Microfluidic Device for a Nanofabrication Apparatus

BME 301

Team: Jiacomo Beckman, Nick Pauly, Bob Meuler, Jason Wang, Kevin Koesser

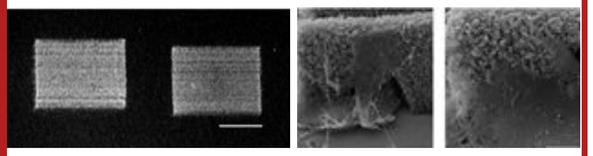
Client: Dr. Paul Campagnola, PhD **Advisor:** Dr. Filiz Yesilkoy, PhD

Abstract

Dr.Campagnola's lab has designed and constructed several microscope-based instruments for creating 3D nano/microstructure tissue engineered scaffolds. He seeks an automated system capable of introducing protein solution and recovering unpolymerized protein solutions for re-use. A final design was devised and can be broken down into three components: inflow, the microfluidic device, and filtering. Due to unprecedented circumstances, the hypothetical design was not fully realized. Regardless, theoretical protocols and calculations were done to promote the design idea.

Introduction

- Extracellular Matrix (ECM) - 3D arrangement of macromolecules
  - assists direction of cell shape, differentiation, migration, and proliferation.



A B

Figure 1: A) Fabricated BSA matrices B) Stem cells interacting with BSA matrices

- ECM becomes altered and remodelled throughout the progression of cancer [1].
- Goal of our client: artificially fabricate ECM
  - multiphoton excited (MPE) photochemistry.

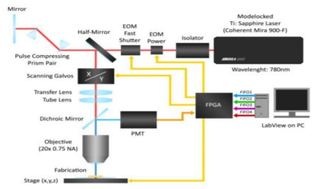


Figure 2: Optical configuration for the ECM fabrication system

- Current method is extremely tedious
  - Three hour period
  - Manual insertion and removal of proteins
- Excess protein solution becomes wasted
  - These proteins are expensive, and cannot be reused.

Last semester

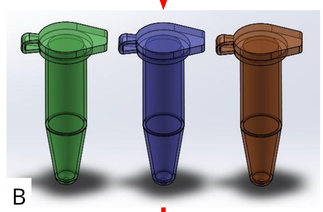
- Initial design: microfluidic device, pump, and in-line filter
- Material testing for microfluidic device

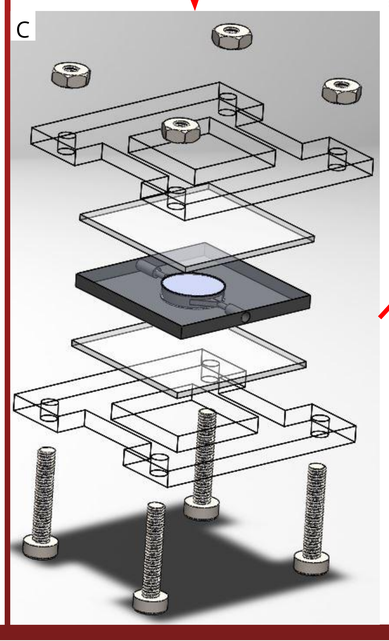
Design Criteria

Client Requirements:

- Three to four compartments that house protein solutions. These may hold proteins such as collagen, laminin, and fibronectin. ✓
- These proteins that are separated and collected should be reusable in future procedures. ✓
- Must be incorporated with LabVIEW software. ✓
- Must maximize the recovery of the major proteins with fibronectin and laminin taking precedence. ✓
- Can be used for other projects. ✓
- Budget: combined $1,500 ✓

Final Design





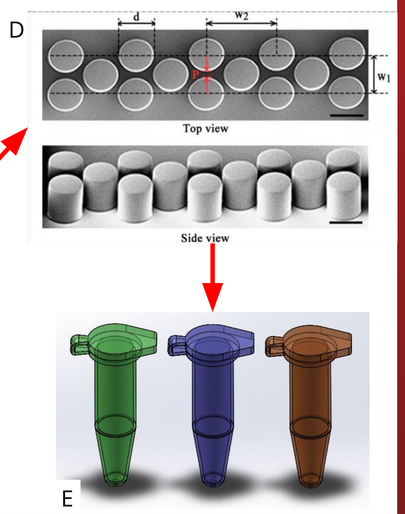


Figure 3: Assembly of microfluidic device:

- Elveflow OB1 (A) pumps protein solution(s) (B) into microfluidic device (C)
- Pumping stops and scaffold is created
- Protein solution passes through pillar filters (D) to remove scaffold debris
- Pure protein solutions (E) are recycled

Testing

Testing Flowchart

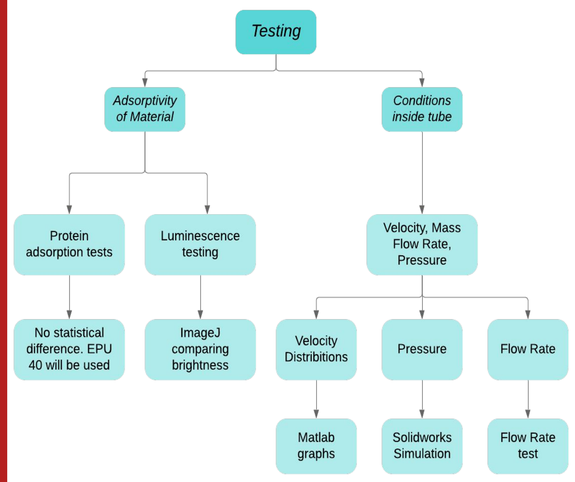


Figure 4: Testing flowchart (pre and post COVID-19 crisis)

Protein Adsorption

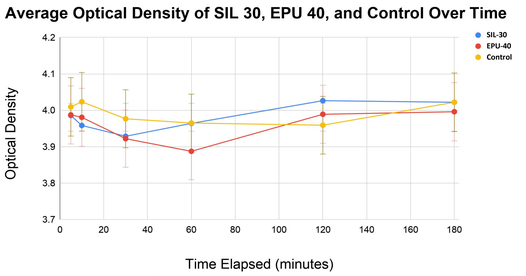
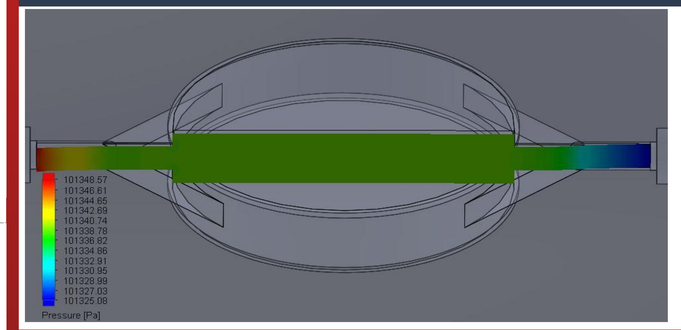


Figure 5: Graph of each material's average optical density

- Determination of which material is less protein adsorbent than the other
  - Measure of BSA solution optical density over time
- Each material was placed in a petri dish containing BSA (protein solution)
- Observable trend of increasing optical density -> protein adsorption

Figure 6: Sample of SIL-30 after experiment from last semester to regular SIL-30

Pressure Flow Diagram



$$v_z(r) = \frac{(p_0 - p_L)}{4\mu L}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

$$p(z) = p_0 - (p_0 - p_L)\frac{z}{L}$$

$$Q = \frac{\pi(p_0 - p_L)R^4}{4\mu L}$$

Figure 7: Simulation of pressure gradient inside microfluidic chamber

Future Work

Input:

- Multiple input lines for 1-setup procedure
- Bubble Detector to attach to input lines

Output:

- Preliminary filter to filter out larger chunks of solid
- Vacuum pump to assist in producing output flow

Further Testing:

- Amount filtered vs net output from flow
- Output contamination from ECM scaffold

Acknowledgements

Dr. Paul Campagnola, PhD
Dr. Filiz Yesilkoy
Sam Alkmin, M.S.
Midwest Prototyping
UW-Madison BME Design

Sources

[1] V. Ajeti, C.-H. Lien, S.-J. Chen, P.-J. Su, J. M. Squirrell, K. H. Molinarolo, G. E. Lyons, K. W. Eliceiri, B. M. Ogle, and P. J. Campagnola, "Image-inspired 3D multiphoton excited fabrication of extracellular matrix structures by modulated raster scanning," Optics Express, vol. 21, no. 21, p. 25346, 2013.

[2] Y. D. Sie, Y.-C. Li, N.-S. Chang, P. J. Campagnola, and S.-J. Chen, "Fabrication of three-dimensional multi-protein microstructures for cell migration and adhesion enhancement," Biomedical Optics Express, vol. 6, no. 2, p. 480, Dec. 2015.