Design, Fabrication and Simulation of Microchannel Network for MEMS

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Introduction: The greatest challenge being faced for realization of Micro-Electro Mechanical System (MEMS) technology is the lack of a simple, quick and reliable method for the fabrication of 3-D microchannel in the range of micrometers [1,2]. A novel fabrication technique which opens possibilities for the production of these microfluidic channels is Micro Ultrasonic Machining.

Machining Set-up: In this process the removal of material takes place because of the impact forces generated by the vibrating tool on to the abrasive particles [3]. A schematic view of micro USM is shown in Figure 1.

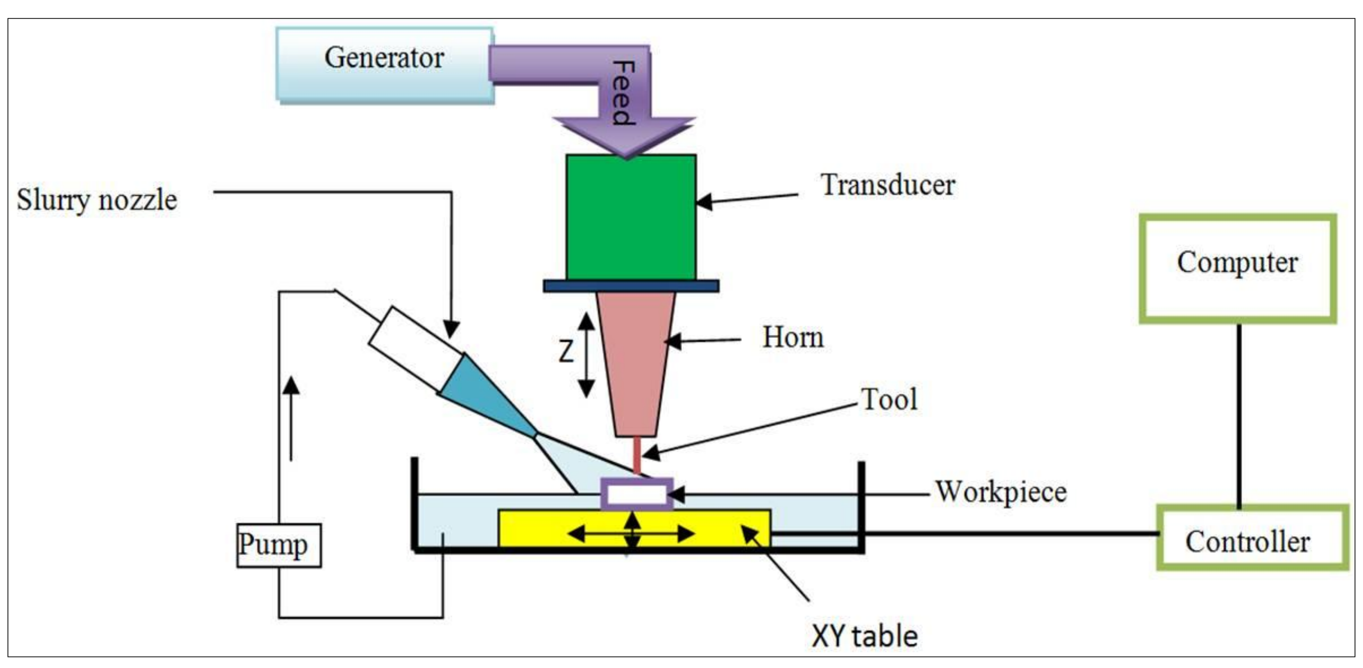

Figure 1. Micro USM SET-UP

Modeling of Microchannels: As the channel size decreases to the order of a few microns, the effect of the surface roughness on the flow of liquid through the microchannels becomes important [4].
Therefore, a model is developed and simulation for the flow of liquid is presented by using COMSOL finite element package. The asperities on the glass surface were modelled and approximated as conical blocks of different heights. In the current simulation the aim is to study the effect of channel surface roughness on fluid flow phenomena and thereby drop in velocity and pressure occurring in a microchannel. The flow is considered to be laminar, non-gravity, incompressible, Newtonian and isothermal with velocity field u and governed by the Navier-Stokes and continuity equations, as provided here:

$$\rho(\mathrm{u}.\nabla)\mathrm{u} = \nabla.\left[-\mathrm{pI} + \mu(\nabla\mathrm{u} + (\nabla\mathrm{u})^{\mathrm{T}}) - \frac{2}{3}\mu(\nabla.\mathrm{u})\mathrm{I}\right] + \mathrm{F}$$

Results: The different types of microchannels fabricated on glass substrate are depicted in Figure 2.

