Supporting Information
Determination of the swimming mechanism of Au@TiO_2 active matter and implications on active-passive interactions

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1 Video list

Video S1: Motion of Au@TiO_2 micromotors in different concentrations (0.05%, 0.5%, 1% and 2.5%) of H_2O_2 solution under 100% UV light.

Video S2: Motion of Au@TiO_2 micromotors under different levels of UV light (2%, 10%, 50% and 100%) in 0.5% H_2O_2 diluted solution, the corresponding intensities are listed here [1].

Video S3: Motion of Au@TiO_2 micromotors in 0.5% H_2O_2 diluted solution containing different concentrations of KCl under 100% UV light.

Video S4: Assembly of passive particles induced by one immobilized Au@TiO_2 particle.

Video S5: Active-passive raft formation process with one active Au@TiO_2 micromotor in 1% H_2O_2 solution.

Video S6: Active-passive stable rafts in 0.5% H_2O_2 solution containing different concentrations of KCl under 100% UV light.

Video S7: Active-passive stable rafts in different concentrations of H_2O_2 solution under 100% UV light.

Video S8: Active-passive stable rafts under different intensities of UV light in 0.5% H_2O_2 solution.

2 Summary of the three motion modes during the active-passive raft formation process

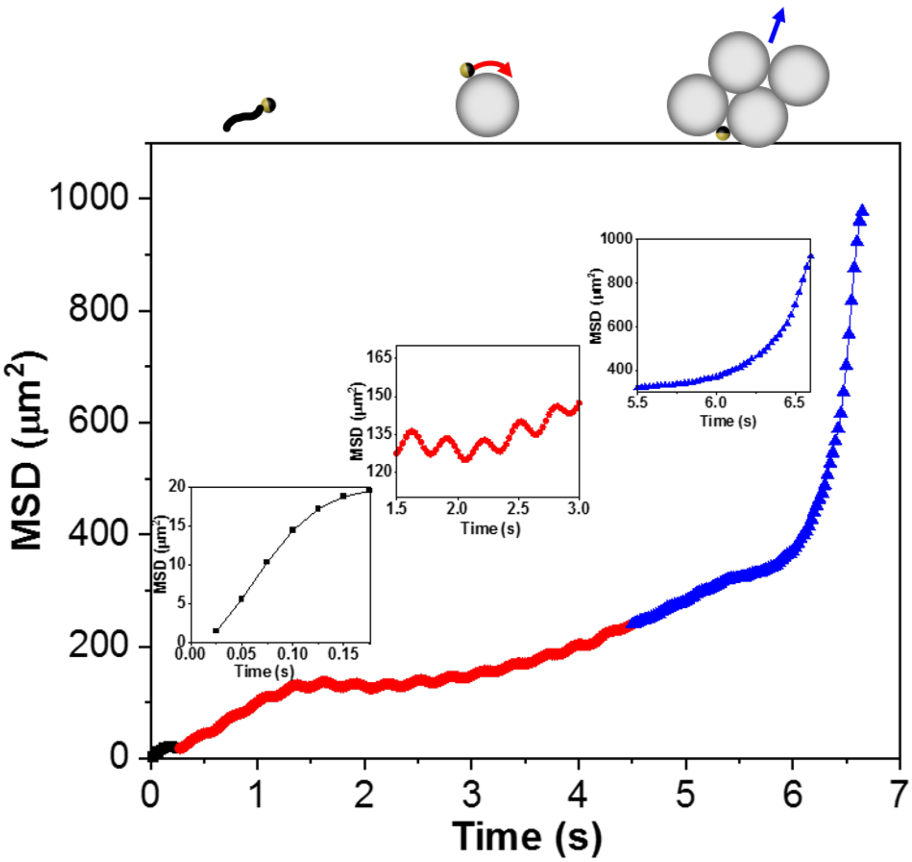

Figure S1: Mean square displacement of active swimmers in 1% H_2O_2 with 100% UV light illustrating three motion stages: Free swimming (black), spinning (red) and ballistics raft (blue). Free active simmers first show ballistics motion. Upon encounter of a passive particle, a pair is formed and results in spinning motion. When more passive particles are captured at the front of the active particle, the small raft shows ballistic motion again, for more info read [2]

