

## Electronic Supplementary Information

### Carboxylated SiO<sub>2</sub>-coated α-Fe nanoparticles: towards a versatile platform for biomedical applications

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## Experimental

- 1. Preparation of SiO<sub>2</sub>-coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles.** The SiO<sub>2</sub>-coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles were prepared according to the procedures described elsewhere [1]. In brief, the Fe<sub>3</sub>O<sub>4</sub> nanoparticles with an average particle size of 25 nm were prepared [2] and the SiO<sub>2</sub> coating was performed through the formation of water-in-cyclohexane reverse microemulsion [3]. To a cyclohexane solution (47.74 g) containing polyoxyethylene(5)nonylphenyl ether (3.65 g) and the Fe<sub>3</sub>O<sub>4</sub> nanoparticles (90 mg), ammonium hydroxide (28%, 0.38 ml) was added, and the resulting mixture was magnetically stirred for 30 min to form a transparent, brown solution of reverse microemulsion. Then, tetraethyl orthosilicate (0.4 g) was added, and the coating reaction was continued for 20 h at room temperature. The SiO<sub>2</sub>-coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles were precipitated by adding ethanol to the reaction solution. They were collected by a magnet, washed with ethanol, and dried in vacuum.
- 2. Reduction with CaH<sub>2</sub>.** The reduction was done according to the method described elsewhere [1]. In brief, a silica-coated sample and a four-weight excess of CaH<sub>2</sub> were finely ground in an Ar-filled glove box, sealed in an evacuated Pyrex tube, and heated at 400 °C for 48 hrs. Residual CaH<sub>2</sub> and CaO produced during the reduction

were washed out with an  $\text{NH}_4\text{Cl}$ /methanol solution in air. The  $\text{SiO}_2$ -coated  $\alpha$ -Fe nanoparticles were collected by a magnet, washed with methanol, and dried in vacuum.

**3. Estimation of Fe content in the  $\text{SiO}_2$ -coated nanoparticles:** The amount of Fe in a sample was determined by means of Thermogravimetry (TG, Bruker AXS, TG-DTA2000SA). Both the  $\text{SiO}_2$ -coated  $\alpha$ -Fe and  $\text{SiO}_2$ -coated  $\text{Fe}_3\text{O}_4$  nanoparticles were transformed to  $\text{SiO}_2$ -coated  $\gamma$ - $\text{Fe}_2\text{O}_3$  nanoparticles by oxidization at 500 °C for 10 hrs in a stream of  $\text{O}_2$ , which were subsequently reduced in a stream of  $\text{H}_2$  at 700 °C to  $\text{SiO}_2$ -coated  $\alpha$ -Fe. The amount of Fe in an initial sample was calculated from the decrease in weight on the reduction by assuming that  $\text{SiO}_2$  remained intact during the reduction.

**4. Modification with COOH-silane:** To a 40 wt% ethanolic aqueous solution (30 g) of the  $\text{SiO}_2$ -coated  $\alpha$ -Fe nanoparticles (40 mg) was added COOH-silane (0.3 g, N-(trimethoxysilylpropyl) ethylenediamine triacetic acid trisodium salt) and the resulting mixture was kept at 80 °C for 3 days while stirring. Thus-obtained  $\alpha$ -Fe@ $\text{SiO}_2$ @COOH NPs were collected by centrifugation, washed with water, and

centrifuged again. The collected powder was redispersed in water and stored at room temperature.

