Mixed metal Prussian blue analogues as working electrodes for rechargeable batteries and their electrochemical properties

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What are we doing?

- Need for high-energy storage for rechargeable batteries
How?

• Mixing metals with Prussian blue analogues (PBAs)
  – Analogue: “a compound with a molecular structure similar to that of another”

  – Hexacyanoferrate (HCF) & hexacyanocobaltate (HCC)
What is Prussian blue

• A dark blue pigment
• Used in medicine as an antidote for heavy metal poisoning
• Work as efficient electrodes due to redox properties
Prussian blue composition

- Open framework crystal structure
- Properties:
  - Stores countercations
  - Ion-exchange selectivity
  - Ability to catalyze electrochemical reactions

Prussian blue SEM image, Cao et al.
Materials and Methods

• Nickel Cobalt hexacyanoferrate. NiCoHCF.
• NiCoHCF @ 60 degrees Celsius.
• Iron Manganese hexacyanocobaltate. FeMnHCC.
• Tin hexacyanocobaltate. SnHCC.
Materials and Methods

• Facile method
  – Mixed metals in deionized water, mixed PBA with DI water
  – Add mixed metals drop-wise to PBA
  – Constant stirring 1 hr.
  – Sit for 1 day

• Centrifuged and washed with ethanol
Materials and Methods

- Dried in oven
- annealed at 150 degrees Celsius (16 hrs.)
Materials and Methods

• Paste created
• Painted onto carbon tape (electrodes)
• Carbon tape electrodes annealed at 150 degrees for 2 hrs.
Testing

- Set up in three-electrode battery
- Scanning electron microscope (SEM)
- Cyclic voltammetry
- Galvanic cycling
Three-electrode Battery

• Working electrode – painted carbon tape
• Reference electrode – glass tube with silver nitrate and small silver metal rod
• Anode/Negative electrode – graphite rod
• Placed in electrolyte.
Results – SEM NiCoHCF vs. PB

NiCoHCF SEM image

Prussian blue SEM image, cubical
SEM – NiCoHCF

NiCoHCF stacked particle SEM image
Cyclic Voltammetry

• Applying voltage to the battery and observing the current.
• Plot of Current versus applied Voltage
• Looking for multiple peaks in graph.
Cyclic Voltammetry example
Cyclic Voltammetry

CaCoHCF with Zn in Propylene Carbonate (a)
Cyclic Voltammetry – NiCoHCF

NaCoHCF with Na Perchlorate in PC-EC
Galvanic Cycling

- Testing charge/discharge
- Voltage vs. Time
- Provides quantitative and electrochemical information about battery
Galvanic Cycling – NiCoHCF

NiCoHCF with Na Perchlorate in PC:EC

Graph showing a cycle of potentials over time with peaks at approximately 0.5 Volts and troughs at 0 Volts.
Discussion/Future applications

• Continue testing mixed metal hexacyanoferrate and hexacyanocobaltates
• Attempt to understand the framework and further understand the electrochemical properties.
• Exciting new properties to explore that may create efficient batteries.
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References


