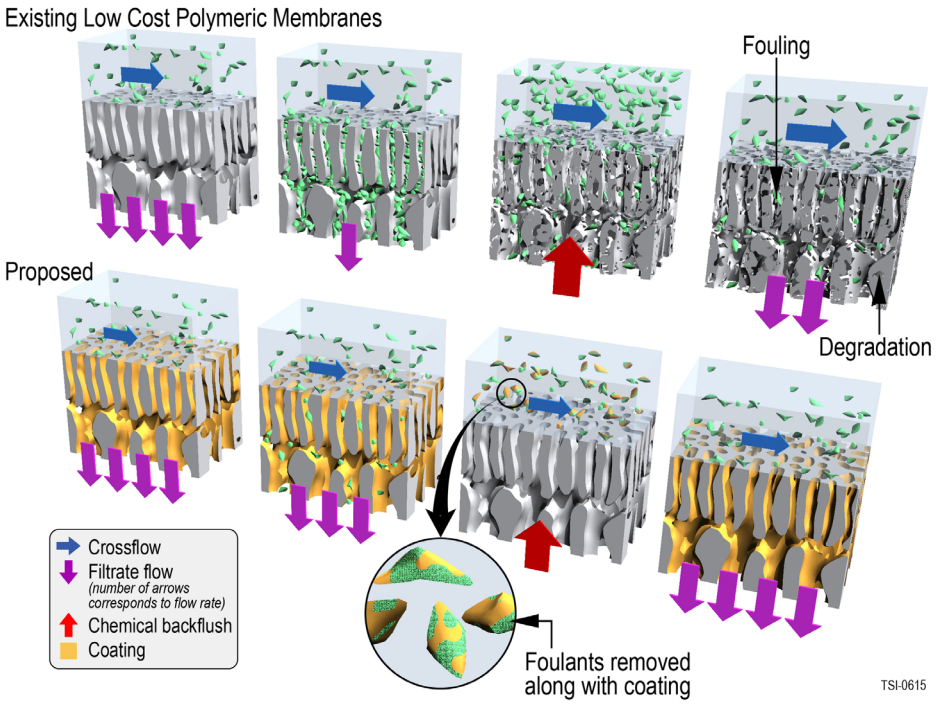
Sacrificial Protective Coating Materials That Can Be Regenerated *In-Situ* to Enable High-Performance Membranes

Membrane Technology Provides Energy-Efficient Method to Concentrate Weak Black Liquor

Among the various manufacturing processes employed across all U.S. industries, the process of concentrating weak black liquor (WBL) in the pulp and paper industry is identified as one of the largest energy reduction opportunities for separation technologies. The concentration of WBL in the pulping process is currently performed by multiple stages of steam-heated evaporators, which concentrate the liquor from approximately 15% solids to about 65%–80% solids. This process consumes large amounts of energy due to the high heat needed to vaporize water.

The technical feasibility of ceramic membrane separation offering a non-evaporative, pressure-driven alternative to concentrating WBL has been demonstrated, but ceramic membranes have higher capital costs, making them prohibitively expensive. Polymeric membranes are available at much lower cost but, untreated, the membranes are attacked by the harsh nature of the WBL. Moreover, membrane fouling leads to clogging, increasing operation costs.

This project will leverage research and materials from a previously developed, low-cost coating process and apply the research to lower cost polymer membranes that are already used in established markets, such as municipal water treatment and water desalination. The coating will make it difficult for various foulants in the WBL to adhere to the membranes while also providing protection from harsh conditions. The coating process enables a thin 2–5 nanometer coating, both on the membrane surface and within the membrane pores, allowing the coating to chemically protect the membrane effectively and prevent fouling. The pressure drop across the membrane can be used as a sensor to activate a backwash for removing the loosely-bound foulants. The coating can also be periodically reformed in-situ using apparatus that is standard practice in membrane-based separations.



A protective coating (yellow) on the polymer membrane will provide chemical and fouling resistance. Removing the foulants and/or coating during chemical backflush and subsequent in-place regeneration increases longevity. *Photo courtesy of Teledyne*

Benefits for Our Industry and Our Nation

Preliminary analysis indicates the chemically resistant, antifouling, low-cost membrane coatings have the potential to provide the following benefits:

- Reducing energy requirements for black liquor concentration by more than 35%, consequently reducing greenhouse gas emissions.
- Reducing water demand in the separation step, which will require less energy to heat process water.
- Projected payback period of approximately 2 years with lower operating costs, providing a competitive advantage to the U.S. pulp and paper industry.
- Potential production of higher value-added products by fractionation of lignin and hemicellulose with an optimal choice of membrane pore size.

Applications in Our Nation's Industry

This novel technology could enable major reductions in energy use in the paper industry, while also making membrane separation of challenging feed streams in other industries commercially viable. Applications in other industries include treatment of water in oil and gas drilling, waste streams from metal and mining, and biologically loaded streams in food processing.

Project Description

A chemically resistant, antifouling, low-cost membrane coating will be developed for application in the paper industry. The coated membranes are proposed to be used in place of multi-stage, steam-heated evaporators for concentration of WBL in paper pulping. The novel renewable coating protects the membranes against the harsh feed and reduces fouling.

Barriers

Major barriers to be overcome include the following:

- Lifetime uncertainty for the polymeric membranes and coating materials in constant contact with hot, caustic black liquor.
- Feasibility of cleaning and recoating the membranes while in place.

Pathways

To ensure successful maturation of the technology, the project will:

- Develop critical proof-of-concept of membrane protection and antifouling and refine target specifications for the membrane separation process;
- Provide lab-scale demonstration of all components, including membrane cleaning and recoating and a plan to meet target specifications;
- Demonstrate hot black liquor filtration in a lab-scale unit; and
- Develop a detailed business case for commercializing the demonstrated technology.

Milestones

This project began in 2012.

- Achieve environmental stability (pH 13-14, Temperature >80°C) of coating materials on chosen membranes (2013).
- Demonstrate coating regeneration after black liquor filtration with <10% drop in flux after recoating process (2014).
- Establish a black liquor treatment process for >3 days with <20% drop in total flux (2014).
- Establish a black liquor treatment process for >7 days with <20% drop in total flux with backflush, chemical clean, and in-place coating reformation (2015).
- Demonstrate a black liquor concentration process in a lab unit on both hardwood and softwood black liquor streams for >14 days of continuous operation and analysis of black liquor and filtrate streams (2015).

Commercialization

Early engagement of pulp and paper manufacturing partners will be a key contributor to successful development of this technology. The industrial partners will provide expertise in industrial operations, including the design of filtration modules and the complete design of filtration systems appropriate for black liquor concentrations. Industrial partners may also provide on-site lab demonstration and validation trials to ensure an adequate supply of black liquor and validate test results to the end users. Validation by the supply chain vendors will bridge the gap between R&D and commercial implementation and speed the project towards manufacturability and integration.

Project Partners

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