Electronic Supplementary Information for Soft Matter manuscript:

Reconfigurable Paramagnetic Microswimmers: Brownian Motion Affects Non-reciprocal Actuation

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Swimming Strokes Achieved with Different Eccentric Ratio

Using Brownian dynamics (BD) simulation without thermal forces, one can see how different λ values change the swimming stroke for a simple 1t1a swimmer. Fig. S1A shows the stroke diagram under different values of λ and azimuthal shear stress $\tau=2\pi\eta f$, where η is the viscosity of the surrounding electrolyte solution. Here we use τ instead of the commonly used Mason number [1] because electrostatic force is involved. The swimmer always orients itself at a fixed angle from the DC offset due to the larger susceptibility on the long axis, which prevents orientation loss. Therefore, we only consider $\beta = 0$. There are four different strokes in terms of arm motion: asymmetric surrounding motion (AS), symmetric surrounding motion (SS), intermediate surrounding motion (IS) and unilateral motion (UL), whose DPC's are shown in Figs. 1B and arm trajectories in the torso frame in Figs. S1B~G, respectively, in colors corresponding to the markers in Fig. S1A. In the AS region with small τ and λ, the arm trajectory is always a slightly distorted but smooth circle, leading to slight net propulsion. Increasing either τ or λ drives the stroke into the SS region where the swimmer fails to fully relax to the rotation of the magnetic field and the arm trajectory is self-crossed. This is similar to the non-relaxed motion of a single particle [2] or a particle pair [3] in a CRM field. In this region, the arm trajectory is completely symmetric, as are the locations of the knot, and therefore, no net locomotion is generated. Further increasing τ leads to the IS region, where the positions of the knot become asymmetric and chaotic. Increasing λ from either the SS region or the IS region leads to the UL region, where the arm no longer orbits around the torso but instead remains on one side of the torso and forms a closed trajectory. In this region, changing λ or τ significantly changes the area enclosed by the curve and thus the swimming speed (Figs. S1F and G). We use $\lambda=\sqrt{2}$ which can be easily achieved using commercial one-axis AC power supply.

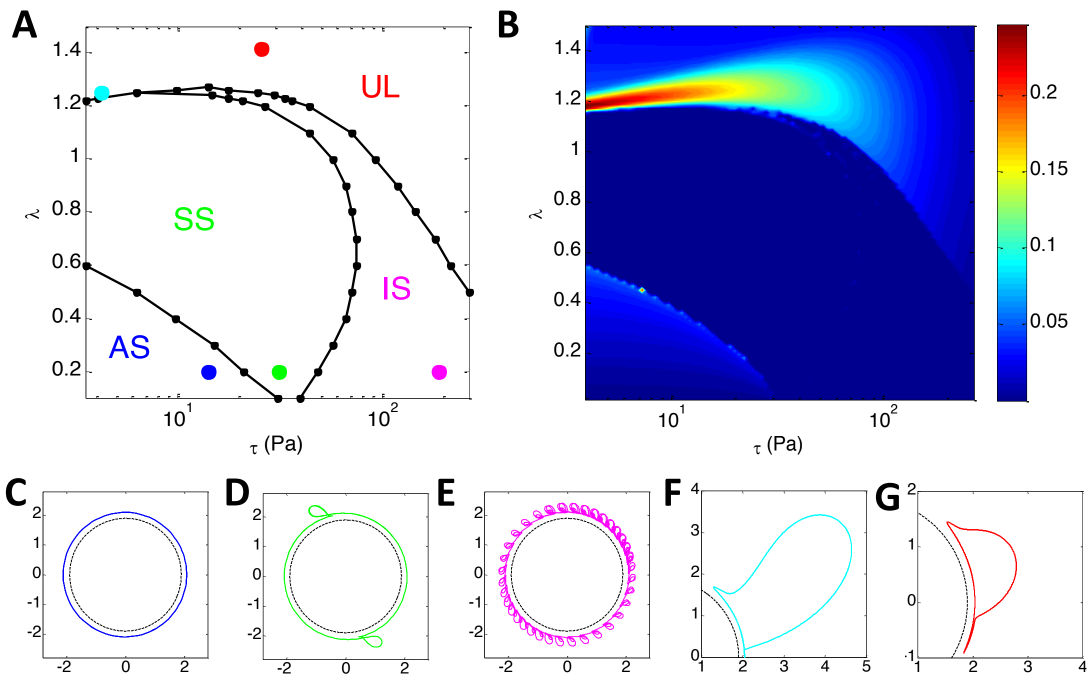
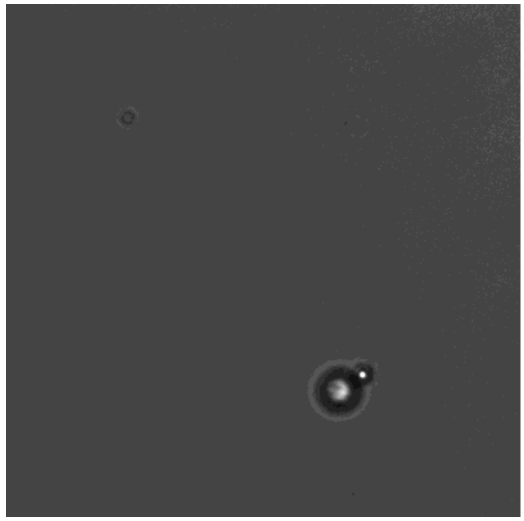


