Supplementary materials

Material and methods

Force measurement of PDMS deformation

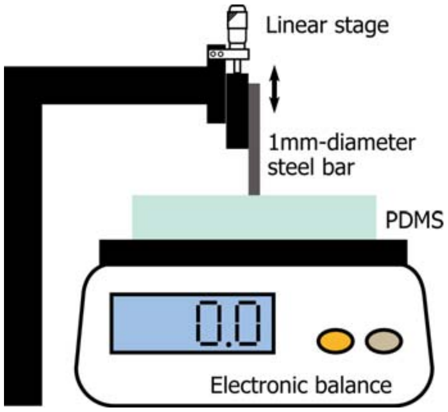

Figure S1. Apparatus for force measurement of PDMS deformation by a 1mm-diameter steel bar. PDMS blocks with defined thickness were sequentially placed on the electronic balance for force measurement. The weight of the PDMS blocks was tarred to zero the reading before the measurement. A linear stage fixed at a firm cantilever can specify a precise displacement to define the depth of deformation. The relationship between PDMS deformation and required force can then be obtained directly from the reading of the electronic balance. Three curing ratios (1:5, 1:10, 1:20) and three thicknesses (0.7mm, 1.1mm, 1.6mm) of PDMS specimens were prepared and measured with five repetitions.

Force measurement of permanent magnets

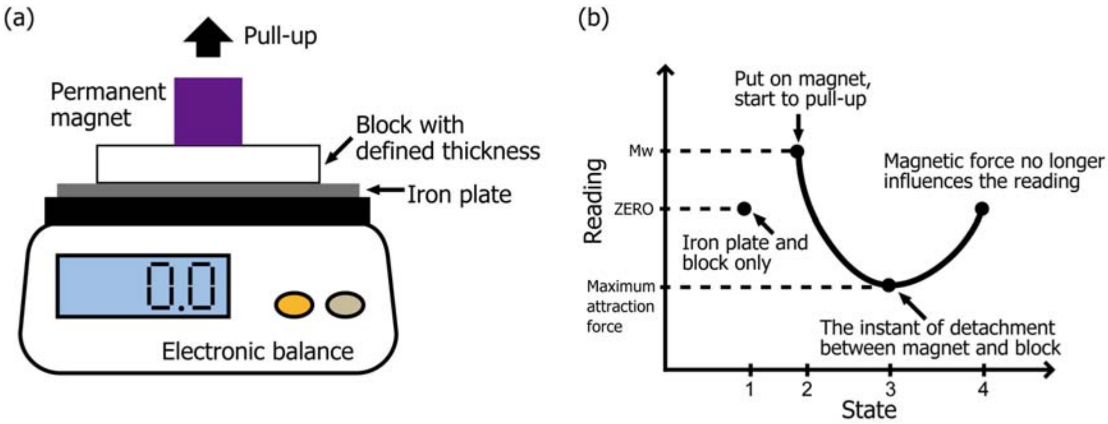

Figure S2. (a) Apparatus for force measurement of a permanent magnet. A permanent magnet, a block with defined thickness, and an iron plate were placed on the electronic balance sequentially. The blocks chosen here were glass material with three different thicknesses, 1.1mm, 1.5mm, and 2.2mm. A cantilever (not shown in the figure) will pull the magnet up during the recording to find out the maximum attraction force between magnet and iron plate at a certain distance. (b) Relationship between the reading of the electronic balance and experimental states. First, we placed the iron plate and the block on the electronic balance and zeroed the reading (State 1). Then the magnet was placed on the block (State 2). The reading shown at this moment was the weight of the magnet denoted by M_w. When the cantilever started to pull the magnet upward, the reading decreased gradually and attained the maximum reading (with negative sign) at the instant of detachment between the magnet and the block (State 3). Right after the detachment, the magnetic force still affected the reading until the magnet was moved a certain distance away from the plate and the reading returned to zero (State 4). We performed the experiments with three blocks with different thicknesses by five permanent magnets purchased in the same batch.

Results and discussion

Choice of magnet

To choose appropriate permanent magnet, first, we need to understand the force required to deform PDMS (with certain thickness) at a desired depth. Three PDMS curing ratio (1:5, 1:10, 1:20) and thickness (0.7mm, 1.1mm, 1.6mm) was experimentally examined to obtain the relationship between PDMS deformation and required pressure, as shown in Fig. S3a. Basically curing ratio caused major influence on required pressure for PDMS deformation. Besides, at the same PDMS curing ratio, thicker PDMS deforms easier for the same depth. However, thicker PDMS needs deeper deformation for a successful valving so that comparatively larger pressure was necessary. It can also be observed from the arrows in Fig. S3a which indicated minima pressures needed for a complete valving at different PDMS thickness (predicted from the simulation results in Fig. 2c).

