ACADEMIC PRESS

Available online at www.sciencedirect.com
SCIENCE DIRECT®

Journal of Colloid and Interface Science 259 (2003) 411–413

JOURNAL OF Colloid and Interface Science

www.elsevier.com/locate/jcis

Letter to the Editor

Synthesis of one-dimensional magnetic Co nanoparticles in a novel solution system

Cuiying Wang, Jiye Fang,* Jibao He, and Charles J. O'Connor

AMRI, SC2015, University of New Orleans, New Orleans, LA 70148, USA

Received 25 June 2002; accepted 8 November 2002

Abstract

Magnetic Co nanoparticles with different morphologies were synthesized in a novel solution system using a UV irradiation technique. By adjusting the compositions in the solution, long nanowires with different aspect ratios as well as spherical nanoparticles with controllable particle size could be obtained.

Keywords: UV irradiation; Nanowire; Aspect ratio

1. Introduction

The development of uniform magnetic nanoparticles with controlled morphology is very important because of their application to ultra-high-density magnetic storage devices [1]. Several synthetic techniques have been applied to synthesize magnetic metal (Fe and Co) nanoparticles, including thermal [2] and sonachemical decomposition of organometallic precursors [3], high-temperature reduction of metal salts [4], and reduction with reverse micelles [5]. However, most of the studies on nanoparticles are focused on the synthesis of uniform spherical particles and the control of their particle sizes [6–8]. Recently, shape control of nanoparticles is attracting more attention and is a very challenging problem [9]. In particular, anisotropic magnetic nanoparticles are expected to exhibit interesting magnetic properties because of the shape anisotropy. Only a few systems consisting of anisotropic magnetic nanoparticles have been developed so far [10]. The UV irradiation reduction technique has been used to prepare many metal nanoparticles. However, most of them are noble metals [11]. The objective of the present work is to control the morphology of Co nanoparticles by varying the solution composition using a clean and simple UV irradiation reduction technique.

2. Experimental

In a typical experimental procedure, cobalt (II) acetate tetrahydrate (Aldrich) was added to a closed quartz sample tube containing deionized water, isopropanol (99.5%, Aldrich) with different volume ratio, and sodium 1-dodecyl sulfate (SDS) (99%, Aldrich) as surfactant. The reaction system was irradiated by UV light with a wavelength of 253.7 nm for 24 h to reduce $Co(Ac)_2$ into metal Co nanoparticles. The products were washed with ethyl alcohol several times and dried in vacuum for 5 h.

3. Results and discussion

The formation of metal Co by UV light irradiation can be identified by related X-ray diffraction (XRD) patterns. Figure 1 shows the XRD patterns of the products corresponding to different volume ratios of water to isopropanol in solution. The resulting powders were deposited on a Si wafer for XRD measurements. Curve a shows a typical XRD pattern for nanoparticles produced with a 0.05 mol/l $Co(Ac)_2$ solution containing 0.2 mol/l SDS in a 20-ml mixed solvent of water and isopropanol with a volume ratio 1:1. All of the peaks in curve a can be indexed as metal Co with hexagonal phase according to the standard JCPDF card (No. 5-727). Curve b corresponds to the products obtained from the solution corresponding to the volume ratio 9:1 of water to isopropanol

* Corresponding author.
E-mail address: cuiyingwang@hotmail.com (C. Wang).

0021-9797/03/$ – see front matter
doi:10.1016/S0021-9797(02)00182-0

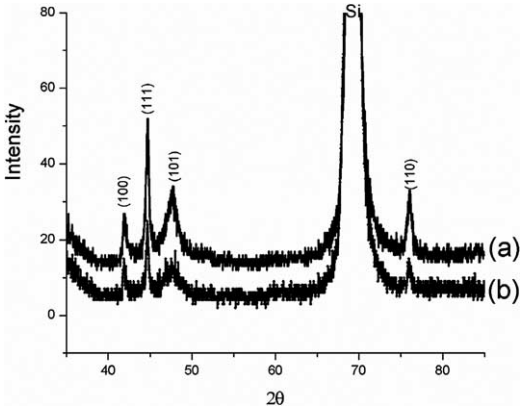

Fig. 1. The XRD patterns of the products from (a) 0.05 mol/l $Co(Ac)_2$, 0.2 mol/l SDS, with the volume ratio 1:1 of the solvent of water to isopropanol and (b) 0.05 mol/l $Co(Ac)_2$, 0.2 mol/l SDS, with the volume ratio 9:1 of the solvent of the water to isopropanol.

under the other same conditions as sample a. It was clear that all the noticeable peaks in this pattern are also attributed to the formation of hexagonal cobalt.

Figures 2a–2c illustrate the TEM images of the products obtained from different solutions. Figure 2a shows the morphology of the product corresponding to curve a in Fig. 1. It is seen in Fig. 2a that the morphology of the product is wirelike with a diameter around 100 nm and a length up to several micrometers. By further TEM investigation, it is found that these wires are formed from the connected nanoparticles. It is observed in Fig. 2b, which corresponds to curve b in Fig. 1, that much thinner nanowires are formed when the volume ratio of water to isopropanol is changed to 9:1. If the reaction solution corresponding to the product in Fig. 2a is diluted with water, it is noticed in Fig. 2c that spherical nanoparticles will form rather than homogeneous nanowires.

