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Strontium ferrite nanoparticle study: Thermal decomposition synthesis, characterization, and optical and magnetic properties

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ABSTRACT

Monoferrite strontium ferrite nanoparticles were successfully synthesized in the presence of strontium oxalate, [(SrC_2O_4)], as strontium precursor by using solid-state thermal decomposition method. X-ray diffraction study was used to determine phase purity, crystal structure, and average crystallite size of the strontium ferrite nanoparticles. The electrical conductivity measurement of the sintered sample was carried out at 300 °C. Metal nitrates and oxalate precursor without any solvent or surfactant were used in this method; later, they were decomposed at 850 °C for 2 h in a gas mixture of 85% Ar and 15% H_2. The average diameter of the strontium ferrite nanoparticles was 40 nm. The as-prepared strontium ferrite nanoparticles were characterized extensively by techniques like XRD, transmission electron microscope (TEM), high-resolution TEM (HRTEM), scanning electron microscopy (SEM), Fourier transform infrared (FT-IR), vibrating sample magnetometer (VSM), room temperature photoluminescence (Pl), ultraviolet–visible spectroscopy (UV–vis), and energy dispersive spectrometry (EDS).

1. Introduction

Contemporary studies of magnetic nanoparticles are significantly motivated by their current and potential applications in biology and medicine like cells and biomolecules magnetic separation, drug delivery, contrast agents for magnetic resonance imaging and colloidal mediators for cancer magnetic hyperthermia [1]. $SrFe_{12}O_{19}$(s), $SrFe_2O_4$(s), $Sr_2Fe_2O_5$(s) and $Sr_3Fe_2O_6$(s) are few stoichiometric ternary oxides exist in $SrO–Fe_2O_3$ binary system and stable in air [2,3]. Spinel ferrites are of great fundamental and technological important due to their structural, electronic, magnetic and catalytic properties [4–6]. Among the pigment classes, one of the most important is the spinel group, AB_2O_4, due to its capacity of accommodating different cations, leading to a variety of colors and tonalities. It has been recognized that they were used as permanent magnets, recording media, telecommunication, components in microwave, higher-frequency, and ceramic and magneto optical devices [7–13]. The physico-chemical properties of the ferrites are strongly dependent on the sites and the nature of the catalyst [14,15], which are closely related to the method of preparation. There are two kinds of lattices for cation occupancy. A and B sites has tetrahedral and octahedral coordination, respectively. In the normal spinel structure divalent atom, occupying tetrahedral A sites, while trivalent atom, are sitting on the octahedral B sites. When 'A'

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sites being trivalent ions, while 'B' sites equally populated by divalent and trivalent ions, the spinel structure is referred to as the inverse kind [16,17]. Several methods have been used to prepare strontium ferrites such as citrate–nitrate gel combustion [18], citrate gel method [19], chemical precipitation [20], glass crystallization [21], and self propagating high temperature synthesis [22]. However, most of these methods cannot be economically applied on a large scale because they require expensive and often toxic reagents, complicated synthetic steps, and long reaction times. This not only results in waste of energy but also harms our environment. Spinel ferrites are found to be highly active towards many aromatic alkylation reactions such as methylation of phenol, aniline, pyridine, phenol *tert*-butylation, etc. [23–25]. Herein, we report on the facile synthesis of strontium ferrite nanoparticles via solid state thermal decomposition method. This work has provided a general, simple, and effective method to control synthesis of strontium ferrite, which revealed potential new insight into inorganic synthesis methodology. The studies on the optical properties of strontium ferrite nanoparticles were carried out by UV–vis absorption and photoluminescence spectrum.

