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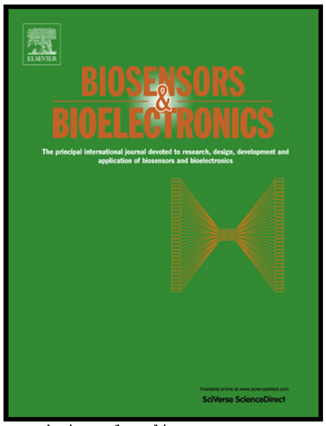

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Microscale microbial fuel cells: advances and challenges

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Abstract:

The next generation of sustainable energy could come from microorganisms; evidence that it can be seen with the given rise of *Electromicrobiology*, the study of microorganisms' electrical properties. Many recent advances in electromicrobiology stem from studying microbial fuel cells (MFCs), which are gaining acceptance as a future alternative "green" energy technology and energy-efficient wastewater treatment method. MFCs are powered by living microorganisms with clean and sustainable features; they efficiently catalyse the degradation of a broad range of organic substrates under natural conditions. There is also increasing interest in photosynthetic MFCs designed to harness Earth's most abundant and promising energy source (solar irradiation). Despite their vast potential and promise, however, MFCs and photosynthetic MFCs have not yet successfully translated into commercial applications because they demonstrate persistent performance limitations and bottlenecks associated with scaling up. Instead, microscale MFCs have received increasing attention as a unique platform for various applications such as powering small portable electronic elements in remote locations, performing fundamental studies of microorganisms, screening bacterial strains, and toxicity detection in water. Furthermore, the stacking of miniaturized MFCs has been demonstrated to offer larger power densities than a single macroscale MFC in terms of scaling up. In this overview, we discuss recent achievements in microscale MFCs as well as their potential applications. Further scientific and technological challenges are also reviewed.

Key words: Microscale microbial fuel cells, biofuel cells, microfabrication, electromicrobiology

1. Introduction

The last three decades have witnessed significant developments and performance improvements in microbial fuel cell (MFC) technology.[1] These advances are reflected in an increasing number of scientific publications and patents.[2-11] Many see MFCs as a promising alternative technology (clean and green, with self-sustaining potential) that could alleviate energy crises and environmental pollution. For this reason, MFCs have provided a focus for renewable energy production research.[12] Despite advances, however, it is difficult to see how MFCs can meaningfully contribute to solving the impending energy crisis and environmental pollution in the short term, due to existing MFCs demonstrating low performance, having expensive core parts and materials, and experiencing bottlenecks in scale-up.[10,13] Instead, special applications of microbial energy production at the "microscale" level might be more applicable and potentially realizable; (i) powering battery-reliant devices that consume reasonably small amounts of energy,[14-17] and (ii) facilitating studies of microbial behavior at a new level of detail and efficiency.[18-20] First of all, microscale (containing a microliter-sized anode chamber) MFCs are rapidly gaining attention for their potential as a micro-power source in a wide variety of military mobile and wireless field applications.[21-23] The motivation for this interest is clear: it would be ideal for such field-based devices to operate continuously under a variety of conditions for long periods of time, without the need for regular battery maintenance/replacement/recharge.