Design of a Nucleic Acid Biosensor Using COMSOL Multiphysics®

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Introduction : The detection of target biomarkers (proteins, DNA or antigens) from biological samples is the starting point of developing effective therapy for many diseases including cancers. Currently available bio sensing techniques do not have the adequate sensitivity and limit of detection to be effectively detect early stage of cancer. To address these issues, we proposed a low-cost and high-throughput technique based on dielectrophoresis (DEP). In this work, we have used the COMSOL software to design electrodes and nano-detection spots which were used in DEP based biomarker detection. The DEP force, F_DEP=1/2 α $\nabla|E|^2$, depends on the electric field gradient ($\nabla|E|^2$) therefore, we used COMSOL software to design electrode that produce large electric field gradients.

Computational Methods:

1.Geometry : Electrode designs were drawn according to the scale in AutoCAD software and imported to COMSOL 3D model and extruded by 100nm. Gold material was used for electrode and PBS buffer solution was filled over it and it was densely meshed into finite elements for calculations.

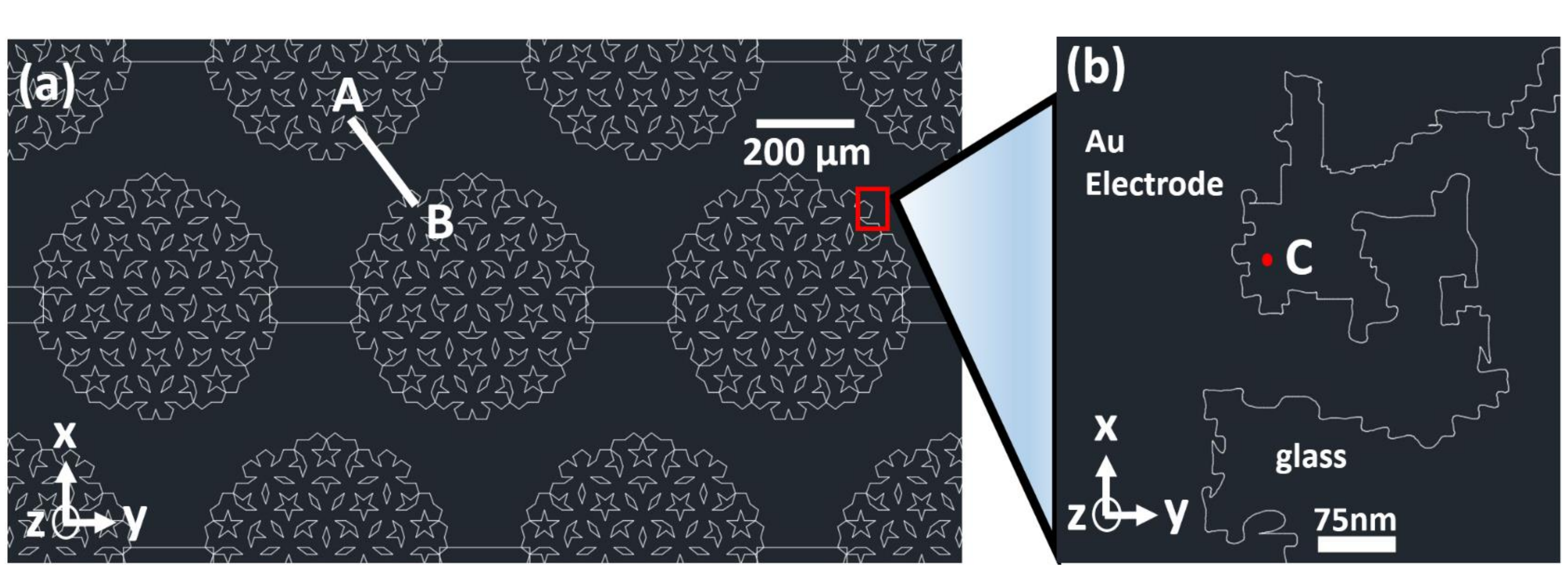

Figure 2.(a) Electrode design, (b) nano-detection spots design, for biomarker detection device.

2.Physics and Governing Equations: AC/DC Electric current (ec) physics and frequency domain studies was utilized in calculations.

❖ Electric field strength was calculated by using the $\boldsymbol{E} = -\boldsymbol{\nabla V}$ equation, and the electric field gradient ($\nabla|E|^2$) was calculated in X-Y plane by using the equation

$$\boldsymbol{Grad} = \sqrt{\left(\frac{\boldsymbol{d(ec.normE^2)}}{\boldsymbol{dx}}\right)^2 + \left(\frac{\boldsymbol{d(ec.normE^2)}}{\boldsymbol{dy}}\right)^2}$$

Results: We have calculated E and ($\nabla|E|^2$) in X-Y plane and Z plane, and plotted the ($\nabla|E|^2$) through the cut lines.

