Highly Active Nanostructured Ni-Cu Electrocatalysts for the Oxygen Evolution Reaction

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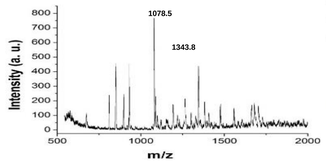
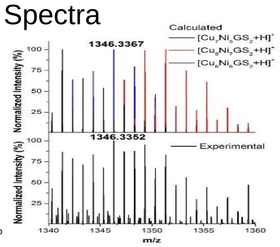
Introduction

- Hydrogen can be produced in a clean and renewable manner from the electrolysis of water.
- The efficiency of current water electrolyzer is limited by the slow kinetics of the oxygen evolution reaction (OER).
- OER involves several proton and electron transfer steps which give rise to large reaction barriers and therefore require high overpotential to drive the reaction in reasonable rates.
- Ni-based materials are promising electrocatalysts for the OER for water splitting in alkaline media.
- An optimal molar ratio of nanostructured Ni-Cu bimetallic compositions show superior OER performance in alkaline media.
- Ni-Cu nanostructured bimetallic compositions are one of the most efficient nonprecious metal OER electrocatalysts reported.

MALDI-TOF and ESI Mass Spectra

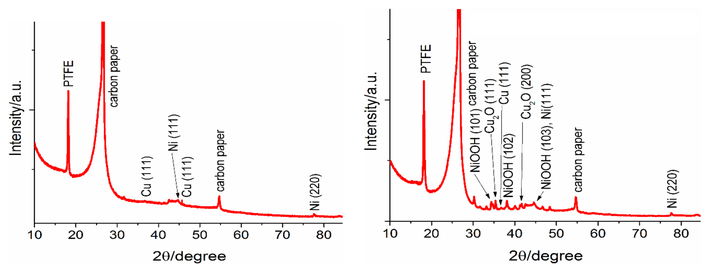


Positive-mode MALDI-TOF mass spectrum of 52:48 mol% Ni-Cu nanoclusters



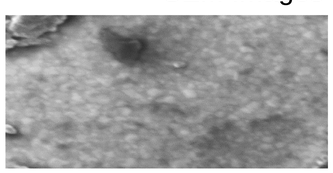
Calculated (top panel) isotopic pattern and experimental mass spectrum obtained from high resolution ESI mass spectrometry (bottom panel) of the nanoclusters

XRD of Nanoclusters

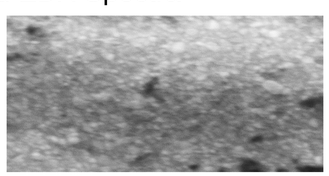


XRD spectra of the 52:48 mol % Ni-Cu nanoclusters before (Left panel) and after (right panel) OER catalysis

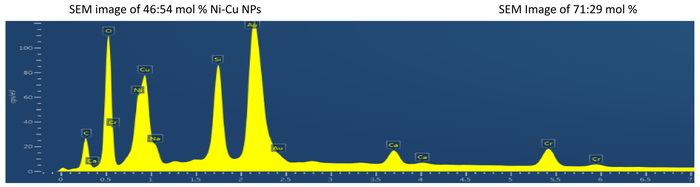
SEM Images and EDX Spectra



SEM image of 46:54 mol % Ni-Cu NPs

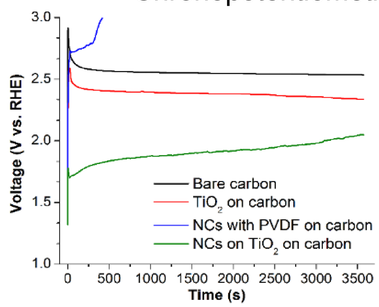


SEM Image of 71:29 mol %



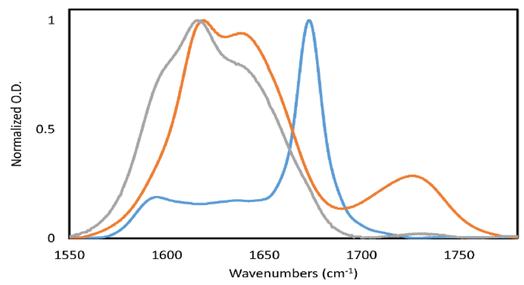
Representative energy-dispersive X-ray (EDX) spectrum of Ni-Cu bimetallic nanoparticles on a Au/Cr/glass substrate

Chronopotentiometry



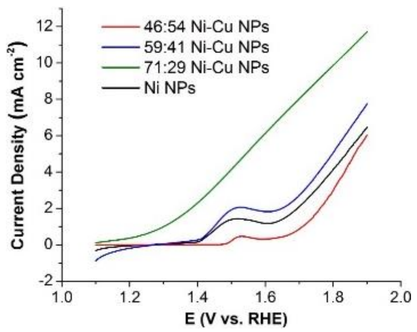
Chronopotentiometry curves of carbon (black line), TiO_2 nanoparticles on carbon (red line), Ni-Cu nanoclusters with PVDF on carbon (blue line), and Ni-Cu nanoclusters on TiO_2 nanoparticles on carbon (green line) electrodes at a current density of 10 mA cm^{-2} in 1 M NaOH.

