Preface

III-V compound semiconductor devices have the advantages of higher operating speed and lower power consumption compared to conventional silicon devices Some of them have a direct band gap Hence, III-V semiconductors are widely used in optoelectronic devices such as solar cells, light emitting diodes, and semiconductor lasers They are also used in high speed digital circuits realised in GaAs, and in heterostructure-based devices that are even faster (still under development)

For the better performance of devices, the materials should be of high purity, defect free, and should have other properties depending upon the requirement of device features This is often achieved to a greater degree in epitaxial films than in single crystal substrates A number of techniques are available to grow epitaxial layers, such as, liquid phase epitaxy (LPE), molecular beam epitaxy (MBE) and metalorganic vapor phase epitaxy (MOVPE) MBE and MOVPE are capable of meeting the stringent requirements of interface abruptness and layer purity required for many device applications, whereas abrupt interfaces are difficult to obtain by LPE However, MBE is an expensive and low throughput process The MOVPE process is more flexible, and growth at higher rates can be obtained in relatively simple reactors This process is also scaleable and well suited for large scale device fabrication

High quality layers, i e, of uniform thickness and composition and, with smooth surface, are necessary for the batch fabrication of devices Hence, these characteristics of GaAs layers, grown predominantly by LPE and MBE, have been studied and reported However, only limited reports are available on the morphology of GaAs epilayers grown by low pressure-MOVPE, and no such study has been reported on epilayers grown by atmospheric pressure MOVPE

While GaAs is widely used for discrete and intergrated microwave devices, $Al_xGa_{1-x}As$ is a crucial material for optoelectronics as well as for heterostructure devices This is because the band gap can be tailored by varying x, and because of the close lattice match with GaAs for all values of x from 0 to 1 The MOVPE process has also been extended to the growth of AlGaAs and of GaAs/AlGaAs heterostructures

We have therefore undertaken in this thesis a study of certain aspects of the epitaxial growth of GaAs and AlGaAs by MOVPE

The surface morphology of GaAs grown by MOVPE, as well as the nature and extent of defects in such layers, has been found to depend on the various growth parameters, the most important of them being the molar ratio (V/III) of the reactants during growth Relatively high V/III ratios are required to obtain good quality epilayers This is because arsenic is a more volatile element, and excess partial pressure of arsenic is required during epitaxial growth to maintain the stoichiometry in GaAs We have therefore studied the growth rate, surface morphology, and optical quality of GaAs layers grown by atmospheric pressure MOVPE, as V/III ratio was varied from 5 to 37

Temperature of epitaxial growth is significant especially in the case of AlGaAs because, during growth of GaAs/AlGaAs heterostructures, the abruptness of the interface is likely to be affected The growth temperature is also an important parameter in the formation of defects in AlGaAs layers As such, we have studied the growth and characteristics of epilayers of $Al_{0\ 32}Ga_{0\ 68}As$ grown by atmospheric pressure MOVPE

The organization of the thesis is as follows

An introduction to the epitaxial growth of III-V semiconductors by MOVPE is provided in Chapter I A survey of the literature relevant to the development of surface morphology and defects in such epilayers has also been provided here In particular, the link between substrate orientation, V/III ratio, and surface morphology is discussed in detail

Chapter II is devoted to a detailed description of the experimental aspects of this work The various aspects of the epilayer growth, such as the MOVPE reactor, substrate preparation , and control of growth parameters are discussed at length The tools and techniques used in the characterizations of the epilayers grown, such as microscopy, Hall measurements, photoluminescence (PL) are discussed in the latter half of the chapter

Finally, the results of the investigation undertaken here are discussed in Chapter III, starting with the surface morphology and defects observed in GaAs as a function of the V/III ratio *A significant conclusion is offered in this regard* The results of extensive PL studies are then discussed, and linked to the surface morphology observed The Hall and PL measurements on AlGaAs epilayers are then discussed, noting that no significant new result on the effect of growth temperature on such epılayers has been observed Fınally, a few comments are offered on the scope for further work regardıng the effect of the V/III ratıo on the propertıes of III-V epılayers grown by MOVPE

Part of thıs work has been reported/presented as lısted below

1 *Morphologıcal and Electrıcal Varıatıons ın Epıtaxıal GaAs due to V/III Ratıo Changes Durıng Growth By MOCVD*, ın **Proc of the Conference on Emergıng Optoelectronıc Technologies,** Shashı Paul, S K Agarwal, Mahavır Sıngh , M V G Padmavatı, Renu Tyagı, and S A Shıvashankar, Ed A Selvarajan, B S Sonde , K Shenaı, and V K Trıpathı, (Tata McGra-Hıll Publıshıng Company Ltd , New Delhı, 1994), pp **244-247**

2 *Effect of V/III Ratıo on Surface Morphology and Photolumınescence ın GaAs grown by Atmospherıc pressure MOVPE* Shashı Paul and S A Shıvashankar, (presented at the Wınter School on Quantum Optoelectronıcs held at the Tata Instıtute of Fundamental Research, Bombay, January, 1995)