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Urea Electro-Oxidation Catalyzed by an Efficient and Highly Stable Ni–Bi Bimetallic Nanoparticles

Ajay V. Munde, Balaji B. Mulik, Raviraj P. Dighole, and Bhaskar R. Sathe*

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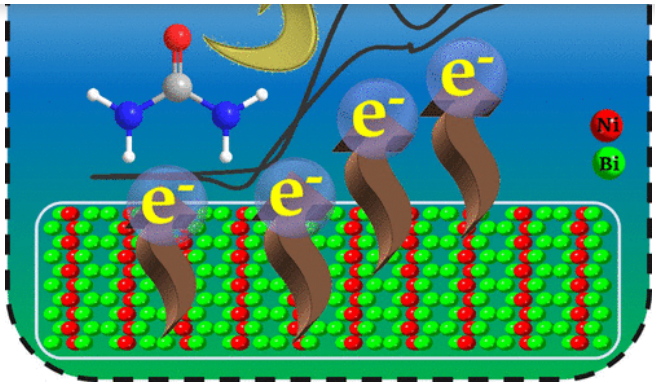
SUBJECTS: Bimetals, Molecules, Oxidation, Oxidation reactions, Urea

Abstract



Direct urea fuel cells (DUFCs) are proficient technology for sustainable energy applications as well as for urea waste present in water. Basically, urea oxidation suffers from sluggish electrokinetics and the proposed complex formation eventually needs six electron transfers due to their large scale utilization. The electrochemical oxidation of urea on Ni nanoparticles (Ni NPs) is perceived as energetic, but it has lower stability due to catalyst deactivation and limited active sites and is found to be responsible for inferior activity towards oxidative conversion of urea. Herein, we have demonstrated the synthesis of Ni–Bi bimetallic nanoparticles by using the chemical reduction method, structurally characterized by X-ray diffraction (XRD), having mixed phases of FCC and a rhombohedral structure, corresponding to Ni and Bi, respectively. BET surface area measurement concluded that the surface area of Ni–Bi bimetallic nanoparticles is higher than that of individual Ni and Bi NPs. TGA exhibited that the Ni–Bi bimetallic composite is thermally more stable compared to individual Bi and Ni NPs. Morphological studies from transmission electron microscopy (TEM) confirm heterostructured interface formation of Ni (5 nm) with Bi (3 nm) nanoparticles. Furthermore, electrochemical activity of Ni–Bi bimetallic NPs was investigated by cyclic voltammetric studies, showing a high current density of catalyst of 37.5 mA/cm^2 with an ultralow potential of E = 0.29 V vs SCE compared to individual Ni and Bi NPs, which may be due to their synergetic structural and electronic effects at the nanoscale. The EIS reveals that the Ni–Bi bimetallic NPs have faster electron transfer, which could be due to having merits like stabilization of the intermediate, synergetic effect, and comparatively more adsorption of urea molecules. This work provides the noble metal-free electrocatalyst for the mechanistic path for urea oxidation and assists in significant implication toward H_2 production from natural and manmade wastes like animal/human urine, urea-rich industrial effluent water, and other industrial and medical wastes.

KEYWORDS: urea electro-oxidation, fuel cell reactions, energy and environmental issues, Ni–Bi bimetallic system, synergetic effect, oxophlic character of Bi, electrocatalysis

CONTINUE

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsaem.1c02755.

- Characterization and electrochemical results related to the electrocatalyst; TEM and HR-TEM images; XPS spectra of Ni-2P in Ni–Bi NPs; XPS spectra of Ni–Bi and Bi NPs; cyclic voltammetry (CV) for (i) Bi NPs/GCE, (ii) Ni NPs/GCE, and (iii) bimetallic Ni–Bi NPs/GCE; electrochemical and electrocatalytic studies; equivalence circuit and value of Ni–Bi NPs; chronoamperometric (*I*–*t*) stability test; cyclic stability; effect of Ni/Bi ratio on electrocatalytic performance; electrochemical active surface area (ECSA) of Ni–Bi NP catalysts; and equivalence circuit and value of Ni–Bi bimetallic nanoparticles (PDF)

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