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Preparation of silver nanoparticles on the surface of fine magnetite particles by a chemical reduction

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ABSTRACT

We demonstrate a modified polyol process to synthesize silver nanoparticles on the surface of larger magnetite nanoparticles. The overall process consists of two step reactions. First the magnetite particles of 100–200 nm in diameter are functionalized with a coupling agent 3-mercaptopropyltrimethoxysilane (MPTMS) through a sol–gel reaction. The functionalization of the magnetite surface is confirmed with IR spectra. For the second step silver nitrate is reduced at the site of thiol groups of the functionalized magnetite surface with ethylene glycol (EG) and polyvinylpyrrolidone (PVP). It was observed that silver nanoparticles were formed on the surface of the magnetite particles from transmission electron microscopy images and chemical composition analysis with energy dispersive spectrometer.

1. Introduction

Magnetite nanoparticles have been long used in many industrial applications such as magnetic recording media, printing inks, magneto-rheological fluids and sensors. Recently their applications have been more diversified to targeted drug delivery, contrast agents for magnetic resonance imaging (MRI) [1,2], photonic crystals [3,4], and electrically conductive materials [5]. These magnetite particles are of few to hundreds nanometers in size and they are handled in the state of colloidal solution either at the final products or on the manufacturing process. Therefore the magnetite particles are commonly required to be dispersed well in liquid and to maintain stable dispersion. Environment of the application is also a critically important factor determining the property requirement for the magnetite particles. To meet these requirements, it is usually necessary to modify the surface of the magnetite particles. Silica coating of the magnetite particles is a typical example [6–8]. Since silica is negatively charged, it causes Coulombic repulsion. And it retards dipole interaction between the magnetite particles. Hence these two effects contribute to preventing aggregation of magnetite particles. Moreover the silica easily offers silanol group which helps in attaching specific ligands to the surface of the magnetite particles.

Similarly silver can be used as a coating material for the magnetite particles. It provides not only the stability of magnetic

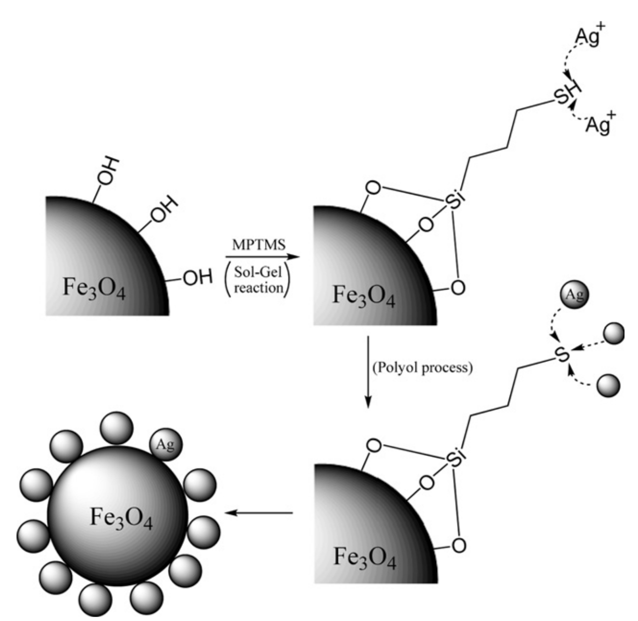

Fig. 1. Schematic diagram for the modified polyol process of present work.

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dispersion, but also the compatibility with biological cells and coupling agents. In addition it is electrically and thermally conductive. Incorporating this electrical or thermal conductivity of silver and the magnetic property of magnetite into a core-shell structure allows us to design novel materials with the controllable electrical and magnetic properties. There have been few reports on the synthesis of silver nanoparticles on the surface of magnetite particles [5,9]. A well-known method to synthesize silver is polyol process which is an alcohol-reduction reaction. The polyol process reduces silver ions ($AgNO_3$) to metallic silver (Ag^0) using reducing agents such as ethylene glycol and glucose. However this method has two drawbacks. One is that silver nanoparticles formed on the surface of the magnetite particles can be detached. The other is that it is difficult to obtain uniform coating of the silver since silver can form nuclei without attaching to the surface of the magnetite. In order to improve these drawbacks we present a modified polyol method to form silver nanoparticles on the surface of magnetite particles. We use 3-mercaptopropyltrimethoxysilane (MPTMS) as a coupling agent with a functional group which has a high affinity to the metallic surfaces. The first step is a sol–gel reaction to graft the hydroxylated surface of the magnetite particles with MPTMS. Then the surface of the magnetite is terminated with the thiol group with high affinity to silver ions and metallic silver. The next is the polyol process in which silver ions in $AgNO_3$ are reduced to Ag^0 at the surface of the magnetite particles using ethylene glycol. The coupling agent MPTMS plays a very important role for stable coating of the surface of the magnetite particles with silver. The thiol functionalized coupling agents such as MPTMS have been often utilized for binding

