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Supplementary Materials for

Active particles as mobile microelectrodes for selective bacteria electroporation and transport

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The PDF file includes:

Other Supplementary Material for this manuscript includes the following:

(available at advances.sciencemag.org/cgi/content/full/6/5/eaay4412/DC1)

Movie S4 (.mp4 format). Electroconvection around the JP visualized using 720-nm polystyrene particles as tracers.
Movie S5 (.mp4 format). Electroporation process using a train of AC pulses consisting of 2-min collection of *E. coli* (300 kHz and 10 V) under GFP channel, a train of sinusoidal AC pulses (number of pulse: 10 pulses; pulse duration: 0.5 ms; frequency: 30 kHz; amplitude: 30 V) for electroporation under GFP channel, 4-min holding (2 MHz and 10 V), and observing PI uptake under GFP, PI, and GFP/PI channels and release under PI channel.

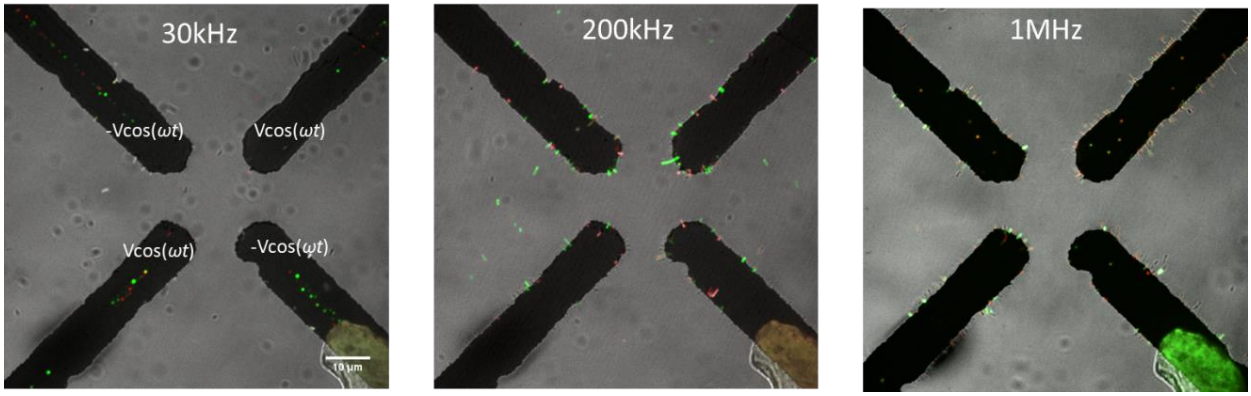

Fig. S1. Positive DEP response of both CFDA [live (green fluorescent)] and PI-stained [dead (red fluorescent)] *E. coli* within a quadrupolar electrode array and a solution conductivity of 9 µS/cm. At low frequency of 30kHz the alternating-current-electro-osmotic (ACEO) flow resulted in accumulation of the bacteria on the stagnation lines at the electrodes center.

