

Micro Gas Generator for Ethanol Vapor

PTFE vs. PDMS Membrane Performance

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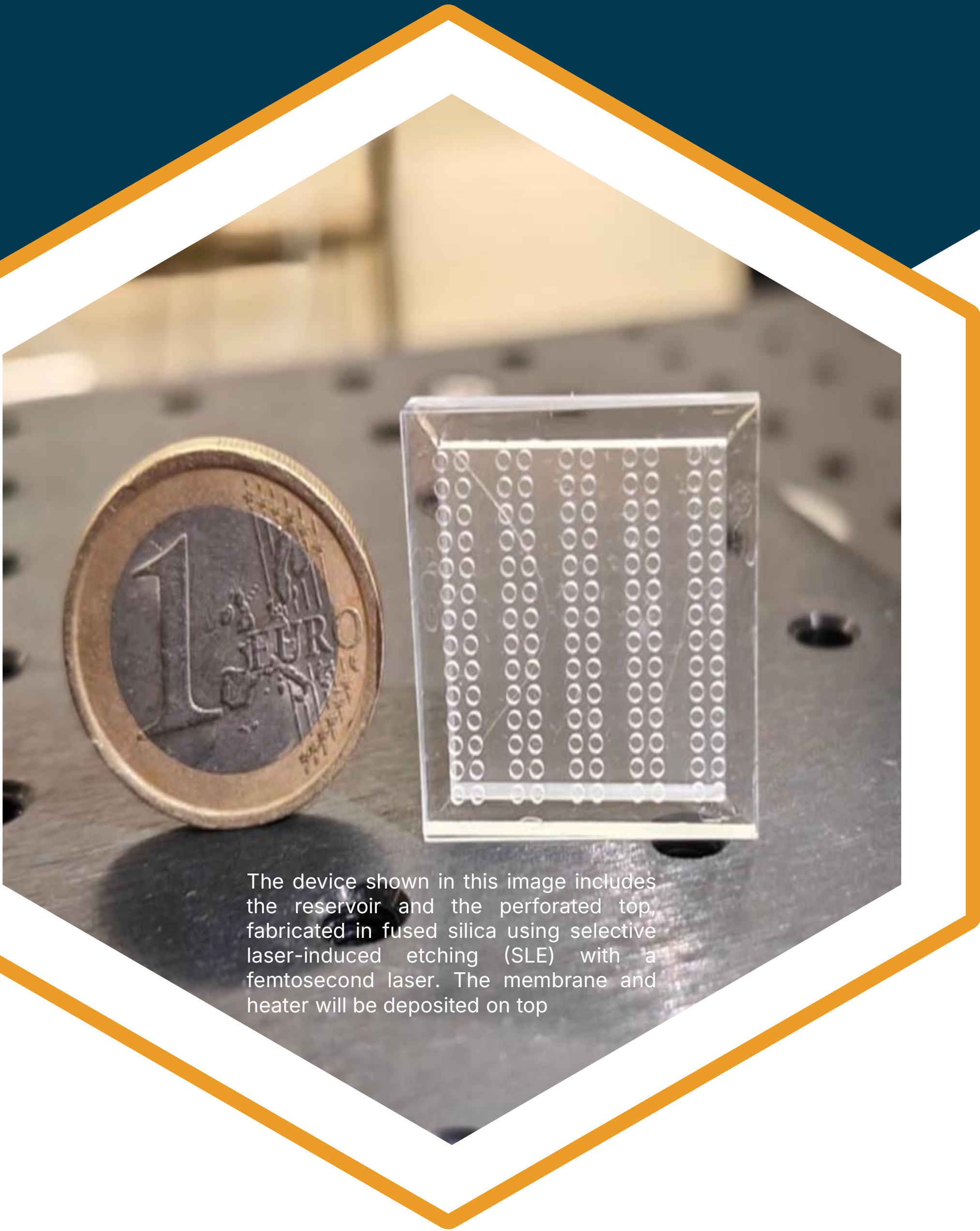
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Summary

