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Original Research Paper

Preparation of silica coated iron oxide nanoparticles using non-transferred arc plasma

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ABSTRACT

Silica coated iron oxide nanoparticles were prepared using non-transferred arc plasma. The plasma was discharged with argon. Vapors of iron pentacarbonyl ($Fe(CO)_5$) and tetraethyl orthosilicate (TEOS, $Si(OC_2H_5)_4$) were injected into a plasma torch with carrier gas and reacted in the plasma chamber. In addition, two types of reaction chambers that are a hot wall reactor and a cold wall reactor were used to investigate the effect of temperature gradient on the synthesis of silica coated iron oxide nanoparticles. The synthesized nanoparticles were collected on the chamber wall and bottom. Phase compositions of the obtained nanoparticles were characterized by X-ray diffractometer (XRD) and the morphologies and the size distributions of the synthesized particles were analyzed by scanning electron microscopy (SEM) and transmission electron microscope (TEM). Additionally, elements mapping of the coated particles was performed by energy dispersive spectroscopy (EDS). The phase composition of the prepared particles was mainly composed of amorphous silica and polycrystalline Fe_3O_4. It was confirmed that the silica was adsorbed on iron oxide particles or encapsulated iron oxide particles. Furthermore, the mechanism of the formation of silica coated iron oxide in the plasma chamber was predicted.

1. Introduction

Magnetic materials have been widely applied to magnetic fluids [1,2], data storage [3], biochemical applications (e. g. magnetic resonance imaging [4,5], drug delivery [6]) and environmental remediation [7]. Among magnetic materials, iron oxides including magnetite (Fe_3O_4), hematite (α-Fe_2O_3) and maghemite (γ-Fe_2O_3) are attracting considerable interest because iron oxide particles below 100 nm exhibit superparamagnetic properties [8].

Especially, biochemical applications of iron oxide have been actively studied in recent years [4,5,9]. However, pure iron oxides cannot be applied because of large agglomeration, change of the magnetic properties and degradation in biological systems. Therefore many researchers have studied inert material coated iron oxides or iron oxide/inert material composites [10–12] as favorable candidates to solve those problems. Coating inert material (e.g. silica) on iron oxide provides a large specific surface area, enhanced colloidal stability and increased chemical resistance, while keeping the original magnetic property.

Various methods have been researched to prepare coated particles which include carbon/metal or ceramic [13–15], ceramic/ metal [16,17], metal/ceramic [18,19] and ceramic/ceramic [20–22], as well as SiO_2/Fe_3O_4. The preparation methods include liquid phase methods such as sol–gel, co-precipitation and controlled hydrolysis, in which additional processes have to be carried out to remove organic compounds used in the preparation process which limit their applications. Nevertheless it is hard to remove completely the organic compounds adsorbed on the products. To solve this problem, interest in employing a vapor phase method has grown [14–16,22]. As alternative to a liquid phase method, vapor phase method leads to high purity products without post-treatment.

Non-transferred arc plasma, that is one kind of thermal plasma, possesses a high temperature with activated chemical species such as ions, radicals, etc. In the thermal plasma process for preparation of nano-sized particles, the raw material is dissociated by high temperature and high chemical activity of the thermal plasma [23]. The dissociated raw material reacts with desirable precursors and forms nano-sized particles through the cooling process.

In this study, we prepared silica coated iron oxide nanoparticles using non-transferred arc plasma method at atmospheric pressure. Two types of reactors, a cold wall reactor and a hot wall reactor were used to alter the temperature gradient as an experimental

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