Numerical study on the impact of the geometric shape of micropillar array electrodes on the performance of a microfluidic biosensor

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Micropillar array electrodes have piqued the interest of researchers as a promising new technology because they have a much larger surface area and cause an increase in the electrical signal arrays[1]. They have many benefits, such as increased mass transport, lower detection limit, and the potential to be miniaturized[2]. Geometrical parameters of micropillar array electrodes affect the surface area of the electrode and improve the operation of biosensors considerably. In this study, we considered two different shapes of micropillars on the working electrode (WE) and investigated their influences on the performance of a microfluidic biosensor. To achieve this goal, a 3D simulation was conducted using the electroanalysis module of the COMSOL Multiphysics software.

Initially, we considered cylindrical pillars on the WE to study the effects of the micropillars' shape. We designed WE with several configurations from 4*4 to 10*10 and monitored the current. Although the current density becomes larger as the number of pillars is enhanced, the range of current is not ideal. To address this problem, we designed WE with new shape micropillar array electrodes. The results demonstrate a noticeable improvement in the amount of current in the electrodes with the new shape. In addition, we studied the effects of spacing between micropillar array electrodes on the amount of adsorption of the analyte.

In the last part of this work, we used cyclic voltammetry (CV) to assess the electrochemical behavior of the biosensor, and the results achieved from this technique were used to determine the sensitivity of the biosensor. According to cyclic voltammetry, the biosensor exhibited a sensitivity of 1.61 $\mu A.cm^{-2}\ mM^{-1}$.

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1 C. Chen et al., "Development of micropillar array electrodes for highly sensitive detection of biomarkers," RSC Adv, vol. 10, no. 67, pp. 41110–41119, Nov. 2020, doi: 10.1039/D0RA07694E.

2 X. Hu et al., "Miniaturized electrochemical sensor with micropillar array working electrode for trace lead online measurement in tap water," JMiMi, vol. 29, no. 10, p. 105005, Jul. 2019, doi: 10.1088/1361-6439/AB284E