Supplementary Information

Chemical effects induced by gas–liquid jet flow

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Experimental detail

The gas-liquid jet flow setup consists of a tee connected by a horizontal tube with the inner diameter and length of 1.5 mm (ϕ3×1.5 mm) and 25 cm, respectively (Fig. S1). The schematic diagram of gas-liquid jet flow process is shown in Fig. S2. The whole system includes an air compressor, buffer tank, gas flow meter, plunger pump, feed/discharge tank, gas-liquid jet setup, liquid flow meter, and condenser. The flow rate of gas and liquid are controlled by flow meter. Methylene blue (MB, Sinopharm, Nanjing, purity >98%) aqueous solution with an initial concentration of 10 μmol/L was used as an indicator to detect the chemical effects. The operation temperature was controlled at 25 °C. The liquid was pumped (flow rate of 13 L/h) by the plunger pump (2J-XZ, Zhejiang Petrochemical Co. Ltd, Hangzhou, China) to meet with compressed air from the buffer tank in the tee and accelerated by high-speed gas in the tube. The gas-liquid mixture was ejected from the tube, thus forming gas-liquid jet flow. After leaving the tube, water vapor and droplets in the gas phase was condensed before discharging the gas into atmosphere. The condensed water and the remaining liquid were collected and mixed for the next cycle. All experiments were cycled for 120 min.

A UV-vis spectrophotometer (Lambda 35 spectrophotometer, PerkinElmer) was employed to analyze the concentration change of MB with time at a maximum absorbance wavelength of 664 nm.[1] A high-speed camera (FASTCAM SA-X2 type 200k, Photron) was employed to capture the photos of gas-liquid jet flow.

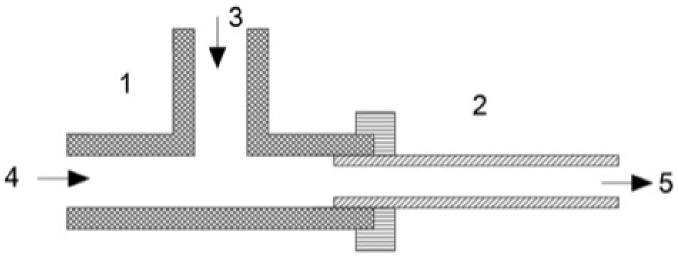

Fig. S1. Schematic view of the gas-liquid jet flow setup. 1-tee; 2-horizontal tube; 3-gas inlet; 4-liquid inlet; 5-gas/liquid outlet.

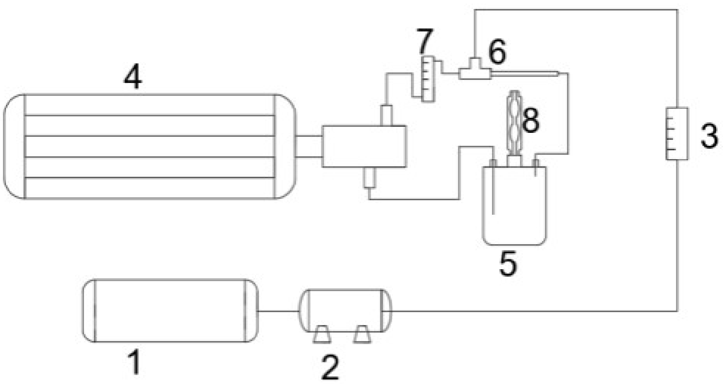

Fig. S2. Flow diagram of the gas-liquid jet process. 1-air compressor; 2-buffer tank; 3-gas flow meter; 4-plunger pump; 5-feed/discharge tank; 6-gas-liquid jet setup; 7-liquid flow meter; 8-condenser.

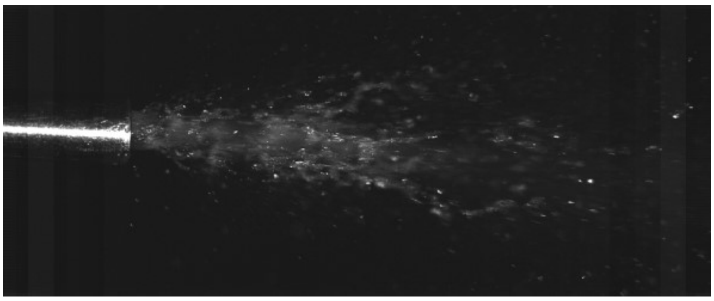

Fig. S3. The typical picture of gas-liquid mixture ejected from the tube.

