Geometry Optimization of Electrochemical Glucose Sensor using COMSOL Multiphysics

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Introduction

- Regular blood glucose monitoring demands non-invasive glucose sensors for diabetic patients.
- Numerical simulation allows us to design and optimize electrochemical amperometric biosensors by incorporating concepts of physics.
- In present study, various 2D and 3D models were analyzed to optimize the electrode geometry for best possible electrical response.

Reactions

- $Glucose + GOx_{(ox)} \rightarrow Gluconic\ Acid + GOx_{(red)}$ (1)
- $GOx_{(red)} + 2Fe(III) \rightarrow GOx_{(ox)} + 2Fe(II) + 2H^+$ (2)
- $Glucose + 2Fe(III) \rightarrow Gluconic\ Acid + 2Fe(II) + 2H^+$ (3)
- $2Fe(II) \rightarrow 2Fe(III) + 2e^-$ (4)

Governing Equations

- Michaelis-Menten model

$$V = \frac{V_{max}[Glucose]}{(K_m + [Glucose])} \quad (5)$$

- Fick's I and II laws

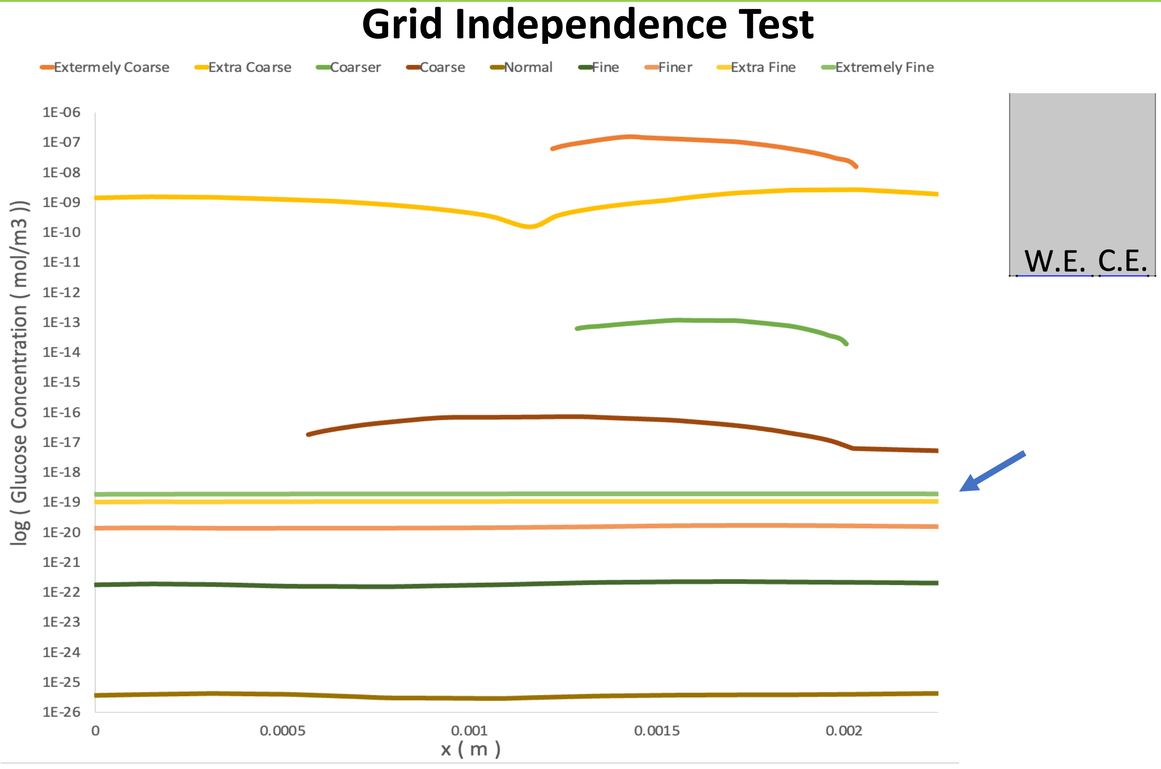
$$J(x) = -D\frac{\partial C(x)}{\partial x} \quad (6)$$

$$\frac{\delta C}{\delta t} = -D\frac{\partial^2 C(x)}{\partial x^2} \quad (7)$$

- Cottrell Equation

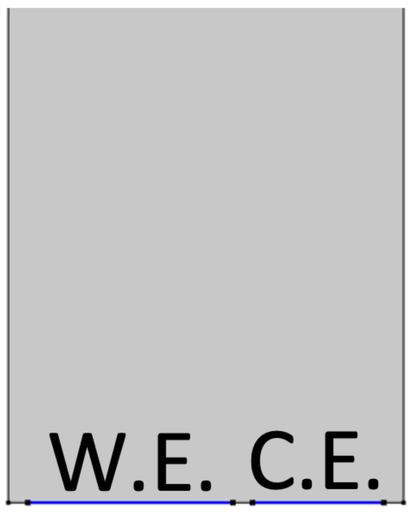
$$i = \frac{n\,FAc^{\circ}\sqrt{D}}{\sqrt{\pi t}} \quad (8)$$

