Bonding of membranes by viscous polymers: Infiltration kinetics and its impact on mechanical integrity of the bonded polymer/membrane structure

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Motivation
Ultrafiltration (UF) or microfiltration (MF) membranes are bonded with a thermoplastic polymer for insertion to housing/casings. However, under normal operating conditions, these bonded filters fail or blister causing leakage.

Infiltration Verification for 200 nm via AFM
(a) Optical image of the cross-section of a PES_U and PP bonded at 180 °C for 3 min, showing a tri-layer structure. (b) Topography of (a) and (c) modulus map across bonded region.

Thermomechanical Properties

Infiltration Kinetics for symmetric 200nm PES Membranes
The solid and dash lines represent predictions of LW model and Cai model respectively. The Cai model, accounts for membrane structure, pore geometry, α, and tortuosity, r; better estimating for infiltration depth. Lucas Washburn model $L(t) = \frac{\alpha t}{4g(\alpha t)^{1/2}}$ Cai model $L(t) = \frac{\alpha t^{2}}{4\pi r_{0}^{2}b_{0}^{2}}$ $180 °C$

Infiltration Kinetics for asymmetric 20nm PES Membranes
The PES asymmetric structure (above a.) possesses a range of pore radii. Upper and lower bound Cai model prediction curves account for such and are presented to the right. PP is in contact with the surface imaged above, presenting a surface porosity of 3.6%.

Post Peeling Membrane Surface Scans for 20 nm

T-Peel test Failure Behavior for 20 nm and Peel Force Achieved
(a) Complete Peel (b) Incomplete Peel (c) Membrane Failure
The bonding strength of PP/PES for 20 nm presented 3 types of failure. The bond strength is loosely related to infiltration depth.

Conclusions
Capillary infiltration kinetics were found for modified, MF, polyethersulfone (PES) membranes with nominal pore sizes of 200 nm and 20 nm.

Infiltration kinetics were better described by the Cai model that takes into consideration membrane structure characteristics. Chemical modification did not alter bonding ability with polypropylene. AFM scan showed a tri-layer structure presence within the bonded region PP/PES with corresponding modulus values. The bonding strength of PP/PES, i.e. peak load (d), was loosely related to infiltration depth and is instead dominated by the strength of the membrane.

Research Objective
✓ Understand the infiltration kinetics of a viscous polymer in porous membranes.
Specifically, what is the influence of membrane asymmetry, hydrophilicity as well as bonding time, and temperature?
✓ What is the mechanical integrity for those bonded regions (i.e. polymer/membrane structure)?

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Infiltration time (hr)
Infiltration depth (um)
"ab" Complete Peel Incomplete Peel Membrane... T Complete Peel Incomplete Peel Membrane Fail Force (N)
Infiltration Depth (um) Peeling Force vs Infiltration Depth

T-Peel test set-up. b) the force distance curve representing the peak force achieved. c) image of membrane failure at the bonded interface. (d) Infiltration depth vs peak load achieved in (b)