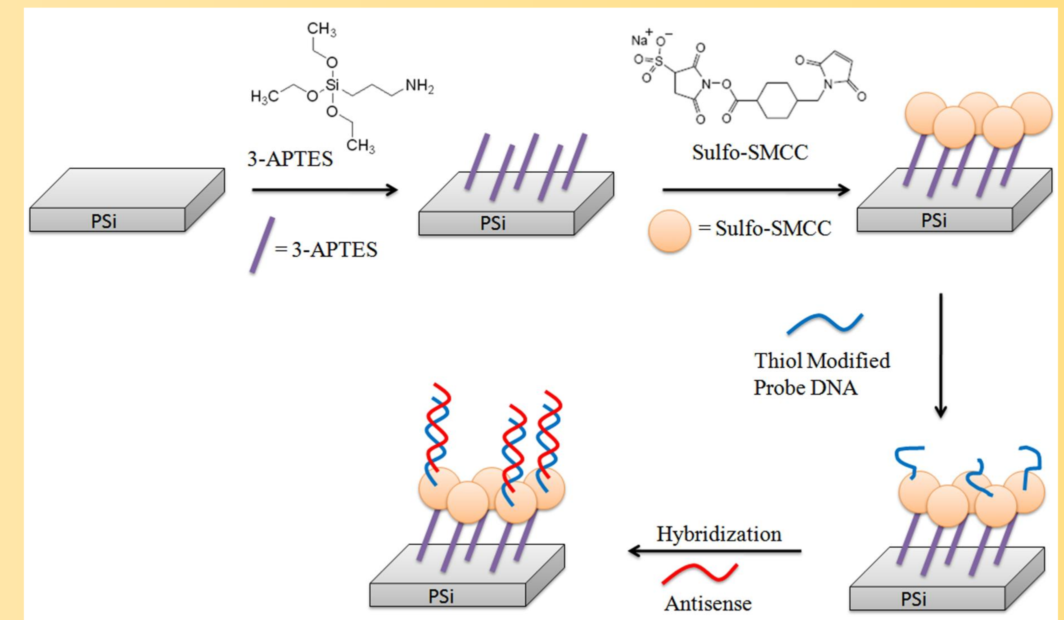
### Saline Test

- Increasing concentrations of NaCl injected
- Shifts pronounced and nearly instantaneous
- Demonstrated very fast diffusion speed for a buried sensing region




