# Low Cost Portable Biosensors Made From Porous Silicon Annular Bragg Resonators


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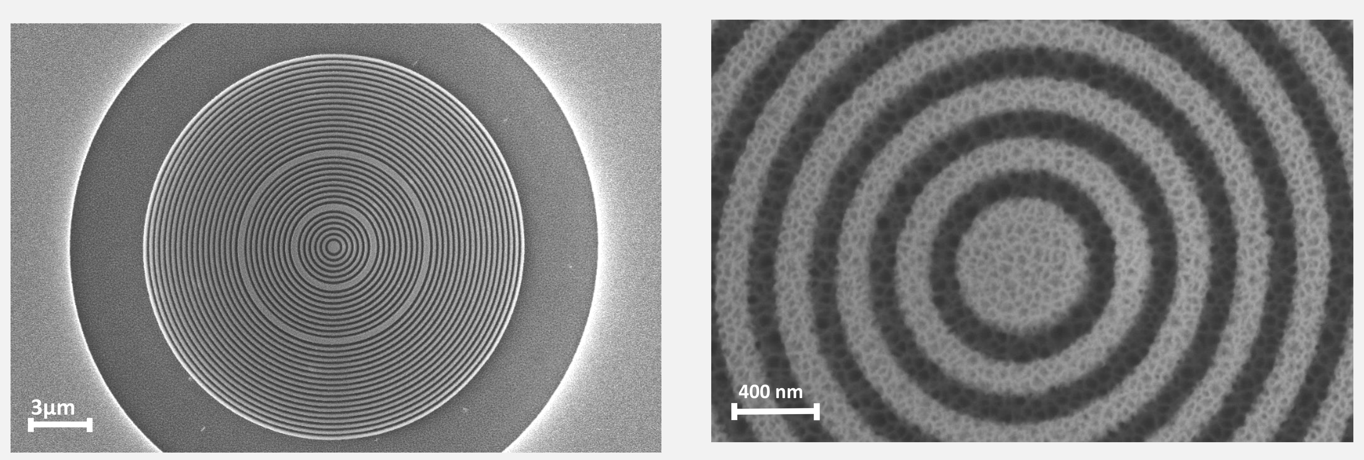
## Introduction

**Motivation:**

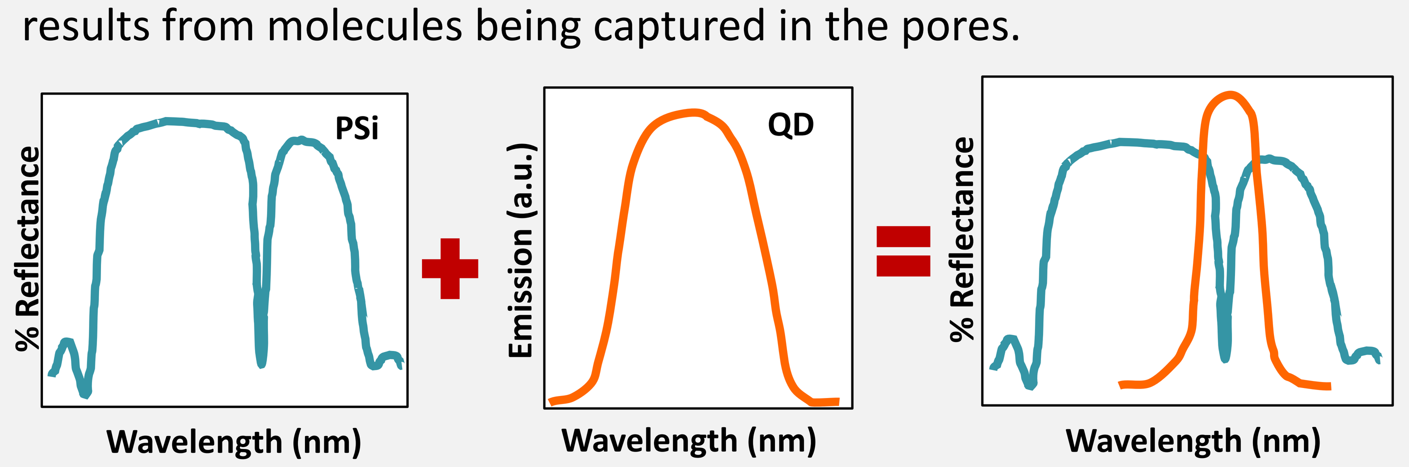
- Low-cost, portable biosensors are especially important for low resource environments, but many existing commercial biosensors are large, expensive, and need skilled personnel to operate.
- Porous silicon (PSi) is a promising material for low cost optical biosensors due to its ease of fabrication and 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.



