SYNTHESIS AND CHARACTERIZATION OF
NANOMATERIALS AND ITS APPLICATIONS

A SUMMARY OF THE THESIS

SUBMITTED FOR FULFILMENT OF THE REQUIREMENT OF THE AWARD OF THE DEGREE

OF

DOCTOR OF PHILOSOPHY

IN

PHYSICS

Submitted by

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(Regn. No. 11/Ph.D/Physics-15)

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2014
SUMMARY OF THE THESIS

The present thesis entitled “Synthesis and characterization of Nanomaterials and its Applications” is an attempt to synthesize the nanoparticles of different ferrites and to study the effect of doping on their structural and magnetic properties.

Many scientific and technological advances recently made depend on the properties of the materials at a very-very small scale. Such technological advances are known as ‘nanotechnology’, the prefix ‘nano’- being derived from the Greek word ‘nanos’, which means ‘dwarf’. Engineered nanomaterials are resources designed at the molecular (nanometer) level to take advantage of their small size and novel properties which are generally not seen in their conventional bulk counterparts. The two main reasons why materials at the nano scale can have different properties are increased relative surface area and new quantum effects. Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength. Also at the nano scale, quantum effects can become much more important in determining the materials properties and characteristics, leading to novel optical, electrical and magnetic behaviors.

Summary of my work done is as follows:

(a) Synthesis of the following series:-

1. I have prepared series of Ni-Zn, ferrite nanoparticles by modified sol-gel method of the composition Ni$_x$Zn$_{1-x}$Fe$_2$O$_4$ for (x=0.25,0.45,0.65,0.85).

2. I have prepared series of Al Substituted Ni-Zn, ferrite nanoparticles by modified sol-gel method of the composition Ni$_{0.65}$Zn$_{0.35}$Al$_x$Fe$_{2-x}$O$_4$ for (x=0.25,0.45,0.65,0.85).

3. I have prepared series of Cu-Zn, ferrite nanoparticles by modified sol-gel method of the composition Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ for (x=0.25,0.45,0.65,0.85).

4. I have prepared series of Mg-Zn, ferrite nanoparticles by modified sol-gel method of the composition Mg$_x$Zn$_{1-x}$Fe$_2$O$_4$ for (x=0.25,0.45,0.65,0.85).

(b) Characterization of synthesized samples:-

1. I have studied the structural properties of nanoferrite particles using X-Ray Diffraction,
Transmission Electron Microscopy (TEM) and Fourier Transform Infrared (FTIR) Spectroscopy.

2. I have studied the magnetic properties of prepared nanoferrite particles by using Vibrating Sample Magnetometer (VSM) at room temperature.

The present study is covered in the seven chapter of the thesis and is summarized as follow:

CHAPTER 1:- This chapter gives the introduction about nanomaterials, magnetism, history of magnetism, nanomagnetic materials, ferrites, nanoferrites, aim of the present work and outline of the thesis.

CHAPTER 2:- This chapter gives brief description of technique used for preparation of ferrite nanomaterials and experimental techniques used for the characterization of the nanomaterials.

CHAPTER 3:- This chapter gives the results and discussion of the synthesis, structural and magnetic properties of Ni$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites samples by using X-Ray Diffraction, Transmission Electron Microscopy (TEM), Fourier Transform Infrared Spectroscopy (FTIR) and Vibrating Sample Magnetometer (VSM). The effect of Ni$^{2+}$ ion on structural and magnetic properties of Ni$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites studied.

(a). X-Ray Diffraction studies confirmed the formation of nanoferrite samples of the spinel phase.

(b). Size of the particles decreases with increase in nickel ion concentration.

(c). Size of the nanoparticles increases with increase in calcinations temperature.

(d). TEM analysis shows that particles are nearly spherical. Mean particle size from TEM image is in good agreement with XRD data.

(e). FTIR confirmed that the structure remains cubic spinel after nickel substitution. In the wave number range of 300 –1000 cm$^{-1}$, two main broad metal–oxygen bands are seen in the infrared spectra of all spinel ferrites. The higher one ($v_1$) generally observed in the range 550–600 cm$^{-1}$, is caused by the stretching vibrations of the tetrahedral metal–oxygen bond. The lowest band ($v_2$) usually observed in the range 385–450 cm$^{-1}$, is caused by the metal–oxygen vibrations in the octahedral sites.
(f). VSM is used to investigate the magnetic properties of Ni$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites. Saturation magnetization first increases and then decreases with increase in nickel concentration at room temperature.

