Numerical Modelling of High Aspect Ratio µPillars at Different Viscosities and Flow Rates.

A. Mustafa[1], A. Erten[2], A. Eser[3], A. Cenk Aksu[3], A. Kiraz[1], M. Tanyeri[4], O. Yalcin[3]

1. Department of Physics, Koç University, Istanbul, Turkey
2. Department of Electrical Engineering, Osmaniye University, Osmaniye, Turkey
3. Department of Bio Medical Engineering/ School of Medicine, Koç University, Istanbul, Turkey
4. Institute of Molecular Engineering, University of Chicago, Chicago, IL, USA

Introduction: In this work we present a device that can be used for analyzing coagulation of blood in a microchannel by measuring the displacement of µPillars. The measure of displacement/bending of these micro structures is used as a tool to see the effects of fluids of different viscosities on pillar movement. The microfluidic device was fabricated using soft lithography process. PDMS curing agent and base agent were mixed (1:10) degassed and poured on Al with dimensions given in Fig2.

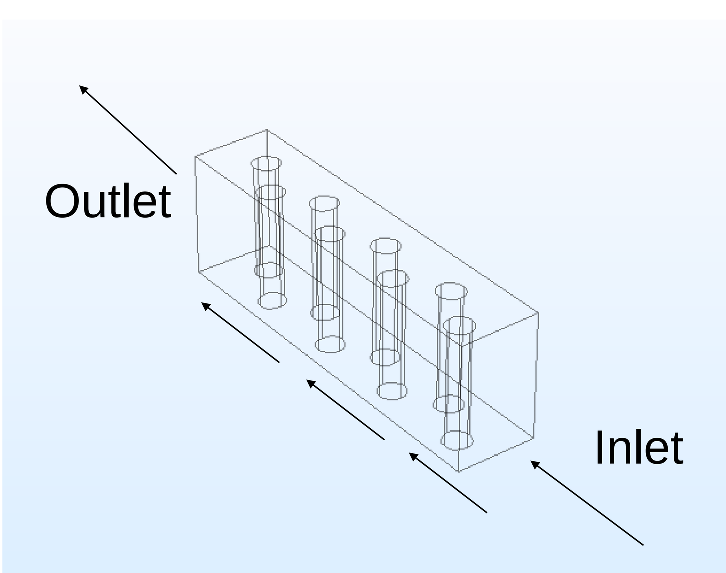

Figure 1. Microfluidic Chip Design
Pillar Height= 1200 µm
Pillar Diameter= 300 µm
Channel Height= 1300 µm

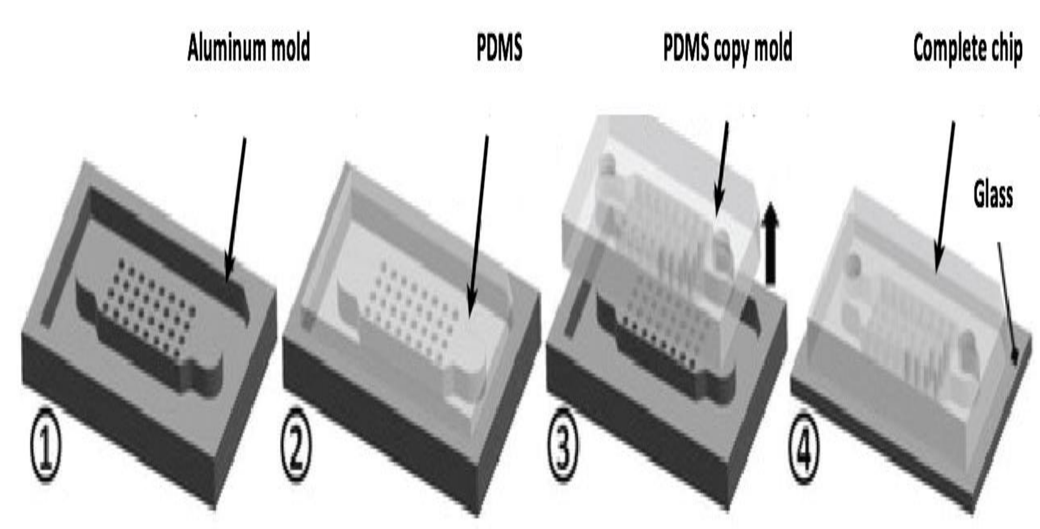

Figure 2. Soft lithography Fabrication Steps

Computational Methods: Laminar flow and solid mechanics modules were used to model experiments. If the fluid is an incompressible flow (ρ is constant), the mass continuity equation simplifies to a volume continuity equation: which means that the divergence of velocity field is zero everywhere. Incompressible flow was considered with no slip boundary condition to model our flow experiment. Isotropic solid model was used in solid mechanics module.

