

Sacrificial Protective Coating Materials that can be Regenerated In-Situ to Enable High Performance and Low Cost Membranes

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Project Objective

Problem

- Pulp & Paper Industry weak black liquor (BL) byproduct must be concentrated for reuse
- Concentration is carried out using energy intensive evaporators

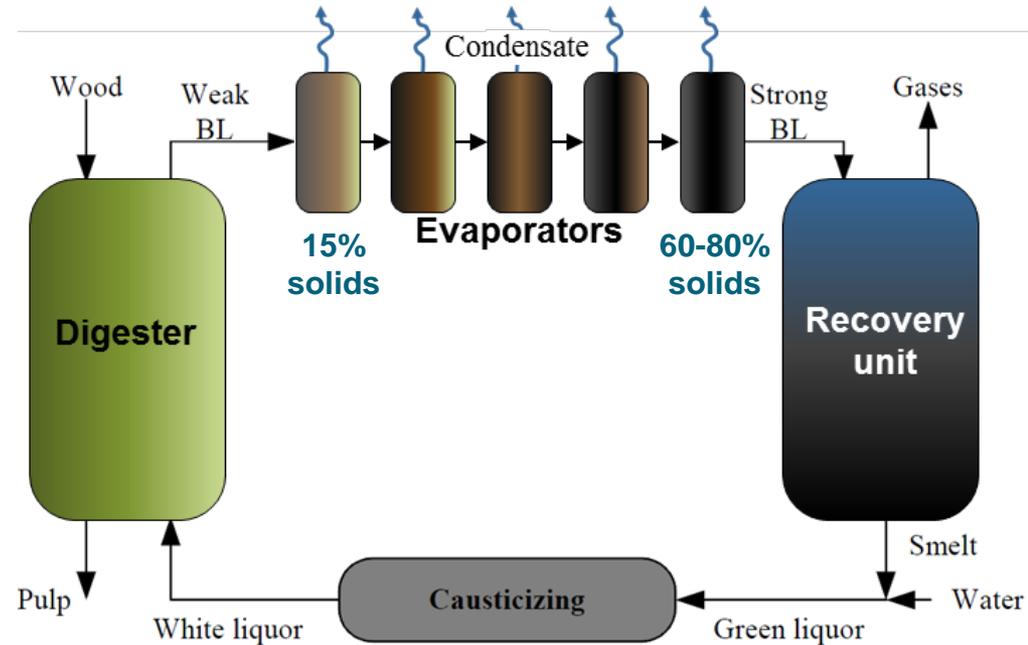
Goal

- Reduce energy consumption during weak BL concentration via **membrane-based separation of water from BL**

➤ **pressure-driven separation of water saves energy over heat-driven**

Challenges

- Membrane clogging and fouling from organics and ions is a major problem
- Fouling increases operational maintenance and cost
- Must retain sulfate (recycled by reducing to sulfide) and organics (burned in recovery boiler to generate energy and reduce sulfate)
- Membrane must sustain hot ($>85^{\circ}\text{C}$) BL at pH of 13-14



Innovation: Black Liquor Concentration

Current technologies

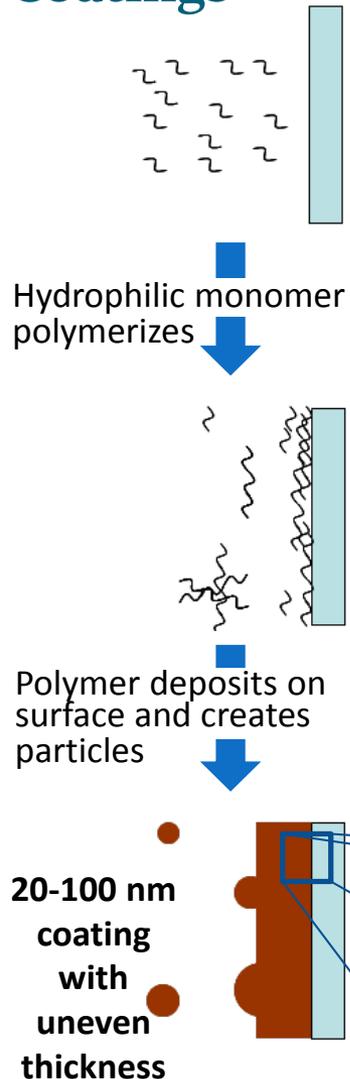
- **400 TBtu/year** required by pulp & paper industry to concentrate weak black liquor using multi-effect **evaporators**
- Membrane-based systems limited to separating lignin from weak black liquor
 - Feed is destructive (pH 12-14, 85 °C)
 - Membrane fouling (small organics, high dissolved solids)

