**Experimental Characterization and Mathematical Modelling of Miniature Microbial Fuel Cells with Three-dimensional Anodes**

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**Highlights**

* Three miniature microbial fuel cells with 3D anode are proposed
* The cells are characterized for hydrodynamics and mass transfer
* The performances of the cells for bioelectricity generation are assessed
* A versatile mathematical model of the system has been implemented

**1. Introduction**

Bioelectrochemical systems, such as MFCs exploit the direct transfer of electrons during oxidation of organic compounds by electroactive microorganisms. Very low values of current density are usually obtained with such devices, so that anodes with high specific surface should be used to increase the electricity generation. Carbon felt, and other carbon-based 3D materials with high surface per unit of volume are largely adopted as anodes in MFCs, although may show significant lack in efficiency due to mass transfer limitations, concentration gradients, velocity distribution and resistivity of the material. [1,2]. Several factors should be then considered in a suitable design of the MFCs with 3D anode.

In this work, the effect of aspect ratio and hydrodynamics on the performance of miniature MFCs with carbon felt anodes was studied. The cells were experimentally characterized for hydrodynamics and mass transfer, as well as for bioelectrochemical activity towards oxidation of acetate.

A mathematical model of the cells was then used to quantify the effect of operative parameters on the bioelectrochemical processes under steady state conditions.

**2. Methods**

Air-cathode single-cell MFCs were used: the anode compartments have a cross section of 5X5 mm and lengths from 30 to 50 mm. The cells operate in flow-through single-pass mode. Hydrodynamics of the anode compartments was characterized with pulse-response experiments with inert tracer, the mass transfer was characterized by limiting current densities with the standard redox ferricyanide/ferrocyanide couple. The enrichment of electroactive biofilm was performed by feeding the fuel cells with anaerobic sludge, after enrichment the cells were fed with a synthetic waste water [2].

All the electrochemical tests were performed with a potentiostat-galvanostat (Autolab).

A mathematical model was implemented, which combines fluid flow (Navier-Stokes equations for incompressible fluids in free and porous media), kinetics of electrochemical and bioelectrochemical reactions, chemical equilibria and Ohm's law with conservation of current.

**3. Results and discussion**

Pulse-response curves show that the system is under non-ideal flow conditions and behave as a plug-flow reactor with axial dispersion.

The steady-state current response with different organic load in the feed stream and inlet flow rates was tested: the curves obtained show a Monod-type behavior, substrate inhibition was also observed, depending on length of the anode and organic load.

Polarisation tests show the presence of significant mass transfer limitations, mainly with low concentration of acetate in the feed.

The model solution provided distribution of velocity, current and potential, and concentration of substrate within the anode chamber. The predicted flow is laminar, as it was expected with the low flow rates used. The concentration profiles show the consumption within the porous anode: depending on organic load in the feed stream, low concentrations of substrate were predicted, which can lead to local starvation. The mass transfer limitations observed from the polarisation studies can be related mainly to concentration gradients in axial direction.

**4. Conclusions**

The effect of design and operative parameters in the performance of flow-through microbial fuel cells with three-dimensional anodes was investigated. A mathematical model was implemented, which was used to understand and predict the effect of flow rate and organic load of the inlet flow on conversion, potential distribution and electricity production of the cell.

**References**

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