Effect of Substitution of Divalent Cation on Structural and Magnetic Properties of Spinel Ferrite

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Abstract— Nanoparticles of metallic element substituted divalent cation of spinel ferrites were successfully synthesized by sol-gel auto-combustion technique. The influence of a modification within the molar quantitative relation of Co and Ni metal cation strongly affected on the structural and magnetic properties has been examined very well. With the assistance of the diffraction machine, the section formation and structural analysis of the samples are dispensed. The surface morphology of those particles has been studied by Transmission microscopy (TEM). The magnetic properties of the synthesized samples were examined by vibratory Sample magnetometer (VSM). Ultimately during this analysis module, we have a tendency to correlate the structural and magnetic properties on the premise of the quantitative relation of Co and Ni metal substitution. During this article, we have a tendency to additionally investigate the structural parameter with the assistance Rietveld refinement technique. The terms consistency, X-Ray density, and Bulk density are deeply mentioned during this analysis activity, we have a tendency to found the crystallite size of the ready sample below fifty nm, and also the lattice parameter was found to be within the vary of around 8Å it's noted that the lattice parameter is varied sample to sample and are mentioned during this research module.

Keywords—Soft Ferrite, Structural properties, TEM, Magnetic Properties,

I. Introduction

We all are surrounded by magnetic fields and magnetic materials, so researchers are more interested in magnetic materials and magnetic materials. This scientific revolution's magnetic system and magnetic material plays a very important role in this period [1]. Since Ferrari is an important magnetic material for individual industrial and biological applications, we are dealing with a ferrite substance in the current research module, because Ferrari is divided into two major types of soft ferrite and hard ferrite [2 ] Is. Soft ferrite and hard ferrous atom's individual-made and geometric arrangements are available in individual and different ways that are present in their crystalline system. [3] The soft ferrite structure is also a cubic crystal structure known as spherical ferrite, which has general formula MeFe2O4 where Me is divalent cation. Ferrite's cubic crystal structure contains total 56 atoms, one of the 56 Ethernet 32 is oxygen, which has an ion and 8 as well as 16 remaining references [4]. 64 tetrahedral sites (or websites) will be captured in a generally distributed event. The company and Ni are both strong magnetic materials which are magnetic moments of 3 μB and 2 μB. So Co-Ni’s site preferences and their welding proportion have been made of lemon-converted spherical magnet magnetic. From the literature survey, we found that based on the structural and chemical distribution parameters, the content of the magnetic formulation are in the research work, which we focus on the system-based magnetic asset-based system [5].

II. Experimental

Ni1- xCoxFe2O4, where x = 0, 0.6, 1 nanoparticles were synthesized by sol-gel auto combustion technique dealing with urea as a fuel [6]. The stoichiometric proportions of metal nitrate severely dissolved in 10 ml double distilled water and adding 1mole urea in it. Then the resulting solutions were mixed properly and stirred at room temperature [7]. The mixed solution was taken for heat treatment at 60˚C till one-fourth solution is left, up to the mark of formation of a viscous gel, then the gel was kept in a microwave oven for an instant fire at 600 watts. The dried gel started and finally, the powder was obtained. Prepared ferrite powder was grinded for 4 hrs and annealed at 800 OC for 4 hrs in a muffle furnace. At last the powdered material is grinded in mortar for another four hours to obtain the final product [8].

III. Characterization of materials

The single phase recognition of materials were obtained by using X-Ray Diffraction (XRD) using Cu Kα- radiation in the range of 10 -80˚ of the 20. The surface morphology of the powder samples were analyzed by transmission electron microscopy (TEM) and Scanning Electron Microscopy (SEM). The magnetic measurements were made by using vibrating sample magnetometer (VSM) at room temperature