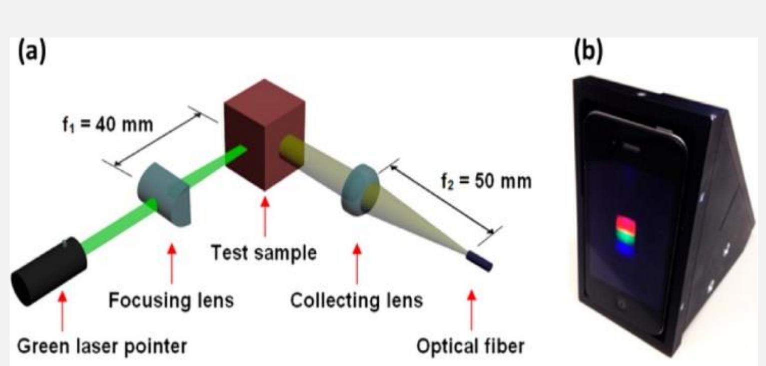

**SEM images of fabricated PSi ABR devices**

**Concept:**

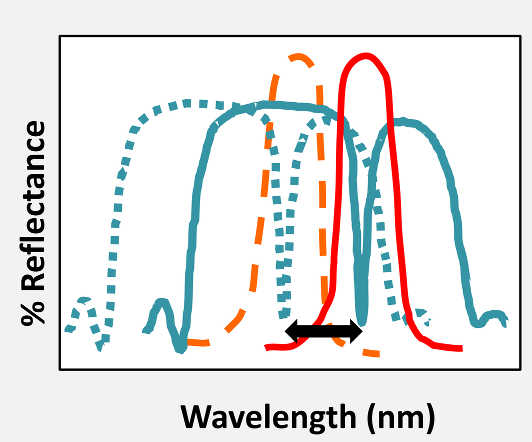
PSi ABRs infiltrated with light emitting $AgInS_2$/ZnS quantum dots (QDs) can be used as sensitive colorimetric sensors. A color change results from molecules being captured in the pores.




*Reflectance of Optical Cavity* | *QD emission spectrum* | *Cavity Modified QD emission*




*Schematic illustration of the smartphone compatibility of the biosensing platform. (Yu, et al. Anal. Chem., 86, 2014)*



