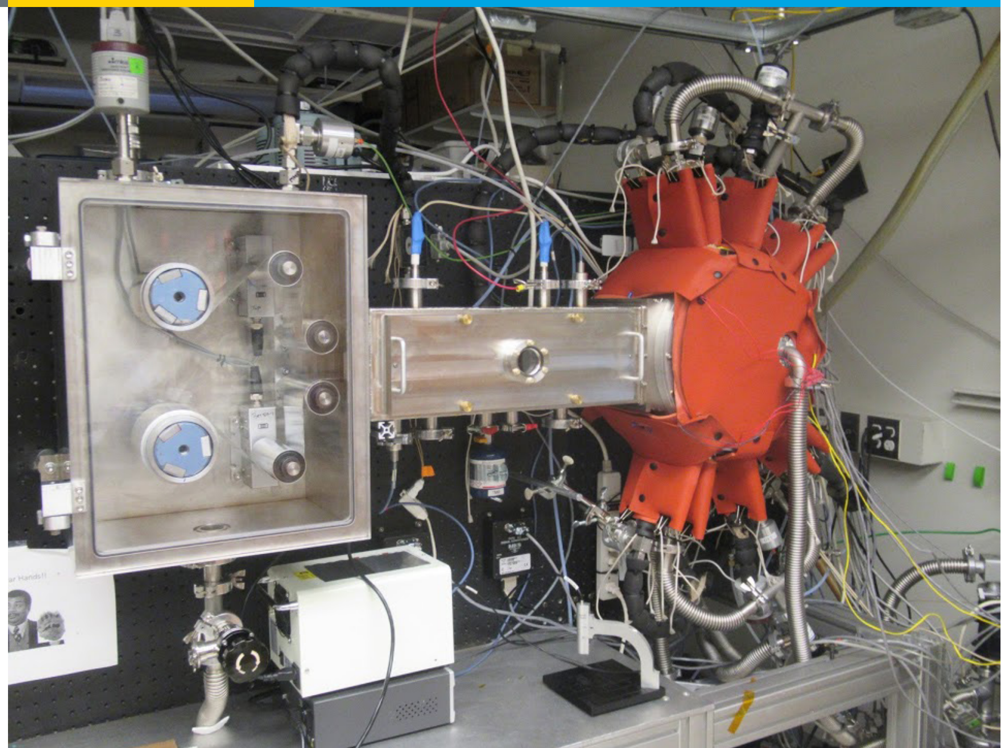
Novel Membranes and Systems for Industrial and Municipal Water Purification and Reuse

Decreasing energy consumption of reverse osmosis membrane separation processes



University of Colorado is developing a roll-to-roll coater for the fabrication of molecular layer-by-layer synthesis (mLbLS) reverse osmosis (RO) membranes.
Photo courtesy of University of Colorado

Water is essential for life and critical to economic activity. It impacts a wide range of U.S. industries, including power generation, oil and gas production, mining, food processing, and chemical production. In 2010, the U.S. Geological Survey estimated the United States used 355 billion gallons of water daily, more than 51% of which was used by the manufacturing, power generation, and mining industries. Climate concerns, population growth, and increasing water scarcity are leading to greater consideration of industrial and municipal wastewater reuse and desalination of brackish water and seawater to meet anticipated future water supply needs. Global water demand is also expected to grow significantly in the next 20 years.

Reverse osmosis (RO) membrane-based processes are used worldwide for water treatment and industrial and municipal wastewater reuse. Today, RO membranes are the leading technology for new desalination installations, and they are applied to a variety of seawater, brackish water, and wastewater sources. However, current membrane performance is less than optimal, resulting in inefficient, energy-intensive separation processes.

To reduce the cost and energy requirement of water production by RO processes, innovations in membrane materials, manufacturing methods, and system designs are needed to significantly increase membrane water permeance, improve fouling resistance, and enhance rejection of contaminants. Operating the RO process at lower hydraulic pressure while maintaining similar water throughput is the key to reducing energy consumption for membrane-based water purification.

This project aims to develop technology capable of decreasing the energy consumption of RO membrane separation processes by 50%, while also decreasing the cost of water purification and reducing environmental impacts. This will be accomplished through the development of nano-engineered, high permeance membrane materials with more than double the permeance of current conventional RO membranes, as well as manufacturing technologies for cost-effective production of the novel materials.

Benefits for Our Industry and Our Nation

Advanced membrane technology could improve U.S. manufacturing energy productivity while at the same time reducing its environmental footprint. Additionally, water scarcity issues facing the United States could lead to periodic shutdowns in manufacturing industries that require large amounts of cooling tower, boiler, or process water. The membranes developed for this project could help prevent such shutdowns by improving the economics of new and alternative water sources for manufacturing industries, making existing manufacturing infrastructure more sustainable. In addition, the technology could open new opportunities for economic development in water-stressed areas.

Applications in Our Nation's Industry

U.S. manufacturing industries requiring large amounts of cooling tower, boiler, or process water will benefit from more energy-efficient RO membrane processes. In addition, RO-purified water could be used in the food and beverage industries, as well as for municipal water sources.

Project Description

The project has three main objectives to be achieved: (1) develop and optimize novel nano-engineered RO membranes with at least three times the permeance of current conventional RO membranes, (2) design and build lab scale manufacturing processes for promising materials, and (3) analyze the competitiveness of developed technologies compared to current commercial systems and validate energy savings estimates.

Barriers

- Ensuring molecular layer-by-layer synthesis (mLbLS) RO membrane materials and process are robust.
- Developing a mLbLS membrane fabrication process that can be scaled up from lab to pilot.
- Avoiding mLbLS membrane fabrication steps that are too complex to meet economic goals.

Pathways

Project partners first developed and characterized nano-engineered RO membrane materials using mLbLS (solution phase and gas phase) RO membrane manufacturing approaches. Based on this work, gas phase mLbLS process was identified as the most promising manufacturing approach. The gas phase mLbLS manufacturing process will be further developed and optimized for the production of RO membranes that meet performance specifications. In addition, estimated energy savings were calculated over a range of feed water salinities and compared with thermodynamic minimums and the targeted 50% energy reduction to be enabled by the new membrane materials.

Milestones

This four-year project began in December 2014.

- Develop nano-engineered membranes with both solution phase molecular layer-by-layer synthesis (mLbLS) and gas phase mLbLS approaches and demonstrate permeance that is at least two times greater than currently available RO membranes while maintaining 98% or higher salt rejection (Completed).
- Conduct preliminary techno-economic analysis for developed membrane manufacturing approaches and water treatment processes (Completed).
- Design, build, and optimize lab scale membrane manufacturing process for the most promising technology approach (2018).

Technology Transition

After this project, the manufacturing approaches are still expected to be at a laboratory scale and further technical development will be needed before the technology can enter the market. Successful development of this technology would provide high permeance membranes and systems with greatly reduced energy consumption, making them well positioned to capture significant market share in the rapidly expanding desalination and water reuse membrane element and equipment markets. Because the technology is modular and scalable, it is expected that future deployment efforts can target a broad range of commercial market segments, from small single skid systems to large-scale industrial and municipal water facilities.

Project Partners

University of Colorado
Boulder, CO
Principal Investigator: Steven George
Email: steven.george@colorado.edu

GE Global Research
Niskayuna, NY

National Institute of Standards and Technology
Gaithersburg, MD

For additional information, please contact

Bob Gemmer
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5885
Email: Bob.Gemmer@ee.doe.gov ■