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# NEW TYPE OF LOW COST, LONG CYCLE LIFE, HIGH POWER, AND SAFE BATTERY

Robert A. Huggins
Dept. of Materials Science and Engineering
Stanford University
Stanford, CA 94305

## Introduction

Renewable energy sources such as solar and wind require support by energy storage over a wide range of time scales. One challenge for the integration of renewable energy sources with the electrical grid is the high frequency of extremely costly short-term transients. Conventional battery technology cannot offer the long cycle life, high power, and high energy efficiency needed to mitigate the effects of these transients.

We have recently shown that open-framework materials with the Prussian Blue structure can be used as battery electrodes in a variety of aqueous alkali ion electrolytes. These electrode materials operate at extremely high rates for tens of thousands of deep-discharge cycles. They are easily synthesized in bulk from earth abundant precursors near room temperature, and operate in safe, inexpensive aqueous electrolytes. Therefore, Prussian Blue analogues may be attractive for use in large-scale stationary batteries integrated with the energy grid.

## Experiments and Results

Recent observations of the physical properties and electrochemical performance of a number of Prussian Blue analogue positive electrodes, which operate by insertion reactions, in a variety of aqueous electrolytes will be reported.

These cathodes are most advantageously paired with anodes that have comparable cycle life and kinetics. One alternative is to use the activated charcoal that is employed in commercial ultracapacitors, and we have recently demonstrated the attractive properties of this combination. However, the low capacity of such carbon electrodes, which operate as capacitive electrodes, severely limits the specific energy of such cells.

We have now been able to construct cells in which materials with the Prussian Blue crystal structure are active in both electrodes. The result is a new type of safe, fast, inexpensive, long-cycle life aqueous electrolyte battery, in which the output voltage does not vary appreciably with the state of charge.

These high rate cells have demonstrated a 96.7% round trip energy efficiency when cycled at a 5C rate, and a 84.2% energy efficiency at 50C. In addition, they have shown zero capacity loss after 1000 deep-discharge cycles.

## Conclusions

The unusual properties of open-framework crystal structure materials in the Prussian Blue family that will be discussed open up a whole new area of application for battery technology.

## References

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