1. Microchannel geometry

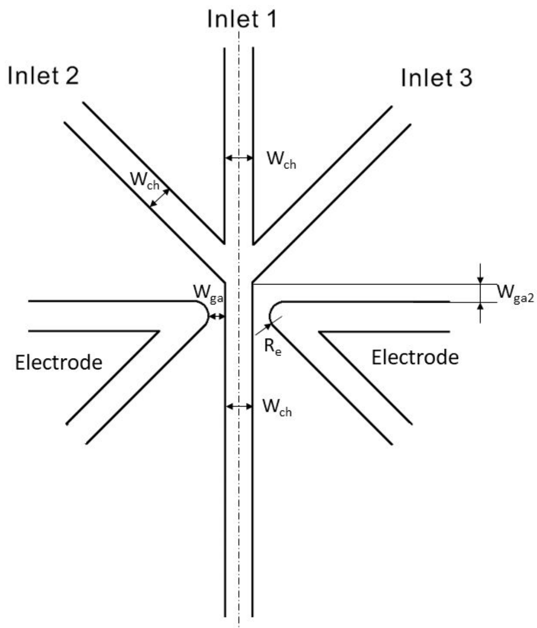

Figure S-1 Geometry parameters

Table S-1 Geometry parameters

Parameters	Value (μm)
W_{ch}	100
W_{ga}	50
W_{ga2}	55
R_e	50

The microchannel is a symmetric geometry and the channels for electrodes share the same height of 35 μm with the fluidic channels.

2. Material properties

Viscosity of the fluids

Table S-2 Viscosities of the fluids

Fluids	Viscosity (mPa·s)
70% w.t. Glycerol 0.2% w.t. in DI water	18
Poly(dimethylsiloxane), viscosity 100 cSt	97
Mineral oil	33
1-Octadecene	3
1,6-Hexanediol diacrylate	7
Hexane	0.3

The viscosities are obtained by measuring with the TA instruments Discovery Hybrid Rheometer (DHR-2), the literature[1] and the supplier.

Interfacial tension between the fluids

Table S-3 Interfacial tension of the fluidic pairs

Fluidic pairs	Interfacial tension (mN/m)
70% w.t. Glycerol 0.2% w.t. Tween 20 in DI water/ Poly(dimethylsiloxane)	30.3
70% w.t. Glycerol 0.2% w.t. Tween 20 in DI water/ Mineral oil	3.8
70% w.t. Glycerol 0.2% w.t. Tween 20 in DI water/ 1-Octadecene	2.8
70% w.t. Glycerol 0.2% w.t. Tween 20 in DI water/ 1,6-Hexanediol diacrylate	56.7
70% w.t. Glycerol 1% w.t. Sodium dodecyl sulfate in DI water/ Hexane	7.7

The interfacial tensions are measured by the tensiometer (FTA 200), using pendent droplet method.

Dielectric constant of the fluids

Table S-4 Dielectric constant of the fluids

Fluids	Relative permittivity
70% w.t. Glycerol 0.2% w.t. in DI water	32.5
Poly(dimethylsiloxane)	1.9
Mineral oil	2.8
1-Octadecene	11.3
1,6-Hexanediol diacrylate	10.4
Hexane	1.9

The dielectric constants are measure by filling the fluids into a capacitor. The capacitances are measured by a precision LCR meter (keysight E4980AL).

3. Breakup Location of disperse phase

Flowing as the disperse phase, the PDMS layer is cut by the electric field. Due to greater electric voltage or electric frequency can induce more intense disturbance at the interfaces, the coalescence between the interfaces occurs faster after the flow is influenced by the electric field, which makes the breakup location moving to the upstream.

After the DC electric field activates, the higher voltage amplitude of electric field results in the faster breakup of the PDMS layer, therefore, the complete breakup location moves to the channel junction. The increase of the voltage and the frequency of the AC electric field is also able to change the breakup location of the PDMS layer.

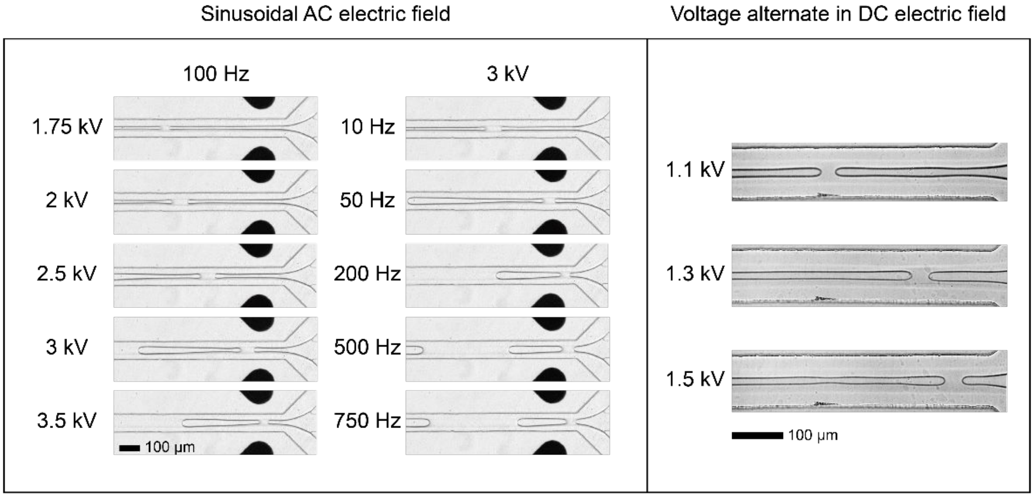

Figure S-2 The breakup of PDMS layer under electric field.

