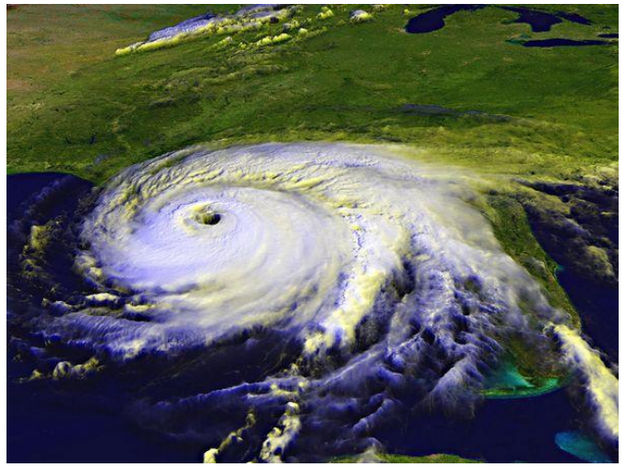
Exceptional service in the national interest

Sandia National Laboratories

energy.sandia.gov



Nitrogen/Oxygen Battery

A Transformational Architecture for Large Scale Energy Storage

September 18, 2014

Frank Delnick, David Ingersoll, Karen Waldrip, Todd Monson

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

N_2/O_2 Battery Project Overview

- Provide a low cost, environmentally benign electrochemical platform for load leveling and for grid-integrated storage of energy generated by wind, solar and other sustainable but variable sources.

Two Configurations:

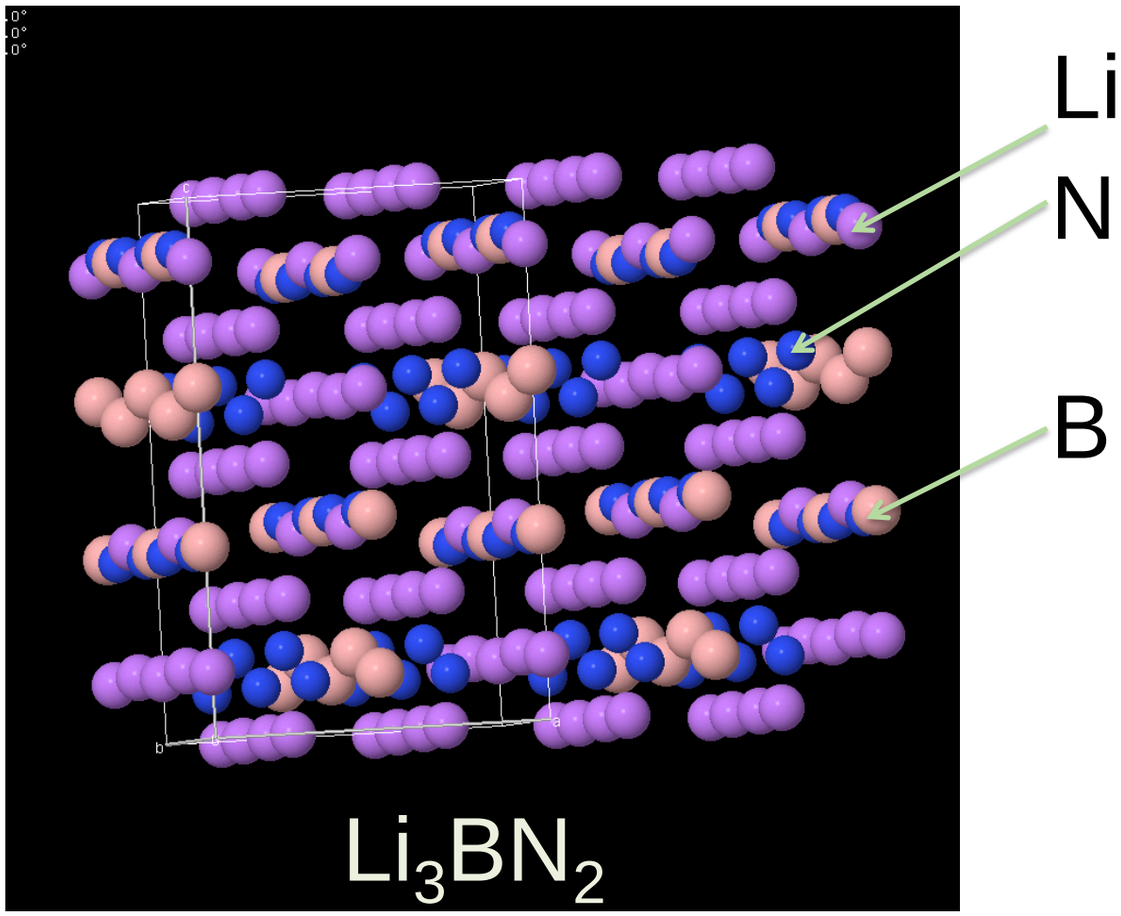
1) High Temp. Molten Salt, Thermal Battery Architecture.
2) Ambient Temp. Mediated Redox Flow Configuration.

