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Surface roughness-induced speed increase for active Janus micromotors

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Supplementary figure S1

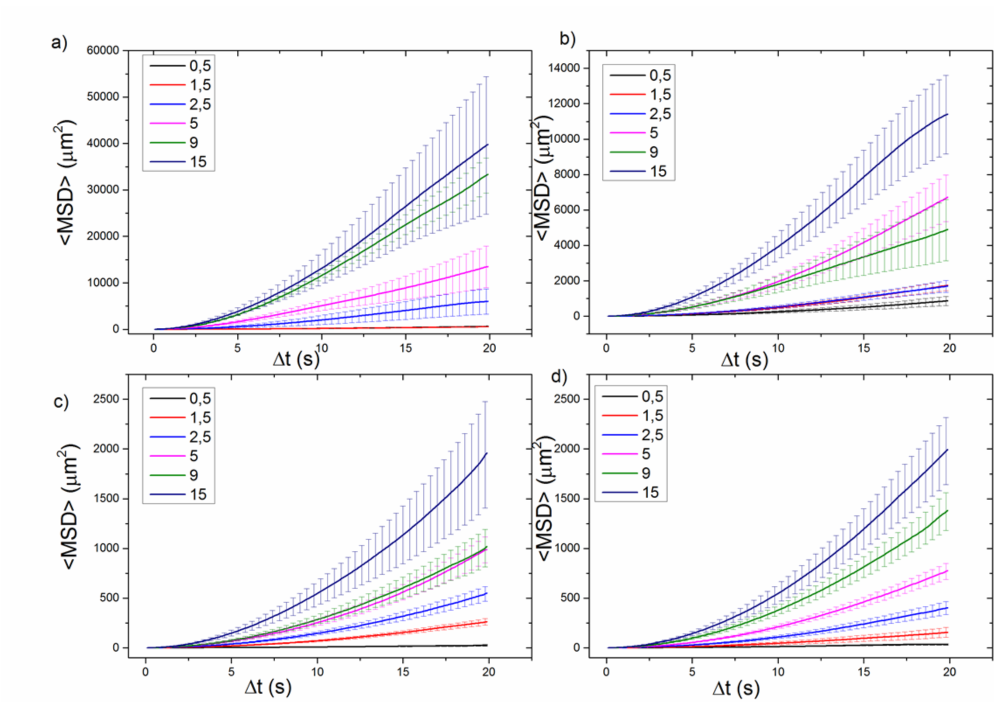

Fig. S1. 1a,1b,1c,1d are the plots of Mean Squared Displacement for Particles R_1,R_2,S_1 and S_2 respectively. MSD from 0 to Δt=2s is used to fit and calculate D_{diff} from the plots.

Supplementary figure S2

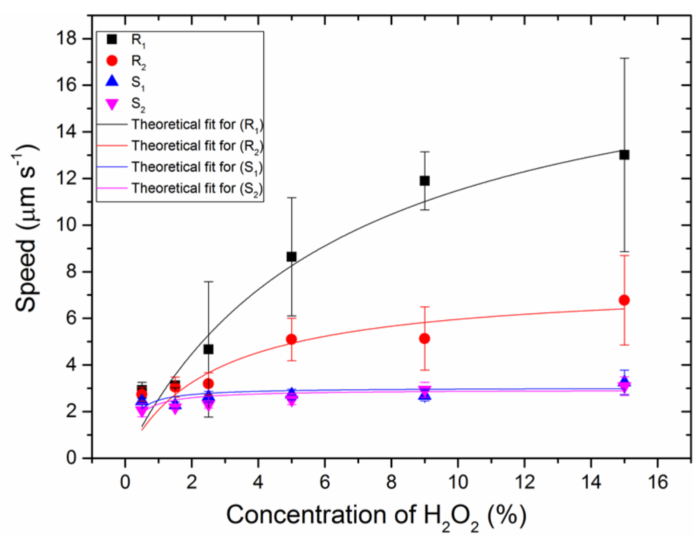

Fig.S2 Theoretical fit of Equation 3 and Equation 5 to velocity of Particles R_1,R_2,S_1 and S_2 to obtain reaction rate constants k_1 and k_2

Supplementary videos S3

Videos R1: Particle R_1 at peroxide concentrations 0.5%,1.5%,2.5%,5%,9% and 15 % .

Videos R2: Particle R_2 at peroxide concentrations 0.5%,1.5%,2.5%,5%,9% and 15 %

Videos S1: Particle S_1 at peroxide concentrations 0.5%,1.5%,2.5%,5%,9% and 15 %

Videos S2 : Particle S_2 at peroxide concentrations 0.5%,1.5%,2.5%,5%,9% and 15 %.

Supplementary discussions S4(Reaction rates)

Since the velocity plateaus at higher peroxide concentrations, and the diffusiophoretic velocity is directly proportional to the reaction rate , the breakdown can be modeled as a two-step process with rate constants α_1 and α_2 [1,21] :

$$2H_2O_2 + Pt \xrightarrow{\alpha 1} Pt.(H_2O_2)_2 \xrightarrow{\alpha 2} 2H_2O + O_2 + Pt,$$

with,

$$k = \alpha_2 \frac{[H_2O_2]_{vol}}{[H_2O_2]_{vol} + \alpha_2/\alpha_1},$$

We can solve the unknown reaction rate constants α1 and α2 as a function of the H2O2 concentration by fitting equation (3) and equation (5) to the speed of particles R_1, R_2, S_1 and S_2 in Fig.4a. We assume a = 1Å and λ = 5 Å,1 and obtain the best fit line for Eqn. (3) to the speed data (see supplementary Fig S2). The experimentally determined reaction rates for different particles at 10% H_2O_2 concentrations are summarized in Table 1(main text).

Further,from the Oxygen evolution test for smooth wafer surfaces we find the rate of oxygen production is 0.6mmol cm^{-2} Pt min^{-1} which translates to $6x10^{10}$ molecules μm^{-2} s^{-1}. This compares well with the reaction rate obtained for smooth surfaces (S_1 and S_2) which are both close to 2.5 x 10^{10} μm^{-2} s^{-1}.

The surface coverage for smooth particles (S1) can be calculated by $2\pi R^2 = 39\mu m^2$. A direct comparison of the reaction rates yields the effective surface area for rough particles R_1 as 153 μm^2 and for particle R_2 as (39 x 5/2.5) =78 μm^2. We can thus deduce that the effective catalytic surface area increased due to the growth of nanostructures on the surface.

Quantitative direct comparisons are not possible since the geometry of the systems are not identical. The rates are expressed in units of μm^{-2} s^{-1} to facilitate the comparison of surface reaction rates with turnover rates in homogeneous solutions.

Supplementary discussions S5 (Experimental methods)

After verifying the higher catalytic rates for the rough surfaces, we investigated the different swimming characteristics of the Janus microparticles. The Janus particles were released from the wafer into deionized water by sonication and the suspension was washed and purified by centrifugation. Aqueous suspensions of Janus micromotors were pipetted onto a silicon wafer piece, which was previously cleaned with O2 plasma, and increasing amounts of H2O2 were added sequentially to obtain the desired H2O2 concentration. The videos of the self-propelled particles were recorded with a Leica optical microscope coupled to a CCD camera recording at 30 fps.