

Effect of fabrication method on the structural and magnetic properties of copper ferrite

Siriwipa Pongpadung¹, Teerasak Kamwanna¹, and Vittaya Amornkitbamrung¹

¹ Khon Kaen University

Department of Physics, Faculty of Science

Materials Science and Nanotechnology Program

Nanotec-KKU Center of Excellence on Advanced Nanomaterials for Energy Production and Storage

Integrated Nanotechnology Research Center (INRC)

Khon Kaen 40002, Thailand

Phone: +66-8-4610-9597 E-mail: teekam@kku.ac.th

Abstract

Copper ferrites (CuFe_2O_4) were fabricated by self-combustion urea and glycine process (UNP, and GNP), polymerized complex (PC), solid-state reaction (SSR), and molten-salt (MS) methods. The synthesized powders were calcined in static air at different temperature from 700 – 900°C. The effects of the fabrication method on the microstructural and magnetic properties were investigated. X-ray diffraction (XRD) analysis results reveal the cubic CuFe_2O_4 spinel structure for original powder of UNP, GNP and MS samples and tetragonal CuFe_2O_4 spinel structure for UNP, GNP, PC, and SSR samples after calcination. By using vibrating sample magnetometer (VSM) technique, a significant change in the magnetic properties was absorbed in CuFe_2O_4 system with fabrication method and heat treatment.

1. Introduction

Copper ferrite (CuFe_2O_4) spinels have attracted interest because of their applications in advanced technologies due to its high thermal stability. Polycrystalline CuFe_2O_4 is ferromagnetic with a Curie temperature around 500 °C. At room temperature it crystallizes in the tetragonal spinel structure ($t\text{-CuFe}_2\text{O}_4$) and transform to a cubic one ($c\text{-CuFe}_2\text{O}_4$) at about 400 °C [1]. It is well known that magnetic properties of the ferrite are related to the anisotropy of the shape and crystallite size of particles. In this work, we present a detailed study of the phase evolution of CuFe_2O_4 with different fabrication methods by x-ray diffraction. The magnetic properties of synthesized samples are presented and discussed on the basis of the microstructures of the samples.

2. Experiments

Experimental details

In this work the polycrystalline CuFe_2O_4 powders were synthesized by 4 methods: (1) self-combustion urea and glycine nitrate process (UNP, and GNP), (2) polymerized complex (PC), (3) solid-state reaction (SSR), and (4) molten-salt (MS). In order to obtain the different crystallite size, heat treatments of the samples are required. The phase and

crystal structure of the synthesized CuFe_2O_4 were characterized by x-ray diffraction (XRD). The magnetizations vs magnetic field (M-H) curves were conducted using in Quantum Design VersaLab3 Tesla Cryogen-free equipped with a vibrating sample magnetometer (VSM) at room temperature. The magnetization dependence on temperature was measured in the zero-field cooling (ZFC) and field cooling (FC) from 50 to 380 K at 0.1 T.

Structural characterizations

Fig. 1 shows the XRD patterns of CuFe_2O_4 powders. The standard JCPDS card (No. 77-0010) of $c\text{-CuFe}_2\text{O}_4$ and JCPDS card (No. 34-0425) of $t\text{-CuFe}_2\text{O}_4$ are also shown for comparison. MS sample results in $c\text{-CuFe}_2\text{O}_4$. All SSR and PC samples result in $t\text{-CuFe}_2\text{O}_4$. Original powder of UNP and GNP samples result in $c\text{-CuFe}_2\text{O}_4$. Phase pure $t\text{-CuFe}_2\text{O}_4$ was obtained after calcinations of 700 – 900 °C. In Table I, calcination temperature, crystalline structure, and crystallite size (D) for the CuFe_2O_4 samples are listed. It is evident that the crystallite size increases with calcinations temperature.

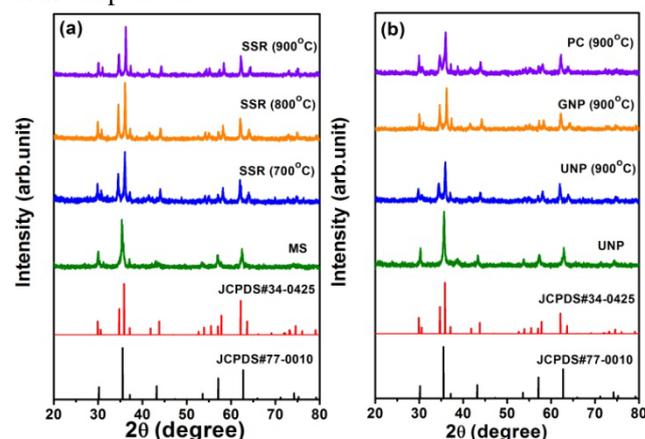


Fig. 1 XRD patterns of the CuFe_2O_4 powders prepared by (a) SSR and MS, and (b) UNP, GNP, and PC methods.

Magnetic properties

The magnetic properties of CuFe_2O_4 samples were determined using a VSM at 300 K with an applied magnetic field H ($-30 \leq H \leq 30$ kOe), as shown in Fig. 2. Table I also lists the saturation magnetization (M_s), and coercivity (H_c).

