

Core/Shell Structured Magnetic Nanoparticles for Biological Applications

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1. Introduction

Magnetic nanoparticles have been widely used for biomedical applications [1, 2], such as magnetic resonance imaging (MRI), hyperthermia, drug delivery and cell signaling. The surface modification of the nanomaterials is required for biomedical use to give physiological stability, surface reactivity and targeting properties. Among many approaches for the surface modification with materials, such as polymers, organic ligands and metals, one of the most attractive ways is using metals.

The fabrication of metal-based, monolayer-coated magnetic nanoparticles has been intensively studied. However, the synthesis of metal-capped magnetic nanoparticles with monodispersities and controllable sizes is still challenged.

Recently, gold-capped magnetic nanoparticles have been reported to increase stability and to provide biocompatibility [3, 4]. Magnetic nanoparticle with gold coating is an attractive system, which can be stabilized in biological conditions and readily functionalized through well-established surface modification (Au-S) chemistry. The Au coating offers plasmonic properties to magnetic nanoparticles. This makes the magnetic/Au core/shell combinations interesting for magnetic and optical applications.

Herein, the synthesis and characterization of gold capped-magnetic core structured nanomaterials with different gold sources, such as gold acetate and chloroauric acid have been reported. The core/shell nanoparticles were transferred from organic to aqueous solutions for biomedical applications.

2. Methods and Results

Methods and results parts are divided into four sections. First, the synthesis of magnetic core nanoparticles is described. Second, the synthesis of Au-coated magnetic nanoparticles is mentioned. Third, characterization of the resulting nano-structured materials is discussed. At last, phase transfer of the products is described. As mentioned in Figure 1, the phase transferred core/shell nanoparticles can be decorated with targeting moiety, such as antibodies, peptides, aptamers, small molecules and ligands for biological applications, which is the one of our long-term goals.

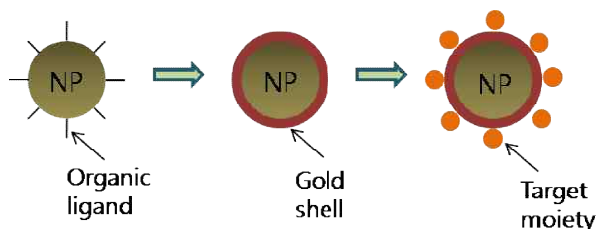


Fig. 1. Schematic illustration of core-shell nanoparticles. Magnetic cores were prepared using a thermal decomposition method and coated with gold. The surface of the nanoparticles can be decorated with targeting moiety for biological applications.

2.1 Synthesis of magnetic nanoparticles

Magnetic nanoparticles were prepared with a thermal decomposition method [5]. Briefly, to prepare monodisperse iron oxide nanoparticles, $\text{Fe}(\text{acac})_3$ was mixed in phenyl ether with 1,2-hexadecanediol, oleic acid and oleylamine under nitrogen gas. The solutions were heated to reflux for 1 h. After cooled to room temperature, ethanol was added to the reaction mixture to precipitate the magnetic nanoparticles. The resulting solutions were centrifuged to give the product. The product was dissolved in hexane.

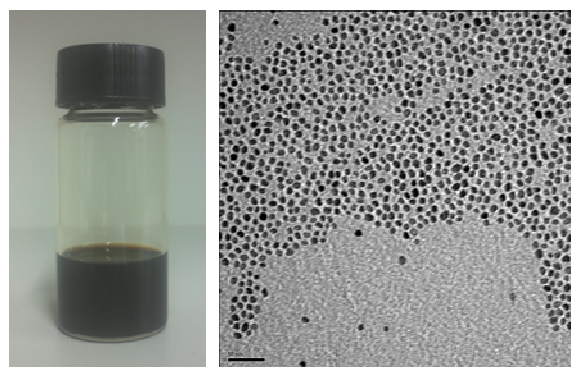


Fig. 2. The picture and TEM images of magnetic nanoparticles.

2.2 Synthesis of gold-capped magnetic nanoparticles

The resulting magnetic nanoparticles were used as seeds. The reaction solution of magnetic nanoparticles was mixed with gold acetate (or chloroauric acid), oleic acid, oleylamine and 1,2-hexadecanediol. The various amounts of gold sources, such as gold acetate and chloroauric acid were added into the reaction mixture. The reaction solution was heated to $\sim 200^\circ\text{C}$ and was

kept at this temperature for 1.5 h. After cooled to room temperature, ethanol was added to the solution. The dark-purple materials were precipitated and separated by centrifuging. The resulting product was washed with ethanol and redissolved in hexane solutions. The gold-coated magnetic nanoparticles showed a clear band at around 520 nm.

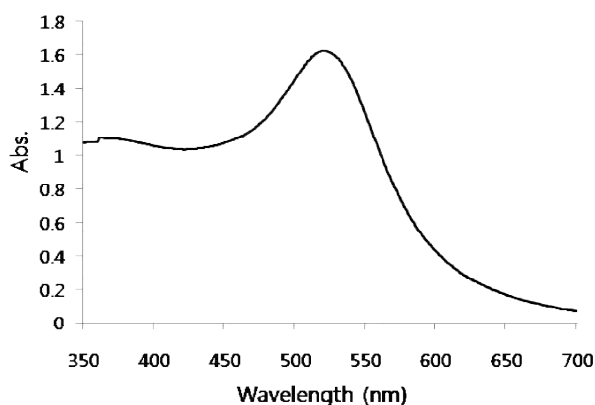


Fig. 3. UV-Vis spectrum of gold-capped magnetic nanoparticles.

2.3 Characterization of the resulting nanomaterials

The hexane solutions containing the nanoparticles were dropped onto a carbon-coated copper grid, and then dried at room temperature for Transmission Electron Microscopy (TEM) analysis. The nanoparticle solution dispersed in hexanes was also measured with a dynamic light scattering method for size determinations. Ultraviolet visible (UV) spectra of gold-coated nanoparticles were acquired with a UV 2550 spectrophotometer (Shimadzu) over the range of 250-1000 nm.

2.4 Phase transfer of gold-capped magnetic nanoparticles

The resulting magnetic nanoparticles dispersed in hexanes were mixed with DMSA solutions dissolved in dimethyl sulfoxide (DMSO). After centrifugation, the resulting nanoparticles were redispersed in water. Another route for the phase transferring of nanomaterials is using cetyltrimethylammonium bromide (CTAB). The core/shell nanoparticles were mixed with the aqueous solutions containing CTAB and sodium citrate.

3. Conclusions

Magnetic core/shell structured nanoparticles have been prepared and transferred from organic phase to aqueous solutions. The resulting Au-coated magnetic core nanoparticles might be an attractive system for biomedical applications, which are needed both magnetic resonance imaging and optical imaging.

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