3 Oxygen generation measurement

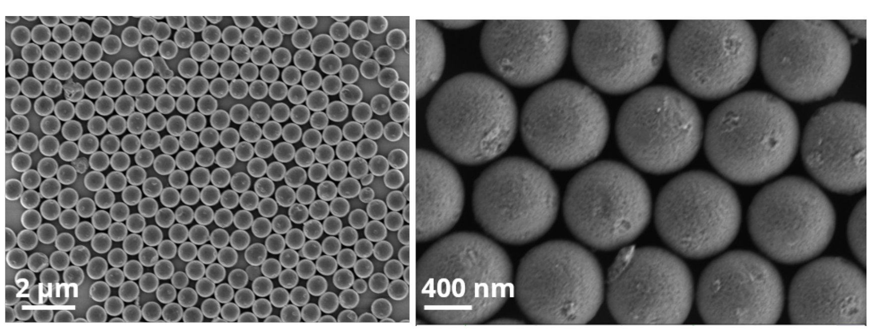

Figure S2: SEM images of a monolayer of TiO_2 particles.

4 COMSOL

4.1 Simulated electric field vs. H_2O_2 concentration

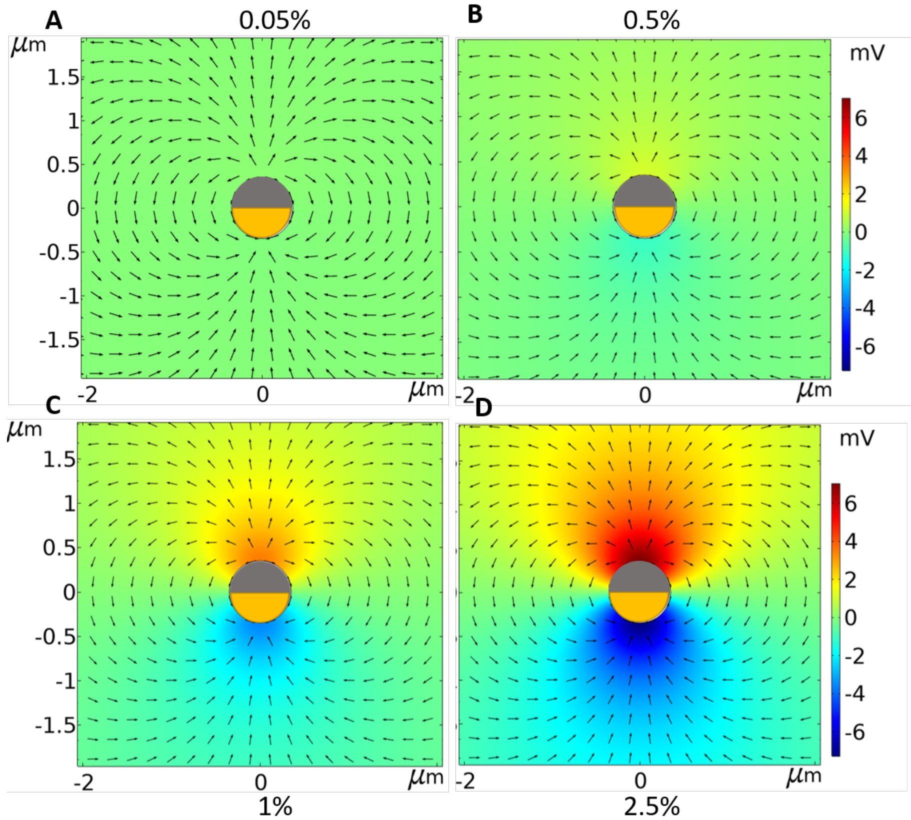

Figure S3: (A-D) Electric potential distribution around an active swimmer in different concentrations of H_2O_2 solution (0.05%, 0.5%, 1% and 2.5%). The arrows represent the direction of electric field.

