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Supporting Information

S1: Chip fabrication process

The ablation process was performed using a continuous mode VII-12 CO_2 laser (Giant Technologies Incorporated) with a maximum power output of 12 W and a wavelength of 10500 nm (see Fig. S1). During the machining process, the PMMA substrates were fixed individually to the stationary working table and the XYZ stage carrying the laser source, reflecting mirrors and focusing lens was driven by the computer in accordance with the relevant AutoCAD design in order to produce the required micro-features, e.g. ports, mixing chamber, collection chamber, etc. The output power and laser travel speed have a critical effect on the profile and structure of the ablated microchannel. In performing the ablation process, the output power and laser travel speed were specified as 4.8 W and 30 mm/s. The total machining time for the four PMMA substrates was less than 2 min. Note that the detailed fabricated method using the CO_2 laser is provided in previously by the current authors (Ref. [43]). After the ablation process, the three patterned PMMA substrates were carefully aligned, and packaged using a hot-press bonding technique. In the bonding process, the substrates were maintained under a light contact pressure of 0.5 kg/cm^2 as the temperature was increased to 98°C. The pressure was then increased to 1.5 kg/cm^2 and the temperature maintained at 98°C for a further 10 min. Finally, the pressure was released and the microchip was cooled to room temperature.

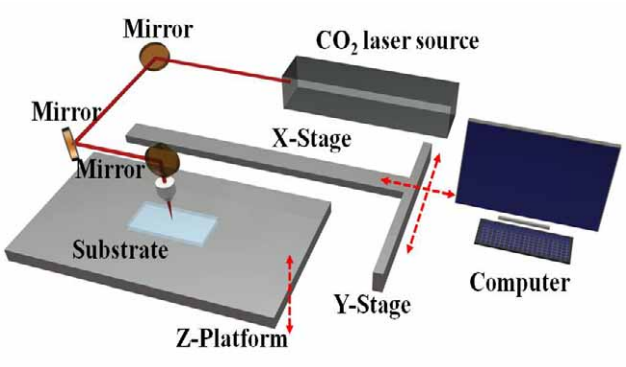

Fig. S1: Schematic illustration of CO_2 laser ablation system used to pattern PMMA substrates.

Adhesive bonding

As shown in Fig. S2, the sealed PMMA microchip was bonded to the two aluminum plates, and the plates were then attached to a micro-heater and a thermoelectric cooling chip, respectively. Note that aluminum was deliberately chosen for the present device due to its high heat transfer coefficient, which results in an improved heating and cooling performance. The aluminum plates were attached to the PMMA microchip using PDMS (polydimethylsiloxane). In the bonding process, PDMS (elastomer: elastomer curing agent = 10:1) was spread on the under surface of the microchip using a roller and the smaller and larger aluminum plates were carefully aligned with the inlet reservoir region and serpentine microchannel region of the chip, respectively. A light contact pressure was then applied and the chip / aluminum plate assembly was maintained at a temperature of 90°C for 50 min. The chip was then cooled to room temperature. Finally, the aluminum plates and PMMA microchip were bolted together under a light pressure in order to ensure a robust sealing of the wells; thereby preventing liquid leakage. Having attached the aluminum plates to the PMMA chip, a micro-heater and a thermoelectric cooling chip were mounted on the surfaces of the small and large aluminum plates, respectively, using an alumina gel cured at a temperature of 90°C for 30 min.

