

Chemical Synthesis of Magnetic nanoparticles and their Applications to Recording Media & Biomedical Materials

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Recent progress in nanotechnology has produced a variety of extremely small materials with a nanometer size, such as nanoparticles, nanofilms, and nanowires. These nano-materials have been studied all over the world because of their attractive characteristics remarkably different from bulk materials in terms of both physical and chemical features. Especially, nanoparticles show fascinating structural, electronic, magnetic, spectroscopic, chemical features due to their unique electronic states and expected to be applicable in various fields including ultra-high density magnetic recording media, drug delivery systems (DDS) and medical resonance imaging (MRI) [1–3]. In addition to the unique characteristics, the size itself and the high specific surface area are also fruitful when they are applied to practical devices. Second, the small size is originally comparable to biomaterials (e.g., DNA and cells), which means that nanoparticles can effectively interact with biological entity of interest. Thus, a variety of researches have been reported on biological application of nanoparticles. Third, the size and the shape are controllable, and high-order (highly-ordered) structures can be spontaneously constructed by self-assembly.

Magnetic Recording Media Materials

FePt alloy particles with the L1₀ structure have drawn much attention because of their potential applications in ultra high density magnetic recording system, because it possess a very high uniaxial magnetic anisotropy, and superpara-magnetic fluctuation of magnetization at room temperature can be neglected even for particles of 2.7-3.0 nm in diameter.

A chemical synthesis of FePt nanoparticles, which was first reported by Sun, is attracting attention because of its simplicity, and making an appropriate array of these nanoparticles is a promising candidate for future ultra-high density magnetic recording media [1]. Unfortunately, as-synthesized FePt nanoparticles usually arrange in face-centered cubic lattice which exhibits low magnetic anisotropy. We focused our attention in a crystal *growth temperature* as the temperature at which the atomic interdiffusion between Pt and Fe-rich phase. Controlling the *growth temperature* provides an atomic level uniform structure of FePt nanoparticle changeable to L1₀ throughout a post thermal annealing process.

We confirmed that the *growth temperature* influences the as-synthesized particle shape and its crystal structure, and magnetic properties after the annealing, whereas no such temperature dependence was observed for their composition and size. The FePt nanoparticles synthesized at a *growth temperature* lower than 215 C° and higher than 255 C° have a spherical shape with an estimated average size of 5.6 ± 0.5 nm, while those obtained at the *growth temperature* between 215 C° and 255 C° have a cubical shape with an estimated average size of 5.5 ± 0.5 nm. The composition ratio of chemically synthesized FePt nanoparticles keep almost constant of Fe: Pt = 53: 47 in every *growth temperature*. The cubical particle

synthesized at the *growth temperature* of 255 C° exhibits the maximum in the magnetization after the annealing.

In addition to this synthesis, we introduced our study to develop the techniques of two- or three- dimensional alignment of synthesized particles with its magnetic anisotropy orientated vertical to a substrate.

Biomedical Application of Magnetic Nanoparticles

For the first step of the biomedical application of magnetic nanoparticles, we examined incorporation of Fe₃O₄ nanoparticles into immune cell for the purpose of establishment of magnetically mediated immunotherapy. Immunotherapy has been vigorously investigated in the field of oncology because of specific anti-tumor activity and less side-effect compared to other therapies. Cancer treatment by immunotherapy takes advantage of having efficient effector cells like cytotoxic T lymphocyte (CTL) and natural killer (NK) cells which exhibit specific killing activity against cancer cells. However, local accumulation inside the tumor of these effector cells remains one of critical issues to be overcome from a point of the clinical view. Therefore, DDS utilizing magnetic carriers is a good candidate to achieve the efficient localization of drugs in the tumor. Actually, successful local delivery of drugs is reported using magnetic nanoparticles such as magnetite (Fe₃O₄) or maghemite (γ-Fe₂O₃) as a nanocarrier. Thus, the application of magnetic DDS to immunotherapy could make the development of magnetically mediated immunotherapy possible in the clinical field.

This section describes synthesis and medical application of iron-oxide nanoparticles. First, facile synthesis of magnetite nanoparticles with various sizes and magnetic properties was realized by proposition of controlled hydrolysis. As a result, the control of nanoparticle size in the range from 10 to 40 nm in mean diameter, which is significantly advantageous in bioapplication, was accomplished as well as the control of magnetic properties. Furthermore, preparation of human lymphocytes containing iron-oxide nanoparticles was carried out for the first step of the development of magnetically mediated immunotherapy for cancer. Human lymphocytes incorporated magnetite nanoparticles by endocytosis, which promises the achievement of a novel magnetically mediated immunotherapy using the T cells containing magnetic nanoparticles with specific killing activity against tumor cells.

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