Nanoporous Silicon Structures for Toxin Detection

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Abstract

In this project, we are aiming towards the development of an impedimetric biosensor based on nanoporous silicon structures for the detection of small molecular size and low weight food toxins (like Aflatoxin). Existing sensors for such toxin detection fail to achieve high sensitivity because Aflatoxin molecules are so small in size that they are unable to cause significant impedance change on the sensor surface. But, in nanoporous silicon, the toxin molecules are expected to be entrapped in the nanopores of the structure. This confinement of small molecules in pores of dimensions that are comparable to the size of the biomolecules is expected to maximize the biomolecule activity, resulting in increased sensitivity. Moreover, in nanoporous silicon structures where the thickness of the pores is of the order of 100nm, the field lines are expected to be confined near the electrodes within 200nm thus enabling sensitive detection even with widely spaced electrodes. In the nanoporous structures, widely spaced electrodes are used. For detection, the electric field lines through the pores near the electrodes are modulated. A few nanoporous silicon 3D structures were simulated using COMSOL Multiphysics in order to observe the field lines. Figure 1 and Figure 2 shows the cross-sectional view and top view of the first structure (Structure 1) respectively. The nanopores are of dimensions 50nm x 50nm x 100nm. The ratio(R) of the height of the pores to the oxide layer length containing the pores is roughly 1:5. The second structure (Structure 2) is similar to Structure 1. The only difference is that R is now roughly 1:10. In both structures, for simulation, a potential difference was applied between the two electrodes. Figure 3 shows the current flow distribution of Structure 1. Current lines from the electrodes enter the pores and then pass through the silicon substrate. Pores adjacent to the electrodes have the maximum current density which decreases gradually in the pores away from the electrodes. Figure 4 shows the current flow distribution of Structure 2. Here, less current lines flow horizontally when compared to the previous structure. In practice, R will be much less than 1:10 and from our simulation results, we conclude that as this ratio will be very small (about 1:10000) negligible current will flow horizontally and most of the current will pass through the pores. The small-sized toxin molecules entrapped in the pores will modulate the electric field lines and cause significant impedance change. This impedance change is then measured quantitatively. Using the proposed method, it is possible to achieve higher sensitivity compared to the common already existing detection methods.
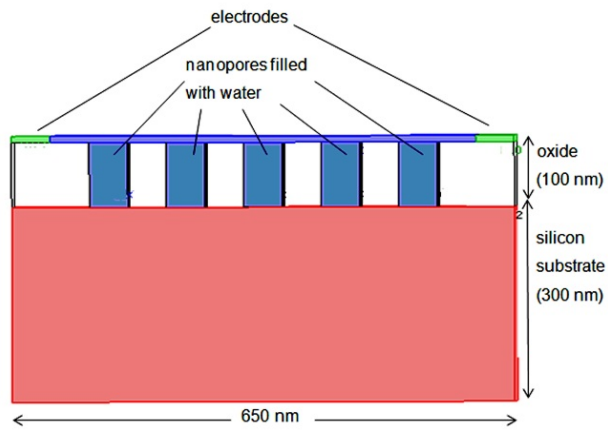
Figures used in the abstract

Figure 1: Cross-sectional view of structure 1.
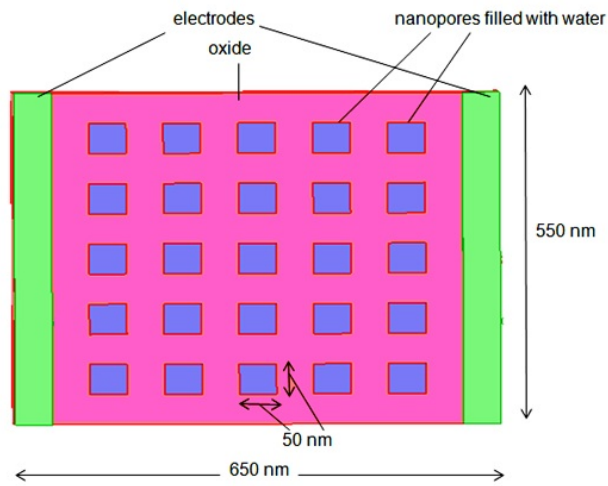

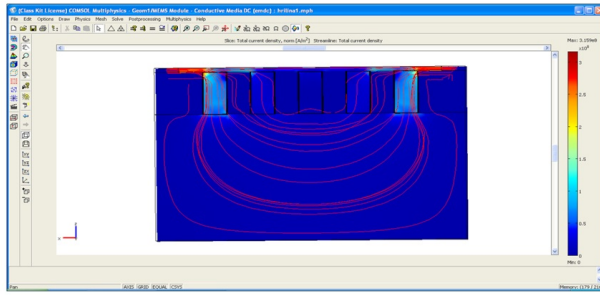**Figure 2**: Top view of structure 1.

Figure 3: Simulation result of Structure 1
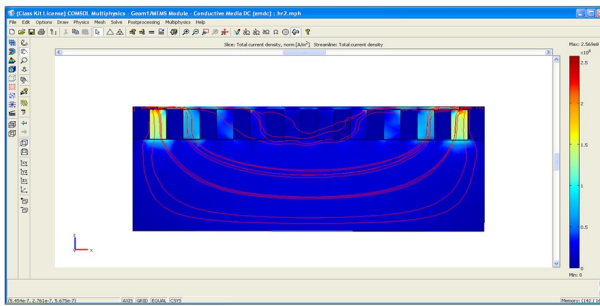
Figure 3: Simulation result of structure 1.

Figure 4: Simulation result of Structure 2

Figure 4: Simulation result of structure 2.