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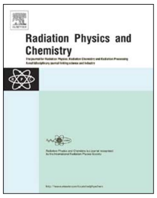

# Dielectric and complex impedance properties of γ-rays irradiated Neodymium substituted Co-Zn nanoferrites

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## ABSTRACT

Nanosized $Co_{1-x}Zn_xFe_{2-y}Nd_yO_4$ ferrites with x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0; y = 0.0 and 0.1 were synthesized by solution combustion method. All the compositions have been characterized by XRD, SEM technique and irradiated by γ–rays of $^{60}$Co source. Dielectric constant, dielectric loss tangent, ac conductivity and complex impedance are studied in the frequency range 100 kHz–10 MHz for pristine and irradiated composition. The X-ray diffraction patterns revealed the spinel cubic structure. The lattice parameter has increased with increasing $Zn^{2+}$ ion concentration. The values of dielectric constant, loss tangent, real and imaginary parts of impedance have been decreased while ac conductivity increased with increasing frequency. The dielectric parameters and ac conductivity were found to increase and attain maximum at x = 0.4; y = 0.0, x = 0.6; y = 0.10 and beyond that decreased for further substitution of $Zn^{2+}$ ion concentration. The lattice parameter and dielectric parameters were significantly reduced with $Nd^{3+}$ ion substitution and increased after γ-irradiation attributed to the conversion of ferric ions to ferrous due to ionizing effect of γ-radiation. Nyquist plots revealed existence of multiple electrical responses.

## 1. Introduction

Nanotechnology is very diverse field, ranging from extensions of conventional device to completely new approaches based upon molecular self-assembly and development of new materials with nanoscale dimensions to investigate the direct control on the atomic level (Safarik and Safarikova, 2002). Nanocrystalline ferrites are effectively a bridge between bulk materials and atomic or molecular structures (Safarik and Safarikova, 2002). Nanoferrites have attracted much attention due to great scientific and technological applications as microwave devices, high speed digital tapes and disk recording, active components of ferrofluids, magnetic refrigeration systems (Shaikh et al., 2010; Al-Saie et al., 2011; Inui et al., 2008), biosensors, recording colour imaging, targeted drug delivery, detoxification of biological fluids, magnetically controlled transport of anti-cancer drugs, and magnetic resonance imaging (MRI) contrast enhancement and magnetic cell separation (Cao et al., 2010). Among spinel nanoferrites, cobalt ferrites have unique properties such as high coercivity, moderate saturation magnetization, high magneto crystalline anisotropy, excellent chemical stability and mechanical hardness (Balavijayalakshmi et al., 2012). Nowadays, Cobalt ferrite, owing to strong ferromagnetism and high Curie temperature, is used in electronic appliances as it causes the materials to stay magnetized even when the applied magnetic field is turned off, leading to a useful way of storing information, high frequency magnets, magnetic bulk cores, microwave absorbers high sensitivity sensor, and biomedical industries (Yadav et al., 2013; Mata-Zamora et al., 2007; Caltun et al., 2008). Zinc substituted cobalt nanoferrites exhibited enhanced properties and excellent chemical stability, high corrosion resistivity, magnetocrystalline anisotropy, magnetization and magneto-optical characteristics for magneto-mechanical stress sensors (Vaidyanathan and Sendhilnathan, 2008).

Rare-earth oxides are good electrical insulators and have resistivities at room temperature greater than $10^5$ Ω cm. Rare-earth elements have unpaired 4f electrons and strong spin–orbit coupling of the angular momentum shielded by 5 $s^2 5p^6$ sub shells and almost unaffected by the potential field of surrounding ions. On the other hand, Rare-earth (RE) elements have large magnetic moments, large magnetocrystalline anisotropy and very large magnetostriction at low temperatures due to their localized nature of 4f electrons. A significant change in the physical properties attributed to the occurrence of 4f-3d

