Geometry Optimization of Enzymatic Electrochemical Glucose Sensor

Diabetes is a metabolic disorder that is on rising tide. Diabetic patients must regularly monitor their blood glucose levels. One method for designing such a device is using electrochemical principles, specifically amperometry to determine glucose concentration. It is essential to develop devices with higher sensitivity to achieve better sensing resolution. Improving surface area is one solution to this problem, and several works have been reported in the literature where nano materials are incorporated to improve device sensitivity. The other option is to change the geometrical arrangement of the electrodes, which directly affects the electric field distribution and, thus, the current. In this study, we used COMSOL Multiphysics, a finite element (FEM) software, to optimise the electrode geometry of an electrochemical glucose sensor, and then validated it by performing experiments on the optimised electrodes. Two aspects of electrode geometry are investigated: the spacing between the working and counter electrodes and the various electrode shapes. finger type, interdigitated, and circular/arc electrode geometries chosen for this study are shown in figure 1a, 1b and 1d respectively. Figure 1c is the modified version of 1b, where the interdigitated electrodes are considered as array of alternate working and counter electrode. Figure 2 (a-d) shows the average current density for various glucose concentrations plotted for each parameter for geometries shown in figure 1a-d respectively. Because the electrochemical response (average current density) decreased with increasing electrode spacing, an optimised spacing of 0.15mm was chosen while keeping the limitations of the printing processes. As shown in figure 3a, the geometries with the greatest overlap of perimeter between working and counter electrodes had the best electrochemical response. Geometry 2 and 3 are interdigitated but constructed in such a fashion that the overlap of perimeter is reduced in geometry 3 while keeping the areas of the counter and working electrode constant. As a result, geometry 2b with the greatest perimetric proximity provided the best sensor response. Glucose sensing experiments performed using the optimised geometries by drop-casting glucose oxidase and nafion over the working electrodes. The glucose sensing measurements were carried out in 100 mM (pH 7.4) phosphate buffer saline. As seen in figure 3b, the experimental results followed a similar pattern; however, an offset was observed for the absolute average current density in between the experimental and simulated data (figure 3a and 3b).

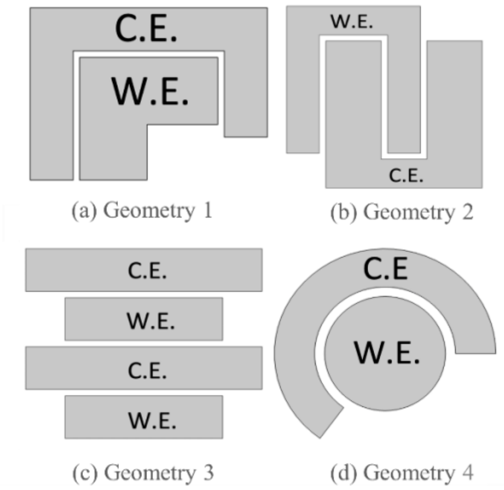

Figure 1: Various electrode geometries (a) finger type, (b) Interdigitated (c) simplified version of (b) and (d) circular/ arc type.