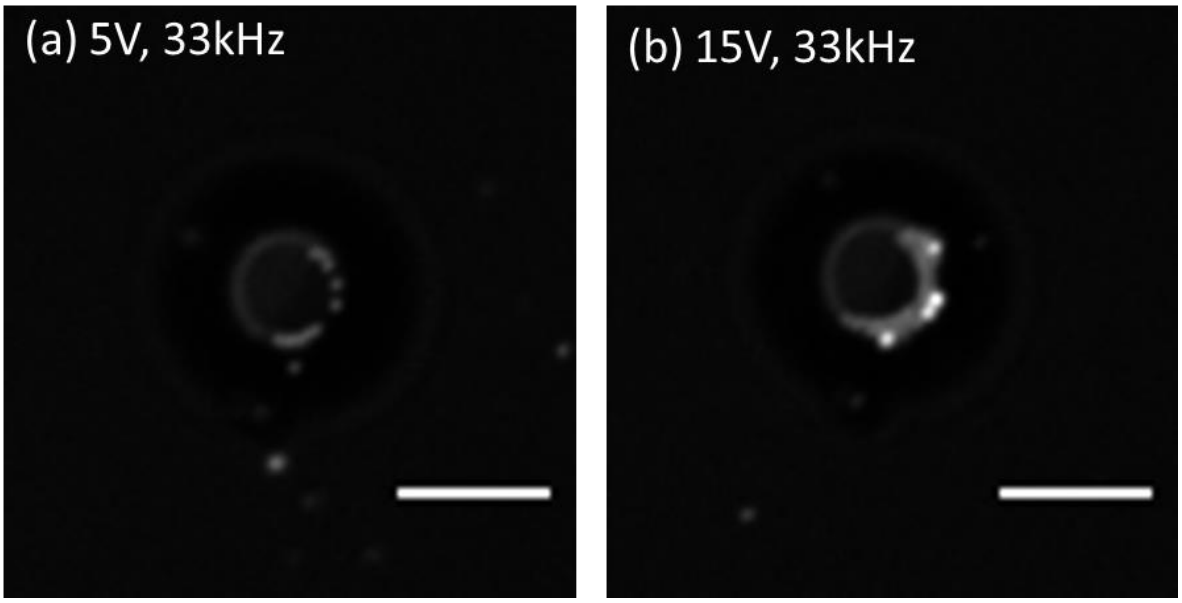

Fig. S2. Polystyrene particles (2µm) trapped under the metallic coated hemisphere of the JP forming a: (a) single layer under 5V and (b) multi-layer under 15V. Scale bar=5µm.

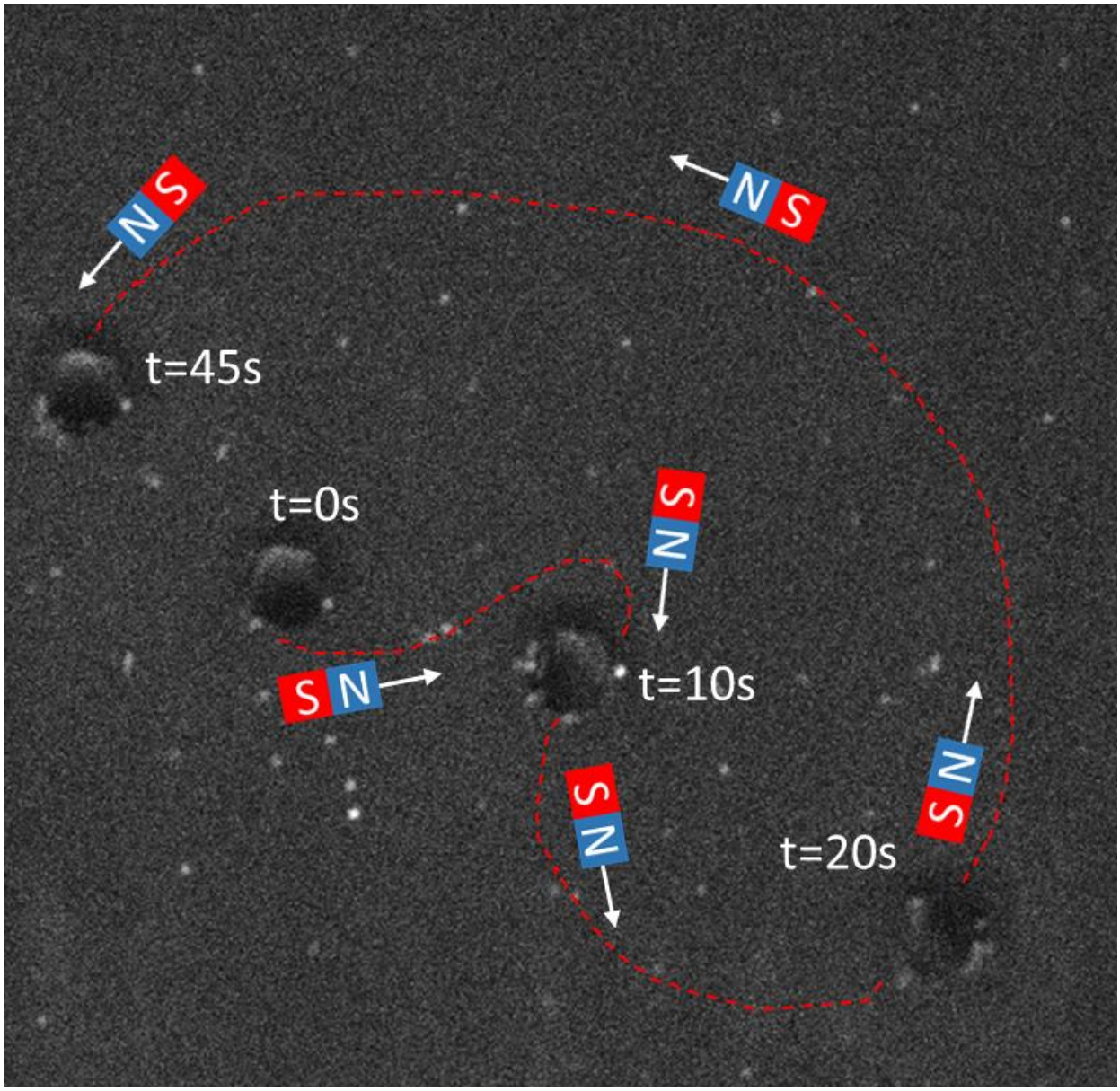

Fig. S3. JP (10 µm) path during the trapping process of *E. coli*, as obtained by superimposing microscope images at different times, operated under 10 V and 200 kHz. Steering of the JP is achieved by rotating a permanent magnet. This path represents the first 45 seconds of Movie S2 in the supplementary material and Fig.2A.

