Spring 2015

Development of Anti-Fouling, Anti-Microbial Membranes by Chemical Patterning

Steven Weinman
Clemson University

Na Li
Clemson University

Viatcheslav Freger
Israel Institute of Technology

Moshe Herzberg
Zuckerberg Institute for Water Research

Scott Husson
Clemson University

Development of Anti-Fouling, Anti-Microbial Membranes for Wastewater Treatment

Steven Weinman[a], Na Li[a], Viatcheslav Freger[b], Moshe Herzberg[c], Scott Husson[a]

[a]Department of Chemical & Biomolecular Engineering, Clemson University, Clemson, SC 29634

[b]Wolfson Department of Chemical Engineering, Technion - Israel Institute of Technology, Haifa, 32000 Israel

[c]Zuckerberg Institute for Water Research, Ben Gurion University of the Negev, Sede-Boqer Campus, Midreshet Ben Gurion, 84990 Israel

Introduction

- Over **1 billion people** lack access to clean drinking water.
- Treatment of impaired waters exposes membranes to feed waters containing biological and abiotic species, which leads to **fouling and loss of membrane productivity over time**.
- Fouling is one of the **largest costs** associated with membrane processes in water treatment.

Hypothesis

Combining **chemical coating** (Figure 1) **and patterning** (Figure 2) will yield membrane surfaces that are **more effective** at fouling control than either method alone.

Resists live microorganisms (PASSIVE) and releases dead microorganisms

Kills adsorbed microorganisms (ACTIVE)

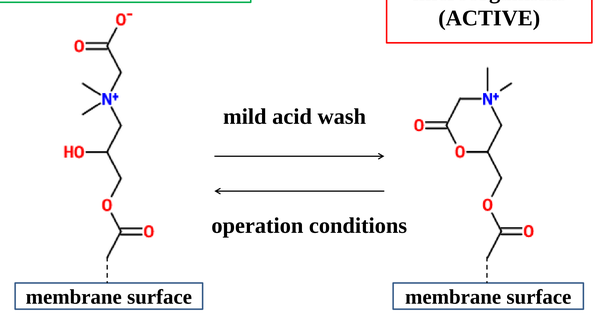


Figure 1. Reversible coating chemistry. **Our strategy differs fundamentally from most other surface modification strategies** that rely solely on passive control or active control (e.g., adding biocides).

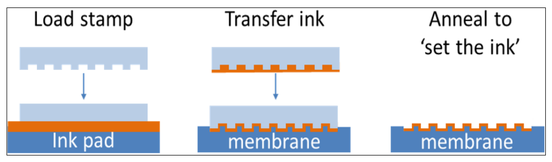
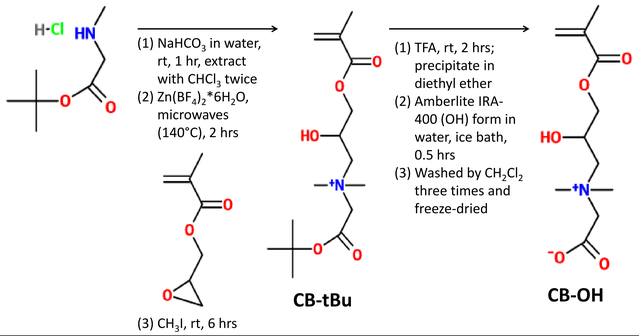


Figure 2. Methods of combining chemical coating and patterning on a membrane surface by deformation (i.e., embossing) of the membrane substrate. Test ink is a poly(ethylene glycol) diglycidyl ether solution in water.

Enabling Chemistry



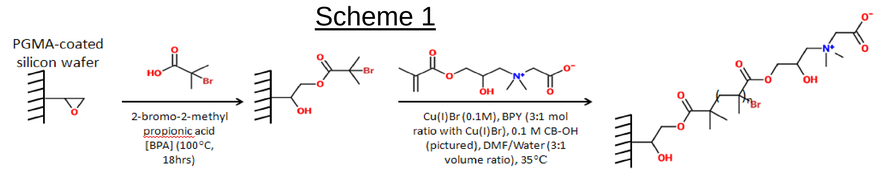
Overall Project Objectives

- Prepare and characterize membranes with surfaces that can switch reversibly between passive and active modes
- Evaluate surface chemistry effects on membrane performance
- Evaluate anti-fouling, anti-microbial function of membranes
- Prepare membranes that are patterned uniformly with chemical coatings that are chosen to limit fouling
- Evaluate the effects of patterning on membrane performance
- Evaluate the anti-fouling function of the chemical patterns

Surface Modification Fundamentals

- Scheme 1 illustrates the surface modification strategy that uses surface-initiated ATRP

Scheme 1



- Figure 3 illustrates the surface modification strategy that uses a stamp.