$$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \cdot [-p\mathbf{I} + \mu(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)] + \mathbf{F}$$

$$\rho\nabla \cdot (\mathbf{u}) = 0$$

Eq.1 Continuity and Momentum Equation

$$\nabla \cdot \mathbf{s} + \mathbf{F_v} = 0$$

Eq.2 Out of Plane Strain Displacement

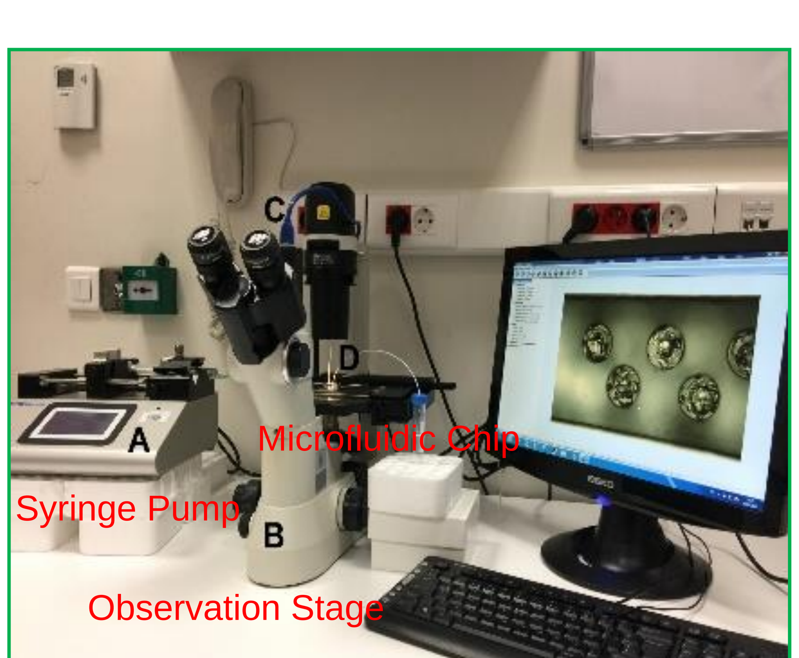

Figure 3. Experimental Setup

1) Syringe pump is used to flow glycerol into the microfluidic chip.
2) Observation stage consists of a camera connected to a microscope.
3) The pillar movement is recorded as the fluid flows using a flycap2 software.

Results: The result section includes comparison of Experimental and simulation studies.

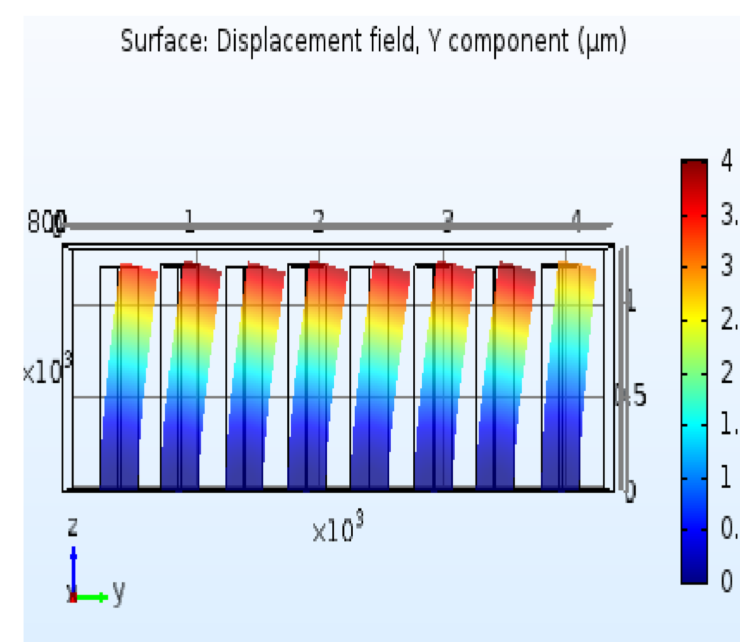

Figure 4. µPillar Displacement for different flow rates and Viscosity.

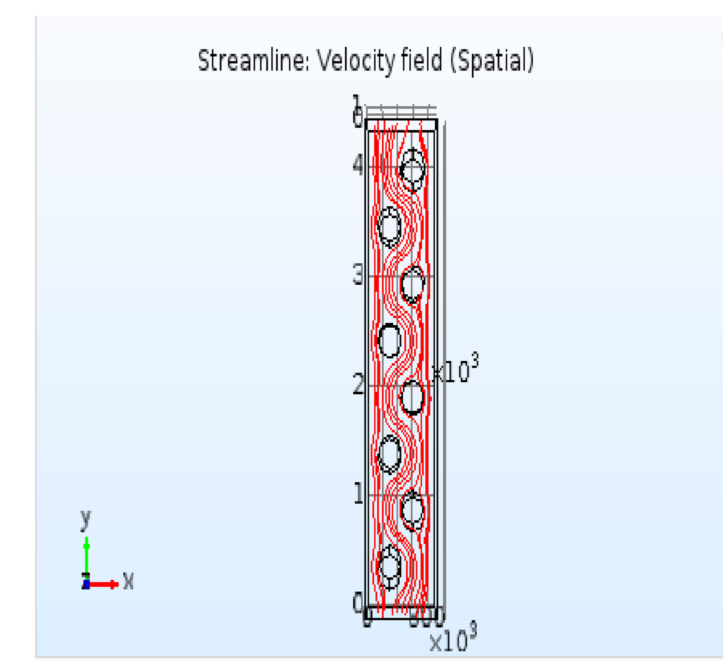

Figure 5. Fluid Stream lines Showing interaction of fluid with µPillars.

