Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

Resilience of roof-top Plant-Microbial Fuel Cells during Dutch winter

Marjolein Helder [a], *David P.B.T.B. Strik* [a,*], *Ruud A. Timmers* [a], *Sanne M.T. Raes* [a], *Hubertus V.M. Hamelers* [b,1], *Cees J.N. Buisman* [a,b,1]

[a] *Wageningen University, Sub-department of Environmental Technology, Bornse Weilanden 9, 6708 WG Wageningen, PO Box 17, 6700 AA Wageningen, The Netherlands*

[b] *Wetsus, Centre of Excellence for sustainable water technology, Agora 1, Leeuwarden, The Netherlands*

ARTICLE INFO

Article history:
Received 29 April 2012
Received in revised form
5 October 2012
Accepted 10 October 2012
Available online 13 February 2013

Keywords:
Plant-Microbial Fuel Cell
Sustainable electricity
Spartina anglica
Temperature
Natural conditions

ABSTRACT

The Plant-Microbial Fuel Cell (P-MFC) is in theory a technology that could produce sustainable electricity continuously. We operated two designs of the P-MFC under natural roof-top conditions in the Netherlands for 221 days, including winter, to test its resilience. Current and power densities are not stable under outdoor conditions. Highest obtained power density was 88 mW m^{-2}, which is lower than was achieved under lab-conditions (440 mW m^{-2}). Cathode potential was in our case dependent on solar radiation, due to algae growth, making the power output dependent on a diurnal cycle. The anode potential of the P-MFC is influenced by temperature, leading to a decrease in electricity production during low temperature periods and no electricity production during frost periods. Due to freezing of the roots, plants did not survive winter and therefore did not regrow in spring. In order to make a sustainable, stable and weather independent electricity production system of the P-MFC attention should be paid to improving cathode stability and cold insulation of anode and cathode. Only when power output of the Plant-Microbial Fuel Cell can be increased under outdoor conditions and plant-vitality can be sustained over winter, it can be a promising sustainable electricity technology for the future.

1. Introduction

The Plant-Microbial Fuel Cell (P-MFC) is in theory a technology that could produce sustainable electricity continuously [1]. In a P-MFC plants provide organic matter to microbes at their roots in the form of rhizodeposits. Rhizodeposits consist of excretions, secretions, dead plant material and gases [1,2]. So-called electrochemically active microbes around the plant-roots break down the organic matter and donate their electrons to the anode of a Microbial Fuel Cell, thus producing electricity. The technology is solar powered, via plant photosynthesis, but not dependent on direct sunlight, since organic matter excretion by the plant continues day and night, although a diurnal pattern sometimes can be observed [2]. The P-MFC has been first reported in 2008 [1,3,4]. Since then, several experiments with the system have been performed [5] but except from the experiment by Kaku et al. [4] no experiments were performed under natural outside conditions. The experiment of Kaku et al. was performed in a sediment-type system, in which organic matter is present in the sediment

* *Corresponding author*. Tel.: +31 (0)317 483228.
E-mail addresses: marjolein.helder@wur.nl (M. Helder), david.strik@wur.nl (D.P.B.T.B. Strik), bert.hamelers@wetsus.nl (H.V.M. Hamelers).
[1] Tel.: +31 (0)582843000.

0961-9534/$ – see front matter
http://dx.doi.org/10.1016/j.biombioe.2012.10.011

as well, apart from the plant [4]. No other experiments with a P-MFC without added organic matter were performed under outdoor conditions. To develop the P-MFC into a sustainable renewable energy technology, the technology should be operable stably under natural conditions, preferably weather independent.

We operated two designs of the P-MFC at natural roof-top conditions in the Netherlands for 221 days, including winter, to test the resilience of the P-MFC under outdoor conditions.