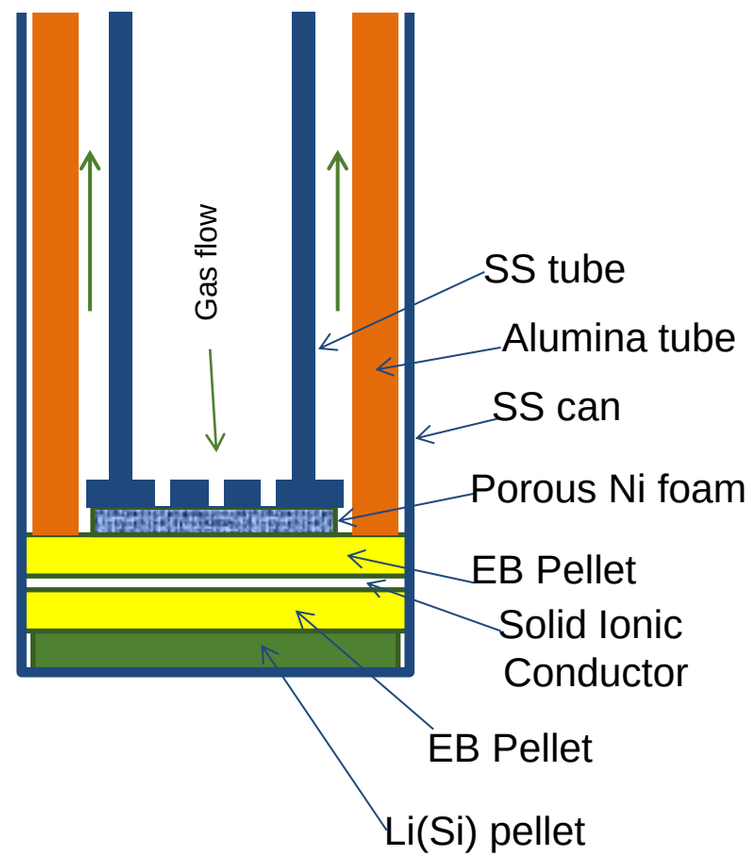
Reversible Reduction of N_2 in Molten Salt

