Kinetic Analysis of Porous Silicon Biosensors

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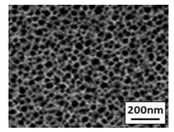
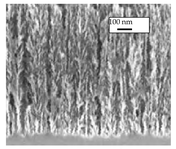
Introduction

Background and Motivation:

Porous silicon (PSi) is a material formed by electrochemical etching of single crystal silicon in HF-containing solutions. This nanostructured material has been demonstrated as an effective biosensing platform due to its large surface area, tunable pore sizes, and compatibility with standard silicon fabrication processes.[1] PSi membranes have great potential for lab-on-chip sensor arrays capable of fast response, high sensitivity, and simultaneous detection of multiple analytes.[2]



Top view, SEM image



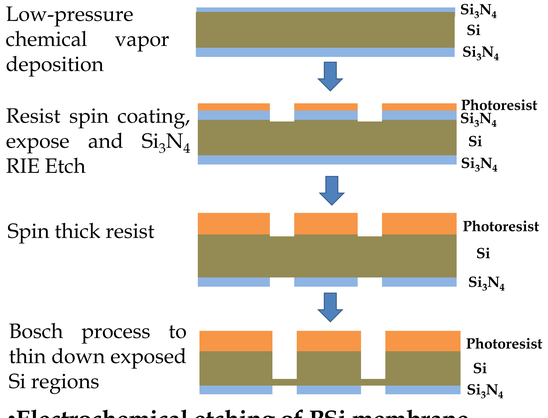
Cross-sectional view, SEM image

Objective:

In this work, we investigated the molecular binding kinetics and detection sensitivity of two different types of PSi biosensors: a close-ended, flow-over PSi single layer film and an open-ended, flow-through PSi membrane. Different flow rates of biomolecules were also tested on PSi films in order to determine the relationship between flow rate and response time of PSi biosensors.

Methods

•Fabrication of PSi membrane



Membrane area: 1 mm x 1 mm, Thickness: 25 µm

•Electrochemical etching of PSi membrane

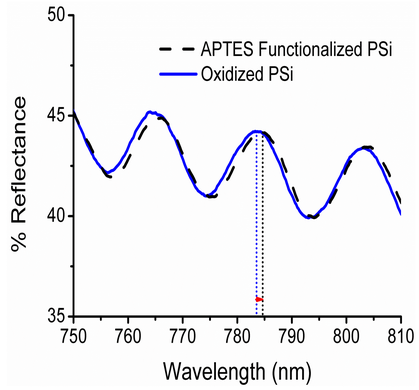
Etching current: 48mA/cm^2, Etching time: 400 sec for closed-end PSi, and 800 sec for open-ended membrane

•Flow cell fabrication

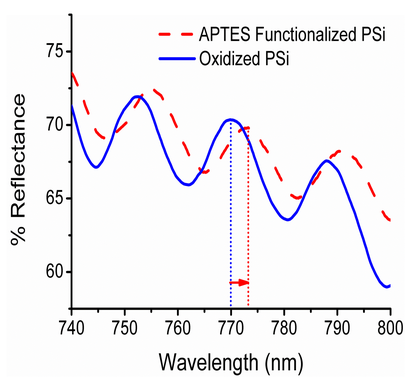
•Surface functionalization of PSi biosensor

Oxidation at 800 °C for 5 minutes. Then flow (3-Aminopropyl)triethoxysilane (APTES), prepared by 50:48:4 volume ratio of DI water, methanol and APTES respectively.

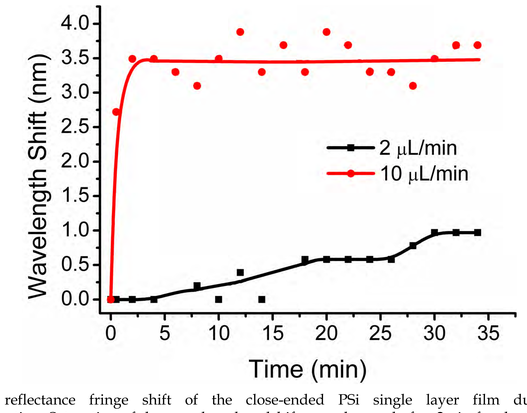
Results



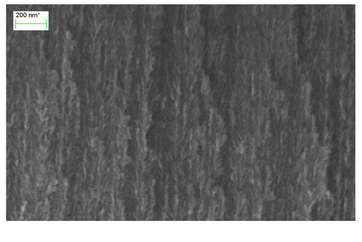
Close-ended PSi. APTES flow rate 2 µL/min for 34 minutes. A wavelength redshift of approximately 1 nm was observed from oxidized PSi to APTES functionalized PSi.



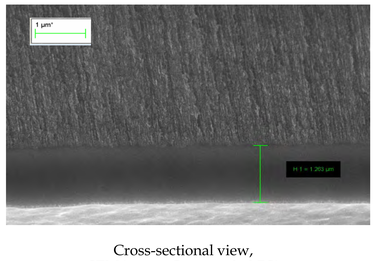
Close-ended PSi. APTES flow rate 10 µL/min for 34 minutes. A wavelength redshift of approximately 3.5 nm was observed from oxidized PSi to APTES functionalized PSi.



Real-time reflectance fringe shift of the close-ended PSi single layer film during APTES functionalization. Saturation of the wavelength redshift was observed after 2min for the fast flow rate (10 µL/min) and after 30min for the slow flow rate (2 µL/min) separately.



Cross-sectional view, SEM image. Open-ended PSi.



Cross-sectional view, SEM image. Open-ended PSi.

Conclusion

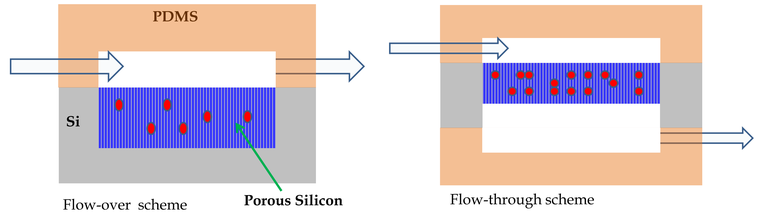
•Faster flow rate increased the binding rate of biomolecules, resulting in a larger wavelength shift within the same detection time.

• Detection sensitivity increased for the faster flow rate. This was shown by the saturation of the wavelength shift due to APTES attachment.

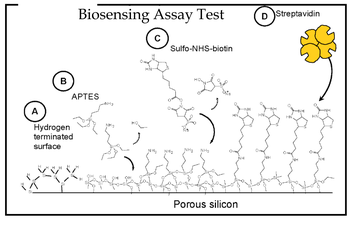
Future Work

•Increase the mechanical stability of PSi membrane by scaling down the area of membrane to micrometers.

•Integrate PSi membrane into flow cell to allow for fast and high sensitivity detection



•Monitor biotin-streptavidin binding kinetics



References

[1] Gupta, B; Zhu, Y; Guan, B; Reece, J. P; Gooding, J. J; Analyst, 2013, 138, 3593-3615.

[2] De Stefano, L; Orabona, E; Lamberti, A; Rea, I; Rendina I; Elsevier, 2013, 179, 157-162.

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