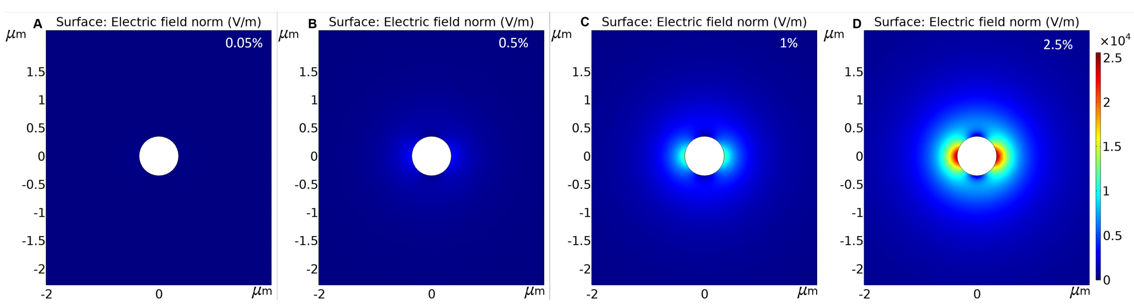

Figure S4: (A-D) Self-induced electric fields produced by active swimmers in different concentrations of H_2O_2 simulated by COMSOL Multiphysics. The intensity of the electric field increases with the increase of H_2O_2 concentration.

5 Speed

Sample condition	Experimental speed (μm/s)	Self-diffusiophoretic speed (μm/s)	Self-electrophoretic speed (μm/s)	COMSOL simulated speed (μm/s)
0.05% H_2O_2	24.98	7.44×10^{-7}	3.82	3.45
0.5% H_2O_2	138.50	1.32×10^{-5}	50.07	44.3
1% H_2O_2	165.57	4.86×10^{-5}	157.46	140.1
2.5% H_2O_2	204.09	1.23×10^{-4}	301.66	239.1

Table S1: The experimentally measured, calculated self-diffusiophoretic, self-electrophoretic and COMSOL simulated speed of active Janus $AuTiO_2$ swimmers. The calculated and simulated speed based on self-electrophoretic motion are in reasonable range while the diffusiophoretic speed is several orders magnitude smaller than experimentally analyzed speed.

6 Salt addition influences the zeta potential of Janus Au@TiO_2 particles, the conductivity of the solution and the speed of active swimmers

Sample name	Zeta potential (mV)	Conductivity (mS/cm)
Janus	-30.02	0.0078
Janus+$1.25*10^{-5}$ M KCl	-20.23	0.0047
Janus+$1.25*10^{-4}$ M KCl	-18.10	0.0166
Janus+$1.25*10^{-3}$ M KCl	-15.23	0.1183
Janus+$1.25*10^{-2}$ M KCl	-12.23	0.1867
Janus+$1.25*10^{-1}$ M KCl	-10.71	0.6000

Table S2: Table of zeta potential and conductivity of Janus Au@TiO_2 in 0.5% H_2O_2 solution containing different concentrations of KCl.

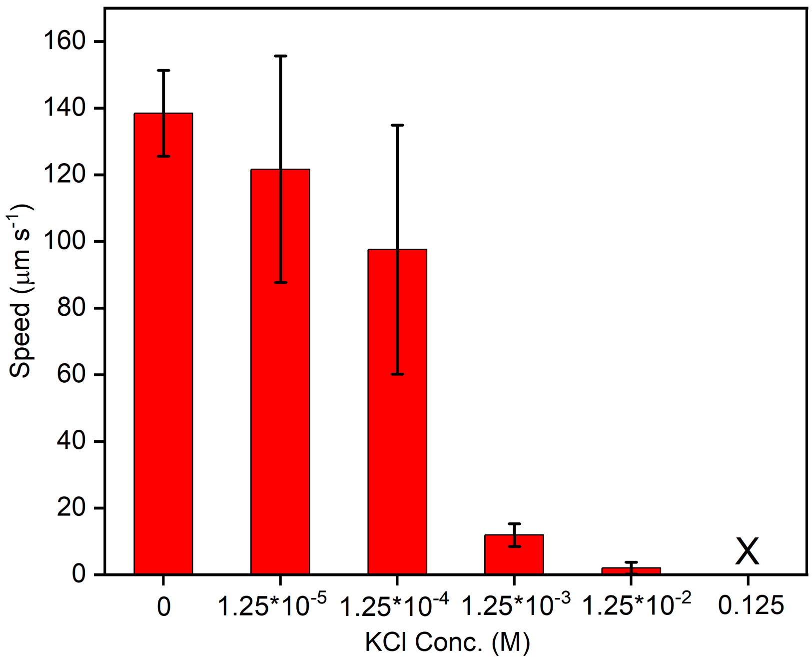

Figure S5: Speed of active swimmer in 0.5% H_2O_2 containing different concentrations of KCl. The speed decreases after adding KCl salt. At a concentration of 0.125 M, Au@TiO_2 particles are stuck on the substrate.

