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Magnetic Behavior of Transition Metal-Doped Zinc Ferrites Synthesized via Sol-Gel and Co-Precipitation Routes: Correlation of Structural Distortions and Cation Distribution

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ABSTRACT

Cobalt-doped zinc ferrite ($CoZnFe_2O_4$) nanoparticles were prepared using sol-gel and co-precipitation methods with 0.05 M Co and calcined at 600 °C. The structure, vibrations, and magnetic behavior were studied using X-ray diffraction (XRD), Raman spectroscopy, and vibrating sample magnetometry (VSM). XRD confirmed the formation of a pure spinel ferrite with nanocrystalline features. Raman spectra showed cation distribution in the tetrahedral and octahedral sites. VSM results showed soft ferrimagnetic behavior with moderate magnetization. The results indicate that Co substitution and the synthesis method affect the crystal size, lattice strain, and magnetic properties, making these nanoparticles suitable for sensors, high-frequency devices, and biomedical applications.

Keywords: $CoZnFe_2O_4$, spinel ferrite, sol-gel, co-precipitation, XRD, Raman, VSM, magnetic properties.

INTRODUCTION

Spinel ferrites are materials with the general formula MFe_2O_4 (M = Co, Zn, Mn, etc.) and are widely used due to their tunable magnetic properties. Zinc ferrite is a non-magnetic spinel ferrite, but when Co^{2+} is added, magnetic ions replace Zn^{2+}, creating mixed cation sites. This changes the magnetic behavior and anisotropy of the ferrite [1–3].

Nanoparticles made by sol-gel or co-precipitation methods are uniform, have high purity, and controllable size, which makes them useful for magnetic devices [4–6]. This study examines 0.05 M Co-doped zinc ferrite nanoparticles prepared by both methods. We focus on their structure, cation distribution, and magnetic properties using XRD, Raman, and VSM.

2. Experimental Methodology

2.1 Materials

Cobalt nitrate, zinc nitrate, ferric nitrate, citric acid, and sodium hydroxide were used without further purification. Deionized water was used as the solvent.

2.2 Synthesis

Sol-Gel Method: Nitrate solutions of Zn, Co, and Fe were mixed. Citric acid was added to form a gel. The gel was dried at 120 °C and calcined at 600 °C for 3 h.

Co-Precipitation Method: Nitrate solutions were mixed and NaOH was added to precipitate hydroxides. The precipitate was washed, dried, and calcined at 600 °C for 3 h.

2.3 Characterization

XRD: To check crystal structure and size.

Raman spectroscopy: To study cation distribution in tetrahedral and octahedral sites.

VSM: To measure magnetic properties at room temperature.

RESULTS AND DISCUSSION

3.1 XRD Analysis

XRD patterns show that Co-doped zinc ferrite nanoparticles have a single-phase spinel structure. No secondary phases were observed. Peak broadening indicates nanocrystalline particles, with size depending on the synthesis method.

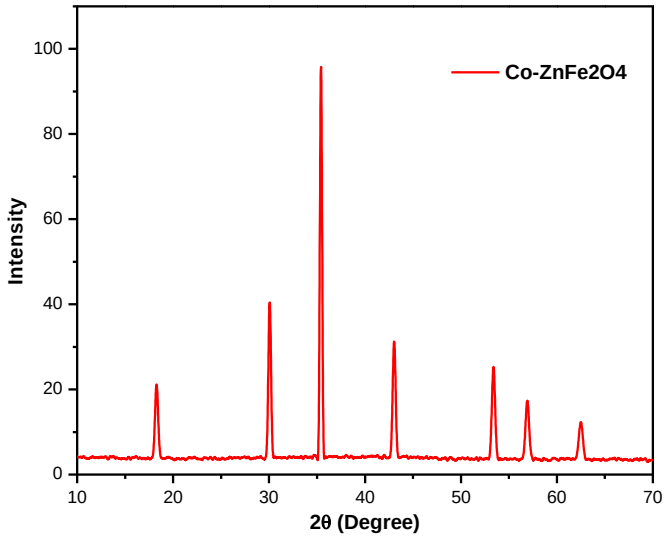

Figure 1: XRD patterns of Co-doped zinc ferrite nanoparticles synthesized by sol-gel and co-precipitation methods.

3.2 Raman Spectroscopy

Raman spectra confirmed the spinel ferrite structure and showed cation distribution between tetrahedral and octahedral sites.

