Supplementary Information

Microfluidic generation of aqueous two-phase-system (ATPS) droplets by oil-droplet choppers

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Part I. Supplementary Figures

Part II. Supplementary Table

Part III. Supplementary Movies

Part I. Supplementary Figures

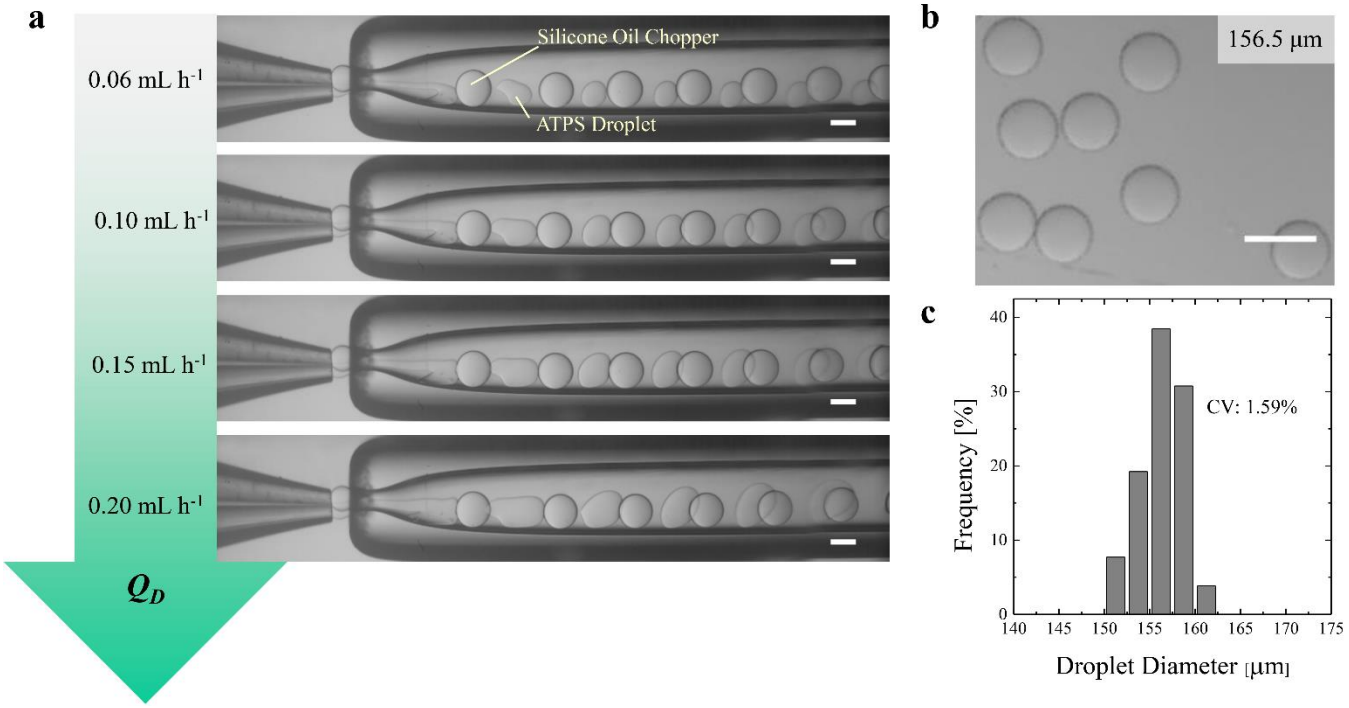

Fig. S1 Generation of ATPS droplets by silicone oil choppers where the ATPS is produced by phase separation of 25 wt% dextran and 20 wt% PEG, with the interfacial tension of γ_{ATPS} = 0.164 mN m^{-1}. (a) Micrograph of ATPS droplet generation. Q_o = 0.15 mL h^{-1} and Q_P = 1.00 mL h^{-1} are constant, while Q_D increases from 0.06 mL h^{-1} to 0.20 mL h^{-1} from top to bottom. As such, the frequency of ATPS droplet generation is ~3.42 Hz with the increasing size from top to down. (b)-(c) ATPS droplets of the average diameter to be 156.5 μm (c) and CV to be 1.59% (d). Scale bars, 200 μm. The material properties of ATPS used in experiments are summarized in Table S1.