7 Passive particles' influence on proton concentration and generated electric field

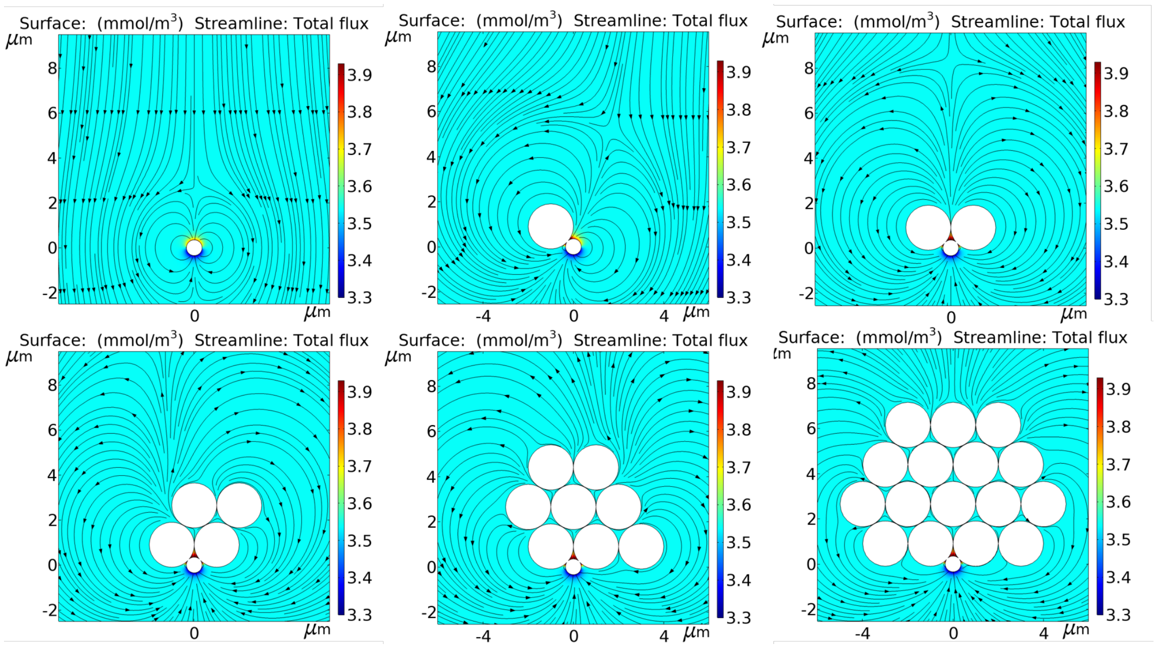

Figure S6: Proton concentration distribution when different numbers (0, 1, 2, 4, 8, 16) of passive particles stay at the front of active particle. Stream lines are the proton flux.