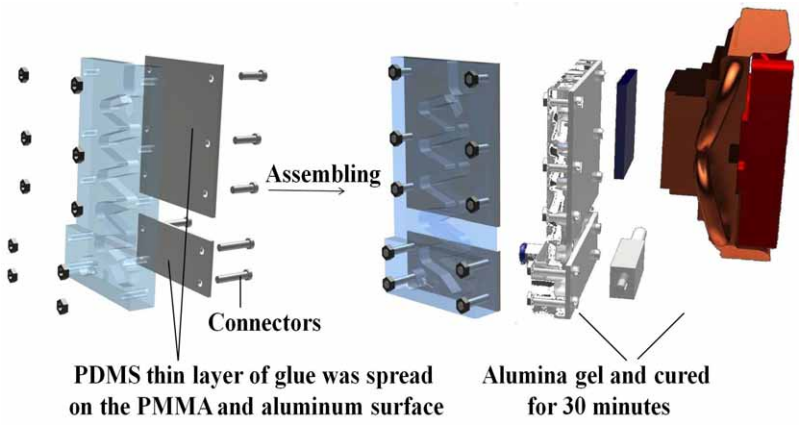

Fig. S2: Schematic illustration showing assembly of major components in micro-distillation chip, namely PMMS substrates, aluminum plates, micro-heater and thermoelectric cooling chip.

Detection system and measurement

As shown in Fig. S3, the major components in the miniaturized SO_2 distillation system include a pair of microfluidic distillation chips, a power control module, and a carrier gas pressure control module. The basic steps in the experimental detection procedure are as follows: (1) H_2SO_3 solution (50 – 500 ppm) was injected into the reservoir using a syringe pump (KDS200, USA). (2) DI water was injected into the collection tank. (3) the inlet of the microchip was connected to a micro-gas valve, which was connected in turn through the gas pressure control module to a N_2 gas supply. (4) The micro-heater was activated, causing the H_2SO_3 solution in the inlet reservoir to reach boiling temperature (100°C) after approximately 10 min. (5) Having reached the boiling temperature, the micro-valve was opened, causing the water vapor and gaseous SO_2 to enter the serpentine channel under the effects of the carrier gas. (Note that the N_2 gas flow rate was maintained at a constant 15 ml/min.) The serpentine channel was maintained at a temperature of approximately 8°C by means of the thermoelectric cooling chip. Thus, the water vapor condensed in the form of droplets and remained in the serpentine channel. However, SO_2 has a condensed temperature of −72.4°C, and thus the SO_2 remained in a gas phase and was carried

into the collection tank by the carrier gas. (6) The inlet reservoir was heated for a further 20 min, and the gaseous SO_2 and DI water were then removed from the collection tank. (7) The SO_2 and DI water were blended with a mixed indicator (Methyl Red - Methylene Blue) and pipetted into an eppendorf to form a mixed solution. (8) Following a colorimetric reaction between the mixed indicator and the H_2SO_3 solution (as indicated by a change in color from colorless to purple), the mixed solution was pipetted into a cuvette and transferred to a commercial spectrophotometer (UV-6100, Great Tide Instrument Co., Ltd) in order to detect the SO_2 absorbance value. (9) Having measured the SO_2 absorbance value, the corresponding SO_2 concentration was inversely derived.

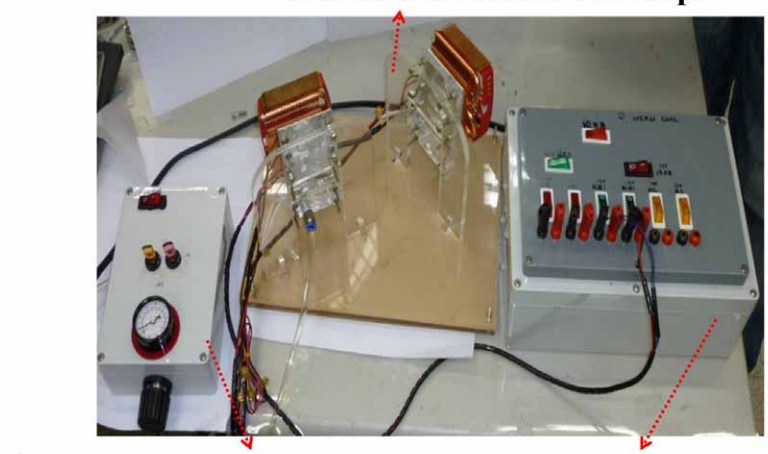

Fig. S3: Photograph of experimental set-up.