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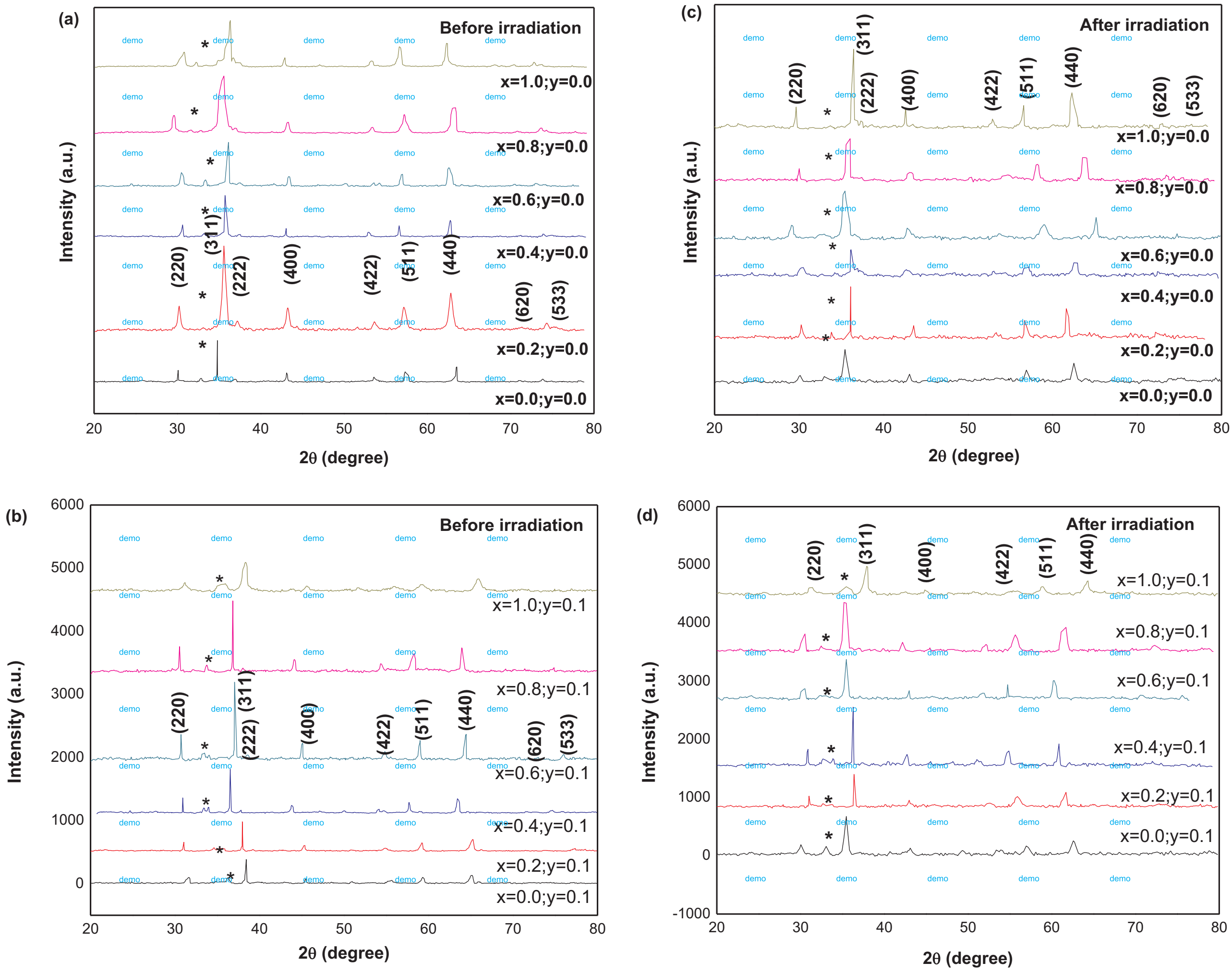

**Fig. 1.** (a)–(d) XRD pattern of $Co_{1-x}Zn_xFe_{2-y}Nd_yO_4$ (x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0; y = 0.0, y = 0.1) nanoferrites (a)–(b) before irradiation (c)–(d) after irradiation.

**Table 1**
Lattice parameter, crystallite size for $Co_{1-x}\,Zn_xFe_{2-y}Nd_yO_4$ nanoferrites before and after irradiation at room temperature.

| Comp | Lattice Parameter (a) nm | | Crystallite size ($d_x$) nm | | X ray density ($d_x$) gm/cc | |
|---|---|---|---|---|---|---|
| | Before Irradiation | After Irradiation | Before Irradiation | After Irradiation | Before Irradiation | After Irradiation |
| 0.0;0.0 | 0.8322 | 0.8384 | 20.07 | 20.79 | 5.41 | 5.29 |
| 0.2 | 0.8342 | 0.8397 | 22.30 | 22.37 | 5.40 | 5.29 |
| 0.4 | 0.8351 | 0.8432 | 31.49 | 34.35 | 5.41 | 5.26 |
| 0.6 | 0.8375 | 0.8439 | 19.56 | 33.68 | 5.39 | 5.27 |
| 0.8 | 0.8382 | 0.8440 | 23.90 | 28.95 | 5.41 | 5.30 |
| 1.0 | 0.8395 | 0.8458 | 12.42 | 19.33 | 5.41 | 5.29 |
| 0.0;0.1 | 0.8319 | 0.8392 | 21.05 | 21.61 | 5.62 | 5.47 |
| 0.2 | 0.8384 | 0.8418 | 16.97 | 17.15 | 5.52 | 5.45 |
| 0.4 | 0.8385 | 0.8441 | 15.46 | 15.72 | 5.55 | 5.44 |
| 0.6 | 0.8391 | 0.8446 | 14.08 | 19.38 | 5.56 | 5.45 |
| 0.8 | 0.8406 | 0.8448 | 14.79 | 28.34 | 5.56 | 5.48 |
| 1.0 | 0.8412 | 0.8471 | 38.04 | 38.24 | 5.58 | 5.46 |

couplings depending on the type and amount of rare earth element used. Magnetic therapy rare earth ferrite products studies have shown that they are more effective for the relief of acute and chronic pain or discomfort due to the various injuries and ailments (Ahmed et al., 2002; Ahmed et al., 2003a, 2003b). The dielectric phenomenon in case of ferrites originates from its microstructural factors. Dielectric properties are stable at high frequency depending on several factors including the method of preparation, sintering time and temperature, chemical composition, type and quantity of additives and grain structure (Saafan et al., 2012). The study of dielectric properties may provide valuable information for potential applications (Saafan et al., 2012).

Impedance spectroscopy is a powerful technique for investigating the electrical response of grain and grain boundary inside a ferrite material as a function of frequency. The properties and applications of materials depend on the close control of structure, composition, ceramic texture, dopants or defects and dopant distribution (Kingery et al., 1976; Macdonald, 1987). The basic information about the dielectric properties of materials can be obtained from the complex impedance analysis which allows separation of several contributions of total impedance, arising from grain, grain boundary and other electrode