Synthesis and characterization of PVP coated ultra-small Fe_3O_4 nanowires

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Abstract

Nanotechnology has developed to such an extent that it has become possible to fabricate, characterize and specially tailor the functional properties of nanoparticles for biomedical applications and diagnostics. These applications need special surface coating of the magnetic particles, which has to be not only nontoxic and biocompatible but also allow a targetable delivery with particle localization in a specific area. As an example, superparamagnetic iron oxide nanoparticles with proper surface coatings are increasingly being evaluated for clinical applications such as hyperthermia, drug delivery, magnetic resonance imaging, transfection and cell/protein separations.

In this work, coated iron oxid magnetic nanoparticles, called carriers, which are very useful for delivering chemotherapeutic drugs has been prepared by precipitation in an aqueous solution of iron (II) and iron (III) chlorides under basic condition. Surface modifications were carried out by using polyvinylpyrrolidone (PVP). Characterization of Iron oxide coated nanoparticles have been successfully performed by Fourier transform infrared (FTIR) spectroscopy, Powder X- ray diffraction (XRD), transmission electron microscopy (TEM) and Energy dispersive X-ray (EDX) spectroscopy. The particle sizes as measured from TEM images and XRD were found to have mean diameters of 10 for the coated particles. The results obtained from FTIR spectroscopy revealed that the PVP molecules in the coated magnetite particles were bounded.

Keywords: Polyvinylpyrrolidone; Supermagnetic iron oxide; Drug delivery; Magnetic resonance imaging

Introduction

Magnetic nanoparticles (especially, iron-oxide nanoparticles) have attracted intensive attention in biomedical applications, such as separation of biomacromolecules, magnetic resonance imaging (MRI), biological labels and targeted drug delivery[1–7]. Therefore, the synthesis of ultra-small Fe_3O_4 nanoparticles with size less than 10 nm is highly desired for biomedical applications [9, 10]. Todate, several approach on the synthesis of ultra-small magnetic nanoparticles have been reported.[11–16] Among them, coprecipitation method, as an economic, biocompatible, and environmentally friend method, has been used for synthesizing Fe_3O_4 nanoparticles[17, 18], but ultra-small Fe_3O_4 nanoparticles have not been successfully synthesized by this method yet. In this paper, we used polyvinylpyrrolidone (PVP) as a stabilizer to synthesize ultra-small Fe_3O_4 nanoparticles at 75°C by the coprecipitation method. PVP has been widely used as a coating material for nanoparticles due to the following properties: 1) easy excretion through the kidney; 2) low interfacial free energy water; 3) excluded volume effect; 4) nonimmunogenic properties; and 5) nonantigenic properties. The successful formation of the ultra-small Fe_3O_4 nanoparticles was confirmed by means of X-ray diffraction (XRD), transmission electron microscopy (TEM), infra spectrum (FTIR), and X-ray photoelectron spectroscopy (XPS). When exposed directly to biological environments, the ultra-small Fe_3O_4 magnetic nanoparticles presented biocompatibility and showed encouraging applications in MRI and magnetic delivery of drug.

Material and Methods

Materials : Ferrous chloride tetrahydrate ($FeCl_2 .4H_2O$), ferric chloride ($FeCl_3.6H_2O$), Polyvinylpyrrolidone (PVP, average MW: 7000–11 000) and sodium hydroxide (NaOH) were purchased from Merck. MO. Distilled water was deaerated by purging with nitrogen for 15 minutes.

Preparation of iron oxide magnetic nano-particles: Required amounts of $FeCl_2 .4 H_2O$ and $FeCl_3.6H_2O$ in a molar ratio of 1:2 were dissolved in 200 ml of deaerated distilled water in a round bottom flask and kept at desired temperature. After 30 minutes purging of the stirred reaction mixturewith nitrogen, stoichiometric amount of NaOH was added drop wise into the solution. During the experiment, nitrogen gaz was kept passing through the solution to prevent oxidation of Fe^{2+} in the system and addition of the NaOH, was noticed the solution changed color from the original brown to dark brown and then to black. The black iron oxide product responded to a magnetic field as expected. This physical property is very sensitive to the solution pH and is helpful in separation of the particles from the liquid reaction solution.

Preparation of PVP coated of iron oxide nanoparticles: The polyvinylpyrrolidone (PVP)-coated iron oxide nanoparticles were prepared by adding the above prepared