Using COMSOL Multiphysics to Establish Tolerances and Limits of Failure for Sample and Reagent Flow on a Microfluidic Immunosensor Platform

S. Kumar[1], D. Dendukuri[1]

1. Achira Labs Pvt Ltd, Microfluidics R&D, Bangalore, Karnataka

Goal is to:

- Predict the flow resistance offered by the microchannel embedded with different dimension & number of biosensors.
- Experimentally validate the results from simulation.

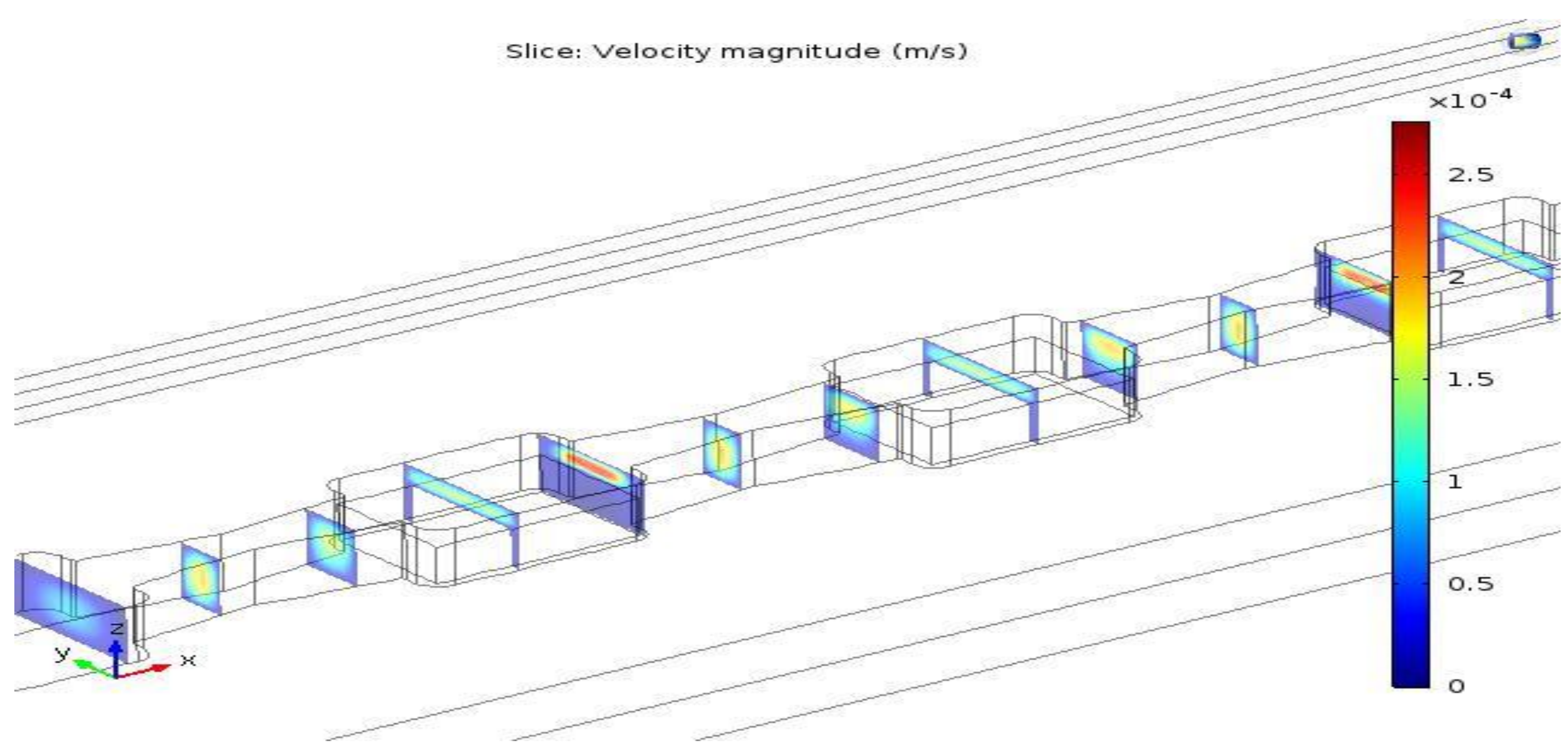


Figure 1. Achira's microfluidic channel with flow over biosensors

Computational Methods:

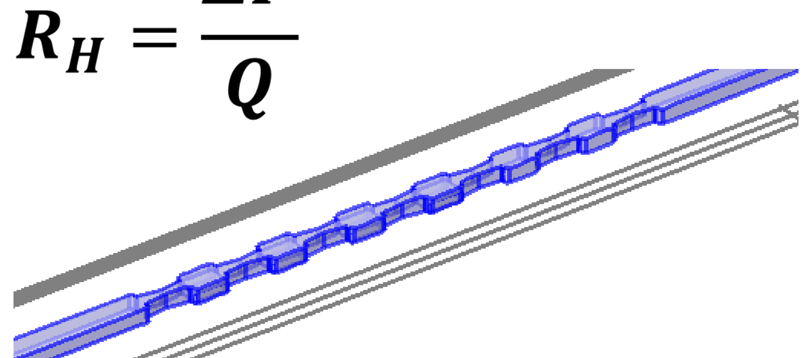
Laminar flow module:

$$\rho(u.\nabla)u = \nabla.[-p + \mu(\nabla u + (\nabla u)^T)] + F$$
$$\rho\nabla.(u) = 0$$

The pressure difference between inlet and outlet port is given as input, the hydraulic resistance of channel is calculated as the ratio of ΔP and Volume flow rate

$$R_H = \frac{\Delta P}{Q}$$

Outlet

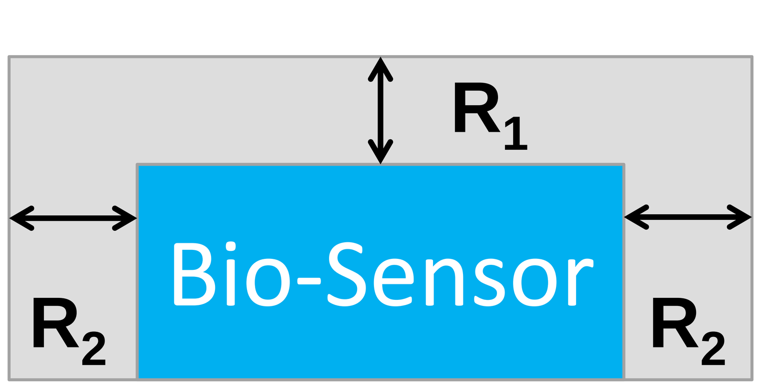


Inlet

Figure 2. Isometric view of the microfluidic channel

Analytical Method:

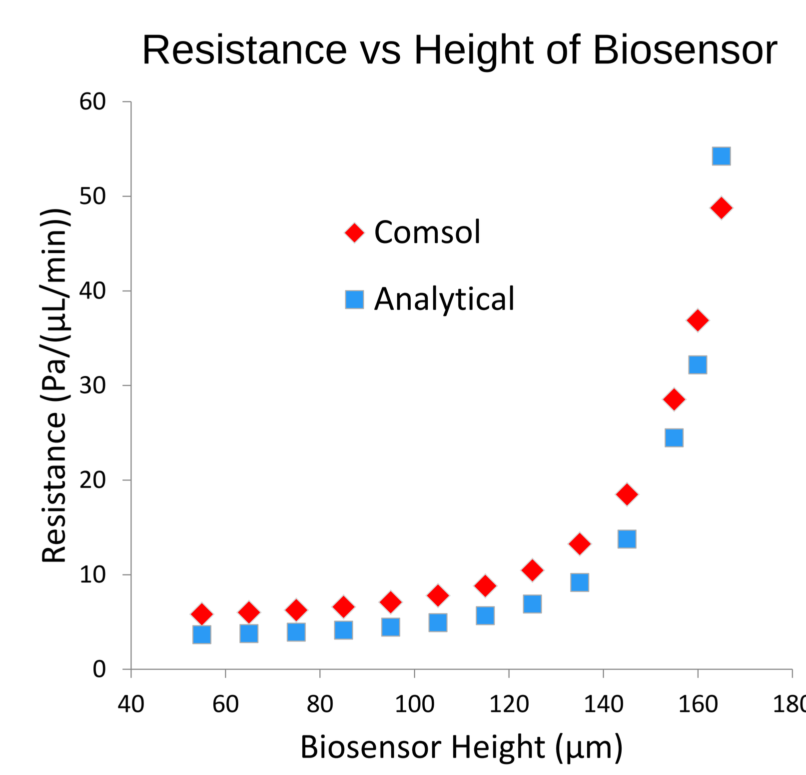
$$R_H = \frac{12\mu L}{wh^3}\left[1 - \frac{192h}{\pi^5 w}\tanh\left(\frac{\pi w}{2h}\right)\right]^{-1} \quad [1]$$