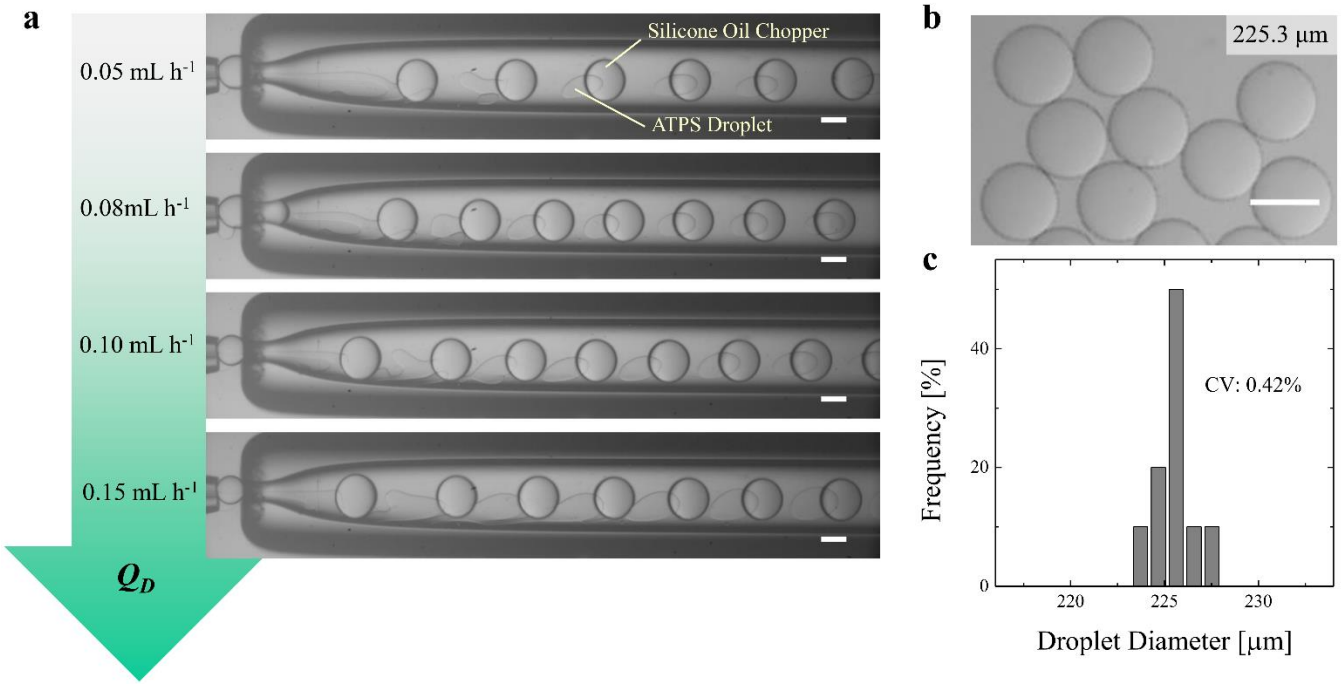

Fig. S2 Generation of ATPS droplets by silicone oil choppers where the ATPS is produced by phase separation of 20 wt% dextran and 15 wt% PEG, with the interfacial tension of γ_{ATPS} = 0.064 mN m^{-1}. (a) Micrograph of ATPS droplet generation. Q_o = 0.30 mL h^{-1} and Q_P = 1.20 mL h^{-1} are constant, while Q_D increases from 0.05 mL h^{-1} to 0.15 mL h^{-1} from top to bottom. As such, the frequency of ATPS droplet generation is ~4.33 Hz with the increasing size from top to down. (b)-(c) ATPS droplets of the average diameter to be 225.3 μm (c) and CV to be 0.42% (d). Scale bars, 200 μm. The material properties of ATPS used in experiments are summarized in Table S1.

