Modeling of nutrient transport through porous Tissue engineering scaffold

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Necrosis in Tissue engineering scaffolds

Today's challenge in Tissue Engineering is building a 3D scaffold of clinical relevance with efficient nutrient transport to the core to minimize necrosis. Necrosis causes non-homogenous tissue formation with cells concentrated at the periphery of the scaffold.

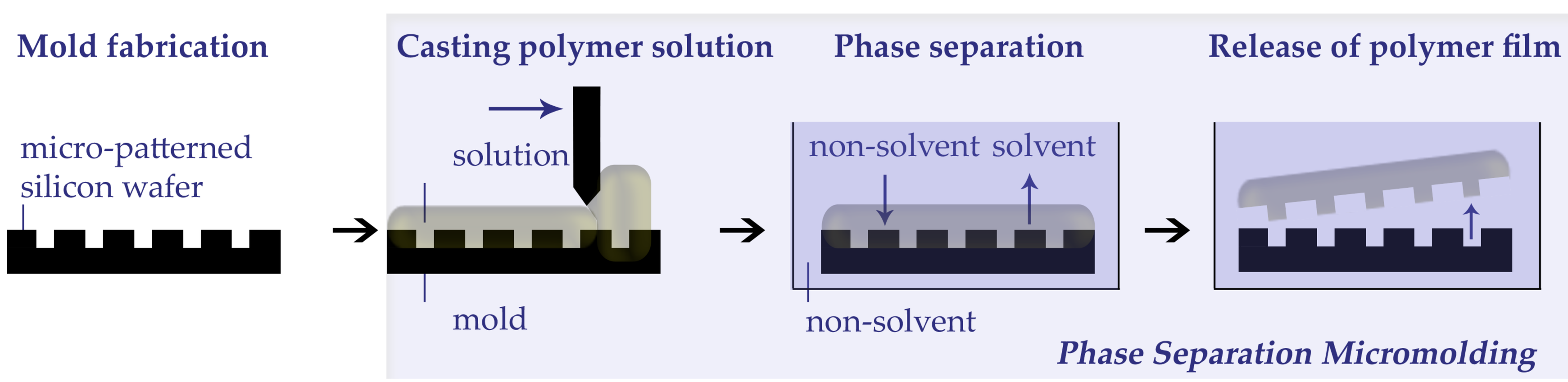


Fig. 1 *Illustration of PSμM flat sheet membrane casting method*

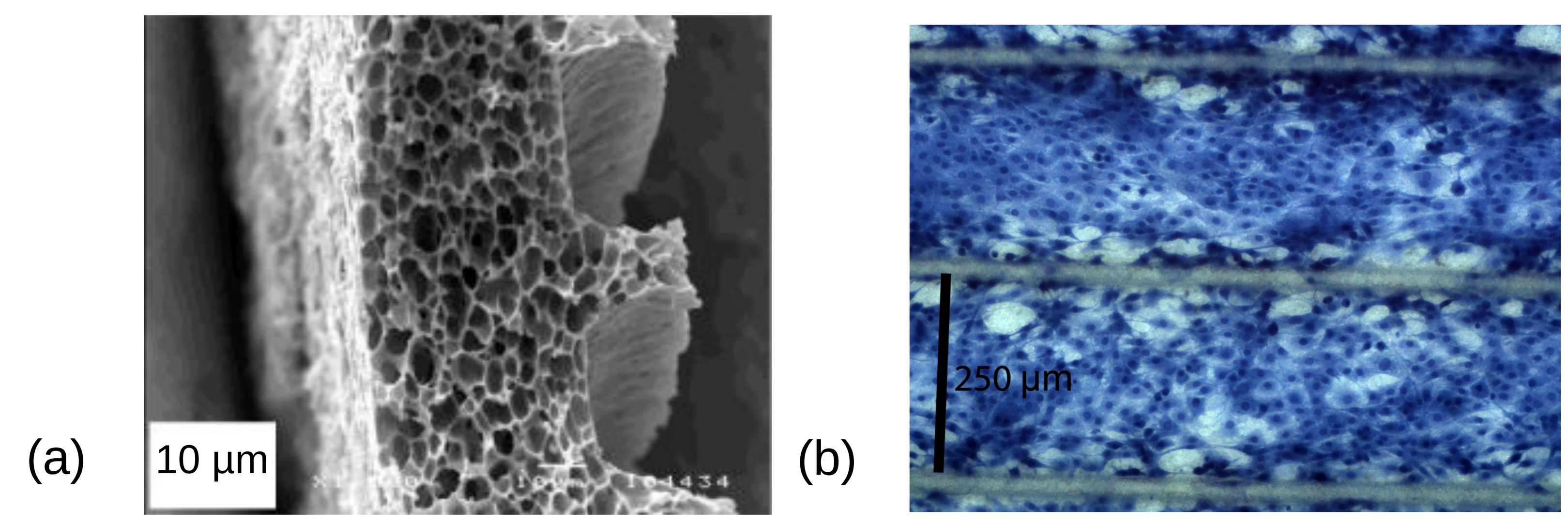


