Journal of Superconductivity and Novel Magnetism (2020) 33:1611–1617
https://doi.org/10.1007/s10948-019-05192-8

ORIGINAL PAPER

Effect of Magnesium Substitution on Structural and Magnetic Properties of Nickel Ferrite Nanoparticles

C. N. Anumol[1] · M. Chithra[1] · Shantinarayan Rout[2] · Subasa C. Sahoo[1]

Received: 30 January 2019 / Accepted: 17 June 2019 / Published online: 26 June 2019

Abstract

Magnesium-substituted Ni-ferrite ($Mg_xNi_{1-x}Fe_2O_4$; $0 \le x \le 1$) nanoparticles were prepared by sol-gel method and were annealed at 550 °C and 900 °C in air. All the as-prepared samples and the samples annealed at 550 °C were single phase whereas some additional peaks of α-Fe_2O_3 was observed for the samples annealed at 900 °C. Lattice constant increased with the increase in Mg^{2+} concentration. Crystallite size did not show any systematic variation with the increase in Mg^{2+} concentration and was increased after annealing in these nanoparticle samples. The highest M_S values of 42 and 46 emu/g were observed at 300 and 60 K respectively for the as-prepared sample with $x = 0.05$ and the lowest values of 21 and 26 emu/g were observed at 300 and 60 K respectively for the 550 °C-annealed sample with $x = 1$. The magnetization and coercivity decreased with the increase in Mg^{2+} concentration. The non-saturation behavior was found to be increased with the increase in Mg^{2+} concentration in these samples. The observed magnetic behavior can be understood on the basis of increase in nonmagnetic Mg^{2+} concentration, cation distribution in the lattice sites, growth of crystallite size, and the decrease in anisotropy with the increase in Mg^{2+} concentration in these nanoparticle samples.

Keywords Ferrite · Nanoparticles · Substitution · Annealing · Magnetic properties

1 Introduction

Ni-ferrites ($NiFe_2O_4$) with several interesting properties like moderate saturation magnetization, low coercivity, low electrical losses, high electrical resistivity, and good chemical stability find many applications in technology, environmental, and biomedical fields [1, 2]. Ni-ferrite has inverse spinel structure with 8 Fe^{3+} in the tetrahedral A-sites and the rest 8 Fe^{3+} together with 8 Ni^{2+} in the octahedral B-sites in the unit cell [3]. When these ferrites are prepared in nanoscale, its physical properties are modified due to smaller crystallite sizes and their distribution in the nanomaterial samples. The magnetic properties of these ferrites can also be modified by substituting different cations and site occupancy of these cations in the spinel structure. Mg^{2+} is a nonmagnetic ion with no unpaired electron and prefers to occupy the B-site in the spinel structure. So, the substitution of Mg^{2+} in place of Ni^{2+} is expected to modify the super-exchange interaction and the physical properties of Ni-ferrite [4–6].

Substitution of Mg^{2+} has been reported to modify the electrical, optical, electrochemical, and photocatalytic properties of Ni-ferrite nanoparticles. Hirthna et al. reported the decrease in dielectric properties and increase in electrical conductivity with increasing Mg^{2+} concentration in $Mg_xNi_{1-x}Fe_2O_4$ nanoparticles [4]. The dielectric properties of $Mg_xNi_{1-x}Fe_2O_4$ nanoparticles have also been studied by many other researchers [7–9]. Shobana et al. suggested from their electrochemical study that Mg^{2+} substituted Ni-ferrite nanoparticles can be used as anode material for rechargeable batteries [10]. Nadumane et al. studied that Mg^{2+} substituted Ni-ferrite nanoparticles show better photocatalytic properties than the Ni-ferrite nanoparticles [11]. In the present work, we studied the effect of Mg^{2+} concentration and annealing temperature on the magnetic behavior of $Mg_xNi_{1-x}Fe_2O_4$ nanoparticles prepared by sol-gel method.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10948-019-05192-8) contains supplementary material, which is available to authorized users.

✉ Subasa C. Sahoo
subasa.cs@gmail.com

[1] Department of Physics, Central University of Kerala, Kasaragod, Kerala 671316, India

[2] Department of Physics, Ravenshaw University, Cuttack, Odisha 753003, India