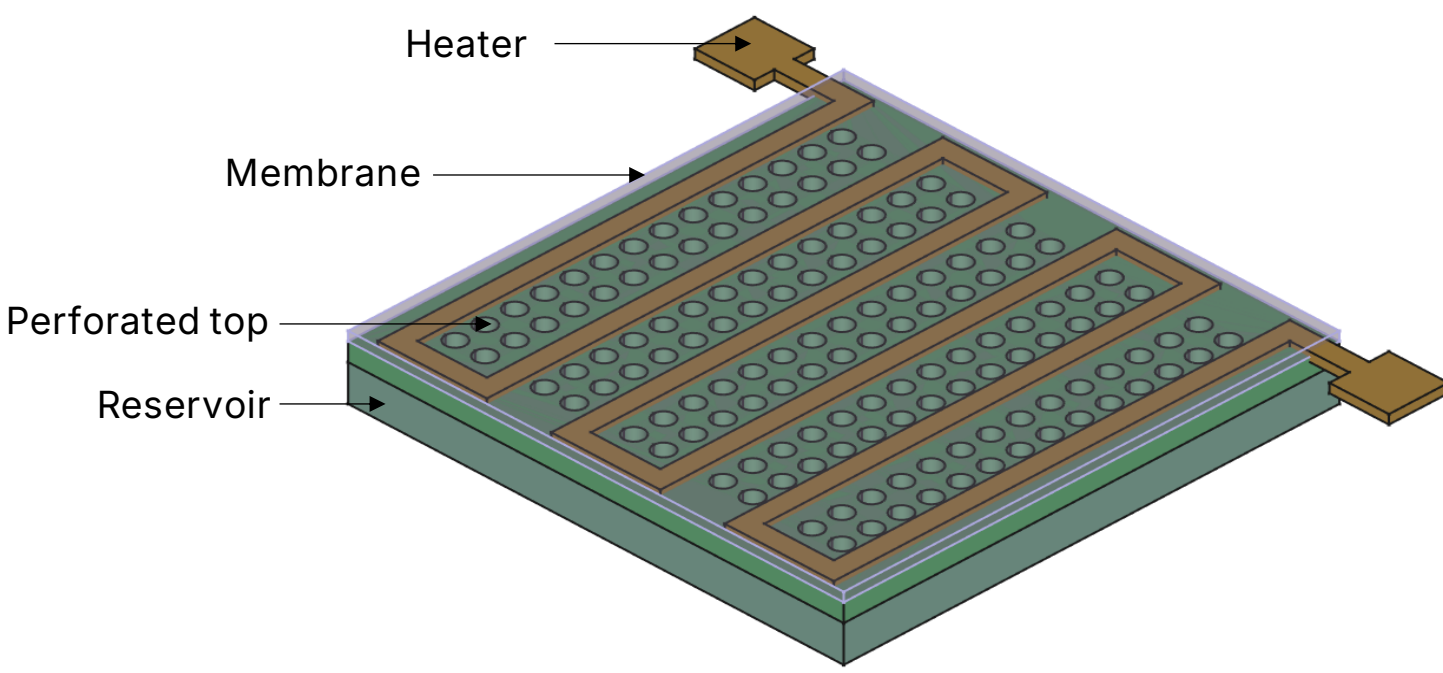
This work compares PTFE and PDMS as membrane materials for a micro gas generator, with the aim of replacing PTFE with PDMS. Using COMSOL Multiphysics®, molar concentration and flux of ethanol permeating through the membrane into the ambient are investigated under pulsed heating conditions. Complementary simulations of surface temperature and heat flux are carried out to define suitable heater parameters for the device.



The device shown in this image includes the reservoir and the perforated top, fabricated in fused silica using selective laser-induced etching (SLE) with a femtosecond laser. The membrane and heater will be deposited on top.

Introduction/Background

Micro gas generators produce controlled ethanol vapor from a heated reservoir sealed by a permeable membrane, used as compact calibration sources for gas sensors. PTFE (polytetrafluoroethylene), the conventional membrane material, is chemically inert but belongs to the PFAS family, raising concerns over environmental persistence and toxic decomposition products under heating.



Experiments/Methods

This study evaluates PDMS (polydimethylsiloxane) as a PFAS-free alternative to PTFE, comparing the two membranes under identical geometry and temperature conditions in terms of Molar flow behavior, ethanol flux, and thermal response.