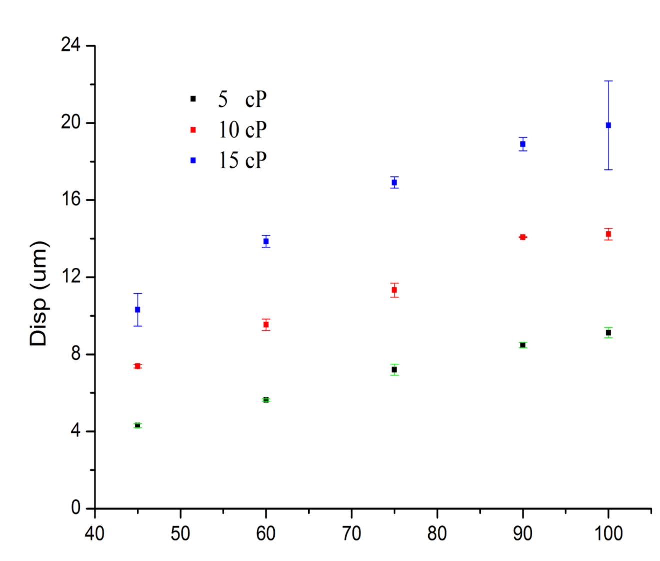

Figure 6. Pillar Bending at different Flow Rates and Viscosities of Glycerol (Experimental Result)

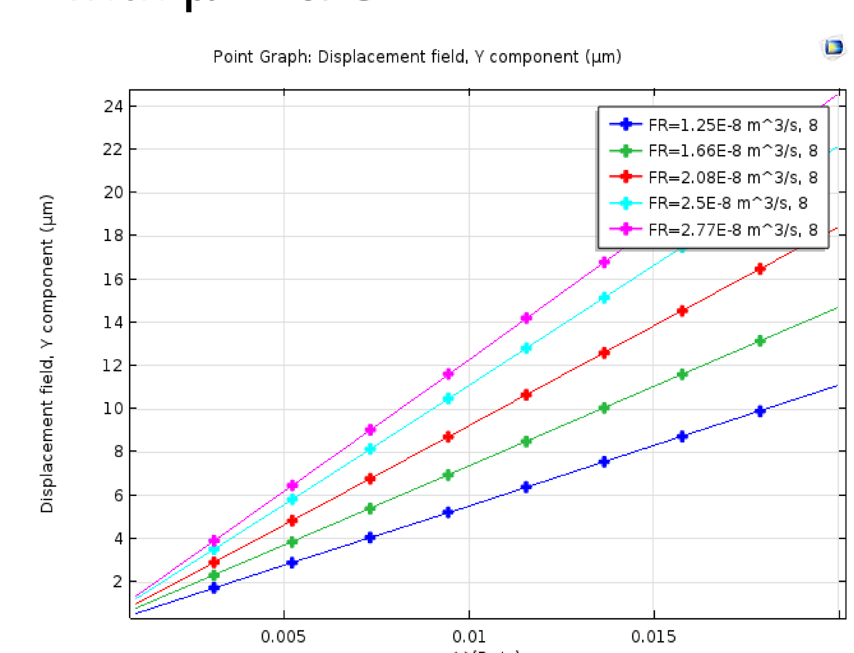

Figure 7. Pillar Bending at different Flow Rates and Viscosities (Simulation Result)

Conclusions: The simulation and Experimental results clearly show the dependence of displacement on flow rate and viscosity. Fig.6 and Fig.7 clearly show that µPillars have more displacement with increasing flow rates and viscosity. The preliminary results show that our device can be employed for analysis of blood coagulation process in a microchannel device as viscosity of blood changes as it coagulates. The minimum force required to bend the pillars is 0.51N.

Material	Property	Value	Unit
PDMS	Elastic Modulus	750	KPa
PDMS	Viscosity	3.5	Pa.s
Glycerol	Viscosity	5,10,15	cP

Table 1. Materials Used

$$\mathbf{F} = \frac{3\pi E D^4}{64 L^3}$$

Eq.3 Bending Force

References:

1. Sniadecki, Nathan J; Chen, Christopher S; ,Microfabricated silicone elastomeric post arrays for measuring traction forces of adherent cells, Methods in cell biology, Elsevier,83,,313-328,2007
2. Liang, Xin M; Han, Sangyoon J; Reems, Jo-Anna; Gao, Dayong; Sniadecki, Nathan J; ,Platelet retraction force measurements using flexible post force sensors, Lab on a Chip, Royal Society of Chemistry,10,8,991-998,2010.