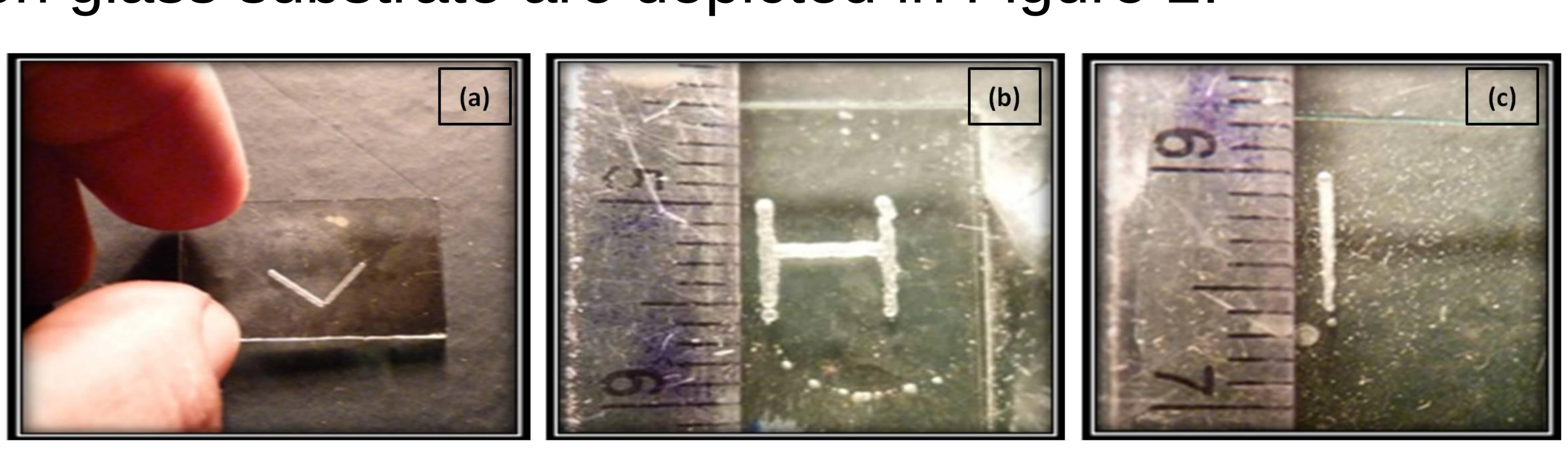

Figure 2. : Different types of Microchannels on Glass

The average roughness (R_a) of 500 nm (Figure 3 & 4) was modelled only at the base of the channels and walls were treated as smooth.

