Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary information

Appendix 1

Derivation of the time dependant liquid penetration into the circular porous material from unlimited source

The basis of the described pumping mechanism is the imbibition of the working liquid into a porous material. The flow into two-dimensional circular porous material is derived from the Darcy's law:

$$\frac{Q}{S} = -\frac{k}{\mu}\frac{\partial P}{\partial r} \quad (1)$$

where Q is the volumetric flow through cross section of area S, k is the permeability of porous material, μ is the dynamic viscosity of the liquid, P and r are pressure and radius. After integration from r to r_0 we get the expression for the pressure inside the porous material:

$$P_c = P(r_0) - P(r) = \frac{Q\mu}{2\pi hk} ln\frac{r}{r_0} \quad (2)$$

where r is the radius of wetted area, r_0 is the radius of liquid source, h is the thickness of the porous material. After expressing Q by average liquid velocity ($Q=2\pi rh\,(dr/dt)$), capillary pressure with $P_c=2\gamma cos(\theta)/a$ (a is an effective porous radius and γ a surface tension) and inserting the appropriate permeability model we arrive to implicit equation which describes time development of liquid penetration into circular porous material from unlimited circular source:

$$\left(\frac{r}{r_0}\right)^2\left(ln\frac{r}{r_0} - \frac{1}{2}\right) + \frac{1}{2} = \frac{\gamma a cos\theta}{6\mu r_0^2}t \quad (3)$$

where θ, is the wetting angle of liquid on porous material. Detailed derivation of this formula can be found in Fries[28] and Hyväluoma et al.[29]. This is the so called capillary model which is based on description of water penetration in capillary tubes; however, if an effective pore radius is used to characterize the material, this can be used to describe the penetration into porous media.

Appendix 2:

The forces that influence the liquid transport through the microfluidic chip

First is the Young-Laplace pressure drop across the surface due to surface tension and curvature of the surface:

$$\Delta P_{YL} = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2}\right) \qquad (1)$$

here R_1 and R_2 are the principal radii of curvature and γ a surface tension. The pressure drop/rise (depending on the wettability properties of the side walls) is always observed across the curved surface.

Second force which resists the liquid movement is the friction force. A pressure drop due to the viscous friction in cylindrical channel can be described by Hagen-Poiseuille equation:

$$\Delta P_{HP} = \frac{128\mu L Q}{\pi d^4} = \frac{32\mu L v}{d^2} \qquad (2)$$

where, μ is the dynamic viscosity of the liquid, L is the length of the liquid-filled channel, Q is the volumetric flow through cross section of area, d is the diameter of the channel and v is the velocity.