Preface

Nanotechnology deals with the phenomena and structures of materials of size in the range 1 to 100nm. Nanoparticles show many novel properties that are significantly different from those shown by their bulk counterparts. Chemical compounds with Iron (III) oxide Fe₂O₃ as their principal components are known as ferrites. Nano ferrites find wide range of applications in magnetic memories, noise filters, isolators, ferro fluids, transformer cores, gas sensors, smart sensors etc.

Nano zinc ferrite is an important member of the nano ferrite family due to its important properties like chemical stability, high electromagnetic performance, mechanical hardness, low coercivity and moderate saturation. Due to these unique properties, zinc ferrite finds a wide range of applications in gas sensors, photo catalyst, MRI contrast agent, catalyst and so on.

The properties of ferrites can be tailored as desired, by substituting the divalent and trivalent atoms in the crystal structure. The right choice of substituents and the right composition helps to activate those properties that are desired for a specific application.

This thesis deals with the variations observed in the structural, electrical, magnetic and nonlinear optical properties of various divalent and trivalent ion substituted zinc ferrite. Furthermore the effect of particle size, concentration and divalent ion concentration (Co²⁺ ion) of zinc ferrite nanoparticles on fresh water micro algae, Chlorella pyrenoidosa, have also been investigated.

This thesis entitled “Characterization of Nano Zinc Ferrites and Investigations on their Optical Limiting and Antialgal Applications” consists of 10 chapters.

Chapter 1 presents an overall basic introduction to the thesis. Various topics like magnetism, nano magnetism, nonlinear optics, and optical limiting are discussed. Classification of ferrites, spinel structure, magnetic and electrical properties of ferrites as well as the characteristics and applications of the micro alga, Chlorella pyrenoidosa, have been outlined. The motivation and objectives of the work are also presented.
Chapter 2 discusses the sol-gel method adopted for the synthesis of nanoparticles as well as the basic theories regarding the various characterization techniques used in this work.

Chapter 3 discusses the effect of sintering temperature/particle size on the structural and electrical properties of zinc ferrite. X–Ray Diffractometer (XRD), Transmission Electron Microscope (TEM), X–Ray Florescence Spectrometer (XRF), and Thermo Gravimetric Analysis methods are used for the structural characterization. The electrical properties are studied in detail using an impedance analyzer. Variation in electrical properties as a function of frequency, temperature and grain size has also been discussed in this chapter.

Chapter 4 deals with the effect of gadolinium substitution on the structural, electrical and magnetic properties of zinc ferrite. The data from the XRD analysis is used to study the structural parameters like lattice constant, grain size, X–ray density etc. TEM technique is used to evaluate the morphology of the nanoparticles. XRF is used to confirm the composition of the prepared samples. Magnetic properties of the samples are analyzed using the VSM and are discussed on the basis of the hysteresis curve obtained for the samples. The variation in DC resistivity of ferrites as a function of temperature and composition are studied in detail. Variation of dielectric constant, and AC conductivity with temperature, frequency and composition are also discussed.

Chapter 5 presents the structural, electrical and magnetic properties of gadolinium substituted Mg–Zn mixed ferrite with general formula, \( \text{Mg}_{0.75}\text{Zn}_{0.25}\text{Fe}_{2-x}\text{Gd}_x\text{O}_4 \). The structural changes with increase in the concentration of Gd\(^{3+}\) ion is analyzed using the XRD technique. TEM images are used to confirm the particle size of nano particles and the WD–XRF technique is used to check the stoichiometry of the synthesized ferrite samples. Detailed evaluation of the magnetic property of the samples is done using the VSM technique. The variation in DC resistivity with temperature and composition is explained with the help of hopping conduction mechanism. The dielectric constant, dielectric loss factor and AC
conductivity of the samples are explained using the Maxwell-Wagner two layer model and Koop’s phenomenological theory.

In chapter 6, Magnesium-zinc mixed ferrite with the general formula Mg$_{1-x}$Zn$_x$Fe$_2$O$_4$, is synthesized using the sol–gel technique. The structural characterization using XRD, TEM, XRF is also discussed in detail. Magnetic characterization is done using the VSM and is explained in detail from the hysteresis curve. The variation of dielectric constant and AC conductivity at room temperature for different frequencies, for the series are presented in detail. The optical properties are evaluated and presented in detail. The variation of optical limiting property with zinc and magnesium content is also discussed in detail.

Chapter 7 discusses the sol-gel synthesis of iron substituted zinc chromite and also the changes in the structural, electrical, optical properties of zinc chromite with iron substitution. The structural characterizations of the prepared samples are done using the XRD, TEM and XRF techniques. A UV-Visible spectrometer is used to analyze the optical properties, while the band gap is calculated from the Tau plot. Variation in the nonlinear absorption coefficient with Fe$^{3+}$ ion content is studied using the z-scan technique.

Chapter 8 presents the effect of concentration as well as the particle size of zinc ferrite on the micro algae, *Chlorella pyrenoidosa*, based on the cell count and chlorophyll a content of the algal cells both with and without the presence of any nanoparticles. The structural and morphological changes in the algal cells due to their interaction with the nanoparticles are studied using a phase contrast microscope and a scanning electron microscope. The magnetic characteristics of the prepared ferrite samples are also investigated using a vibrating sample magnetometer.

Chapter 9 deals with the effect of cobalt substitution on the anti-algal property of zinc ferrite, by analyzing the variations in the algal cell counts and in the chlorophyll a content of the algal cells in the presence as well as in the absence of zinc–cobalt mixed ferrite nanoparticles. The structural characterization is done using an X–Ray Diffractometer. The SEM images detail the surface morphology of the
nanoparticles as well as that of the algal cells, both interacted and uninteracted with nanoparticles. Magnetic characterization of the ferrite nanoparticles using the VSM technique is also discussed.

**Chapter 10** is the concluding chapter of the thesis and this chapter contains an outline of the major findings and important results of the study. It also provides some suggestions for further research.

The work presented in this thesis has either been published or has been communicated in international journals or conference proceedings.