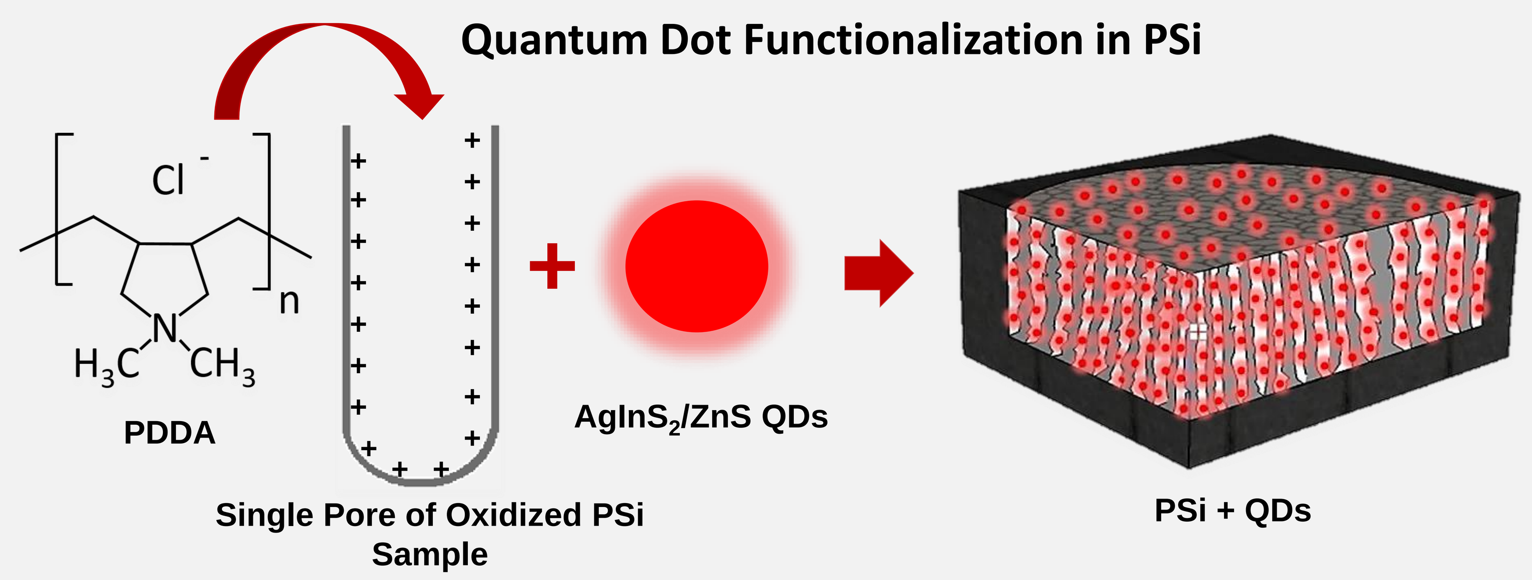

*Sensing Mechanism (color change)*

**Research Goal:**

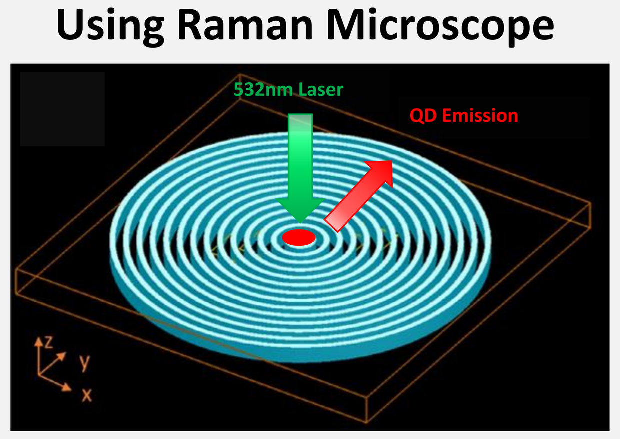
To create a low cost, low power, portable biosensors that enable color-based detection by a camera and can be easily integrated with mobile devices such as a smartphones.

## Methods

**Quantum Dot Functionalization in PSi**

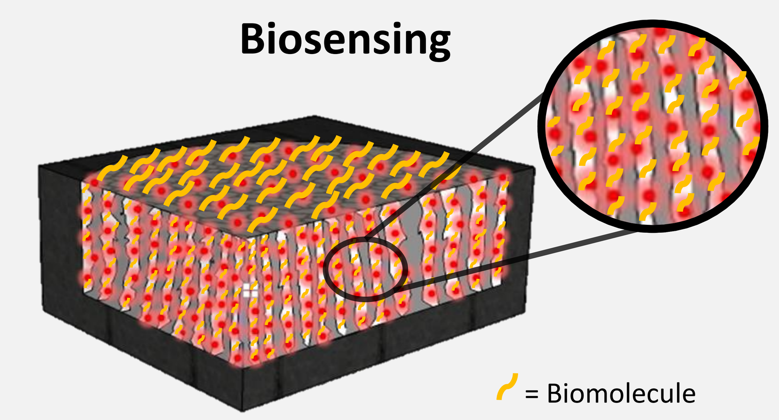



**Photoluminescence Measurement Using Raman Microscope**




Laser excites fluorescence emission from QDs. In real world applications LEDs may be used.

