Easy Synthesis and Magnetic Properties of Iron Oxide Nanoparticles

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Easy preparation of iron oxide nanoparticles [5- and 11-nm maghemite (γ-Fe₂O₃) and 19-nm magnetite (Fe₃O₄)] by thermal decomposition of Fe(CO)₅ in the presence of residual oxygen of the system and by consecutive aeration were investigated by TEM/HREM, XRD, and Mössbauer spectroscopy. Also, the magnetic properties of the nanoparticles were studied by SQUID magnetometer and optical microscopy. It was suggested that the intermediate iron oxide nanoparticles (before aeration) were formed by the competing processes of oxidation and crystal growth after decomposition of Fe(CO)₅. At room temperature, the aerated 5-nm particles were superparamagnetic without interaction among the particles, whereas the 19-nm particles were ferrimagnetic. The 11-nm iron oxide nanoparticles were superparamagnetic with some interactions among the particles.

Introduction

Iron oxide nanoparticles have been of great interest, not only in fundamental properties caused by their multivalent oxidation states, abundant polymorphism, and the mutual polymorphous changes in nanophase, but also in technological applications such as high-density magnetic recording media, sensors, catalysts, and clinical uses.1-6 Clinical application requires that iron oxide nanoparticles be discrete and superparamagnetic with sizes smaller than 20 nm, and have narrow size distribution for uniform physical and chemical properties.3,6 Magnetite and maghemite nanoparticles are commonly studied magnetic iron oxides for clinical applications. The advantage of using iron oxide nanoparticles relies on their chemical stability in contrast to that of commonly used nanoparticles of pure Fe metal.

Iron oxide nanoparticles prepared by classical methods7 have been quite limited to meet the requirement for clinical applications. Recently, thermal decomposition of the iron precursor in surfactant solution has been developed for the synthesis of high-quality iron oxide nanoparticles satisfying the requirement. For example, direct decomposition of FeCups produces iron nanoparticles and the subsequent oxidation by a chemical reagent can lead to monodisperse magnetite nanoparticles.8 The thermal decomposition of Fe(CO)₅ produces iron nanoparticles and the following oxidation by a chemical reagent can lead to monodisperse maghemite nanoparticles.9 Also, the high-temperature reaction of iron (III) acetylacetate in phenyl ether in the presence of alcohol and surfactant can be used to make monodisperse maghemite nanoparticles.10 Then, the oxidation of magnetite to maghemite nanoparticles requires high temperature (250 °C) and oxygen for 2 h.10

Meanwhile, most of the recent advances in the synthesis of high-quality nanoparticles have used highly pure organometallic precursor and precisely controlled inert conditions such as purified high-grade reagents and freeze–thaw technique. An easy and economic synthesis would be desirable for clinical and industrial applications. From the known fast oxidations of unprotected iron nanoparticles11 and of ferrous ion to ferric

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