The Architectural Diversity of Metal Oxide Nanostructures:

An Opportunity for the Rational Optimization of Group II Cation Based Batteries.

Esther S. Takeuchi, Kenneth J. Takeuchi, Amy C. Marschilok

esther.takeuchi@stonybrook.edu, kenneth.takeuchi.1@stonybrook.edu, amy.marschilok@stonybrook.edu

OFFICE OF ELECTRICITY DELIVERY & ENERGY RELIABILITY

Stony Brook University

Impact on DOE OE Energy Storage Mission

This project targets some of the unique needs of **large scale power storage**:

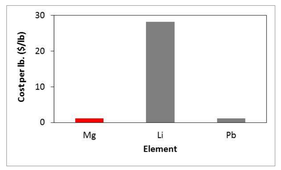
1) reduced cost
2) low environmental impact
3) scalability
4) reversibility
5) capacity retention

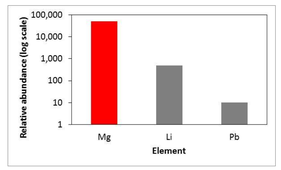
Strategy

Utilize **earth abundant, low cost elements** with minimal environmental impact as battery materials.

Exploit magnesium due to air stability and ~1,000X higher natural abundance than lithium and ~5,000X higher abundance than lead.

Cathode materials feature Mn, Fe or V metal centers.





Results

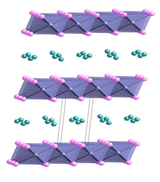
Synthesis and Characterization of Mg_xMnO_y

Two-Step Synthesis

Precipitation

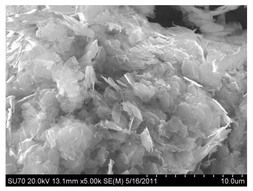
Ion-Exchange

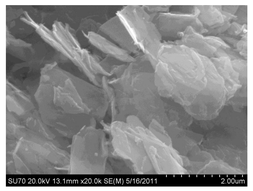
Synthesis
Mg_xMnO_y was prepared by a two-step **scalable process** where the first step was a precipitation reaction followed by ion-exchange.



Structure
Mg_xMnO_y has a layered structure of edge sharing MnO_6 octahedra, where Mg^{2+} cations are found between the layers.

Results



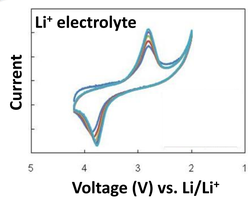


Scanning Electron Microscopy (SEM)
Mg_xMnOy exhibits a platelet morphology.

Mg/Mn =0.23 ± 0.07.

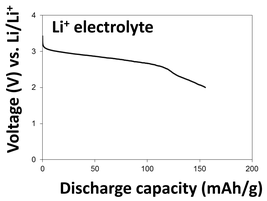
ICP-OES was used to quantify the elemental composition of > 40 samples.

Electrochemical Testing of Mg_xMnO_y



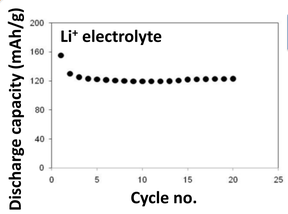
Cyclic voltammetry of three-electrode cell

Mg_xMnO_y showed electrochemical **reversible** behavior between 2.8 V and 3.8 V.



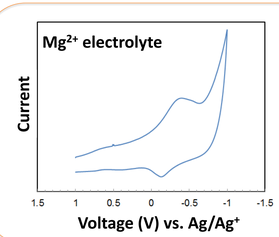
Discharge curve

Discharge of Mg_xMnO_y results in a sloping profile, with **~160 mAh/g** delivered above 2 V.



Cycle life of cells at C/20

The material showed initial capacity of 160 mAh/g with **good capacity retention** at 120 mAh/g



Cyclic voltammetry in Mg^{2+} electrolyte

Electrochemical **reversibility in Mg^{2+} based electrolyte** was observed.

Results

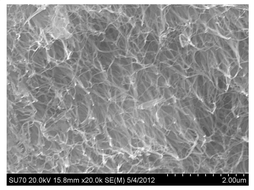
Synthesis and Characterization of $Mg_xV_2O_y$

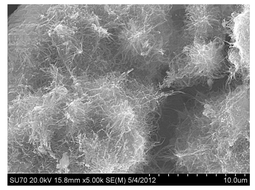
Two-Step Synthesis

Sol-Gel Reaction

Ion-Exchange

Synthesis
$Mg_xV_2O_y$ was prepared by a two-step **scalable process** where the first step was a sol-gel reaction followed by ion-exchange.



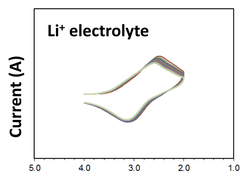


Scanning Electron Microscopy (SEM)
$Mg_xV_2O_y$ exhibits a fibrous morphology.

Mg/V =0.12 ± 0.01.

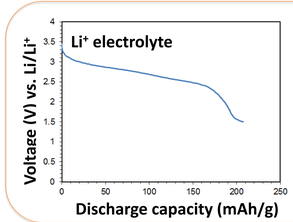
ICP-OES was used to quantify the elemental composition of > 12 samples.

Electrochemical Testing of $Mg_xV_2O_y$



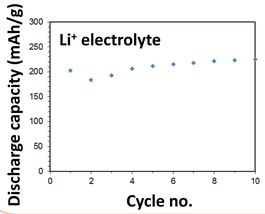
Cyclic voltammetry of three-electrode cell

$Mg_xV_2O_y$ showed electrochemical **reversible** behavior between 2.0 and 4.0V



Discharge curve

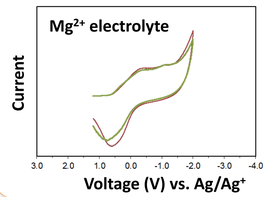
Discharge of $Mg_xV_2O_y$ results in a sloping profile, with **205 mAh/g**



Cycle life of cells at C/12

The material showed initial capacity of 205 mAh/g with **good capacity retention.**

Results



Cyclic voltammetry in Mg^{2+} electrolyte

Electrochemical **reversibility in Mg^{2+} based electrolyte** was observed.

Summary

Successful **scalable aqueous based** syntheses of pure Mg_xVO_y and pure Mg_xMnO_y.

Observed **electrochemical reversibility** in lithium electrolytes.

Delivered capacities > **200 mAh/g** (Mg_xVO_y) and > 150 mAh/g (Mg_xMnO_y).

High capacity retention observed in lithium electrochemical cells.

Observed electrochemical **reversibility in magnesium electrolytes.**

Student Participants

Graduate

David Bock	PhD - Chemistry
Chia-Ying Lee	PhD - Chem. Eng. (graduated Aug 2012)
Shu Han Lee	PhD - Chem. Eng.
Chris Milleville	PhD - Chemistry
Corey Schaffer	MS - Chem. Eng. (graduated Dec 2011)
Shali Yau	PhD - Chemistry (graduated Dec 2011)

Undergraduate

Jeffery Marvin - Chemistry
Sheree Chen – Chemistry

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