Chapter X

SUMMARY AND SUGGESTIONS FOR FUTURE WORK

Structuring of new materials for achieving specific functionality, are attracting a great deal of attention and is a challenge to scientists. Inorganic nanostructures are becoming ideal systems for revealing novel phenomena at the nanoscale leading towards a wide range of applications. Composites make up a very broad and important class of engineering materials. A nanocomposite is defined as a composite material where at least one of the dimensions of one of its constituents is on the nanometre size scale. Nanocomposite materials are complex of nanophase materials and other materials. Currently, we are striving to understand the behavior of just the smallest building blocks in such materials which are the natural versions of nanocomposites.

Nanotechnology is one of the most popular areas of scientific research, especially with regard to medical applications. Nanomaterials play a pivoting role in providing comfort and safety in anticancer activity. In recent years, an increasing number of nanomaterial’s products have been reported to display anticancer activities. Biological nanoscience has drawn increasing attention due to its avant-garde nature and the efficacy of produced nanoparticles in industrial, biomedical, and electronic applications such as catalyst, cancer detection and bioimaging.

In Chapter IV, the pure metal oxides of zinc and tin and pure metal sulphides of zinc and cadmium were successfully synthesized using the hydrothermal approach. This approach is simple and environmentally benign. The XRD analysis was carried out on all the four metal oxides and metal sulphides, their phase structures were determined and indexed to the respective JCPDS files. The lattice parameters and other data like crystallite size, average strain and dislocation density were calculated from XRD data. The focus is to study the samples in its pure form and to note structural, optical and photoconductivity properties of the metal oxides and metal sulphides. Thereby the properties can be compared to study its effectiveness as nanocomposites.

In Chapter V, ZnO-CdS nanocomposites were effectively synthesized by the hydrothermal method taking three different molar ratios. The variation in the nanocomposites by
changing the molar ratios was investigated. The powder XRD results demonstrate that the samples have peaks of both zin oxide and cadmium sulphide in the hexagonal phase. The XRD analyses were also used to study other characteristics like crystallite size, average strain and dislocation density. Additionally the size and strain contributions from the XRD peaks was also analysed by the Williamson-Hall method and a comparison was made between the two calculated data. The SEM analysis revealed the morphological features of the nanocomposites whereas the EDAX studies confirmed the presence of the elements. From the optical absorption spectra, the values of the band gaps of tin oxide and copper oxide were observed to exhibit a blue shifting which may be attributed to the quantum size confinement effect. FTIR revealed that the formation of ZnO-CdS nanocomposites. In addition, dielectric response was noted for various frequencies using LCR meter and photoconductivity of ZnO-CdS nanocomposite with respect to voltage shows the variation in photocurrent and dark current. It is seen that ZnO-CdS exhibits positive photoconductivity, the phenomenon attributed to the generation of mobile charge carriers caused by absorption of photons.

In Chapter VI, the facile hydrothermal method was used to synthesize ZnO-ZnS nanocomposites taking three different molar ratios [25:75 / 50:50 / 75:25]. From the XRD spectra of the nanocomposite system shows a clear set of diffraction peaks. A comparison of the parameters calculated using the Scherrer’s formula and the Williamson-Hall plot were tabulated. The absorption spectra of the as-prepared nanocomposites show blue shifts from the bulk peaks of ZnO and ZnS. The blue shift can be attributed to the transition of electron, mediated by oxygen vacancies. The elemental compositions of the ZnO-ZnS nanocomposites were analysed by EDAX and the studies confirm the existence of zinc, oxygen and sulphide species on the surface of the nanocomposites. The SEM micrographs revealed clusters of flakes found aggregated together but oriented differently. FTIR revealed that the formation of ZnO-ZnS nanocomposites. The responses of the nanocomposite materials were tested by the electrical analysis using an LCR meter. The dielectric response of the samples was recorded in air and we have studied photo conducting characteristics of ZnO-ZnS. Based on these readings various graphs were plotted and analyzed.

To summarize Chapter VII, the metal oxide nanocomposite of SnO$_2$-ZnS was prepared by the versatile hydrothermal method under three different ratios. Various characterizations were
carried out to study the materials synthesized. The XRD pattern confirmed the crystallization of the tetragonal phase of SnO$_2$ and in cubic phase of ZnS. The presence of tin oxide and zinc sulphide was however confirmed by EDAX and FTIR analysis. Further calculations like crystallite size, lattice strain and dislocation density were also reported from both the Scherrer and Williamson-Hall calculations. The excitation wavelengths were noted for all three ratios and in all three cases a blue shift was observed. The SEM micrographs gave an insight of the morphology of the nanocomposites that were investigated systematically by studying the three molar ratios. The pelletized nanocomposites where subjected to an electrical analysis using an LCR meter. The dielectric response of the samples was recorded in air and nanocomposite exhibited enhanced photo response characteristics using Keithley 6514 electrometer.

In Chapter VII, SnO$_2$-CdS nanocomposites were successfully synthesized by the hydrothermal method taking three different molar ratios of the precursors. The crystal structure of the nanocomposites was investigated and the peaks of both tin oxide with a tetragonal structure and cadmium sulphide in the hexagonal phase were observed and were found to vary according to the different ratios. A correlation of data like crystallite size and lattice strain acquired from the Scherrers’s formula and the Williamson-Hall plot were calculated and compared. The optical absorption of the nanocomposites in the wavelength range 300-1100 nm was investigated and found to exhibit a blue shift compared to the bulk oxides. The SEM and EDAX analysis gave an insight into the morphology and elemental composition for all three ratios of the nanocomposites. The pelletized nanocomposites were subjected to an electrical analysis using an LCR meter. The dielectric response of the samples was recorded in air and the photoresponse of a SnO$_2$-CdS is observed to be much greater than the dark current. Based on these readings various graphs were plotted and analyzed.

In the final chapter HepG2 cells were treated with different concentrations of (20, 40, 80, 100, 140 and 180 $\mu$g / ml) nanoparticles and their growth were monitored. The nanocomposites ZnO-CdS, ZnO-ZnS, SnO$_2$-ZnS and SnO$_2$-CdS decreased the viability of HepG2 cells in a dose-dependent manner. The maximum inhibition of cell growth (54 % with IC50) was observed at the concentration of 180 $\mu$g / ml of nanocomposite ZnO-ZnS and whereas inhibition of cell growth (49 %, 44 % and 39 % with IC50) was observed at the concentration of 180 $\mu$g / ml for the nanoparticles of SnO$_2$-ZnS, ZnO-CdS and SnO$_2$-CdS respectively.
The Cytotoxicity and Apoptotic activity of the nanocomposites were examined. The nanocomposites ZnO-CdS, ZnO-ZnS and SnO\textsubscript{2}-ZnS treated HepG2 cells (Human hepatocellular liver carcinoma cell line). The molecular mechanism of the nanoparticles ZnO-CdS, ZnO-ZnS and SnO\textsubscript{2}-ZnS induced apoptosis in the HepG2 cells; the expression levels of apoptosis-related genes were examined and reported.

With regards to characterisation techniques analysis like Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM) will throw more light on the morphology of the nanocomposites on a deeper level. Photocatalysts, because it rapidly generates electron-hole pairs under photo excitation, and exhibits a relatively high activity for H\textsubscript{2} production under UV light. Other tumor animal models could be used to further evaluate the therapeutic efficacy of these delivery systems in cancer treatment. In addition, a broader range of tumor types, such as prostate cancer, breast cancer, brain cancer, may be adopted to establish the versatile therapeutic effects of the developed nanoparticles.