It is found that the composition of the solution greatly affects the morphology of the products. To study the formation mechanism of the Co nanoparticles with different morphologies, the influence of the solution composition on the morphology was investigated. If the concentration of SDS decreases to 0.02 mol/l while maintaining the other experimental conditions the same as those in Fig. 2a, it is found that the as-prepared nanoparticles are almost spherical with a size around 6–8 nm in diameter, indicating that the concentration of the SDS plays an important role on the morphology of the products. In addition, the effect of the $Co(Ac)_2$ concentration on the morphology of the product has also been studied. It is seen that the dominant morphology of Co particles tends to change from spherical to wirelike by decreasing the concentration of $Co(Ac)_2$. The influence rising from the ratio between the amount of water and isopropanol in the solvent was also studied. The experimental results illustrate that the Co product is in the form of spherical nanoparticles without any growing trend along one direction when the amount of isopropanol was over 5 ml in the solvent of total 10 ml, under the same conditions as those in sample b.

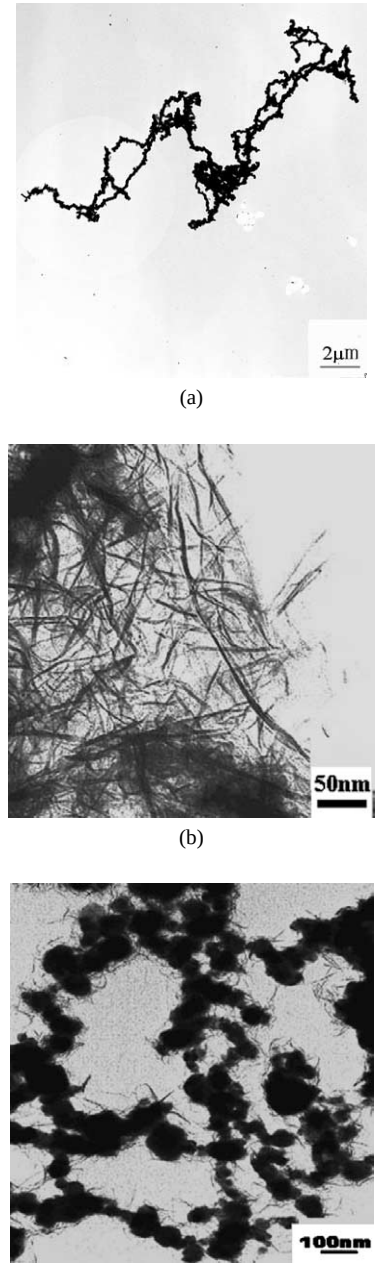

Fig. 2. TEM images of the products from (a) 0.05 mol/l $Co(Ac)_2$, 0.2 mol/l SDS, water:isopropanol = 1:1 (v/v); (b) 0.05 mol/l $Co(Ac)_2$, 0.2 mol/l SDS, water:isopropanol = 9:1 (v/v); and (c) 0.03 mol/l $Co(Ac)_2$, 0.12 mol/l SDS, water:isopropanol = 2:1 (v/v).

It is notable that the composition of the solution greatly affects the morphology of the as-formed particles. It is well known that the surfactants usually acted as a kind of soft template to control the morphology of the as-produced nanoparticles [12]. The morphology of the micelle in the surfactant system is closely dependent on its own concentration and the environmental media [13], especially the solvent,

which itself also plays an important role on the orientation of growth of the initially produced nanoparticles [14].

4. Conclusions

A novel colloidal system containing surfactant SDS was utilized to tune the morphology of as-prepared metal Co nanoparticles produced by UV irradiation. By verifying a number of parameters, such as concentration of surfactant, ratio of water to isopropanol, and concentration of cobalt salt, we were able to produce cobalt colloids with different morphologies with spherical and wirelike structures. The detailed mechanism of the formation of those nanoparticles with different morphologies is related to the particular micelle structure in the surfactant-containing system and is being further studied.

Acknowledgments

This work was supported by the LA Board of Regents, NSF/LEQSF (2001-04)-RII-03. We thank Dr. M. Tarr for the UV lamp and Professor J. Tang for XRD measurements.

References

[1] S. Sun, C.B. Murray, D. Weller, L. Folks, A. Moser, Science 287 (2000) 1989.
[2] T.W. Smith, Wychich, J. Phys. Chem. 84 (1980) 1621.
[3] K.S. Suslich, M. Fang, T. Hyeon, J. Am. Chem. Soc. 118 (1996) 11960.
[4] S. Sun, C.B. Murray, J. Appl. Phys. 85 (1999) 4325.
[5] C. Petit, A. Taleb, M.P. Pileni, J. Phys. Chem. B 103 (1999) 1805.
[6] C.B. Murray, D.J. Norris, M.G. Bawndi, J. Am. Chem. Soc. 115 (1993) 8706.
[7] A.P. Alivisatos, Science 271 (1996) 933.
[8] C.B. Murray, C.R. Kagan, M.G. Bawndi, Science 270 (1995) 1335.
[9] C.P. Gibson, K.J. Putzer, Science 267 (1995) 1338;
M.P. Pileni, B.W. Ninham, T. Gulik-Krzywichi, Adv. Mater. 11 (1999) 1358;
M. Li, H. Schnablegger, S. Mann, Nature 402 (1999) 393;
X. Peng, M. Li, W. Yang, J. Wickham, Nature 404 (2000) 59.
[10] K. Bridger, J. Watts, M. Tadros, G. Xiao, J. Appl. Phys. 61 (1987) 3323;
S.J. Park, S. Kim, S. Lee, J. Am. Chem. Soc. 122 (2000) 8581.
[11] K. Mallik, M. Mandal, N. Pradhan, T. Pak, Nanoletters 6 (2001) 319.
[12] N.R. Jana, L. Gearheart, C.J. Murphy, Chem. Commun. 617 (2001).
[13] B.A. Simmons, C.E. Taylor, F.A. Landis, J. Am. Chem. Soc. 123 (2001) 2414.
[14] C.Y. Wang, M.H. Chen, G.M. Zhu, Z.G. Lin, J. Colloid Interface Sci. 243 (2001) 362.