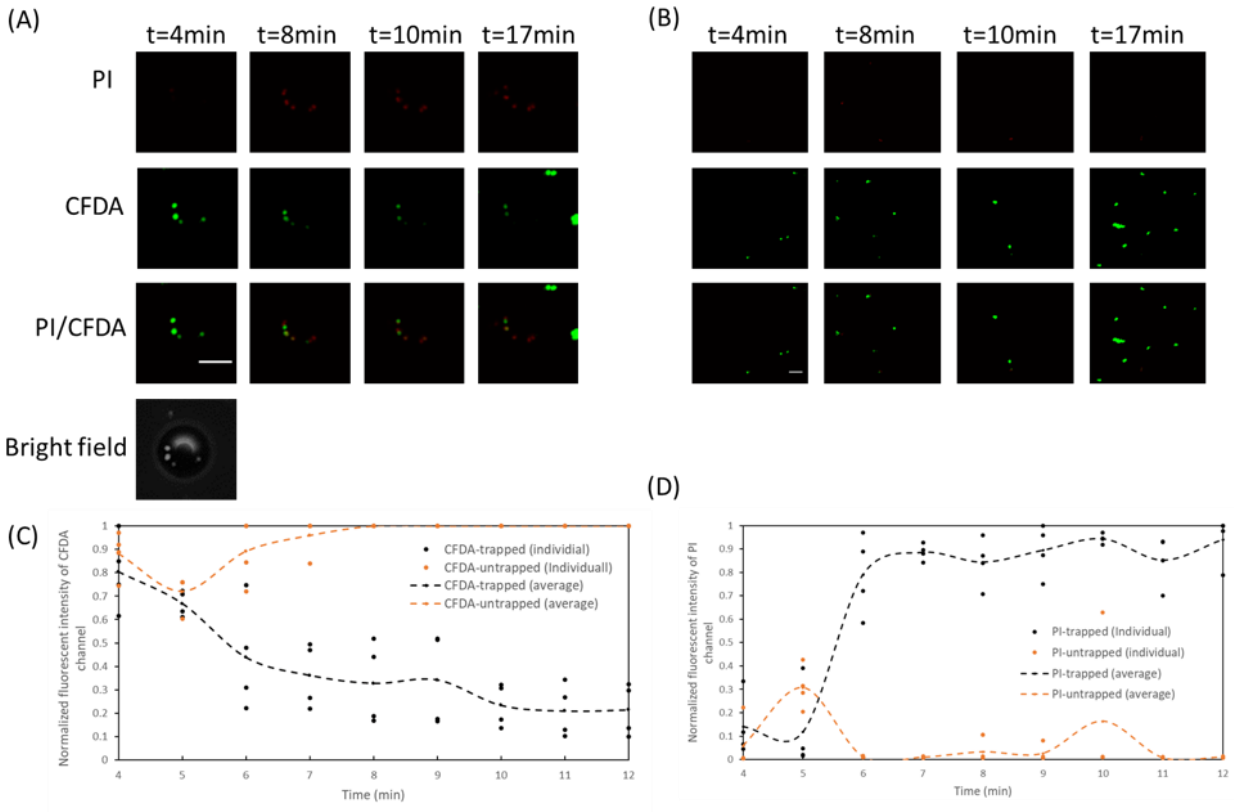

Fig. S4. Microscopy images of PI- and CFDA-stained trapped versus nontrapped *Rhodococcus* at low frequency of 33 Hz, 10 V, and various operation times. PI (red fluorescence) indicates cell electroporation and CFDA (green fluorescence) indicates cell viability. Microscopic images of (A) trapped *Rhodococcus* and (B) untrapped *Rhodococcus*. Normalized fluorescent intensity (i.e. ratio of the overall fluorescent intensity within a circle of 3μm in diameter around each bacteria to the maximum overall fluorescent intensity value obtained for the trapped bacteria) in CFDA channel (C) and PI channel (D) of both trapped and untrapped Rhodococcus versus time. Continuous lines represent averaged values of the individual bacteria depicted as points. Janus particle of 10μm in diameter was used. Scale bar = 5 μm.

