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Gamma-ray synthesis of magnetic nanocarrier composed of gold and magnetic iron oxide

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Abstract

Magnetic nanocarrier consisting of iron oxide and gold was synthesized in an aqueous solution by using γ -ray irradiation. UV–vis absorption spectra showed surface plasmon resonance of nano-sized metallic gold. The surface of quasicore–shell structured magnetic iron oxide nanocarriers was almost covered with gold grains after having the gold grains grow over the iron oxides.

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1. Introduction

In recent years, magnetic nanoparticles are studied because of their potential applications as magnetic carriers for various biomedical uses such as cell and DNA separation, drug delivery system (DDS), magnetic resonance contrast enhancement and gene cloning [1–6]. In particular, magnetic beads with a few micrometers in diameter are

already commercialized and used for cell separation, DNA isolation and protein isolation [7]. For these applications, their surfaces are coated with a layer to combine with the functional biomolecule for each purpose and to avoid nonspecific adsorption. However, the commercially available magnetic beads cannot be used as a general purpose carrier. For each biomolecule it is necessary to coat the particles with an appropriate layer, which does not deactivate the biomolecule. On the other hand, gold nanoparticles are also widely studied in the field of biotechnology [6,8–10]. Gold combines firmly with biomolecules possessing mercapto

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groups and exhibits a characteristic reddish color due to surface plasmon resonance. The color changes when gold nanoparticles aggregate with the molecules attached on their surface, for which colorimetric detection of specific biomolecule is possible.

Recently, our group succeeded in synthesizing composite nanoparticles consisting of magnetic iron oxide nanoparticles and gold nanoparticles supported on their surface using γ -ray [11]. The composite nanoparticle takes over both the functions of the gold metal and magnetic maneuverability of the iron oxide. We have proposed that the composite nanoparticle is a very useful magnetic nanocarrier for the applications described above, because gold can serve as a specific tag for the mercapto group included in functional biomolecules. The composite nanoparticles may realize colorimetric detection and magnetic separation of the specific target biomolecules. Another merit of the composite nanoparticles is that they are synthesized in an aqueous solution without harmful surfactants or organic solvents. Carpenter et al. and Kim et al. claimed that iron–gold nanoparticles of a core–shell structure is synthesized by a reversed micelle method in an octane solution using CTAB as a surfactant [12,13]. Their particle must be coated with the surfactant molecules, which are not suitable for the biotechnological applications. We have already confirmed that the gold in our composite nanoparticles combine with molecules possessing mercapto group by using a glutathione as a model compound. However, an adsorption by the magnetic iron oxide surface was still observed. So, it is required to increase the amount of gold nanoparticles covering the iron oxide surface in order to suppress the nonspecific adsorption. The gold layer on the magnetic iron oxide should avoid nonspecific adsorptions.

In this work, we tried to enhance gold deposition on iron oxide by controlling an initial charge of iron-oxide dispersed in the suspension. We aimed at synthesizing core–shell nanoparticles; the surface of iron oxide nanoparticles is almost fully coated with gold layer, by growing the gold grains by a chemical treatment.

2. Experimental procedure

Iron oxide nanoparticles of γ -Fe₂O₃ with average diameter of 26 nm synthesized by physical vapor synthesis which are purchased from Nanophase Tech. Corp. were used as magnetic carriers. It contains γ -Fe₂O₃ particles of several nanometers to a hundred nanometer. Chemicals, such as HAuCl₄, 2-propanol and polyvinyl alcohol (PVA) were purchased from Wako Pure Chemical Industries Ltd. The iron oxide nanoparticles were dispersed in an aqueous solution containing Au(III) ion together with 2-propanol and PVA, then closed up in a glass vial. Concentration of the Au(III) ion, 2-propanol and PVA was fixed at 0.5, 0.125 mmol/l and 10 g/l, respectively. The amount of iron oxide nanoparticles dispersed in the suspension was 1.0 or 0.1 g/l. The suspension was sonicated for 15 min in an ultrasonic bath before γ -ray irradiation to disperse the iron oxide nanoparticles. The suspension was irradiated at room temperature with a ⁶⁰Co γ -rays source at a dose rate of 3 kGy/h for 0–6 h. During the irradiation, suspensions were continuously stirred to maintain the dispersion by rotating the disk on which the vials were mounted [14]. The sample suspension thus obtained was divided into magnetic and nonmagnetic fractions by a permanent magnet. Composite nanoparticles were obtained from the magnetic fraction.

To grow the gold grains on the γ -Fe₂O₃, we proceeded reduction of Au(III) ions at the surface of composite nanoparticle. The magnetic fraction of the irradiated suspension was mixed with an aqueous solution of HAuCl₄. After stirring 20 min, aqueous solution of NH₃, also purchased from Wako Pure Chemical Industries Ltd., was slowly added to the suspension under vigorous stirring to reduce gold ions. After stirring for 2 h, the aqueous suspension was magnetically separated to magnetic fractions and nonmagnetic fractions. The process was iterated 6 times until the surface of γ -Fe₂O₃ nanoparticles are enough coated with gold nanoparticles.

The UV–vis absorption spectra of the aqueous suspensions were measured by a spectrometer, Varian Cary 50. Au(III) ion concentration, which remains unreduced in the nonmagnetic fraction,

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