**Biosensing**




Different protein molecules were exposed to the PSi-QD ABRs for proof-of-concept biosensing experiments.

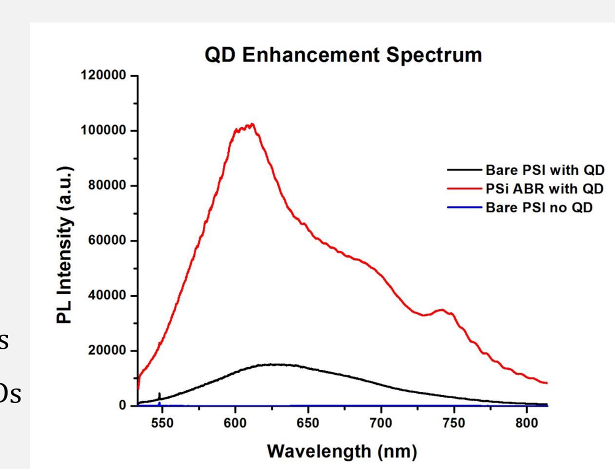
## PL Enhancement From ABRs

Enhancement confirms QD infiltration in the PSi pores and modification of QD emission by the ABRs.

$$EF = \frac{I\ sample - I\ background}{I substrate - I\ background}$$

Liu, et al. *Opt. Express* 18, 2010.

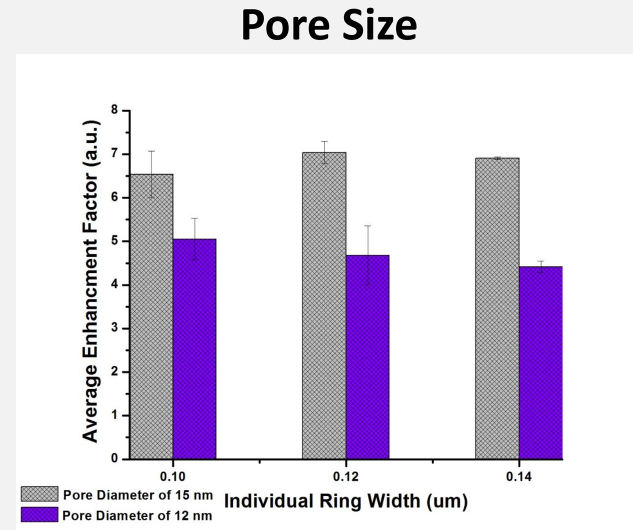
EF: Enhancement Factor
I: Area Under The PL Curve
Sample: PSi ABR with QDs
Substrate: Bare PSi with QDs
Background: Bare PSi no QDs



