

Synthesis and magnetic properties of $Y_{3-x}Dy_xFe_5O_{12}$ nanoparticles

Zhongjun Cheng^a, Hua Yang^{a,*}, Yuming Cui^a, Lianxiang Yu^a,
Xueping Zhao^b, Shouhua Feng^c

^aCollege of Chemistry, Jilin University, Changchun 130023, PR China

^bCollege of Physics, Jilin University, Changchun 130023, PR China

^cState Key Laboratory of Inorganic Synthesis and Preparative Chemistry, Jilin University, Changchun 130023, PR China

Received 18 October 2005; received in revised form 2 February 2006

Available online 6 March 2006

Abstract

Dy^{3+} -substituted garnet nanoparticles $Y_{3-x}Dy_xFe_5O_{12}$ ($x = 0, 0.2, 0.4, 0.6, 0.8$ and 1.0) were fabricated by a sol–gel method and their crystalline structures and magnetic properties were investigated by using X-ray diffraction (XRD), infrared spectroscopy and vibrating sample magnetometer (VSM). The XRD patterns of $Y_{3-x}Dy_xFe_5O_{12}$ have only peaks of the garnet structure and the sizes of particles range from 37 to 63 nm. Results of VSM show that the saturation magnetization of $Y_{3-x}Dy_xFe_5O_{12}$ ($0 < x \leq 1$) particles is not only obviously less than pure Yttrium iron garnet, but also decreases with increasing the Dy concentration (x) in a linear manner. Meanwhile, it is observed that with the enhancement of the surface spin effects, the saturation magnetization rises as the particle size is increased. © 2006 Elsevier B.V. All rights reserved.

PACS: 75.50; 81.05; 81.16; 72.15.L; 07.85.F; 68.37.R; 65.80

Keywords: Magnetization; YIG; Rare earth Dy ions

1. Introduction

Yttrium iron garnet (YIG) is a ferromagnetic material which is extensively used in optical communication and magneto-optical devices [1,2]. Ferromagnetic garnets are assigned to cubic structure (space group Ia3d), every cell contains eight $R_3^3+Fe_5^3+O_{12}$ molecules, and the ion distribution structure can be represented by writing the garnet formula as $\{R_3\}[Fe_2](Fe_3)O_{12}$; $\{\}$, $[\]$ and $()$ are represented for 24c (dodecahedral), 16a (octahedral) and 24d (tetrahedral), respectively. YIG is the most representative and well-known compound among the rare earth iron garnets [3], and the various magnetizations can be achieved by substitution in the YIG [4]. Thongmee and Winotai [5] studied the magnetic properties of dilution of the Fe^{3+} by Al^{3+} in the substituted $Y_3Fe_{5-x}Al_xO_{12}$. They discovered that the saturation magnetization and coercivity both decreased in samples containing Al^{3+} . Furthermore,

because of the unique magneto-optical property of YIG, researchers have done a lot of work and succeeded in substituting Bi^{3+} and Ce^{3+} for Y^{3+} , and Co^{3+} and Co^{2+} for Fe^{3+} in YIG so as to obtain materials with different magneto-optical properties.

When YIG is prepared by ceramic methods, $YFeO_3$ and Fe_2O_3 are produced as intermediates and these phases remain as impurities unless heated to high temperatures [6,7], so the sol–gel method has attracted attention due to the lower synthesis temperature and finer and more homogeneous particles produced. A systematic study of the sol–gel technique for the synthesis of $Y_3Fe_5O_{12}$ is presented by Vaqueiro [3,8], and the results show that the citric is a suitable chelating agent to obtain the fine particles, which exhibit a rounded surface morphology and are without faceted borders. Meanwhile, YIG could be formed by a single-step process, where an amorphous precursor powder is formed first and then transformed to YIG during calcination, without any intermediate phase formation. The experimental results [9,10], obtained using the sol–gel method, indicate that the saturation

*Corresponding author. Tel.: +86 431 8499151; fax: +86 431 5095011.

E-mail address: huayang86@sina.com (H. Yang).

magnetizations of Ce:YIG and La:YIG materials are different from pure YIG. Furthermore, Leleckaite and Kareiva use the sol–gel method to prepare rare earth-doped yttrium aluminum garnets YAG:Ln (Ln = Ce, Nd, Ho and Er), which are important solid-state laser materials widely used in luminescence systems, window materials for a variety of lamps and fiberoptic telecommunication systems [11].

In this article, we substituted the magnetic rare earth ion Dy^{3+} for some non-magnetic ions Y^{3+} in YIG, and prepared $\text{Y}_{3-x}\text{Dy}_x\text{Fe}_5\text{O}_{12}$ ($x = 0, 0.2, 0.4, 0.6, 0.8$ and 1.0) nanoparticles using a sol–gel method. At the same time, the crystalline size and magnetic properties were observed and studied in detail.

2. Experiment

A stoichiometric mixture of $\text{Fe}(\text{NO}_3)_3$, $\text{Dy}(\text{NO}_3)_3$, $\text{Y}(\text{NO}_3)_3$ (Dy_2O_3 and Y_2O_3 were dissolved in HNO_3) was dissolved in an aqueous solution of citric acid, and then $\text{NH}_3 \cdot \text{H}_2\text{O}$ was added to adjust $\text{pH} = 2$. The resulting solution was heated at 353 K in order to obtain the gel; to obtain the $\text{Y}_{3-x}\text{Dy}_x\text{Fe}_5\text{O}_{12}$ samples, the gels were dried initially at 383 K for 36 h and further heat treated in air between 1023 and 1373 K for 3 h.