Teledyne technology

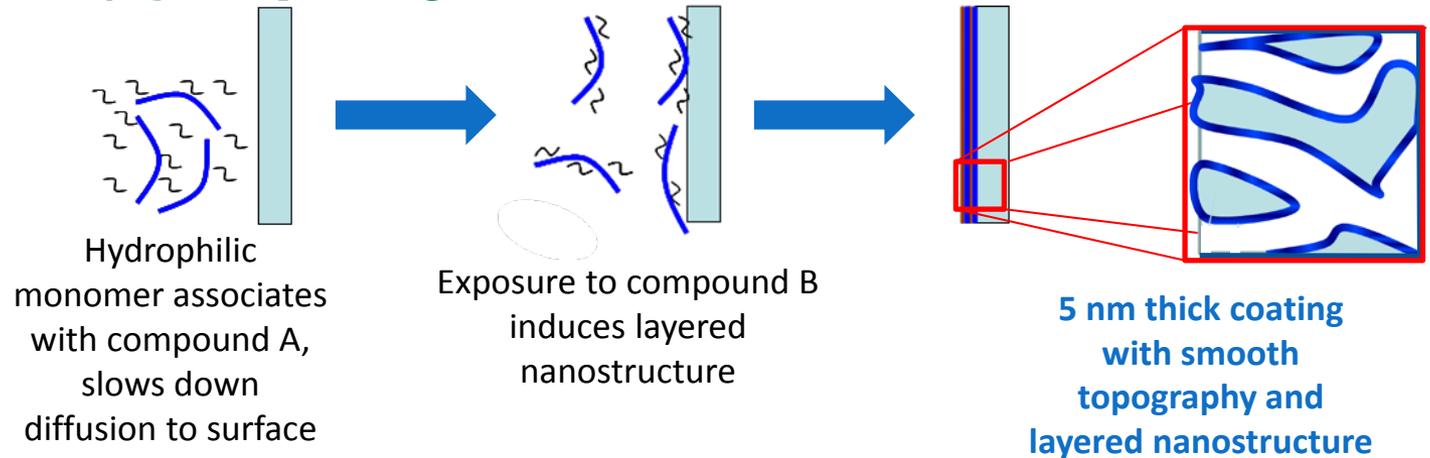
- Anti-fouling membrane coating that can be regenerated *in-situ* saves energy and cost of weak black liquor concentration
 - Protects underlying membrane from destructive feed (makes membranes feasible)
 - Mitigates membrane fouling (decreases maintenance and capital cost)
 - Tunes permeability of salts using charged coatings

