Abstract

Oxygen evolution reaction (OER) and oxygen reduction reaction (ORR) are critical to many important technologies such as fuel cells, electrolysis, and many other energy conversion and storage devices. A material that can catalyze both OER and ORR would allow for the advent of new technologies, such as reversible fuel cells and rechargeable metal-air batteries. Currently, most catalysts are only capable of catalyzing either OER or ORR, but not both. There are few bifunctional catalysts which catalyze both OER and ORR, but the ones that do exist, such as iridium oxide, are too expensive or scarce. The purpose of this project is to create a low-cost bifunctional catalyst that can catalyze both OER and ORR.

Methods and Techniques

**Dealloy NiFeMn Samples in (NH₄)₂SO₄**

- Dealloying removes some manganese from the alloy, leaving behind a nanoporous material.
- Perform Energy Dispersive X-ray Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) on samples.

**Make Slurry for Cyclic Voltammetry (CV) Testing**

- 70% NiFeMn (5 grams)
- 20% carbon (1.5 grams)
- 10% PVDF Binder (0.0179 mL)
- Grind all of this together and spread out on carbon paper. Place in vacuum oven at 90 Celsius to dry overnight.

**Run CV Tests to Determine OER and ORR Catalytic Activity**

- Working electrode: Slurry
- Counter electrode: Platinum
- Reference Electrode: Hg/HgO in 1M KOH
- Electrolyte: N₂-saturated 1M NaOH
- Electrodes are connected to the potentiostat, where the data can be analyzed remotely.

**Run Simulations to Examine Nanoparticle Interactions with Light**

Simulation: The model successfully determined the absorption, scattering, and extinction cross sections for nanoparticles. The next step is to apply the same model to a nanoporous geometry, simulating a material like the nanoporous NiFeMn alloy created.

Results and Future Direction

**EDS of Samples**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ni (at.%)</th>
<th>Fe (at.%)</th>
<th>Mn (at.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>60.3</td>
<td>23.9</td>
<td>15.8</td>
</tr>
<tr>
<td>Sample 2</td>
<td>65.0</td>
<td>22.7</td>
<td>12.6</td>
</tr>
<tr>
<td>Sample 3 (Not dealloyed, at.% estimated)</td>
<td>15</td>
<td>15</td>
<td>70</td>
</tr>
</tbody>
</table>

**CV Curves**

- Blue curves represent the reference material, red curves represent the slurry with the NiFeMn alloy.

**Sample 1:**

- Sample 1 showed both OER and ORR activity. Sample 2 showed OER activity but minimal ORR activity. Sample 3 showed OER activity, but the reduction peak (black arrow) cannot be conclusively determined to be ORR until the test is done again in a nitrogen saturated environment. It seems that dealloying for too long, as in the case of Sample 2, removes too much manganese and reduces the ORR activity. The future step is to dealloy a series of samples with residual Mn content varying from minimal to pristine and test them under nitrogen saturated environments.

**Sample 2:**

- Sample 2 showed OER and ORR activity.

**Sample 3:**

- Sample 3 showed OER activity but minimal ORR activity.

Acknowledgements

- Professor Eric Detsi, University of Pennsylvania
- Jintao Fu, University of Pennsylvania
- Dr. Ann Vernon-Grey, CURF Director
- Jumpstart for Juniors Grant
- 3DAFSN Group