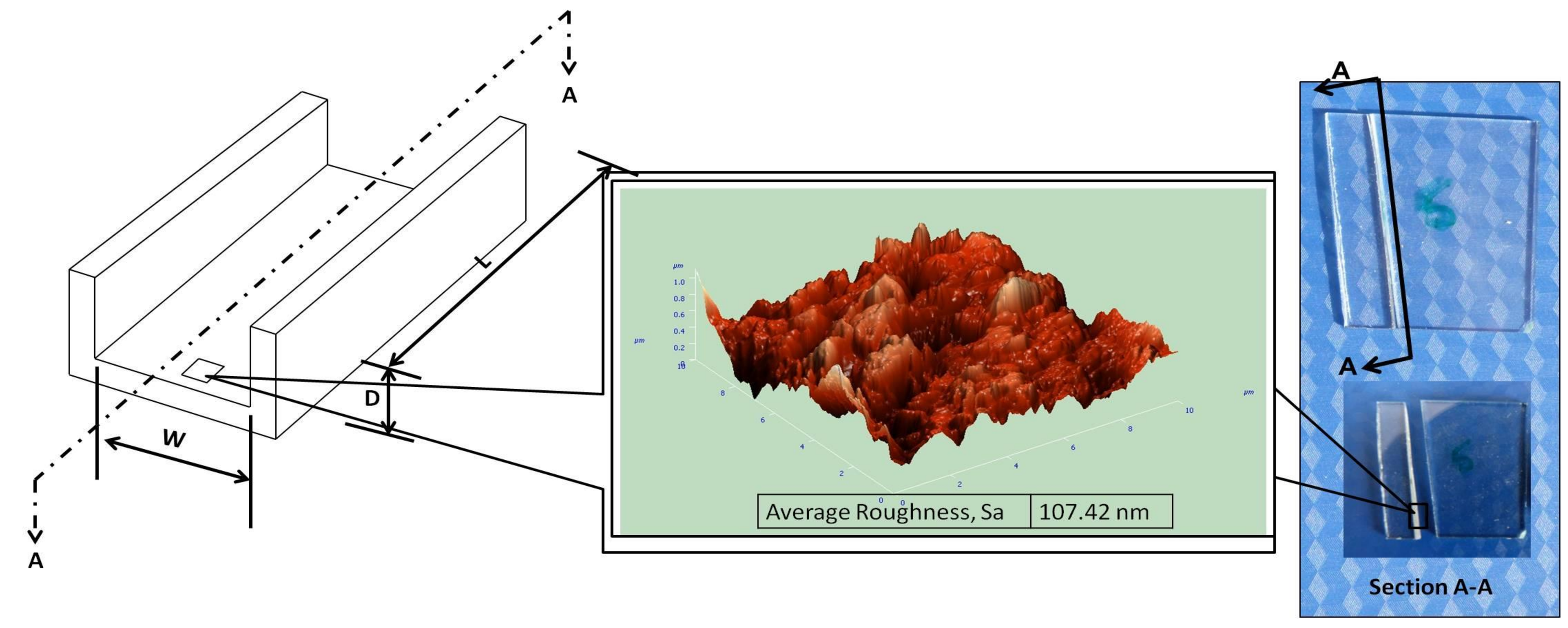

Figure 3. A Scheme of AFM Measurement and AFM Image of Glass Microchannel

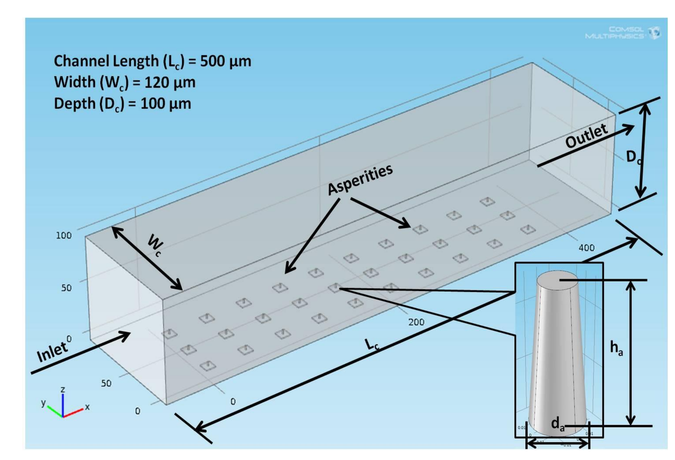

Figure 4. Geometry of Microchannel

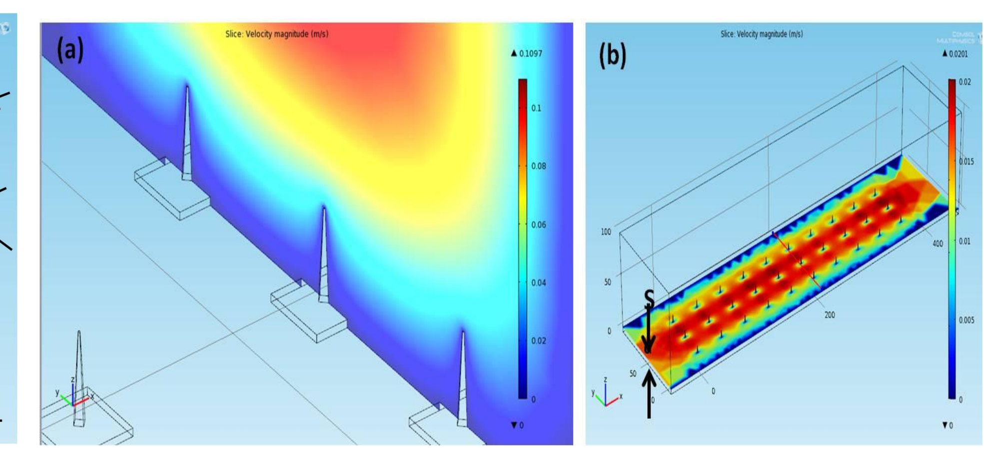

Figure 5. Velocity Contour in (a)Y-Z Plane (b) X-Y Plane

The variation in the velocity profile was 18% corresponding to smooth channel and a rough channel (R_a = 0.5 μm) whereas, it was found 36% (from average velocity of 0.0125 m/s to 0.008 m/s) in case of microchannels with average surface roughness from 0.5 μm to 3 μm. The drop in the pressure is 3.32% for 0.05 m/s flow rate corresponding to the smooth microchannel to a channel with average roughness of 0.5 μm.