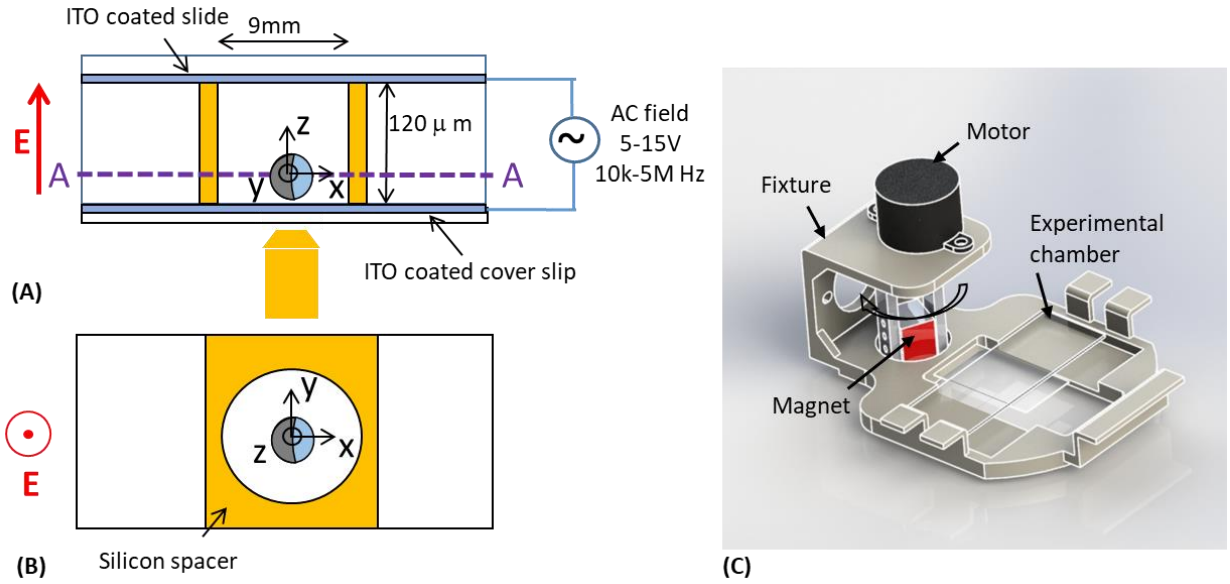

Fig. S5. Experimental setup. Two ITO coated slides are separated by a 120 µm thick silicone spacer. An external magnet is used for steering the JP. (A) Side view of experimental chamber. (B) Cross section A−A as visualized by the microscope. (C) Schematics of the experimental apparatus. The experimental chamber is placed 30 mm away from the magnet that is driven by a step motor. The experimental chamber, magnet and motor are all mounted on a fixture.

Table S1. Parameters used for the calculation of the *E. coli* transmembrane potential.

Parameters used for the calculation of the *E. coli* transmembrane potential

Symbol	**Explanation**	**value**
E_{appl} *(V/cm)*	Applied field strength	833.3
f (Hz)	Frequency	33×10^{3} 5×10^{6}
Ω (rad/s)	*2πf*	
A (cm)	Radius of the cell	$1x10^{-4}$
C_{membr} (F/cm^2)	Capacitance of the membrane	$0.6x10^{-6}$
ρ_{int} (Ω cm)	resistivity of the internal fluid	454.55
ρ_{ext} (Ω cm)	Resistivity of external medium	$1.11x10^{5}$
τ (µs)	Relaxation time of membrane	3.36
$\Delta\psi_{membr}$ *(V)*	Transmembrane potential	0.103 (f=$33\cdot10^{3}$ Hz) 0.002 (f=$5\cdot10^{6}$ Hz)

Movie S1. JP velocity for different frequencies (10 kHz, 30 kHz, 300 kHz, and 5 M Hz) under 10 V.

Movie S2. Electroporation process using continuous AC signal of low frequency consisting of 2-min collection of *E. coli* (300 kHz and 10 V) under GFP channel, 22 min of electroporation (55 kHz and 10 V) under GFP, and PI and GFP/PI channels and release under PI channel.

Movie S3. Electroporation process using continuous AC signal of high frequency consisting of 2-min collection of *E. coli* (300 kHz and 10 V) under GFP optical channel, 22 min of electroporation (5 MHz and 15 V) under GFP, and PI and GFP/PI channels and release under PI channel.

Movie S4. Electroconvection around the JP visualized using 720-nm polystyrene particles as tracers. Electroconvection is shown to bring new *E. coli* cells to the JP and eject them (33k Hz, 10 V).

Movie S5. Electroporation process using a train of AC pulses consisting of 2-min collection of *E. coli* (300 kHz and 10 V) under GFP channel, a train of sinusoidal AC pulses (number of pulse: 10 pulses; pulse duration: 0.5 ms; frequency: 30 kHz; amplitude: 30 V) for electroporation under GFP channel, 4-min holding (2 MHz and 10 V), and observing PI uptake under GFP, PI, and GFP/PI channels and release under PI channel.