CHAPTER 13

SUMMARY AND SUGGESTIONS FOR FUTURE WORK
13.1 Summary

Single crystals of SbI$_3$, AsI$_3$, BiI$_3$ and SbBr$_3$ were grown from vapour. They grow as platelets. In the case of crystals grown by the temperature oscillation method by oscillating the source zone temperature for SbI$_3$ vapour-liquid-solid mechanism of growth was found to take place whereas in the case of crystals grown by non-oscillatory method, the growth was initially of dendritic nature and proceeds by layer growth mechanism to end up as a platelet. It was also found that the growth of other crystals BiI$_3$, AsI$_3$ and SbBr$_3$ proceeds by layer growth process.

Sb$_2$S$_3$, Sb$_2$Se$_3$, Sb$_2$Te$_3$, Bi$_2$S$_3$, Bi$_2$Se$_3$, As$_2$S$_3$, As$_2$Se$_3$ and As$_2$Te$_3$ single crystals were grown from vapour. They grow both as platelets and needles depending upon the temperature difference between the two zones. Crystals of As$_2$Te$_3$, Sb$_2$Se$_3$, Bi$_2$S$_3$, Bi$_2$Se$_3$ show well developed faces of (010) and (110). Surface studies of Sb$_2$S$_3$ by SEM shows that the growth is initiated by layer growth mechanism.

Antimony chalcohalides like SbSI, SbSBr, SbSeBr, SbSeI and SbTeI were grown from vapour. They grow both as platelets and needles depending upon the temperature difference between the two zones. In the case of crystals grown by iodine transport, platelets of SbSI showing (110) faces have been obtained. SbSeI was found to grow only as needles, irrespective of change in growth parameters. Deficiency in selenium was found below 440°C and only above this temperature the crystals have stoichiometric composition. SbSBr, SbSeBr and
SbTel easily grow as platelets and show (110) faces. The size of the platelets decreased when the growth zone temperature was decreased in the case of SbSeBr.

Bismuth chalc halides like BiSI, BiSeI, BiSBr, BiSeBr were grown from vapour, both by oscillating the source zone temperature and without oscillating the source zone temperature. When the temperature difference between the two zones was high, polycrystalline boules were obtained. These crystals grow as platelets, showing (110) faces.

Larger size crystals of BiSeI were grown from vapour by temperature oscillation method. The crystals grown were of the dimension 25 mm x 8 mm x 6 mm. Crystals grown with excess BiI$_3$ were found to grow by vapour-liquid-solid mechanism. The surface features of the grown platelets show that the growth takes place by layer growth mechanism.

Arsenic chalcohalides easily form glasses and hence the difficulty in growing single crystals of these compounds. AsSeI glass was crystallized by isothermal annealing in the present investigation. The grain morphology was found to depend upon the annealing time. It is found that -AsSeI, -AsSeI and As$_2$Se$_3$ nucleates and finally -AsSeI, is formed due to the mixing of -AsSeI and As$_2$Se$_3$ with -AsSeI.

Whiskers of Sb$_2$S$_3$, Sb$_2$Se$_3$, SbSeBr and SbSeI were grown from vapour. Antimony chalcocalide whiskers were found to grow by vapour-liquid-solid mechanism. They also show kinking and bending during the growth.

Hollow crystals of As$_2$Te$_3$, Sb$_2$S$_3$-Sb$_2$Se$_3$, Bi$_2$Se$_2$S, SbSI, BiSI, BiSeI, SbSeBr and SbSeI were also grown for the first time. Hollow crystals show both open and closed lateral surfaces. A possible growth mechanism of these crystals were also discussed.
Microhardness studies of chalcogenides chalcohalides of arsenic, antimony and bismuth were also reported in the present investigation. It was found that the microhardness increases with increase of load for single crystals and decreases with increase of load for glassy compounds. The microhardness value was also correlated with energy gap and found to have a good empirical relation.

Etchants like ethanol, methanol, and mixture of both were found to etch SbSI type compounds. These etchants produced triangular etch pits and the size of the etch pits was found to depend upon the etching time.

13.2 Suggestion for future work

A detailed study on the experimental part regarding the nucleation kinetics of SbSI type compounds comprising the relation with composition of the constituents for maximum growth rate, the temperature corresponding to the maximal growth is necessary. Temperature oscillation method was found to be effective in the bismuth chalcohalides to grow larger size crystals in the present investigation. But SbSI and SbSeI grow only as needles and small platelets of SbSI was obtained with difficulty. So, experimental conditions should be established to improve the size of the crystals by TOM.

Reports on growth aspects of arsenic chalcohalides are very less since they form glasses easily. There is also little study on their properties and elaborate study on them will reveal interesting results.
ESCA/AUGER studies near the phase transition temperature will be very much useful in understanding the mechanism involved during the phase transition. Though microhardness studies have been done in the present investigation, it will also be interesting to study the same for crystals grown by different methods. This will give some idea regarding the variation of the physical properties of crystals grown by different methods.