Innovation: Coating Technologies

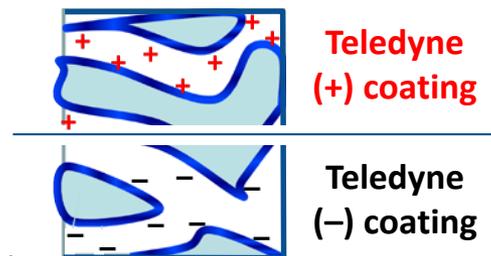
Conventional Coatings



Teledyne Coatings



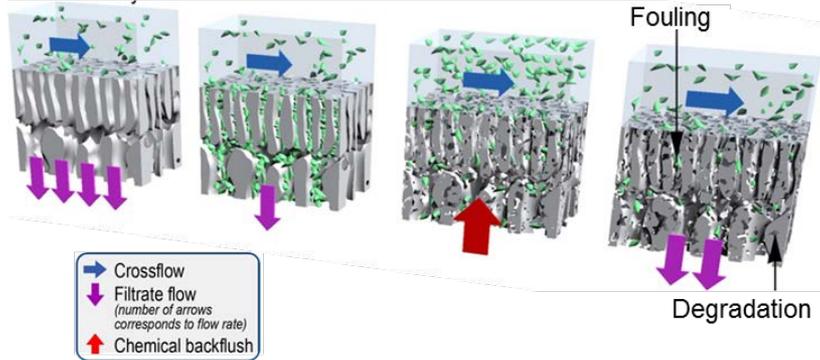
- Conventional technologies result in coatings on membrane surface due to monomer polymerization in solution
- Teledyne technology controls reaction kinetics
 - Monomer deposits on membrane surface and pore walls
 - Polymerization occurs after monomer deposition
 - **Membrane surface and pore walls are coated**
 - Can control surface charge to tune ion rejection



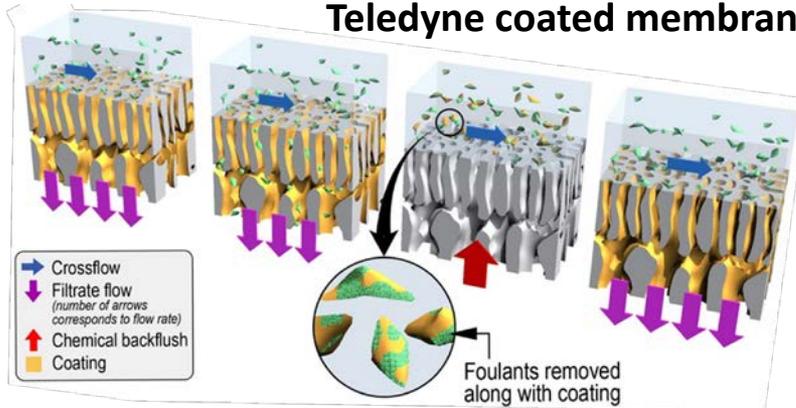
Approach: Anti-fouling coatings for BL concentration

Sacrificial anti-fouling coating

Existing low cost polymeric membranes

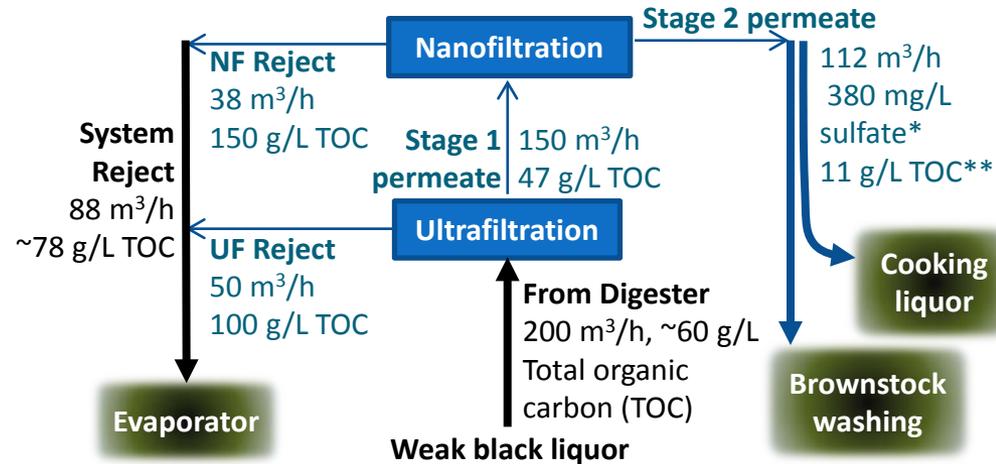


Teledyne coated membrane



- Teledyne process coats surface and pore walls
- Resists BL fouling (foulants adhere weakly to coating)
- Coating is periodically re-applied in the field
- Result is higher flux, higher recovery, and lower maintenance

