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Biohybrid Fluidized CO_2 Electrolysis for Enhanced Formate Production and In-situ Bioconversion to Valuable Products

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Abstract:

Conventional CO_2 electrolysis methods typically rely on flat/static gas diffusion electrodes for CO_2-to-formate conversion. However, these approaches often encounter limitations such as insufficient mass transfer, potential electrocatalyst loss, and a constrained electrocatalytic surface area, resulting in reduced CO_2 conversion efficiency to formate. Additionally, formate can serve as a sole substrate for various microbial strains. Here, we developed a biohybrid fluidized CO_2 electrolysis system that integrates CO_2-to-formate conversion with in-situ bioconversion using *Cupriavidus necator*. Initially, we evaluated different fluidized electrocatalytic particles (Sn, In, and Bi) for their performance in CO_2 reduction to formate. The fluidized catalysts significantly enhanced formate production rates, achieving 0.24 mmol h^{-1} cm^{-2} compared to 0.13 mmol h^{-1} cm^{-2} with flat electrodes, with superior performance of Sn particles. Moreover, the fluidized reactor achieved a coulombic efficiency (*CE*) of up to 92%, while flat electrode reached 70%. Finally, we successfully integrated the CO_2 electrolysis system with in-situ bioconversion using *C. necator* to utilize formate into valuable bioproducts. Our results showed that the fluidized design effectively overcomes the limitations of conventional CO_2 electrolysis, demonstrating enhanced efficiency and scalability for industrial applications. Furthermore, the biohybrid integration allows for the direct utilization of formate as a microbial substrate, streamlining the process by eliminating intermediate steps and significantly improving the system's sustainability.

Keywords: CO_2 electrolysis, formate, biohybrid, fluidized electrocatalyst, *Cupriavidus necator*