Simulation and Design of a Microfluidic Respirometer for Semi-Continuous Amperometric Short Time Biochemical Oxygen Demand (BODST) Analysis

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Abstract

Introduction: This work presents the design of a novel flow cell based miniaturized electrochemical respirometer to monitor organic content in water samples semi-continuously, in contrast to current Biochemical Oxygen Demand, BOD, methods. Simulation techniques has been used to parameterize and optimize aspects such as height and length of the channels, materials and thickness, flow and oxygen supply and biomass concentration in the projected device. Use of COMSOL: The 2D model presented here includes: 1) laminar flow microfluidics; 2) diffusion and convection in different materials (water and permeable membrane) of oxygen and organics; 3) a simplified self-implemented biological reaction (bacteria + organics (Glu) + O2 → Bacteria + CO2 + H2O); and self-implemented electrochemistry simulating the electrical response of the electrode. Several simulations has been run to compare different geometries and materials (length of the channel, height of the reaction chamber and electrolyte channel, thickness and material of oxygen membrane (PDMS and PTFE)) and different flows of electrolyte which is the control parameter for the total oxygen supplied to the system. Results show: 1) the importance of device dimensions and geometry to full use of microfluidics and micro-fabrication advantages as no stirring requirement; 2) the role of the flow velocity as coupled to overall oxygen supplied in adapting the system to a wide range of organic loadings; 3) the key role of biomass in the experiment to reduce overall analysis time; and 4) the expected signal intensity to be obtained by the electrode on each situation. Conclusions: The design presented here uses an electrochemical oxygen sensor, and the whole system is amenable to fabrication using standard micro-fabrication and rapid prototyping techniques. Upon simulations results the system can provide a good estimate of organic content in samples in about 1 hour of running in contrast to current BOD methods that need 5 days for results. In addition the microfabrication techniques permits to develop an on-site analysis device. This can be important for several purposes, as is to control and monitor wastewater treatments on semi-continuous basis.

Reference

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Figures used in the abstract

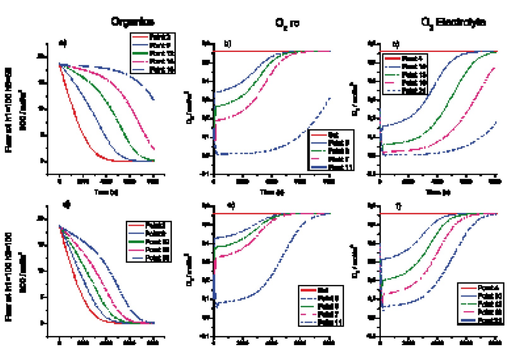

Figure 1: Transient concentration profiles of the simulations. (a and d) Consumption of organics (Glu) at several points of the reaction channel. (b and e) Oxygen concentration at different points in the reaction channel. (c and f) Oxygen concentration at the electrolyte channel, where it can be electrochemically measured. Difference between upper and bottom graphics is the height of the cannels (see y-axis).

Figure 1: Simulation results for different channel heights (50 and 100 microns).

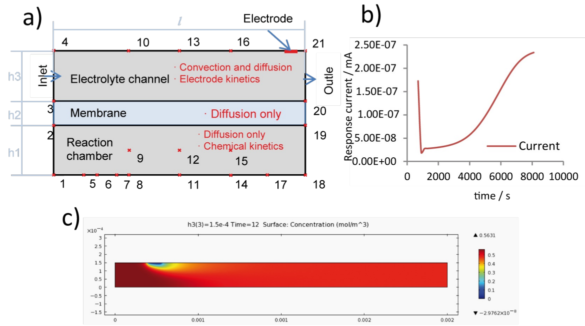

Figure 2: a) Schematic representation of the model. Subdomains, boundaries and modules used are shown. b) Expected electrical signal over time from the electrode. c) Picture of the oxygen consumption at the electrode during the electrochemical analysis.

Figure 2: Model schematic.