Process Flow



Participants

- Agenda 2020 (paper industry consortium)
 - Economic models, business plans
- WestRock Company (paper manufacturer)
 - Provide WBL, manufacturing insight

Risk/Mitigation

- Sulfate loss to pulp during brownstock washing
 - Introduce permeate to washer and condensate to final washer
- TOC buildup during cooking
 - Scrub organics from permeate

Transition (beyond DOE assistance)

Pulp & paper industry

- 3rd largest energy-using manufacturing sub-sector in U.S.
 - Accounted for 7% of total U.S. industrial energy
 - Goal: double energy productivity and reduce manufacturing energy demand from 23 MBtu/ton to 11.5 MBtu/ton by 2030

Teledyne sacrificial protective coating

- If first two stages of evaporators are replaced with membrane separation
 - ~**55 TBtu/yr reduction in energy**
- Estimated payback period for membrane-based WBL concentration:
3-4 years
- TRL 5 validation at a pulp and paper mill begins July 2017
 - Enables continued development beyond TRL 5
- Teledyne pursuing other adjacent areas, e.g. filtration of frac water in Oil and Gas
 - Assists in adoption of membranes

Measure of Success

Through the end of this program (August 31, 2017)

- **TRL 5** demo at pulp and paper mill site
- Confirmation of quantified energy savings to end-user

Beyond this program

- Development of **TRL 7** prototype: will require funding beyond this program from DOE and/or paper industry
- Energy savings estimated by paper consortium
 - Reduction in energy from 3.5 MMBtu/adt to <2.8 MMBtu/adt

Project Management & Budget

- Project duration: 36 months (Ending August 31st)
- Progress measured by quantitative milestones
 - October 31, 2016: Document optimal parameters for in-place coating and backflushing
 - August 31, 2017: Demonstrate black liquor treatment process for >7 days with <20% drop in total flux with semi-automated backflush, chemical clean, and in-place coating reformation

Total Project Budget	
DOE Investment	\$ 2,109,297
Cost Share	\$ 973,888
Project Total	\$ 3,083,185

Results and Accomplishments

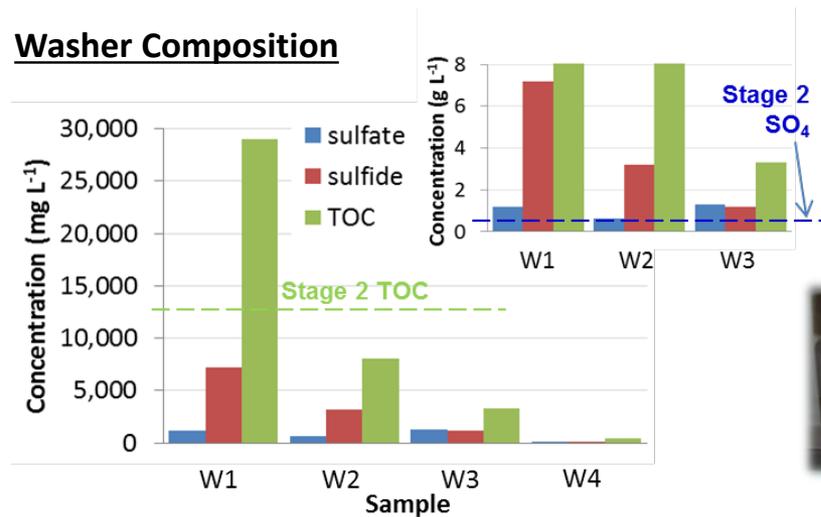
Milestone 5 successfully completed

- Optimal parameters for in-place coating documented

Membrane permeate quality comparable to pulp wash

- Possible to wash pulp using permeate at W2 or W1

Washer Composition



Vacuum Drum Washer



Remaining work

- Integrate TRL 5 membrane system in trailer
- Transport trailer to paper mill
- Demonstrate membrane-based weak BL concentration at WestRock paper mill in Covington, VA