COMSOL Multiphysics® Model

Heat Transfer In Solids & Fluids

Models conduction through the reservoir, substrate, and membrane.
Nested within it: Heater parameters

Chemical Species Transport

Transport of Diluted Species
Transport of Diluted Species in Porous Media
Nested within it: Diffusion

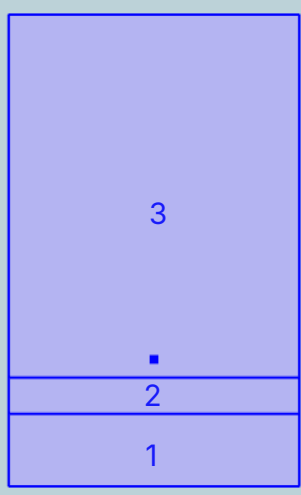
Fluid flow

Porous media and subsurface flow.
Nested within it: Permeation

Domains, Boundaries & Initial Values

Domains from bottom to top:

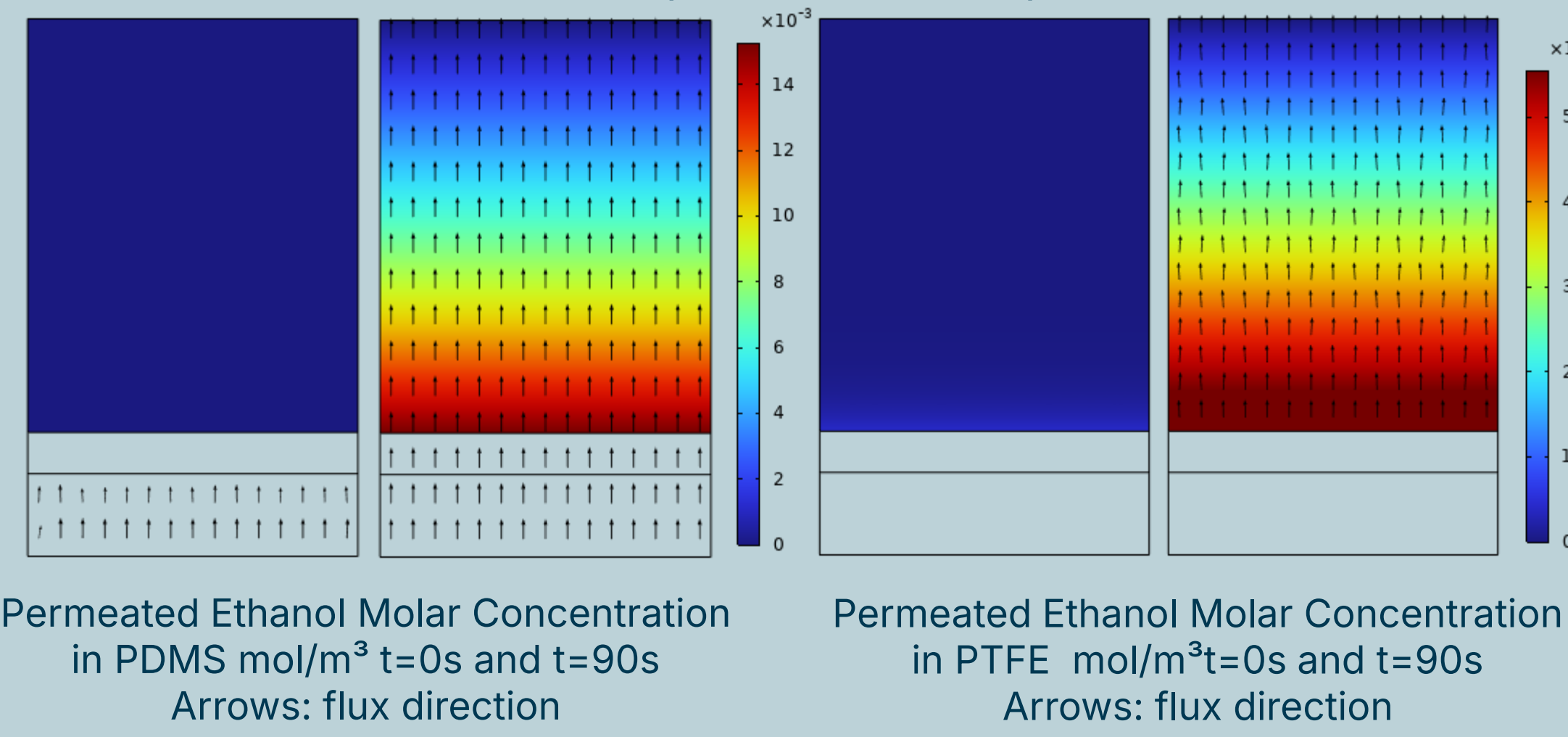
1. Headspace (Ethanol vapor at saturated pressure)
2. Membrane (Material alternated between PTFE and PDMS)
3. Ambient.