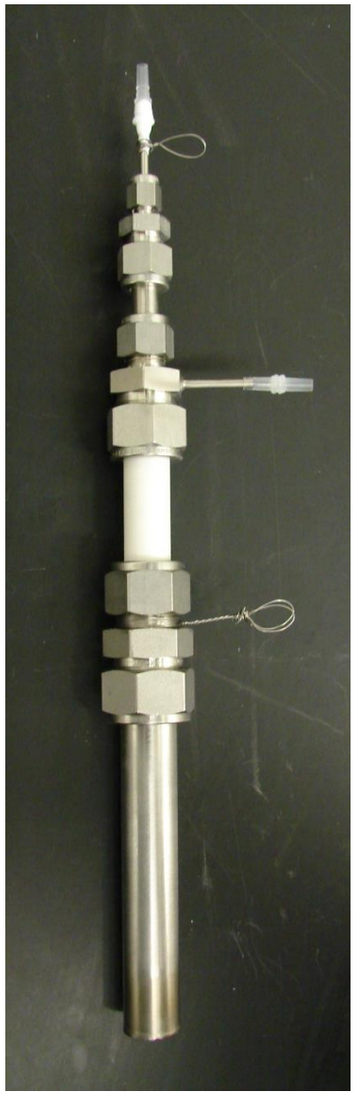
$$6Li + N_2 \rightarrow 2Li_3N + 2BN \rightarrow 2[\text{-Li-N-B-N-} + 2Li^+] = 2Li_3BN_2$$

