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REVIEW

A comprehensive review of microbial electrolysis cells (MEC) reactor designs and configurations for sustainable hydrogen gas production

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Hydrogen production rate (HPR);
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Cathode

Abstract Hydrogen gas has tremendous potential as an environmentally acceptable energy carrier for vehicles. A cutting edge technology called a microbial electrolysis cell (MEC) can achieve sustainable and clean hydrogen production from a wide range of renewable biomass and wastewaters. Enhancing the hydrogen production rate and lowering the energy input are the main challenges of MEC technology. MEC reactor design is one of the crucial factors which directly influence on hydrogen and current production rate in MECs. The rector design is also a key factor to up-scaling. Traditional MEC designs incorporated membranes, but it was recently shown that membrane-free designs can lead to both high hydrogen recoveries and production rates. Since then multiple studies have developed reactors that operate without membranes. This review provides a brief overview of recent advances in research on scalable MEC reactor design and configurations.

Contents

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Nomenclature

MEC	microbial electrolysis cell	CE	coulombic efficiency
HPR	hydrogen production rate	CEA	cloth electrode assembly
GHG	greenhouse gas	TW	titanium wire
PEM	proton exchange membrane	SS	stainless steel
H^+	proton	dWW	domestic wastewater
AEM	anion-exchange membranes	GDE	gas diffusion electrode
CMM	charge-mosaic membranes	Y_{H2}	hydrogen yield
BEAMR	bio-electrochemically assisted microbial reactor	DSSC	dye-sensitized solar cell
MFC	microbial fuel cell	MRECs	microbial reverse-electrodialysis electrolysis cells
A_S	specific surface area	MDC	microbial desalination cell
NH_3	ammonia gas	MEDC	microbial electrodialysis cell
CEM	cation exchange membrane	MSC	microbial saline-wastewater electrolysis cell
COD	chemical oxygen demand	MEDCC	microbial electrolysis desalination and chemical production cell
BESs	bioelectrochemical systems		
SMP	soluble microbial products		

1. Introductions-microbial electrolysis cells (MECs)

In 2003, Nobel Laureate Dr. Richard Smalley stated that "energy is the single most critical challenge facing humanity" [1]. The world is facing an epic dilemma. The majority of energy (>86%) is derived from fossil fuels (oil, coal, and natural gas), which are non-sustainable resources that at some point may be completely exhausted [2]. Furthermore, increasing concerns over the impacts of these resources on global climate, human health, and ecosystems around the world are prompting researchers to find renewable alternatives for meeting our growing energy demand [3]. Hydrogen has tremendous potential as a fuel and energy source. Burning hydrogen does not contribute to greenhouse gas (GHG) emissions, acid rain or ozone depletion due to the fact that its oxidation product is only H_2O vapors [4–6]. Furthermore, hydrogen is highly efficient: it has the highest energy content per unit weight among the gaseous fuels, energy content 120 MJ/kg for H_2, 44 MJ/kg