



A Modular Microfluidic Platform for Cell Culture Modeling

Capstone Team: Nabil Ghafour, Joan John, Jocelyn Pineda, Rhea Rajesh

Advisors: Bowen Xu, Dr. Ran An
University of Houston - Houston, Texas



OBJECTIVE

Design and fabricate a microfluidic co-culture platform with versatile interfacing for in-vitro blood vessel modeling.

BACKGROUND

Microfluidic in-vitro modeling has become an important tool for facilitating studies of cells with enhanced physiological relevance.

- By varying the flow rate, these small controlled fluid systems allow for an important biomimetic principle relating to shear-stress to occur. This mechanical force stimuli changes cell morphology and, as a result, intracellular signaling.

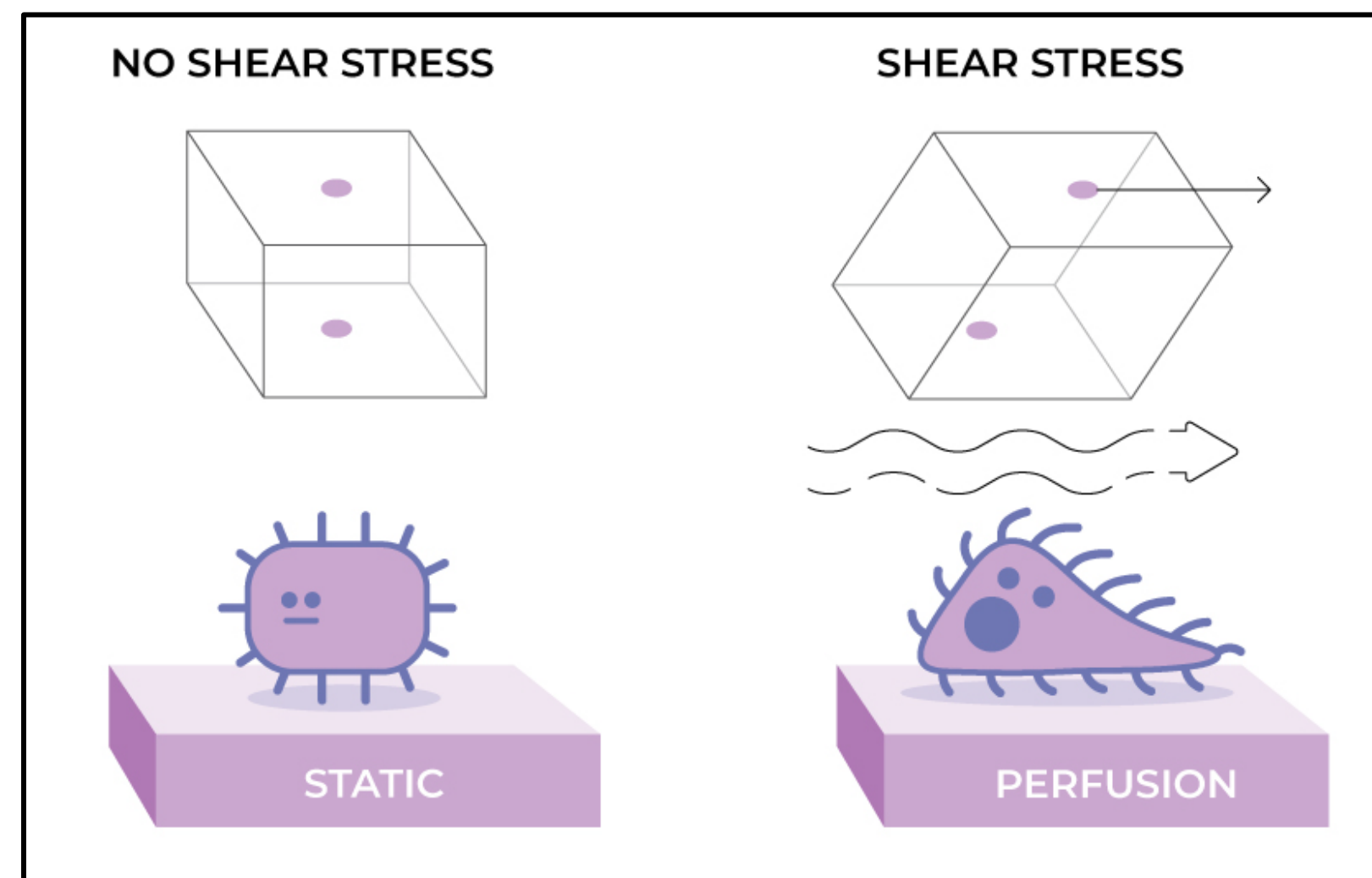


Figure 1 | General schematic of cell elongation under shear-stress conditions

- Existing co-culture platform designs fall under the category of planar vs. vertical architecture.
- Advantages of vertical architecture includes that it more closely mimics existing in-vivo structures and allows for better cell-cell interaction by minimizing the distance between the cultured cell types.
- Current limitations for cell culture microfluidic devices include laborious interfacing, unreliable sealing, expensive platforms, and limited capabilities for co-culture systems.

