

Supplementary online materials for Modified Kirkendall Effect for Fabrication of Magnetic Nanotubes

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S-1. Experimental Section.

Preparation of Zinc Oxide Nanorod. ZnO nanorods were prepared as follows: 10 mL of 0.1 M of zinc acetate stock solution in ethanol was mixed with 20 mL of 0.5 M NaOH solution in ethanol to get a clear solution which was transferred to a Teflon-lined stainless steel autoclave and heated at 150 °C for 24 hours.

Preparation of Iron Hydroxide. All the chemicals were received from Beijing Chemicals Co. (Beijing, China) and used without further purification. In a typical procedure, 0.18 g FeCl₃·6H₂O were added to 8 mL distilled water to form a yellow solution. The as-obtained ZnO nanorods (0.081 g) were dispersed in the yellow solution. After stirred for 15 min, the reaction was stopped and the rufous precipitate was collected by centrifugation and washed with ethanol several times.

Polymer-functionalized of Magnetite Nanotubes. The obtained magnetite nanotubes was dispersed in 20 mL of ethanol. 0.137 mmol of trimethoxysilyl-functionalized PEG and 300 μL of ammonium hydroxide were added to the magnetite nanotube solution in sequence, followed by stirring for 2 h. After centrifugation and washing with ethanol three times, the resulting PEG-MNT was redispersed in 4 mL of water.

Characterization. The products are characterized by scanning electron microscopy (SEM, Hitachi S-4800), transmission electron microscopy (TEM, JEM JEOL 2010), X-ray powder diffraction (XRD, XRD-6000 X-ray diffractometer with CuKα radiation, $\lambda = 0.1542$ nm, 40 kV, 100 mA). The magnetic properties are studied by using a Quantum Design SQUID magnetometer on the MPMS-7 system at 298 K.

MRI experiments. The transverse T₂-weighted spin-echo images are acquired using a 3.0 T Siemens Tim Trio MR Scanner. Echo times were 11–132 ms in 11-ms steps with a repetition time of 2000 ms. Gel preparations in 2-mL vials were placed in a holder for insertion into the eight-channel volume head resonator. The long axis of the vials was parallel to the static magnetic field, and a transverse tomographic plane orientation was used. A gradient echo

acquisition was used with a repetition time of 2000 ms, an echo time of 1.8 ms, a slice thickness of 12 mm, and a flip angle of 20°. In-plane resolution was 0.41 mm. The normal first-order shim process was applied, and the phantoms were imaged at room temperature (20 °C). For SKBR-3 cell experiments, $\sim 10^7$ SKBR-3 cells with attached magnetite nanoparticles and magnetite nanotubes are mixed into 4 % agarose gel at 40 °C before imaging.

S-2. Additional images of the initial ZnO nanorods.

The morphology of the origin ZnO nanorods is shown in Figure S1.

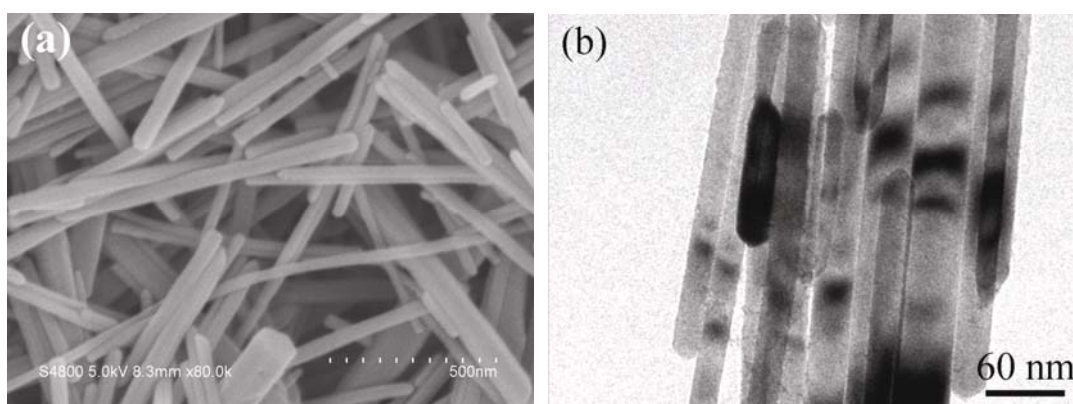


Figure S1. (a) SEM and (b) TEM images of the initial ZnO nanorods.

S-3. The transformation course of the ZnO rods to Fe(OH)₃ nanotubes.

