Sol-gel auto Combustion Synthesis and Structural Analysis of Cobalt Ferrite Nanoparticles

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ABSTRACT

In the present paper, we report synthesis of cobalt ferrite nanoparticles using well known sol-gel auto combustion technique and investigations of structural properties. Glycine which is considered as a green fuel was used for the synthesis of cobalt ferrite nanoparticles. The metal nitrate to fuel ratio was selected as 1:3 in accordance with the propellant chemistry approach. The phase purity and crystal structure was determined through X-Ray diffraction technique. The analysis of XRD pattern proves the formation of single phase cubic spinel structured cobalt ferrite. The particle size was determined by Scherrer's formula which is found to be 31 nm, confirming the nanocrystalline nature of the prepared cobalt ferrite.

Keywords: Cobalt ferrite, Sol-gel synthesis, XRD.

INTRODUCTION

In the recent years, research into nanoscience and nanotechnologies has grown tremendously in a large panel of scientific and technological fields. The importance of nanotechnology and nanoscience has been increased due to their drastic effects in improving the properties of the materials and newer applications. It is the establish fact that, the materials when brought to nano dimension from micro dimensions exhibit important, unusual and superior properties. Due to advancement of the measuring techniques

viz. atomic force microscopy, scanning electron microscopy etc. it has become possible and convenient to understand the structure and properties of nanomaterials [1]. Magnetic nanoparticles of ferrite have become prime importance in the field of medical science, environment, magnetic recording media, sensors, catalyst due to their very good magnetic properties [2-3]. The magnetic nanoparticles exhibit super paramagnetic behaviour and quantum effects which are useful in many applications. Spinel ferrites on account of their excellent magnetic and electrical properties are very much useful in various technological devices such as switching circuits, high density magnetic storage, microwave based instruments, magnetic fluids, gas sensors, catalyst, water purification etc [4-5]. Generally, a spinel ferrite is described as (MFe_2O_4) where M is a divalent metal ion such as Co, Ni, Zn, Mg, Cu Mn etc. Spinel ferrite possesses two interstitial sites namely tetrahedral A and octahedral B site. The cations of different valence and nature can accommodate in these sites bringing wide variations in the structural and magnetic properties. On the basis of distribution of cations at tetrahedral A and octahedral B sites, the spinel ferrites are classified as normal ferrite, inverse ferrite and random ferrites [6].

Among the spinel ferrites, cobalt ferrite is a hard magnetic material with large coercivity and moderate saturation magnetization. It possesses inverse spinel structure. It is important to note that the sol-gel auto-combustion method have definite advantages over other wet chemical methods [7-8]. The method is simple, cost effective and produces homogeneous fine particles of nanometer dimensions. Thus, the aim of the present work is to synthesize cobalt ferrite nanoparticles using sol-gel auto combustion method taking glycine as a fuel and to investigate the structural properties.

METHODOLOGY

Nano structured cobalt ferrite were prepared by the sol-gel auto-combustion method using glycine as a fuel and complexing agent. The analytical reagents of $Fe(NO_3)_3 \cdot 9H_2O$ and $Co(NO_3)_2 \cdot 6H_2O$ were used as a raw materials for synthesis. Depending upon the composition, the appropriate amount of metal nitrates and citric acid were dissolved in deionized water to obtain a mixed solution. During the mixing process, the solution was continuously stirred for 30 min at 100 °C using a magnetic agitator. The mixed solution was kept stirred at 100 °C for 3 h to transform into gel. The dried gel was burnt in an auto combustion manner to form a loose powder. The prepared powder was sintered at the temperature 1000 °C for 6 h. The powder X-ray diffraction pattern of as-prepared samples was carried out using Bruker D8 Advance X-ray diffractometer with Cu-Kα radiation (λ = 0.15406 nm) to identify the phase and structure of prepared sample.

RESULTS AND DISCUSSIONS

X-ray diffraction (XRD) pattern of cobalt ferrite is shown in fig 1. The XRD pattern reveal the (220), (311), (222), (400), (422), (511) and (440) reflections belonging to cubic spinel structure. The analysis of XRD pattern proves that the sample possess single phase cubic spinel structure. Using XRD data the lattice constant, unit cell volume and X-ray density were obtained using standard relations.
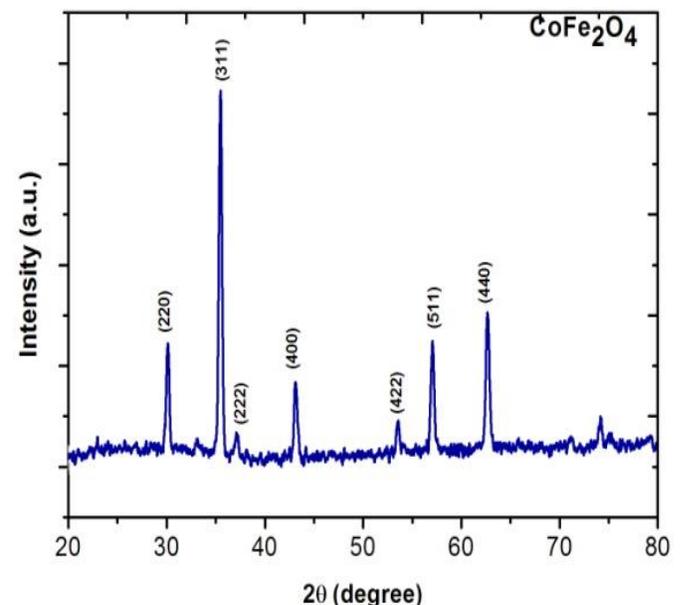

Fig. 1 X-ray diffraction pattern of cobalt ferrite nanoparticles

Table 1 Lattice parameter (a), unit cell volume (V), X-ray density (d_x) and Particle size (D) of cobalt ferrite nanoparticles

Composition	a (Å)	V (Å^3)	d_x (gm/cm^3)	D (nm)
CoFe$_2$O$_4$	8.383	589	5.29	31

In order to confirm the nanocrystalline nature of the prepared sample, the crystallite size was calculated using Scherrer's formula. The most intense peak (311) was considered to obtain crystallite size. The crystallite size found to be 31 nm which clearly indicates the nanocrystalline nature of the samples. The other structural parameters such as unit cell volume and X-ray density were calculated from the known values of lattice constant and are presented in table 1.

CONCLUSION

Single phase cubic spinel structured cobalt ferrite can be synthesized at low cost and at low temperature with improved structural properties. Glycine can be used as a green fuel for synthesis of nanocrystalline cobalt ferrite. The value of crystallite size indicates the nanocrystalline nature of the samples.

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