Supporting Information

Visible Light-Driven BiOI-Based Janus Micromotors in Pure Water

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Experiment:

Synthesis of BiOI microspheres:

0.728 g $Bi(NO_3)_3$•$5H_2O$ in 20 mL absolute ethanol in 100 mL flask and 0.249 g KI in 40 mL distilled water were prepared first. After completion of dissolution, KI solution was added drop-wise into the $Bi(NO_3)_3$•$5H_2O$ solution with stir. Adjust the pH of the mixture to 7 by adding 1.5 M NH3•H2O, then, put the mixture in oil bath maintained at 80 for 3 h. The precipitates were collected by centrifugation, washed several times with distilled water and ethanol and finally dried in an oven overnight at 60 C. Finally, BiOI microspheres (diameter: 2~4 μm) were obtained.

Characterization of BiOI microspheres:

The scanning electron microscopy (SEM) images (Figure S1A) of BiOI microspheres show that the average diameter of the particles is about 2~4 μm. The BiOI particles have flower-like shape and disordered BiOI flakes on the surface (Figure S1A inset). The corresponding X-Ray Diffraction (XRD) patterns in Figure S1B confirm the well-crystalline phase of BiOI (PDF No.: 73-2062). X-ray photoelectron spectroscopy (XPS) survey spectrum which is used to further confirm the chemical states of BiOI. The XPS of BiOI shows the main peaks of Bi 4f, I 3d and O 1s. There are two peaks of Bi 4f in spectrum (Figure 2C b). One peak with binding energy of 158.4 eV is Bi $4f_{7/2}$ and the other one with binding energy of 163.7 eV is Bi $4f_{5/2}$ region. As a result, the main chemical state of Bi is +3 valence. The O 1s region (Figure 2C c) can be divided into two peaks at 530.1 and 532.1 eV. The higher peak at 530.1 eV belongs to Bi-O bond while the peak at 532.1 eV can be attributed to the hydroxyl groups on the surface of sample. The XPS spectrum of I 3d is shown in Figure 2C(d).The peaks with binding energy

of 618.0 and 629.5 eV are for the I $3d_{5/2}$ and I $3d_{3/2}$ region for BiOI, respectively, which indicates that the state of I in the sample is -1 valence. As a result, these BiOI samples are reliable for fabricating visible light driven BiOI-based Janus micromotors.

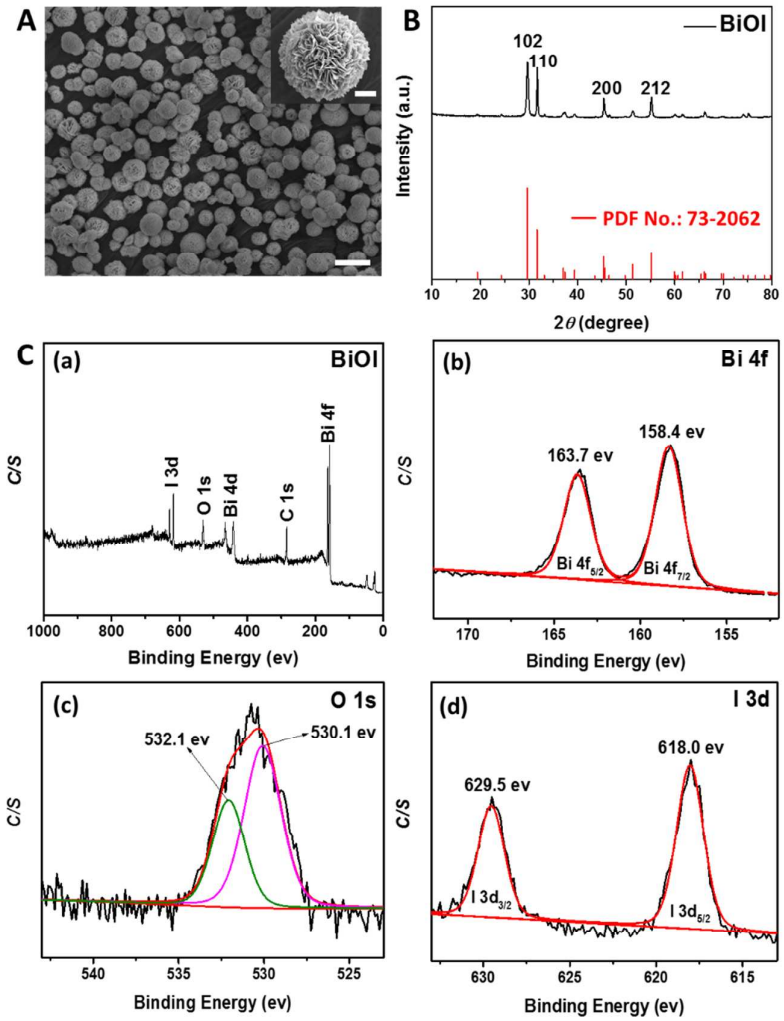

Figure S1 (A) SEM image of spherical photocatalyst BiOI monolayer. Scale bar, 5 μm. Inset is a SEM image of single BiOI particle. Scale bar, 500 nm. (B) X-Ray Diffraction (XRD) pattern of the BiOI microspheres. (C) High-resolution X-ray photoelectron spectroscopy (XPS) spectra of BiOI sample. Total survey (a), Bi 4f (b), O 1s (c) and I 3d (d).

Preparation of BiOI-based Janus micromotor：

10 μg BiOI microspheres were first dispersed in 150 μL ethanol. The sample was then spread onto glass slides and dried uniformly to form particle monolayers. The particles were sputter coated with a thin metal layer using a Quorum Q 150T ES Sputter Coater for 3 cycles with 60 s per cycle. The gold layer thickness was found to be 20 nm, as measured by the Veeco

DEKTAK 150 Profile-meter. The micromotors were subsequently released from the glass slides via pipette pumping and dispersed into double distilled water.

