Low Cost Portable Biosensors Made From Porous Silicon Annular Bragg Resonators

Yasmin M. Graham\textsuperscript{1}, Yiliang Zhao\textsuperscript{2}, Girija Gaur\textsuperscript{2}, and Sharon M. Weiss\textsuperscript{2, 3}

1. Department of Mechanical Engineering, University of Maryland, Baltimore County
2. Interdisciplinary Graduate Program in Materials Science, Vanderbilt University
3. Department of Electrical Engineering and Computer Science, Vanderbilt University

Motivation:
- Low-cost, portable biosensors are especially important for low resource environments, but many existing commercial biosensors are large, expensive, and need skilled personnel to operate.
- Porous silicon (PSi) is a promising material for low cost optical biosensors due to its ease of fabrication and large surface area that can accommodate binding of a large quantity of small molecules.
- Annular Bragg Resonators (ABRs) are radially symmetric structures with a cavity region surrounded by highly reflecting mirrors.
- Through the use of ABRs on PSi substrates, the light matter interaction is strong and leads to enhanced fluorescence from light emitters embedded in the ABRs.

SEM images of fabricated PSI ABR devices

Concept:
PSI ABRs infiltrated with light emitting AgInS\textsubscript{2}/ZnS quantum dots (QDs) can be used as sensitive colorimetric sensors. A color change results from molecules being captured in the pores.

Introduction

Methods

Quantum Dot Functionalization in PSI

Photoluminescence Measurement Using Raman Microscope

Measurement

Results: Biosensing

Proteins and APTES molecules were adsorbed onto the PSi surface in order to study the effect of molecular size on the biosensing performance of PSI ABRs.

<table>
<thead>
<tr>
<th>Biomolecules</th>
<th>Molecular Weight</th>
<th>Net Shift After Molecule Attachment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalase (CAT)</td>
<td>240 kDa</td>
<td>41 nm</td>
</tr>
<tr>
<td>Horseradish Peroxidase (HRP)</td>
<td>44 kDa</td>
<td>31 nm</td>
</tr>
<tr>
<td>(S-Amino propyltriethoxy silane (APTES))</td>
<td>220 Da</td>
<td>40 nm</td>
</tr>
</tbody>
</table>

Conclusions From Control Experiment:
- QDs photobleaching depends most strongly on length of time irradiated by laser beam; the more times the QDs are excited by the laser, the lower the PL.
- After first laser exposure, peak PL wavelength shifts by ~ 8.5 nm.

Conclusions From Molecule Adsorption Experiment:
Adsortion of the proteins resulted in a greater wavelength shift and intensity decrease compared to the control experiment. (See table above)
- Shifts resulting from proteins suggest molecule infiltration into the nanoscale pores and defect rings within ABRs instead of simple photobleaching of QDs.
- For molecules that do not easily enter the pores, larger molecular weight leads to larger shifts.
- For small molecules that easily infiltrate the pores, a larger peak wavelength shift results.

Conclusions

- ABRs can be fabricated in PSi and enhance the PL emission of QDs immobilized in PSi.
- Choosing the appropriate ABR design is important for achieving maximum PL enhancement and modification of the QD emission spectrum.
- The PSi ABR platform could be made to be low cost, easy to operate, and smart phone compatible.

Future Work

- Design and fabricate PSI ABR with resonance wavelength that better overlaps with the QD PL spectrum.
- Improve the stability of QDs in order to minimize the photobleaching effect.

Acknowledgements

I would like to extend my appreciation to the Vanderbilt Institute of Nanoscale Science and Engineering (VINESE) for giving me the opportunity to conduct research this summer. This work was supported by the NSF REU grant DMR-1263182 and the Army Research Office grant W911NF-15-1-0176.