Electronic Supplementary Material (ESI) for Lab on a Chip

Electronic supplementary information (ESI) for:

Effective Pressure and Bubble Generation in a Microfluidic T-junction

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Electronic Supplementary Information (ESI) S1

Relation between (P_e*) and (l×f/v) for droplet generation in flow focusing structure

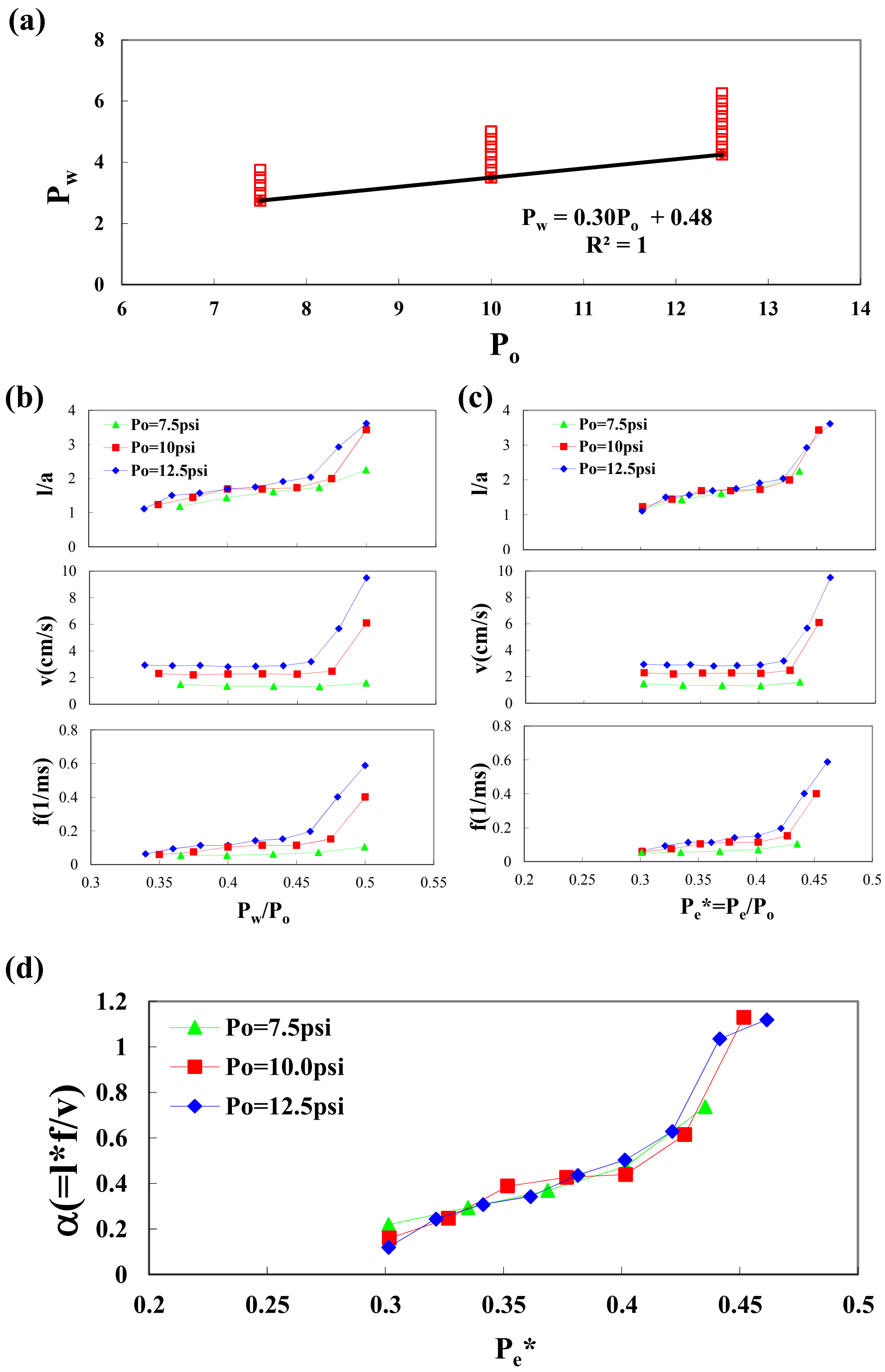

Fig. S1 The replotted results of flow focusing structure for water droplet generation by Ward et al.[1] (a) the flow map; two-phase flow characteristics (l/a, v and f) vs. (b) P_w/P_o and (c) P_e*(= P_e/P_o); (d) void fraction(α) vs. P_e*.

