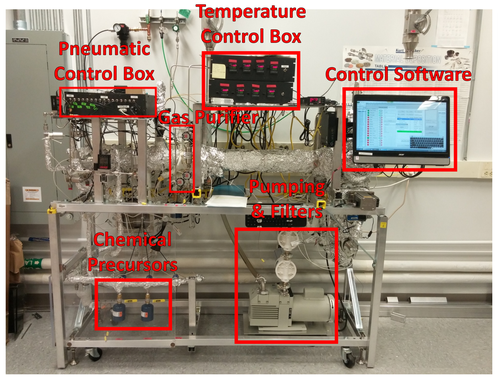
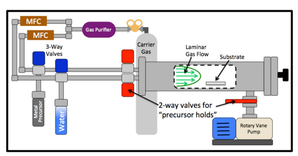
The Losego PUMP Lab

Phenomenological Understanding of Material Processes

Reactor Design & Construction

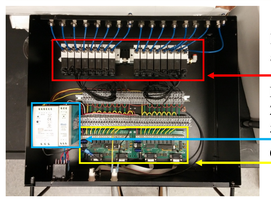




Homemade reactor is capable of both atomic layer deposition (ALD) and vapor phase infiltration (VPI). Gate valves (shown in red in diagram above) can hold precursor gases inside the main chamber.

LabVIEW software communicates with pneumatic control box, which sends air pressure signals to valves.

Thermocouples work in conjunction with temperature control boxes.

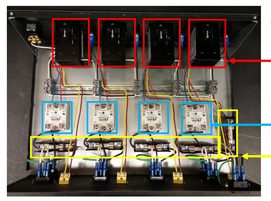


Pneumatic actuators and manifolds

Power converters
24 VDC (wide)
5 VDC (thin)

Control cards

Inside a pneumatic control box



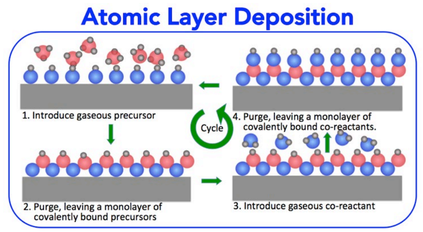
Temperature Controllers

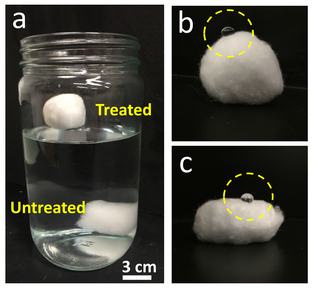
Solid State Relays

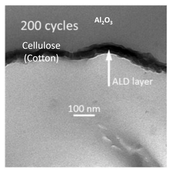
Fuse-blocks

Inside a temperature control box

Atomic Layer Deposition (ALD)







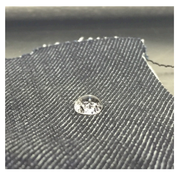
← Conformal surface coating of alumina on cotton fiber

We are able to convert cellulosic fibers from hydrophilic to hydrophobic using a single exposure cycle that takes < 1 min.

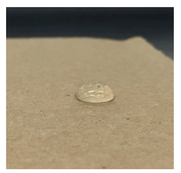
This effect is irrespective of the cellulose's form factor because gaseous precursors can diffuse everywhere!

(a) Cotton

(b) Paper

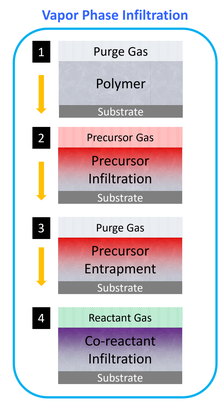


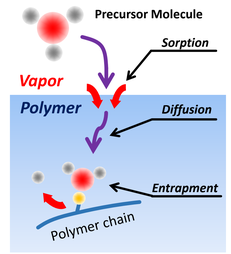
(c) Denim



(d) Cardboard

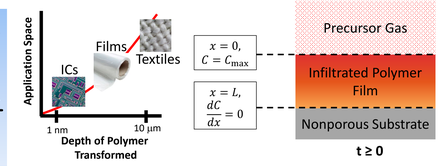
Vapor Phase Infiltration (VPI)



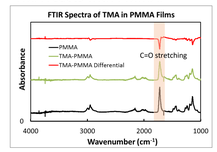


Mathematical modeling can help guide experiments of different depths and chemistries.

