Anode surface modification with activated carbon for improved power generation in urine fed Microbial Fuel Cells

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Microbial Fuel Cells (MFCs) utilise organic feedstocks such as urine as fuel for direct electricity production, by employing anode respiring microbes that convert organic matter into electrons while treating waste. One possible approach to bring this technology into real-world applications, is the multiplication of units connected together as modules (stacks) for usable power levels. The main challenge is therefore to improve the power output of a single MFC, using affordable and simple in preparation materials, which can then be multiplied in a stack. Anode electrode composition and surface morphology are key elements in improving performance and reducing costs, since the electron transfer rate from bacteria towards the electrode surface is one of the critical limiting factors. So far, carbon fibre veil has been successfully used as an anode electrode in numerous practical demonstrations. This work aims to explore simple and inexpensive modifications of this substratum with the addition of microporous activated carbon powder to produce a three-dimensional (3D) structure in order to improve the output of a single MFC unit as a building block for a modular stack.

Materials and Methods. Twelve small-scale terracotta cylinders were constructed as MFCs with an internal cathode and external anode and tested in four experimental groups. Anodes were prepared by coating a sheet of carbon veil with activated carbon slurry and heat treated. The resultant microporous material was wrapped around the cylinder and tested in two configurations: wrapped (M-CV) and continuously incised (MF-CV) with slits evenly spaced to open the available electrode sites for biofilm growth; this resembles a ‘fluffy’ 3D structure. To compare with the control, an unmodified carbon veil was tested both as wrapped (CV) and continuously incised (F-CV) anode. Each reactor was inoculated with a mixture of activated sludge and fresh human urine and following maturation, fed with neat urine in batch mode.

Results. The MF-MFC produced a maximum power of 3.2 mW and M-CV 2.0 mW, under a polarisation run, after just 12 days of operation; this is 2.6 and 0.8 times respectively better than the control CV and F-CV, which both produced 1.2 mW. The higher performance of the treated and incised anode (MF-CV) may be due to a higher active surface area and efficient extracellular electron transfer between the anodic biofilm and the constructed microporous electrode. Linear Sweep Voltammetry (LSV) showed that both treated anodes: M-CV and MF-CV achieved up to 10 times higher anodic current at -0.1V than the respective controls, indicating that the microporous modification enhanced the bio-electroactivity of the anode system that improved biofilm formation.

Conclusions. With an ease of scale-up, preparation simplicity and high performance, the activated microporous anode could well serve as an effective and affordable MFC anodes for large applications.