Researchers look at crystalline zeolite membranes to be fountain of youth for renewable energy batteries

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While efficient and affordable electrical energy storage batteries are critical to the success of renewable solar and wind power systems and smart grids, the current high cost and short life of storage batteries remain the two major hurdles for widespread market acceptance.

University of Cincinnati researchers are looking at inorganic, crystalline zeolite membranes that exhibit extraordinary stability against the metal ions inside electrical energy storage batteries. This offers the opportunity for developing a new generation of purely inorganic membrane-electrode-assemblies for a more robust, low-cost redox flow battery (RFB) for electrical energy storage in renewable power systems and future smart grids.

Junhang Dong, UC professor of chemical engineering in the Department of Biomedical, Chemical and Environmental Engineering is looking specifically at how the crystalline zeolite membranes improve the stability of the ion transfer process.

Looking primarily at this synthetic crystalline material with sub-nanometer sized pores, Dong found that the pore openings in the zeolite material allow the necessary transfer of metallic ions to penetrate the separating membrane inside renewable batteries, creating the energy-causing ions needed to give the batteries their power. But to his surprise, he found that because the pores are so small, they effectively prevent the transfer of the larger hydrogen and oxidative chemical molecules to cross over and mix, thus preventing the harsh environment that ultimately results in the premature breakdown and death of the battery.

Dong's research was published in the November issue of the prestigious *Chemical Communication* Journal, "Zeolite ion exchange membrane for redox flow battery." He continues to focus primarily on understanding the fundamentals of how the ions and molecules move across the Zeolite membrane.

- In looking closely at the process by which zeolite's rigid structure and sub-nanometer pores effectively discriminate between molecules that can fit through its entrance and those that can't, Dong's goals are two-fold:
- to specifically investigate the ion and molecular transfer across the zeolite membrane — primarily looking at how the ion transfer process works on this material and what influences the transport efficiency
- to develop the most efficient materials for RFB ion exchange membranes (IEM) based on these fundamental understandings

Current ion exchange membranes typically used inside renewable batteries are flexible, polymer based materials that eventually breakdown. Through this NSF funded research, Dong is gaining a fundamental understanding of the structure-performance relationship of the zeolite-based IEMs so that they can better define the problems involved and solve those problems through rational design and improvement of the materials. Dong's long-term goal is to apply this understanding to the development of a completely new class of ion exchange membrane for high performance RFBs with reduced cost and longer lifetime.

Enhanced RFB Performance

The zeolite membranes are being developed as novel ion exchange membranes (IEM) for high performance, long life RFBs. And, RFBs are considered potentially the most affordable type of battery for large-scale electrical energy storage.

"We are presently focusing on developing new types of ion exchange membranes. In particular, membranes of nanoporous zeolitic materials that are the key elements in the flow battery's system," says Dong. "To do this we must better understand the mechanisms of ion diffusion or conduction in the zeolitic channels and the factors controlling the ion transport behavior so we can optimize the membrane material and take this technology to the next level and improve the battery's performance.

"We ultimately hope to make a positive impact on society, industry and the economy by helping to develop a more prevalent, efficient and affordable battery for the fast growing renewable energy industry."

Some of the research findings from Dong's team have recently been filed for two U.S. patents (currently provisional) and published in the leading journals such as *Chemical Communications* (50,2014, pp2416-2419) and *Journal of Membrane Science* (450, 2014, pp12-17).

His current battery research team includes chemical engineering PhD students Zhi Xu and Ioannis Michos, and Fiona Shaw, a second-year Chemical Engineering undergraduate who spent her summer doing research in Dong's lab on zeolite-polymer composite IEMs under the NSF and WISE-program supports.

Zeolite's Earlier Success

In earlier research, Dong found zeolite's functionality and capability for separating water from solutions of dissolved salts and metal ions. He and his coworkers pioneered the application of zeolite membranes in the desalination of produced brines from oil and gas drilling.

Typical RFB Operation

During the battery's operations, the electrons go from the negative electrode to the positive electrode through the external circuit to perform electrical work, while the nonreactive ionic charge carriers, often protons, transfer internally through the IEM that maintains electrical balance and completes the entire circuit.

These chemicals inside the battery, however, create a highly oxidizing and acidic environment, which results in the gradual breakdown of the conventional polymer IEMs and lower its performance and shorten its life.

Zeolite Shows Promise

Dong explains how zeolite is fundamentally different from the conventional polymeric IEMs, especially in terms of its material nature and mechanisms of ion conduction and separation. Zeolites are crystalline solid oxide molecular sieves with a rigid, non-swollen framework that produces a much stronger resistance to the oxidants and acids. And even more critically, the extremely uniform subnanometer pores avoid the major weaknesses associated with polymer IEMs.

Dong is demonstrating the versatility, high performance and cost effectiveness of the zeolite-based IEMs. By better understanding how this size-exclusion mechanism works in the crystalline zeolite material, Dong's research team aims to develop efficient new ways to lower the cost and extend the life of RFBs for electrical energy storage batteries in renewable solar and wind power systems and future smart grids for more affordable and prevalent use worldwide.

More information: Zhi Xu, I. Michos, X. Wang, R. Yang, X. Gu, J. Dong, Zeolite Ion Exchange Membrane for Redox Flow Battery. *Chem. Commun*. 50 (2014) 2416-2419

R. Yang, Z. Xu, S. Yang, L. Li, A. Angelopoulos, J. Dong, Nonionic Zeolite Membrane as Potential Ion Separator in Redox-Flow Battery. *J. Membr. Sci.* 450 (2014) 12-17

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