Motion calibration experiments.

To determine the relationship between the active motion of BiOI-based Janus micromotor and light, we use the ND Filter in the microscope (4X, 8X, 16X) to control the illumination intensity. The light illumination intensity has 4 levels. 43900 Lux (level 1); 11280 Lux (level 2); 5410 Lux (level 3); 2450 Lux (level 4).100 Lux (level 5, background light). All the videos were recorded only with the microscope system's light in a dark room. The wavelength of green light ranges from 510-560 nm, and the wavelength of blue light is 450-490 nm. The propulsion calibration experiments were performed by mixing 2 μL of the motor dispersed in deionized water. For investigating the effects of ions, we prepared 2 Mm, 20 Mm NaCl solution, The propulsion calibration experiments were performed by mixing 1 μL of the motor solution and 1 μL NaCl solution.

Speed analysis.

The velocity of motors has been calculated by the NIS-Elements AR 4.3 software. The enhanced diffusion coefficients of the motors were experimentally estimated with the software Matlab. The motors (number of motors n =30) were tracked over 10 s. The mean squared displacement (MSD) was calculated and the diffusion coefficient (D) was calculated by the equation $D=MSD/i\cdot\Delta t$, where Δt is the time interval. Here, in the case of two-dimensional analysis from the recorded video, i is equal to 4.

Electrochemical Potential Measurements

Tafel plots are used to obtain the potential established at each motor segment (Pt, Au, and BiOI) in a deionized water environment with and without illumination (illumination intensity is 43900 Lux, distance from sample: 10 cm). Pt, Au and BiOI films (all the films' thicknesses, about 100 nm) on ITO glass disc (diameter, 1.0 cm) were used as the working electrode in the electrochemical potential measurements, respectively. BiOI electrode was prepared according to the Zhang's report[1]. Briefly, in one cycle of reaction, the ITO substrate was immersed in $Bi(NO_3)_3\cdot 5H_2O$ solution and KI solution in sequence and in-between washing steps were removed. After several cycle reactions, the sample was washed with deionized water and dried in air. We use the CH Instrument Model CHI600C to test the potential at a scan rate of 5 mV/s

and over a potential range of −0.2 to 0.9 V (vs Ag/AgCl, 3 M KCl reference) along with a Pt counter electrode. The second method (open circuit potentials) measures the electrode potential with respect to an Ag/AgCl (3 M KCl) reference electrode at zero current, which is the open circuit voltage (OCV). The stabilizing potential was identified as the electrode potential (vs Ag/AgCl, 3 M KCl) in deionized water along with a Pt counter electrode.

Aggregation behavior.

Such Janus micromotors display a visible light-responsive aggregation behavior and dispersed due to the Brownian motion when the light turned off (Figure S2B). A possible explanation for such behavior is the electrostatic attraction between the BiOI and metal components of the

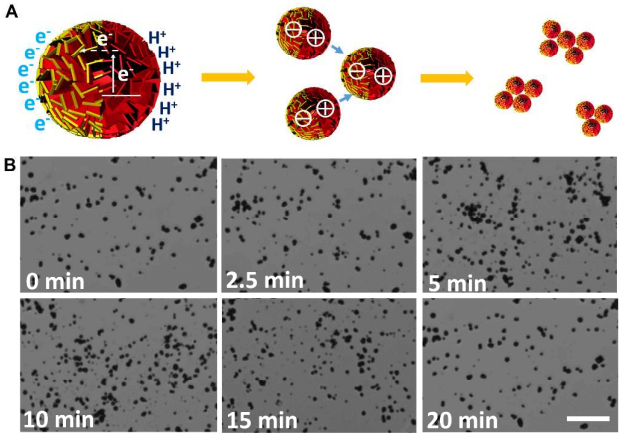

Figure S2. (A) Schematic mechanism of aggregation behavior of BiOI-metal Janus micromotors. (B) Microscopic images illustrating the time-dependent reversible swarming behavior of BiOI-Au Janus microspheres. The particles are under level 1 green light for 5 mins, followed by darkness for 15 mins. Scale bar, 20 μm.

neighboring micromotors when they approach each other (Figure S2A).

Equipment.

XRD patterns were obtained by X-Ray Diffractomer (Panlytical Inc. X'Pert Pro, Holland), SEM and EDX patterns were obtained by Tescan MAIA 3 and Oxford x-act. XPS analyses were performed using KRATOS Axis Ultra (Kratos Analytical, Manchester, United Kingdom). An incident monochromated X-ray beam from the Al target (15 kV, 10 mA) was focused on a 0.7 mm × 0.3 mm area of the surface of the sample 45° to the sample surface. The electron energy analyser was operated with a pass energy of 20 eV enabling high resolution of the spectra to be obtained. The step size of 0.02 eV was employed and each peak was scanned twice.

Visible light was generated by Mercury lamp sockets and dichroic mirror DM 400. Barrier filter BA520 was used to generate blue light and barrier filter BA590 for green light. Illumination intensities were controlled by ND filters (4×, 8×, 16×) (all from Nikon). Videos were captured by an inverted optical microscope (Nikon Instrument Inc. Ti-S/L100), coupled with 40× objectives, and a ANDOR Zyla sCMOS digital camera using the NIS-Elements AR 4.3 software. Green lamp for electrochemical potential measurements purchased from ENlux, power: 22w. All the illumination intensities were calculated by TASI digital light meter TA8120.

References

1. K. Wang, F. Jia, Z. Zheng, L. Zhang, Electrochem. Commun. 2010, 12, 1764-1767.