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Electrode and membrane materials; Reactor design, scale-up, and peripherals
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Air-breathing cathodes for microbial fuel cells based on activated carbon cloth and spin-coated PDMS membranes as hydrophobic diffusion layer

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Summary of key findings

We present an easy to implement air-breathing cathode for microbial fuel cells, based on activated carbon cloth equipped with spin-coated PDMS (polydimethylsiloxane) membranes as hydrophobic diffusion layer. Operated as air-breathing cathode in neutral carbonate buffer, the novel activated carbon cloth shows a superior performance compared to commercial platinum or manganese oxide catalysts operated under the same conditions.

Background and relevance

Air-breathing cathodes are of great relevance for the practical application of microbial fuel cells. Compared to immersed cathodes they enable higher current densities before oxygen mass-transfer becomes limiting, and do not require energy intensive active aeration of the catholyte solution. However, their development faces two main challenges: Firstly, the leakage of electrolyte across the cathodes' air-liquid interface can lead to the formation of salt crusts which effectively block oxygen from reaching the catalytically active sites (Fig. 1A). Secondly, less costly catalyst materials for oxygen reduction are required to replace the expensive platinum in practical application.
In literature, several approaches to form the air-liquid interphase are reported. For instance, water-tight and oxygen permeable membranes (e.g. made from Gore-Tex) are placed in front of the cathode to prevent leakage. Alternatively, diffusion layers from hydrophobic materials such as PTFE and PDMS are manually painted on the air side of the cathode structure (Luo et al., 2011). On this account we present the application of spin-coated PDMS membranes as hydrophobic diffusion layer for air-breathing cathodes. The spin-coating process enables the facile and precise fabrication of pinhole-free membranes with controlled thickness. It is thus ideal for the development of cathodes with optimized oxygen transport characteristics. In terms of electrode materials, we introduce a commercially available activated carbon cloth (C-Tex 13, MAST Carbon, UK) as novel cathode structure. Its performance is compared to a conventional platinum catalyst (GDE Freudenberg H2315 I2C6 for DMFC, QuinTech, Germany) as well as a commercial air-breathing cathode based on a manganese oxide catalyst with a laminated hydrophobic PTFE membrane (MOC PTFE, Gaskatel, Germany).

Results

As shown in Fig. 1 B, the application of a 50 µm thin spin-coated PDMS membrane effectively prevents the leakage of electrolyte and the associated salt crust formation.

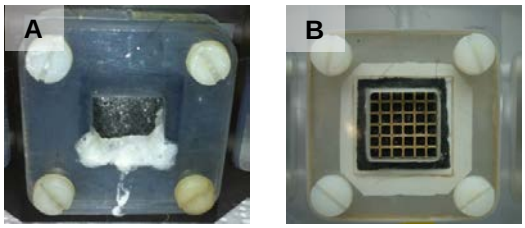

Figure 1. A) Picture of a commercial platinum cathode after 3 weeks of operation in carbonate buffer. Despite coating of the backside with a cation-exchange polymer electrolyte leakage and salt crust formation occurs at the electrolyte-air interface. B) Image of the activated carbon cloth cathode with a 50 µm spin-coated PDMS layer that effectively prevents electrolyte leakage.

Furthermore, when applied as hydrophobic diffusion layer it enables sufficient oxygen transfer within the investigated current density range of up to 350 µA/cm² (Fig. 2). In terms of oxygen reduction performance the novel activated carbon cloth outperforms the commercial platinum electrode equipped with the same 50 µm thick PDMS layer. At a current density of 300 µA/cm² the activated carbon cloth electrodes show a potential of 72 ± 7 mV vs. SCE, compared to -6 ± 6 mV vs. SCE in the case of a platinum catalyst. In comparison, the commercial manganese oxide cathode with a laminated PTFE membrane shows the lowest performance with a significantly lower open circuit potential.

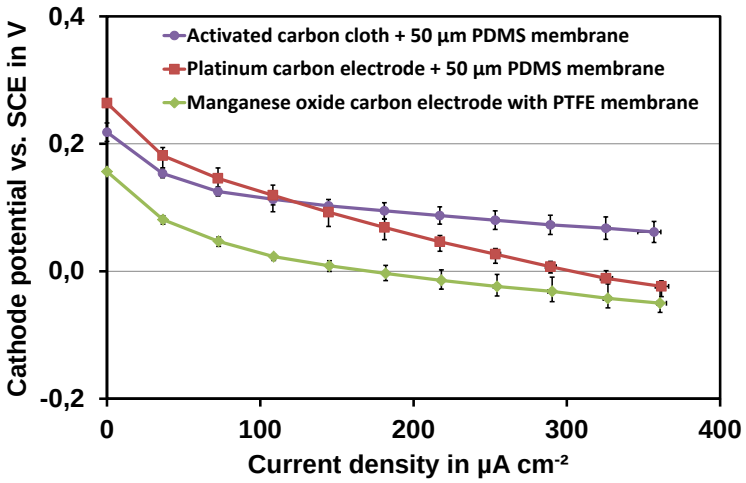

Figure 2. Polarization curves of activated carbon cloth with a spin-coated 50 µm PDMS membrane, a commercial platinum electrode with a spin-coated 50 µm PDMS membrane and a commercial manganese oxide electrode with a laminated PTFE layer, tested as air-breathing cathodes in carbonate buffer. Each data point depicts the mean value of at least 3 measurements. Bars show minimum and maximum values.

Discussion

In air-breathing cathode configuration the activated carbon cloth shows better oxygen reduction performance than commercial platinum and manganese oxide catalysts. Compared to the conventional approach, where carbon is formed into an electrode with the help of polymer binders and manually coated with hydrophobic diffusion layers (Zhang et al., 2010), our concept also significantly facilitates the fabrication of air-breathing cathodes. As we observed no mass-transfer limitation within the investigated current density range, our future work will focus on the optimization of the PDMS membrane towards maximized oxygen supply at higher current densities. In this context, the spin-coating process is advantageous since it enables the precise control of the membrane thickness.

References

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