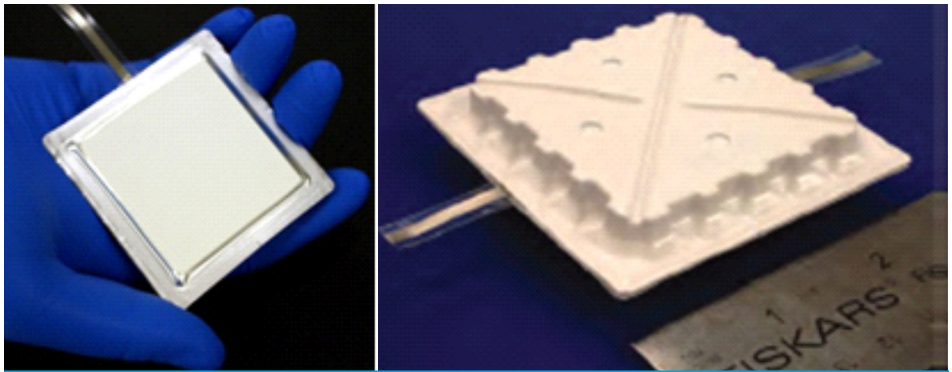
Manufacturing of Protected Lithium Electrodes for Advanced Lithium-Air, Lithium-Water, and Lithium-Sulfur Batteries

Developing a Lower Cost and Higher Energy Density Alternative to Lithium-Ion Batteries

The world is moving towards increased electric transportation and use of renewable sources of energy for grid power. However, advanced electrochemical energy storage is necessary for these growing trends and the United States is in a highly competitive market along with Japan, Korea, and China in the development of these technologies. The introduction of electric vehicles in the U.S. and abroad has fueled a global race for manufacturing advanced secondary batteries, but widespread adoption of electric vehicles will not take place until battery technologies are developed that are more cost effective and offer higher performance.

Lithium-air, lithium-water, and lithium-sulfur batteries, which have been enabled by the development of protected lithium electrodes (PLEs), can help boost domestic battery manufacturers in these competitive, emerging technology areas. Low active raw materials cost for these types of lithium batteries combined with exceptionally high energy densities (two to ten times higher than the competition) should lead to reduced costs (at volume production) compared to competing lithium-based technologies.



(left) An 11 Ah water-stable protected lithium electrode (PLE) (right) a lithium air cell.
Photo courtesy of PolyPlus

However, the only commercial source of the lithium-ion-conductive ceramic membranes used to construct PLEs is foreign-based. Providing a domestic source of these membranes would help to reduce costs and give the United States a competitive advantage. In order to realize the reduced cost, it is imperative to demonstrate that PLE-based chemistries can be manufactured and scaled to high-volume production.

This project will involve producing solid electrolyte membranes for the production of PLEs that have sufficient mechanical strength, ionic conductivity, and chemical stability to be competitive in the global battery market. It will also focus on developing the novel manufacturing technologies required to produce PLEs at scale.

Benefits for Our Industry and Our Nation

The technology to produce advanced PLEs will enable the manufacture of advanced lithium batteries with higher energy densities and should lead to more than a 50% reduction in cost (relative to competing technologies). If successful, this technology will advance new and emerging product markets and provide U.S. manufacturers a significant competitive advantage. Using lithium batteries with PLEs in electric vehicles would significantly reduce greenhouse gases and energy consumption. Also, PLE technology could reduce solid and liquid wastes by recycling the waste lithium from used batteries.

Applications in Our Nation's Industry

There is significant market potential for applications using PLEs, including electric vehicles, grid storage, military applications, and others. Low-cost, higher performance, ultra-lightweight, and compact batteries based on PLE technology may enable a new generation of portable devices. Other applications may include oceanographic exploration, oil and gas exploration, autonomous underwater vehicles and buoys for the U.S. Navy, and possibly unmanned aerial vehicles for the U.S. military.

Project Description

This project will develop the manufacturing technology that can produce advanced PLEs for lithium-air, lithium-water, and lithium-sulfur batteries. Project objectives include the development of solid electrolyte membranes that provide sufficient lithium-ion conductivity, mechanical strength, and chemical stability and can be scaled to high-volume manufacturing and ultimately reduce the cost of these batteries relative to competing products. If achieved, the technology will facilitate the emergence of a domestic supplier of solid electrolyte membranes and accelerate the commercialization of PLE-enabled battery technologies.

Barriers

- Cost-competitiveness of novel battery technologies depends on demonstrating manufacturability through high-process efficiency, scale-up, and safety.
- Developing thinner membranes that provide higher rate performance is challenging for secondary lithium-air applications because some degree of shape-change and surface roughening of lithium electrodes is unavoidable.
- Solid electrolyte stability can be compromised in certain salt-water environments.

Pathways

During this project, the chemistry and processing of solid electrolytes will be optimized and modified for use in lithium-air, lithium-water, and lithium-sulfur batteries. A pilot production line will be used to build PLEs with the membranes developed. These PLEs will be tested in lithium-air, lithium-water, and lithium-sulfur batteries. Testing results will be used to adjust membrane chemistry and processing as needed, ultimately resulting in pre-commercial technology. The technology will be transferred from bench-scale to pilot scale, demonstrating the capability of high-volume production of PLEs. The full manufacturing process will be addressed, including raw material selection, powder preparation, tapecasting and sintering, and final part finishing and handling.

Milestones

This project began in 2012.

- Pilot line is fully operational and guidelines established for lithium-water PLE (2013).
- Develop specifications for primary lithium-air PLE and process for lithium-water membranes (2014).
- Develop specifications for rechargeable lithium-air PLE and process for lithium-air membranes (2014).
- Develop specifications for lithium-sulfur PLEs and process for lithium-sulfur membranes (2015).
- Complete scale up of PLE pilot manufacturing and scale up of membranes for pilot manufacturing (2015).

Commercialization

The PLE manufacturing technology being developed in this project is necessary for the commercial success of lithium-water, lithium-air, and lithium-sulfur battery technologies. After manufacturability of the PLE technology has been demonstrated on the pilot scale, focus will be placed on market development and commercial introduction of the lithium-water battery first, followed by commercialization of the primary lithium-air batteries and rechargeable lithium-air and lithium-sulfur technologies. Early introduction of the lithium-water battery technology is expected to provide the necessary revenue and market feedback to facilitate development of PLEs for the other batteries.

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