The magnetic attraction/repulsion force of permanent magnets could be difficult to estimate analytically. We therefore performed a direct measurement of the attraction force when a permanent magnet was placed at a distance from an iron plate, as shown in Fig. S3b. To ensure the space can be fully pressed in to the flexible PDMS, the distance between magnet and iron plate should include spacer thickness, PDMS thickness, and glass substrate. From the simulation result, we performed the valving process upon 1 mm-thick PDMS (1:10 curing ratio) with a 0.4 mm-thick spacer. The distance between magnet and iron plate was 1.55mm (include thickness of glass substrate) and hence the magnet could generate ~1.4N attraction force, which is larger than the minima criterion ~0.5N of such valve design (see results in Fig. S3a). This serves as a simple guideline when the proposed valve is being designed and fabricated.

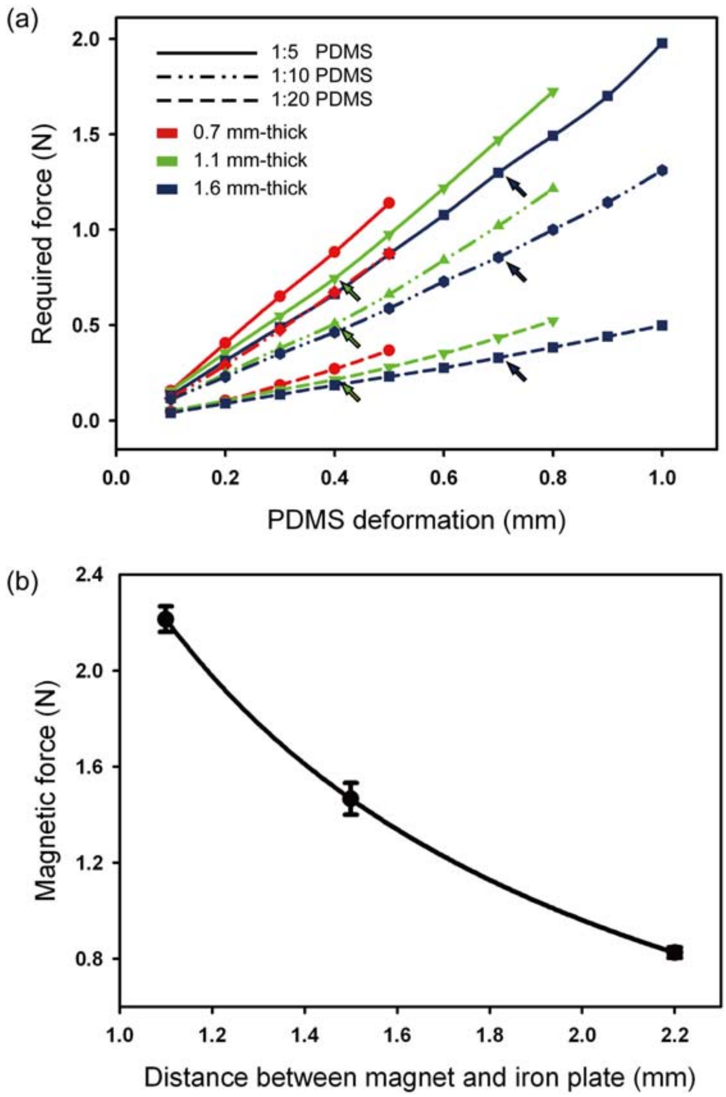

Figure S3 (a) Relationship between PDMS deformation and required pressure (corresponding force for 1mm-diameter spacer). Three PDMS curing ratios (1:5; 1:10; 1:20) and thickness (0.7mm, 1.1mm, 1.6mm) were tested. The arrows indicate minima criteria in particular PDMS thickness to fully close the microchannel (predicted from the simulation results in Fig. 2c). (b) Measured magnetic force of present permanent magnet with respect to different distance between magnet and iron plate.

Simulation

Video S1: The video shows the simulation result of a 100µm-wide, 50µm-high microchannel (aspect ratio=2). As the spacer progressively pressing against the PDMS microchannel at different depth, the deformable PDMS gradually filled up the entire cross-section of the microchannel to complete valving function.

Video S2: Enlarged view of video S1 in the cross-sectional area of the microchannel.

Video S3: The video shows the simulation case which has an aspect ratio of 8. Obviously, the upper PDMS wall deformed and reached the bottom surface rapidly to occupy the majority of the cross-sectional area of the microchannel, and hence increased the speed of valve closing.