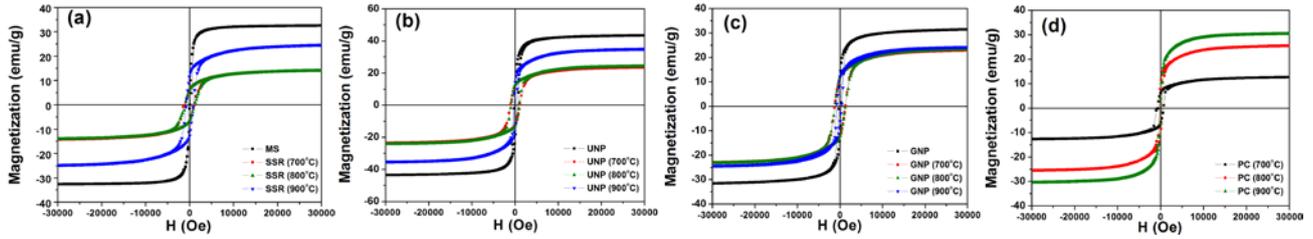


Fig. 4 M-H curves of CuFe_2O_4 samples prepared by different methods: (a) SSR and MS, (b) UNP, (c) GNP, and (d) PC.

It is clearly seen that the saturation magnetization depends strongly on the calcinations temperature and fabrication methods. As shown in Fig. 2, rising calcinations temperatures and thus larger crystallite sizes cause slightly increasing saturation magnetization, and decreasing coercivity. As can be seen, the maximum saturation magnetizations were observed for the c - CuFe_2O_4 samples, giving rise to 42.9 emu/g in GNP sample.

Table I. Crystalline structure, crystallite size (D), saturation magnetization (M_s), and coercivity (H_C) for the CuFe_2O_4 samples prepared by various methods.

Methods	Calcination temp. (°C)	Crystalline structure	D (nm)	M_s (emu/g)	H_C (Oe)
SSR	700	t - CuFe_2O_4	35.9	14.1	1,082
	800		42.5	14.0	1,043
	900		48.7	24.6	811
MS	900	c - CuFe_2O_4	17.0	32.6	40
UNP	Non	c - CuFe_2O_4	25.1	42.9	399
	700	t - CuFe_2O_4	34.6	23.6	1,056
	800		25.5	24.2	963
	900		33.1	35.1	307
GNP	Non	c - CuFe_2O_4	14.8	31.6	261
	700	t - CuFe_2O_4	38.0	22.9	1,258
	800		38.8	23.8	1,242
	900		40.7	24.4	379
PC	700	t - CuFe_2O_4	41.5	12.6	658
	800		42.6	25.5	285
	900		44.8	30.6	167

To investigate the magnetic transition of CuFe_2O_4 , the temperature dependence of ZFC and FC susceptibility (χ) curves has been studied between 50 and 380 K at a magnetic field of 0.1 T. Since the sample with c - CuFe_2O_4 spinels structure showed a higher saturation magnetization in this series, we studied its magnetic properties in detail. Fig. 3 shows ZFC/FC susceptibility curve for original powders of UNP, GNP, and MS samples. As temperature increases in ZFC measurement for GNP sample, initially, the χ_{ZFC} increases and reaches a maximum value at certain temperature, which is called blocking temperature T_B . Above T_B , the χ_{ZFC} decreases with increasing temperature. This behavior can be attributed to superparamagnetic characteristics of GNP at room temperature [2]. As can be seen in Fig. 3(a) and (b), no T_B is obtained for MS and UNP samples. This can be attributed that the T_B was shift to lower temperatures due to large applied field [2]. In the FC curves, χ_{FC} decreases monotonously with the increasing temperature [3].

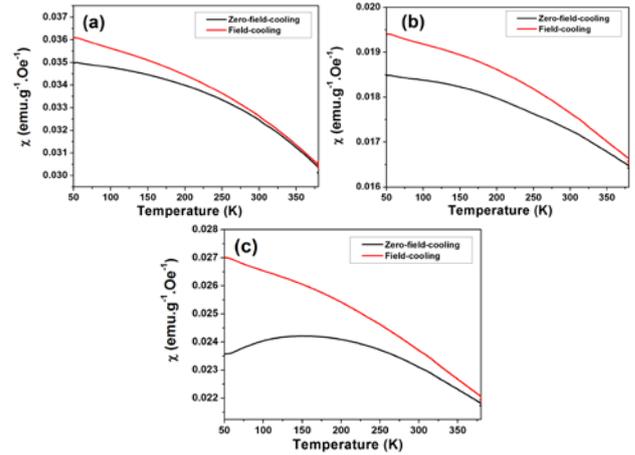


Fig. 3 Temperature dependence of zero field cooling (ZFC) and field cooling (FC) susceptibility for (a) MS, (b) UNP, and (c) GNP samples measured at 0.1 T.

3. Conclusions

Nano-crystalline CuFe_2O_4 powder were synthesized by SSR, MS, UNP, GNP, and PC methods. Phase-pure cubic CuFe_2O_4 spinel structure was obtained for MS, UNP, and GNP methods. After heat treatment of UNP and GNP powders, the tetragonal CuFe_2O_4 spinel structure was obtained. The crystallite size increases with calcinations temperature. The magnetic measurements at room temperature show different magnetic properties depending on fabrication method, their particle sizes, and heat treatment. The susceptibility evaluation for GNP indicated the presence of superparamagnetic phase at room temperature.

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