Electronic Supplementary Material (ESI) for Soft Matter.

Critical Condition for Organic Thread Cutting under Electric Fields

1. Fluid properties, measurements of viscosity, interfacial tension coefficient and permittivities

- The viscosities are measured with the TA instruments Discovery Hybrid Rheometer (DHR-2). The low molecular weight PEO solution used in the experiments remains Newtonian [1]. The interfacial tension coefficient is measured with the tensiometer (FTA 200).

Table S-1 Interfacial tension

Fluidic pairs	Interfacial tension (mN/m)
70 wt% Glycerol 0.2 wt%. Tween 20 in DI water/ Silicone Oil	25

Table S-2 Viscosities of fluids

Fluids	Viscosity (mPa·s)
70% w.t. Glycerol 0.2% w.t. in DI water	18
Silicone oil	97

- By filling the fluids into a cylinder capacitor, the capacitances of it is measured by an LCR meter (keysight E4980AL). The relative permittivity of the fluids can then be deduced.

2. Electric stress at interfaces

With the $\varepsilon_{r,A}E^n_A = \varepsilon_{r,O}E^n_O$ and $T^E = \varepsilon_0\varepsilon_r(EE - \frac{1}{2}|E|^2 I)$, the jump in the normal electric stress across the interface is [2]:

$$[\![n \cdot T^E \cdot n]\!] = \frac{1}{2}\epsilon_0(\epsilon_{r,A} - \epsilon_{r,O})(E_t^2 - \left(\frac{\epsilon_{r,A}}{\epsilon_{r,O}}\right)E_A^2) \tag{s-1}$$

Here, E_t denotes the tangential electric field at the interface, which is neglected here because the electric field is mainly in normal direction in our experiments. Thus the electric stress can be approximated as $\frac{1}{2}\frac{\varepsilon_0\varepsilon_{r,A}(\varepsilon_{r,A} - \varepsilon_{r,O})}{\varepsilon_{r,O}}{E_A}^2$.

3. Effects of viscosity of organic phase

To investigate the effects of viscosity of organic phase on the critical conditions for the thread cutting, we carried out the experiments with silicone oil 10 cSt, 20 cSt, 100 cSt and 350 cSt (viscosity ranges from 9.3 mPa·s to 340 mPa·s). Figure S-1 shows the critical electric field between the electrodes with different organic thread width d*. The change of viscosity has little impact on the critical value of the electric field for triggering the cutting. Due to these silicone oil shares similar permittivity and interfacial tension with the aqueous phase, the viscosity should also have little effect on the Ca_E.

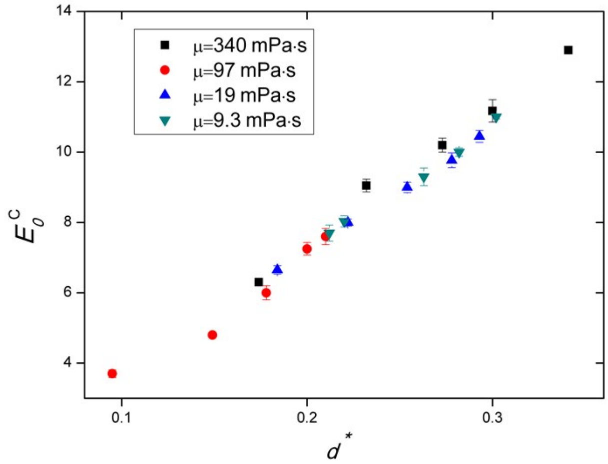

Figure S- 1 Critical electric field strength under different dimensionless widths of organic thread and viscosities.

4. The equivalent electric circuit model

Due that the corresponding charge relaxation time scales of the PDMS gap and the silicone oil $\tau = \frac{\varepsilon_r \varepsilon_0}{\sigma}$ (σ is the electric conductivity) are, under our experimental conditions, much greater than the electric field period $T = \frac{1}{f}$, two PDMS gaps are considered as capacitors in the circuit.
The capacitance (C_{PDMS}, C_O), resistance of aqueous phase (R_A) and impedances (Z_{PDMS}, Z_A, Z_o)can be estimated as:

$$C_A \approx \frac{2\varepsilon_0 \varepsilon_{r,\ A} bH}{W_C - d} \tag{s-2}$$

$$X_A \approx \frac{-1}{2\pi f C_A} \tag{s-3}$$

$$R_A = \frac{L}{\kappa A} \approx \frac{W_C - d}{2\sigma_A H b} \tag{s-4}$$

$$Z_A = \frac{X_A^2 R_A - jX_A R_A^2}{X_A^2 + R_A^2} \tag{s-5}$$

$$C_O \approx \frac{\varepsilon_0 \varepsilon_{r,\ O} bH}{d} \tag{s-6}$$

$$C_{PDMS} \approx \frac{\varepsilon_0 \varepsilon_{r,PDMS} bH}{W_{gap}} \tag{s-7}$$

$$Z_{PDMS} \approx \frac{-j}{2\pi f C_{PDMS}} \tag{s-8}$$

$$Z_O \approx \frac{-j}{2\pi f C_O} \tag{s-9}$$

where the σ_a denotes the electric conductivity of the aqueous phase. *d* is the width of organic thread. W_C, H, b, W_{gap} represent the width of the fluidic channel, the height of the channel, the length of the electrode tip and the width of the PDMS gap. $\varepsilon_{r,\ O}$, $\varepsilon_{r,\ A}$ and $\varepsilon_{r,PDMS}$ denote the relative permittivity of organic phase, aqueous phase and PDMS wall, respectively. j is the imaginary unit.

The values of the parameters are measured or referred to the literatures [3]: $W_C = 1 \times 10^{-4}$ m, $\sigma_A = 2 \times 10^{-7}$ S/m, , $H = 3.5 \times 10^{-5}$ m, $b = 1 \times 10^{-4}$ m, $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m, $\varepsilon_{r,\ PDMS} = 3$, $\varepsilon_{r,\ O} = 3$, $W_{gap} = 5 \times 10^{-5}$ m.

References

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2. Sherwood, J.D., *Breakup of fluid droplets in electric and magnetic fields.* Journal of Fluid Mechanics, 1988. **188**: p. 133-146.
3. Trajkovikj, J., J.-F. Zürcher, and A.K. Skrivervik. *Soft and flexible antennas on permittivity adjustable PDMS substrates*. IEEE.