# ABSTRACT

Nanotechnology is an emergent technique for developing our global life in versatile arena such as engineering, electronics and communication, power generation, disease detection and treatment etc. Nanoparticles exhibit potentiality for application in multi-functional nano-devices that are helpful in optoelectronics, spintronics, chemical and biosensors, drug delivery, catalysis, etc. Zinc Oxide (II-VI metal oxide semiconductor) and its modified nanocrystalline compounds have generated a growing interest among researchers due to the ease in tuning the electrical, optical, multiferroic properties of the compounds suited to the needs of the specific devices. ZnO is an *n*-type direct wide band gap (3.37 eV) semiconductor with high exciton binding energy of 60 meV, high electron mobility, high redox potential, stable chemical composition and have strong luminescence at room temperature. It reveals a strong excitonic emission peak in UV region mainly due to the recombination of free excitons. Attracting luminescent property of ZnO, positions it as a promising candidate for various optoelectronic devices. ZnO has promising applications in chemical sensor, low voltage phosphor material, varistor, solar cells and photocatalysis etc. Dilute magnetic semiconductor (DMS), wherein both the semiconducting and magnetic properties coexist, are in high demand in the electronic industry. Application capability of diluted magnetic semiconductors in spintronic and multiferroic devices has drawn an intense interest of recent researchers. Multiferroicity in DMS is one of the necessary requirements for spintronic device application. The doping of transition metal ions (Mn, Co, Ni, V and Fe) in ZnO matrix develops room temperature ferromagnetism (RTFM) in addition to the change in band gap and other associated properties and is a strong member in the DMS category of materials. Ferromagnetic properties in some non-magnetic element like magnesium (Mg) and lithium (Li) doped ZnO also have been observed. Although, ferromagnetism in transition

metal modified ZnO is forecasted in the year 2000, reports on the magnetoelectric (ME) coupling and multiferroicity of these compounds are very few.

The degree of magnetization in these DMS compounds depends on the particle size and shape of the nanoparticles which vary according to the growth technique. TM doped ZnO nanostructures can be synthesized using various growth techniques, such as co-precipitation, sol-gel, hydrothermal, microemulsion, pyrosol and electrochemical method. The chemical precipitation and sol-gel method result in the synthesis of the ZnO based DMS nanoparticles with controlled sizes (10-30 nm) and shapes and are inexpensive and easy compared to other classical methods of synthesis.

Further, the effluents of textile industries with major amounts of non-fixed dyes, azo dyes and inorganic salts are a major source of environment pollution. Destruction of industrial pollutants through photocatalytic degradation is considered to be a trendy method. Nanoscale wide band gap semiconductors are attracting worldwide attention for their enhanced photocatalytic degradation properties. Suitably doped ZnO nanostructures have a bright prospect as a fruitful photocatalyst for the degradation of organic pollutants and furthering sustainable ecology. $Mg^{2+}$ doping in ZnO matrix is expected to accomplish such enhanced photocatalytic activities. Addition of rare earth elements in some compounds results in better optical and photocatalytic effects. Recently, it has also been conveyed that optically active rare earth $Nd^{3+}$ ion doped ZnO nanoparticles perform as interesting photocatalyst for the purification of pollutant water.

The main focus of this research exertion is to establish doped ZnO nanoparticles as potential candidate for optoelectronic devices and striking DMS material for spintronic and multiferroic applications. We thus inspired to study the optical, electrical, magnetic and magnetoelectric coupling properties of ZnO nanoparticles synthesized through simple and inexpensive chemical precipitation and sol-gel technique using hydroxyoxalate type materials. Also the other important objective has been to study the prospect of modified ZnO as an enriched photocatalyst for degradation of aqua pollutants.

In the present work, pure and doped ZnO nanoparticles have been synthesized successfully through the chemical precipitation and sol-gel technique. Ni, Co, Fe, Mg and Nd doped ZnO nanoparticles were characterized by structural, optical, electrical, magnetic and ME characterization. All the prepared materials crystallize with hexagonal wurtzite structure. Average crystallite size of the fabricated nanopowders remained in the range of 15-30 nm. The nanocrystalline nature and self-organization of the nanoparticles have been confirmed through SAED study. Chemical bonding and composite elements of the samples was detected through FTIR and EDX characterization. The variations of band gap in case of doped ZnO were deliberated according to the Moss-Burstein band filling effect, which is generally observed in *n*-type semiconductors. The intense fluorescence emission at 367 nm has been discussed through exciton recombination corresponding to near band edge emission. The visible emission bands have been assigned to the defect states likes oxygen vacancies and zinc interstitials. The tuned optical properties of doped ZnO make it suitable for application in photonic and optoelectronic devices. All these materials have low dielectric loss. Ferroelectric loops observed in these compounds can be explained through the interaction of dipoles in the non centro-symmetric structure. The origin of observed ferromagnetism in doped ZnO nanocompounds at low temperature is correlated to the relevant mechanisms referred in the literature based on bound magnetic polarons (BMP), oxygen vacancies and zinc interstitials. The variation of room temperature ME voltage coefficient as function of magnetic field has been studied to investigate the interplay between charge carriers and spin ordering. The TM doped ZnO nanoparticles exhibit a strong ME coupling coefficient which facilitates their application in multiferroic devices. It has been shown through various characterizations that the doped ZnO nanocompounds are superior for various photonic, spintronic, magnetoelectric and multiferroic devices (tunnel magneto-resistance, magnetic sensor, multiple state memory devices).

Photocatalytic reactions are processed through $OH^{\bullet}$ and $O_2^{\bullet-}$ radicals created on the surface of Mg and Nd modified ZnO nanoparticles. Photocatalytic activity enhances with higher doping concentration due to separation efficiency of the electron–hole pairs and modifications of physical and chemical properties. Both band gap energy and crystallite size are monitoring factors of photocatalytic performance. The observed superior photocatalytic properties in the Mg and Nd doped ZnO nanoparticles make them promising candidates for efficient sunlight-assisted photocatalytic effect, self-cleaning and photovoltaic applications. The prepared Mg and Nd doped ZnO nanoparticles are found to have sunlight assisted photcatalytic degradation property with a rate constant far higher to that of other II-VI semiconductor based compositions and have the capability to effectively and promptly clean the waste water from its dye based contaminants.