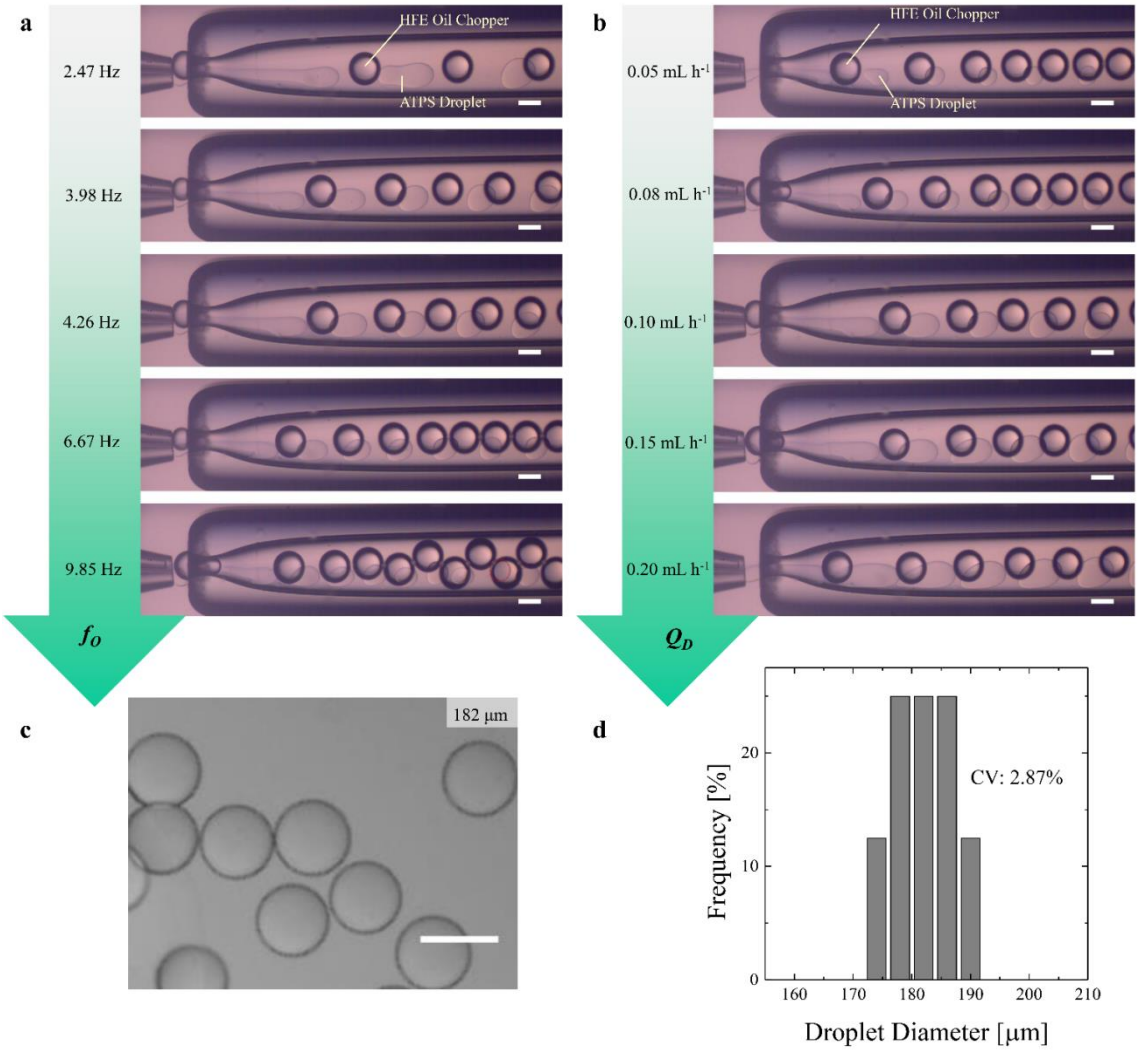

Fig. S3 ATPS droplet generation by fluorinated oil choppers (HFE 7100, density: ~1523 kg m^{-3}). (a) Micrograph of ATPS droplet generation at 2.47 Hz, 3.98 Hz, 4.26 Hz, 6.67 Hz, and 9.85 Hz by tuning the flow rate of HFE 7100 oil phase (Q_o) to be 0.10 mL h^{-1}, 0.15 mL h^{-1}, 0.20 mL h^{-1}, 0.25 mL h^{-1}, and 0.30 mL h^{-1}, respectively. The flow rates of the dispersed dextran-rich phase (Q_D) and the continuous PEG-rich phase (Q_P) are maintained at 0.10 mL h^{-1} and 1.00 mL h^{-1}, respectively. (b) The size of ATPS droplets increases with Q_D (shown at the left of each micrograph) at a constant generation frequency of ~5.06 Hz. The flow rates of HFE 7100 oil phase and the PEG-rich phase are constant to be 0.20 mL h^{-1} and 1.00 mL h^{-1}, respectively. (c)-(d) ATPS droplets of the average diameter to be 182 μm (c) and CV to be 2.87% (d). Scale bars, 200 μm.

