Electronic Supplementary Information (ESI)

PDMS-based Turbulent Microfluidic Mixer

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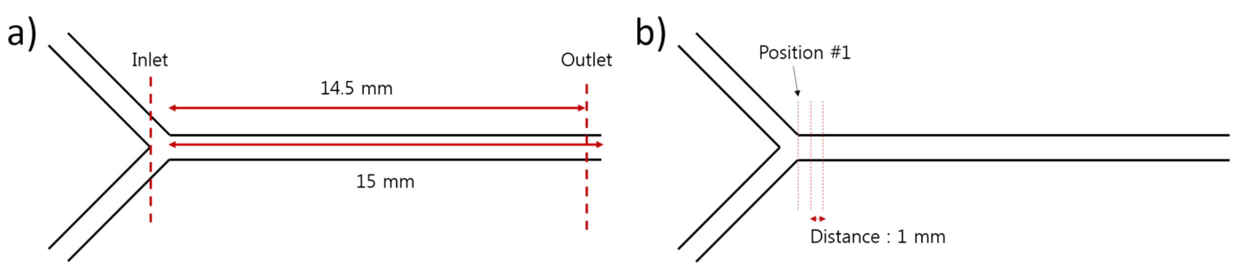
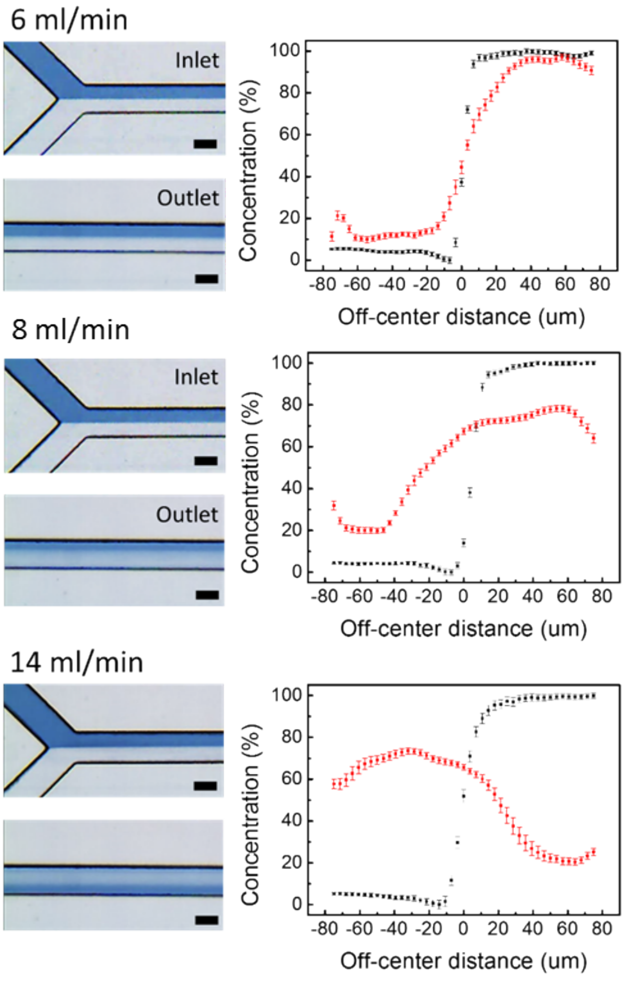
Figure S1. Analysis locations



Details of locations at which analyses were performed: (a) inlet and outlet intensities and (b) coefficients of variation.

Figure S2. Inlet and Outlet images and concentration profile for 6, 8 and 14 ml/min



S3. Details of computational fluid dynamics

The Reynolds-averaged Navier–Stokes equations for mass and momentum conservation are as follows:

$$\frac{\partial u_i}{\partial x_i} = 0,$$

$$\rho\frac{\partial u_i}{\partial t} + \rho u_j\frac{\partial u_i}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu\left(2D_{ij} - \frac{2}{3}\frac{\partial u_k}{\partial x_k}\delta_{ij}\right) - 2\mu_t D_{ij} - \frac{2}{3}\rho k\delta_{ij}\right].$$

The symbols $\rho, u_i, D_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right), p, \mu, \mu_t$, and k are the density, velocity, rate-of-deformation tensor, hydrostatic pressure, dynamic viscosity, turbulent viscosity, and turbulent kinetic energy, respectively.

