THE AQUEOUS ELECTROLYTE SODIUM ION BATTERY: A LOW-COST SOLUTION FROM AQUION ENERGY

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ABSTRACT

A new low-cost energy storage solution is presented that is based on an alkali-ion manganese-oxide intercalation cathode (positive electrode) and low-cost activated carbon anode (negative electrode). The electrolyte is a neutral pH solution containing dissolved sodium sulfate (Na_2SO_4) and the battery current collection and packaging system is comprised of low-cost materials produced and processed by highly scalable manufacturing techniques. Results presented include a description of the device and materials, an assessment of battery performance, and a description of ongoing large-scale demonstration projects.

Keywords: Sodium ion battery, hybrid supercapacitor, low-cost energy storage, flow battery, NaS battery, lead-acid battery

INTRODUCTION

As the electricity grids of the world grow and age, and as renewable power sources (such as solar arrays, wind turbines, micro sterling engines, solid oxide fuel cells) proliferate, there is an increasing need for large-scale secondary (rechargeable) energy storage capability. Both distributed and centralized systems are needed, with storage capabilities ranging from under 10 kilowatt hours (kWh) to hundreds of megawatt hours (MWh). Batteries for these stationary applications are typically based on the lead-acid, sodium sulfur (NaS), or lithium-ion (Li-ion) chemistries, and to date there are hundreds of MW of installed capacity for a total of thousands of MWh globally. Further, it is predicted that the annual global market for stationary storage will exceed $20B by 2021 [1].

While the current state-of-the-art electrochemical batteries are functional and appealing for some applications, there is still a need for a lower-cost, more stable, longer-lived chemistry. Proposed solutions include a range of flow batteries, low-cost Li-ion chemistries, advanced lead-acid, and next-generation NaS. Of these, it is not apparent which will be able to be manufactured in a timely fashion at the right cost at the required scale. The approach described here represents a new alternative. By first assessing raw materials cost and availability of potential precursor materials, and then only accepting those that meet cost and performance criteria into the device development pipeline, we have arrived at a uniquely optimized device.

Work was therefore undertaken starting in 2008 to develop an aqueous electrolyte sodium ion battery system based on interaction electrodes. The resulting technology allows for the use of thick format electrodes (on the order of multiple millimeters), extremely inexpensive separator and current collector materials, and the use of benign electrolyte salts. The cells can be assembled in an open-air environment using simple equipment, and so can be manufactured at a very low cost.

DESCRIPTION

Sodium is probably the most readily available and inexpensive alkali metal and has very similar electrochemical characteristics as Li. Furthermore, Na actually demonstrates better ionic conductivity in aqueous solution. There are a handful of high-performing Na-based intercalation electrode materials systems that have been shown to function in non-aqueous environments, and of those, manganese (Mn)-based cathode materials systems were determined to be most cost-advantaged. There are many potential anode materials that might function; however, low-cost activated carbons offer particularly appealing robustness and performance attributes.

The core device, therefore, consists of an activated carbon anode with a proprietary surface preparation to significantly enhance specific pseudocapacitance, a λ-manganese dioxide (MnO_2) alkali-ion intercalation cathode, and a non-woven fibrous separator. These active materials are mixed with a binder and are processed into multi-millimeter-thick freestanding electrodes. These electrodes and separators are then configured into large-format polypropylene battery packages using a true stacked prismatic architecture. The Aquion Battery 0 engineering/manufacturing model unit has an energy density of approximately 30 Wh with a usable voltage range of up to 0.5 to 1.8 volts.

PERFORMANCE DATA

Figure 1 shows an image of the Aquion Battery 0 device and a typical 10-hour discharge curve indicating a total capacity of over 30 Wh. The internal volume of this device is approximately 1 liter, and the external volume is larger, but is not optimized to maximize energy density.

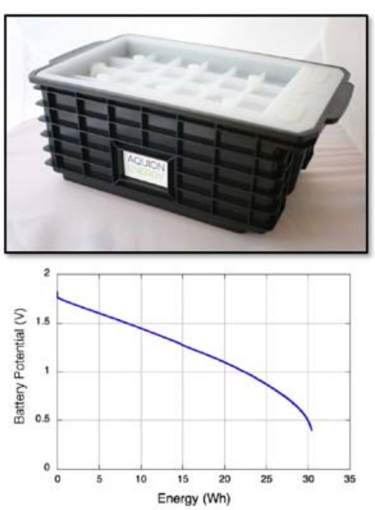

Fig. 1. Image of packaged battery (top) and 10-hour rate discharge curve (bottom).

