Facilitating Flow: The Design and Fabrication of a Flow Cell for a DIY Flow Cytometer

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Abstract

Flow cytometry analyzes cells in solution, quantifying characteristics based on the light scatter produced when a laser intercepts the cell. The chamber through which cells flow (flow cell) impacts data quality. Here, strategies for development of an inexpensive alternative to the standard quartz flow cell are investigated.

Introduction

- Flow cytometry is a technique that can measure the physiochemical properties of cells/particles suspended in solution
  - Cell size and granularity
  - The presence of intracellular pathogens[1]
    - Malaria
- Modern flow cytometers regularly cost > $50,000
  - Not feasible in resource poor settings
- The flow chamber and flow cell on the flow cytometer directly influence data quality
- Flow chamber
  - Where the sample is injected into the sheath fluid
  - Where the cells are focused into a single file line
- Flow cell
  - Where the cells flow through the laser
  - Where the data are generated
- Traditionally quartz cuvettes are used for the flow cell
  - Regularly cost $450+
- Isolated flow chambers are not available for purchase

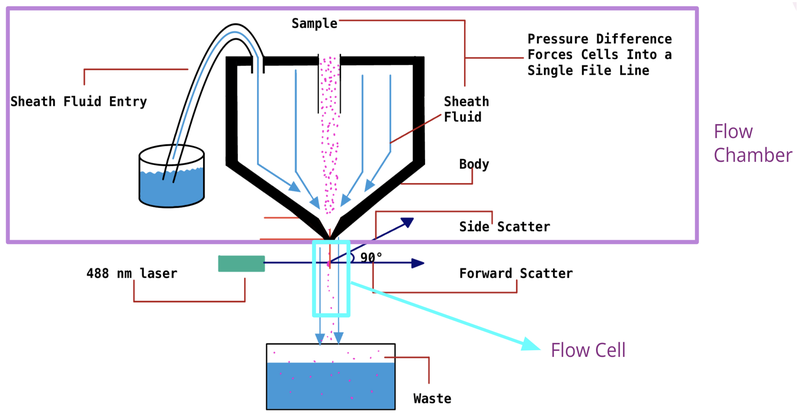

Figure 1. The flow cell and flow chamber

Methods and Materials

- <u>The Flow Chamber</u>
  - Designed in Fusion 360
  - Sliced for printing using PrusaSlicer 2.5.2
  - 3D printed using PLA filament with a layer height of 0.08 mm
  - Tested for laminar flow using a solution of food-coloring and water
- <u>The Flow Cell</u>
  - ANSI data for 4 different materials were compared to fused quartz to determine which one had the most similar mechanical properties (Table 1)
  - Published data for 4 different materials were compared to fused quartz to determine which one had the most similar optical qualities (Table 2)

Results and Discussion

- <u>The Flow Chamber</u>
  - Flow chamber printed with Creality Ender-3 S1 3D printer
  - Print durability enhanced via horizontal printing
  - Cyanoacrylate was used to mount the flow cell into the flow chamber
  - Laminar flow was confirmed using a solution of food-coloring and water
  - Further calculations are necessary to:
    - Optimize flow rate
    - Determine pressure differential required focus cells
- <u>The Flow Cell</u>
  - Soda-lime glass has mechanical properties comparable to fused quartz (Table 1)
  - Soda-lime glass does not have the proper optical qualities (Table 2)
  - Aluminosilicate glass has optical properties akin to fused quartz (Table 2)
  - Aluminosilicate glass is hard to obtain
  - Borosilicate glass has the highest transmissivity of all the alternatives (Table 2)
    - Will lead to a stronger data signal

Results and Discussion continued

Table 1. A comparison of mechanical properties

Material	Tensile Strength (psi)	Young's Modulus (psi)	Softening Point (˚C)	Hardness (Moh's Scale)
Quartz	7,000	10.5×10^6	1683	5.5 - 6.5
Acrylic	10,878	464,121	110	3.0
Aluminosilicate Glass	N/A	1.3×10^7	1010	6.6-7
Borosilicate Glass	40,610	9.3×10^6	>800	7.5
Soda Lime Glass	5,900	10.0×10^6	726	6-7

Table 2. A comparison of optical properties

Material	Refractive Index	Transmission Range	Transmissivity	Cost
Quartz	1.54 – 1.55	270 nm - 2.5 µm	92.5%	$450
Acrylic	1.30 – 1.69	> 375 nm	86.0%	$0.24
Aluminosilicate Glass	1.50-1.53	350 nm -2.7 µm	91.8%	$0.50
Borosilicate Glass	1.51–1.54	300 nm – 2.0 µm	91.0-93.0%	$0.46
Soda Lime Glass	1.51-1.52	200 nm – 800 nm	80.0%	$0.07

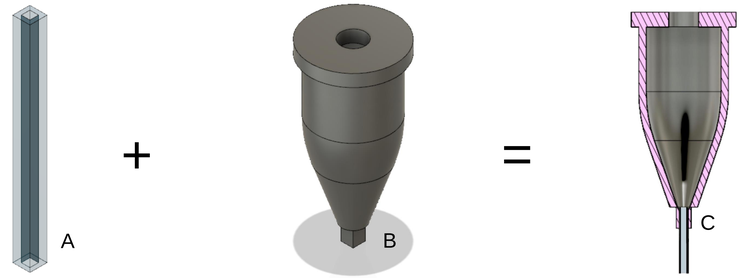

Figure 2. The design for the flow cell (A) and flow chamber (B) rendered in Fusion 360. The combined unit is also shown (C).

Conclusions

- A flow chamber can be printed using a standard filament-based 3D printer
  - A resin-based 3D printer could be utilized for enhanced precision
- Borosilicate glass capillary tubes should serve as a viable alternative for the standard quartz flow cell

Acknowledgements

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References

1) Janse, C. J., & Van Vianen, P. H. (1994). Flow cytometry in malaria detection. *Methods in Cell Biology*, *42 Pt B*, 295–318. https://doi.org/10.1016/s0091-679x(08)61081-x