$+6e^-$ ↑ reduction $\qquad\qquad$ $-6e^-$ ↓ oxidation

$6Li^+ \qquad\qquad 6Li^+ + N_2 + 2BN$



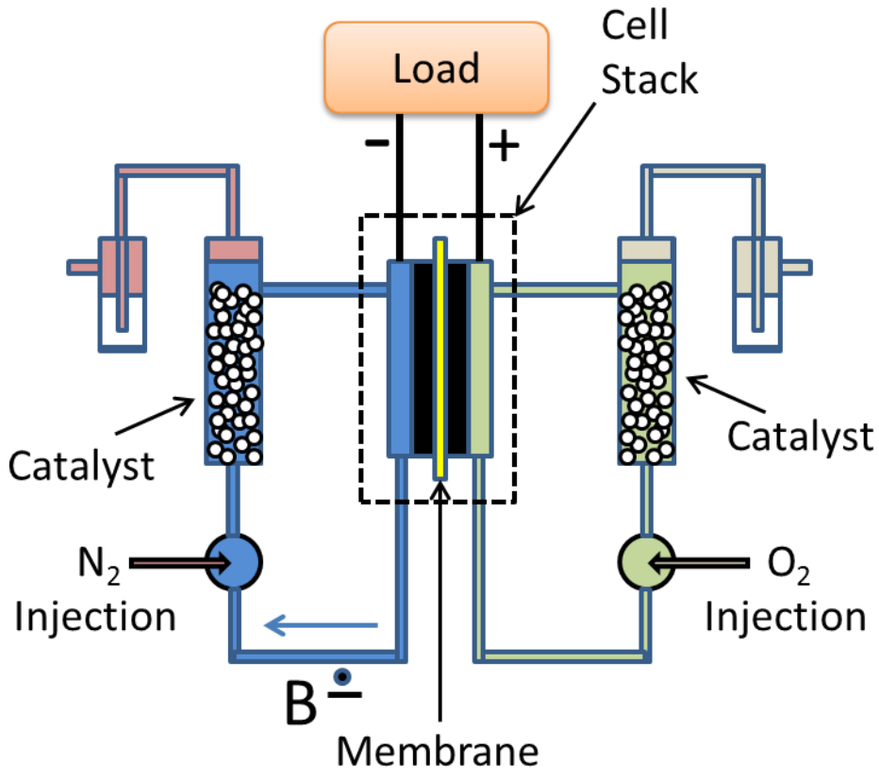


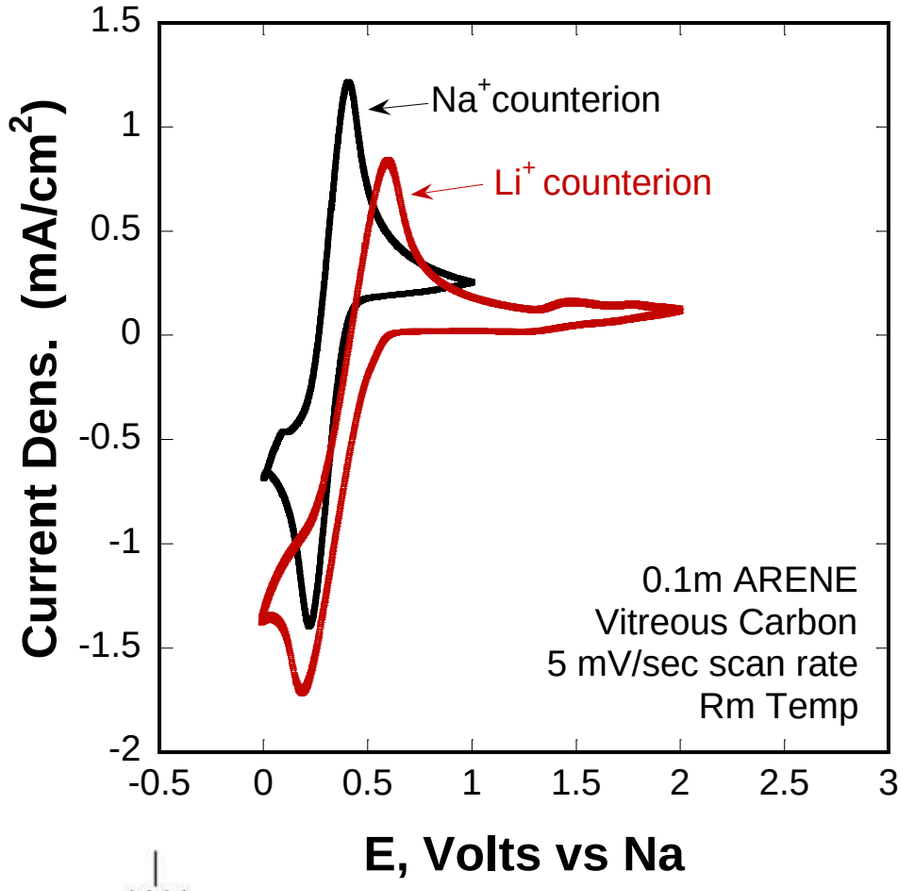


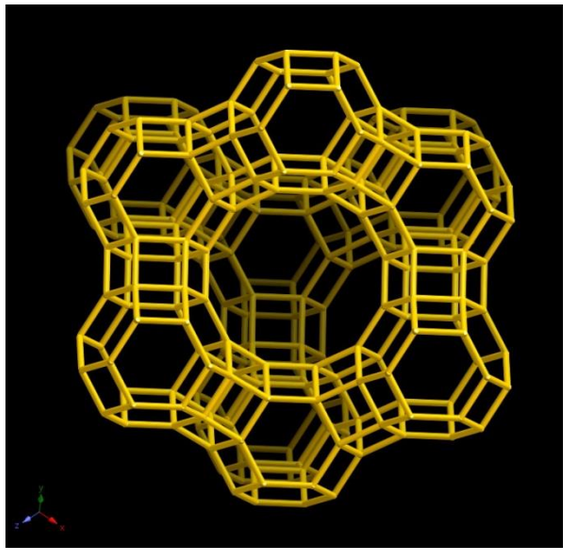
The dinitridoborate anion $(BN_2)^{3-}$ can be viewed as N^{3-} absorbed to a neutral diatomic BN molecule*

