Engineering a BiPO4–CuBi2O4 Heterojunction for Highly Selective and Stable Electrochemical Conversion of CO2 Into a Liquid Hydrogen Carrier

Alaithan, Zainab (School: Alanjal Private School)

Global carbon dioxide (CO2) emissions exceed 37 billion tons annually, intensifying climate change and motivating technologies that convert CO2 into valuable chemicals. Electrochemical CO2 reduction(eCO2RR) provides a promising pathway for utilizing captured CO2 while storing renewable electricity. Among potential products, formic acid (HCOOH) is an attractive liquid organic hydrogen carrier, many existing catalysts suffer from insufficient selectivity toward formate and poor stability. This research investigates whether constructing a BiPO4–CuBi2O4 heterojunction electrocatalyst can improve catalytic activity, selectivity, and durability for CO2-to-formate conversion. A BiPO4–CuBi2O4 heterostructure catalyst was synthesized using a hydrothermal method and deposited onto carbon paper electrodes. The catalyst structure and composition were verified through standard characterization techniques. eCO2RR performance was evaluated in a CO2-saturated electrolyte using voltammetry, product quantification, and long-term tests. To assess scalability, the catalyst was further implemented in a membrane electrode assembly (MEA) electrolyzer for continuous formic acid production. The heterojunction catalyst achieved 99% faradaic efficiency for formate at -0.9 V vs. RHE, with a partial current density of 30 mA·cm-2 and stable operation for over 70 hours. In the MEA electrolyzer, the system enabled direct production of pure formic acid at low cell voltages (3–4V), reaching current densities up to 200 mA·cm-2 and maintaining 50 mA·cm-2 for more than 70 hours of continuous operation. These results demonstrate that heterojunction engineering significantly enhances catalytic performance, offering a promising strategy for scalable CO2 utilization and sustainable hydrogen-carrier production.

Awards Won: