Supplementary Material (ESI) for Lab on a Chip
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Laminar Flow used as "Liquid etch Mask" in Wet Chemical Etching to Generate Glass Microstructures with an Improved Aspect Ratio†

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Supplementary information

Experimental details

Photolithographic and wet chemical etching techniques were used for fabricating positive relief pattern onto a 1.7 mm thick 63×63 mm glass plate with chromium and photoresist coating (Shaoguang Microelectronics Corp., Changsha, China)[1]. The glass with positive relief was silanized to become hydrophobic in 3% (v/v) octadecyl trichlorosilane (Sigma, St.Louis, MO, USA) in order to be employed as a mold[2]. PDMS prepolymer (10 monomer: 1 curing agent) (Sylgard 184, Dow Corning, Midland, MI, USA) was cast on this mold and cured thermally (75°C). After 1.5h, the PDMS plate was peeled off from the mold. The reservoirs were then punched and trimmed. As is testified, the glass mold has a much longer lifespan than the photoresist (SU-8) one because glass is stiffer. Hundreds of molding was accomplished with careful handling.

The PDMS layer should be with viscidity on its surface so as to be reversibly and conformally sealed against a soda lime glass plate (26mm×76mm±0.5, 1-1.2mm thick) (Bright Pearl, Qinning glass Co., Ltd). The microchip was filled with fluids by a water vacuum pump (SHB-III, Zhengzhou Great wall industry Co., Ltd) that providing vacuum from 0 to -100kpa. And the flow rate is controlled by a homemade pressure adjustment system.

The etchant consists of several ingredients as HF: Hcl: H_2O=2:2:1. (Caution: Hydrofluoric acid is considered highly toxic and corrosive. It should be handled with extreme care).

The profile of the glass ridge in Fig.2B was measured in a profilometer Ambios XP-1 (Ambios Technology Inc. USA). It is worth pointing out that the step profiler is not capable to measure the channels with certain geometry (high aspect ratio). Otherwise, the profile would be distorted. All the cross-sectional profiles of glass channel were gained by an electronmicroscope (SM-6301, JEOL Inc., Tokyo, Japan).

The calculation of Reynolds number

The Reynolds Number (Re) is calculated by the following equation:

$$\mathrm{Re}=v\rho L/\eta \qquad (1)$$

where p is the effective density (kg m^{-3}), v is the average flow velocity (m s^{-1}), η is the effective viscosity (Pa s) and L is the characteristic dimension of the flow (m). Since water is the majority of the etchant solution, we use the physical properties of pure water instead of that of HF solution to calculate Re. The required physical properties both of water and ethanol are listed below.

The PDMS layer was reversibly sealed against a glass plate. The fluid streams of etchant and ethanol were pumped into the resulting closed channel. The initial height of water flow is equal to the depth of PDMS channel (~20μm) and the width of the central etchant flow, measured by CCD camera, is about 22μm. The characteristic diameter of water flow is calculated to get 2.1×10^{-5}m. The measured flow velocity is 0.1m/s.

Table 1. The physical properties of water and ethanol

	Water (20°C)	Ethanol (20°C)
Density (kg m^{-3})	1000	789
Viscosity (Pa s)	1×10^{-3}	1.17×10^{-3}

The Re number of water flow is 2 by equation (1). After 13minutes, the depth of the etching flow rises up to 81μm (20μm in PDMS and 61μm in glass), and the width of the etching flow is expanded to 60μm. So the characteristic dimension of water flow is altered and changes to 71μm, if the channel profile is still proposed to be rectangle. And the measured flow velocity is up to 0.28m/s for the enlargement of channel which results in the decrease of the hydrodynamic resistance. So the Re number of water flow increases to 20. The Re number Both before etching and after etching is far below ~2000, which is the threshold between laminar flow and turbulent flow. Thus the flow streams during the LAWE would be always laminar and no turbulence, what is observed during the whole experiment, is developed at the interface between the streams.

The calculation of aspect ratio

The aspect ratio is defined for structures on the glass plate as the following equation:

$$R=D/W_{0.5} \qquad (2)$$

where R is the aspect ratio, D is the depth of channel, and the $W_{0.5}$ is the width at half maximum depth. It is an analogy to the analysis of peak width using Full Width at Half Maximum (FWHM) in chromatogram.[3] The exact width and depth of glass structures was marked in Figure S1.