The structure and the crystallite sizes were tested by X-ray diffractometer (SHIMADZU Co., Tokyo, Japan) in the 2θ range $25\text{--}60^\circ$ using $\text{CuK}\alpha$ radiation ($\lambda = 0.15405\text{ nm}$), and the crystallite sizes of the samples are estimated from the line width of the (422) XRD peaks. The infrared (IR) spectra were recorded as KBr pellets on Perkin–Elmer Spectrum One FT/IR spectrometers.

Magnetic measurements were carried out at room temperature using a vibrating sample magnetometer (VSM; Digital Measurement System JDM-13) with a maximum magnetic field of 10 000 Oe.

3. Results and discussion

3.1. Structure characterization

3.1.1. X-ray diffraction

Fig. 1 shows XRD of samples with Dy concentration (x) from $x = 0$ to 1 treated at 1073 K for 3 h. Through Fig. 2, the evolution of the crystalline phase of $\text{Y}_2\text{DyFe}_5\text{O}_{12}$ was investigated as a function of heating temperature, and the treating temperatures are from 1023 to 1373 K. From these XRD patterns, one can observe that all samples have only a single phase of garnet structure and crystallization occurs around 1023 K, which is lower than the 1573 K used in the ceramic method [6]. This lower crystallization temperature could be related to the good homogeneity of the gel prepared at $\text{pH} = 2$. At the same time, one can observe that the crystallization of samples is more complete as the annealing temperature is increased.

According to the Scherrer's relationship, we calculated the crystalline sizes for samples with the same Dy concen-

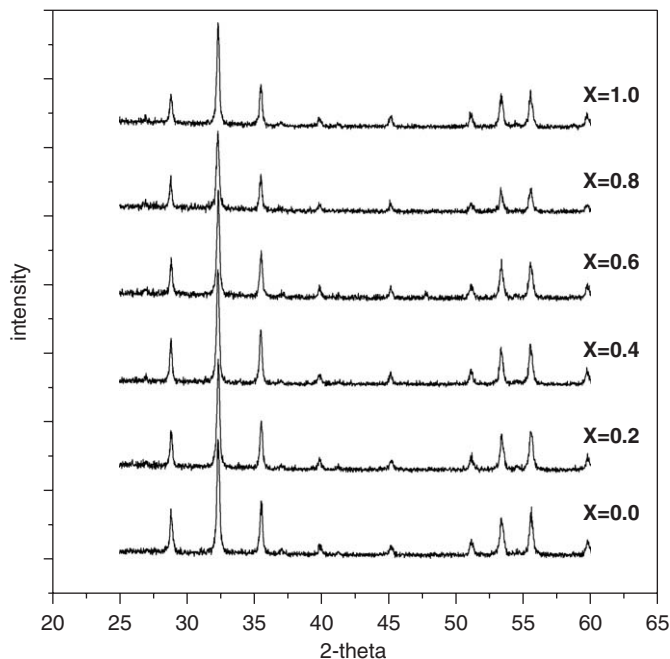


Fig. 1. XRD of samples with Dy concentration (x) from $x = 0$ to 1, treated at 1073 K for 3 h.

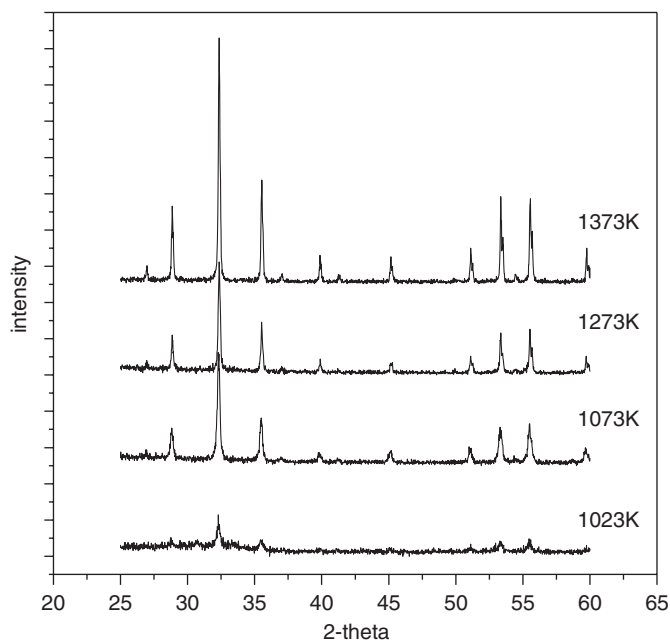


Fig. 2. XRD patterns of $\text{Y}_2\text{DyFe}_5\text{O}_{12}$, samples heated from 1023 to 1373 K.

tration (x) but treated at different temperature. The obtained sizes increase as the heating temperature is increased from 1073 to 1373 K (Fig. 3). Furthermore, we can also observe that for similar annealing, the crystallite sizes of $\text{Y}_{3-x}\text{Dy}_x\text{Fe}_5\text{O}_{12}$ ($0 \leq x \leq 1$) are similar to each other and the variation has no apparent regularity (Fig. 4). The phenomenon is probably due to the similar ionic

Download English Version:

<https://daneshyari.com/en/article/1802419>

Download Persian Version:

<https://daneshyari.com/article/1802419>

[Daneshyari.com](https://daneshyari.com)