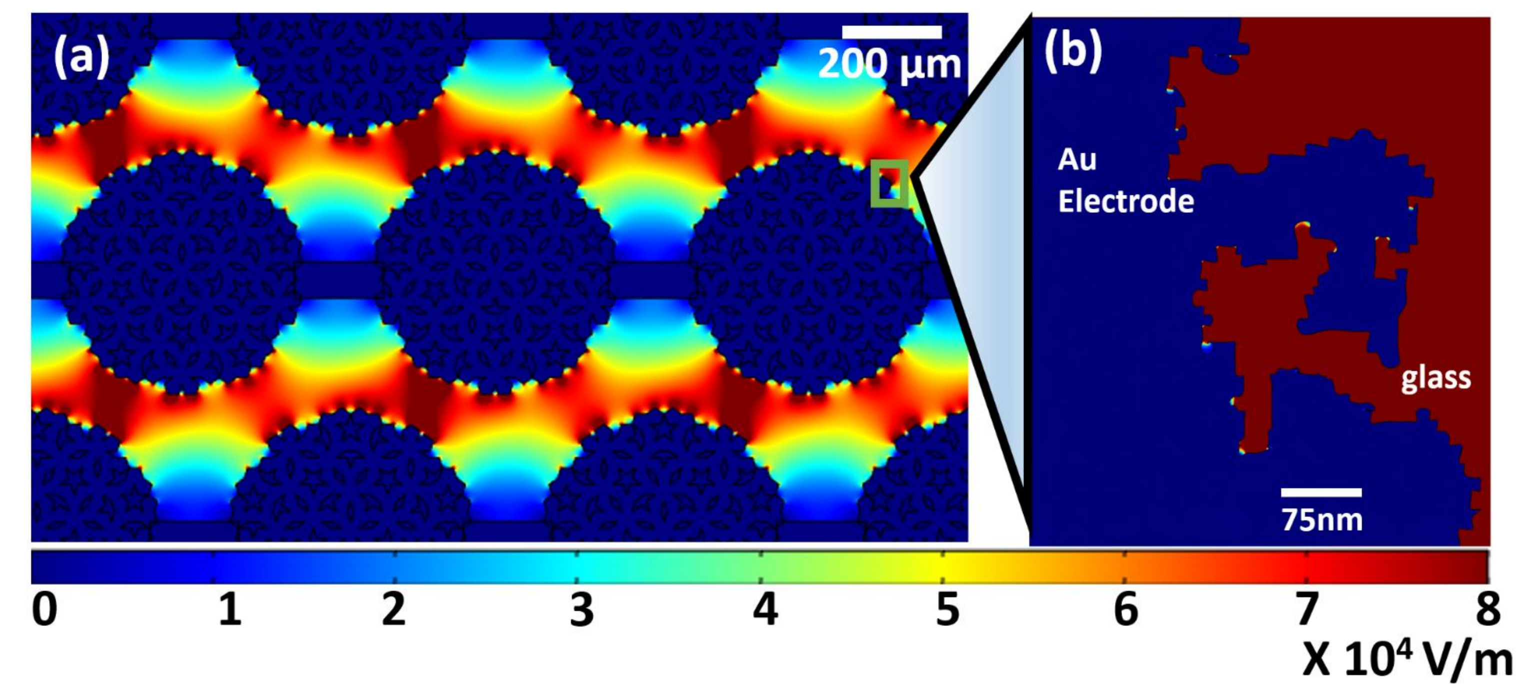

Figure 3. Calculated (a,b) E in X-Y plane in the electrode and the nano-detection spots

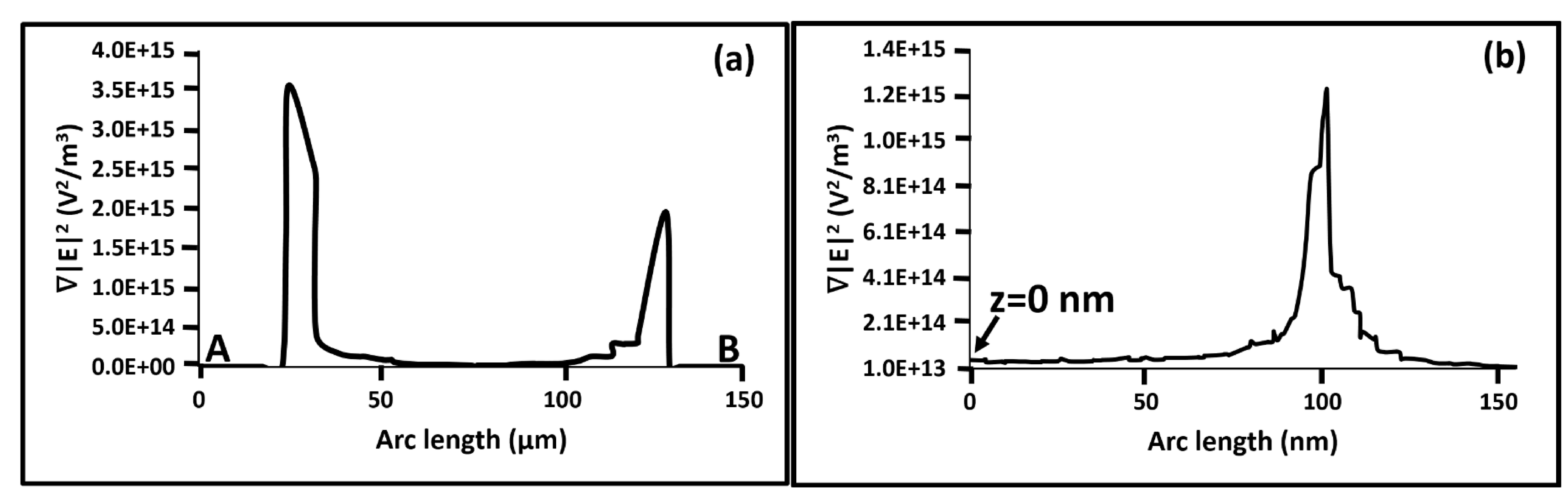

Figure 5. Calculated ($\nabla|E|^2$) through (a) cut lines in A-B , (b) through cutline C in Figure 1.

The maximum ($\nabla|E|^2$) in X-Y plane is 3.89x10^{15} V^2/m^3 and it is found to be at the top of the nano-detection spots (100nm) .

Conclusions : We successfully utilized AC/DC ,electric current (ec), physics and frequency domain studies to calculate E and ($\nabla|E|^2$) , generated by the electrode cell trap. We fabricated the electrode using photolithography process following by metal deposition and lift off process . Currently experiments are being performed to find out the throughput of the biomarker detection device.

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