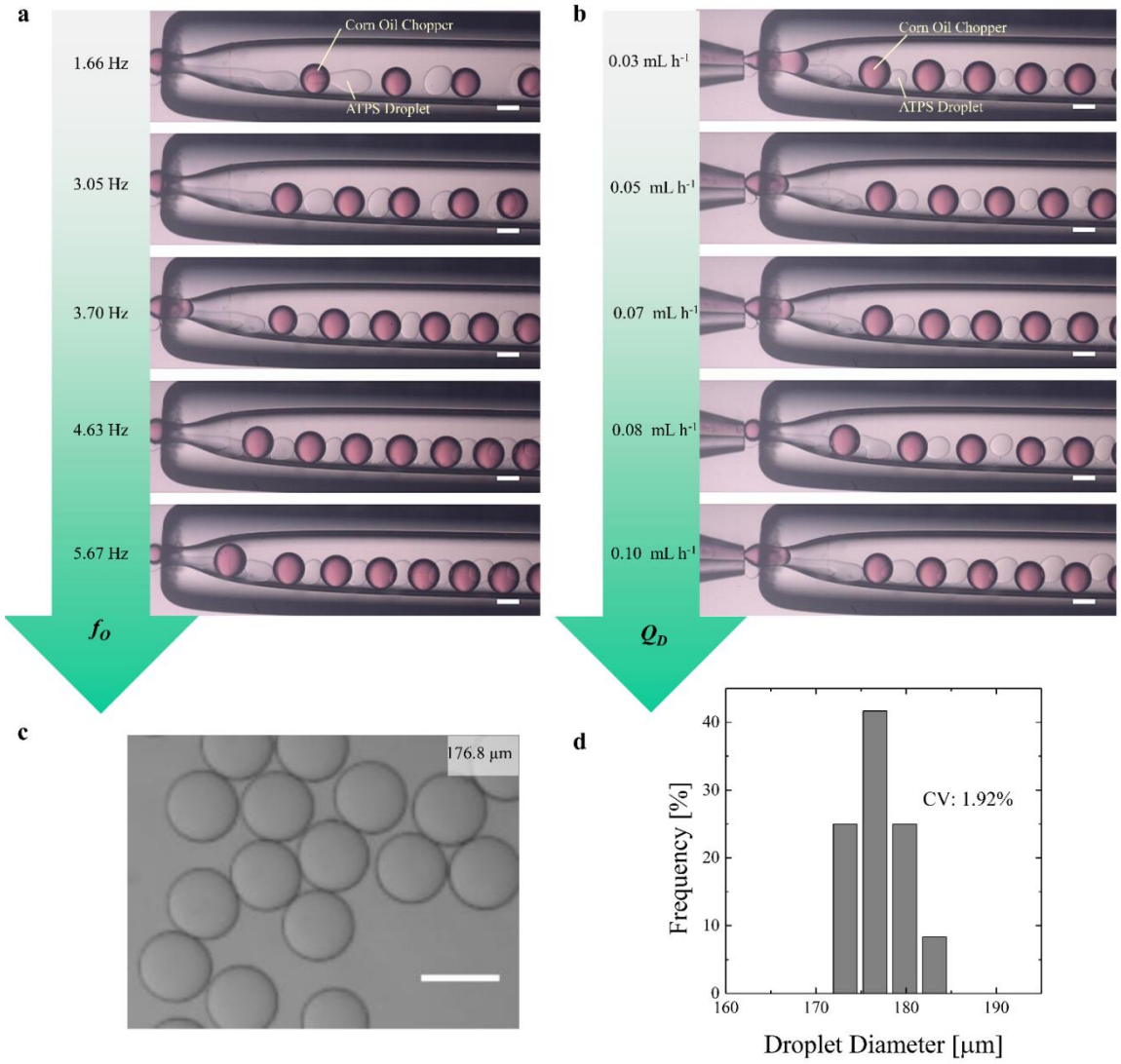

Fig. S4 ATPS droplet generation by corn oil choppers (density: ~933.4 kg m^{-3}). (a) Micrograph of ATPS droplet generation at 1.66 Hz, 3.05 Hz, 3.70 Hz, 4.63 Hz, and 5.67 Hz by tuning the flow rate of corn oil phase (Q_o) to be 0.08 mL h^{-1}, 0.12 mL h^{-1}, 0.15 mL h^{-1}, 0.18 mL h^{-1}, and 0.20 mL h^{-1}, respectively. The flow rates of the dispersed dextran-rich phase (Q_D) and the continuous PEG-rich phase (Q_P) are maintained at 0.08 mL h^{-1} and 0.8 mL h^{-1}, respectively. (b) The size of ATPS droplets increases with Q_D (shown at the left of each micrograph) at a constant generation frequency of ~3.64 Hz. The flow rates of corn oil phase and the PEG-rich phase are constant to be 0.15 mL h^{-1} and 0.80 mL h^{-1}, respectively. (c)-(d) ATPS droplets of the average diameter to be 176.8 μm (c) and CV to be 1.92% (d). Scale bars, 200 μm.

Part II. Supplementary Table

Table S1 Material properties of the three different ATPS used in experiments

Composition	ρ_P^* (kg m^{-3})	ρ_D^* (kg m^{-3})	μ_P (mPa s)	μ_D (mPa s)	γ (mN m^{-1})
Dextran: 25 wt% PEG: 15 wt%	1062.6	1138.9	11.043	44.05	0.103
Dextran: 25 wt% PEG: 20 wt%	1059	1155	13.29	69.54	0.164
Dextran: 20 wt% PEG: 15 wt%	1057.1	1130.3	8.625	32.12	0.064

* Subscripts '*P*' and '*D*' denote the PEG-rich and dextran-rich phase, respectively.

Part III. Supplementary Movies

Movie S1: Formation of a stable ATPS jet without perturbation

The ATPS is produced by phase separation of 25 wt% dextran and 15 wt% PEG, with the interfacial tension to be γ_{ATPS} = 0.103 mN m^{-1}. The flow rates of the dispersed dextran-rich phase (Q_D) and continuous PEG-rich phase (Q_P) are 0.10 mL h^{-1} and 1.20 mL h^{-1}, respectively. The video is recorded at 1000 frames per second (fps) and played at 200 fps.

