

## A Miniature Membrane-less Biofuel Cell Operating Under Physiological Conditions

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We report a miniature biofuel cell operating under physiological conditions (20 mM phosphate, pH 7.4, 0.15 M chloride) at a power density of  $244 \mu\text{W}\cdot\text{cm}^{-2}$  at 0.36V (37°C) (Figure 1). Unlike earlier cells operating under physiological conditions, the cell operates without a membrane separating its anode and cathode compartments. The cell is 180 times smaller than earlier reported biofuel cells operating under physiological conditions while its power density exceeds eight-fold that of the highest reported. (1,2).

In 2001 Chen et al (3) reported a miniature compartment less biofuel cell consisting of two  $7\mu\text{m}$  diameter 2 cm long carbon fibers in which glucose was electrooxidized to gluconolactone at the anode and dissolved  $\text{O}_2$  was electroreduced to water at the cathode. At 37°C the cell delivered  $0.6\mu\text{W}$  at 0.4 V, enough to power the slower and least power consuming CMOS circuits. (4) Under physiological conditions (20 mM phosphate, pH 7.4, 0.15 mM NaCl, 37°C) the cathode, based on the “wiring” of laccase, was inhibited by chloride and  $\text{OH}^-$ , losing 99% of its output at neutral pH. (5) To overcome this problem, we recently developed a carbon cloth cathode allowing the electroreduction of  $\text{O}_2$  to water under physiological conditions at a current density of  $5 \text{ mA}\cdot\text{cm}^{-2}$  and at a potential only 0.18V reducing versus that of the reversible  $\text{O}_2/\text{H}_2\text{O}$  electrode at pH 7.4.(6) The electrocatalyst of this cathode is the crosslinked electrostatic adduct of bilirubin oxidase from *Myrothecium verrucaria*, a polyanion at  $\text{pH}>4.1$ , and the polycationic redox polymer of poly (vinyl pyridine) complexed with  $[\text{Os} (4,4'\text{-dimethoxy-2,2'-bipyridine})_2\text{Cl}]^{+2+}$ . As seen in Figure 2 this electrocatalyst is not inhibited by chloride. The biofuel cell based on it operates for a week.

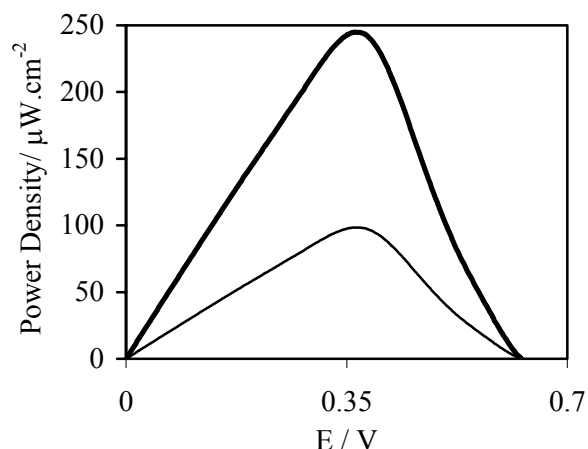
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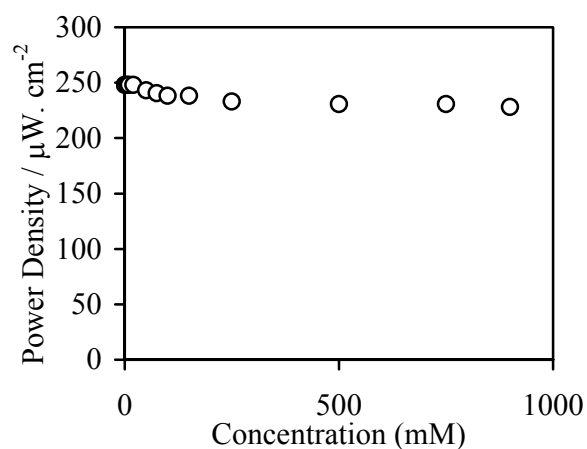
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**Figure 1.** Dependence of the power density on the cell voltage. Quiescent solution under air, 20 mM phosphate buffer, 0.15M NaCl, 15 mM glucose. Fine line 23° C, heavy line 37.5°C.



**Figure 2.** Dependence of the power density of the cell operating at 0.36 V on the chloride concentration. Quiescent solution under air, 37.5 °C, 20 mM phosphate buffer, 15 mM glucose.