Porous Silicon based Optical Sensing in Complex Media: Antifouling Coating

Hayat Abdurahman[1], Rabeb Layouni[2], Bradley A. Baker[2], Tengfei Cao[3], Paul E. Laibinis[2], Sharon M. Weiss[3,4]

1. *Department of Engineering, Community College of Baltimore County*
2. *Department of Chemical and Biomolecular Engineering, Vanderbilt University*
3. *Interdisciplinary Graduate Program in Materials Science, Vanderbilt University*
4. *Department of Electrical Engineering and Computer Science , Vanderbilt University*

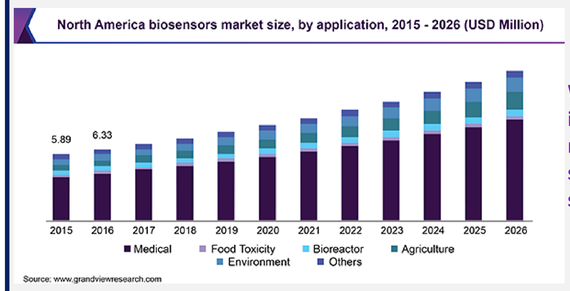
Objective

- Enhance porous silicon based biosensor specificity in serum by preventing nonspecific binding of proteins and contaminants via an antifouling layer.

Introduction

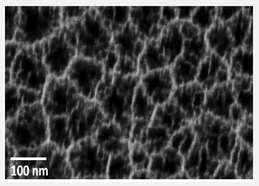
Background :

- Optical biosensors offer several advantages over conventional analytical techniques by enabling direct, real-time and label-free detection of biological and chemical substances.

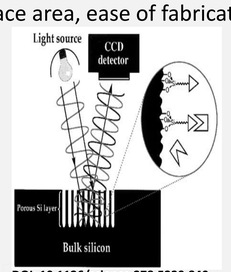


Wider biosensor implementation requires highly sensitive and specific devices.

- Porous silicon (PSi) is a promising nanomaterial for label free optical biosensing due to its large surface area, ease of fabrication, and convenient surface chemistry.



SEM image of PSi



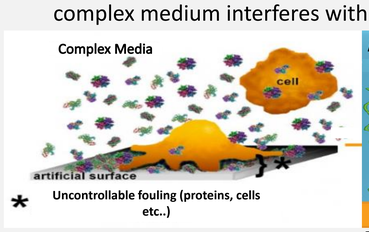
Single layer PSi based biosensor

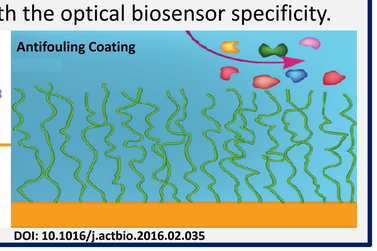
DOI: 10.1126/science.278.5339.840

- Although a lot of progress has been achieved in designing PSi based optical biosensors, most research studies focus on their use in ideal/ purified solutions with limited data for applications in complex media[3].

Concept:

- Design a PSi based optical biosensor for clinical diagnosis in complex media such as blood or serum.
- Challenge: fouling due to nonspecific binding of proteins in a complex medium interferes with the optical biosensor specificity.

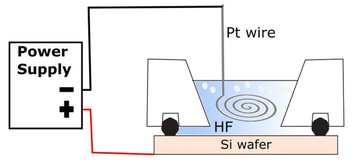




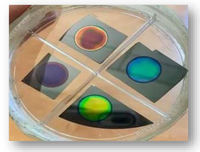
DOI: 10.1016/j.actbio.2016.02.035

Methods

PSi Preparation by Electrochemical Etch



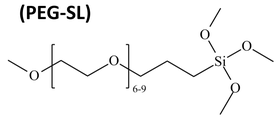
Electrochemical Etch Cell



Porous Silicon (PSi)

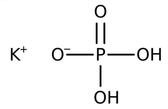
Antifouling Coating

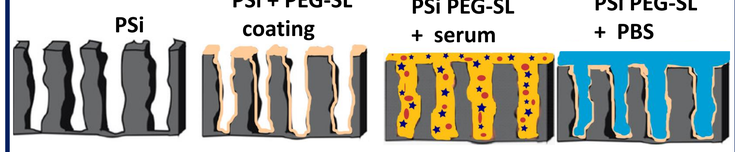
Polyethylene glycol silane (PEG-SL)