Movie S2: Generation of uniform ATPS droplets by oil-choppers

The flow rates of the dispersed dextran-rich phase (Q_D), silicone oil chopper phase (Q_o), and continuous PEG-rich phase (Q_P) are 0.10 mL h^{-1}, 0.40 mL h^{-1}, and 1.20 mL h^{-1}, respectively. The generation frequency is 4.13 Hz. The video is recorded at 1000 fps and played at 250 fps.

Movie S3: High frequency of uniform ATPS droplet generation

The flow rates of the dispersed dextran-rich phase (Q_D), silicone oil chopper phase (Q_o), and continuous PEG-rich phase (Q_P) 0.05 mL h^{-1}, 0.50mL h^{-1}, and 6.00 mL h^{-1}, respectively. The generation frequency is ~2137 Hz. The video is recorded at 5000 fps and played at 10 fps.

Movie S4: Top view of uniform ATPS droplets generation at the junction

The flow rates of the dispersed dextran-rich phase (Q_D), silicone oil chopper phase (Q_o), and continuous PEG-rich phase (Q_P) are 0.10 mL h^{-1}, 0.10 mL h^{-1}, and 2.00 mL h^{-1}, respectively. The video is recorded at 1000 fps and played at 200 fps. The video is obtained in a top-view manner.

Movie S5: The transportation of ATPS and oil droplets in the collection capillary

The flow rates of the dispersed dextran-rich phase (Q_D), silicone oil chopper phase (Q_o), and continuous PEG-rich phase (Q_P) are 0.10 mL h^{-1}, 0.10 mL h^{-1}, and 2.00 mL h^{-1}, respectively. The video is recorded at 1000 fps and played at 200 fps. The video is obtained in a side-view manner.

Movie S6: The separation of ATPS and oil droplets

The flow rates of the dispersed dextran-rich phase (Q_D), silicone oil chopper phase (Q_o), and continuous PEG-rich phase (Q_P) are 0.10 mL h^{-1}, 0.10 mL h^{-1}, and 2.00 mL h^{-1}, respectively. The video is recorded at 1000 fps and played at 200 fps. The video is obtained in a side-view manner.