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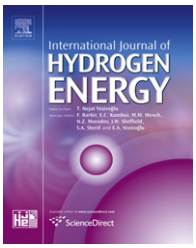

Reduced internal resistance of microbial electrolysis cell (MEC) as factors of configuration and stuffing with granular activated carbon

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ABSTRACT

With limited external applied voltage, the microbial electrolysis cell (MEC) could produce hydrogen by exoelectrogenic microorganisms. The present study revealed that a cubiod-shaped chamber effectively reduces the distance between electrodes and thereby reduces the internal resistance of the entire cell. With 0.6 V of applied voltage, the cuboid MEC had a columbic efficiency of 33.7%, much higher than that achieved in the H-shaped MEC test (ca. 15%) of comparable size. Filling the anode chamber with granular activated carbon further enhanced the columbic efficiency to 45%. The corresponding hydrogen conversion rate could reach 35%.

1. Introduction

Microbial electrolysis cell (MEC) is a device for bio-hydrogen production with exoelectrogenic microorganisms [1,2] under finite external voltage to overcome the Gibbs free energy barrier [3]. The lab-scale MEC could convert biomass to hydrogen at high efficiency [4–6]. Internal resistance of cell limits the efficiency of MEC. Jang et al. [7] noted that an MEC of size 7 L had an internal resistance of 3.9 MΩ. Rozendal et al. [6] reported resistance and leakage problem that deteriorated the efficiency of their 3.3 L MEC. Optimization of cell configuration and prevention of produced electron loss enhance the performance of MEC [8–12]. Modifying electrode materials and chamber/membrane configuration promotes efficiency of MEC [4,13–18]. Call and Logan [4] and Cheng and Logan [5] adopted MEC of size of only 14 mL and 28 mL, respectively, to minimize internal resistance. However, such small-sized MEC could have little practical interest.

During the past two decades there were fewer and limited studies on MEC compared to the progress on microbial fuel cell (MFC) on improving power densities and Coulombic efficiencies [8,19,20]. The maximum level of power density and Coulombic efficiency has been up to 10,000 mW m^{-2} [29] and 90% respectively. However, thus perfect effects were always achieved on the trend of reduced-volume or low volumetric loading [30]. Based on all improvements, there are still huge problems on how to scale up without a large cost of Coulombic efficiency. The key factors controlling power output were reported on reactor configuration related including electron transfer in anode biofilm, electrode surface

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area and the resistance between electrodes. Those limiting factors need much more understanding and questing on the way to practical and economical requires.

To the authors' best knowledge, no study has proved that the reduced electrode distance enhances the efficiency of medium-to-large-sized MEC. This work tested a cuboid-shaped MEC at reduced electrode distance for minimizing the internal resistance of MEC. A synthetic municipal wastewater was used as the substrate.

2. Materials and methods

2.1. Reactor and materials

A two-chamber MEC with working volume in each chamber of 0.34 L was proposed (Fig. 1). The reactor was made of polymethylmethacrylic of 5-mm thickness, with the anode and cathode chambers separated by a proton exchange membrane (25.2 cm^2, Nafion® 117, DuPont, USA). Plain carbon cloth (without wet proofing; E-Tek Div, PEMEAS, USA) was used as the anode and carbon paper with 0.35 mg cm^{-2} Pt catalyst (E-Tek DIV, PEMEAS, USA) was the cathode. The chambers were in a cuboid shape to reduce electrode distance from 14 cm adopted in the H-shaped reactor [11] to 4 cm. Three quarters of anode chamber was filled with plain granular activated carbon (diameter of 4 mm, specific area 500–900 $m^2 g^{-1}$ and packing density 0.45–0.55 g cm^{-3}) to reduce local resistance and anode potential. The graphite rod of diameter 2 mm connected electrode and circuit to avoid electrochemical reactions of connecting wires. An Ag/AgCl reference electrode (+0.2 V *versus* NHE) was used to measure the electrode potentials in two chambers.