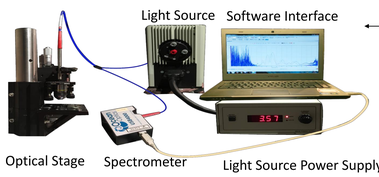
Antifouling and Stability Assessment

Phosphate Buffered Saline (PBS)

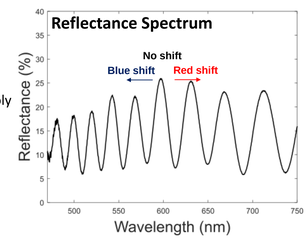




Reflectance Measurement



Reflectance Spectrometer setup



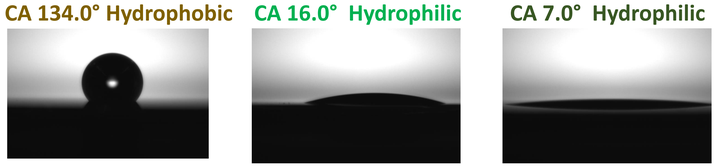
- A red shift indicates addition of material to the surface.
- A blue shift indicates a loss of material from the surface.

Results

PEG-SL Monolayer Coating Characterization

1. Contact Angle (CA) Measurements

CA 134.0° Hydrophobic **CA 16.0° Hydrophilic** **CA 7.0° Hydrophilic**



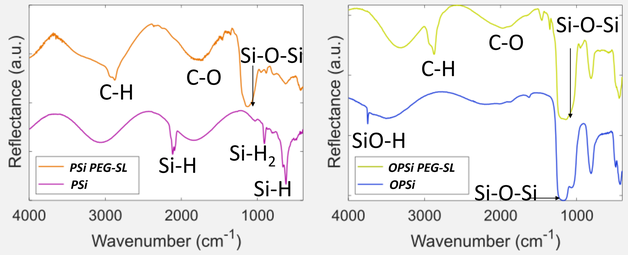
Porous Silicon (PSi) PEG-SL on PSi PEG-SL on oxidized PSi

CA measurements on PSi and oxidized PSi (OPSi) after PEG-SL coating showed an increase in hydrophilicity indicating the surfaces might be able to prevent protein adhesion.

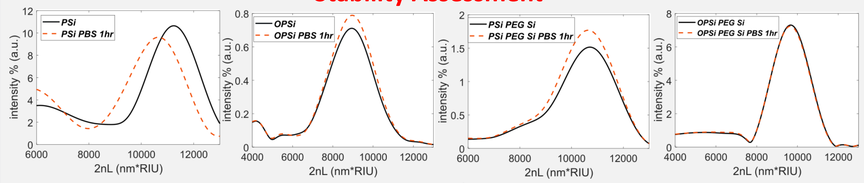
Results

2. Ellipsometry: suggests that a PEG SL layer has a thickness of ~ 1 nm.

3. FTIR Spectroscopy: shows peaks consistent with PEG-SL attachment.

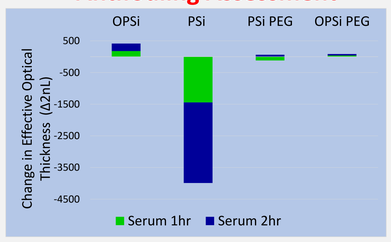


Stability Assessment



- OPSi is more resistant to corrosion compared to PSi.

Antifouling Assessment



- PEG-SL antifouling layer reduced the nonspecific binding of proteins in serum by 80%.

Conclusion

- A PEG-SL antifouling monolayer applied on PSi based biosensor helps reduce nonspecific binding in serum by 80%, which improves its specificity.
- The oxidized porous silicon surface showed a higher stability when exposed to serum and phosphate buffered saline (PBS).

Future Work

- Test performance of other antifouling coatings on OPSi.
- Test biotin-streptavidin assay in serum on OPSi.

Acknowledgements

This research was funded in part by VINSE NSF REU (Grant Number: DMR 1560414). Special thanks to everyone in the Weiss group for their support and to the Vanderbilt Institute of Nanoscience and Technology (VINSE) for granting me the opportunity to do research this summer.

References

1. Lísalová, H. (2019, February 13)."Molecular-level mechanisms of biofouling at functional surfaces: From new theories to novel bio-inspired materials".
2. Damborský, P., Švitel, J., & Katrlík, J. (2016, June 30). Optical biosensors.
3. Tieu, T., Alba, M., Elnathan, R., Cifuentes-Rius, A., & Voelcker, N. H. (2018, October 10). Advances in Porous Silicon–Based Nanomaterials for Diagnostic and Therapeutic Applications - Tieu - 2019 - Advanced Therapeutics - Wiley Online Library.