SIMULTANEOUSLY DISSOLVED OXYGEN AND PH CONTINUOUS MONITORING THROUGH BIOFILMS USING MINIMALLY INVASIVE MICROSENSOR

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INTRODUCTION

The technical limitations found in the study and monitoring of biofilms have been solved from the design and development of a wide range of microsensors. However, available microsensors showed important limitations that have hindered a widespread use for biofiltration systems monitoring. Microelectromechanical systems (MEMS) technology have been used to improve microsensors design and fabrication, allowing specific design for particular applications, even biofilms monitoring. A novel microsensor has been developed based on MEMS technology: This microsensor, specially designed for biofilms profiling enables simultaneous biofilm monitoring along time at different biofilm locations. The aim of this work is to show the capabilities of these microsensors for biofiltration process monitoring, obtaining continuous microgradients of both species within biofilms.

MICROSENSOR DEVELOPMENT

The microsensor is based on a first prototype, based on oxygen amperometric principle and designed to obtain dissolved oxygen (DO) concentration profiles of 1 mm depth via single measurement (Moya et al., 2015). The novel prototype (Fig. 1) was modified to simultaneously monitor DO concentration and pH. This device also include several technological modifications to improve microsensor performance.

Sensor response characterization: Experimental sensitivities were quantified at 2.06±0.08 nA mg⁻¹ L⁻¹ for DO detection, and 61.2±0.7 mV pH⁻¹ for pH detection.

Besides, pH and protective membrane ensures a stable response along time (Tab 2), allowing long term measurements. Microsensor performance for biofilm monitoring was validated against commercial microsensors (Fig 3).

RESULTS AND DISCUSSION

Firstly, the developed microsensor was employed in internal mass transport characterization through aerobic biofilms. Diffusivity (D) measurements from oxygen profiles recorded by DO-MEA microsensor were conducted through an aerobic heterotrophic biofilm growth in a flat plate bioreactor (FPB). Mass transport was studied as function of biofilm structure along the reactor. For this purpose a density profile (A0), ranging from 10 to 60 gVSS L⁻¹, was obtained along the biofilm, by varying the environmental conditions such as substrate load and liquid velocity.

The mass transport was described using a non-steady state diffusion model (Fick’s second law)

\[ \frac{dC}{dt} = D \frac{d^2C}{dx^2} \]

Diffusivity inside biofilms is usually presented as relative diffusion relating solute diffusivity within biofilm with the solute molecular diffusivity in water

\[ D = \frac{D_0}{D_m} \]

The simultaneous oxygen and pH profiles were used to estimate biofilm diffusivities measured at different biomass densities (Fig 4).

BIOFILM MONITORING

The novel microsensor, based on MEMS technology, was validated for DO and pH continuous monitoring within a sulphide-oxidizing biofilm, grown on a gas phase biofilm reactor. During biofilm monitoring, gas phase residence time was reduced from 60 s to 6 s, corresponding to a load increase from 6 g m⁻³ h⁻¹ to 60 g m⁻³ h⁻¹. The seven Au-disk electrodes were used to record DO evolution along time. Due to acquisition system technical limitations, pH could not be monitored continuously, and using IrOx coated Pt electrodes, complete pH profiles were acquired and after each load increase.

The multi-electrode design of the novel MEMS microsensor has simplified experimental procedure required for biofilm profiling, obtaining a 7-point DO and pH profile in a single measurement. Technological modifications have improved the microsensor performance, allowing continuous monitoring of biofilm systems. Internal mass transport has been exhaustively characterized, defining the relationship between diffusion rate and biofilm structure. These results improved mass transport monitoring information and description. Besides, this device allow continuous monitoring of biofilm biomass, opening the possibility of advancing both in the study and control of biofilms operation.

CONCLUSIONS

The technical limitations found in the study and monitoring of biofilms have been solved from the design and development of a wide range of microsensors. However, available microsensors showed important limitations that have hindered a widespread use for biofiltration systems monitoring. Microelectromechanical systems (MEMS) technology have been used to improve microsensors design and fabrication, allowing specific design for particular applications, even biofilms monitoring. A novel microsensor has been developed based on MEMS technology: This microsensor, specially designed for biofilms profiling enables simultaneous biofilm monitoring along time at different biofilm locations. The aim of this work is to show the capabilities of these microsensors for biofiltration process monitoring, obtaining continuous microgradients of both species within biofilms.

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