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Microstructural investigation of ternary alloyed magnetic nanoparticles

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Abstract

Analytical transmission electron microscopy is a proper method so as to uncover microstructure and composition of novel magnetic nanocrystals potentially used as biological markers. The focus of this study is the preparation and characterization of the $(Fe_{1-x}Co_x)_{1-y}Pt_y$ alloyed nanoparticles utilizing high-resolution transmission electron microscopy and dispersive X-ray analyses.

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1. Introduction

Novel ligand stabilized magnetic nanocrystals which could be interesting for the next generation as markers for biological applications have been synthesized by various chemical preparation routes.

The potential of some of these nanocrystals has been evaluated answering the question whether colloidal synthesized superparamagnetic or ferromagnetic Co, FePt, CoFePt and FeCo nanocrystals with superior magnetic moments [1–7] could replace the iron oxide particles as magnetic carriers

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in in vitro separation and therapeutic in vivo technology. Therefore, the magnetophoretic mobility μ_m in the same liquid medium has been compared and the magnetic analysis has revealed that $Fe_{50}Co_{50}$ nanoparticles are superior from the magnetophoretic mobility point of view [1,2]. Finally, one goal of magnetic drug targeting should be that a maximum concentration of drug should be easily administered and transported to the site of choice with the least amount of magnetic particles [8]. One step to reach this request could be the use of $Fe_{50}Co_{50}$ nanoparticles, because calculations [1,2] have shown that there is only a $\frac{1}{25}$ or $\frac{1}{21}$ of the number of nanoparticles typed $Fe_{50}Co_{50}$ necessary which are deposited on a bead compared to the number of Fe_3O_4 or Fe_2O_3 particles per bead to gain the same efficiency.

The particles have been subsequently studied utilizing high-resolution transmission electron microscopy (HRTEM) aiming for the particles lattice structure. One advantage of this characterization technique is the possibility to simultaneously analyze the phase structure as well as the composition of nanocrystals. Using energy dispersive X-ray spectroscopy (EDX) in nanoprobe mode and electron energy-loss spectroscopy (EELS) the composition of individual Co, FePt, CoFePt and FeCo alloyed nanoparticles could be determined.

In addition, the nanoparticles have been investigated by using a field emission scanning electron microscope (FESEM) equipped with a special scanning transmission electron microscope (STEM) unit. STEM is a combination of the transmission and scanning electron microscopy and allows a less-time consuming imaging of electron transparent specimens in SEM microscopes with a better resolution.

The objective of our research is the development of magnetic nanoparticles which are surrounded by different steric organic ligands enabling the link to biotechnological applications. The size-controlled preparation and characterization of $(Fe_{1-x}Co_x)_{1-y}Pt_y$ alloyed nanoparticles comparing HRTEM and the more quantitative dispersive X-ray (XRD) analyses so as to reveal their microstructure are discussed in detail.

2. Materials and chemical preparation

Co [1–3], FePt [6,7], FeCo [1,2] and CoFePt alloyed nanocrystals have been synthesized with different nanocrystalline size distributions and concentration ratios. Hence, FeCoPt nanocrystals have been fabricated in mainly different ways as is given in the reaction scheme in Fig. 1. Firstly, preparation method PM1, following the chemical preparation route recently proposed by Chen et al. [9] the ternary alloyed particles have been produced with cobalt acetylacetonate. Secondly, the cobalt acetylacetonate has been substituted by dicobaltoctacarbonyl, $Co_2(CO)_8$. In detail, the synthesis to prepare FePt nanoparticles found by Sun et al. has been varied inasmuch that $Co_2(CO)_8$ had been injected into the solution in the presence of platinum acetylacetonate, $Pt(acac)_2$, and ironpentacarbonyl, $Fe(CO)_5$. The cobalt carbonyl has been injected at the same temperature (ca. 100 °C) as the $Fe(CO)_5$ to allow a two-step-preparation process, preparation method PM2. To produce bigger particles, preparation method PM3, which are found to be more than double the size of the FeCoPt particles described above the $Co_2(CO)_8$ has been added in an o-dichlorobenzene refluxing bath (181 °C) according to the preparation route by the work of Puntes [3]. At last, preparation method PM4, FeCoPt have been prepared in another different way in which Pt particles have been synthesized separately and in the next step heated to reflux again and during this process

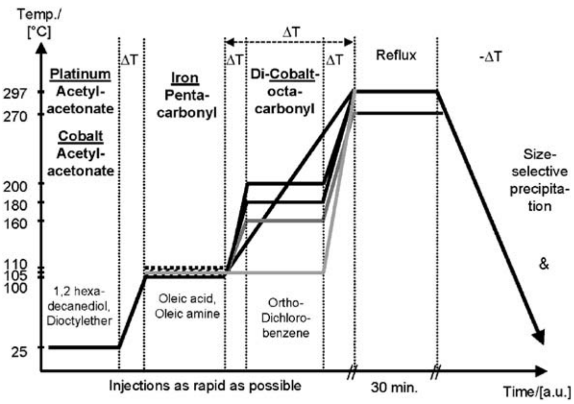

Fig. 1. Scheme of the reaction to produce FeCoPt nanoparticles by high-temperature solution-phase synthesis.