2.2. Reactor startup

Activated sludge collected from the aeration tank in a municipal wastewater treatment plant in Harbin, China was fed into the anode chamber with granular activated carbon. The reactor was started up for a period of two weeks with synthetic feed of the following composition (per L, pH 6.9): KCl 0.2 g; NH_4Cl 0.4 g; $NaH_2PO_4 \cdot 2H_2O$ 0.6 g; $NaC_2H_3O_2$ 1.0 g; NaCl 2.0 g; Wolfe's vitamin solution 10 mL; and Wolfe's mineral solution 10 mL [ATCC medium]. The hydraulic retention time (HRT) was maintained at 24 h. The medium was not autoclaved before feeding. The phosphate buffer solution (PBS, 50 mM at pH 7.0) was used in the cathode chamber. All experiments were carried out at 25 °C.

2.3. Testing and data processing

After successful startup the same feed stated in Section 2.2 was fed into the anode chamber and the PBS (pH 7.0) was fed into the cathode chamber in batch mode. At the end of one cycle the anode solution was completely discharged. After the chamber was sparged with nitrogen for 20 min, fresh substrate was pumped into the anode chamber for another cycle. The hydrogen yield was calculated in each batch cycle at 0.6 V.

The concentrations of acetate in the collected samples were determined using an ionic chromatograph (Dionex 4500i, USA). The hydrogen in the cathode headspace was

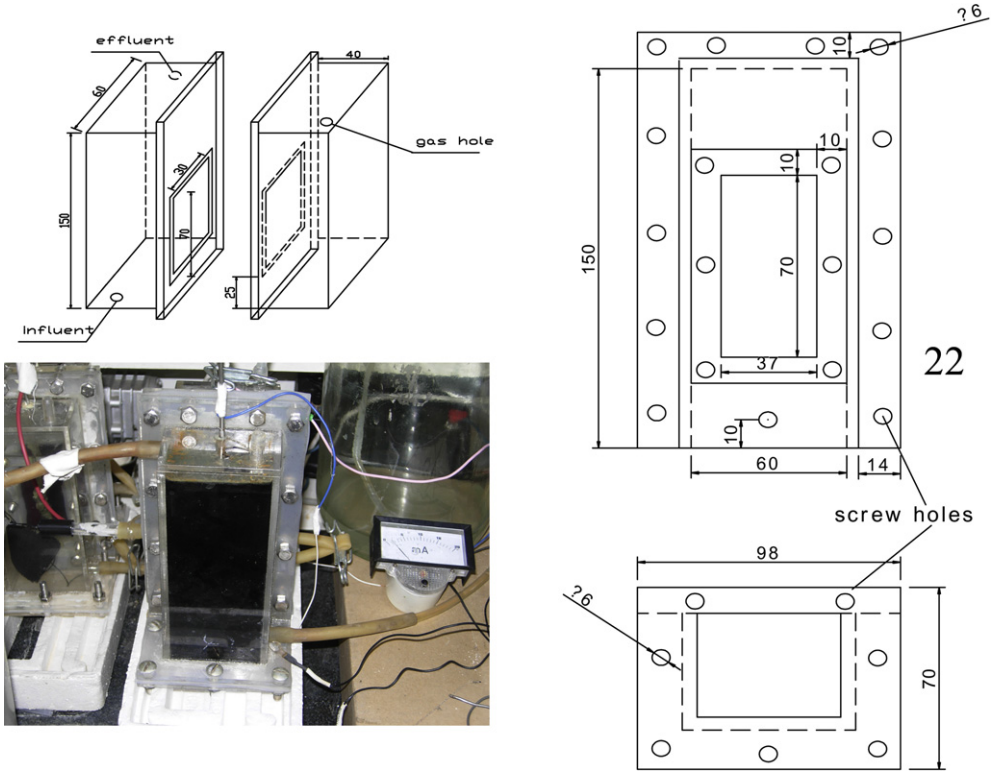

Fig. 1 – Schematic of the cuboid MEC filled with activated carbon granules (unit: mm).