ScienceDirect

Journal of Alloys and Compounds
Volume 818, 25 March 2020, 152830

Structural, magnetic and thermo-magnetic properties of NiMn Y-Type strontium nano-hexaferrites

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Highlights

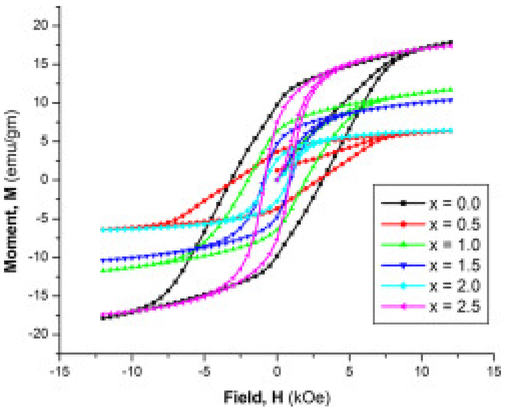
- TiCo substituted Y-type hexaferrite samples were synthesized by sol-gel method.
- Effects of TiCo substitution were investigated by XRD, SEM and TEM.
- Y-type nano-hexaferrites were obtained at low temperature of 950 °C.
- The magnetic and thermo-magnetic properties of these samples were investigated.
- The high H_c single domain materials with smaller grain sizes may be useful as perpendicular recording media (PRM).

Abstract

Six chemical compounds of poly-crystalline NiMn Y-type strontium nano hexaferrites doped with hybrid $Ti^{4+}Co^{2+}$, having chemical formula $Sr_2NiMnFe_{12-X}(TiCo)_{X/2}O_{22}$ ($0 \leq x \leq 2.5$ and $\Delta x = 0.5$) synthesized by sol-gel auto-combustion through microwaves and calcined at 950 °C for 5 h. The refined XRD analysis shows compounds are in single Y-type hexagonal phase. The lattice parameter '*a*' slightly increases and easy magnetized '*c*' axis undergoes more expansion with the content of TiCo. The grain size measured from XRD data is in the range of 41 nm–71 nm. The microstructure was visualized and studied by SEM, TEM, HRTEM and SAED. TEM images show that the compounds are in hexagonal shape with grain size in the range of 42 nm–89 nm.

Saturation magnetization (M_s), Retentivity (M_r) and Coercivity (H_c) were observed through vibrating sample magnetometer (VSM). All the six compounds are found to be ferrimagnetic at the room temperature and remain so up to the transition temperature (T_M). Above this transition temperature the compounds start becoming paramagnetic. The transition temperature (T_M) was determined from the derivative of the thermo-magnetic susceptibility curve. The strong (negative) derivative peak confirmed a single magnetic phase and the narrow peak profile predicts magnetic homogeneity of the compounds.

Graphical abstract



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Introduction

The research advancement for ferrites is increased because of its technological applications started initially to co-fine magnetic flux and guide through ferrite [1]. Ferrites are divided into two types depending on magnetic coercivity. Soft ferrites have low coercivity while hard ferrites have high coercivity and difficult to demagnetize. Polycrystalline hexaferrites exhibit outstanding magnetic and dielectric properties which depend on chemical composition, processing conditions, sintering time and temperature.

On the basis of crystal structure, hexaferrites are classified into six (M, W, X, Y, Z, U) categories. Among them, Y-type ferrites ($Sr_2Me_2Fe_{12}O_{22}$) composed of hexagonal M type and cubic spinel ferrites unit [2]. These are well-suited for widespread applications viz. Ferrite cores, Multilayer ferrite chip inductor, refrigerator magnets, loudspeakers, small electric motors, magnetic latches and magnetic levitation, wave absorber and magnetic recording media.

