Design of diffuser/nozzle

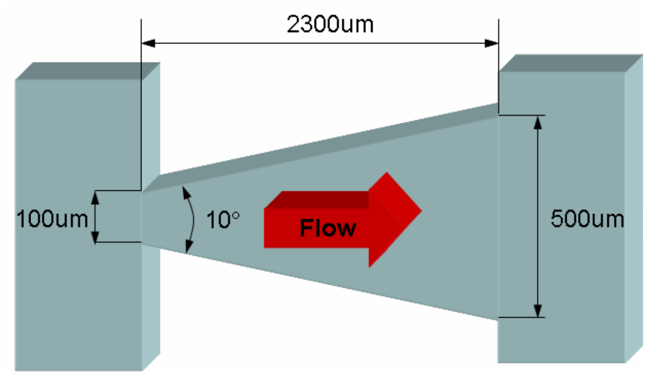


Fig. S1 Design of diffuser element in microchannel.

According to a model from the reference (Jiang et al., 1998) the mean flow rate Q of nozzle-diffuser pump is calculated by:

$$Q = 2\Delta V_m f \frac{\sqrt{\xi_n / \xi_d} - 1}{\sqrt{\xi_n / \xi_d} + 1} \qquad (1)$$

where ΔV_m is the volume variation amplitude per pumping cycle, f is the pulse frequency, ξ_n and ξ_d are the coefficients of pressure loss of the nozzle and diffuser, respectively. For a circular membrane of radius R that is clamped at the boundary, the vertical displacements of membrane can be written as (Loy et al., 1999)

$$w = W_0 (1 - \frac{r^2}{R^2})^2 \qquad (2)$$

where, W_0 is the vertical displacement at the centre, r is the distance from the centre. Using eq (2), the volume change per pumping cycle can be calculated as

$$\Delta V_m = \int_0^{w_f} \pi r^2 dw - \int_0^{w_0} \pi r^2 dw \qquad (3)$$

where w_0 and w_f are the initial and the final vertical deflection on thin membrane, respectively.

From our experimental results, the actuating frequency of cell-polymer membrane was between 0.2 to 0.4 Hz and the vertical movement was about 8 μm, and the ξ_n/ξ_d at 10° angle could be obtained from the reference (Jiang et al., 1998). Therefore, theoretical mean flow rate should be 7.148 nl/min.

