Chapter - 5

Summary and Suggestions for Future Work

5. SUMMARY AND SUGGESTIONS FOR FUTURE WORK

We provide here in this Chapter a summary of the present research work along with the conclusions derived. Some suggestions for future work are also provided.

5.1. Summary and Conclusions

Man has admired crystals ever since he realized the beauty and rarity of the crystals. The subject crystal growth and characterization forms a frontier area of research in science and technology, owing to their vivid physical and chemical properties. The availability of appropriate crystalline materials is a crucial factor for the development of advanced technologies as well as for breakthrough in applied and basic sciences.

Nonlinear optical (NLO) materials have a significant impact on laser technology, electro-optic modulation, optical communication and optical storage technology. Metal complexes of polarizable ligands are currently explored for their nonlinear optical properties. These have been commonly referred to as semiorganics, as their physical and chemical properties set them apart from the usual organic and inorganic materials. The search for new frequency conversion materials over the past decade has led to the discovery of many semiorganic materials. Semiorganics share advantages of both organic and inorganic materials, which include extended transparency, high optical nonlinearity, good mechanical hardness and chemical inertia.

Zinc tris(thiourea) sulphate, ZTS, is an efficient semiorganic nonlinear optical material for second harmonic generation. It has a high damage resistance and low UV cutoff of about 260 nm which makes it suitable for frequency conversion of high power lasers. Its second harmonic capability also makes it potentially useful for electro-optic applications.

Microelectronics industry needs replacement of dielectric materials in multilevel interconnect structures with new low dielectric constant (ε_r) materials. Impurity addition leads to change in properties. So, studies made on interesting dielectric materials added with different types of impurities are expected to bring fruitful results.

With an aim of discovering new useful dielectric materials, We have grown ZTS single crystals by the free evaporation method and investigated the effect of three impurities (urea, Ni^{2+} and Mg^{2+}) added with five different impurity concentrations in each case on various properties of it. A total of sixteen crystals were grown and characterized by different characterization techniques.

In order to reveal the crystalline perfection of the specimen crystals grown, high resolution X-ray diffraction (HRXRD) curves were recorded for selected crystals (only 1.0 mol % impurity added and pure ZTS). HRXRD analysis carried out shows that the incorporation of impurities changes the crystalline perfection. Urea added ZTS and Ni^{2+} added ZTS single crystals were found to have good crystalline perfection when compared to the Mg^{2+} added single crystals.

Density was measured by using the flotation technique. X-ray diffraction data were collected from the powder samples of the crystals using an automated X-ray diffractometer. The reflections were indexed and the lattice parameters were determined. These data were used to estimate the impurity concentration in the crystal. Atomic absorption spectroscopic measurements were also carried out on Ni^{2+} and Mg^{2+} added ZTS crystals to confirm the Ni and Mg atom contents. The microhardness measurements carried out on selected crystals (only 1.0 mol% impurity added and pure ZTS) show that the crystals grown are hard.

All the crystals grown are found to be stable and transparent. FT-IR spectral studies have been carried out on all the grown crystals. The important groups associated with the sample crystals were identified and their respective bands were assigned. Also, UV-Vis and photoluminescence (PL) spectral studies were carried out. In addition, the second harmonic generation (SHG) behaviour was analysed.

The SHG behaviour was found to be better than that of the standard KDP. All the crystals are found to be transparent to UV radiation in the wavelength region of 260-400 nm. Moreover, the present study indicates that the impurities do not change the UV spectrum of ZTS significantly. The PL spectral study (made on 1.0 mol % impurity added and pure ZTS crystals) indicates that the metal dopants (Ni^{2+} and Mg^{2+}) change the luminescence property of ZTS significantly.

AC electrical measurements were carried out along the three (a-, b- and c-) directions by the parallel plate capacitor method at various temperatures ranging from 40-150°C for a fixed frequency of 1 kHz. The dielectric parameters, viz. dielectric constant (ε_r), dielectric loss factor (tanδ), AC electrical conductivity (σ_{ac}) and AC activation energy (E_{ac}) were determined.

The dielectric parameters, viz. ε_r, $\tan\delta$ and σ_{ac} increase with the increase in temperature. However, all the dielectric parameters vary nonlinearly with impurity concentration which could be explained by considering the complex situation created by the impurity molecules in the dielectric phenomenon of ZTS crystals. The ε_r value is around 4.0 for some of the crystals grown which indicates that these crystals can be considered as low ε_r value dielectric materials. So, it can be expected that these crystals will be highly useful in microelectronics industries.

In effect, the present study indicates that ZTS is not only a potential NLO material but also a promising low ε_r value dielectric material.

5.2. Suggestions for Future Work

Crystal growth and characterization is an important branch of materials science having scientific as well as technological importance. Scientific research on crystal growth and characterization is normally constituted by the following:

(i) Nucleation and growth of crystals;

and (ii) Structural and physical characterization.

Technological research on crystal growth and characterization is normally constituted by the following:

(i) Growth of large crystals;

and (ii) Fabrication of devices with the grown crystals.

The present research work (reported in this thesis) is of scientific nature and not technological.

Several studies have been carried out in the present research work and several important results have been obtained. However, the present research work suggests that several studies are to be carried out in the future to understand the full potential of compounds with the general formula M [tu]X, where M = Zn, Cd, etc, X = Cl, SO_4, etc and tu = thiourea. That is, the search for low ε_r value dielectric materials can be done with crystals of all these materials. Moreover, the utility of the low ε_r value crystals of this kind can be understood by actually using them in the microelectronics industries. If necessary, large crystals also have to be grown.