Effect of the Three-Dimensional Geometry of an Electrode on the Electron Transfer Process Through Electrochemical Analyses

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The search for renewable energy sources is an important focus of modern research due to challenges such as climate change and the reduction of fossil fuels. Microbial fuel cells (MFCs) are considered a promising alternative for electricity generation through the bioelectrochemical oxidation of organic matter by exoelectrogens. However, electrode-related factors, such as charge transfer resistance and electrode geometry, can significantly affect the overall performance of the system. This study evaluates the effect of three-dimensional electrode geometry on electron transfer using electrochemical analysis. Two electrodes were constructed: one with a smooth surface and another with an internal surface geometry. Both electrodes were designed in SolidWorks and fabricated using conductive PLA. Their performance was analyzed using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). Both electrodes exhibited double-layer capacitance (Cdl) in the μF cm?^{2} range, consistent with values reported for PLA based electrodes. The smooth electrode showed a higher Cdl value of 9.4 × 10?? F/cm^2, while the electrode with internal surface showed a lower value of 1.2 × 10?? F/cm^2. Impedance results indicated that the electrode with internal geometry had higher resistance to current flow, suggesting structural limitations. In contrast, smooth electrode showed lower impedance and a response similar to a glassy carbon electrode (GCE), indicating more efficient electron transfer. Results suggest that smooth electrode geometries allow better electron transfer, even with lower surface area. In contrast, the other design with complex internal structures may increase resistance due to higher tortuosity, negatively affecting electron transport.

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