微生物與植物微生物燃料電池之開發與優化

Development and optimization of microbial/plant microbial fuel cells

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Microbial fuel cells (MFCs), which convert chemical energy into electricity using microbes, are an emerging sustainable energy technology. However, high costs and low power output limit the advanced development of MFCs. Our study utilized the agricultural waste, *Trapa natans* husk (TNH), to obtain low-cost nanoporous carbons and used them as electrode materials in *Escherichia coli* system-based MFCs. The performance of MFC was optimized by varying the carbonization temperature (T) during preparation of TNH. The MFC with the TNH-800 (T = 800 °C) anode and the TNH-1000 (T = 1000 °C) cathode exhibited the highest average power density of 5712.5 mW m^{-2}, which is twice as large as the MFC using the commercial activated carbon (CAC) electrodes. We showed that TNH had better bacterial adhesion and electrochemical activities owing to a favourable pore size distribution, suitable functional groups, a high surface area, and excellent biocompatibility and conductivity. Furthermore, we utilized the supercapacitors (SCs) with TNH-based electrodes to store the energy generated from MFCs. In a two-electrode system, the SC with the TNH-600 (T = 600 °C) electrodes exhibited a high specific capacitance of 85 F g^{-1} at a current density of 1 A g^{-1} after 1000 cycles. As a proof-of-concept, we additionally assembled a TNH-based MFC-SC system with a DC-DC converter and succeeded to light up a LED. We also used TNH as the anode in *Canna indica*-based plant microbial fuel cells (PMFCs). Our preliminary results of polarization curve measurements showed that the maximum power density of the PMFC utilizing the TNH-coated graphite felt as the anode and the CAC-coated graphite felt as the cathode could reach 67 mW m^{-2}, which was higher than that of the PMFC with a graphite felt anode (9 mW m^{-2}). When the PMFC with a TNH-coated graphite felt anode was connected to an external load (1000 Ω), the power density of 21.2 mW m^{-2} could maintain over 10 days, demonstrating that TNH is a promising sustainable electrode material for PMFCs, which can simultaneously produce plant biomass and generate electricity for green energy. Overall, using TNH as a raw material as the electrodes in MFC/PMFC and SC increases the economic value of the agricultural waste and reduces CO_2 emissions that are generated during waste disposal, demonstrating TNH-based MFC/PMFC as a promising system for sustainable energy.

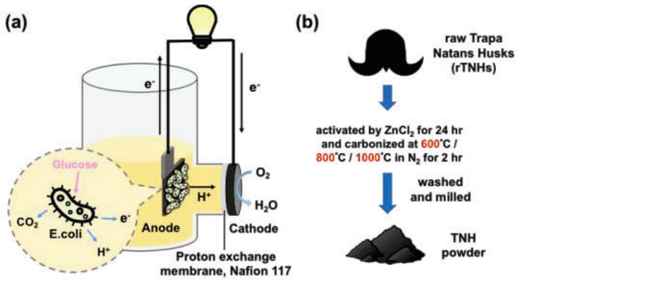

Figure 1. (a) MFC construction and (b) synthesis process of *Trapa natans* husks-derived nanoporous carbon (TNH).

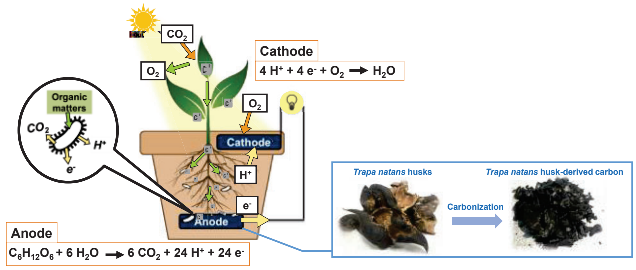

Figure 3. Mechanisms of PMFC with the *Trapa natans husk*-derived carbon anode

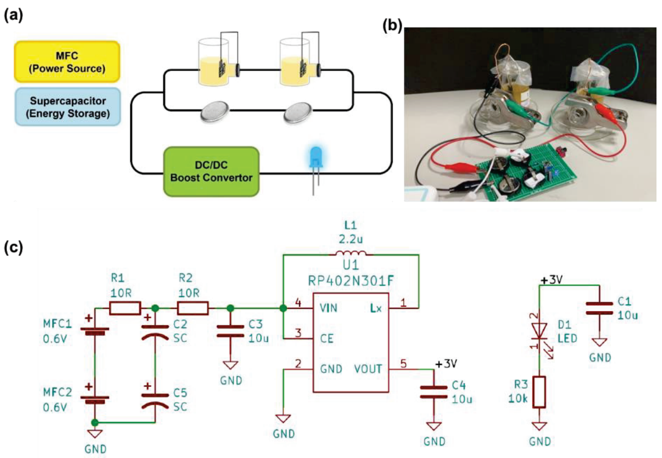

Figure 2. (a) Schematic and (b) photography of the MFC-SC-LED system; (c) Schematic of the DC/DC boost converter circuit system.

Two MFCs were placed in series and were parallel-connected to supercapacitors after achieving a 1.8 V OCV value. Within the 45-second time interval, two supercapacitors connected in series were changed from 0.46 V to 1.2 V. Then, the output of the DC/DC boost converter boosts the voltage of supercapacitors from 1.2 V to 3 V, which is capable to drive a blue LED. Consequently, the voltage of supercapacitors dropped from 1.2 V to 0.7 V. After the output of the converter was enabled, the blue LED kept glowing for 15 sec.

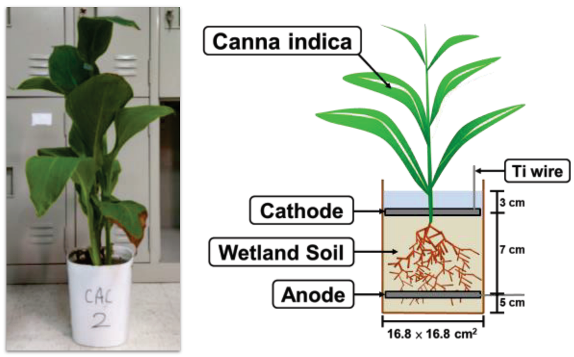

Figure 4. Setup of *Canna indica*-based PMFC

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