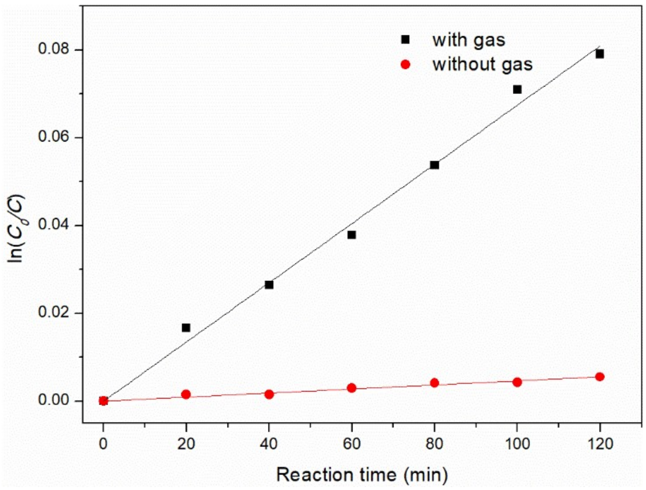

Fig. S4. Plots of ln(C_0/C) *vs* reaction time for the degradation of rhodamine B in the gas-liquid jet flow system (rhodamine B concentration: 7.5 μmol/L; gas flow rate: 600 L/h; temperature: 25 ◦C). A linear relationship between ln(C_0/C) and the reaction time t could be found, and the reaction rate constant k was determined to be 0.0405 h^{-1}, indicating the degradation of rhodamine B in the gas-liquid jet flow system also follows a pseudo-first-order kinetics.

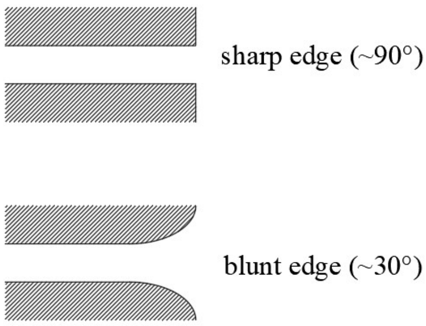

Fig. S5. Schematic view of the outlets with ~90º sharp edge and ~30º blunt edge.

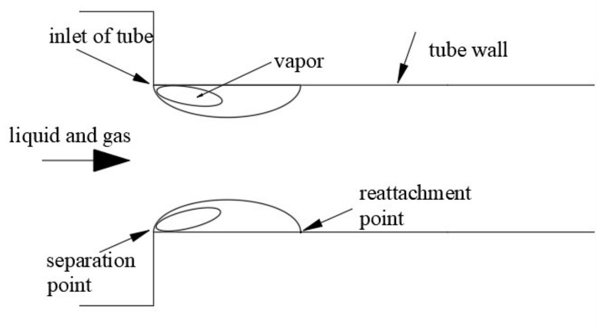

Fig. S6. Change of flow direction caused by the geometry changing.[2]

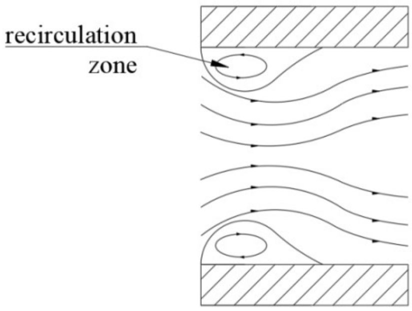

Fig. S7. The recirculation zone inside the tube.[3]

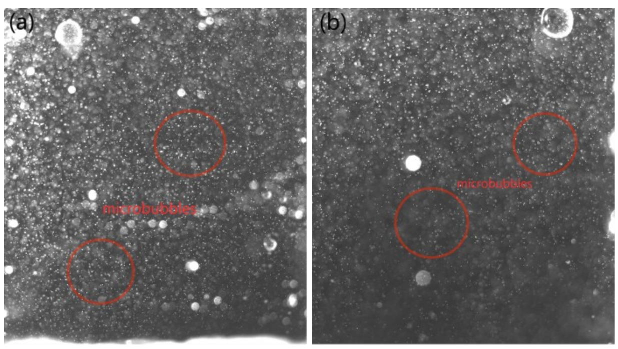

Fig. S8. The high-speed camera images of the liquid collected from the gas-liquid jet flow system. (a) gas flow rate of 100 L/h; (b) gas flow rate of 300 L/h.

Calculation of shear rate at the outlet of pipe

The calculation method could refer our previous paper for more detail.[4] In the case of gas-liquid jet flow ejected from pipe under gas flow rate of 100 L/h, the velocity of gas-liquid jet flow is ~16 m/s, and the corresponding shear rates for the ~90^{o} sharp edge and the ~30° blunt edge are ~1.51×10^{7} s^{-1} and ~0.755×10^{7} s^{-1}, respectively. When the gas flow rate is 600 L/h, the velocity of gas-liquid jet flow is ~28 m/s and the shear rates are ~2.64×10^{7} s^{-1} for sharp edge and ~1.32×10^{7} s^{-1} for blunt edge, respectively.

References

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