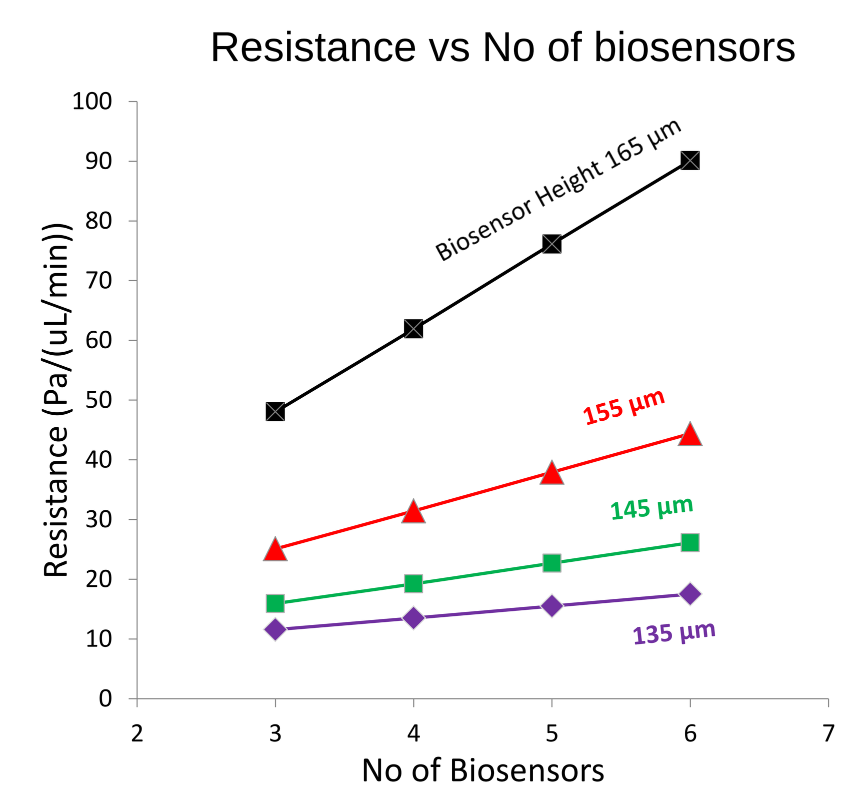


$$R_{total} = R_{sensor\ area} + R_{channel}$$

$$R_{total} = 4\left[\frac{R_1 R_2}{R_2 + 2R_1}\right] + R_{channel}$$

Results:





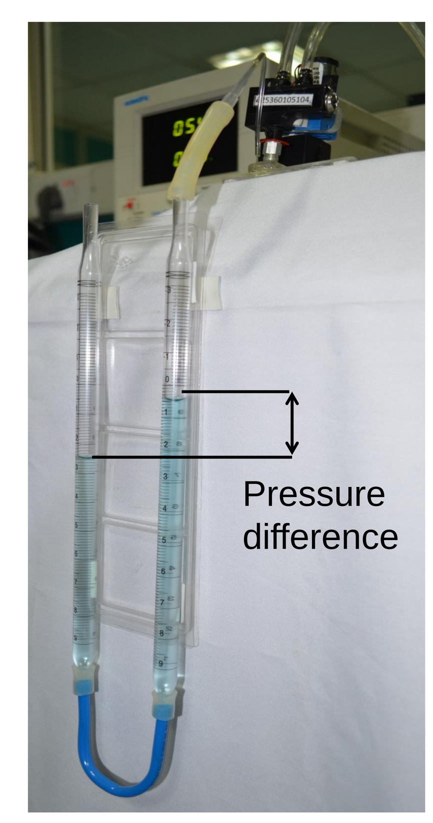


Figure 3a

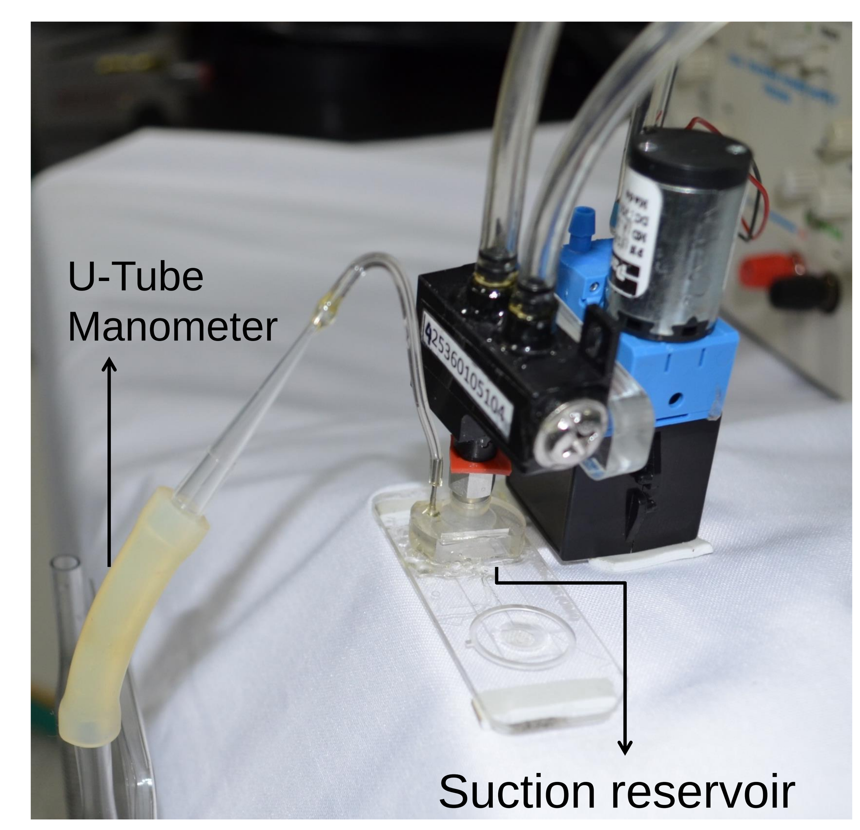


Figure 3b

Figure 3a & 3b. Experimental setup to measure the suction pressure applied across the ends of microchannel. A U-Tube manometer is connected to a tapped point from the suction reservoir of the microfluidic cartridge.
Typical pressure applied is around -100 Pa gage which can be easily measured using U tube manometer with an accuracy of 10 Pa (1mm of Water).

$$Experimental\ R_H = \frac{Pressure\ from\ Manometer}{Observed\ Flow\ rate}$$

Table 1. Experimental comparison between resistances

Sensor 1 (µm)	Sensor 2 (µm)	Sensor 3 (µm)	Sensor 4 (µm)	Velocity (µm/s)	Q (µl/min)	Resistance (Pa*min/µL)	Experimental R
159	143	147	147	963.69	6.59	23.06	32.41
164	155	131	162	695.60	4.76	31.94	32.41
147	138	151	153	1057.30	7.23	21.02	22.88
147	155	155	155	842.45	5.76	26.38	33.82
151	146	153	153	937.94	6.42	23.69	25.93
142	144	142	164	918.64	6.28	24.19	25.93
153	163	153	140	802.36	5.49	27.69	32.41

Conclusion: This simulation has helped us set the quality control standards on the height of bio-sensor, to limit the channel resistance to a tight band.

References:

[1] H.A. Stone,2007,Introduction to Fluid Dynamics for Microfluidic Flows, CMOS Biotechnology.

Excerpt from the Proceedings of the 2016 COMSOL Conference in Bangalore