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Spontaneous generation of a biomimetically nanostructured Cu/Ag electrocatalyst for sustainable nitrogen cycle management

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Biography

Kenneth received his bachelor's and master's degrees in chemistry from the University of Texas Rio Grande Valley, and PhD in chemistry from the University of Texas at El Paso. His research revolved around utilization of nanomaterials for water treatment applications including adsorption, photocatalysis, and novel nano analytical techniques for nanomaterial detection. Currently Kenneth is in the third year of his NSF MPS Ascend Postdoctoral Fellowship at Arizona State University in the School of Sustainable Engineering and the Built Environment. His current research focus is on engineering nanostructured bimetallic electrocatalysts for the electrocatalytic reduction of nitrate (ERN) to ammonia, as a resource recovery strategy.

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Abstract

The electrocatalytic reduction of nitrate emerges as a valuable opportunity to remediate nitrate pollution while providing a chemical free pathway for ammonia electrosynthesis. Herein, a biomimetically nanostructured Cu/Ag bimetallic electrocatalyst was optimized by fine-tuning metal ratios through an electroless galvanic replacement reaction. The bimetallic electrocatalyst with nano-fern structures was optimized at 2.9% w/w Ag loading that generated highly active catalytic centers upon the three-dimensional Cu substrate. The nano-fern catalytic centers were predominately Ag, but intercalation of Cu generated a versatile bimetallic electrocatalyst surface which accelerated nitrate to ammonia conversion. Nano-fern electrocatalytic domains synergized the first initial reduction step, when compared to the performance of the monometallic Cu, while the applied current density to the system modulated the second reduction of nitrite towards complete ammonia formation. With optimized synthesis and operational parameters, the Cu/Ag bimetallic electrocatalyst converted 96 % of nitrate, with a 95 % selectivity towards NH_3 formation in 60 min.

Simultaneously, the Cu/Ag bimetallic electrocatalyst showcases outstanding performance for the electrocatalytic oxidation of ammonia (EOA), highlighting a bifunctional catalytic technology. Liquid ammonia is an energy source dense in hydrogen, allowing it to be utilized as a low cost and safer alternative to the transportation of pure hydrogen for energy-driven applications. The Cu/Ag electrocatalyst is capable of rapid and efficient degradation of ammonia to release hydrogen on site, with a large emphasis on maximizing energy efficiency when compared with conventional water splitting. Maximizing system efficiency was accomplished through tailoring the KOH electrolyte concentration, initial NH_3 concentration, and the applied current density of the EOA system. Through this dual functionality, this research aims to reduce nitrate pollution, create a sustainable pathway for ammonia electrosynthesis, and leverage ammonia as an effective fuel source for hydrogen driven technologies. In addition, both ERN and EOA reactions were carried out with cost effective electrodes, on a modular system, which can be deployed in a field or laboratory setting alike.