The $k - \omega - SST$ turbulent model

The equations for the kinetic energy k and turbulence energy dissipation rate ω are as follows:

$$\rho\frac{\partial k}{\partial t} + \rho u_j\frac{\partial k}{\partial x_j} = \tau_{ij}\frac{\partial u_i}{\partial x_j} - \beta^*\rho\omega k + \frac{\partial}{\partial x_j}\left[(\mu + \sigma_k\mu_t)\frac{\partial k}{\partial x_j}\right],$$

$$\rho\frac{\partial \omega}{\partial t} + \rho u_j\frac{\partial \omega}{\partial x_j} = \frac{\gamma}{\nu_t}\tau_{ij}\frac{\partial u_i}{\partial x_j} - \beta\rho\omega^2 + \frac{\partial}{\partial x_j}\left[(\mu + \sigma_\omega\mu_t)\frac{\partial \omega}{\partial x_j}\right] + 2(1 - F_1)\rho\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j}.$$

The constants σ_k, γ, and σ_ω, denoted by ϕ collectively, are computed from the weight-average constants σ_{k1}, γ_1, and $\sigma_{\omega 1}$, denoted by ϕ_1, of the shear-stress transport (SST) model, and the constants σ_{k2}, $\gamma_2, and\ \sigma_{\omega 2}$, ϕ_2, of the $k - \varepsilon$ model: $\phi = F_1\phi_1 + (1 - F_1)\phi_2$, where the blending function F_1 is

$$F_1 = \tanh\left\{\left\{min\left[max\left(\frac{\sqrt{k}}{0.09\omega y};\frac{500\nu}{y^2\omega}\right);\frac{4\rho\sigma_{\omega 2}k}{CD_{k\omega}y^2}\right]\right\}^4\right\} \text{ with } CD_{k\omega} = max\left(2\rho\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j};10^{-20}\right).$$

The constants are $\sigma_{k1} = 0.85$, $\sigma_{\omega 1} = 0.5$, $\beta_1 = 0.075$, $a_1 = 0.31$, $\beta^* = 0.09$, $\kappa = 0.41$, and $\gamma_1 = \beta_1/\beta^* - \sigma_{\omega 1}\kappa^2/\sqrt{\beta^*}$ for the SST model, and $\sigma_{k2} = 1.0$, $\sigma_{\omega 2} = 0.856$, $\beta_2 = 0.0828$, $\beta^* = 0.09$, $\kappa = 0.41$, and $\gamma_2 = \beta_2/\beta^* - \sigma_{\omega 2}\kappa^2/\sqrt{\beta^*}$ for the $k - \varepsilon$ model.

The following definitions are used:

$$\tau_{ij} = \mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\frac{\partial u_k}{\partial x_k}\delta_{ij}\right) - \frac{2}{3}\rho k\delta_{ij}$$

$\nu_t = \frac{a_1 k}{max(a_1\omega;SF_2)}$; $F_2 = \tanh\left\{\left[max\left(2\frac{\sqrt{k}}{0.09\omega y};\frac{500\nu}{y^2\omega}\right)\right]^2\right\}$; *S* is the second invariant of the rate-of-deformation tensor *D*.

Convection–diffusion equation for dye transport:

The concentration of a dye, denoted by c, is described by the following convection–diffusion equation:

$$\frac{\partial c}{\partial t} + u_i\frac{\partial c}{\partial x_i} = \frac{\partial}{\partial x_i}\left[\left(D_m + \frac{\nu_t}{Sc_t}\right)\frac{\partial c}{\partial x_i}\right]$$

where D_m, ν_t, and Sc_t are the mass thermal diffusion coefficient, turbulent kinematic viscosity, and turbulent Schmidt number, respectively.