S2: Optimal reaction time and distillation time

In order to determine the optimal reaction time between the mixed indicator and the H_2SO_3 solution, the SO_2 absorbance values of various standard H_2SO_3 solutions with SO_2 concentrations ranging from 100 ~ 500 ppm were measured following reaction times of 0 ~ 20 min. The corresponding results are presented in Fig. S4(a). It

can be seen that given a reaction time of 0 ~ 10 min, the absorbance value varies randomly. In other words, the chemical reaction between the mixed indicator and the H_2SO_3 solution is incomplete. However, given a reaction time of more than 10 min, the absorbance attains a steady value; indicating that the chemical reaction is complete. Thus, in performing the distillation experiments using the proposed microfluidic device, the reaction process was allowed to proceed for 15 min before the detection solution was transferred to the cuvette.

Figure S4(b) shows the variation of the SO_2 absorbance value with the distillation time given a reaction time of 15 min and a H_2SO_3 solution with a SO_2 concentration of 100 ppm. The results indicate that a minimum distillation time of 20 min is required to ensure the complete separation of the H_2SO_3 solution into its SO_2 and H_2O components.

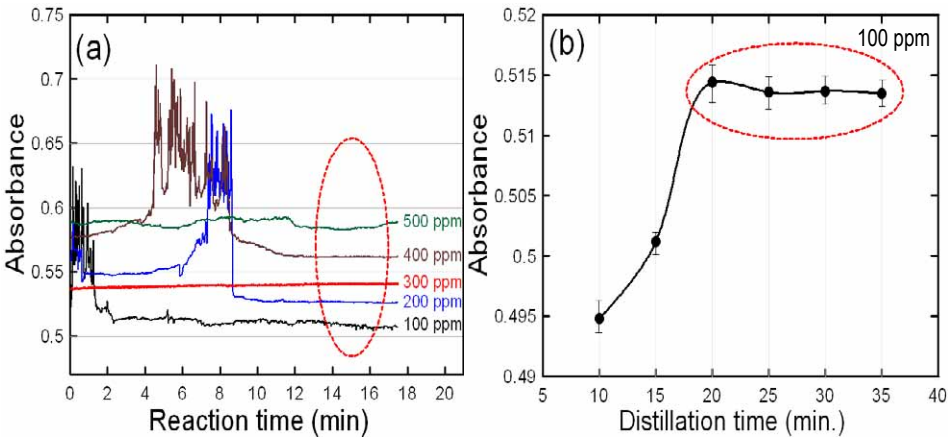

Fig. S4: (a) Variation of absorbance value with reaction time for standard H_2SO_3 solutions with SO_2 concentrations in the range of 100-500 ppm. (b) Variation of absorbance value with distillation time.

S3: Calibration curve

Figure S5 presents the detection results obtained using the proposed miniaturized distillation system for SO_2 samples with concentrations ranging from 50 ~ 300 ppm. From inspection, the absorbance value and SO_2 concentration are found to be related via the relationship Y = 0.0002078 X + 0.4914. (Note that this equation is referred to hereafter as the *experimental group equation.*) Moreover, the correlation coefficient is found to have a value of $R^2 = 0.9986$.

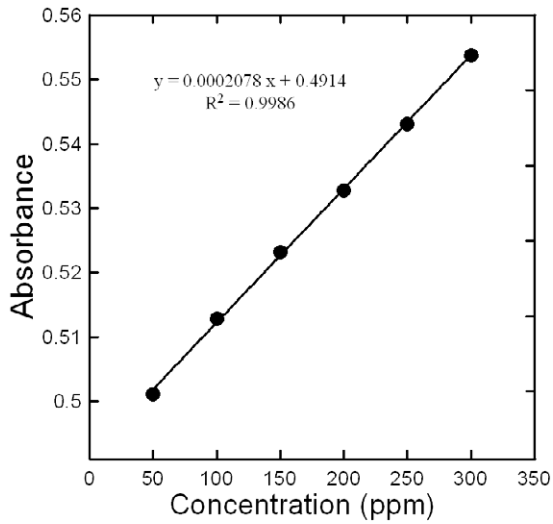

Fig. S5: Variation of absorbance value with SO_2 concentration for distilled H_2SO_3 samples with SO_2 concentrations in the range of 50-300 ppm.