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A comparison of dynamic and static polarization for the characterization of anode performance in microbial fuel cells

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Summary of key findings

In our contribution we show that the choice of characterization method and time-frame can have a significant influence on the observed performance of microbial fuel cell anodes. Anode polarization curves recorded with a galvanodynamic current sweep (7.3 nA/s) after a galvanostatic growth period showed much better performance for activated carbon cloth (**124µA/cm^2** at -0.2 V vs. SCE) compared to graphite felt (**3µA/cm^2** at -0.2 V. vs. SCE). Changing the method and constantly polarizing the anodes at -0.2 V vs. SCE lead to similar performance for both materials, with increased current densities above **200µA/cm^2**.

Background and relevance

An established technique to determine and compare the performance of microbial fuel cell anodes is the recording of polarization curves using dynamic electrochemical methods (Logan, 2012). Such polarization curves give insight into loss mechanisms, and enable the identification of performance-limiting factors. Commonly, comparatively fast methods such as linear sweep voltammetry, galvanodynamic current sweeps, or the sequential change of external load resistance are employed. These enable the recording of a polarization curve within relatively short time-frames, ranging from hours to days. Another possibility to assess electrode performance is the potentiostatic electrode polarization at a constant potential while monitoring the corresponding current response. This technique has the advantage that reliable steady-state performance data can be obtained. However, it comes at the expense that only a single operation point is characterized. This does not necessarily correspond to the optimal operation point in terms of overall fuel cell performance, in particular when considering that increasing anode polarization (more positive potential) can actually lead to lower current densities (Torres et al., 2009). In our work we thus compare both techniques, investigating two different anode materials in the same experimental setup.

Results

Two different microbial fuel cell anode materials (graphite felt and activated carbon cloth) were operated as half-cells, inoculated with activated sludge and sludge from an anaerobic digester at a ratio of 1:4. The anode chambers were continuously fed with sterile carbonate-buffered medium (pH = 7.2) containing acetate (10 mM) and lactate (20 mM) at a hydraulic retention time (HRT) of 24h. The anode chambers were separated with a PEM from the counter electrodes. A saturated calomel reference electrode (SCE) was placed near the anode to allow recording and controlling of the potential. Initially, a constant current of 222nA/cm^2 was applied until the anodes reached a steady potential at -0.5 V vs. SCE. Subsequently, a galvanodynamic polarization curve with a sweep rate of **7.3 nA/s** was recorded, followed by potentiostatic polarization of the anodes at **-0.2 V vs. SCE** for a period of 10 days. The potential response of the current sweep corresponded to sweep rates between 0.02 mVs^{-1} and 0.7 mVs^{-1}.

In Fig. 1 the galvanodynamically recorded polarization curves of the graphite felt and the activated carbon cloth anode are shown and compared in terms of their current density at -0.2 V vs. SCE. As can be seen, the activated carbon cloth exhibits a significantly better performance, yielding a current density of **124µA/cm²**, compared to only **3µA/cm²** observed with graphite felt. Since the nano-porous activated carbon cloth exhibits a much higher specific surface area than graphite felt, we also corrected its polarization curve for the contribution of electrode double layer capacity, as described elsewhere (Hamann et al., 2007). As can be seen, the remaining faradaic current density that can be attributed to microbial activity decreases by approx. 45% to only **68 µA/cm² at -0.2 V vs. SCE**. Nevertheless, even when accounting for its high double-layer capacity the activated carbon cloth performs better than graphite felt in this experiment. In contrast, the subsequent potentiostatic experiment at **-0.2 V vs. SCE** yields a different picture (Figure 2). Here the current density of both electrodes increases to noticeably higher values in the range of **200 µA/cm²** over the course of approx. 5 days. Remarkably, now both electrode materials exhibit similar current densities. The fact that the activated carbon cloth anode shows higher current densities in the galvanodynamic experiment and during the beginning of potentiostatic polarization suggests that a biofilm develops faster on this material. Eventually, both materials perform comparably well as anode material.

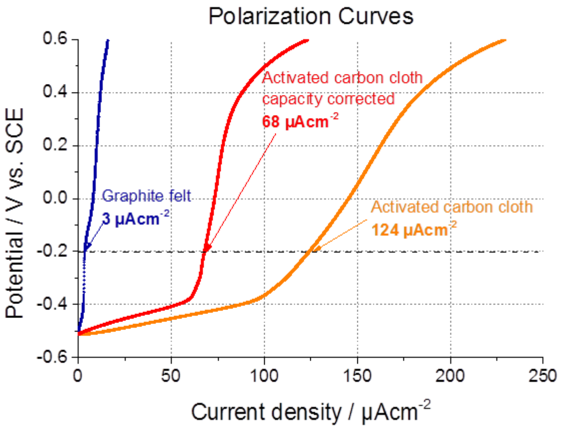

Figure 2: Current sweep at a scan rate of 7.3 nA/s after a galvanostatic growth period at 222 nA/cm². For the activated carbon cloth the capacity was calculated and substracted from original polarization curve

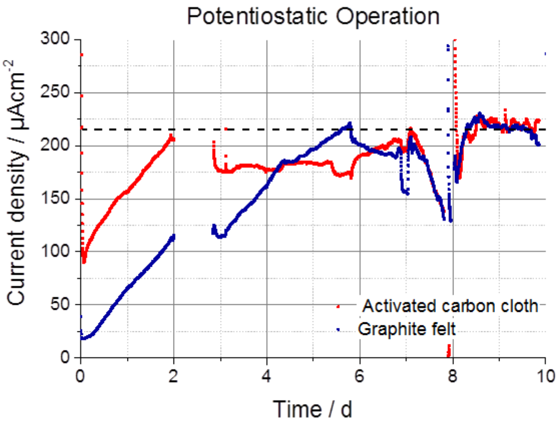

Figure 1: Potentiostatic operation of activated carbon cloth and graphite felt at -0.2 V vs. SCE

Discussion

In conclusion, our experiments demonstrate that great care has to be taken when recording polarization curves to benchmark anode materials for microbial fuel cells. On one side, the electrode biofilm requires time to develop and sustain a stable bioelectric current – dynamic electrochemical methods can thus result in a dramatic underestimation of electrode performance compared to steady-state polarization. On the other hand, the large double-layer capacitance of electrode materials with high specific surface area can lead to comparably high non-faradaic currents – consequently, the performance of such electrode materials may be significantly overestimated.

References

Hamann, C. H., Hamnett, A., Vielstich, W. (2007) Electrochemistry, Wiley-VCH, Weinheim.

Logan, B. E. (2012) Essential Data and Techniques for Conducting Microbial Fuel Cell and other Types of Bioelectrochemical System Experiments, *Chemsuschem,* 5 (6), 988-994

Torres, C. (2009) Selecting Anode-Respiring Bacteria Based on Anode Potential: Phylogenetic, Electrochemical, and Microscopic Characterization, *Environmental Science & Technology,* 43 (24), 9519-9524