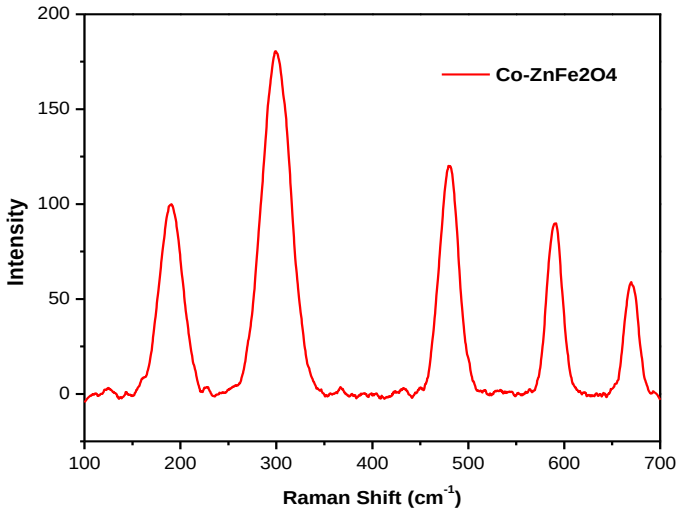

Figure 2: Raman spectra of Co-doped zinc ferrite nanoparticles.

3.3 Magnetic Properties (VSM)

VSM results show soft ferrimagnetic behavior at room temperature. Saturation magnetization is moderate, coercivity is low, and remanence is small. Magnetic properties depend on particle size and cation distribution.

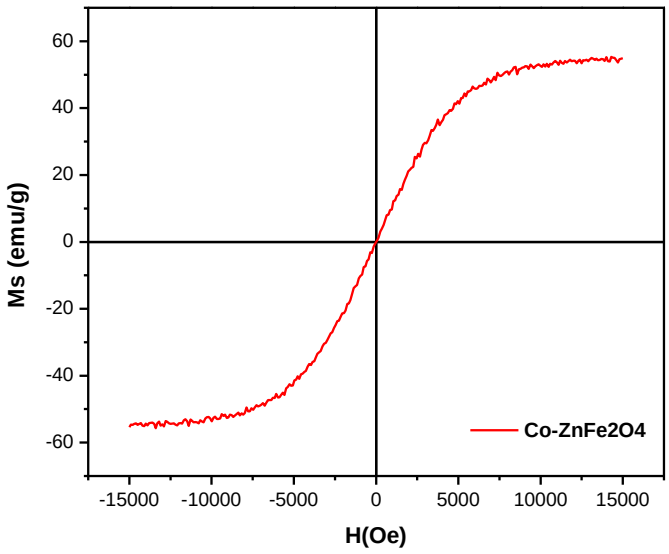

Figure 3: Room-temperature magnetic hysteresis loops of Co-doped zinc ferrite nanoparticles.

CONCLUSION

Co-doped zinc ferrite nanoparticles (0.05 M Co) were successfully prepared using sol-gel and co-precipitation methods. XRD and Raman confirmed the spinel ferrite structure with nanocrystalline particles. VSM results show soft ferrimagnetic behavior at room temperature. The synthesis method influences crystal size, lattice strain, and magnetic properties. These nanoparticles are suitable for sensors, high-frequency devices, and biomedical applications.

REFERENCES

[1]. Liu, C., et al., Applied Physics Letters, 80, 4791–4793 (2002)
[2]. Ueda, K., Tabata, H., & Kawai, T., Applied Physics Letters, 79, 988–990 (2001)
[3]. Smit, J., & Wijn, H.P.J., Ferrites, Philips Technical Library, 1959
[4]. Valenzuela, R., Magnetic Ceramics, Cambridge University Press, 1994
[5]. Goldman, A., Modern Ferrite Technology, Springer, 2006
[6]. Cullity, B.D., & Graham, C.D., Introduction to Magnetic Materials, 2nd Edition, Wiley, 2009
[7]. Verma, R., et al., Journal of Alloys and Compounds, 509, 7940–7945 (2011)
[8]. Sahoo, P.K., et al., Journal of Magnetism and Magnetic Materials, 322, 3010–3014 (2010)
[9]. Gorria, P., et al., Journal of Nanoparticle Research, 13, 2797–2807 (2011)
[10]. Zhang, H., et al., Materials Chemistry and Physics, 129, 1083–1088 (2011)
[11]. Pradeep, T., et al., Journal of Materials Science: Materials in Electronics, 22, 1571–1577 (2011)
[12]. Wang, D., et al., Journal of Applied Physics, 107, 09B520 (2010)
[13]. Ahn, D., et al., Journal of Magnetism and Magnetic Materials, 320, 142–147 (2008)
[14]. Li, Y., et al., Materials Letters, 62, 3347–3350 (2008)
[15]. Chinnasamy, C.N., et al., Journal of Physics D: Applied Physics, 36, 2745–2750 (2003)
[16]. Wang, H., et al., Journal of Nanoscience and Nanotechnology, 10, 4391–4396 (2010)
[17]. Rajendran, R., et al., Materials Science and Engineering B, 168, 75–79 (2010)
[18]. Thakur, V., et al., Journal of Materials Science, 45, 2292–2298 (2010)
[19]. Jana, P., et al., Ceramics International, 40, 2139–2145 (2014)