We followed the same process as mentioned in text to replot the relationship between P_e* and l_d×f/v_d for the case of droplet generation by flow focusing structure in Ward et al.[1] Fig. S1(a) shows the lower border of operation range of droplets has linear relationship of P_w=0.30×P_o+0.48, where the interception is physically contributed by the surface pressure, P_σ. In this case, to eliminate the contribution of surface tension force, the effective pressure can similarly be written as $P_e = P_w - P_\sigma = P_w - 0.48$. Therefore, the data ($l_d/a$, v and f) of Ward et al.[1] with respect to P_w/P_0, as shown in Fig. S1(b), can be replotted as the function of P_e* (=P_e /P_0) as shown in Fig. S1(c). Unlike that in Fig. S1(b), the lower border of data in Fig. S1(c) have shifted to almost the same P_e*-value. Furthermore, the dimensionless two-phase flow characteristics, l_d×f/v_d, with the physical meaning of droplet void fraction (α_d), can be plotted with respect to the effective pressure ratio, P_e*, as shown in Fig. S1(d). The α_d-curves for different P_o-values coincide together. This is the same as the present results by T-junction shown in Fig. 3(d) in the text. Three data points have values of α_d >1, that contravene the definition of void fraction. This overestimation may come partly from the measuring errors and partly from the one-dimensional simplified droplet volume estimation for the void fraction.

