Synergistic Bimetallic MOF Catalysts and Amine Electrolytes for Captured CO_2 Electroreduction to CO

Abdul Hakeem Anwer
Gas Processing Center, College of Engineering, Qatar University, P. O. Box 2713 Doha, Qatar

Mazen Khaled
Department of Chemical Engineering, College of Engineering, Qatar University, P.O.Box 2713, Doha, Qatar

Abdelbaki Benamor *
Gas Processing Center, College of Engineering, Qatar University, P. O. Box 2713 Doha, Qatar
Department of Chemical Engineering, College of Engineering, Qatar University, P.O.Box 2713, Doha, Qatar

Abstract

Electrochemical CO_2 reduction (ECO_2 RR) provides a promising approach for converting captured CO_2 into valuable chemical products. However, its application in amine-based capture media remains challenging because strongly bound carbamate species can limit CO_2 availability, increase energy requirements, and reduce product selectivity. In this study, mono- and bimetallic MOF-derived catalysts were systematically evaluated for ECO_2 RR in amine-containing electrolytes, with particular attention given to optimizing the electrolyte composition. MEA concentrations from 1 to 4 M were first investigated to identify suitable conditions for balancing CO_2 availability, interfacial reaction kinetics, and product selectivity.

Among the tested catalysts, the bimetallic MOF electrode showed the best performance, reaching a CO Faradaic efficiency of 90 ± 3% at −0.91 V vs RHE in 3 M AMP aqueous electrolyte, corresponding to an approximately 1.4-fold improvement compared with 1 M MEA. The enhanced performance is associated with the relatively less stable carbamate species formed in AMP, synergistic interactions between the bimetallic active centers, nano-agglomerated surface sites, and the formation of a compact electrical double layer that facilitates charge transfer and CO_2 activation. These effects also help suppress the competing hydrogen evolution reaction.

Overall, the results demonstrate that combining bimetallic MOF-derived catalysts with carefully optimized amine electrolytes can significantly improve the direct electrochemical conversion of captured CO_2 to CO, offering a practical strategy for integrated carbon capture and utilization.