Electronic Supplementary Material (ESI) for Lab on a Chip

Electronic supplementary information (ESI)

Bonding of glass nanofluidic chips at room temperature by a one-step surface activation using an O_2/CF_4 plasma treatment

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1. Fabrication of nanofluidic chips

The Chip (Fig. 4a) with two sets of microchannel-nanochannel hybrid was fabricated on two fused silica substrates, according to the fabrication process briefly described as follows. Nanochannels were fabricated on a fused silica substrate by electron beam lithography (ELS-7500, Elionix Co., Ltd., Tokyo, Japan) and plasma dry etching (NE-550, ULVAC Co., Ltd., Kanagawa, Japan). The feature sizes of the nanochannels were determined from images obtained with a scanning electron microscope (SEM, ELS-7500, Elionix Co.) and an atomic force microscope (AFM; SPA-400, SII NanoTechnology Inc., Chiba, Japan). Microchannels for injection of the sample were etched on another fused silica substrate after a photolithography process and then the inlet/outlet holes pierced using a diamond-coated drill. The substrates were then washed repeatedly in ultrapure water and a mixed solution of sulfuric acid and hydrogen peroxide (3:1). Finally, the substrate containing the nanochannels was bonded to the substrate containing the microchannels according to the RT bonding process.

2. Experimental method of evaluation of bonding energy: a protocol of the crack opening method (Fig.S1)

The bonding energy of the bonded substrates was characterized using a crack opening method,[12] which is a widely used method to evaluate the bonding strength. As shown in Fig. S1, a 100-μm-thick razor blade was inserted into the bonding interfaces, and the crack propagation length is measured. The bonding energy (γ) is calculated using the following equation:

$$\gamma = \frac{3t_b^2 E t_w^3}{32L^4} \tag{1}$$

where E is Young's modulus for fused silica substrate (6.6×10^{10} Pa), t_b is the blade thickness, t_w is the substrate thickness, and L is the crack propagation length.

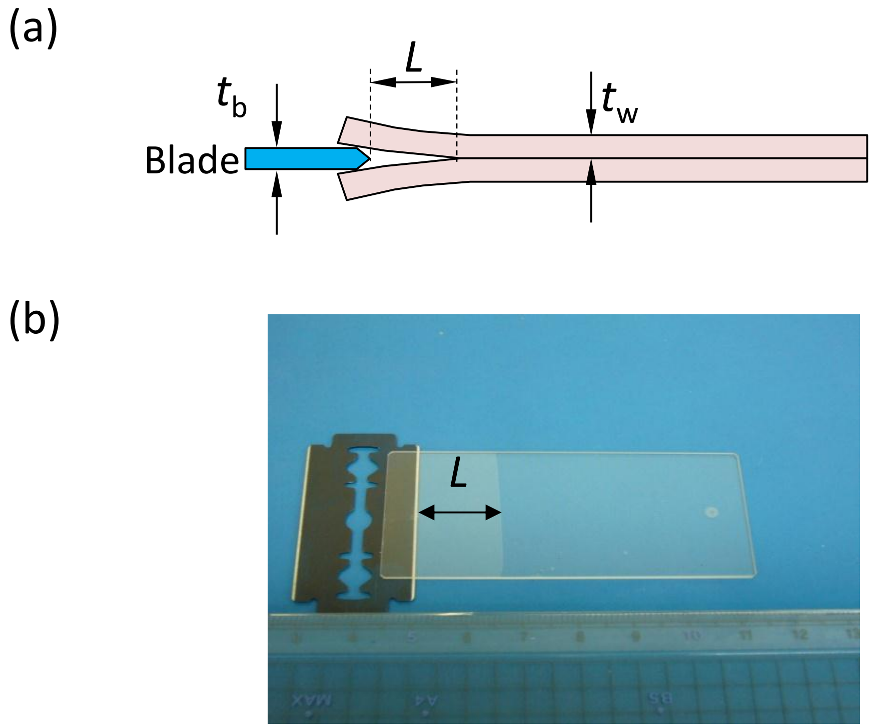

Fig. S1 Schematic illustration of the crack opening method (a) for evaluation of bonding energy and a demonstration of the actual measurement (b).

