Chapter-7

Conclusions and future outlook

This study is an effort to realize that soft chemistry method is a versatile route for the preparation of nanomaterials. Recently there are many developments in the preparation and use of nanoparticulate oxide materials, more specifically isolated nanoparticles of simple and compound oxides. The properties and applications of oxide nanomaterials are determined by the morphology and structure. Considerable efforts have been focused on the synthesis of novel nanostructures with tailored morphology. The ability of shape control over the crystals is still rather limited due to a lack in understanding the principles and mechanics about the formation of multi dimensional nanostructures.

The synthetic methods have many disadvantages and only a very few can be considered as “user-friendly”. Most of the methods require high temperature and solid templates. Majority of the raw materials used are extremely toxic, unstable and expensive. Some methods require sophisticated equipments and inert atmospheres. Also the reactions are not easy to control or to reproduce and have no diversity. Many of them generate a lot of pollutants harmful to the environment. Hence alternative routes should include less expensive and simpler approaches with diversity, which are environmentally benign. It is important to consider the consumption of raw materials and energy and the generation of waste when a synthesis procedure is designed whether it is an original one or an alternative approach. The significance of soft chemical synthesis is in this contest.

In this investigation we have adopted, soft chemical routes like sol-gel method and room temperature chemical precipitation for the synthesis of nanostructures of ferrites, vanadates, tungstates and phosphates with varying dimensionality. We have adopted these synthetic routes since these methods are eco-friendly, energy saving and highly reproducible. These ternary oxide materials are selected for the present study because of their inherent stability after synthesis and due to their potential applications in the fields of magnetism, catalysis and luminescence**.**

As a prelude to the study a detailed literature survey on nanomaterials was done and is presented in the first chapter. This chapter covers the general methods of synthesis, characterization, properties and applications of nanomaterials. The second chapter is a specific review on oxide materials. This chapter describes the structure and properties of ternary oxide materials like ferrites, vanadates, tungstates and phosphates. The various applications of the hetero oxides like copper ferrite, cobalt ferrite, silver vanadate, bismuth vanadate, lead tungstate, silver tungstate, barium tungstate, zinc phosphate and cobalt phosphate are also discussed in this chapter.

The third chapter describes the synthesis of copper ferrite and cobalt ferrite nanoparticles by sol-gel method. The methods used for the characterization, the VSM studies and the microwave dielectric and magnetic properties of the synthesized ferrite nanoparticles are also discussed in this chapter.

The fourth chapter deals with the synthesis of silver vanadate nanorods and bismuth vanadate nanobars by aqueous room temperature precipitation. The methods used for characterization and the visible light photocatalytic studies on the degradation of the dye, methylene blue are also discussed.

In the fifth chapter, the morphology tuning of various tungstate nanostructures with reaction conditions are described. The luminescence and optical study of snowflake-like tetragonal and bamboo leaf-like monoclinic $PbWO_4$ nanocrystals are being investigated. These studies are also extended to cactus and aloe-vera leaf-like $BaWO_4$ nanocrystals. Attempts to schematize the growth mechanism of various nanostructures are also being made in this investigation.

The synthesis of zinc orthophosphate and cobalt orthophosphate nanoplatelets by aqueous room temperature precipitation method, their characterization and property studies are described in the sixth chapter.

The synthesized nanomaterials are characterized by powder XRD, SEM, TEM, FESEM and AFM. The average crystallite sizes of the prepared metal oxides are found to be in the range 12-30 nm. Their thermal degradation studies are done using TGA-DTA. Studies on the magnetic, dielectric and optical properties of the synthesized oxide nanomaterials are investigated.

Our investigations reveal that the morphology of the oxide nanocrystalline materials can be tuned by adjusting the reaction conditions like solvent used, concentration of the reactants and pH of the medium. Magnetic studies of copper ferrite and cobalt ferrite nanocrystals show that they have a tendency towards superparamagnetic nature. Optical studies of monoclinic alpha silver vanadate nanorods and monoclinic bismuth vanadate nanobars show that they have low band gap compared to the other photocatalysts and can be used as efficient visible light photocatalysts. We have succeeded in tuning the morphologies of silver tungstate, lead tungstate and barium tungstate nanocrystals. We have also synthesized zinc orthophoshate and cobalt orthophosphate nanoplatelets by colloidal precipitation. The photoluminescence spectrum of zinc orthophosphate, shows an increase in the intensity of emission peak when it is doped with Mn^{2+}. This shows its potential as a phosphor in cathode tubes. VSM study reveals the paramagnetic nature of cobalt orthophosphate. We presume that the findings from this investigation are a modest contribution to the area of nanomaterial research based on hetero oxides.

Future outlook

One of the fundamental problems faced in nanoscience and nanotechnology is the difficulty in understanding the control of the growth of various nanostructures for ultimate device fabrication. The ability to manipulate the shape and control over the growth of nanostructures is a challenging task. In this context, a detailed investigation in to the dependence of pH, temperature and concentration on the growth of oxide nanomaterials can be explored considering their technological importance in the area of magnetism, luminescence and photocatalysis. Among the reported photocatalysts sensitive to visible light, $BiVO_4$ is an interesting material as it shows high activity for O_2 evolution with $AgNO_3$. However, they do not show any activity for H_2 evolution under visible light irradiation. It is well known that H_2 evolution is important to produce a clean energy source. Therefore a very practical and challenging subject is how to modify these vanadate materials as good candidates for clean energy source in future. Technological applications of oxides, containing nanocomposites can be taken up. Ferrites embedded in polymers can be used in magnetic devices. Magnetic and dielectric properties of ferrites doped with rare earths are another area to be investigated.