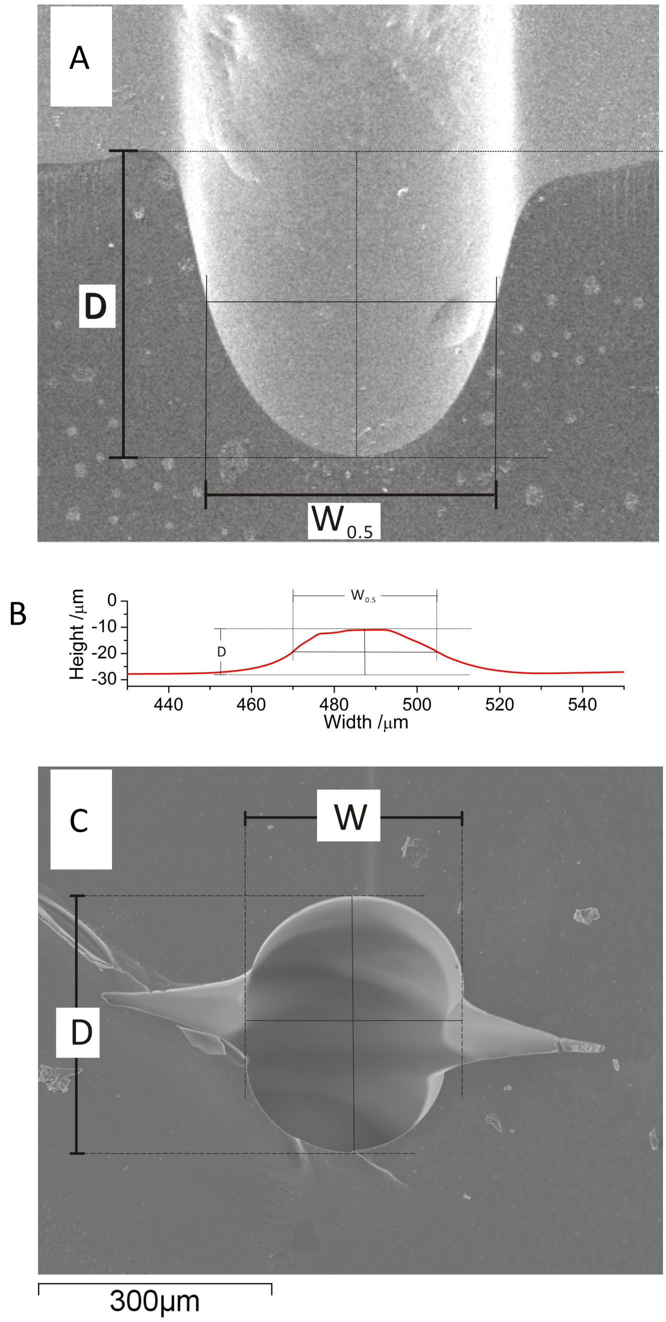

Figure S1. The depth (D) and width (W) of the three structures to calculate the aspect ratio was shown.

In Figure S1A the width at half depth and the depth of glass structure in Figure S1A is 61 and 60µm, respectively. The respect ratio, therefore, is 60/60=1.01. In Figure S1B the width at half depth and the depth of glass structure is 17 and 35µm, respectively. The respect ratio, therefore, is 17/35=0.48.

In Figure S1C the width at half depth and the depth of glass structure is 328 and 255μm, respectively. The respect ratio, therefore, is 328/255=1.28. Although the cross-section of this channel is not a regularly shape, the central part of the channel would be considered as an ellipse that consists 82% of the whole area of the cross section.

In current work, the defect rate is extremely low, because this method is intrinsically simple and reliable. Laminar flow is naturally raised in microchannel, and wet chemical etch is a classical process of microfabrication. The improper receipt of HF solution, however, would results in precipitates.

(1) Yao, B.; Luo, G. A.; Feng, X.; Wang, W.; Chen, L. X.; Wang, Y. M. *Lab on a Chip* **2004**, *4*, 603-607.

(2) Yao, B.; Luo, G.; Wang, L. D.; Gao, Y. D.; Lei, G. T.; Ren, K. N.; Chen, L. X.; Wang, Y. M.; Hu, Y.; Qiu, Y. *Lab on a Chip* **2005**, *5*, 1041-1047.

(3) Rodriguez, I.; Spicar-Mihalic, P.; Kuyper, C. L.; Fiorini, G. S.; Chiu, D. T. *Analytica Chimica Acta* **2003**, *496*, 205-215.