CHAPTER 6

SUMMARY AND SUGGESTIONS FOR FUTURE WORK

6.1 SUMMARY OF THE WORK

Liquid Phase Electroepitaxy (LPEE) is a novel technique for the growth of compositionally uniform, low dislocation with controlled thickness of II-VI, III-V, ferroelectric and garnet epitaxial layers suitable for device fabrication. In this technique, growth is carried out by passing an electric current through substrate-solution interface while the temperature of the whole system is kept constant. The two major factors influencing the growth are Peltier effect and electromigration.

In the present work, the author presented a model on the nucleation kinetics of epitaxial layers during LPEE growth process. The model is based on the two dimensional nucleation model. Expressions for the critical nucleation parameters have been generated.

The one dimensional diffusion and electromigration model based on the transport equation has been developed and solved numerically. The model has been extended to binary GaAs, InP, InAs and GaSb systems. Concentration profiles of the solute atoms have been constructed using computer simulation technique. The influence of Peltier cooling or Peltier heating and electromigration have been studied to understand the growth mechanism of these compounds. The concentration of the solute atoms decreases near the growth interface as the growth proceeds during Peltier cooling conditions whereas during Peltier heating conditions, the dissolution causes an increase in the concentration of the solute atoms near the
substrate-solution interface. Growth rate and thickness of the epitaxial layers have been determined in the absence and presence of convection. It is found that in the absence of convection, the contribution to the growth rate by electromigration is higher compared to Peltier effect. Also, the contribution due to Peltier effect to growth rate is found to vary as function of $t^{1/2}$. In the presence of convection, the growth rate is dominated by Peltier effect due to the formation of solute boundary layers near the growth interface. Thickness of the epitaxial layers have been calculated for all the binary systems. The theoretically calculated values have been compared with the experimentally reported values and the results are found to be in good agreement.

The diffusion and electromigration limited model has been extended to ternary InGaAs, AlGaSb and InAsP systems. Composition of the solute atoms (Ga and As in In rich melt for InGaAs), (Al and Sb in Ga rich for AlGaSb) and (As and P in In rich melt for InAsP) have been determined and simulated for different growth conditions. A model has been developed to determined the new composition based on the solidification path using the phase diagram relationships. Growth rate and thickness of the epitaxial layers have been calculated for different growth conditions. Solid composition of the constituent binary alloys have been determined for various conditions.

A two dimensional model has been developed for better understanding of the growth process. Expression for the heat conduction, electric current under steady conditions and mass transfer in a cylinder growth system have been presented. Concentration profiles of As atoms have been constructed using computer simulation technique for different growth conditions such as time, electric field etc. The depletion of the concentration of the solute atoms have been observed near the interface when the growth is carried out by LPEE process.
6.2 SUGGESTIONS FOR FUTURE WORK

Since liquid phase electro-epitaxial technique is emerging as one of the prominent techniques for the growth of compositionally uniform, low dislocation alloy semiconductors, extensive work on the growth of binary, ternary and quaternary III-V compound semiconductors have been reported by various researchers. The author has made an attempt to understand the growth kinetics of some of the binary and ternary III-V semiconductors based on the diffusion and electromigration. However, a detailed study is necessary to fully understand the fundamentals of nucleation process and growth kinetics of epitaxial growth. There are no exact data on the magnitude of change in interface temperature available in the literature. The effect of Joule heating, influence of resistivity of the whole system, electrical properties of the grown epitaxial layers, ambient conditions, have not been reported so far. Due to lack of data available in the literature, it is very difficult to carry out a detailed study of the growth process by incorporating all the experimental parameters. However, a systematic investigation has to be carried out to fully understand the growth mechanism. Further research in this novel technique can be carried out in the following topics. A few suggestions are stated below.

* The model can be extended to quaternary III-V compound semiconductors to understand the growth mechanism during LPEE growth process.

* The two dimensional model to other binary and ternary systems can be extended.

* Three dimensional model for direct analysis of the growth process and its comparison with the related experimental set-up.
The growth mechanism of II-VI semiconductors, ferroelectric, garnets can be analysed by modifying the existing model.

Investigations on the dopant segregation during LPEE growth can be carried out.

Attempts can be made to fully understand the dependence of interface kinetics of the growth process on the applied current density.

The influence of convection during growth of epitaxial layers can be analysed.

The effect of substrate thickness and its orientation on the growth can be investigated.