Fig. 2 *(a) SEM picture of PLLA flat sheet porous membrane, (b) Light microscope picture after 4 days of culturing (cell density = 25000cells/cm²)*

Phase separation micromolding (PSμM) (Fig 1) is a process to fabricate porous micro-structured membranes [1]. The channels can be designed to mimic the cell density and alignment within the actual tissue.

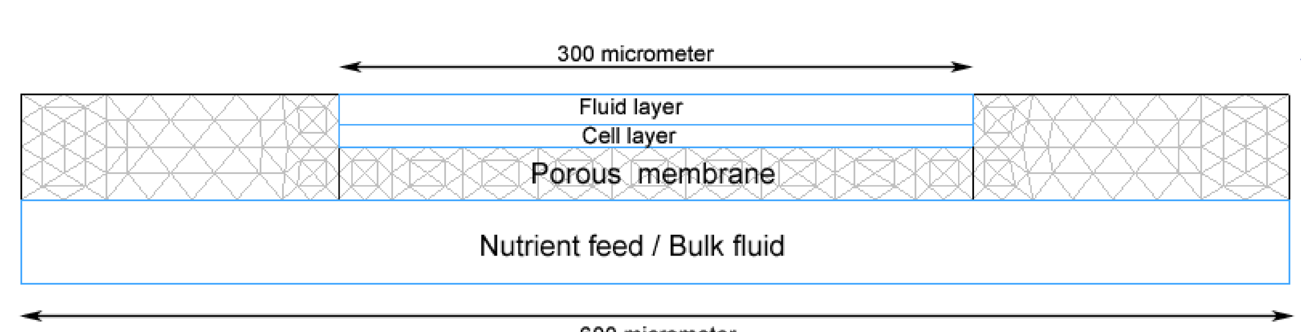
The porous structure within the membrane is used to transport the nutrient (Fig 2a). In-vitro mouse myoblast (C2C12) cell culture experiments (Fig 2b) show the confluent cell growth and alignment within the channels.

