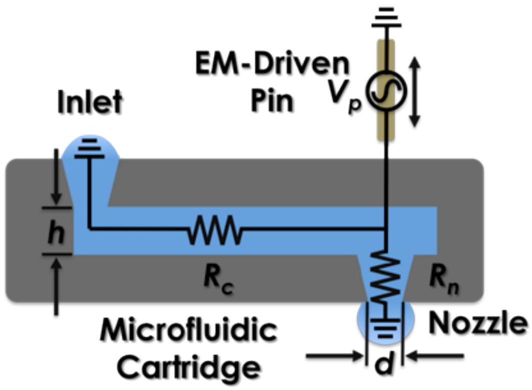
Electronic Supplementary Material (ESI) for Lab on a Chip
This journal is © The Royal Society of Chemistry 2013

Electronic Supplementary Information
Microfluidic Impact Printer with Interchangeable Cartridges for Versatile Non-Contact Multiplexed Micropatterning

Yuzhe Ding[1], Eric Huang[1], Kit S. Lam[2], and Tingrui Pan[1]
[1]Micro-Nano Innovation (MiNI) Laboratory, Department of Biomedical Engineering, UC Davis, USA
[2]Department of Biochemistry and Molecular Medicine, UC Davis, USA

Model



Based on the fluidic circuit model, the fluidic dynamics inside the microchannel of the cartridge can be modeled as a displaced flow (of volume $\boldsymbol{V_p}$) caused by the pin movement-induced membrane deformation.

$$V_p = S\Delta H$$

where $\boldsymbol{S}$ is the tip area of the pin and $\boldsymbol{\Delta H}$ is the pin-induced membrane deflection.

The displaced flow moves towards either the nozzle openings or the adjacent connecting channel, of which the flow resistances are $\boldsymbol{R_n}$ and $\boldsymbol{R_c}$, respectively.

$$R_n = \frac{8\mu t}{\pi(\frac{d}{2})^4} = \frac{128\mu t}{\pi d^4}$$

$$R_c = \frac{12\mu l}{wh^3}$$

where $\boldsymbol{\mu}$ is the viscosity of the fluid, $\boldsymbol{d}$ and $\boldsymbol{t}$ are the diameter and length of the nozzle opening, whereas $\boldsymbol{l}$, $\boldsymbol{w}$, and $\boldsymbol{h}$ represent the length, width, and height of the connecting channel.

Fluid entering the nozzle opening ($\boldsymbol{V_n}$) accelerates along the tapered geometry and is ejected into a discrete droplet. Based on the principle of volume distribution in the parallel channels, the relationship between the printed droplet volume and the geometric parameters of the microfluidic channel and the nozzle opening:

$$V_n = \frac{R_c}{R_c + R_n} V_p$$

Based on the microfluidic design requirement, the flow resistance of the nozzle opening is much larger than the one of the connecting channel (more than 15 times), which can simplify the formula of fluid volume through the nozzle opening to

$$V_n = \frac{R_c}{R_c + R_n} V_p \approx \frac{R_c}{R_n} V_p = \frac{\frac{12\mu l}{wh^3}}{\frac{128\mu t}{\pi d^4}} S\Delta H = \frac{3\pi l d^4}{64twh^3} S\Delta H$$

Moreover, we have further derived the printed droplet shape on the surface by considering the surface energy of the substrate and surface tension of the fluid under the capillary length limit. In the ideal case, the printed droplet on the substrate forms spherical crown with the liquid contact angle (***θ***) and the diameter of the contact area (***D***), which volume can be calculated by:

$$N \cdot V_n = \frac{4}{3}\theta\left(\frac{D}{2sin\theta}\right)^3 - \frac{1}{3}\pi\left(\frac{D}{2}\right)^2 \cdot \frac{D}{2}cot\theta$$

where N indicates the number of the ejections. Reorganizing the formula, we can derive the expression of the diameter of the printed droplet:

$$D = 2\left(\frac{N \cdot V_n}{\frac{4\theta}{3sin^3\theta} - \frac{1}{3}\pi cot\theta}\right)^{1/3} = 2\left(\frac{3sin^3\theta}{4\theta - \pi cos\theta sin^2\theta}\right)^{1/3}\left(\frac{3\pi lS}{64tw}\right)^{1/3} N^{1/3}\frac{d^{4/3}}{h}\Delta H^{1/3}$$

Compared to the Eq. 2 in the main paper, function of liquid contact angle ***f(θ)*** and geometric factor ***g(l,S,t,w)*** can be expressed by:

$$f(\theta) = \left(\frac{3sin^3\theta}{4\theta - \pi cos\theta sin^2\theta}\right)^{1/3}$$

$$g(l,S,t,w) = 2\left(\frac{3\pi lS}{64tw}\right)^{1/3} = \left(\frac{3\pi lS}{8tw}\right)^{1/3}$$

Movie S1 Multiplexed printing of MiNI logo

Movie S2 Four-color combinatorial printing on planar substrate