Design Of A Nucleic Acid Biosensor Using COMSOL Multiphysics®

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Abstract

Cancer is one of the leading causes of deaths worldwide. According to the American Cancer Society, there will be about 700,000 cancer related deaths in US in 2017. Cancer mortality will be reduced if it is detected and treated at the early stages. Previous studies have shown that biomarkers can be used as an effective pointer for detection of cancer at very early stages. Bio sensing techniques that are involving in the detection of biomarker molecules (proteins, DNA or antigens) in patients' samples do not have the adequate sensitivity and limit of detection to be effectively detect early stage of cancer. Especially, the limit of detection of the current biosensing techniques varies from molar (M) to few nano/pico (10^-12) molar and this limit is insufficient for early detection of cancer. To address this critical need, we have designed a biosensor that detect biomarker molecules in the lower molar range (from pico (10^-12) to yocto (10^-23) molar). In this biosensor, we have used dielectrophoretic force (DEP), which is a result of the interaction between AC electric fields and biomolecules.

We have used the COMSOL Multiphysics® software to design the array of micro-electrodes used in experiments. We have use the COMSOL® software to calculate the electric fields (｜E｜) and electric field gradient (｜∇E^2｜) generated by these electrodes. We have used the Electric Current interface of the AC/DC Module of the COMSOL Multiphysics® Software to perform a frequency domain study to determine the ｜∇E^2｜. In addition, we have also used Electromagnetic waves, Frequency domain interface of Optics Module to perform a frequency domain study to determine the plasmonic effects of metal nano-structures used in biosensing experiments. By setting all the required parameters and boundary conditions such as dielectric values of medium, conductivity of the medium, applied electric potential and applied wave length for the excited wave, the simulation was performed and the ｜∇E^2｜ and ｜E｜ were calculated.

From the simulation results, the highest ｜∇E^2｜= 3.89 x 1013 V2/m3 was calculated at the edges of the electrodes and the highest ｜E｜= 3x 106 V/m was calculated at the metal nano-structure as we expected. ｜∇E^2｜value will generate a highest DEP on target biomarkers and trap them on the device. We have then utilized the standard micro-fabrication techniques to develop prototypes of our design. Currently, we are performing experiments to find the purity, recovery and throughput of our device.

Figures used in the abstract

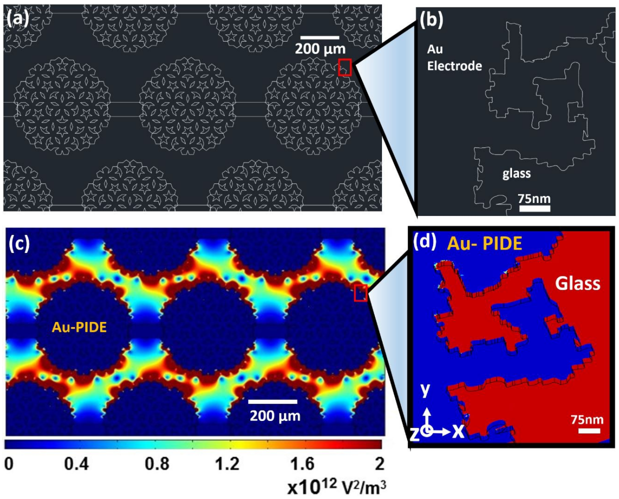

Figure 1 : Design and simulation of the new class of biosensor. (a) AutoCAD drawing of the electrode. (b) AutoCAD drawing of the nan-Structure located at the edge of the electrode. (c) Calculated electric field gradient (│ ∇E^2 │) using COMSOL software. (d) Calculated electric field gradient (│ ∇E^2 │) in the nano-structure using COMSOL software.