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Effects of Calcinations Temperature on the Synthesis, Chemical Structure, and Magnetic Properties of Nano Crystallites Zinc Ferrite Prepared by Combination of Sol-Gel Auto-Combustion and Ultrasonic Irradiation Techniques

Golrokh Mahmoudzadeh* and Saeed Abedini Khorrami

Chemistry Department, North Tehran Branch, Azad University, Tehran, Iran.

*E-mail; gmahmoudzadeh@yahoo.com

ABSTRACT

Nanocomposite zinc ferrites were synthesized using glycine-nitrates by sol–gel auto-combustion technique. The influence of calcination temperatures varying from 400 to 900°C on structural and magnetic properties of spinel $ZnFe_2O_4$ powders have been investigated. The characterization measurements including X-ray diffraction (XRD), scanning electron microscopy (SEM) and vibrating sample magnetometer (VSM) were performed for as-synthesized zinc ferrite particles. In brief, the effect of calcination temperature on magnetic behavior, demonstrated that, the magnitude saturation magnetization (M_s) and remnant magnetization (M_r) were decreased with the increasing temperature for synthesized samples. In turn, the coercivity (H_c) and the shape of the hysteresis curve are affected significantly by calcination temperature. The coercivity (H_c) is closely related to the microstructure, particle/grain size, shape of the pores of the crystals, and many other complex factors. The calcined sample at 400°C has the best magnetic properties with the highest M_s of 16. 24 emug^{-1}, and with H_c of 102.79Oe (at 10 kOe).

Keywords: Nanocomposite; $ZnFe_2O_4$; Calcination Temperature; Characterization; Magnetic Properties.

1. Introduction

Ferrite magnetic materials are among the most important materials used today in modern technology. They are used as an important part in many applications as in wave applications, radio electronics and sensors [1]. Many researchers studied the spinel oxides MFe_2O_4 ferrites (where M is a divalent atom like Zn, Mg, Mn, Co, Ni etc.) [2]. Zinc Ferrite is of interest not only to basic research in magnetism, but also has great potential in technological application. $ZnFe_2O_4$ is a promising semiconductor photocatalyst for various processes, due to its ability to absorb visible light and its high efficiency shows potentially wide applications in photo inducedtransformer, photoelectrochemical cells and photochemical hydrogen production [3-5].

It is worth mentioning that, the stable phase of zinc ferrite ($ZnFe_2O_4$) possesses the normal spinel structure. The tetrahedral site is occupied by Zn^{2+} because there is a very strong tendency for to prefer tetrahedral coordination in oxides with the spinel-type structure and Fe^{3+} ions in the octahedral sites. However, in contrast to bulk compound, the nanocrystalline $ZnFe_2O_4$ system always shows up as a mixed spinel in which Zn^{2+} and Fe^{3+} ions are distributed over the A and B-sites (tetrahedral and octahedral, respectively), therefore the formula is represented by

$$\mathbf{(Zn^{2+}_{1-x}Fe^{3+}_{x})[Zn^{2+}_{x}Fe^{3+}_{2-x}]\ O_4}$$

redistribution of iron ions at A and B sites (Fe^{3+}_{A}- Fe^{3+}_{B}), superexchange interaction is normally different from the (Zn^{2+}_{A}- Fe^{3+}_{B}) interaction, variation of the cation distribution over A and B sites in the spinel leads to different magnetic properties of these oxides even though the chemical composition of the compound remains the same [6]. There are two main factors which make nanomaterials to behave significantly different than that of bulk materials: (I) surface effects (causing smooth properties scaling due to the fraction of atoms at the surface) and (II) quantum effects (showing discontinuous behaviour due to quantum confinement effects in materials with delocalized electrons) [7]. The properties of these materials mainly depend on their shape, size and structure, which are strongly determined by the synthetic processes [8]. These factors affect the chemical reactivity of materials and physical properties such as; mechanical, optical, electrical and magnetic properties. Different methods have been adopted for the fabrication of ferrite nanoparticles such as dry- and wet-milling, sol-gel, co-precipitation, microemulsions.