IV. Results and discussions

4.1. Structural analysis

X-ray diffraction patterns of Ni1- xCoxFe2O4, where x = x = 0, 0.6, 1 spinel ferrite nanoparticles are shown in figure 1. The XRD patterns well match all the characteristic reflections of cubic spinel structure without any extra peaks therefore the structure is single phase [9]. The lattice parameter (a) and average crystallite size (D), Bulk density, X- ray density, Porosity of the entire sample were mention in table 1. The XRD data has characterized through Rietveld refinement method, the XRD refinement was taken continuously until we get the convergence reached with a goodness factor very close to 1. The values of Rwp (discrepancy factor) and Rexp (expected values), with the goodness of fit (R2) have been mention in table 2, from the survey of literature we found that the goodness values of our Rietveld refined sample has the good agreement with the reported values in previous literature [10]. Figure 1 shows the typical Rietveld refined of X-ray pattern for sample x = 0, 0.6, and 1 respectively. The experimental lattice constant and the calculated lattice constant by the Rietveld method are in good agreement with each other mentioned in table 2. The lattice constant increases gradually with the substitution of Co2+ ion and reached maximum for CoFe2O4 sample because the Co2+ has the larger ionic radius as compared to Ni2+ [11] [12]. The present system of Ni1- xCoxFe2O4 under investigation is either mixed spinel ferrite for x = 0.6, 1 and inverse spinel for x = 0 which is understood by table 3 of cation distribution. X-ray density (dx) was determine by using formula, dx = 8M/Na3 where M is the molecular weight of sample and N is known for Avogadro’s number, also ‘a’ indicates as lattice parameter, X-ray density increases linearly with Cobalt concentration because Cobalt atom is slightly heavier than the Nickel atom [13] [14].
4.2. Transmission electron microscopy

The TEM images of Ni1-xCoxFe2O4 is shown in figure 2, spherical as well as square shape particles of 40-70 nm size is clearly visible in the TEM images. From the figure 2 we also notice that a large numbers of small particles held together by interfacial forces which are responsible for agglomerate particles. The appearance of such agglomerates particles has also been reported in the literature [15]. Figure 2 also shows some well separated square shape particles of average size around 40-50 nm range which support the cubic of present ferrite system. The Selected area electron diffraction pattern (SAED) of the particle suggests the highly crystalline nature of the sample and have good agreement with XRD pattern [16].

4.3. Magnetic measurements

Magnetic measurements of Ni1-xCoxFe2O4 sintered spinel type ferrite were recorded at room temperature. A typical hysteresis loop of spinel system has shown in figure 3. The hysteresis loop for the as obtained sample exhibits very small area of hysteresis loop therefore the material synthesized for the present research module is close resemble to super-paramagnetic nature [17] [18]. The saturation magnetization of the samples sintered at 800 OC is increasing order with the substitution of Co2+ ion, which is in good agreement with the calculated Bohr magnetron. The values of Bohr magnetron calculated from X-ray diffraction cation distribution is well accord with saturation magnetization and have reported in table 3. The reduction of saturation magnetization with the reducing cobalt concentration can be acknowledged by the fact that due to relatively high orbital contribution to magnetic moment of Co2+ ions are known to give large induced anisotropy. A decrease in coercivity with an increase in nickel concentration may be assigned to the decrease in anisotropy field, which in turn decreases the domain wall energy [19] [20].

![Figure 2. TEM and SAED pattern of Ni1-xCoxFe2O4](image)

![Figure 3. VSM graph of Ni1-xCoxFe2O4](image)
5. Conclusion

The nano-size Ni1-xCoxFe2O4, where x = x = 0, 0.6, 1 spinel ferrite have been successfully synthesized by the sol-gel combustion method and examined through XRD VSM and TEM. From the above characterization, we conclude that the Co2+ and Ni2+ ions substitution in the spinel ferrite system plays an important role in the context of structural and magnetic properties. With the help of x-ray diffraction technique, we concluded the formation of a single crystal structure which is good agreement with the crystalline nature confirmed by SAED pattern of TEM images. The saturation magnetization of the materials is well matched with the total magnetic moment of individual material. We noticed that the Co2+ doped spinel ferrite have the largest lattice constant and highest magnetization value whereas the Ni2+ substituted spinel ferrite have the lowest lattice constant and smallest magnetization values. Therefore we concluded that the structural and magnetic properties of present spinel system well depended on the substitution of cobalt and nickel.

REFERENCE