2. Materials and methods

Two designs for the P-MFC were placed on a roof-top in Wageningen, the Netherlands (51°97′N, 5°68′E) (Fig. 1). Of each design six set-ups were built. Design 1 (P-MFC 1–6) consisted of a PVC cylinder (diameter 125 mm, height 300 mm), which functioned as the anode-compartment, filled with 2 L of graphite granules (diameter: 1–2 mm; Le Carbone, UK). Current collectors were gold-wires attached to a copper wire and were located 2 cm above the bottom of the cylinder. An open plastic matrix was placed on top of the graphite granules to function as a spacer. The cathode-felt (Grade WDF, 6 mm, National Specialty Products Carbon and Graphite Felt, Taiwan) was placed on top of the spacer. Gold-wire with a copper wire attached to it was woven through the felt to function as current collector. Design 2 (P-MFC 7–12) consisted of the same cylinder as design 1 but with a membrane (heterogeneous cation exchange membrane, Zhejiang Qianqiu Group, Zheijang, China) at the bottom. The six cylinders were placed on a cathode that consisted of graphite felt of 17 × 17 cm. All cathodes were placed in a box that was filled with water. All cathodes were connected to their corresponding anode over an external load of 900 Ω. Of P-MFC 1, 2, and 6 the external load was reduced to 500 Ω at day 38. Each set-up contained one plant of *Spartina anglica*. Plants were off-shoot of the ones used by Timmers et al. [6] Plant weight was between 61 and 242 g

Table 1 – Plant weight and length of *Spartina anglica* plants in each P-MFC at the start of the experiment.

P-MFC	Plant weight (g)	Plant stem and leaf-length (cm)
1	153	449
2	188	456
3	195	214
4	147	334
5	242	380
6	176	452
7	130	218
8	104	254
9	80	278
10	209	374
11	127	212
12	61	189

and total added stem-length was 189–456 cm (overview of weights and lengths in Table 1). The plants were fed with one plant-feed cone each (Pokon voedingskegels, Veenendaal, The Netherlands) at the start of the experiment (composition in Table 2). During the experiment plants were fed with rainwater during rainfall. Plants were manually fed with rainwater to avoid drought in the P-MFCs once (on day 30). At 5 cm under the top, holes were drilled in the cylinder to control water level and keep cathodes of design 1 open to air at all times. The experiment ran for 8 months, from August 2009 through March 2010.

Measurements of cell potential, anode potential and cathode potential were logged every minute with Fieldpoint (Module S, National Instruments) and corresponding LabView measurement software (National Instruments Software). Of all P-MFCs cell potential was measured every minute. Of P-MFC 1, 4, 7, and 10 anode potential and cathode potential were measured against Ag/AgCl reference electrodes (3 mol L^{-1} KCl, +205 mV versus standard hydrogen electrode, ProSense Qis). Plastic tubes with a glass capillary attached to the end filled with 3 mol L^{-1} KCl were used as an extension of the reference

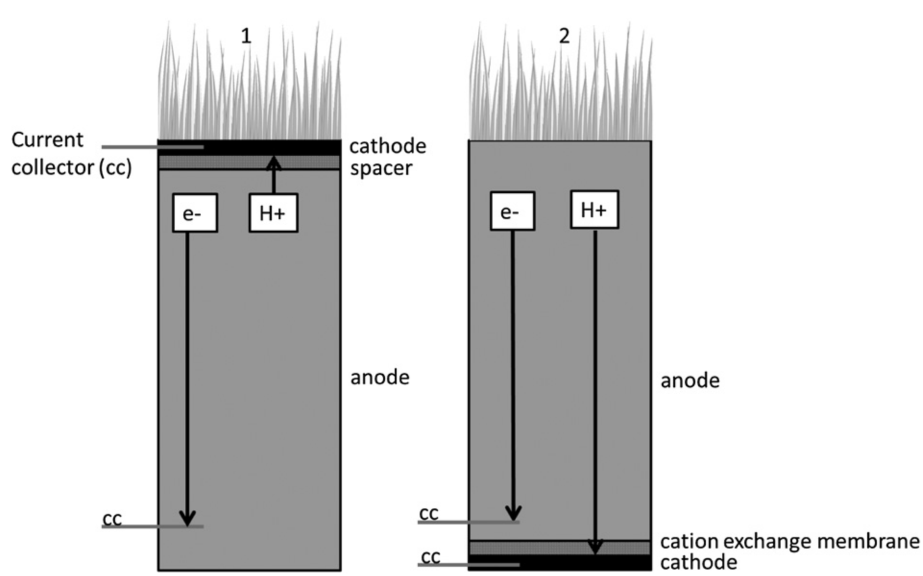

Fig. 1 – Schematic representation of Plant-Microbial Fuel Cells of design 1 (left) and design 2 (right) that were placed on a roof-top in Wageningen, The Netherlands.