Chapter 8

Conclusion and Future Scope of the work

8.1. Conclusion:

Three major objectives were set for the current thesis. The first being the synthesis of the transition metal element (Ni, Co, Fe), rare earth element (Nd) and the alkaline earth metal element (Mg) doped ZnO nanoparticles by simple wet chemical method and their structural optical, electrical and magnetic characterization. The room temperature ferroelectric and ferromagnetism in the doped diluted magnetic semiconductor like ZnO is a potential criterion for application in multiferroic arena. The second objective is to establish the synthesized samples of TM doped and Mg-doped ZnO as emerging candidates for multiferroic device applications. In this aspect ferroelectric, magnetic and magnetoelectric (ME) properties of these composites have been investigated. The third attracting objective of this research work is the enrichment of Mg^{2+} and Nd^{3+} doped ZnO to despoil the environmental pollutant from effluents of dye based industries. To fulfill this concept, the photocatalytic performance of Mg^{2+} and Nd^{3+} doped ZnO have been studied through degradation of MB under sunlight effect.

In chapter 3-5 exertion has described on the synthesis, structural, optical, electrical, magnetic and ME characterization of nickel, cobalt and iron doped ZnO nanoparticles. TEM and XRD study indicate that both the grain and crystallite size of the Ni-doped ZnO nanoparticles is about 20 nm and thus confirming single domain grains. A deep level emission band at 400-525 nm observed for Ni-doped ZnO nanoparticles makes them efficient candidate for application in LED and other visible region optical devices. The room temperature ferroelectric and ferromagnetic nature and the strong first order ME coupling coefficient of the Ni-doped ZnO nanoparticles enable these compounds for reliable multiferroic device applications.

The average crystallite size of cobalt doped ZnO decreases from 25 nm to 15 nm with increasing cobalt concentration. Visible region emissions have been observed in the luminescence performance of Co-doped ZnO nanocompounds. The tuned optical properties of cobalt doped ZnO makes it potential in photonics and optoelectronic devices. All these Co-doped ZnO nanoparticles exhibit low dielectric loss and a ferromagnetic behavior. The observed magnetoelectric coupling coefficient of Co-doped ZnO nanocompounds at 8.65 mV/(cm.Oe) is much higher to that of Ni-doped ZnO nanocompounds and is better suited for electro-magnetically coupled devices.

The average diameter of iron doped ZnO nanoparticles as revealed from TEM photograph is around 17.5 nm. Larger band gap and enhanced emission of the iron doped ZnO nanoparticles are likely to promote their application in photonic and optoelectronic device applications. The iron doped ZnO nanoparticles exhibit lower dielectric constant and higher loss-tangent as compared to that of pure ZnO on account of multiple valency of the Fe ions and higher conduction in these compounds. However, the compound exhibits room temperature ferroelectric loop. The ferromagnetic loop with the antiferromagnetic nature of the ABK plot of these particles indicate canted antiferromagnetic order along an axis that is accredited to weak ferromagnetic moment along a perpendicular axis in the Fe-doped ZnO nanocompounds. The ferroelectric and ferromagnetic behavior of the iron doped ZnO nanoparticles approves these compounds as promising and potential candidate for application in multiferroic and ME device applications.

Chapter 6 and 7 is devoted to photocatalytic application and multiferroic properties of Mg-doped ZnO nanocompounds and photocatalytic application of Nd-incorporated ZnO nanocompounds respectively. The solubility limit of Mg in ZnO is found to be well above 15 mole percentage with substitution of Mg^{2+} ions at Zn^{2+} sites. The loss tangent in the Mg-doped samples is very small even at 1 kHz and found to possess appreciable value of dielectric constant making them suitable for better dielectric applications. The doped ZnO nanoparticles are found to reveal both ferroelectric and ferromagnetic characteristics. The linear ME coefficient of the samples is significant with a value of around 4 mV/(cm Oe). The observed ME coefficient of the compound is higher than that of Ni-doped ZnO. These features make the compound very attractive for multiferroic and magnetoelectric coupling devices.

Enhanced photocatalytic performance has been achieved in both Mg^{2+} doped ZnO and Nd^{3+} doped ZnO nanoparticles. While 15% Mg doping in the host ZnO enhances the photocatalytic rate constant of ZnO by 300%, 15% Nd doping raises the photocatalytic rate by 375%. These values are higher to all those reported earlier on Zn based compounds. Based on the advanced photocatalytic activities and optical properties, Mg and Nd incorporated ZnO nanoparticles can be recommended as advance nanomaterials for effective sunlight-irradiated photocatalytic reaction, self-cleaning and photovoltaic applications.

To sum up, it can be inferred that the prepared Co, Ni, Fe, Mg and Nd doped ZnO nanoparticles could act as important optical materials for application in various optoelectronic devices like LED, blue luminescent laser, UV laser etc. due to possessions of UV and visible region emission. Attracting ferromagnetic, ferroelectric nature and strong ME coupling have been observed in the above TM doped and Mg-doped ZnO nanoparticles. They could be used as potential DMS material for application in various spintronic devices like tunnel magnetoresistance (TMR), high-sensitivity ac magnetic field sensors and electrically tunable microwave devices such as filters, oscillators and phase shifters etc. The prepared Mg and Nd doped ZnO nanoparticles were found to have efficient photocatalytic performance which might be used for degradation of various organic and inorganic dyes in the effluents discharged from dye based industries and help clean the environment.

8.2. Future scope:

The simultaneous possessions of ferromagnetic, ferroelectric, optical properties and environmental applications of the synthesized ZnO based compounds offer a striking opportunity for the innovation of smart devices in various fields. The fabrication of reliable multiferroic devices for today's speedy world is the ultimate goal. The prepared multiferroic materials and their investigated properties might be supportive in the above aspect. In this research work, we have made an effort to improve the functional properties of ZnO nanosystem by introducing some exciting dopants. However, there are various opportunities for enhancement in material properties of the different DMS compounds though proper doping/substitutions, which we would like to pursue in future.

- Preparation of magnanese (Mn) doped ZnO nanoparticles by low cost method and establishes it as multiferroic materials.
- Preparation of rare earth element gadolinium (Gd) doped ZnO nanoparticles by low cost method and to establish it as a good photocatalyst.
- Analysis of photocatalytic activity of transition metal (Ni, Co, Fe) doped ZnO nanoparticles.
- Synthesis of binary metal oxide semiconductor through inexpensive method for significant spintronic and multiferroic device applications.
- Functionalization of nanocompounds to despoil environmental pollutants.