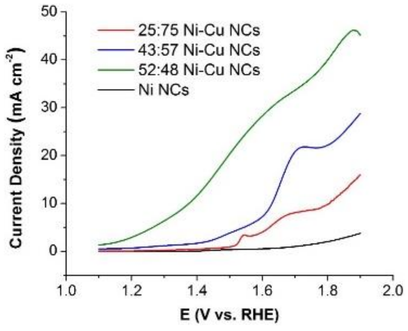
FTIR Spectra



Normalized FTIR spectra of the 52:48 mole % Ni-Cu nanoclusters before (blue) and after (gray) catalysis along with the spectrum of glutathione (orange).

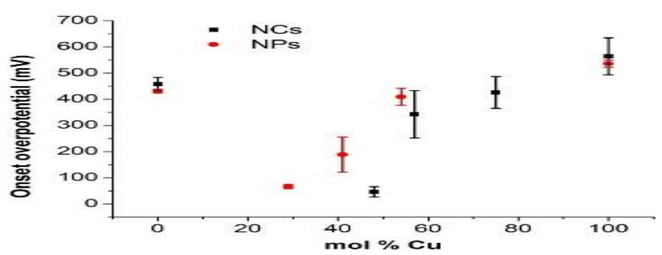
Linear Sweep Voltammograms



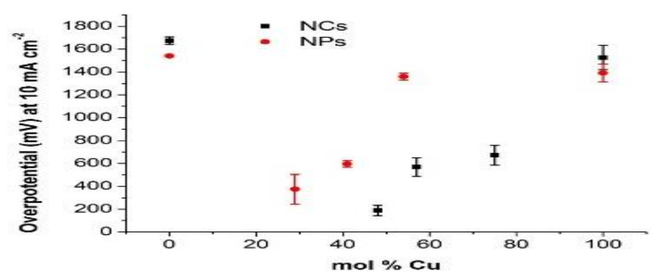


Linear sweep voltammograms at 10 mV s^{-1} of the oxygen evolution reaction in 1 M NaOH using a glassy carbon working electrode modified with a mixture of Ni-Cu bimetallic nanoparticles (NPs) or nanoclusters (NCs), Vulcan XC-72, and PVDF. Current densities are reported against the geometric electrode area.

Onset Overpotential and Overpotential for OER

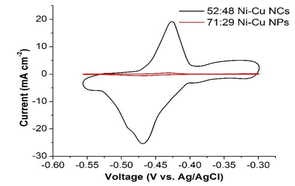


Plot of onset overpotentials for the oxygen evolution reaction in 1 M NaOH using various compositions of Ni-Cu bimetallic nanoclusters (NCs, black) or nanoparticles (NPs, red) on a glassy carbon working electrode.

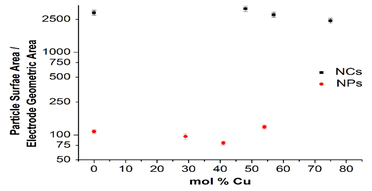


Plots of overpotentials at 10 mA cm^{-2} for the oxygen evolution reaction in 1 M NaOH using various Compositions of Ni-Cu bimetallic nanoclusters (NCs, black) or nanoparticles (NPs, red) on a glassy carbon working electrode.

Pb UPD and ECSA

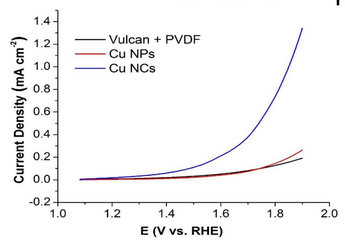


Pb UPD experiments of nanoclusters (black) and nanoparticles (red) in an Ar-sparged solution containing 100 mM $HClO_4$, 1 mM $Pb(ClO_4)_2$, and 20 mM KCl at a scan rate of 10 mV/s

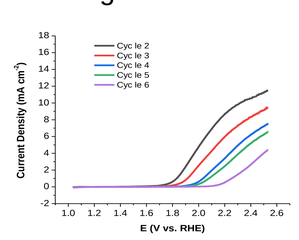


Calculated electrochemically active surface areas of the nanoclusters (black) and nanoparticles (red) as a function of Cu composition in the catalysts

Linear Sweep Voltammograms



Linear sweep voltammograms of the oxygen evolution reaction in 1 M NaOH using Cu NCs and Cu NPs on glassy carbon working electrode that have been modified with Cu nanoclusters (100 mol % Cu NCs, blue line), (100 mol % Cu NPs, red line) and control (Vulcan + PVDF, black line).



Linear sweep voltammograms of multiple cycles of the oxygen evolution reaction in 1 M NaOH using 52:48 molar % Ni-Cu NCs.

Acknowledgments

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