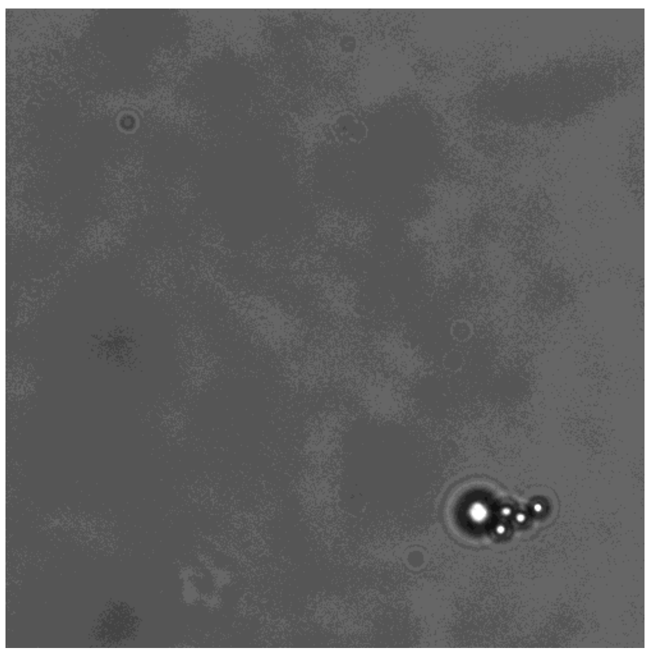
Fig. S1. Swimming strokes for a 1t1a swimmer obtained from BD simulation. (**A**) Stroke diagram. (**B**) DPC for the stroke diagram in (**A**). (**C**)~(**G**), The arm motion trajectories in the torso frame for different strokes (colored solid lines): (**C**) for AS, (**D**) for SS, (**E**) for IS, and (**F**) and (**G**) for UL at different conditions. The dashed lines (black) are circles with diameter of $d_a = \frac{d_1 + d_2}{2}$. The distance from the colored line and dashed line for each shows the minimum surface separation between the two particles.

References

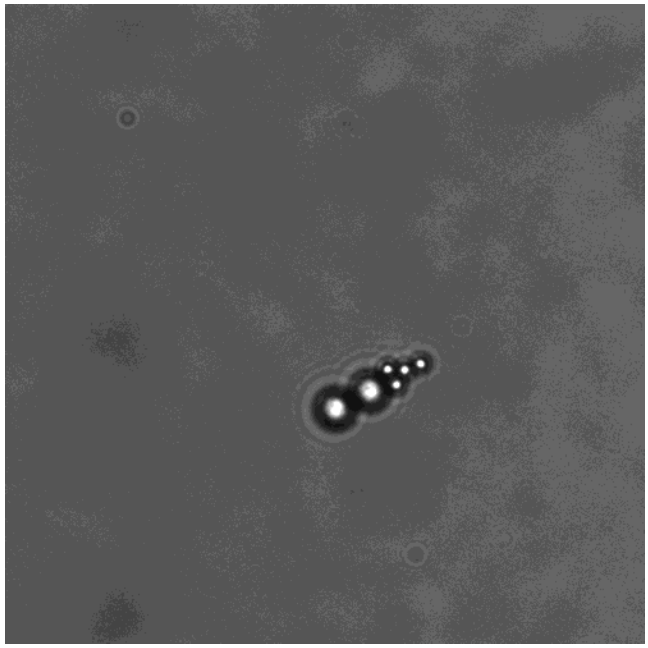
1. S. L. Biswal and A. P. Gast, *Phys. Rev. E*, 2004, **69**, 9.
2. X. J. A. Janssen, A. J. Schellekens, K. van Ommering, L. J. van Ijzendoorn and M. W. J. Prins, *Biosens. Bioelectron.*, 2009, **24**, 1937-1941.
3. G. Helgesen, P. Pieranski and A. T. Skjeltorp, *Phys. Rev. A*, 1990, **42**, 7271-7280.



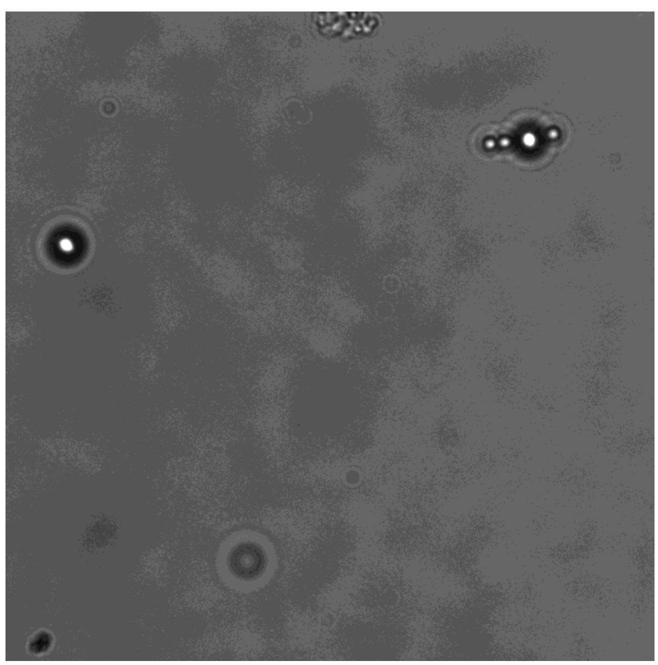
Movie S1. Video of a 1t1a microswimmer using an ERM field.



Movie S2. Video of a 1t4a microswimmer demonstrating arm segmentation using an ERM field.



Movie S3. Video of a 2t4a microswimmer demonstrating arm segmentation using an ERM field.



Movie S4. Video demonstrating in situ assembly of a 2t4a microswimmer using an ERM field.