Magnetic Janus Nanorods for Efficient Capture, Separation and Elimination of Bacteria

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Experimental section

Materials: Iron (III) chloride anhydrous ($FeCl_3$), diethylene glycol (DEG), poly(acrylic acid) (PAA, Mw=1800), tetraethoxysilane (TEOS, 98%), hexadecyltrimethylammonium bromide (CTAB), 3-aminopropyl-trimethoxysilane (APS) was purchased from Sigma-Aldrich. Sodium hydroxide (NaOH), ammonium hydroxide ($NH_3 \cdot H_2O$, 28%), anhydrous ethanol was obtained from Sinopharm Chemical Reagent Co. Ltd. (Shanghai, China). All reagents were used as received without further purification. Peptone, Yeast extract, Agar, Sodium chloride were purchased from Sangon Biotech (Shanghai) Co. Ltd. *Escherichia coli* and *Staphylococcus aureus* were kindly provided by Prof. Feng Xue's group (Jiangsu Entry-Exit Inspection and Quarantine Bureau, China).

Preparation of Superparamagnetic Fe_3O_4 nanoparticles. The magnetic Fe_3O_4 NPs were synthesized via a high temperature hydrolysis reaction according to our previously report.[16] First, a stock NaOH solution was prepared by dissolving 2.0 g of NaOH in 20 ml of diethylene glycol (DEG). We added $FeCl_3$ (0.8 mmol), poly(acrylic acid) (PAA, 8 mmol, Mw=1800) and DEG (34 mL) into a three-necked flask sequentially and heated the mixture to 220℃ for 30 min under nitrogen. Then the above-mentioned stock NaOH solution was dropped rapidly into the mixture and maintain the temperature with vigorous mechanical stirring for an additional 1 h and cooled to room temperature. Thereafter the as-prepared black mixture was washed with deionized water and anhydrous ethanol three times via centrifugation.

Preparation of Janus mesoporous silica nanoparticles (Janus MSNs): The

amino-functionalized CTAB-loaded Janus MSNs were synthesized through a one-pot reaction by follows, 1 mL of fresh and purified Fe_3O_4 nanoparticles in deionized water solution with the concentration of 8.6 mg/mL was added in 10ml deionized water containing 50 mg of CTAB. The mixture solution was applied to ultrasonic treatment for 1h and then was transferred to three-necked flask with mechanically stirring at 40℃, 30 μL TEOS mixed with 5 μL APS was added, following by adding 500 μL ammonium hydroxide (28%). The reaction solution was further mechanically stirred at 40℃ for 30 min. The product was washed with ethanol for 3 times with magnetic separation. After the completion of the reaction, the Janus MSNs were recovered from the reaction system and followed by washing with ethanol and water for several times.

Characterization of Janus MSNs: Transmission electron microscopy (TEM) images were taken with JEM-2100F transmission electron microscope (JEOL, Ltd., Japan) under 200 kV accelerating voltage. The morphology and composition of the nanoparticles were performed on scanning electron microscope (SEM, S4800, Hitachi). Magnetic measurements were carried out using a TDM-B vibrating sample magnetometer (VSM) at 300 K. The specific surface area was determined by the Brunauer-Emmett-Teller (BET) method and the pore size distributions were calculated by the Barrett-Joyner-Halenda (BJH) method. Zeta position were obtained by Zetasize NANO ZS90 (Malvern, UK). The optical density (600 nm) values were measured on a Lambda 950 spectrophotometer (PerkinElmer, America). Fourier□transform infrared (FTIR) spectra was determined using a Bruker model

VECTOR22 Fourier□transform spectrometer.

Bacterial capture test: The pure culture of Escherichia coli and Staphylococcus aureus cells were grown overnight in LB-agar at 37 °C in a controlled shaking incubator. Colonies were picked to prepared bacteria suspension with LB liquid medium and cultivated at 37 °C for 24 h. The bacterial suspension (about 10^7 CFU/ml) was added to LB liquid medium with different concentrations of Janus MSNs and the mixture was shaken by a rotary shaker at 37 °C for 10 min. Then an external magnetic field was applied to collect the Janus MSNs and the OD_{600} of the supernatant was measured using a UV/Vis spectrophotometer, and then calculated the bacteria capture efficiency. LB bacteria suspension with no particles was as a growth control. In addition, the collected bacterial sediment were taken to measure the SEM.

Antibacterial test: The antibacterial activities of Janus MSNs were valuated on *Escherichia coli* and *Staphylococcus aureus*. 100 μL of the bacteria suspension (about 10^9 CFU/ml) was added to 10 mL LB liquid medium containing different concentration of Janus MSNs (0, 6.25, 12.5, 50, 100 μg/ml), then the mixture was incubated at 37℃ with shaken by a rotary shaker (200 rpm). The bacterial growth inhibition was figured out by measuring OD_{600} of the supernatant. The Janus MSNs without CTAB were performed as control. To determine the MIC, a total of 100 μL of bacteria suspension with different concentration of Janus MSNs was plated on a single LB-agar growth plates incubated overnight at 37℃. Colonies were visualized the next day, and digital images of the plates were captured.