**CHAPTER 4:-** This chapter gives the results and discussion of the synthesis, structural and magnetic properties of Ni$_{0.65}$Zn$_{0.35}$Al$_x$Fe$_{2-x}$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites. The effect of Al$^{3+}$ ion on structural and magnetic properties of Ni$_{0.65}$Zn$_{0.35}$Al$_x$Fe$_{2-x}$O$_4$ (x=0.25,0.45,0.65,0.85) was studied.

(a). X-Ray Diffraction studies confirmed the formation of nanoferrite samples of the spinel phase.

(b). TEM analysis shows that particles are nearly spherical. Mean particle size from TEM image is in good agreement with the crystallite size measured from X-ray line (311) broadening using Scherrer’s formula.

(c). FTIR confirmed that the structure remains cubic spinel after aluminum substitution. In the wave number range of 300–1000 cm$^{-1}$, two main broad metal–oxygen bands are seen in the infrared spectra of all spinel ferrites.

(d). Saturation magnetization first increases and then decreases with increase in Al$^{3+}$ concentration at room temperature. From the data it can be concluded that magnetic properties of Ni$_{0.65}$Zn$_{0.35}$Al$_x$Fe$_{2-x}$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites are strongly affect by the size of the particles.

**CHAPTER 5:-** This chapter gives the results and discussion of the synthesis, structural and magnetic properties of Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nanoferrites. The effect of Cu$^{2+}$ ion on structural properties of Cu$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x =0.25,0.45,0.65,0.85) was studied.

(a). X-Ray Diffraction studies confirmed the formation of nanoferrite samples of the spinel phase.

(b). TEM analysis shows that particles are nearly spherical and confirm the size obtained. Mean particle size from TEM image is in good agreement with the crystallite size measured from X-ray line (311) broadening using Scherrer’s formula.

(c). FTIR confirmed that the structure remains cubic spinel after copper substitution. In the wave number range of 300–1000 cm$^{-1}$, two main broad metal–oxygen bands are seen in the infrared spectra of all spinels ferrites.
(d). Saturation magnetization first increases and then decreases as the value of Cu$^{2+}$ content increases.

CHAPTER 6:- This chapter presents the results and discussion of the synthesis, structural and magnetic properties of Mg$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nano-ferrites samples using X-Ray Diffraction, Transmission Electron Microscopy (TEM), Fourier Transform Infrared Spectroscopy (FTIR) and Vibrating Sample Magnetometer (VSM). The effect of Mg$^{2+}$ ion on structural and magnetic properties of Mg$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) was studied.

(a). X-Ray Diffraction studies confirmed the formation of nanoferrite samples of the spinel phase.

(b). TEM analysis shows that particles are nearly spherical, regular and uniform in shape. They also reveal randomly oriented aggregates and formation of nanocrystalline material. The average particle size obtained is in range of 13.0 nm to 23.8 nm. The particle size decreased with increase in Mg concentration. Mean particle size from TEM image is in good agreement with the crystallite size measured from X-ray line (311) broadening using Scherrer’s formula.

(c). In the wave number range of 430–600 cm$^{-1}$, two main broad metal–oxygen bands are seen in the infrared spectra of all spinels ferrites. The higher one ($\nu_1$) generally observed in the range 550-600 cm$^{-1}$, is caused by the stretching vibrations of the tetrahedral metal–oxygen bond. The lowest band ($\nu_2$) usually observed in the range 430–440 cm$^{-1}$, is caused by the metal–oxygen vibrations in the octahedral sites. This is confirmed from fourier Transform Infrared Spectroscopy (FTIR) that the structure remains cubic spinel after magnesium substitution in zinc nano-ferrites.

(d). Vibrating Sample Magnetometer is used to investigate the magnetic properties of Mg$_x$Zn$_{1-x}$Fe$_2$O$_4$ (x=0.25,0.45,0.65,0.85) nano-ferrites. Saturation magnetization first increases and then decreases with increase in Mg concentration at room temperature.

CHAPTER 7:- This chapter gives the applications of the nanomaterials. Ferrite nanoparticles have always attracted lots of attention of the scientific community due to their wide range of applications. Ni-Zn ferrite nanoparticles are soft magnetic material is mostly used as various inductance components, such as a core material for
transformers, deflection, antenna, video magnetic heads and magnetic heads of multiple path communication and so on. Cobalt-zinc nanoferrites have commercially important because they can applied in many data storage devices. This chapter also gives conclusion, suggestions and scope for the future work.