Grid Independence Test

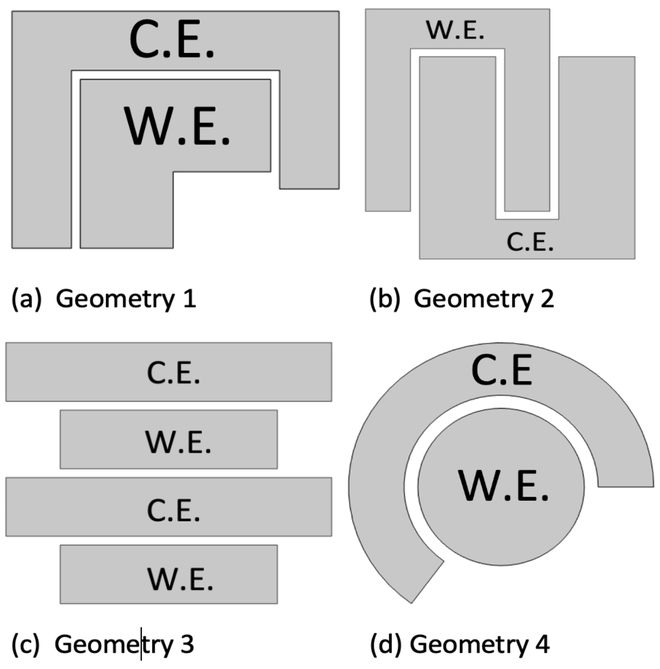


Convergence at extra fine and extremely fine mesh sizes.