We present a cost-effective, modular, microfluidic bioreactor to circumvent these problems for the co-culture modeling of blood vessels.

ACKNOWLEDGEMENTS

Our group would like to recognize Dr. Ran An and Bowen Xu for their support in the development of this project, and Dr. Jerome Schultz for his guidance.

METHODS

Design → Theoretical Validation → Fabricate → Test

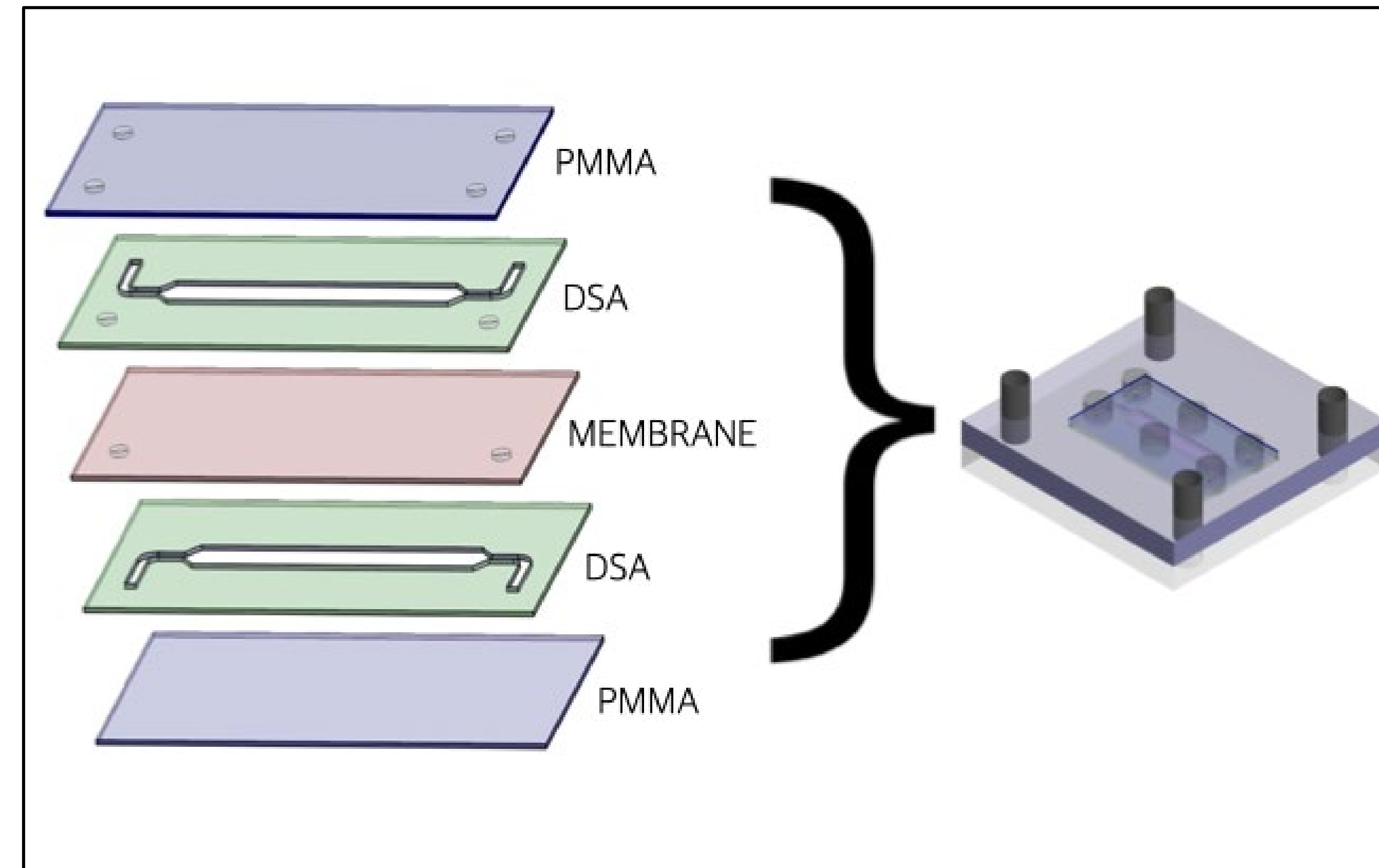


Figure 2 | Microfluidic layer deconstruction and compiled chip in modular clamp

- ✓ The co-culture design takes on a vertical interfacing approach using DSA to form the channel and PMMA which is economical and mechanically stable for seamless integration in the clamp and at the flangeless fittings.
- ✓ The design geometry was then theoretically validated to target the optimal shear-stress on HUVEC cells, focusing 4 dyne/cm^2 [0.4 Pa], and modeling the general velocity field for the tighter junctions using CFD.
- ✓ The chip layers were fabricated using a laser cutter and the clamp was constructed via CNC machining.
- ✓ Following the bioreactors development, laminar flow and cell culture tests were performed to validate theoretical projections across varying flow rates and the targeted $40 \mu\text{L}/\text{min}$.