Research organizations and researchers continuous focus is to develop a revolutionary type of Magneto-electric Memory (data storage) device (MMD) using Nanoscale multiferroic systems (NMS) to achieve improved storage density and performance, enhanced power output, energy efficient, thermal stability and physical size reduction. Perpendicular magnetic recording (PMR-2005) bits align vertically and provide a significant increase in storage density as compared to conventional longitudinal magnetic recording (LMR) technology. The combination of PMR media and shielded magneto resistive head technology enables multi-terabyte drives with densities approaching to one trillion bits/sq. inch. The main disadvantage is to stabilize the magnetization of the material medium due to thermal fluctuations [3]. To use ferrites in a high density recording medium, a high coercivity, high anisotropy, high values of remnant magnetization, nearly squared M-H loop, better thermal stability and single domain particles are the basic requirements [4].

The microwave assisted sol-gel auto-combustion method was used to synthesize the samples because this method has many advantages such as energy efficient, short reaction rate, low calcinations temperature, easy operation, better distribution of particle size, excellent chemical homogeneity and ultra-fine powder of nano-size [5]. As size is reduced to the nanoscale, it can affect the optical, electrical and magnetic behavior of materials. Due to nano size, it is possible to form the structures to achieve specific properties.

In present work, $Sr_2NiMnFe_{12-X}(TiCo)_{X/2}O_{22}$ ($0 \le x \le 2.5$ and $\Delta x = 0.5$) synthesized by sol-gel auto-combustion through microwave and calcined at 950 °C for 5 h. This research focuses on the structural, magnetic and thermo-magnetic properties of NiMn Y-type strontium hexaferrites and the thermo-magnetic effect of TiCo substitution. The magnetic parameters such as saturation magnetization (M_s), coercivity (H_c), retentivity (M_r) and squareness ratio (M_r/M_s) values are obtained and discussed. To understand the temperature dependence of the magnetization, temperature of maximal magnetization i.e. Transition temperature (T_M) and Curie temperature (T_C) was determined. The transition temperature was determined from the derivative of the thermo-magnetic curve. The Curie temperature value is obtained from the usual inverse susceptibility curve. The similar Curie temperature is also obtained from the novel 5th polynomial fit second order derivative of the χ-T curve.

Section snippets

Synthesis

Six polycrystalline chemical compounds of $Sr_2NiMnFe_{12-X}(TiCo)_{X/2}O_{22}$ ($0 \leq x \leq 2.5$ with increment of 0.5) were prepared by microwave assisted sol-gel auto combustion route. The starting chemicals used were high purity analytical reagent grade $Sr(NO_3)_2$ (99.99%, Aldrich), $Ni(NO_3)_26H_2O$ (99.99%, Emsure-Merck KGaA), $Mn(NO_3)_24H_2O$ (99.99%, Emsure-Merck KGaA), $Fe(NO_3)_29H_2O$ (99.99%, Emsure-Merck KGaA), $Co(NO_3)_26H_2O$ (99.99%, Emsure-Merck KGaA), titanium tetra chloride $TiCl_4$ (99.99%, Emsure-Merck KGaA) and…

Structural and phase analysis

The indexed XRD patterns of calcined samples with different TiCo concentration are shown in Fig. 1. The observed peaks of the samples were compared with standard data file ICSD # 024575 (PDF number- 732035) of Y-type ($Ba_2Zn_2Fe_{12}O_{22}$) compiled by- ICSD (Inorganic Crystal Structure Database) and the entire observed pattern is indexable for single phase [6,7]. All XRD patterns exhibit sharp and well-defined diffraction peaks which identify the formation of crystallized Y-type hexaferrite structure. …

Conclusions

The XRD patterns of prepared samples $Sr_2NiMnFe_{12-x}(TiCo)_{x/2}O_{22}$ elucidate a single-phase Y-type hexaferrites belong to the $R\bar{3}m\ (No.\,166)$ space group. The lattice constant ‘a’ slightly increases and easy magnetized ‘c’ axis undergoes more expansion with the content of TiCo. The crystallite size obtained from the most intense peak of (119) plane is in the range of 41 nm–71 nm. HRTEM grain images show that the inter-grain spacing ‘d’ values are in good agreement with the values calculated from XRD…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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