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Review

Langmuir–Blodgett Graphene-Based Films for Algal Biophotovoltaic Fuel Cells

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Abstract: The prevalence of photosynthesis, as the major natural solar energy transduction mechanism or biophotovoltaics (BPV), has always intrigued mankind. Over the last decades, we have learned to extract this renewable energy through continuously improving solid-state semiconductive devices, such as the photovoltaic solar cell. Direct utilization of plant-based BPVs has, however, been almost impracticable so far. Nevertheless, the electrochemical platform of fuel cells (FCs) relying on redox potentials of algae suspensions or biofilms on functionalized anode materials has in recent years increasingly been demonstrated to produce clean or carbon-negative electrical power generators. Interestingly, these algal BPVs offer unparalleled advantages, including carbon sequestration, bioremediation and biomass harvesting, while producing electricity. The development of high performance and durable BPVs is dependent on upgraded anode materials with electrochemically dynamic nanostructures. However, the current challenges in the optimization of anode materials remain significant barriers towards the development of commercially viable technology. In this context, two-dimensional (2D) graphene-based carbonaceous material has widely been exploited in such FCs due to its flexible surface functionalization properties. Attempts to economically improve power outputs have, however, been futile owing to molecular scale disorders that limit efficient charge coupling for maximum power generation within the anodic films. Recently, Langmuir–Blodgett (LB) film has been substantiated as an efficacious film-forming technique to tackle the above limitations of algal BPVs; however, the aforesaid technology remains vastly untapped in BPVs. An in-depth electromechanistic view of the fabrication of LB films and their electron transference mechanisms is of huge significance for the scalability of BPVs. However, an inclusive review of LB films applicable to BPVs has yet to be undertaken, prohibiting futuristic applications. Consequently, we report an inclusive description of a contextual outline, functional principles, the LB film-formation mechanism, recent endeavors in developing LB films and acute encounters with prevailing BPV anode materials. Furthermore, the research and scale-up challenges relating to LB film-integrated BPVs are presented along with innovative perceptions of how to improve their practicability in scale-up processes.

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