ABSTRACT

Nanoparticles show unique, unexpected and divergent optical, electronic and magnetic properties than their bulk form. A bulk material has constant physical properties regardless of its size but at the nanoscale, size dependent properties are observed. Nanoparticles have larger surface to volume ratio compared with the bulk materials which makes them great catalyst. The energy band structure and charge carrier density in the materials can be modified quite differently from their bulk counterpart and in turn will modify the electronic and optical properties of the materials. Now a day, nanoparticles are used in many practical applications for example, fuel cell, catalysis, light emitting devices, phosphors for high definition television, next generation computer chips, elimination of pollutants, sun screen lotion, sensors, biological label, drug delivery etc. Among all other nanoparticles, II-VI semiconductor nanoparticles like CdSe, shows good luminescence properties following quantum confinement effect but does not show magnetic properties. It is an n-type semiconductor. Cadmium oxide (CdO) is also II-VI semiconductor. In the form of nanoparticle, it does not show good optical properties due to its highly non-stoichiometric structure but in pristine form it shows room temperature ferromagnetism. In recent years, extensive research has been focused on CdSe nanoparticles because of their vast technological applications in light-emitting diodes, lasers etc. CdO belongs to the big family of transparent conducting oxides (TCO) like In$_2$O$_3$, SnO$_2$, and ZnO etc. TCOs have enormous practical applications in devices in which a transparent contact is required, eg, LEDs, solar cells, LCDs etc. Transition metal doping in CdSe and CdO can bring changes to their optical and magnetic properties. Transition metal ‘Manganese’ is used as dopant since Mn$^{2+}$ has got many interesting properties in comparison to others. Manganese is remarkable as a luminescent activator. It expands the range of luminescence of the host material. The main aim of the work is to find a material which works both as luminescent as well as magnetic material. Combining basic materials, such as diatom porous silica (DPS) with best suitable semiconductor nanoparticles between the two mentioned above, change in optical properties of DPS is expected. Also, production of low-cost light emitting materials can be synthesized using DPS which is economically useful and important nowadays.
Chapter I is an introductory chapter that gives brief description on different basic properties of CdSe and CdO nanoparticles as well as of DPS. It shows systematically the importance of different systems on which work has been done, that is, pristine and doped CdSe, CdO nanoparticles and fresh water nanoporous Diatoms, their structure and applications.

Chapter II discusses about the synthesis methods that have been adopted and some very important characterization methods that have been used. Both pristine and doped CdSe and CdO nanoparticles are synthesized by chemical method. Diatoms were collected from a pond and they were cultured using W.C. media. Transmission electron microscopy (TEM) was used to take images of the samples. Energy dispersive X-ray spectroscopy (EDX) was used for elemental analysis. Morphological study was done by X-ray diffraction (XRD). Oxidation states of the elements were tested by electron paramagnetic resonance (EPR) spectroscopy and X-ray photoelectron spectroscopy (XPS). Fourier transform infrared (FTIR) spectroscopy was also done to observe the bonds formed.

Chapter III focuses on pH dependent optical properties and dopant induced changes in optical and magnetic properties of CdSe nanoparticles. CdSe nanoparticles were synthesized by a one pot synthesis method at three different pH levels. They show highest luminescence at pH 11. Manganese was doped into CdSe in diluted amounts that were in 1 %, 2.5 % and 5 % molar concentrations. Electron paramagnetic resonance (EPR) spectra confirm presence of manganese as Mn$^{2+}$ ions. Magnetic properties were studied by superconducting quantum interference device (SQUID).

Chapter IV describes influence of different annealing temperatures and effect of doping manganese on the optical and magnetic properties of CdO nanoparticles. CdO nanoparticles were annealed at three different temperatures; 400 °C, 600 °C and 800 °C. From diffuse reflectance spectra (DRS) and PL spectra, it was found that with increase in temperature cadmium interstitial defects move towards the surface and after receiving enough energy they get oxidized. So, blue luminescence intensity corresponding to Cd-interstitials decreases with increase in temperature. Number of oxygen vacancies increase with ascending temperature resulting in increase of green luminescence intensity. From SQUID measurements, room temperature ferromagnetism (RTFM) was found whose origin can be assigned to formation of bound magnetic polarons (BMP).
Chapter V is based on discussion about oxygen vacancy generated optical and magnetic properties of CdO nanoparticles. CdO nanoparticles do not show good luminescence properties due to its small band gap. Good luminescence in CdO nanoparticles was realized by annealing them in vacuum environment (760 mm Hg). Annealing in vacuum creates more oxygen vacancies than annealing in air. Increase in oxygen vacancies is responsible for enhanced green photoluminescence in CdO nanoparticles. EPR spectra confirm presence of Cd$^+$ ions in pure CdO nanoparticles. Origin of RTFM in CdO nanoparticles can be attributed to BMP model.

Chapter VI discusses insertion of nanoparticles in diatom porous silica. Analyzing both CdSe and CdO nanoparticles, it was found that vacuum annealed CdO nanoparticles show enhanced luminescence as well as magnetic properties. Insertion of these nanoparticles into diatom frustule which are made up of porous silica can bring new possibilities of manufacturing devices like low cost light emitting diodes. A simple and cost effective method is proposed to combine DPS with nanoparticles. The combined structure of DPS with CdO nanoparticles shows good luminescence properties as well as good magnetic properties. This kind of combined structure is being studied for the first time.

Chapter VII summarizes the results that have been obtained and also discusses about possible future applications of the work done.