PROJECT IMPACT SHEET

LEVERAGING ZINC MANGANESE DIOXIDE FOR STATIONARY ENERGY STORAGE

UPDATED: FEBRUARY 24, 2016

PROJECT TITLE: Low-Cost Grid-Scale Electrical Storage Using a Flow-Assisted Rechargeable Zinc-Manganese Dioxide Battery
PROGRAM: GRIDS
AWARD: $3,497,133
PROJECT TEAM: City University of New York (CUNY) Energy Institute
PROJECT TERM: September 2010 – March 2015

TECHNICAL CHALLENGE

Advanced energy storage promises to play a key role in modernizing our nation's electricity grid to enable the integration of increasing amounts of renewables, improve operating capabilities, enhance reliability, allow deferral of infrastructure investments and provide backup power during emergencies. To accomplish this, storage systems are needed that can match both the power and energy scale of the electrical grid while minimizing impact on the cost of electric power delivery. Electrochemical energy storage (e.g. batteries) provides significant opportunities to address these needs if lowered cost and increased lifetime can be delivered.

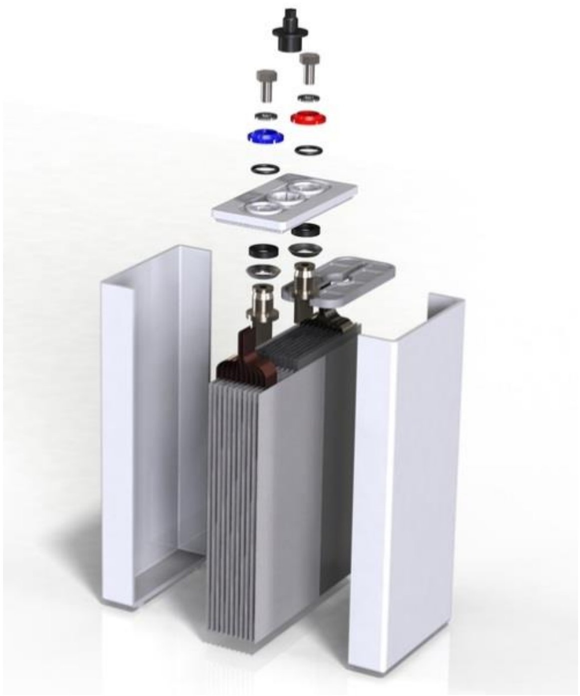
TECHNICAL OPPORTUNITY

The low cost and high performance opportunity presented by zinc (Zn) and manganese (Mn) electrode materials is attractive for creating batteries for grid storage. Traditional consumer-grade disposable "alkaline" batteries that sell for less than $40/kWh are made of Zn and Mn. These materials are inexpensive, abundant, and non-toxic, but disposable alkaline batteries can only be used once. If they are recharged, the Zn in the battery develops filaments called dendrites that grow haphazardly and disrupt battery performance, while the Mn undergoes irreversible chemical reactions and quickly loses its ability to store energy. However, applying advanced materials approaches to the design of electrodes and electrolytes, coupled with a better understanding of battery management, offer new opportunities to dramatically increase the performance of batteries, reduce their cost, and revisit known materials problems in new and innovative ways.

INNOVATION DEMONSTRATION

Prior to the ARPA-E project, researchers at the City University of New York (CUNY) Energy Institute had addressed the issue of dendrite formation by incorporating a "flow-assisted" Zn anode. The CUNY team knew that combining a manganese dioxide (MnO_2) cathode with CUNY's existing Zn anode would result in a very low-cost cell, but CUNY had to address the irreversible chemical changes that result in rapid loss of cell capacity. The CUNY team found specific cycling conditions under which the conventional battery-grade manganese dioxide could be repeatedly charged and discharged. Specifically, the cell's depth of discharge (how much energy was extracted) had to be carefully controlled to a fraction of the material's nominal capacity. MnO_2 was so inexpensive that accessing only part of its capacity did not have a major cost impact on the system. To deliver the controlled depth of discharge, the team – through its award from ARPA-E - developed a sophisticated battery management strategy, as well as optimizing the composition and structure for the positive electrode. Through these innovations, the team demonstrated high cycle life (more than 1,500 cycles) with the new cathode.

Figure 1: UEP's Zinc Manganese Dioxide prismatic cell



To simplify balance of plant and lower system cost, the team also used its ARPA-E award to develop a new approach to the Zn-dendrite problem based on pasted zinc anode. The team improved the performance by modifying the anode microstructure, incorporated novel cell additives, and tested new separator materials. Final cells, incorporating both the improved anode and cathode, cycled over 1,000 times, with projected lifetimes of 5,000 cycles. A chemistry cheap enough to throw away after a single use in consumer electronics, now has the potential to provide a decade or more of service in grid applications.

PATHWAY TO ECONOMIC IMPACT

Members of the CUNY team founded a battery startup, Urban Electric Power (UEP) that has licensed CUNY's Zn-MnO_2 cell technology. Founded in 2013, UEP is supported by private venture and strategic investors. The company reports that it is focused on emerging grid-scale applications, such as energy shifting and renewables integration, as well as in established markets such as uninterruptible power supply (UPS). In the UPS market, the incumbent technology is lead acid batteries, which have moderate energy density, are relatively safe and inexpensive (less than $250/kWh), but also have limited cycle life. UEP reports that batteries resulting from the ARPA-E funded research offer similar energy density and safety, but at a lower cost and with a useful life that is five times as long.

UEP is now (early 2016) offering two grid storage products based on CUNY's technology resulting from the ARPA-E award: a 2 to 50kWh standalone storage system for residential and commercial backup power in developing countries, and a rack-mounted storage unit for use in utility-scale (more than 100kWh) storage applications. UEP reports that the company began shipping small "test units" for potential customers to evaluate in early 2015, and began shipping its standalone storage system for residential and commercial backup power product to customers in late 2015.

LONG-TERM IMPACTS

The rigorous cost requirements of grid-scale batteries have driven re-analysis of old battery chemistries and approaches. The CUNY-UEP collaboration has demonstrated the utility of this approach by developing innovations to make an old chemistry available to provide a decade or more of service in grid applications.

When manufactured in large volumes, UEP believes that its battery packs could have a capital cost of $125/kWh which would deliver storage costs competitive with projections for scaled-up lithium-ion batteries. At this cost level, grid-scale batteries would be well positioned to be economically attractive solutions for a wide range of grid services, setting the stage to enable greatly increased penetration of renewables into the power grid system.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of February 2016, the CUNY team's project has reported 23 invention disclosures to ARPA-E and three U.S. Patent and Trademark Office (PTO) patent applications. The team has also published the scientific underpinnings of this technology in the open literature. A list of publications is provided below:

Ingale, N.D.; Gallaway, J.W.; Nyce, M.; Couzis, A.; Banerjee, S. (2015) *"Rechargeability and Economic Aspects of Alkaline Zinc-Manganese Dioxide Cells for Electrical Storage and Load Leveling"* Journal of Power Sources 276, 7–18.

Gallaway, J.W., Erdonmez, C.K., Zhong, Z., Croft, M., Sviridov, L.A., Sholklapper, T.Z., Turney, D.E., Banerjee, S. and Steingart, D.A. (2014) *"Real-time materials evolution visualized within intact cycling alkaline batteries"* Journal of Materials Chemistry A 2(8) 2757-2764.