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Review

Microbial electrolysis cells turning to be versatile technology: Recent advances and future challenges

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ARTICLE INFO

Article history:
Received 12 December 2013
Received in revised form
11 February 2014
Accepted 16 February 2014
Available online 1 March 2014

Keywords:
Microbial electrolysis cells
Bioelectrochemical systems
Versatile applications
Recalcitrant pollutants removal
Chemical synthesis
Resource recovery

ABSTRACT

Microbial electrolysis cells (MECs) are an electricity-mediated microbial bioelectrochemical technology, which is originally developed for high-efficiency biological hydrogen production from waste streams. Compared to traditional biological technologies, MECs can overcome thermodynamic limitations and achieve high-yield hydrogen production from wide range of organic matters at relatively mild conditions. This approach greatly reduces the electric energy cost for hydrogen production in contrast to direct water electrolysis. In addition to hydrogen production, MECs may also support several energetically unfavorable biological/chemical reactions. This unique advantage of MECs has led to several alternative applications such as chemicals synthesis, recalcitrant pollutants removal, resources recovery, bioelectrochemical research platform and biosensors, which have greatly broaden the application scopes of MECs. MECs are becoming a versatile platform technology and offer a new solution for emerging environmental issues related to waste streams treatment and energy and resource recovery. Different from previous reviews that mainly focus on hydrogen production, this paper provides an up-to-date review of all the new applications of MECs and their resulting performance, current challenges and prospects of future.

Contents

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http://dx.doi.org/10.1016/j.watres.2014.02.031
0043-1354/

1. Introduction

The use of fossil fuels in recent years has accelerated the depletion of non-renewable resources. Furthermore, the unprecedented increase in greenhouse gas emissions due to combustion of fossil fuels causes global warming and climate change. A sustainable and carbon-neutral energy source as alternatives to fossil fuels is highly needed to alleviate the global energy crisis and climate change. Bioenergy technologies which use renewable resources such as wastewater to produce biofuels or valuable chemicals will play a role.

Bioelectrochemical systems (BESs) as a young generation of bioenergy technology possesses a tremendous potential for simultaneous wastewater treatment and electric energy generation or valuable chemicals production (Chaudhuri and Lovley, 2003; Aelterman et al., 2006; Jacobson et al., 2011; Logan et al., 2006; Lovley and P.E, 1988; Zhang and Angelidaki, 2012a, 2013). There are two types of BESs according to the way of using electricity. One is known as microbial fuel cells (MFCs) which produce electricity from organic waste streams, while another is known as microbial electrolysis cells (MECs) which require electricity supply for hydrogen production from organic waste streams (Logan et al., 2006; Kundu et al., 2013). MFCs as one of typical BESs have attracted extensive attentions at the early stage of BESs research (Cheng et al., 2006; He and Mansfeld, 2009; Liu et al., 2005a; Logan, 2005; Rabaey et al., 2005; Zhang et al., 2011). While interesting, researchers are realizing that the economic and environmental value of electricity from MFCs cannot compete with that of other energy sources (e.g., biogas) at this stage. Therefore, a development has been recently initiated to broad the scope of MFCs for more value-added applications, such as hydrogen production by MECs (Fig. 1). The concept of MECs was proposed by two groups almost at the same period (Liu et al., 2005b; Rozendal et al., 2006). This technology was firstly nominated as "electrochemically assisted hydrogen generation", then "biocatalyzed electrolysis", "electrohydrogenesis", and was finally accepted by researchers as "microbial electrolysis cells (MECs)" (Liu et al., 2005b; Cheng and Logan, 2007; Logan et al., 2008; Rozendal et al., 2007; Zhang and Angelidaki, 2012b). MECs have several advantages over other biological hydrogen production processes. Various organic matters such as cellulose, glucose, glycerol, acetic acid, sewage sludge and varied wastewaters can be converted to hydrogen in MECs (Liu et al., 2005b; Cheng and Logan, 2007; Logan et al., 2008; Pant et al., 2012). MECs can even convert the byproducts of dark fermentation (e.g., acetate) into hydrogen with high H_2 yields (e.g., 12 mol-H_2/mol-glucose in theory) (Liu et al., 2005b; Logan et al., 2008). Furthermore, MECs require relatively low energy input (0.2–0.8 V) compared to typical water electrolysis (>2.1 V).

Over the past decade, MECs as a promising platform for H_2 production and alternative applications have drawn much more attention in scientific communities, resulting in rapid advances in the field and extensive journal publications. Fig. 2A shows that the number of publications increased sharply and over 284 articles have been published until January 2013. Furthermore, researchers are distributed in different countries showing that MECs have attracted global attention (Fig. 2B). Similar to the development of MFCs, the

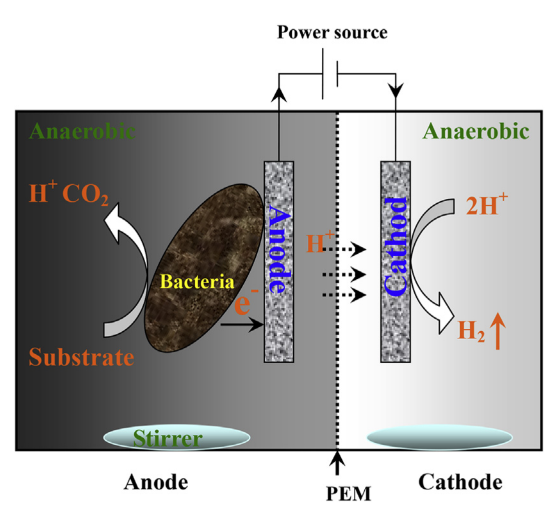

Fig. 1 – Schematic diagram of typical two-chamber MECs for hydrogen production.