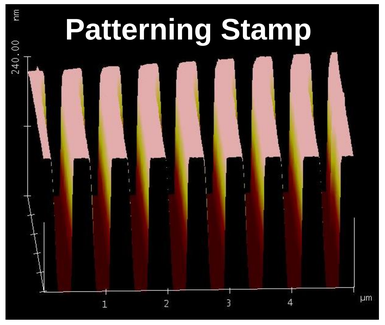
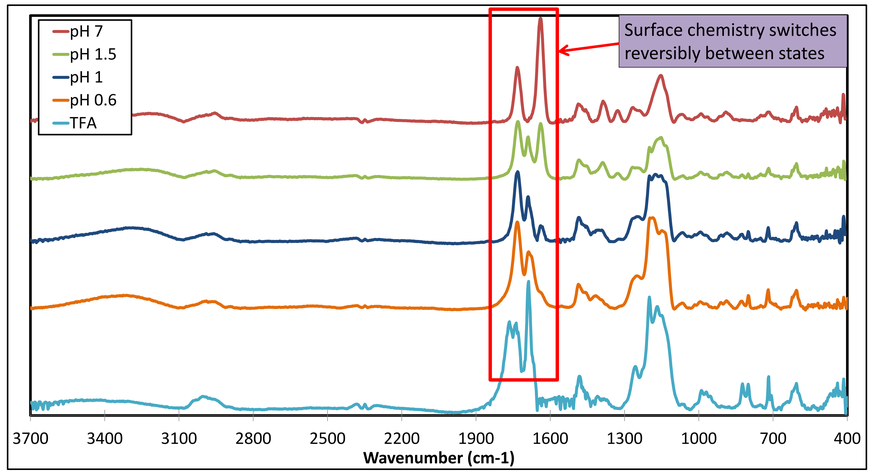


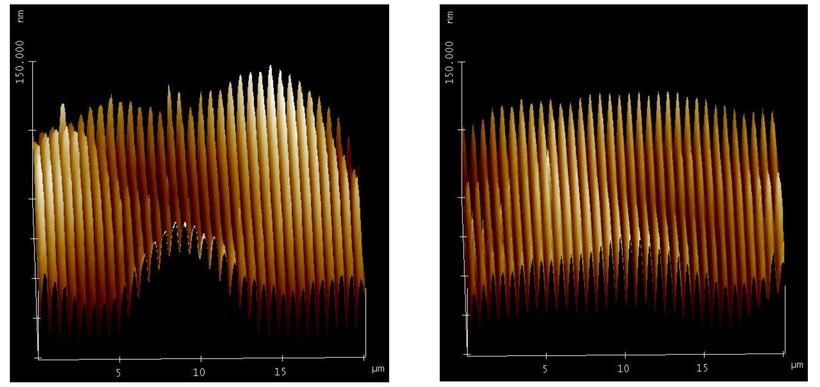
Figure 3. Surface morphology of a linear silicon nanostamp used for patterning membrane surfaces.

In this example, the stamp dimensions are:
Period: 625nm
Line width: 215nm
Groove depth: 250nm

Transmission FTIR



Atomic Force Microscopy Images



No reaction, 60°C, 30 min | 50 wt%, 60°C, 30 min

Figure 4. Effectiveness of creating a pattern on the membrane while deforming the membrane substrate. Common scale is 20 μm × 20 μm × 150 nm. The left image has an average channel height of 51 ± 19 nm, while the right image has an average channel height of 67 ± 11 nm.

Summary of Current Work

- **CB-OH** was **synthesized** successfully
- **Polymerization** of CB-OH was **successful** from silicon substrates
- FTIR showed **successful, reversible switching** between CB-OH and CB-Ring
- PEGDE test ink was **successfully patterned** onto membranes

Future Work

- **Vary initiator density** and measure resulting polymer chain densities and possible effect on switching pH
- Perform polymerization from **glass and QCM sensors** for bacterial deposition and release studies
- Perform polymerization from **NF and RO membranes** and test performance.
- Develop **polymeric stamp** for patterning membranes
- Test fouling performance with **colloidal particles and proteins**
- Investigate effectiveness of **different patterns and chemical coatings**

Acknowledgements

- This work was supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1246875. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.
- We thank the US-Israel BARD Foundation for financial support through Research Grant Agreement No. US-4654-13
- 2014 Tiger Grant Award Proposal Award