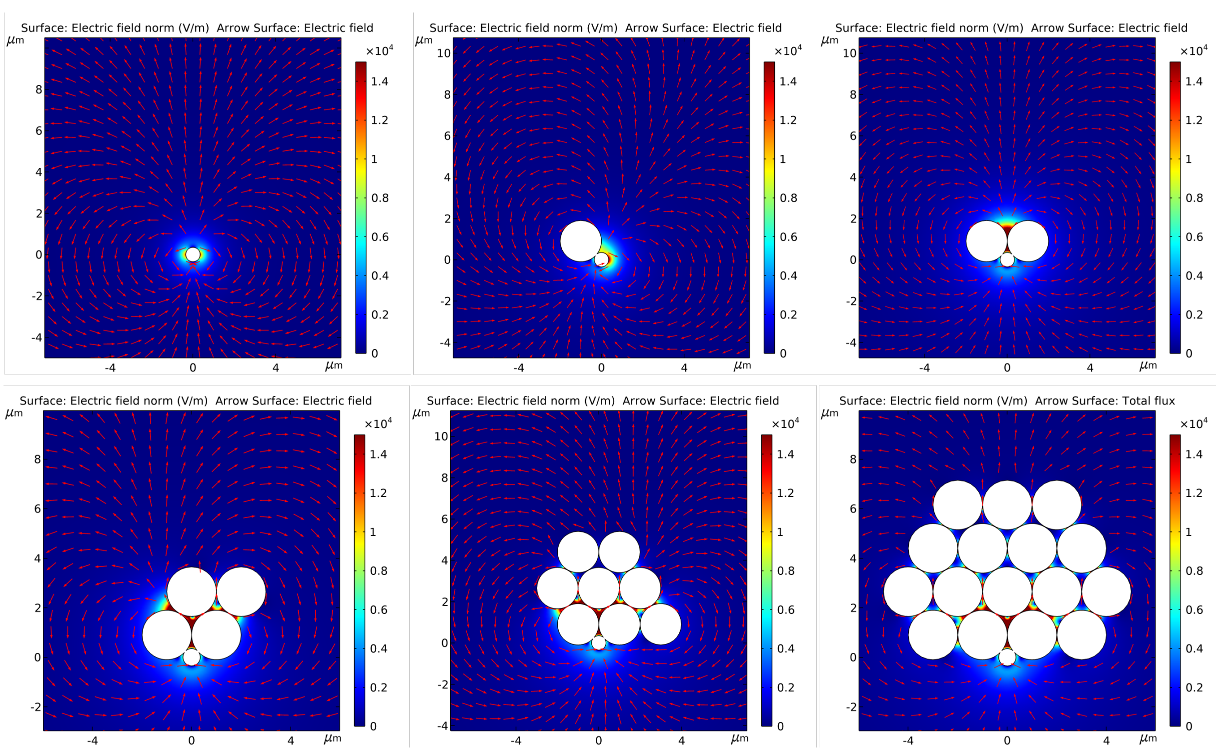

Figure S7: Electrical potential distribution when different numbers (0, 1, 2, 4, 8, 16) of passive particles stay at the front of active particle.The arrows represent the direction of electric field.

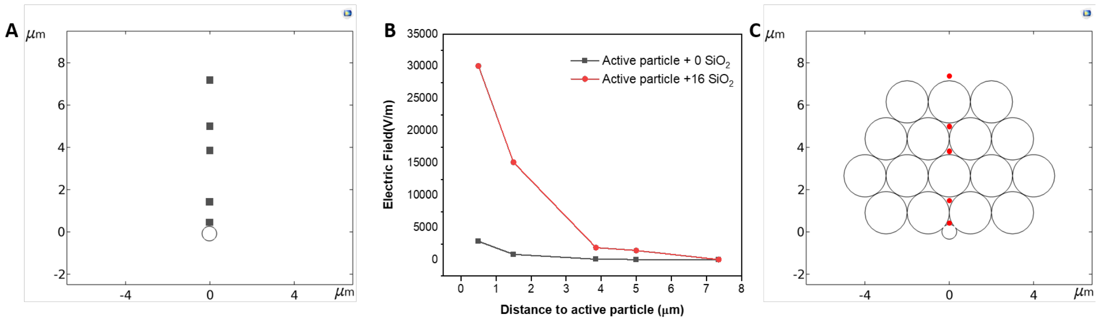

Figure S8: Scheme illustrating the points which are 0.5, 1.5, 3.85, 5, and 7.35 µm away from active particle: (A) active particle + 0 SiO_2 particle, (C) active + 16 SiO_2 particles. (B) The electric field at these certain points. The electric field increases at these points when 16 passive particles are collected at the front of active particle compared to the electric field of pure active particle.

References

[1] Sandra Heckel, Martin Wittmann, and Juliane Simmchen. Measurement of LED Light Intensities in an Inverted Microscope. 2021.

[2] Ian P Madden, Linlin Wang, Juliane Simmchen, and Erik Luijten. Hydrodynamically controlled self-organization in mixtures of active and passive colloids. *Small*, page 2107023, 2022.