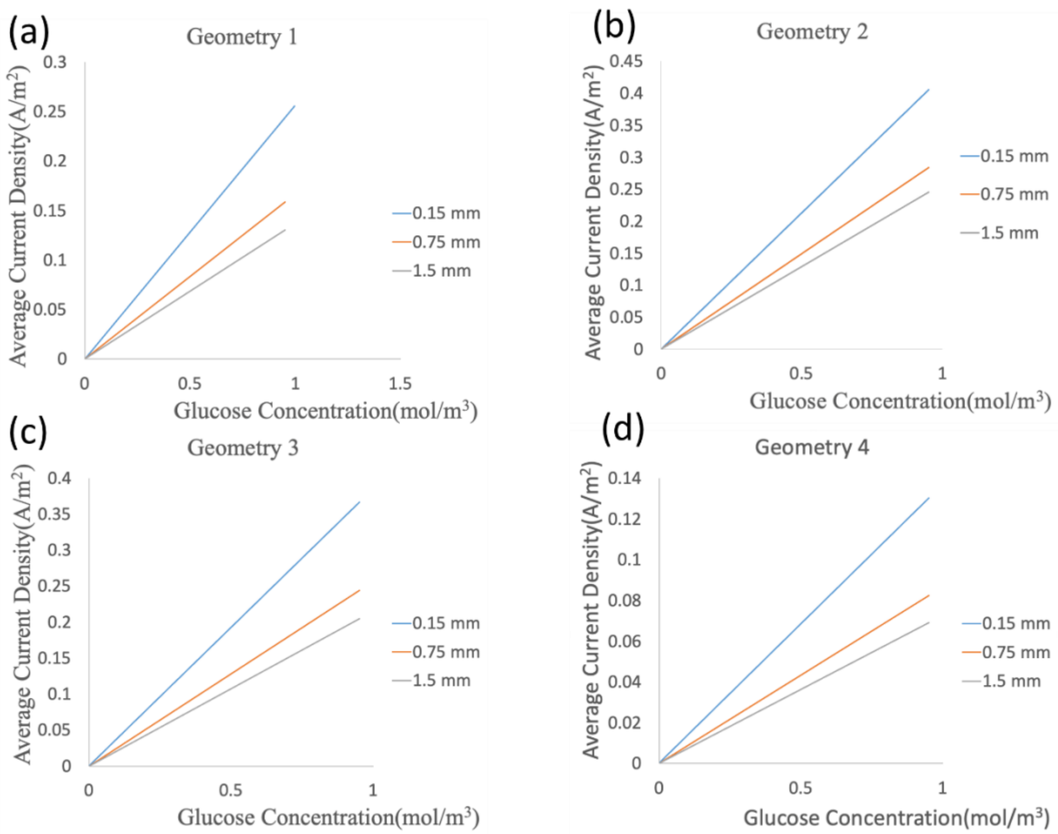

Figure 2: Current vs concentration plots for various electrode spacing for (a) finger type, (b) Interdigitated (c) simplified version of (b) and (d)circular/ arc type electrode.

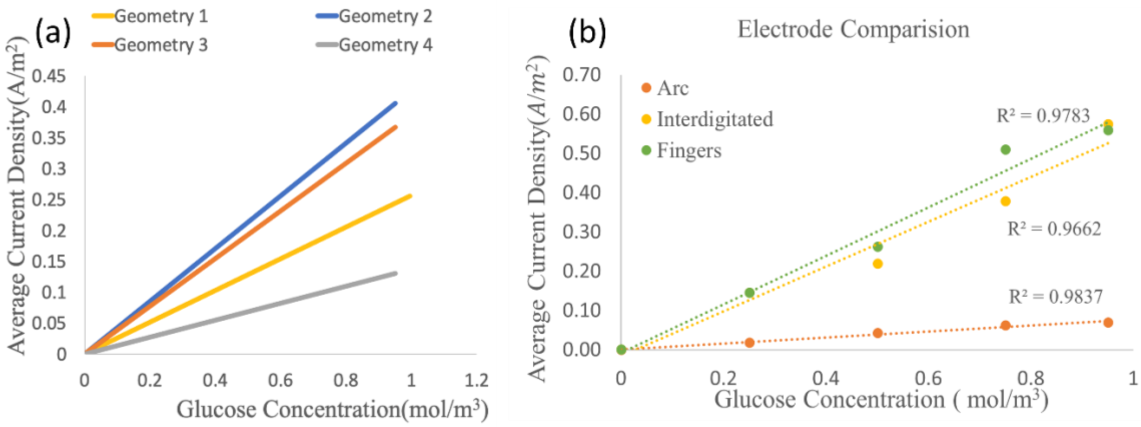

Figure 3: (a) Current vs concentration plots for various electrode obtained via simulation and (b) experimental data for various electrodes fabricated using optimised spacing.