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It is certified that the work contained in the thesis titled *"SYNTHESIS, CHARACTERIZATION AND APPLICATIONS OF METAL OXIDE AND MIXED METAL OXIDE NANOPARTICLES"* by *"Ravi Kant Sharma"* has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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(Department of Chemistry)

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I, *"Ravi Kant Sharma"*, certify that the work embodied in this thesis is my own bona fide work and carried out by me under the supervision of *"Prof. K. D. Mandal"* from *"2012" to "2016"*, at the *"Department of Chemistry"*, Indian Institute of Technology, Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, *etc*., reported in journals, books, magazines, reports dissertations, theses, *etc*., or available at websites and have not included them in this thesis and have not cited as my own work.

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(Ravi Kant Sharma)

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SYMBOLS USED

Symbols	Meaning
^{o}C	Degree centigrade
µ	Micro
T	Temperature (K)
θ	Bragg diffraction angle (degree)
λ	Wavelength (nm)
E_g	Energy band gap (eV)
$F(R)$	Kubelka-Munk function
R	Reflectance
α	Optical absorption coefficient
υ	Frequency
h	Planck's constant (J s)
M	Magnetization (emu/g)
H	Magnetic field strength (A/m, T or Oe)
M_r	Remanent magnetization (emu/g)
H_c	Coercivity (A/m, T or Oe)
H_{ex}	Exchange anisotropy
T_B	Blocking temperature (K)
Tc	Curie temperature
T_N	Neel temperature
D	Crystallite size (nm)

PREFACE

The work comprised in this thesis entitled **"Synthesis, characterization and applications of metal oxide and mixed metal oxide nanoparticles"** play a very important role in various areas of chemistry, physics, biology and materials science because of their interesting properties. When two or more metal oxides are mixed together either by physical or by chemical methods to fabricate mixed metal oxide nanoparticles, a novel set of physical and chemical properties may be obtained that would be completely different from that of the individual constituents. The distinct properties of nanomaterials arise from quantum size effects, quantum tunneling effects and surface effects. An extensively controlled preparation of desired shape, morphology and size depending upon its applications of the nanostructured materials with high purity is still a large challenge for the scientific community. In this context, a simple, low cost and environment friendly for the large-scale production of metal oxide and mixed metal oxide nanostructured materials and their studies on optical, magnetic, catalytic and antifungal properties have not been addressed in details in the literature. The formation of high purity samples at the nano level with high surface area and control of the size, shape, homogeneity and agglomeration of nanoparticles, which is one of the primary aims of this thesis. During my research work, I have synthesized metal oxide CuO, ZnO, NiO, Co_3O_4 and mixed metal oxide CuO–ZnO, ZnO–NiO, Co_3O_4–ZnO nanoparticles by homogeneous precipitation method and nanocrystalline zinc aluminate ($ZnAl_2O_4$) spinel powder by sol–gel method. Many of the present methods in use today are difficult to develop in large-scale industrial applications because they are expensive, complicated, require sophisticated apparatus, high reaction temperatures, long production time, toxic reagents and producing by-products which are harmful to the environment. The present homogeneous precipitation method offers easy control of uniform particle size, good textural properties, environmental friendly and preparing samples at low temperature in short processing time in

large scale production, not employing any expensive raw materials and complicated equipments. The importance of the sol–gel process includes the ability of maintaining a high degree of purity, high homogeneity and also offers simple and low-cost. The thesis is organized in five chapters.

The first chapter contains a general introduction about nanostructured materials (low dimensional systems) and applications of these.

In the second chapter, an overview of various synthesis methods and characterization techniques used for preparing and characterizing the synthesized products.

In the third chapter, the detailed studies on the synthesis, characterization and catalytic activity of nanocrystalline copper oxide (CuO) with dandelion-like morphology are described. In this chapter, the thorough studies on the synthesis, characterization and antifungal activity of zinc oxide nanoparticles (ZnO-NPs) are discussed. The thorough studies on the synthesis, characterization and chemical activity of porous nanocrystalline NiO with hexagonal sheet-like morphology has been presented in this chapter.

In the fourth chapter, the synthesis, characterization and chemical activity nanocrystalline CuO–ZnO mixed metal oxide has been presented. In this chapter, a brief description of the synthesis, characterization, optical and magnetic properties of mixed metal oxide (ZnO–NiO and Co_3O_4–ZnO) nanoparticles are discussed.

In the fifth chapter, the detailed studies on the synthesis and characterization of nanocrystalline zinc aluminate ($ZnAl_2O_4$) spinel powder are described. In this chapter, the thorough studies on the synthesis, characterization and antifungal activity of nanocrystalline zinc ferrite ($ZnFe_2O_4$) are reported.

The work done in the thesis has been published in Journal of Molecular Structure, Ceramics International, Superlattices and Microstructures and Journal of Alloys and Compounds.