Supporting Information for

Bio-catalytic Driven Janus Mesoporous Silica Cluster Motor with Magnetic Guidance

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Experimental Details

Materials

Tetraethylorthosilicate (TEOS, 99%), cetyltrimethylammonium bromide (CTAB, >95%), (3-aminopropyl)triethoxysilane (APTES), hydrochloric acid (HCl, assay 37%), absolute ethanol (EtOH, >99.9%), fluorescein isothiocyanate (FITC), 1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC), N-Hydroxysuccinimide (NHS), catalase (from Aspergillus niger), phosphate buffered saline (PBS) buffer, Succinic anhydride, triethylamine, dimethylformamide (DMF), acetone, and iso-propanol, were obtained commercially.

Instruments

The transmission electron microscopy (TEM) images were captured by Zeiss EM 912 TEM machine at 120 kV. Scanning electron microscopy (SEM) images were taken by Zeiss SEM machine at 5 kV. Fourier transform infrared (FT-IR) spectra were

collected by Frontier FT-IR spectrometer. Confocal microscopy images were taken by a confocal microscope (Leica TCS SP5, 63× oil objective). Videos were taken by Leica optical microscopy with 5× air objective.

Mesoporous Silica Cluster (MSC) preparation

Typically, CTAB (500 mg) was dissolved in deionized H_2O (DI H_2O) (240mL) and then NaOH solution (1.75 mL, 2M) was added. The mixture solution was heated up to 80 °C with vigorous stirring. Then, TEOS (2.5 mL) was added rapidly. (As for FITC labelled MSC, noted as MSC(FITC), a mixture ethanol solution (1.5 mL) containing APTES (5 μL) and FITC (1.3 mg) was prepared. The mixture solution was stirred under dark condition for 30 min to produce APTES-FITC conjugates. After addition of TEOS (2.5 mL), the APTES-FITC conjugate solution was further added immediately. All the other procedures were the same.) After 1h reaction, extra TEOS (0.5 mL) was added and the solution was kept under mild stirring for another 1h. Then, the formed MSC was collected and washed thoroughly with ethanol by centrifugation at 3000 rpm for 5 min.

For the CTAB removal process, the MSC obtained in previous step was suspended in methanol (50 mL) containing HCl (37%, 3 mL) and then refluxed under stirring at 80 °C for 24 h. The as-prepared MSC was collected by centrifugation and washed with DI H_2O and ethanol thoroughly.

MSC-NH_2 preparation

The collected MSC was suspended in absolute ethanol (20 mL) and then APTES (40 μL) was added. The mixture solution was stirred for 24 h. Then, the amino groups

functionalized MSC, noted as MSC-NH_2, was collected and washed with ethanol and DMF sequentially by centrifugation at 3000 rpm for 5 min.

MSC-COOH preparation

The obtained MSC-NH_2 was further suspended in DMF solution containing succinic anhydride (0.72 g) and triethylamine (0.75 mL). After stirring for 24 h, the MSC-NH_2 was converted into MSC-COOH which was collected and washed with DMF and ethanol by centrifugation at 3000 rpm for 5 min. Then, the MSC-COOH was suspended and stored in ethanol for future use.

JMSC@Ni preparation

At first, a monolayer of the MSC-COOH was prepared. Round glass slides with diameter of 50 mm were cleaned by sonication in acetone and iso-propanol for 5 min, respectively. Then, the clean class slides were treated with oxygen plasma for 4 min to make the surface hydrophilic. The ethanol solution (90 μL) containing MSC-COOH (1 mg mL^{-1}) was dropped onto the glass slide which was aired dried at room temperature. An electron beam evaporation (e-beam) system (BOC Edwards FL400, Germany) was used to deposit magnetic metal layer nickel (Ni) on the MSC-COOH sample. The deposition rate is 0.1 nm S^{-1} under vacuum of 5×10^{-6} mbar. The thickness of deposition layer was 15 nm. The formed JMSC was collected by ultrasonication in DI H_2O and collected by centrifugation at 3000 rpm for 5min.

JMSC@Ni-Catalase preparation

The obtained JMSC was suspended in PBS buffer (pH=6.0, 1.5 mL) containing EDC(5 mg)/NHS(3 mg) and kept stirring for 1h to activate the carboxylic acid groups

at the non-deposited side of the JMSC. Afterwards, catalase solution (50 μL, 30 mg mL^{-1}) was added. And NaOH solution (40 μL, 0.2 M) was added to adjust the pH of the mixture solution to about 8.5. After 24 h reaction, the catalase conjugated JMSC, noted as JMSC@Ni-Catalase was collected and washed with DI H_2O three times by centrifugation at 3000 rpm for 5 min.