Figure S2a shows XRD patterns of the products obtained at different conversion durations of 1, 10, and 15 min. In the case of the 1 min, the XRD pattern [Figure S2a(I)] shows a coexistence of ZnO and Fe(OH)₃ phases, indicating that ZnO crystals were partially transformed into Fe(OH)₃. With the increase in reaction time, the relative intensity of ZnO peaks decreases along with the increase in Fe(OH)₃ intensity [Figure S2a(II)]. When the reaction time was extended to 15 min, only pure Fe(OH)₃ structures were obtained according to the XRD [Figure S2a(III)] results. These results reveal that the conversion from ZnO nanorods to Fe(OH)₃ nanostructures continues until the depletion of ZnO with increasing reaction time. Therefore, the ratio ZnO/Fe(OH)₃ can be easily manipulated by changing the reaction time. Figure S2b and c are the TEM images of the Fe(OH)₃/ZnO nanocable, which clearly displays an interconnected Fe(OH)₃ shell around the external surface of the ZnO nanorods and the partially hollow in ZnO cores, respectively.

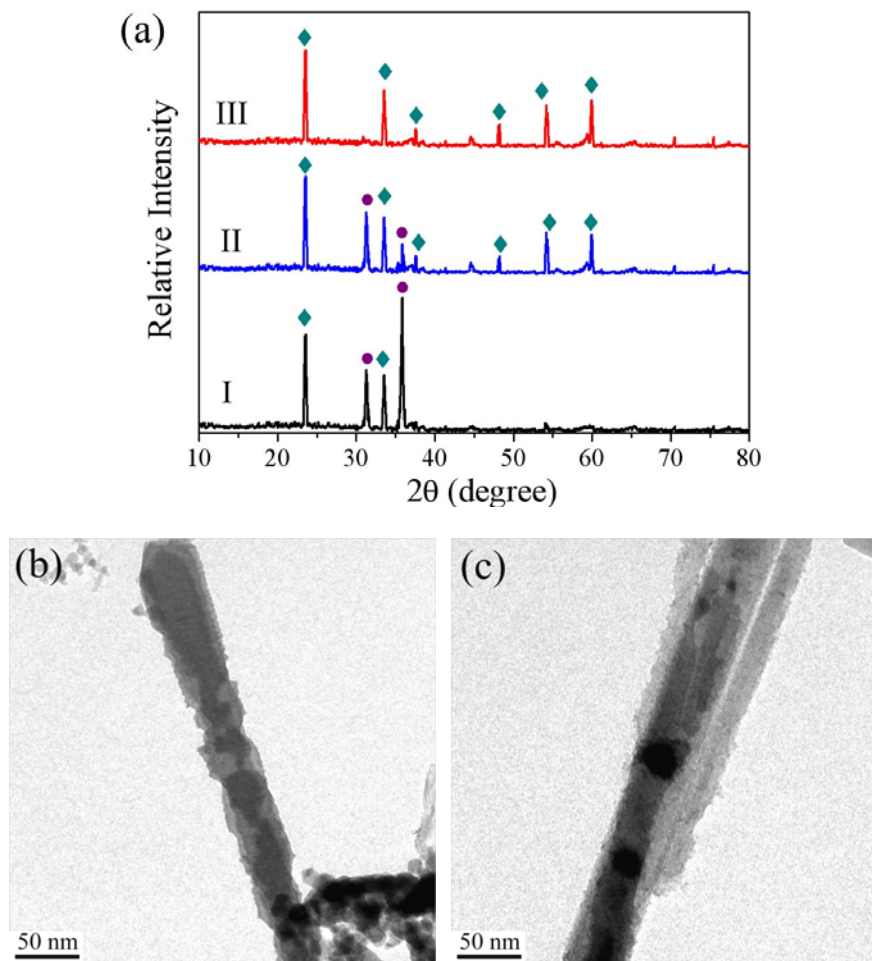


Figure S2. (a) XRD patterns of the products at different conversion periods: (I) 1 min; (II) 10 min; (III) 15 min. (circle: ZnO, diamond: Fe(OH)₃) (b) TEM image of the Fe(OH)₃/ZnO nanocable; and (c) TEM image of partially hollow in Fe(OH)₃/ZnO nanocable.

S-4. Additional images of the converted Fe(OH)₃ nanotubes.