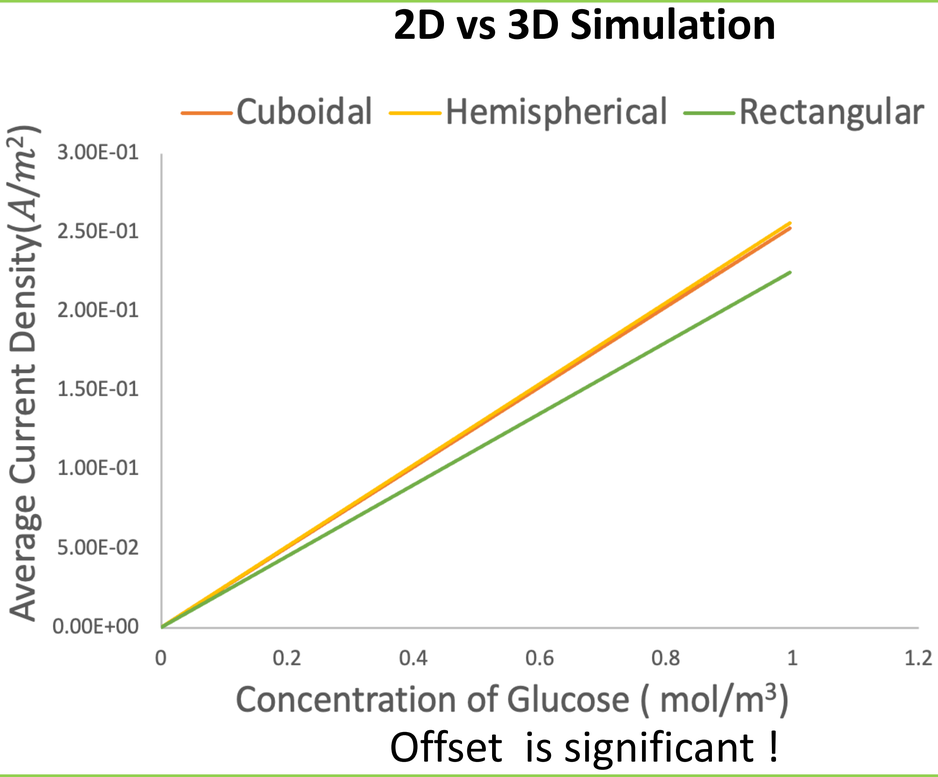
2D Model



3D Models

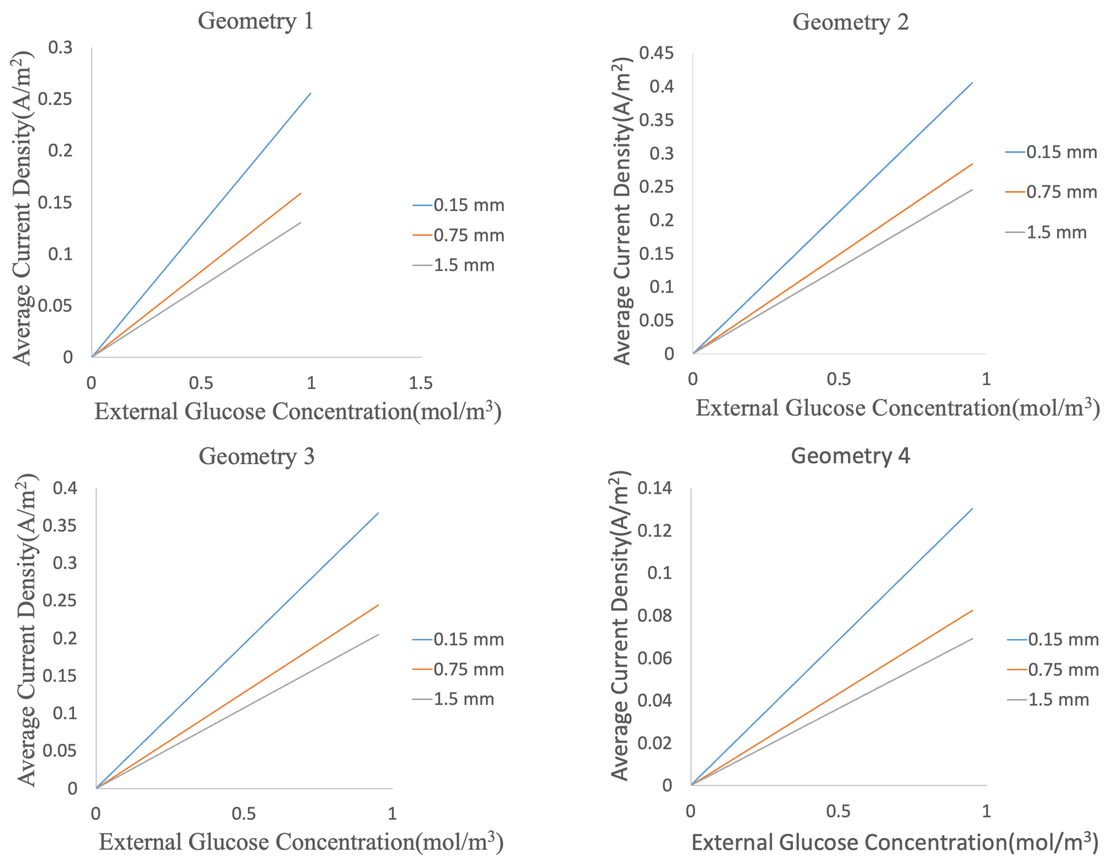


2D vs 3D Simulation



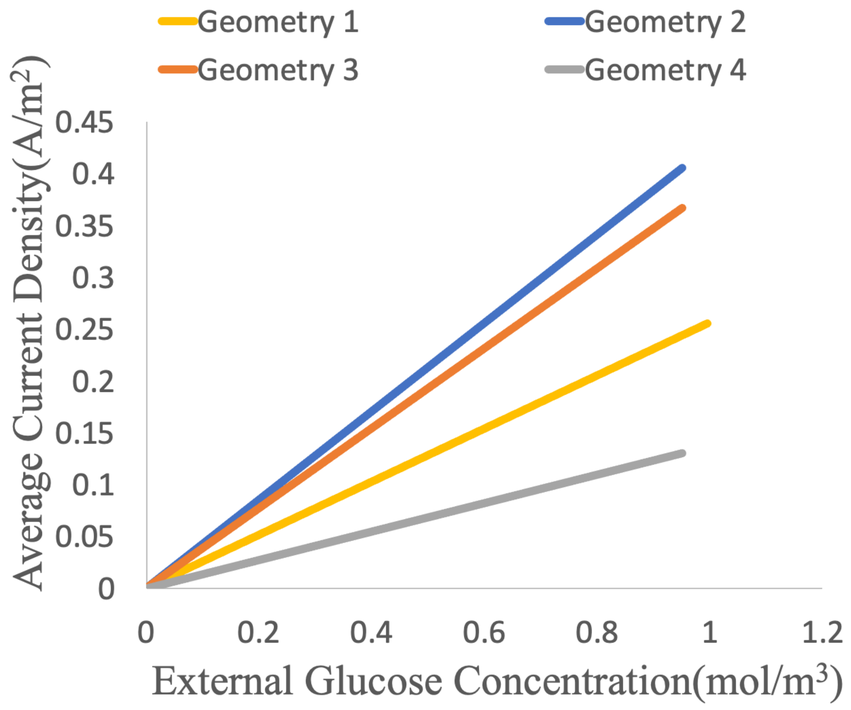
Offset is significant !

Spacing between the electrodes



Inverse relation observed !

Comparison between different electrode geometries with most optimal spacing



Geometry 2 gives best electrochemical response.

My learnings

- Got a taste of research culture.
- Gained an understanding of the sequential steps involved in conducting experiments in a lab and analysing the obtained results and how numerical simulation can be employed as a means to optimize a process or system.

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