Finite Element Method Model

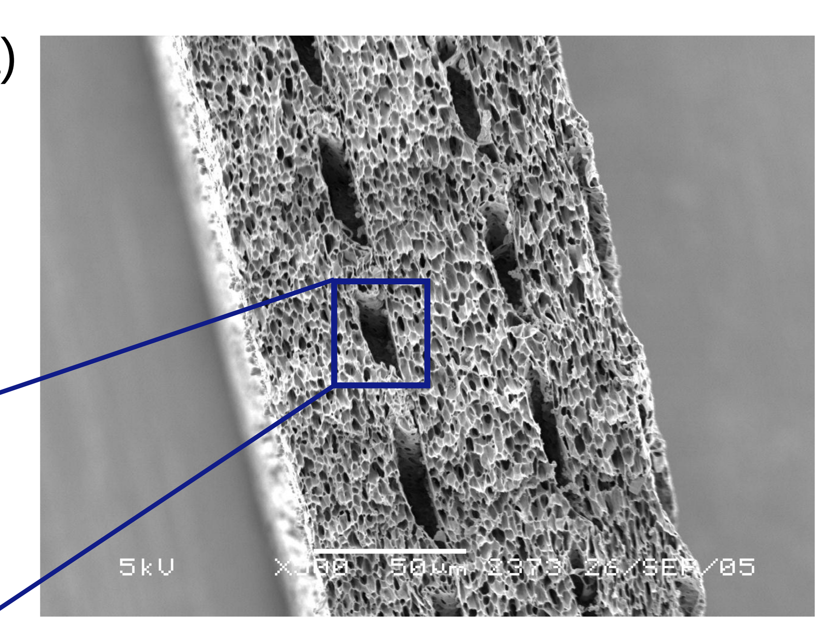
Theoretical analysis of the flow of nutrients through single channel (Fig 3a) are evaluated using COMSOL Multi-physics. The estimated concentration profile indicate efficient nutrient transfer at different time interval (Fig 3b). Similarly Fig 3c depicts mass transfer in a 3D scaffold of 2 cm³.

Model parameters

Cell density	80% of channel area
Bulk concentration	0.055 mol / m³
Diffusion coefficient	8.4 X 10 $^{-11}$ m²/sec
Consumption rate	3.83 X 10 $^{-16}$ mol/m³.sec.cell [2]



3(a)



3(b)

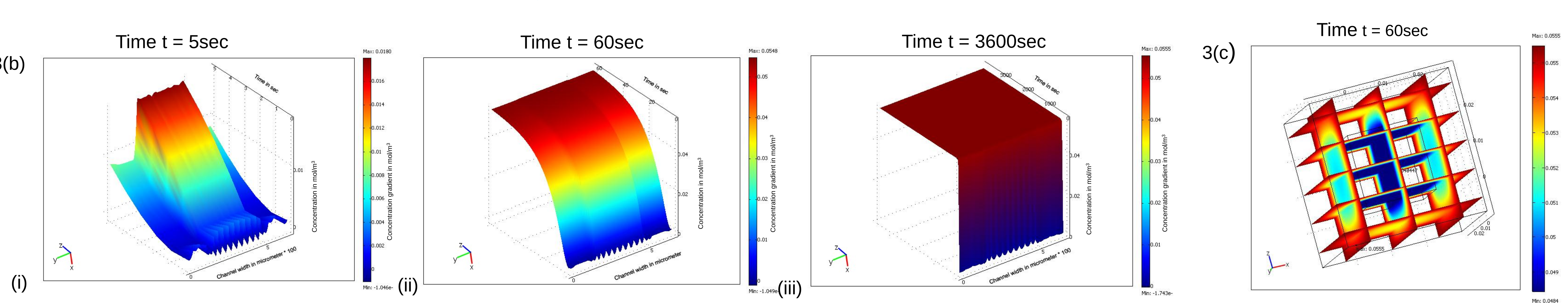


Fig 3. *(a) SEM picture of staked PSμM flat membrane, (b) The predicted concentration profiles through a single channel at different time intervals, (c) Concentration profile through a 3D scaffold of 2 cm³*

Conclusion & Outlook

- The model predicts efficient nutrient transfer within the flat porous membrane and in 3D scaffold of 2cm³
- These porous 3D scaffold could be potentially used for tissue engineering constructs and avoid necrosis
- In-vitro cell culture experiments to confirm the theoretical evaluations *(in progress)*
- Investigation for better seeding techniques, membrane staking and bioreactor design

References : [1] Vogelaar, L., et al. Advanced Materials 15-16 (2003), pp. 1385-1389 ; [2] Hua Ye, et al. Journal of Mem Sci. Vol 272, Issue 1-2, page 169-178