X. N. Jiang, Z. Y. Zhou, X. Y. Huang, Y. Li, Y.Yang, C. Y. Lin, Sensors and Actuators A: Physical, 1998, 70, 81-87.

C. T. Loy, S. C. Pradhan, T. Y. Ng, K. Y. Lam, *J. Micromech. Microeng.*, 1999, **9**, 341-344

Finite element model

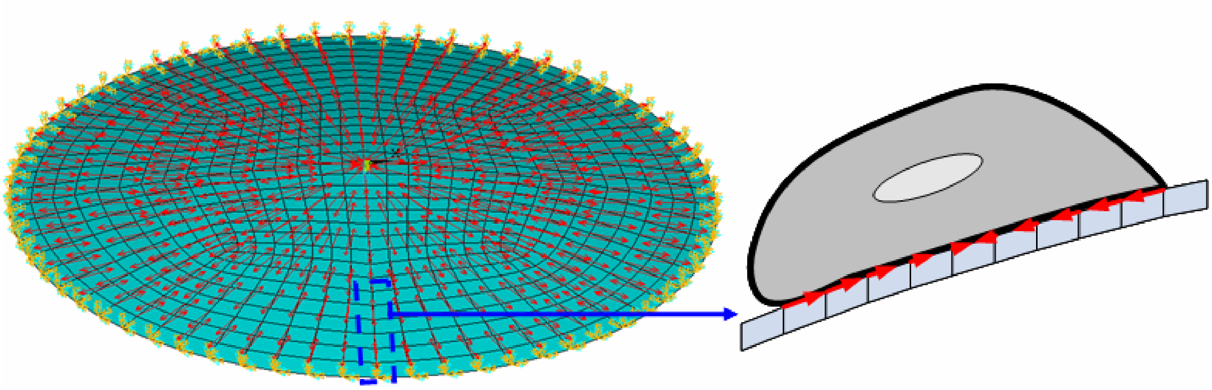


Fig. S2 Schematic diagram of computational modeling for a dome shape membrane

Experimental setup for monitoring microflow

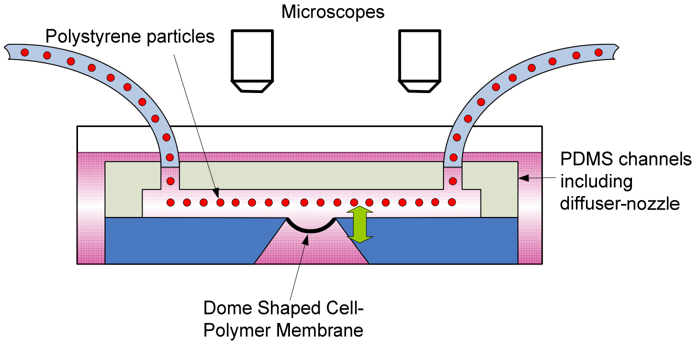


Fig. S3 Experimental setup to monitor fluid motions in microchannels

Fabrication of hybrid micropump

A Si_3N_4 layer was deposited by LPCVD, and patterned with photolithography and RIE to define backside windows for subsequent KOH etching (Fig. S4A). By anisotropic etching of the silicon substrate, a micro-well was formed with the Si_3N_4 thin film remaining at the top. The thin film of PDMS (8 μm) was created by spin-coating PDMS on top of the Si_3N_4 (Fig. S4B). After removing the supporting Si_3N_4 layer with RIE, the backside of the membrane was coated with Cr (150 Å) and Au (800 Å) to form the dome shaped membrane by stress mismatching (Fig. S4C). This Cr/Au layers was also used as a seed layer on which cells adhere via self assembled monolayers (SAMs) treatment. The PDMS microchannel was fabricated by molding after photolithography with a negative photoresist (SU-8, Microchem) (Fig. S4A*). PDMS prepolymer (Sylgard 184, Dow Corning) was prepared by mixing PDMS base with a curing agent in 10:1 ratio, and poured over the fabricated SU-8 master. The PDMS was cured in an oven at 90 °C for 2 hours (Fig. S4B*), and peeled off from the master (Fig. S4C*). The top PDMS channel and the bottom silicon structures were aligned under an optical microscopy and permanently bonded after oxygen plasma treatment (200 mTorr, 40 W).

