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Enhancing Electrochemical CO_2 Reduction: Improved Performance of a Three-Compartment Reactor for Formic Acid Production

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The World Meteorological Organization (WMO) recently announced that atmospheric carbon dioxide (CO_2) concentration has reached 420 ppm, marking a 150% surge from pre-industrial levels. In response, global initiatives like the IPCC's aim for net zero emissions by 2050 and the Paris Climate Conference (COP21) limiting the global temperature increase to below 2.0 oC, with efforts aimed at achieving 1.5 oC.

Among strategies to mitigate CO_2 emissions, electrochemical conversion presents promising avenues, particularly in transforming CO_2 into valuable products like formic acid (HCOOH) or formate ($HCOO^-$). This study focuses on evaluating the performance of a novel three-compartment reactor for electrochemical CO_2 reduction, building upon prior research primarily centered on two-compartment setups. [1]

The reactor comprises a 5 cm^2 carbon-based (50% teflonated) cathode coated with commercial bismuth oxide (Bi_2O_3) ink, and an anode of similar dimensions featuring iridium oxide (IrO_2) catalyst on carbon paper (5% teflonated). CO_2 is introduced to the reactor via a humidified flow through a Vapor Delivery Module (VDM), while appropriate electrolytes are fed into anodic and central compartments, consisting of deionized water (Mili-Q water). [2]

Various operational conditions were tested, including different CO_2 flow rates (20, 40 and 60 $ml\cdot min^{-1}$), CO_2 water content (0.5, 1.5 and 3 $g\cdot h^{-1}$), and current densities (45, 90 and 200 $mA\cdot cm^{-2}$). Results show that the three-compartment reactor achieves formic acid concentrations exceeding 140 $g\cdot L^{-1}$ at 200 $mA\cdot cm^{-2}$, with a Faradaic Efficiency of 63% for HCOOH and remarkably low energy consumption (320 $kWh\cdot kmol^{-1}$) attributed to low cell potentials. [3] Another advantage of the three-compartment reactor is the production of HCOOH instead of $HCOO^-$, rendering it more appealing for industrial applications.

This study presents promising avenues for industrial-scale applications, particularly in terms of reducing energy consumption, offering a potential solution to a significant barrier for wider adoption of this technology on a large scale.

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