Supporting Information

Egg Albumin as a Nanoreactor for Growing Single-crystalline Fe_3O_4 Nanotubes with High Yields

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1. Experimental section

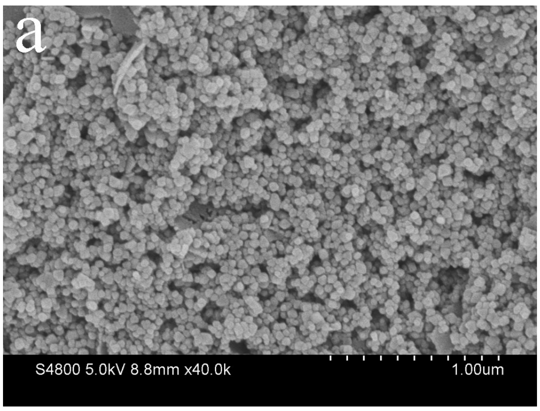
The magnetic Fe_3O_4 nanotubes were obtained by hydrothermal treatment of a $Fe_2(SO_4)_3$ solution in the presence of egg albumin at 140 °C for 24 h. Typically, 20 ml of aqueous $Fe_2(SO_4)_3$ solution (0.05 M) and 5 ml of egg albumin were mixed with stirring. After being stirred with a magnetic blender for 5 min, the solution turned orange. 8 ml absolute ethanol (CH_3CH_2OH) was added to the above solution. Finally, a 10 ml of 80 wt % hydrazine hydrate solution ($N_2H_4 \cdot H_2O$) was added dropwise to the above solution with vigorous stirring. After stirring for 10 min, the mixture was transferred into a 50 ml of Teflon-lined stainless-steel autoclave, which was treated at 140 °C for 24 h. After the autoclave had cooled to room temperature, the precipitate was separated by centrifugation, washed with absolute ethanol and de-ionized water, and dried under vacuum at 60 ^{o}C.

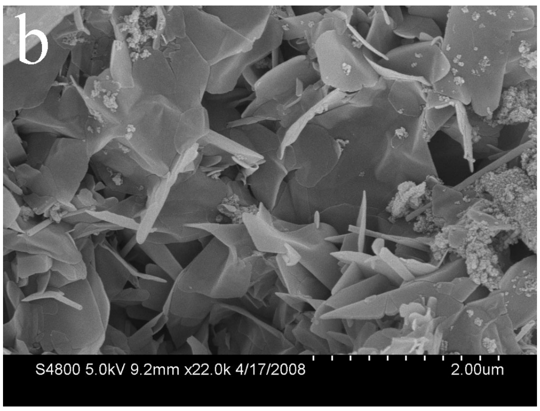
X-ray powder diffraction (XRD) was carried out on an XRD-6000 (Japan) X-ray diffractometer with Cu-Kα radiation (λ=1.54060 Å) at a scanning rate of 0.05 $°\cdot s^{-1}$.

Scanning electron microscopy (SEM) micrographs were taken using a Hitachi S-4800 Scanning electron microscope. Transmission electron microscopy (TEM) micrographs and High-resolution transmission electron microscopy (HRTEM) was performed using JEM 2010 F microscopes operated at optimum defocus with accelerating voltages of 200 kV. Magnetic hysteresis loops are measured using a vibrating sample magnetometer (VSM, BHV-55). For magnetization measurements the powder is pressed strongly and fixed in a small cylindrical plastic box.

2. The amount of the egg albumin affect on the morphology.

Fig. S1(a) shows the SEM image obtained in the absence of egg albumin. Without the addition of egg albumin into the reaction system, uniform nanoparticles were obtained via the direct reaction between aqueous $Fe_2(SO_4)_3$ and $N_2H_4{\cdot}H_2O$ solutions in the present of ethanol at 140 °C for 24 h. When 1 mL egg albumin was used, large-scale flake-like morphology were formed [Fig. S1 (b)]. When egg albumin was increased to 3 mL, compared with the above results [Fig. S1 (c)], some nanotubes and a large number thin sheets were obtained.





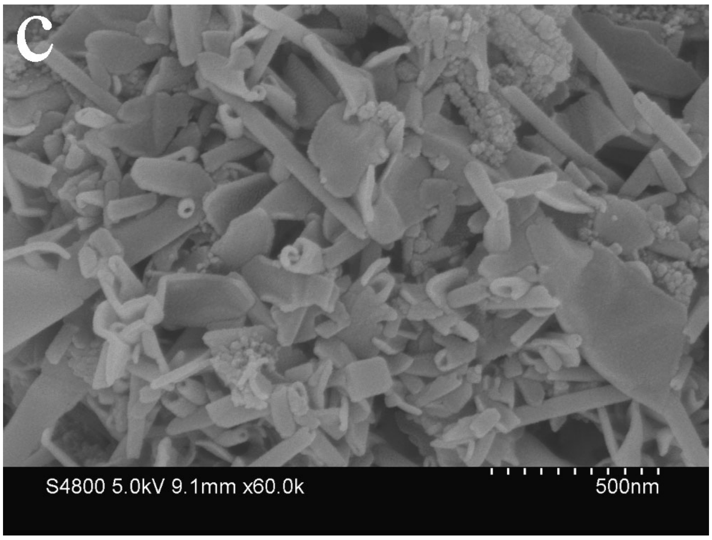


Fig. S1 SEM images obtained for different quantity of egg albumin: a) 0 ml, b) 1 ml and c) 3 ml.