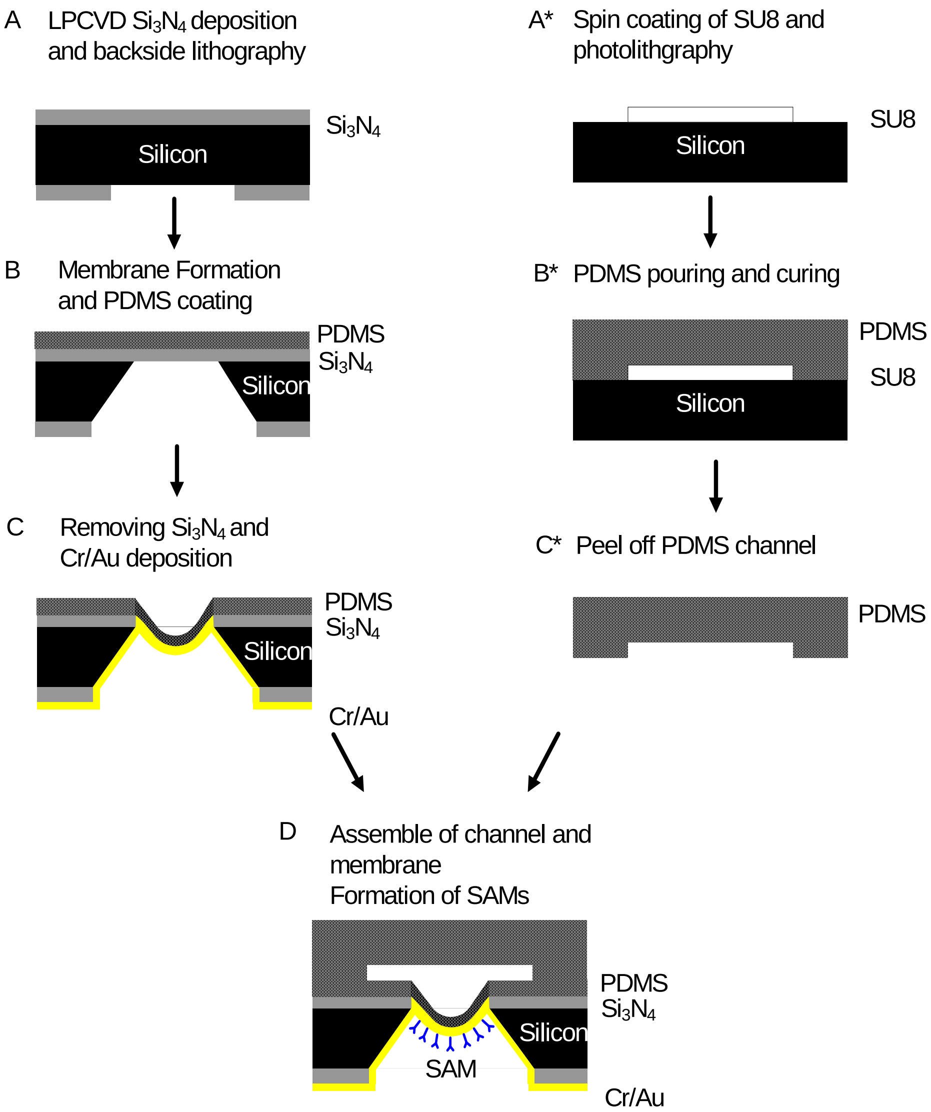
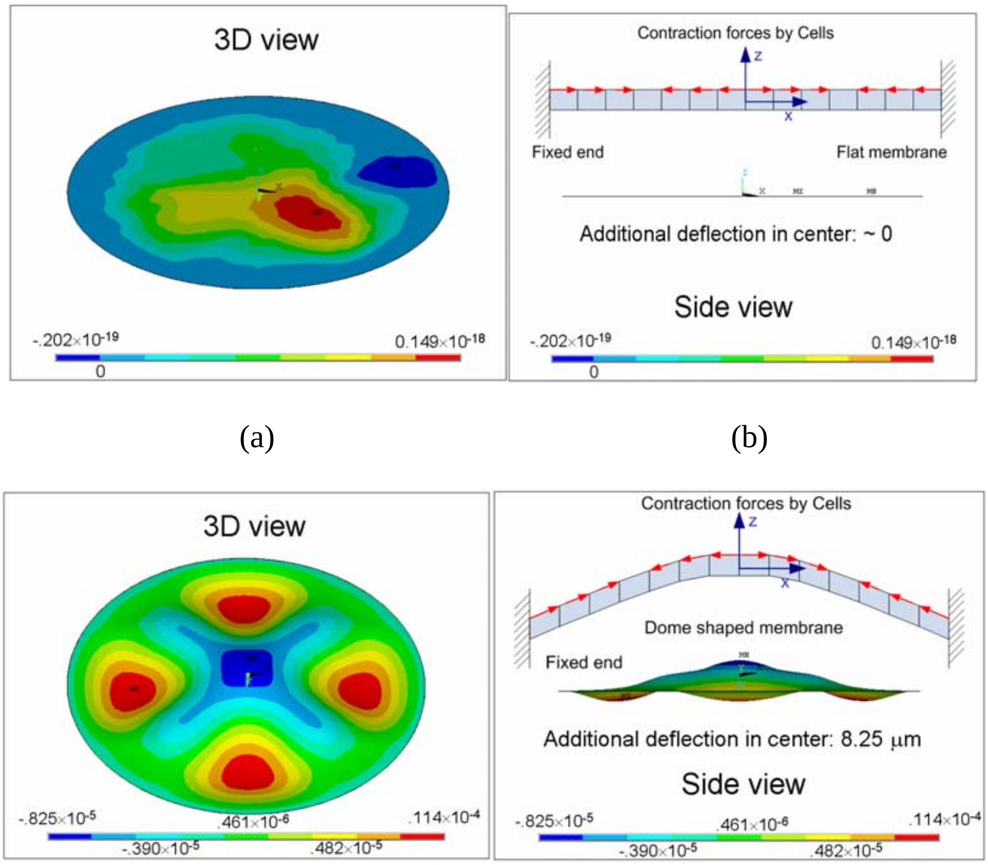


Fig. S4 Fabrication procedures for a hybrid micropump.

ANSYS Simulation results



(c) (d)

Fig. S5 Vertical displacements of a flat membrane (membrane radius: 500 μm, no initial deflection at the center): (a) 3-D view (b) Side view. Vertical displacements of a dome-shaped membrane (membrane radius: 500 μm, initial deflection at the center: 50 μm, additional central deflection due to cell force: 8.25 μm): (c) 3-D view (d) Side view.