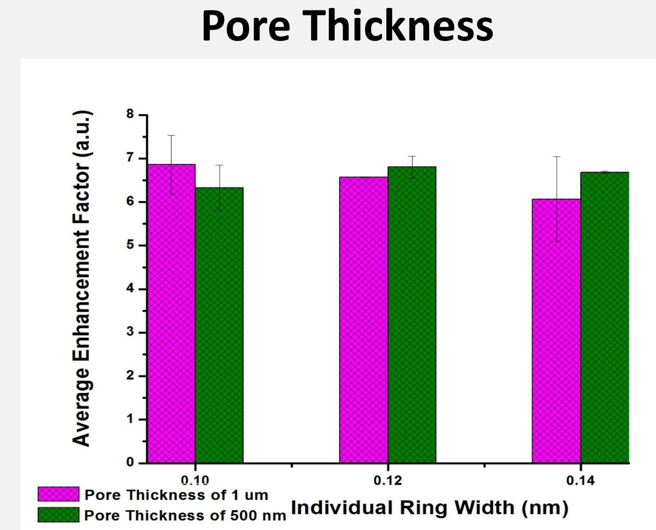

*The average enhancement factor calculated was approximately 7*

**Effect on Pore Size and PSi Layer Thickness:**

**Pore Size**




**Pore Thickness**



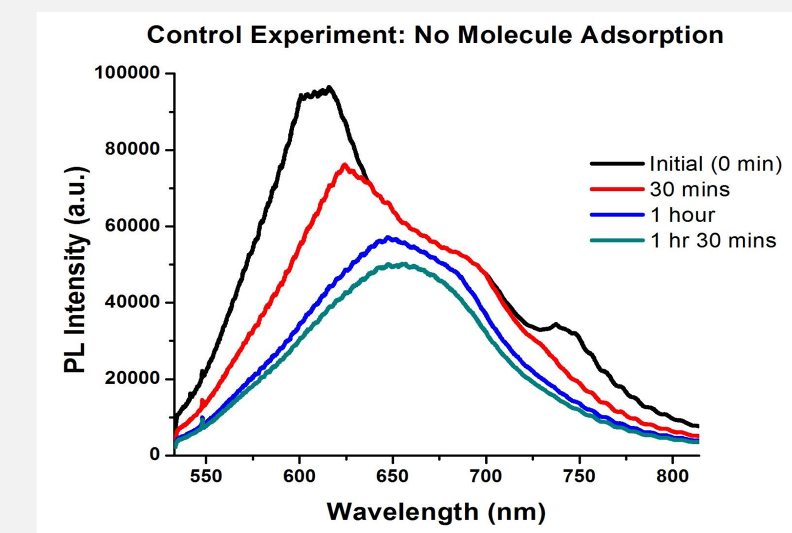

**Conclusion:**

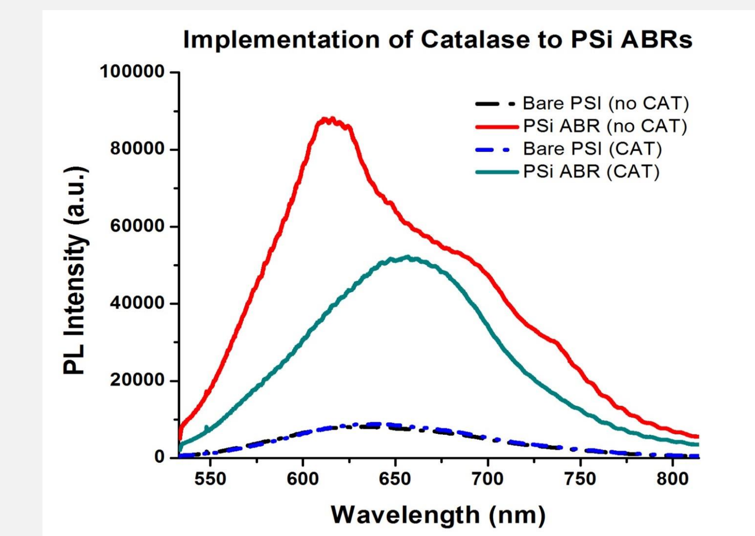
- Larger pore sizes result in a higher enhancement factor: more QDs are able to enter the pores, leading to a higher PL intensity.
- Pore thickness has minimal effect on the PL enhancement for samples with a pore size of 15 nm.

## 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.

| Biomolecules | Molecular Weight | Net Shift After Molecule Attachment |
|---|---|---|
| Catalase (CAT) | 240 kDa | 41 nm |
| Horseradish Peroxidase (HRP) | 44 kDa | 31 nm |
| (3-Aminopropyl)triethoxysilane (APTES) | 220 Da | 40 nm |




**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:**

- Adsorption 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 shift.
- 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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