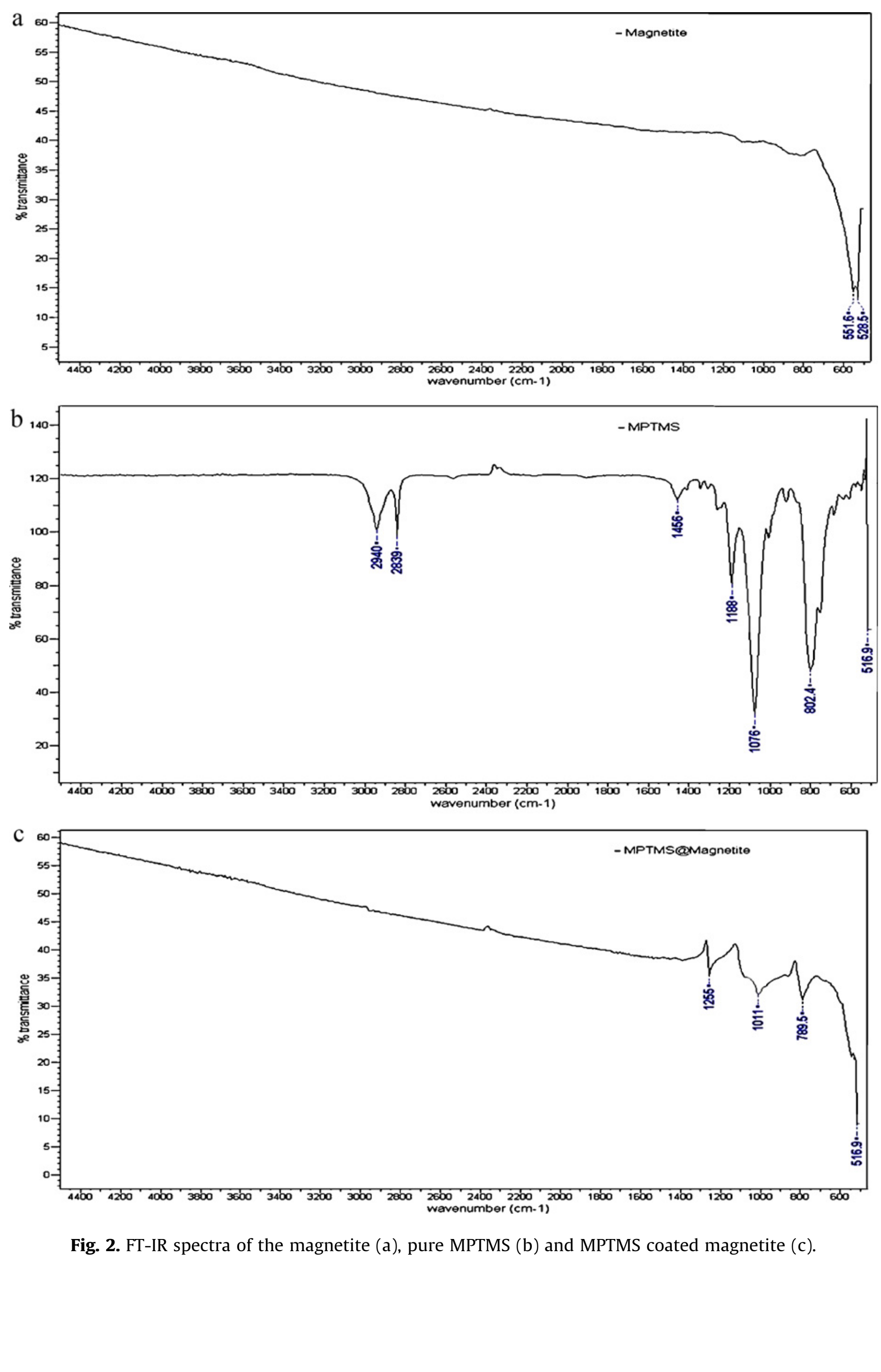

Fig. 2. FT-IR spectra of the magnetite (a), pure MPTMS (b) and MPTMS coated magnetite (c).