### DNA

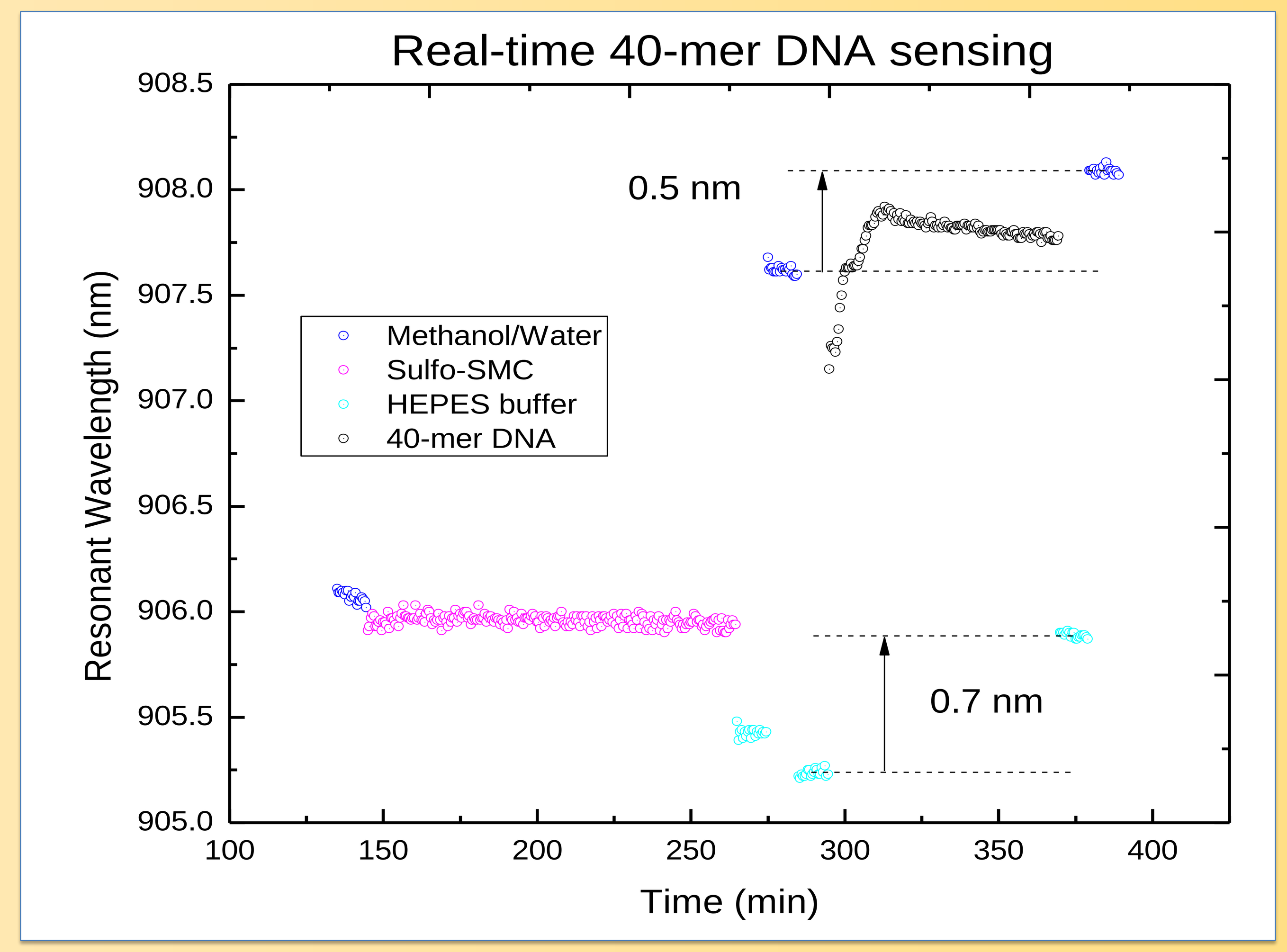
- Surface functionalization was performed with 3-aminopropyltriethoxysilane (3-APTES) and Sulfosuccinimidyl 4 – [N-maleimidomethyl] cyclohexane 1 – carboxylate (Sulfo-SMCC), which also served as small molecule analytes
- Rinses with HEPES buffer and methanol water solution were performed between steps to measure shifts due to binding as well as infiltration




[2] Surface functionalization chemistry

## Results

- Real-time experiments showed that small molecule infiltration times were comparable with "surface" layer sensing structures such as the waveguide
- Small molecules showed substantial shifts
- Large molecule 40-mer DNA showed signs of size exclusion with very small shifts
- Trials also performed without flow cell corroborated real-time results for DNA




Shifts are small for 40-mer DNA, very near spectrophotometer resolution of one tenth of a nanometer

## Conclusions and Future Work

- Porous silicon microcavities hold great promise for real-time sensing of small molecules that fit inside pores
- Large molecules cannot be detected by the microcavities, which suggests that false positive results due to non-specifically bound surface species will not be a significant challenge
- Future work will focus on testing multiple concentrations of molecules to determine saturation and detection limits


**References**

[1] Sailor, Michael. *Porous Silicon In Practice.* Weinheim: Wiley-VCH, 2011. Print.

[2] Xing Wei. (2012). *Porous Silicon waveguide biosensors with a grating coupler.* (Doctoral dissertation). pg. 46. http://etd.library.vanderbilt.edu/available/etd-03262012-231223/



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