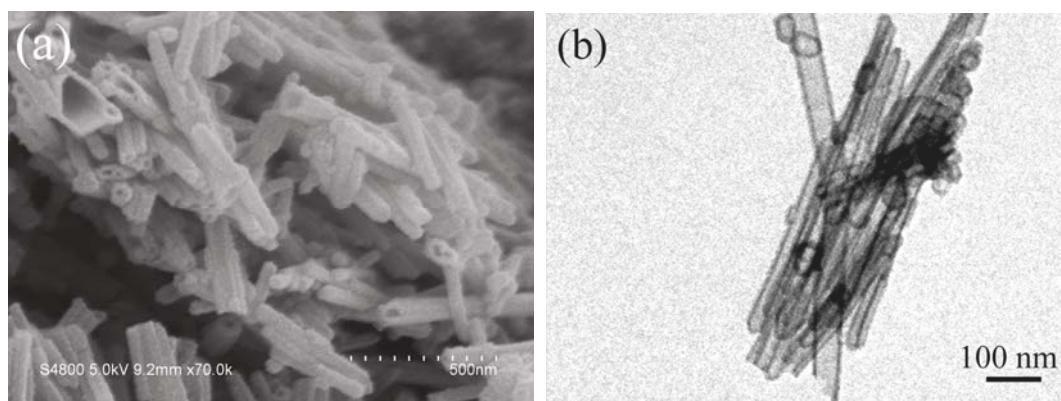


Figure S3. (a) SEM and (b) TEM images of the converted Fe(OH)₃ nanotubes.

S-5. Additional images of the other iron oxide nanotubes.

The morphologies of the obtained α -Fe₂O₃ and γ -Fe₂O₃ nanotubes are exhibited in Figure S4. The lattice fringes of the (110) planes of α -Fe₂O₃ with a *d*-spacing of 0.251 nm and the (220) planes of γ -Fe₂O₃ with a *d*-spacing of 0.296 nm are also clearly seen in the insets of Figure S4b and d, respectively.

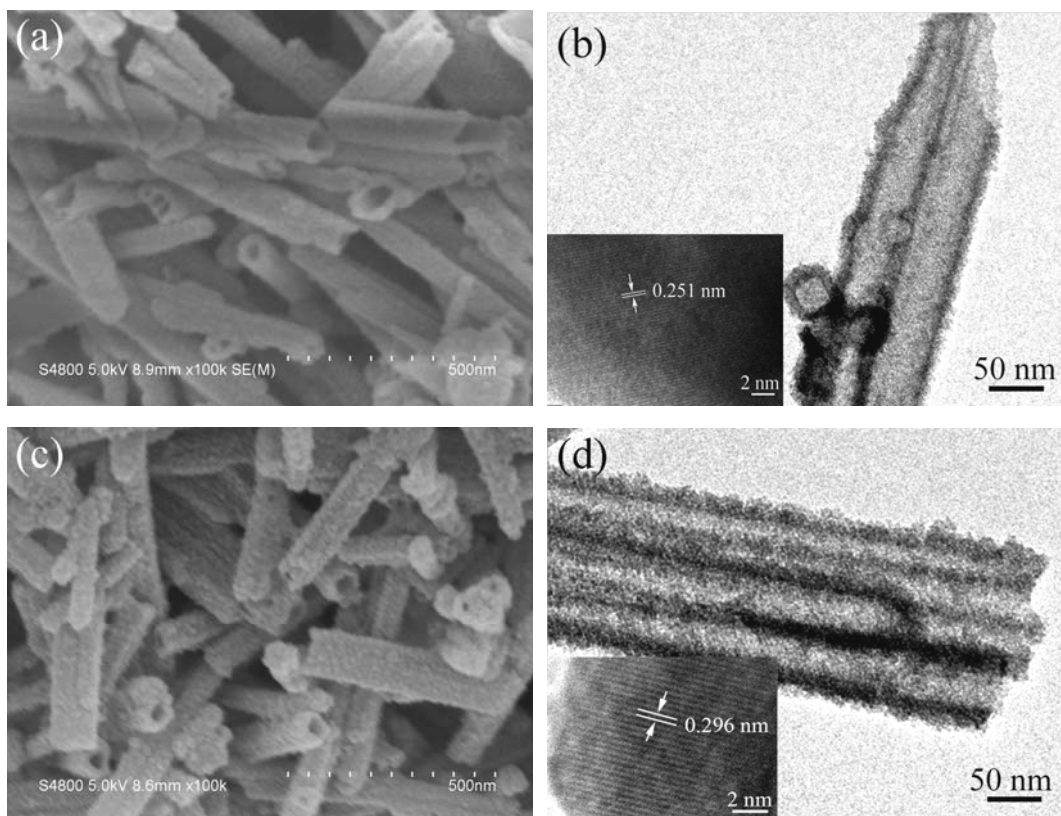


Figure S4. (a) SEM, (b) TEM and HRTEM images of the as-obtained α -Fe₂O₃; (c) SEM, (d) TEM and HRTEM images of the as-obtained γ -Fe₂O₃.