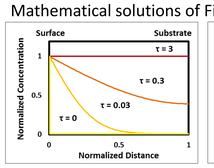
$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

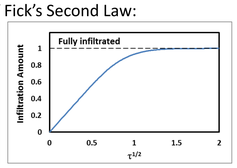


TMA reacts with PMMA:

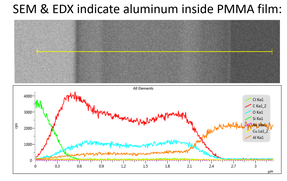


Mathematical solutions of Fick's Second Law:

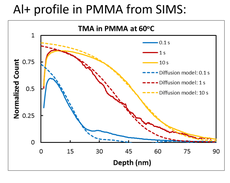




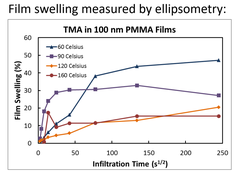
SEM & EDX indicate aluminum inside PMMA film:



Al+ profile in PMMA from SIMS:



Film swelling measured by ellipsometry:



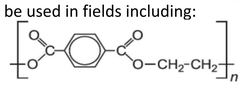
Precursor:
Trimethylaluminum (TMA)

Polymer:
Poly(methyl methacrylate) (PMMA)

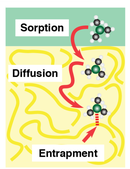
Applications of Organic-Inorganic Hybrid Materials

Vapor phase infiltration is a process that can alter the mechanical, chemical, and optical properties of a polymer. The created organic–inorganic hybrid material can be used in fields including:

- Microelectronics
- Energy Storage
- Smart Fabrics

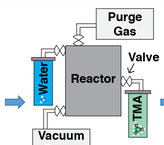


This research was inspired by observing color changes over time of VPI treated polyethylene terephthalate.



Vapor Phase Infiltration (VPI)

Before VPI



After VPI

Precursor:

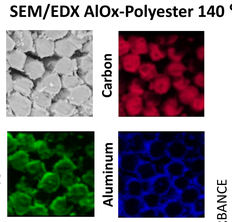
Trimethylaluminum (TMA)

Oxidant:

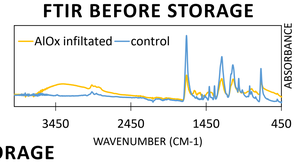
Water

Characterization of AlOx-Polyester Hybrid Fabrics

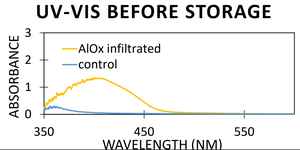
SEM/EDX AlOx-Polyester 140 °C



FTIR BEFORE STORAGE

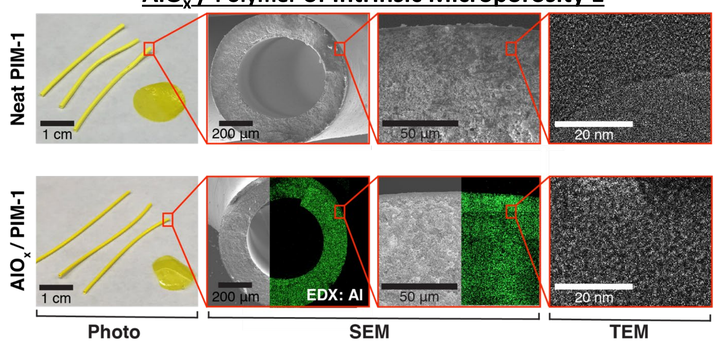


UV-VIS BEFORE STORAGE

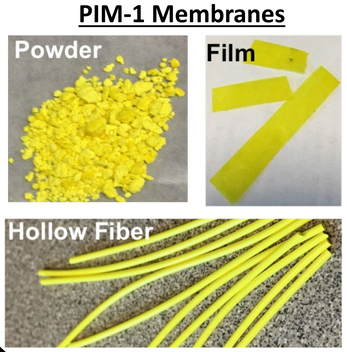


Hybrid Membranes for Chemical Separations

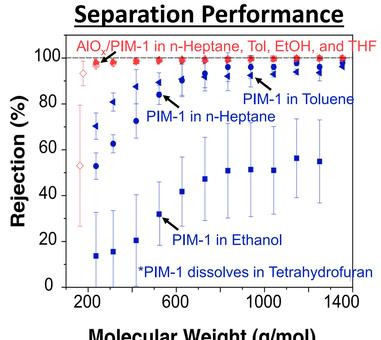
AlO_x / Polymer of Intrinsic Microporosity 1



PIM-1 Membranes

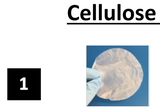


Separation Performance

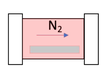


Functionalized Cellulose

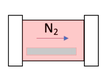
Cellulose Nanofibers



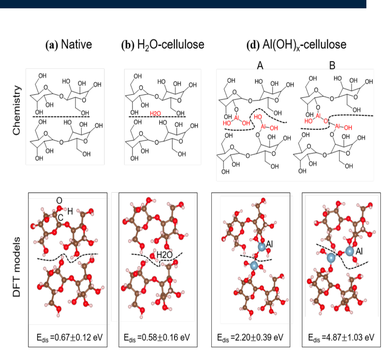
1. *Vacuum filtration to prepare cellulose sheets from cellulose nanofibers*



2. *ALD chamber heating for 3h to remove excess water*



3. *ALD reaction with trimethylaluminum at 120°C*



1) In an aqueous environment, water molecules bind to the CNFs, forming water "cages" around the cellulosic chains, disrupting the cellulose-cellulose hydrogen bonds and replacing them with water-cellulose hydrogen bonds.
2) We find that the M-OH terminations lead to stronger ion-induced dipole interactions between Al and OH groups compared to the interactions between two hydroxyls on pure cellulose.