Point above membrane for evaluation.
Heater (pulsed T), saturated vapor concentration (Antoine equation) applied at reservoir boundary; ambient T and $C_{\text{ETOH}} = 0$ at outer boundary; insulated/no-flux side walls; initial $T = 293.15\text{K}$, $c = 0$ throughout.

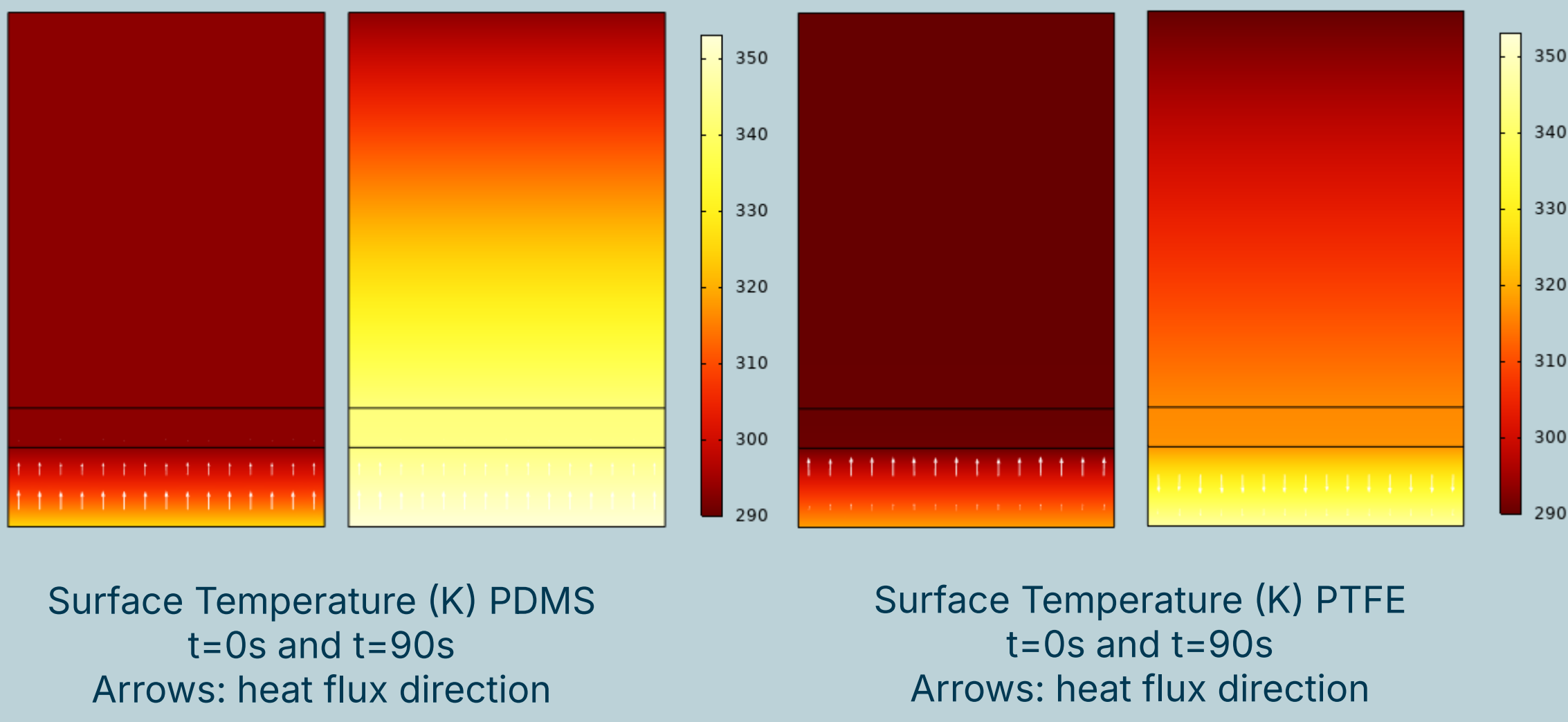
Surface Concentration

- PDMS: dense membrane, Fickian solution-diffusion: Transport of Diluted Species interface*
- PTFE: porous membrane (0.3–0.7 μm pores), Knudsen + molecular diffusion Transport of Diluted Species in Porous Media**