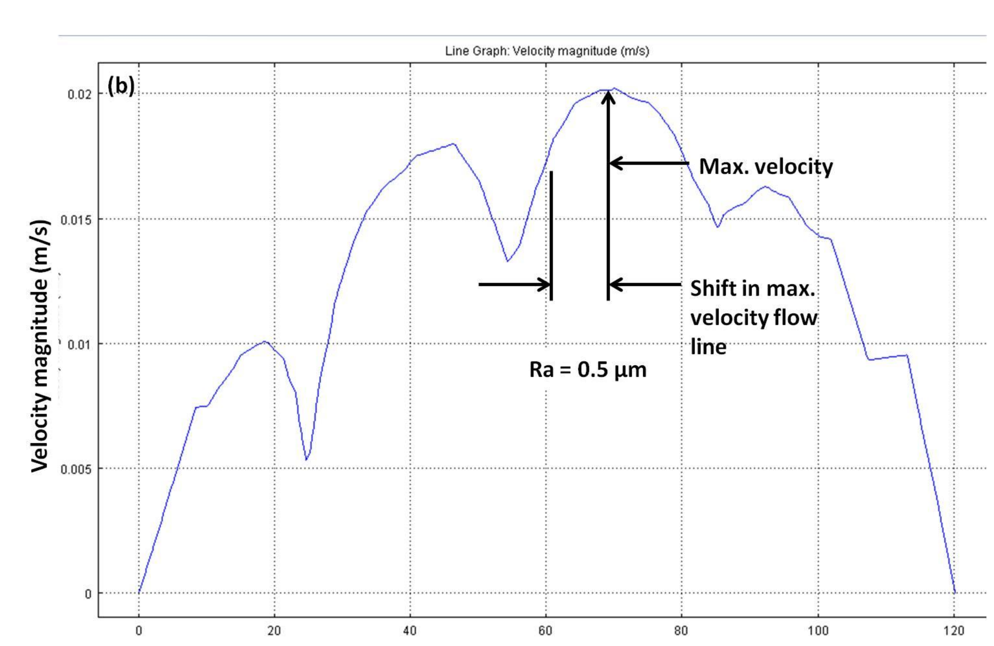

Figure 6. Velocity Profiles in Y-Direction

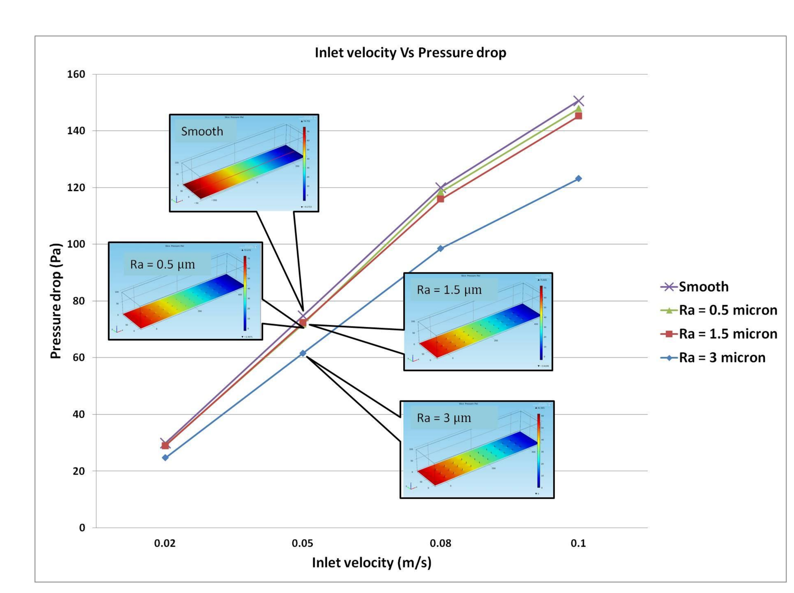

Figure 7. Pressure Drop as a Function of Flow Velocity

The average surface roughness of micro USM fabricated microchannels is below 0.5 μm and velocity and pressure drop is found insignificant within this range of roughness. Hence, the fabricated microchannels can be used for the microfluidic applications.

References:

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