Figure 2 indicates the energy density of the electrode pairs contained inside this battery unit.

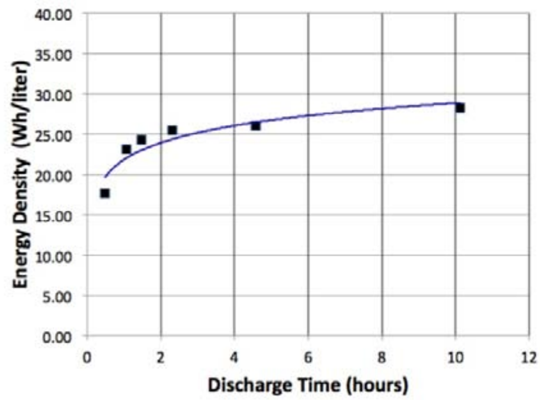

Fig. 2. Energy density of the Aquion Energy electrode stack as a function of discharge time.

These data indicate that >80% of the total possible battery energy can be extracted at discharge times exceeding 4 hours.

The data plotted in Figure 3 show the cycle life performance of the battery under deep discharge galvanostatic use conditions.

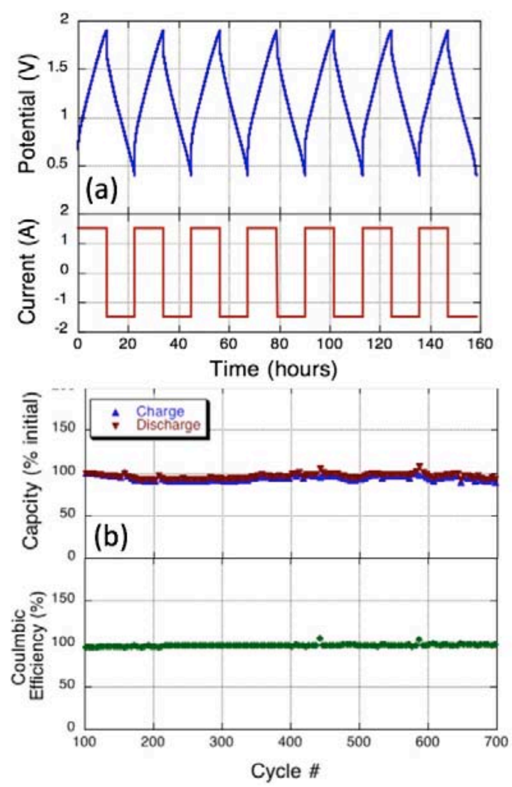

Fig. 3. (a) Battery current and voltage profiles as function of time for deep-discharge constant-current cycle life testing. (b) Cycle life results for 15 months of deep-discharge testing for a representative test fixture. These data indicate the long-term stability of the battery chemistry.

High-temperature testing indicates that this chemistry is also very stable to temperatures at least as high as 60 ˚C. Application-specific-use profile testing also shows that this solution is excellent for a range of stationary storage uses.

SUMMARY

A new hybrid/asymmetric battery chemistry has been developed and scaled to pilot manufacturing level by Aquion Energy. This very low-cost battery chemistry exhibits excellent stability over long-duration use and acceptable energy density values. Large-scale demonstrations of this technology are currently under development and test, and data from these tests are forthcoming.

REFERENCES

[1] Pike Research Report, “Energy Storage on the Grid,” 2011, at www.pikeresearch.com/research/energy-storage-on-the-grid.

BIOGRAPHICAL NOTE

Conference presenter: Dr. J.F. Whitacre received a Ph.D. from the University of Michigan in 1999. He held various positions at Caltech and the Jet Propulsion Laboratory before taking his current Professorship at Carnegie Mellon University (CMU) in 2007. There he develops functional materials systems and performs economic/environmental impact assessment for energy technologies. His early work at CMU resulted in the conception of a novel scalable energy storage device. In 2008 he founded Aquion Energy, a company that has grown to over 60 employees. He is currently on leave from CMU to serve as full-time Chief Technology Officer for Aquion as it scales a pilot manufacturing plant in Pittsburgh, Pennsylvania. Professor Whitacre has over 50 peer-reviewed papers and patents.