1. T. Ward, M. Faivre, M. Abkarian and H. A. Stone, *Electrophoresis*, 2005, **26**, 3716-3724.

Electronic Supplementary Information (ESI) S2

Relationship between β_d and ($P_e^*-G^*$) for whole range of G^*

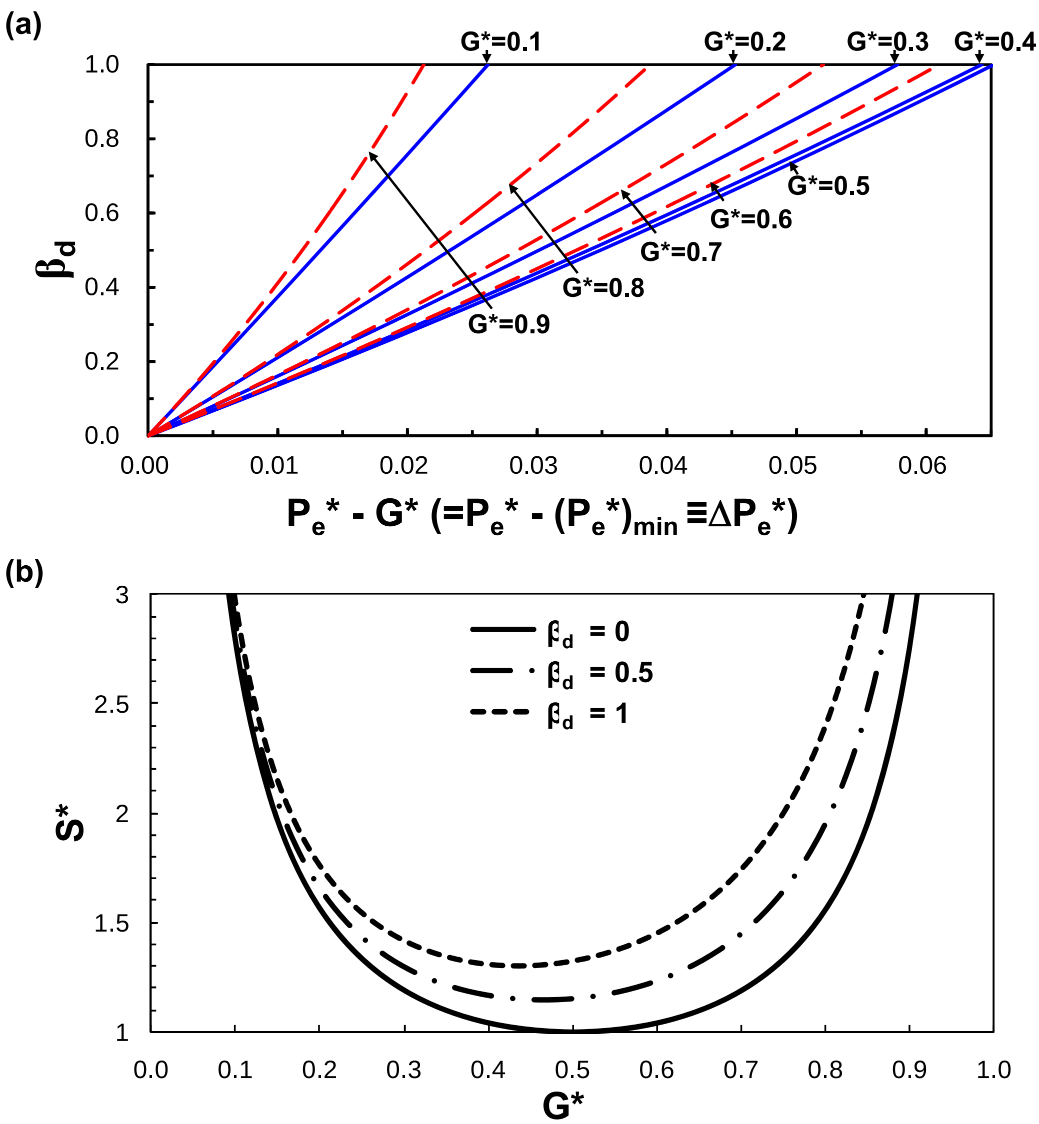

Fig. S2 (a) Predicted β_d - ($P_e^*-G^*$) curves of different G^* and (b) G^* effects on dimensionless slope (S^*) of β_d - ($P_e^*-G^*$) curves.

To further investigate the effect of geometrical design on the gas flow ratio, the β_d - ($P_e^*-G^*$) curves determined by Eq. (13) in text for different G*-values are plotted for the whole range of G* from 0.1 to 0.9 in Fig. S2(a). The (blue) solid lines represent for those curves of $G^* \leqq 0.5$ and the (red) dashed lines for $G^* > 0.5$. It shows that the slope of β_d - ($P_e^*-G^*$) curve decreases for increasing G*-value until $G^* = 0.5$, and the then the slope increases as G* is increasing further from

0.5 to 0.9. This indicates physically that a T-junction, having roughly equal upstream and downstream lengths could have the largest operation range of bubbly/slug flow for a given β_d-value. The slopes of β_d - (P_e*—G*) curves become steeper as G*-value differs from 0.5. Moreover, the nonlinearity of predicted curve in Fig. S3 (a) becomes more significant as the G*-value increases. To get deeper insight into the variations of β_d - (Pe*—G*) curves, the slope S can be determined from the first derivative of Eq. (13) in text as

$$S = \frac{d\beta_d}{d(P_e^* - G^*)} = \frac{1 - G^*}{nG^*(1 - P_e^*)^2}. \quad \text{(S2-1)}$$

The dimensionless slope S*, defined as S normalized by the slope at G* = 0.5 as β_d = 0, were plotted in Fig. S3 (b) in terms of G* for β_d = 0, 0.5 and 1, respectively. It reveals that the curve of β_d = 0, the lower border of bubbly/slug regime, denoted as S_0*-curve and shown as the solid line, is symmetric to the axis of G* = 0.5. However, the S* curve of β_d = 1, denoted as S_1*-curve and shown as the dashed line, is asymmetric and has in general larger slope than that of S_0* except G* -value approaching zero. Physically, the gap difference between S_0* and S_1* for any given G*-value can be interpreted as the indicator of the nonlinearity of β_d - (P_e*—G*) curve. This means that the larger the gap is, the more nonlinear the β_d - (P_e*—G*) curve becomes. It does show a fact that the design with small G* for the same gas flow ratio can have the advantage of a quasi-linear relationship of operation parameter (P_e*—G*), but combines also higher challenges in the manufacture process. This nonlinear phenomenon comes from the weighting competition between the upstream single-phase liquid part with constant viscosity and the downstream two-phase fluid part with nonlinear viscosity relation of β_d. As G* or β_d is small, the linear upstream part dominates or the nonlinear downstream part is negligible and therefore it shows a linear-like character. In opposite, as G* is large, the downstream weighting becomes important and the nonlinear effect thus dominates. Similarly, the nonlinearity becomes also significant for the case of large β_d.