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Direct urea fuel cells: NiO/CuO heterojunction electrodes

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Huge amounts of urea (CO[NH2]2) are industrially produced as fertilizers and naturally generated in livestock farming. Such massive production of urea releases large amounts of wastewater polluted with ammonium into the environment, which is a major concern for environmentally sustainable development. Not only do aquatic ecosystems close to intensive farms suffer from major urea-derived pollution, but ammonia released by urea combines with other pollutants to form particulate matter that affects human health, can release nitrous oxide, which is a powerful greenhouse gas, and raise acidity levels. Thus, direct urea fuel cells (DUFCs), allowing the generation of electric power from the electrooxidation of urea have great potential as a cost-effective technology to simultaneously treat urea-containing wastewater and generate electricity. Herein, a self–supported p-p heterojunction electrode consisting of 2D NiO nanosheets vertically grown on 1D CuO nanowires over a copper mesh (CuM, overall denoted as NiO/CuO@CuM) is synthesized to realize the urea oxidation reaction (UOR). This NiO/CuO@CuM electrode shows an outstanding UOR performance with a potential of 1.35 V vs. RHE at 10 mA/cm2 and 1.39 V vs. RHE at 100 mA/cm2. The large density active sites, high electrical conductivity, and fast kinetics are the factors contributing to this excellent performance. Density functional theory (DFT) calculations show that the NiOOH/CuO heterojunctions modulate the electronic states and benefit urea absorption and CO2 desorption. Stretched Ni-O and Cu-O bonds around the interface and a uniquely elongated N-H bond of urea are calculated, manifesting the favorable catalytic activity of the p-p heterojunction. The assembled DUFCs provide open circuit voltages up to 0.86 V and power densities of 11.35 mW/cm2. This work holds significance for constructing a heterojunction towards modulated and improved UOR catalytic efficiency to enhance DUFCs performance.

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