Figure 3 | CFD Velocity Trajectories of Model

RESULTS

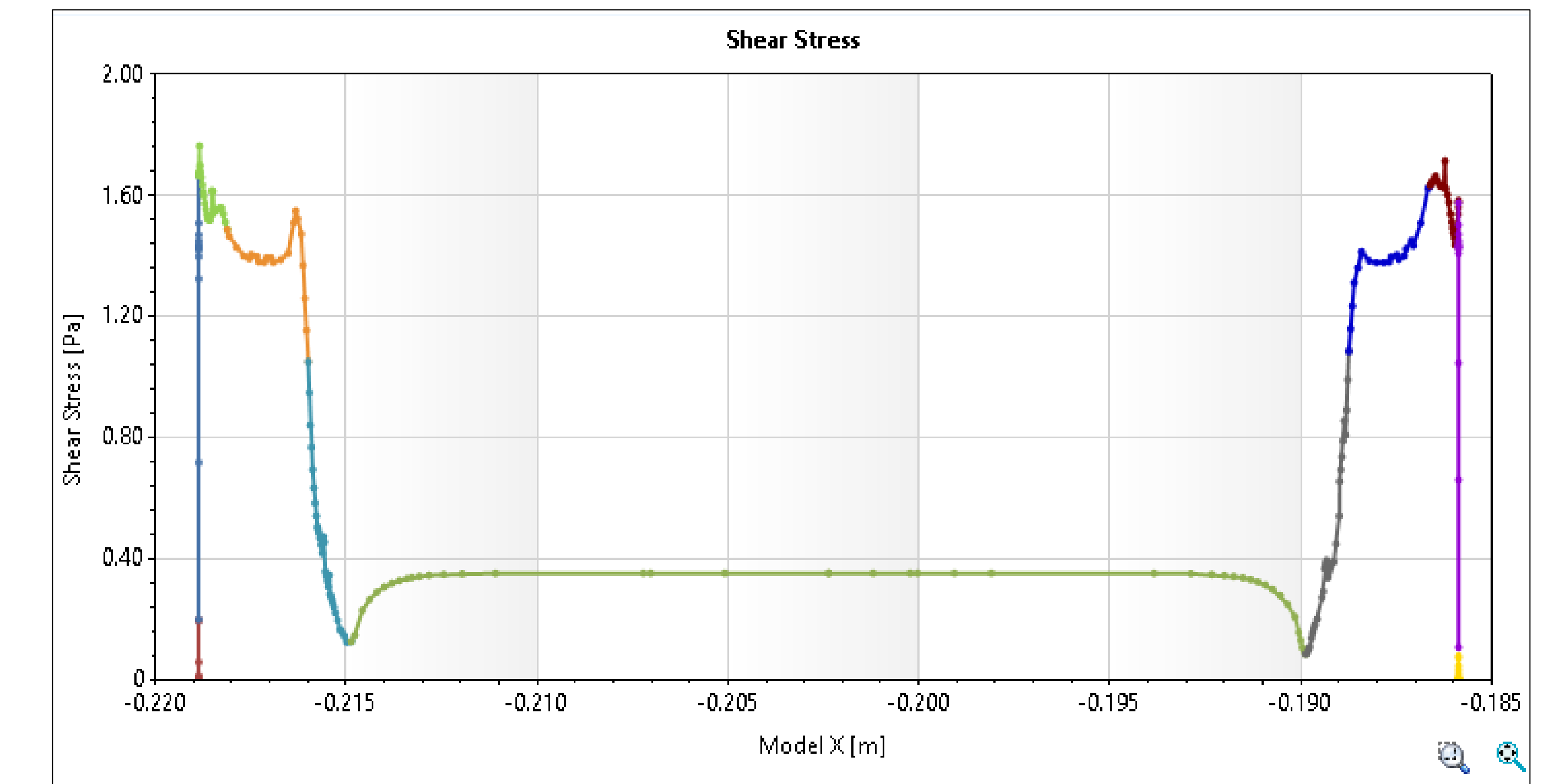


Figure 4 | Theoretical shear stress within co-culture chip

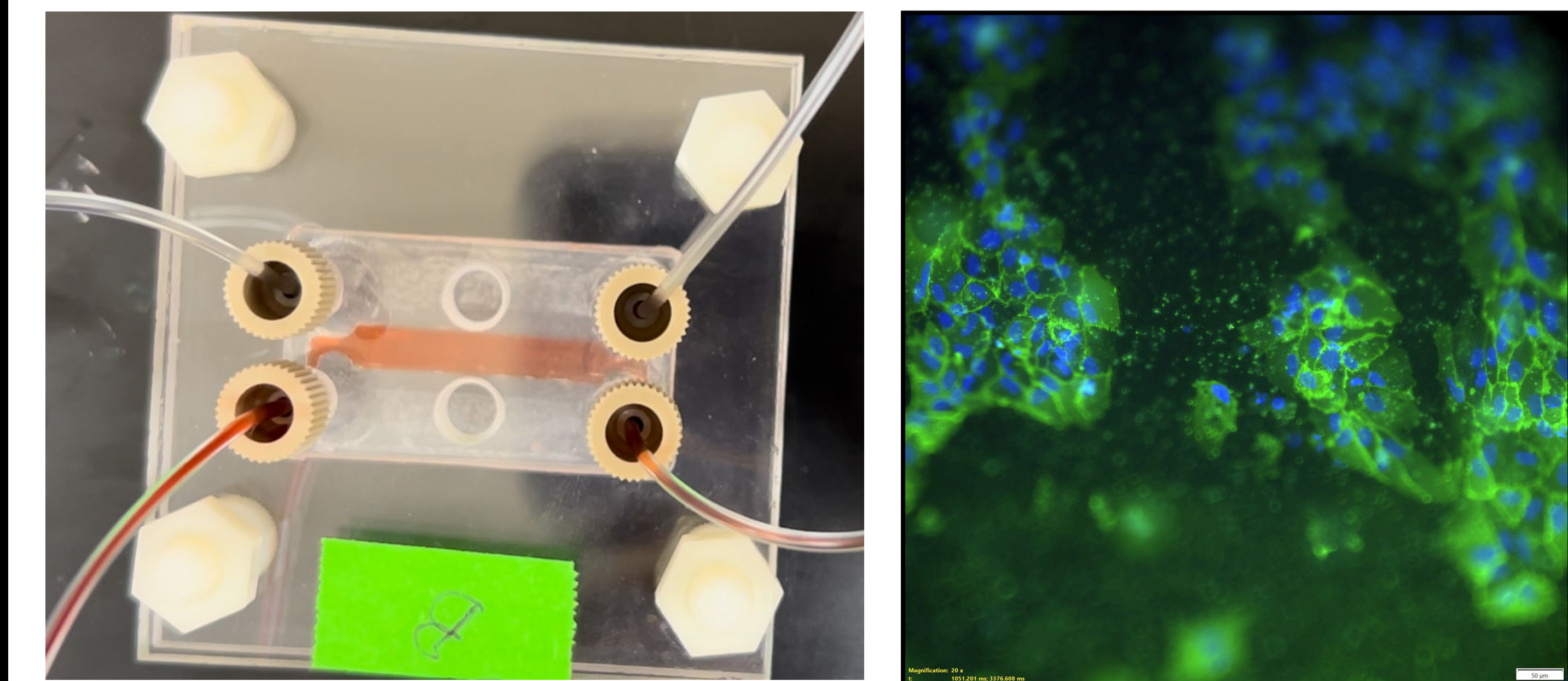


Figure 5 | Leakage test run with Aurora red dye in bottom channel and DI water in top channel

Figure 6 | HUVEC cells cultured in co-culture chip visualized with DAPI and CD31 stain

- Laminar flow was experimentally verified in the flow rate ranges of $22 \mu\text{L}/\text{min}$ – $140 \mu\text{L}/\text{min}$
- HUVEC cells were successfully cultured under a constant flow rate of $40 \mu\text{L}/\text{min}$ for five days
- Chip-tubing interface compatibility confirmed with different chip configurations of size $40 \text{ [mm]} \times 23.00 \text{ [mm]}$

CONCLUSION

We designed and prototyped a microfluidic co-culture platform with a leak-free versatile chip-tubing interface. The platform demonstrated laminar flow within the channel. We also validated the long-term stability of the platform by culturing HUVEC cells for five days in the co-culture chip.