2. Experimental

2.1. Characterization

X-ray diffraction (XRD) patterns were recorded by a Philips-X'PertPro, X-ray diffractometer using Ni-filtered Cu *K*α radiation at scan range of $10 < 2\theta < 80$. Scanning electron microscopy (SEM) images were obtained on LEO-1455VP equipped with an energy dispersive X-ray spectroscopy. Transmission electron microscope (TEM) and high-resolution TEM (HRTEM) images were obtained on a Philips EM208S transmission electron microscope with an accelerating voltage of 200 kV. The energy dispersive spectrometry (EDS) analysis was studied by XL30, Philips microscope. The magnetization measurements were carried out using a vibrating sample magnetometer (Lake Shore 7400) with the maximum field up to 20 kOe. Fourier transform infrared (FT-IR) spectra were recorded on Shimadzu Varian 4300 spectrophotometer in KBr pellets. Room temperature photoluminescence (Pl) properties were studied on a Perkin-Elmer (LS 55) fluorescence spectrophotometer. UV–vis diffuse reflectance spectroscopy analysis (UV–vis) was carried out using Shimadzu UV–vis scanning spectrometer.

2.2. Synthesis of SrC_2O_4 complex

The strontium oxalate [SrC_2O_4] complex was synthesized according to the following procedure: in a typical procedure, 2 mmol of $SrCl_2$ was dissolved in 20 ml of absolute ethanol. In the second step, 2 mmol of $K_2C_2O_4$ dissolved in 20 ml of distilled water was added subsequently to the above solution. This solution was stirred until a homogeneous solution was obtained. The final solution was heated at 70 °C for 1 h under stirring. The prepared white powder was centrifuged and washed several times with distilled water and ethanol. Finally, the product dried at 70 °C for 5 h under vacuum.

2.3. Synthesis of strontium ferrite nanostructures

The strontium ferrite nanostructure was prepared by a solid-state thermal decomposition without any catalyst, surfactant, and solvent at 800 °C for 2 h in a horizontal tube furnace (with inner diameter of 10 cm and length of 120 cm). In the typical procedure, a mixture including 1 mmol of the as-obtained SrC_2O_4 and 2 mmol of Fe $(NO_3)_3 \cdot 9H_2O$, was put into a small quartz boat. The quartz boat was entered into the proper position of the tube furnace in a gas mixture of 85% Ar and 15% H_2. The quartz boat was held in the heating zone at 800 °C for 2 h and; then, it was slowly dragged out of the furnace. The sample was naturally cooled down in ambient conditions.

3. Results and discussion

Fig. 1 shows the XRD pattern ($10 < 2\theta < 80$) of the strontium ferrite nanoparticles. Extremely broad reflection peaks are noticeable in Fig. 1, which indicates the fine nature of particles obtained from strontium ferrite nanoparticles. All reflection peaks of the XRD pattern for

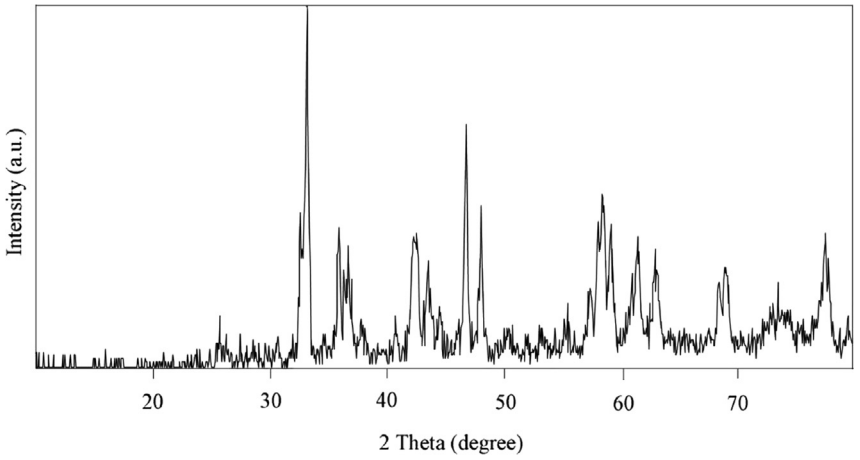

Fig. 1. XRD pattern of strontium ferrite nanostructure.