Synthesis, Characterization, and Growth Mechanism of Iron Oxide Nanoworms

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Magnetic nanoparticles have shown great potential in targeted drug delivery, localized cancer therapy, and as contrast agents in magnetic resonance imaging. A potential challenge of using magnetic nanoparticles for bio-imaging is the low blood circulation time, because of the natural immune response of human body. Recently, it was reported that elongated iron oxide nanoparticles could effectively remain undetected by the phagocytes, in spite of their larger dimension. The increased blood circulation will allow them to reach the treatment targets without quick clearance. Here, we report the size controlled synthesis of highly crystalline iron oxide nanoworms via a modified heat-up method using iron oleate precursor (Figure 1a). A detailed time-dependent growth study showed that the nanoworms resulted from the aggregation of spherical nanoparticles. Aggregation was induced by the high percentage coverage of a weakly bound ligand (trioctylphosphine oxide) on the iron oxide surfaces. The diameter of the nanoworms (12 nm, Figure 1b) was similar to the iron oxide nanoparticles, while their length could be controlled from 50-200 nm by increasing the reaction time. The spheres and the nanoworms both showed maghemite crystal structures (Figure 1c), but the magnetic property of the spheres changed from superparamagnetism to ferromagnetism after aggregating into nanoworms (Figure 1d). It is necessary to retain the superparamagnetism even in the nanoworms for their biomedical applications. Earlier studies had shown that smaller diameter nanoparticles were formed by reducing the synthesis temperature. Spheres of smaller diameter would aggregate to give thinner, superparamagnetic nanoworms. Therefore, the nanoworm reaction temperature was reduced by synthesizing the iron oleate precursor in excess de-ionized water. Indeed, the resulting nanoworms were superparamagnetic in nature (Figure 1e and f). These one dimensional nanoworms offer attractive opportunities in imaging and targeted delivery because of their high blood circulation time and large surface area for bio-labeling. Future efforts are being directed to increase the yield of the nanoworms.

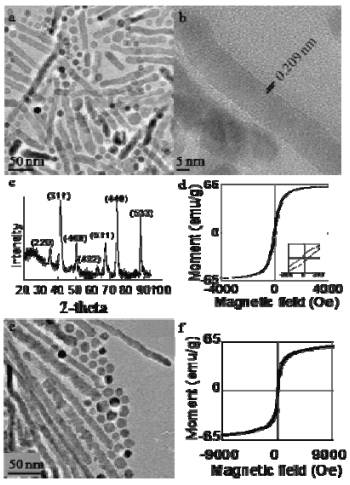

Figure 1: Iron oxide nanoworms: (a) TEM image, (b) HRTEM, (c) XRD scan, (d) *M-H* curve of a, (e) TEM image of superparamagnetic nanoworms, and (f) *M-H* curve of e.