Safe, Inexpensive, and Very High Power Batteries For Use to Reduce Short Term Transients on the Electric Grid

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Abstract

This program involves the investigation and development of safe and inexpensive electrochemical systems to be used to ameliorate problems due to short-term transients in the large-scale electrical grid, and its integration with wind and solar systems.

It has only been underway for less than a half year, but impressive progress has already been achieved.

Introduction

This program is based upon two recent developments in our laboratory. One of these is the demonstration of the use of safe and inexpensive aqueous electrolytes with extended voltage ranges.

The other is our recent demonstration of a new group of electrode materials: the $A_xPR(CN)_6$ family that has a zeolitic open framework type of crystal structure. They have demonstrated truly remarkable properties, combining high power, long cycle life and high energy efficiency.

Work on this program involves four major areas:

1) Further development of this new family of electrode materials with remarkable properties for battery testing and the investigation of another sub-family that have also shown indications of attractive properties.

2) Additional work on aqueous electrolytes with extended voltage ranges that are compatible with these new materials.

3) Use of hybrid-ion electrolytes to enable the use of a wider range of possible electrode materials.

4) Fabrication and testing of larger cells that are more compatible with grid-scale applications.

Background

Most of the attention of the battery research community has been focused upon applications in which specific energy and energy density are paramount. This has been primarily driven by applications in portable devices, e.g. computers, phones and vehicles. This work commonly involves variants of lithium-ion systems.

This emphasis on high specific energy and energy density that is characteristic of batteries for such uses is not relevant to systems used in stationary applications, such as for the support of large intermittent sources, such as solar and wind, and their integration with the large scale electrical distribution grid. Instead, cost, lifetime issues, both the number of cycles and the calendar life, high power and safety are much more important.

In general, the technologies that are being pursued for the high-energy requirements are much too expensive to be considered for larger scale, and cost-sensitive, applications. All of the components in current small lithium-ion cells are expensive; anode materials, cathode materials, electrolyte solvent, salt in the electrolyte, and separator. Studies have shown that the cost of the materials is about 80% of the total cost in today's automated manufacturing technology. This is not apt to change very much for larger devices and/or systems.

Also, these cells have a relatively poor cycle life, only sufficient for relatively short-lived consumer devices. Batteries produced for cell phones, digital cameras and laptop computers are generally designed to be able to undergo 500 discharge cycles and to last for at least 3-5 years. Those intended for vehicle use are expected to undergo one discharge per day for 10 years, or 3,600 cycles.

On the other hand, those to be used for long-term use with alternate energy sources, such as solar and wind, and grid-connected applications must perform well for at least 10,000 cycles. In addition, the output from solar and wind sources can be especially sporadic, with a large number of short-term transients, as well. This requires high rate capability, which cannot be met by current battery technologies.

The fact is that none of the existing battery systems including the lithium-ion, metal hydride/nickel and lead acid systems can meet the requirements for grid scale applications in either performance or cost.

New approaches, such as those being pursued on this program, are urgently needed.

Results

Since this project was just started, the first task was to hire researchers. Now one postdoc and two graduate students are working on it. One student (Richard Wang) has US Government Fellowship support.

We have continue to develop the synthesis and characterization members of the $A_xPR(CN)_6$ family of zeolitic open framework materials. A^+ ions include Li^+, Na^+, K^+ and NH_4^+ have been explored. A number of P and R elements are currently under investigation including Cu, Ni, Fe, Mn, Cr. In addition, we have initiated the electrochemical testing of these materials using divalent ions, A^{2+}: Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}. The initial results are very promising, showing that it is possible to reversible intercalate divalent ions in these novel materials. This is different from the general experience with the oxide positive electrode materials typically used in lithium-ion batteries.

Thus we are making significant progress toward the developments of new high performance and low cost aqueous battery materials and devices to assist grid scale energy storage. If successful, this project will provide exciting advances to speed up the penetration of renewable energy sources such as solar and wind as well as to reduce the emission of greenhouse gases.

Future Work

Since this project has just started, we plan to carry out research according to the initial scope :

1) Further development of this new family of electrode materials that have already shown remarkable properties for use in battery batteries for applications related to the large scale grid.
2) Investigation of aqueous electrolytes with extended voltage stability ranges that are compatible with these electrode materials.
3) Use of hybrid-ion electrolytes to enable the use of a wider range of possible electrode materials.
4) Fabrication and testing of larger battery cells to aim toward their use in grid-scale applications.

Publications

None to date.

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