3. Liquid introduction operation on the bonded nanofluidic chip by high air pressure using a custom-made high pressure-driven fluid control system (Fig.S2)

The bonded chip with two sets of microchannel-nanochannel hybrid was placed in a custom-made chip holder (Ohte Giken, INC., Tsukuba, Japan) and then the inlets and outlets of the chip was connected to the custom-made pressure-driven fluid control system which is schematically shown in Fig. S2. All parts of the holder were made of stainless steel, and all connections were made either by screwing or by silver brazing. A high-pressure air compressor (AC) (EC 1445H, Hitachi Koki, Tokyo, Japan) to generate pressure was first connected to an airline. The airline was then separated into four individual lines, which connected to individual air tanks (AT). The air tanks had the capability to store pressure of a given value through control of a solenoid valve

(SV1) (J262G001AC100, ASCO Japan Co., Ltd., Nishinomiya, Japan) with a pressure transmitter (PT). The airline was connected to a liquid tank (LT) through a solenoid valve (SV2) (SV30A32P4P33E, Circle Seal, CA, USA). A sequencer (MS2-H100, Keyence, Osaka, Japan) was used to control the open and close of the valve. When opening the valve, the liquid (sulfo-rhodamine B solution, 50 μM) in the liquid tank was pressurized into the bonded nanofluidic chip at a predetermined setup pressure. When closing the valve, the liquid tank was exposed to atmospheric pressure.

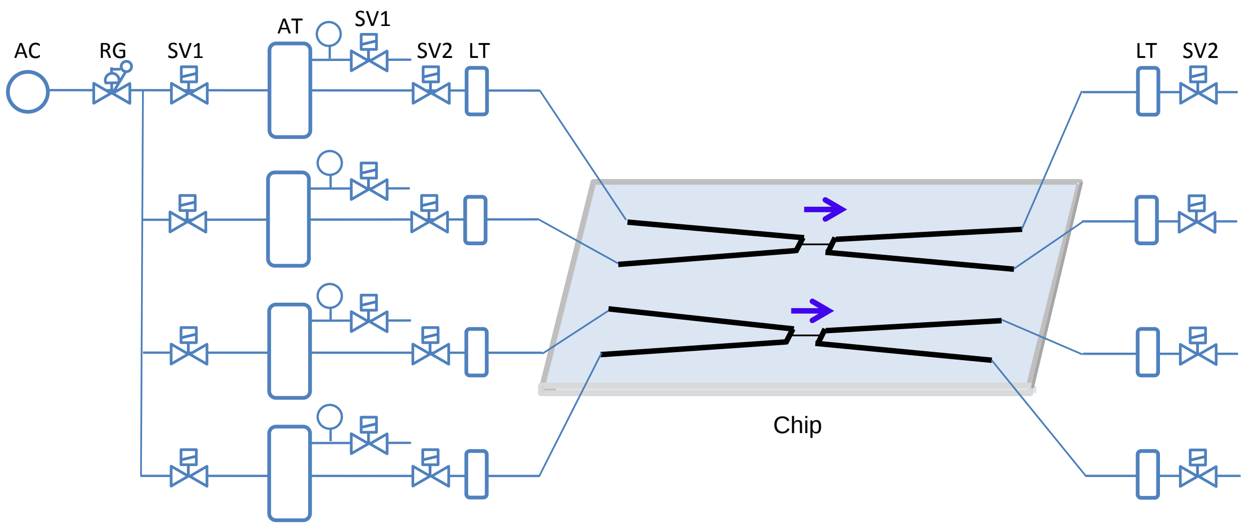

Fig. S2 Schematic illustration of the liquid introduction using a custom-made air pressure-driven fluid control system. AC: air compressor; RG: pressure regulator; SV: solenoid valve; AT: air tank; PT: pressure transmitter; LT: liquid (sample) tank.