4. O/W droplet collected off chip

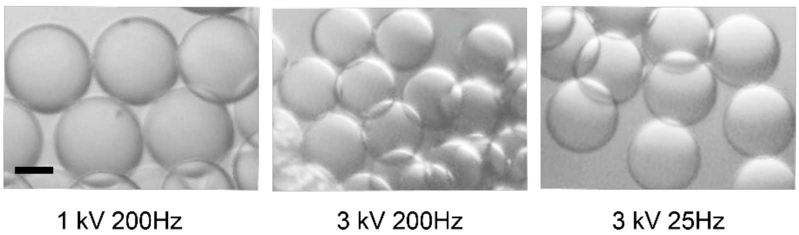

Figure S-3 Collected droplets formed under different electric field conditions (Sinusoidal waveform AC electric field). The scale bar is 50 μm.

We collected the droplet formed in our microchannels under the AC electric field on a glass slide through a flexible tubing.

5. Applicability on ultra-low-viscosity organic substance

To verify the suitability of our approach on low-viscosity organic phase, we test hexane (viscosity: 0.3 mPa·s) as the disperse phase in our microchannels. 70% w.t. Glycerol 1% w.t. Sodium Dodecyl Sulfate in DI water is used as the continuous phase. Square wave form E-field and sinusoidal waveform AC E-field are proven to be capable of triggering breakup of the hexane and tuning the size of hexane droplet generated (Figure S-4).

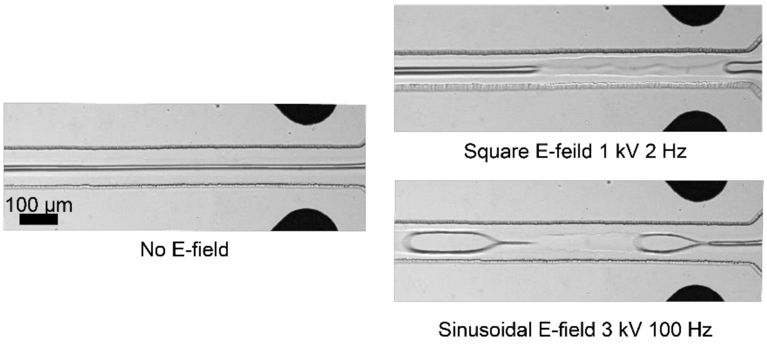

Figure S-4 Controlled hexane droplet formation under square and sinusoidal E-field (Q_d:Q_c=5 µL/s:200 µL/h).

6. Caption list of the uploaded videos

Table 1 Caption list for the uploaded videos

Video Name	Caption	Capture speed (fps)
S 1-1 Breakup under Square waveform E-field of different disperse phases	Triggered breakup of four disperse phases under 2 Hz square waveform E-field. PDMS (Q_d:Q_c=20:200 µL/h), HDDA (Q_d:Q_c=50:200 µL/h), ODE (Q_d:Q_c=50:200 µL/h), Mineral oil (Q_d:Q_c=50:200 µL/h) flow as disperse phase.	1000
S 1-2 Breakup once under Sine E-field	Breakup of PMDS layer under sinusoidal waveform E-field with critical voltage. V=920 V, f=100 Hz. Q_d:Q_c=20:200 µL/h	1000
S 1-3 Continuous breakup under AC E-field 100 Hz	Continuous breakup of PDMS layer triggered by sinusoidal waveform E-field. V=3 kV, f= 100 Hz. Q_d:Q_c=20:200 µL/h	1000
S 1-4 Continuous breakup under AC E-field 25 Hz	Continuous breakup of PDMS layer triggered by sinusoidal waveform E-field. V=3 kV, f= 25 Hz. Q_d:Q_c=20:200 µL/h	1000

References

1. Badev, A.; Abouliatim, Y.; Chartier, T.; Lecamp, L.; Lebaudy, P.; Chaput, C.; Delage, C., Photopolymerization kinetics of a polyether acrylate in the presence of ceramic fillers used in stereolithography. *Journal of Photochemistry and Photobiology A: Chemistry* **2011,** *222* (1), 117-122.

2. Lee, W.; Walker, L. M.; Anna, S. L., Role of geometry and fluid properties in droplet and thread formation processes in planar flow focusing. *Physics of Fluids* **2009,** *21* (3), 032103.