Elucidation of Structure-catalytic Activity of Nickel-based Nanomaterial for Electrocatalytic Water Splitting

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Background
The lack of satisfactory and cheaper catalysts for hydrogen production by electrocatalytic water splitting and hydrogen utilization in fuel cells is the major challenge for this clean energy technology [1]. New advanced nanostructured materials with special properties for green H2 production by water splitting are needed to address this major and urgent challenge [2]. Nanostructured materials have shown promising catalytic performance that exceeds the sum of their individual components [3-4]. Thus, they contribute to the development of industrially applicable and sustainable materials for new alternative clean electrochemical energy technologies. For the discovery of novel advanced energy materials that meet the requirements of emerging clean electrochemical energy technologies, advanced tools for the elucidation of structural (electro)catalytic activity are at the heart of future and sustainable nanomaterial development. These advanced materials require advanced scale-bridge spectroscopic technics characterization to understand the chemistry and the elemental species of nanostructured materials at the nanoscale. We have developed a rational design of easily scalable nickel boride (NixB)-derived catalyst to correlate with optimized catalytic activity through metal elements incorporation in a one-pot synthesis method. Our method overcomes the challenge of conventional annealing-dependent processes which have limited applicability on a large scale since they also require an inert processing environment. Furthermore, we elucidate a structure-activity relationship by utilizing scale-bridging correlative microscopy techniques leveraging transmission electron microscopy coupled with electrochemical characterization.

Methods
To elucidate the structure-electrocatalytic activity functionality of these nanostructures, we conducted a thorough electrochemical and TEM investigation on binary nickel boride and quaternary nickel boride-derived catalysts.

Results & Conclusion
A one-pot synthesis method enabled a rational design of non-noble metal, highly efficient, and durable electrocatalysts for hydrogen production at low-temperature electrolysis in harsh alkaline solutions. This improved catalytic performance is further corroborated by microstructural investigations using TEM. The nanoparticles obtained have an improved porous structure compared to conventionally synthesized NixB (Figure 1), providing more available sites for surface reactions and catalytic performance of this nanostructured material. Furthermore, we demonstrate that activation enables morphological and structural changes, while some transition metal elements act as sacrificial elements to provide more accessible and stable sites for oxygen-forming centers. This paves the way for a better understanding of metal boride-derived electrocatalysts for electrocatalytic water splitting and contributes to future discoveries of non-noble metal catalysts, yet with highly efficient and stable nanostructured materials.

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Graphic:

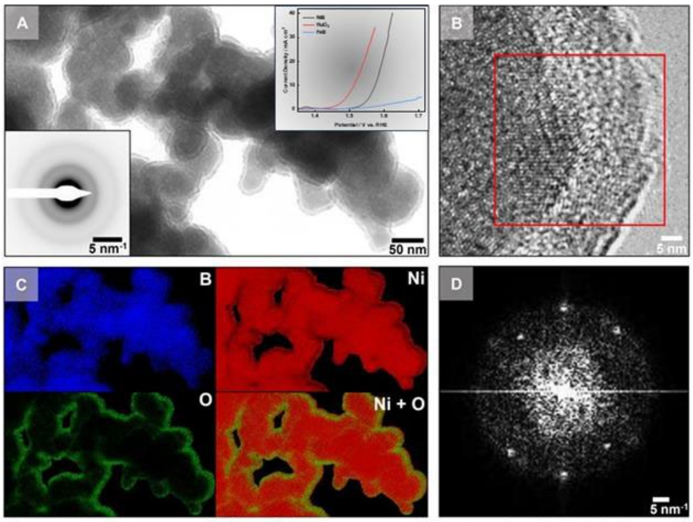

Figure 1. Microstructure and chemical characterization of as-prepared Ni_xB; A) well-dispersed material indicating shell outline and compound amorphous-crystalline heterostructure; B) HRTEM of shell indicating the nano crystalline domains; C) EDXS elemental distribution maps indicating localized enhanced oxidation along the shell structure; D) FFT of ROI (red square) in Ni_xB.

Keywords:

STEM-EELS, catalyst, nanoparticles, water electrolysis

Reference:

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