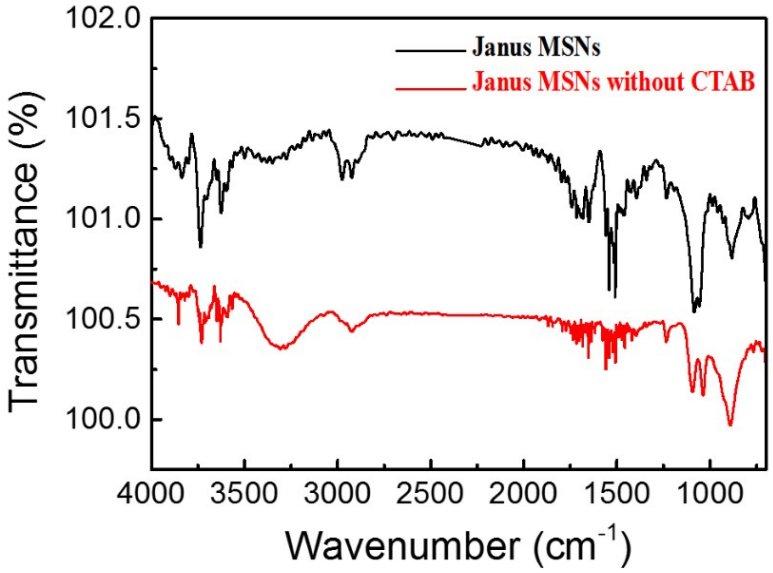

Fig. S1 FTIR spectra of Janus MSNs and Jauns MSNs without CTAB.

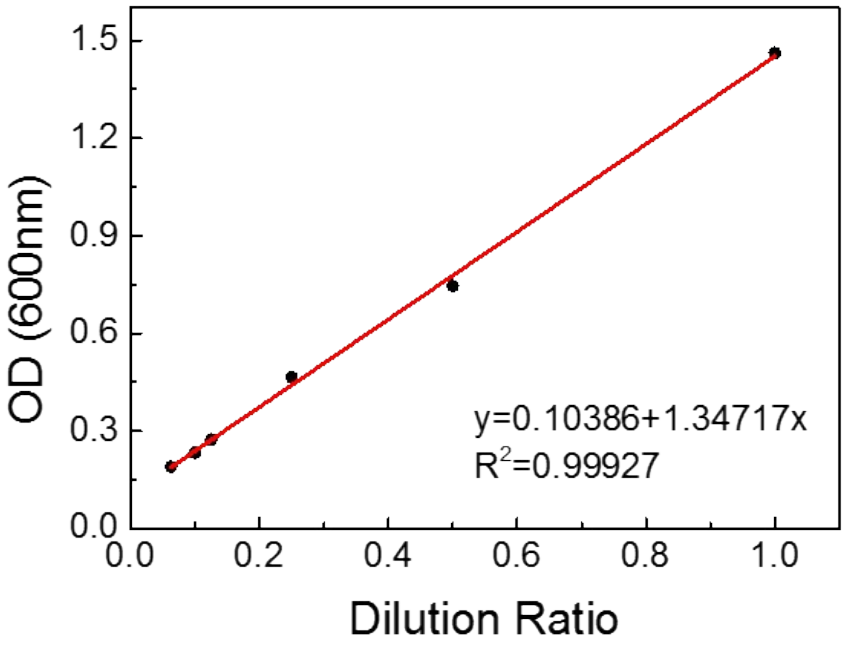

Fig. S2 *Escherichia coli* curve of different dilute ratio in LB liquid medium.

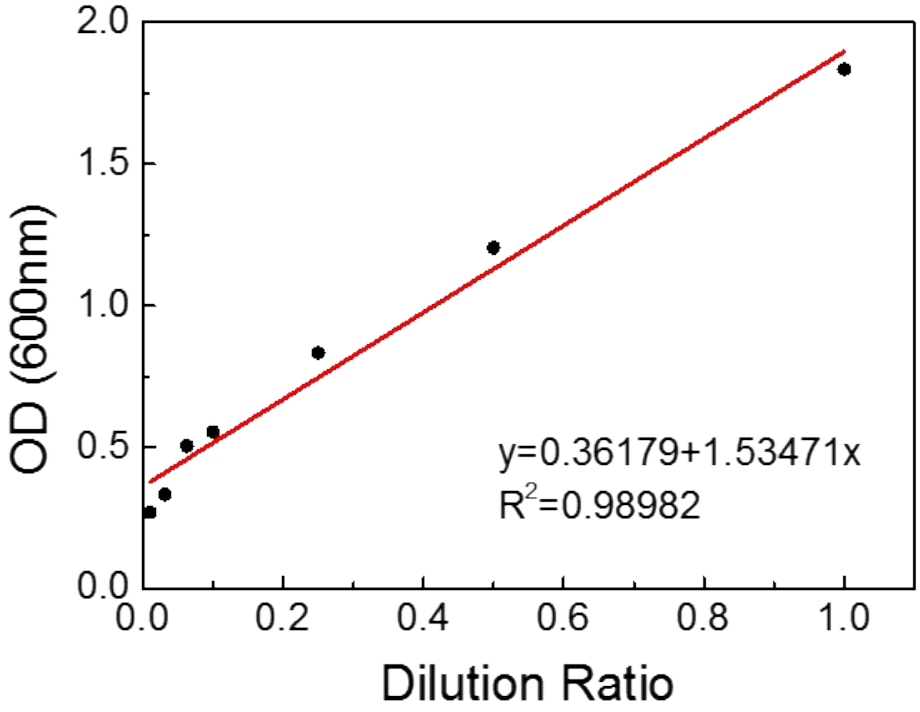

Fig. S3 *Staphylococcus aureus* curve of different dilute ratio in LB liquid medium.