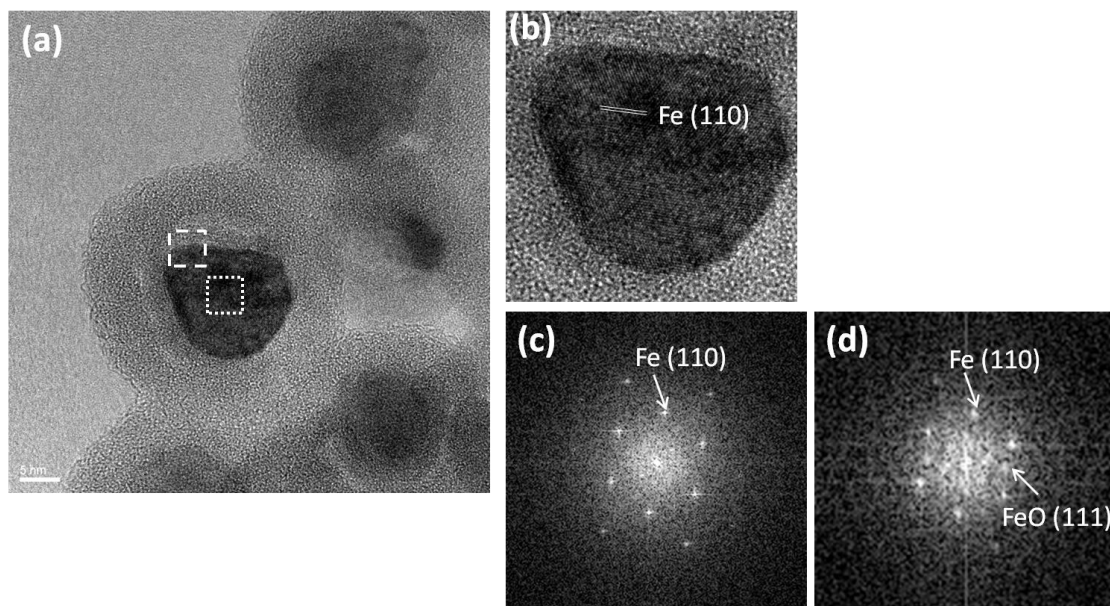
**5. Cell Viability:** The viability of cells treated with nanoparticles was measured using a CellTiter-Glo™ Luminescent Cell Viability Assay (Promega). The cells were seeded onto a 96-well plate at a density of  $1 \times 10^4$  cells per well. After 1 day of culture, different concentrations of the nanoparticles were added to the wells. The cells were incubated for 24 hrs and then 100  $\mu$ l of the reagent was directly added to the wells. After 15 min of incubation at 37 °C, absorbance at 490 nm was measured with a standard microplate reader (Fluoroskan Asent FL, Thermo scientific). Each experiment was done in triplicate. ATP concentration in the cells was estimated based on the emission intensity-ATP concentration calibration. The relative cell viability (%) relative to that for control nanoparticle-free wells was calculated by  $[A]_{\text{exp}}/[A]_{\text{control}} \times 100$ , where  $[A]_{\text{exp}}$  and  $[A]_{\text{control}}$  are the absorbance of the experimental and control sample, respectively.

**6. Other characterization methods.** Low magnification TEM observations were performed by using JEOL JEM-1010D and JEM-1400. High resolution TEM

observation was performed by using JEOL JEM-2200FS. TEM specimens were prepared by dropping a particle-containing solution on a carbon-coated copper grid. Cryogenic transmission electron microscopic (Cryo-TEM) images were obtained with JEOL JEM-2100F(G5) operated at an acceleration voltage of 200 kV. For the specimen preparation, a thin layer of sample solution with 50-500 nm thickness was rapidly frozen in liquid propane maintained at 100 K (Leica, Reichert KF 80 plunger) and then transferred into the cryo-TEM column. The observation was made at 4.2 K using a special sample stage. XRD measurements were performed using Bruker New D8 ADVANCE with Cu K $\alpha$  radiation ( $\lambda = 0.154$  nm). Magnetic properties were characterized by using a Physical Properties Measurement System (PPMS, Quantum Design PPMS-9RST) with a vibrating sample magnetometer (VSM) attachment. IR spectra were collected on JASCO FT/IR-4200. The samples were each mixed with KBr and compressed into pellets. Zeta potential measurements were performed using ZETASIZER Nano-Z (MALVERN).

## References for ESI

- [1] S. Yamamoto, G. Ruwan, Y. Tamada, K. Kohara, Y. Kusano, T. Sasano, K. Ohno, Y. Tsujii, H. Kageyama, T. Ono, and M. Takano, *Chem. Mater.*, **2011**, *23*, 1564.
- [2] Park, J.; An, K.; Hwang, Y.; Park, J.-G.; Noh, H.-J.; Kim, J.-Y.; Park, J.-H.; Hwang, N.-M.; Hyeon, T. *Nature Mater.*, **2004**, *3*, 891.
- [3] Yi, D. K.; Lee, S. S.; Papaefthymiou, G. C.; Ying, J. Y. *Chem. Mater.*, **2006**, *18*, 614.



**Figure S1.**

- (a): high resolution TEM image of the SiO<sub>2</sub>-coated  $\alpha$ -Fe nanoparticles.
- (b): magnified image of the core  $\alpha$ -Fe nanoparticle.
- (c): a fast Fourier transform (FFT) image of the area surrounded by dotted line in (a).
- (d): an FFT image of the area surrounded by broken line in (a).

The core  $\alpha$ -Fe nanoparticle surface was slightly oxidized to FeO due to the washing under air (see **Experimental 2** in ESI) and exposure to air for *ca.* 2 days before high resolution TEM measurements.



**Figure S2.** A photo of dispersion of the dextran-modified sample in phosphate buffered saline. The triangle indicates the fluid level.