Zeolite 4A-confined Ni-Co Nanocluster: An Efficient and Durable Electrocatalyst for Alkaline Methanol Oxidation Reaction

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Abstract : The global energy crisis due to the dependence on fossil fuels and its limited reserves as well as environmental pollution are key concerns to the research communities. However, the implementation of alcohol-based fuel cells such as methanol is anticipated as a reliable source of future energy technology due to their high energy density, environment friendliness, ease of storage, transportation, etc. To drive the anodic methanol oxidation reaction (MOR) in direct methanol fuel cells (DMFCs), an active and long-lasting catalyst is necessary for efficient energy conversion from methanol. Recently, transition metal-zeolite-based materials have been considered versatile catalysts for a variety of industrial and lab-scale processes. Large specific surface area, well-organized micropores, and adjustable acidity/basicity are characteristics of zeolites that make them excellent supports for immobilizing small-sized and highly dispersed metal species. Significant advancement in the production and characterization of well-defined metal clusters encapsulated within zeolite matrix has substantially expanded the library of materials available, and consequently, their catalytic efficacy. In this context, we developed bimetallic Ni-Co catalysts encapsulated within LTA (also known as 4A) zeolite via a method combined with the in-situ encapsulation of metal species using hydrothermal treatment followed by a chemical reduction process. The prepared catalyst was characterized using advanced characterization techniques, such as X-ray diffraction (XRD), field emission transmission electron microscope (FETEM), field emission scanning electron microscope (FESEM), energy dispersive X-ray (EDX), and X-ray photoelectron spectroscopy (XPS). The electrocatalytic activity of the catalyst for MOR was carried out in an alkaline medium at room temperature using techniques such as cyclic voltammetry (CV), and chronoamperometry (CA). The resulting catalyst exhibited better catalytic activity of 12.1 mA cm-2 at 1.12 V vs Ag/AgCl and retained remarkable stability (~77%) even after 1000 cycles CV test for the electro-oxidation of methanol in alkaline media without any significant microstructural changes. The high surface area, better Ni-Co species integration in the zeolite, and the ample amount of surface hydroxyl groups contribute to highly dispersed active sites and quick analyte diffusion, which provide notable MOR kinetics. Thus, this study will open up new possibilities to develop a noble metal-free zeolite-based electrocatalyst due to its simple synthesis steps, large-scale fabrication, improved stability, and efficient activity for DMFC application.

Keywords : alkaline media, bimetallic, encapsulation, methanol oxidation reaction, LTA zeolite.
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