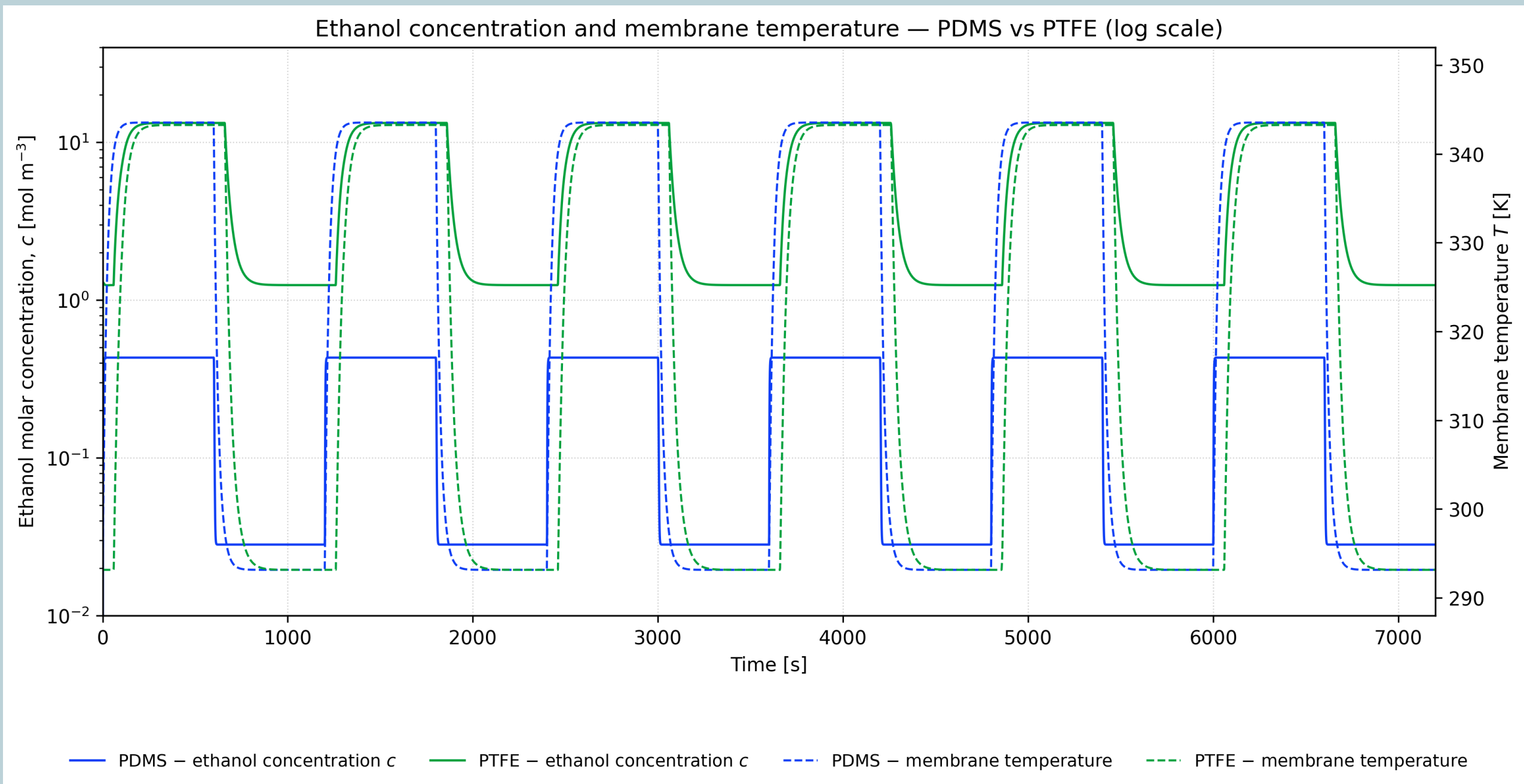
Surface Heat Transfer

- Thermal response is comparable between PDMS and PTFE



Permeance Comparison

- Ethanol molar concentration evaluated at a point on the ambient side, 0.5 mm from the membrane surface, under pulsed heating



Next Steps

- PDMS membrane deposition
- Heater placement & temperature tuned to PDMS's response
- Device fabrication finalization
- Experimental validation against simulated flux/time-lag

Notes:

* E_D for ethanol in PDMS interpolated from three temperature literature diffusivity data; not independently measured across multiple temperatures.

** D_0 and E_a for ethanol in PTFE fitted from two-temperature literature diffusivity data; not independently measured across the device's operating range.

Acknowledgements

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