Nemeth, [cond-mat.mtrl-sci] 1 Apr 2014

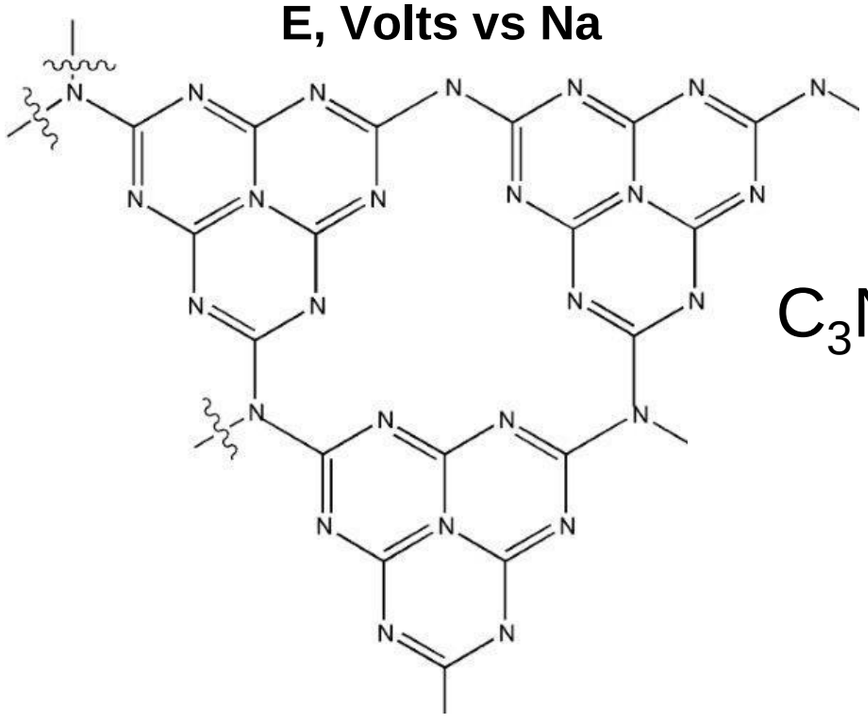
Ambient Temp. Reduction of N_2. Redox Flow Configuration







Zeolite



C_3N_4

Ch. Baerlocher and L.B. McCusker, Database of Zeolite Structures
http://www.iza-structure.org/databases/

Summary/Conclusions

*We have achieved the high rate charge/discharge of the N_2/N^{3-} anode at 550 C by using Li_3BN_2 mediator. However materials problems inhibit further development of the N_2/O_2 battery at this temperature.

*We have achieved N_2 reduction at ambient temperature using a radical anion mediator inside a zeolite catalyst and on C_3N_4. Reaction rate is slow and product yield is low. Reversibility not yet tested.

*Investigations of high energy mediators have yielded spinoff technologies:

Mediated Redox Flow Batteries , F. Delnick, D. Ingersoll, C. Liang US Provisional Patent Application 61/947,7198 SD 13042

Electrolytes for High Energy Density Ultracapacitors, F. Delnick, J. Nanda, C-N. Sun, US Patent Disclosure 201303214

Membrane Separator for Redox Flow Batteries that Utilize Anion Radical Mediators, Technical Advance SD13270

Catalyst for Nitrogen Reduction at Ambient Conditions, F. Delnick, C. Liang, G. Veith, C. Narula, Provisional Patent SD-13272.0/S 136369

Thank You to the DOE OE and especially Dr. Imre Gyuk for his dedication and support to the ES industry and Sandia's ES Program.

Acknowledgements

Dr. Tom Wunsch, Manager, Power Sources R&D Dept. SNL.
Dr. Nancy Dudney, ORNL, Dr. Chengdu Liang, ORNL
Dr. Gabriel Veith, ORNL, Dr. Chaitanya Narula, ORNL
Dr. Loic Baggetto, ORNL, Dr. Jagjit Nanda, ORNL
Dr. Robert Sacci, ORNL, Dr. Che Nan Sun, ORNL/UT
Dr. Doug Aaron, UT
Dr. Tom Zawodzinski, UT

PI: Dr. Frank M. Delnick, Advanced Power Sources Dept., SNL,
and Phys. Chem. of Materials Group, ORNL
fmdelni@sandia.gov, delnickfm@ornl.gov