3. Time-dependent morphology evolution.

The growth mechanism of nanotubes was investigated by systematically studying the evolution of the product morphology at 140 °C for various lengths of time. When the heating time is shorter than 2 h at 140 °C, no solid product is produced, because an incubation period is necessary prior to nucleation. When the reaction time is extended to 5-7 h, nanoparticles and nanosheets appear [Fig. S2 (a)]. A further extension of the heating time to 10 h results in the nanosheets started to curl up at the corners [Fig. S2 (b)]. When the reaction was continued for 15 h, nanoscrolls was clearly observed [Fig. S2 (c)]. When the reaction was performed at 140 °C for 20 h, half-tube and half-scroll structures were yielded [see Fig. S2 (d)]. The rolling up of the nanosheet to form nanoscrolls and nanotubes also can be observed in TEM images (see the Supporting Information, Fig. S3).

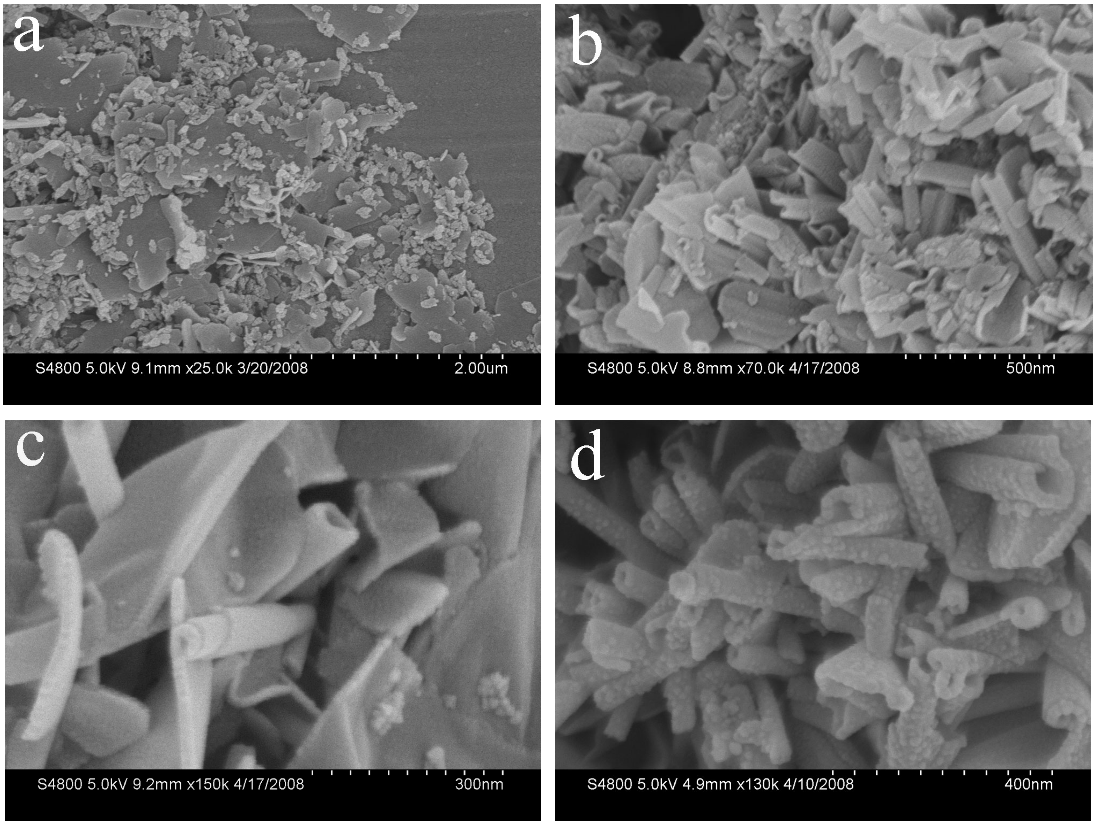


Fig. S2 Morphology evolution of the Fe_3O_4 nanotubes with reaction time: SEM images of the products obtained at 140 ^oC after (a) 5 h, (b) 10 h, (c) 15 h (d) 20 h.

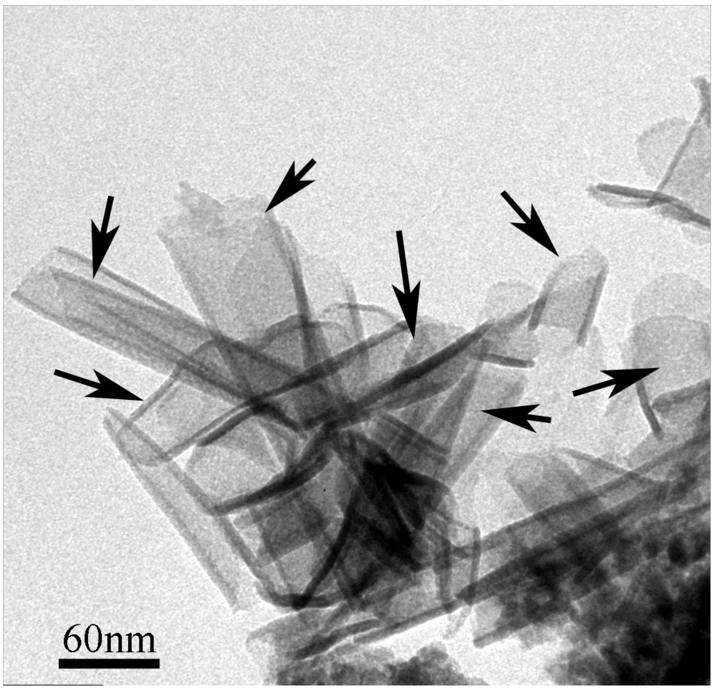


Fig. S3 TEM image shows the rolling up of the nanosheet to form nanoscrolls and nanotubes.