Mathematical Modeling of Nanocolumnar Electrochemical Biosensors

MohammadAli Maleki Bigdeli\textsuperscript{1}, Abebaw B. Jemere\textsuperscript{2}, Kenneth D. Harris\textsuperscript{1,2}, Wylie Stroberg\textsuperscript{1}

\textsuperscript{1}Department of Mechanical Engineering, University of Alberta, Edmonton, Canada
\textsuperscript{2}National Research Council Canada – Nanotechnology Research Centre, Edmonton, Canada
alibigdeli@ualberta.ca, abebaw.jemere@nrc-cnrc.gc.ca, kenneth.harris@nrc-cnrc.gc.ca, stroberg@ualberta.ca

ABSTRACT

Non-invasive testing of blood sugar levels, for instance, measurement of glucose concentration in sweat, saliva, or tears, allows diabetic patients to monitor their blood sugar levels with greater frequency and less difficulty. However, the relatively low glucose concentration in these biofluids compared to blood is one of the most important challenges in non-invasive monitoring systems. Recently, nanostructured nickel-oxide electrodes fabricated by the glancing angle deposition (GLAD) technique have been used to electrochemically measure glucose concentrations in sweat samples with high sensitivity, selectivity and reproducibility. GLAD is a single-step physical vapour deposition combining oblique angle deposition with dynamic substrate motion. Precise substrate rotation in the GLAD technique allows electrode morphologic properties such as porosity and film thickness to be tightly controlled, providing great opportunity to enhance the sensors' performance and sensitivity. Although over the last few years, application of GLAD-based sensors has been expanded considerably, theoretical analyses are still needed to understand the effect of different parameters on the sensor performance. By employing modern computational techniques, we can investigate the effect of various parameters on the sensor performance with much less effort compared to experimental studies. Therefore, here, we developed a 2D reaction-diffusion model for the surface-catalyzed reactions in the nanostructured GLAD electrodes based on finite element method (FEM) simulation. Using this model, we conducted a parametric study on the depth (electrode thickness) and spacing (electrode porosity) of the GLAD structures and for different values of absorption rates and catalytic rates, we have found the optimal electrode structures. This research will play an important role in designing more effective sensors with higher sensitivity and offer lower detection limits.