Molecular Beam Epitaxy

Molecular Beam EpitaxyFrom Research to Mass ProductionElsevier

This first-ever monograph on molecular beam epitaxy (MBE) gives a comprehensive presentation of recent developments in MBE, as applied to crystallization of thin films and device structures of different semiconductor materials. MBE is a high-vacuum technology characterized by relatively low growth temperature, ability to cease or initiate growth abruptly, smoothing of grown surfaces and interfaces on an atomic scale, and the unique facility for in situ analysis of the structural parameters of the growing film. The excellent exploitation parameters of such MBE-produced devices as quantum-well lasers, high electron mobility transistors, and superlattice avalanche photodiodes have caused this technology to be intensively developed. The main text of the book is divided into three parts. The first presents and discusses the more important problems concerning MBE equipment. The second discusses the physico-chemical aspects of the crystallization processes of different materials (mainly semiconductors) and device structures. The third part describes the characterization methods which link the physical properties of the grown film or structures with the technological parameters of the crystallization procedure. Latest achievements in the field are emphasized, such as solid source MBE, including silicon MBE, gas source MBE, especially metalorganic MBE, phase-locked epitaxy and atomic-layer epitaxy, photoassisted molecular layer epitaxy and migration enhanced epitaxy.

The book considers the main growth-related phenomena occurring during epitaxial growth, such as thermal etching, doping, segregation of the main elements and impurities, coexistence of several phases at the crystal surface and segregation-enhanced diffusion. It is complete with tables, graphs and figures, which allow fast determination of suitable growth parameters for practical applications.

Volume II

Thin Film and Nanostructure Texture Analysis

Molecular Beam Epitaxy and Heterostructures

Growth and Properties of Phosphorus Containing III-V Heterostructures

III-nitride

The book is a history of Molecular Beam Epitaxy (MBE) as applied to the growth of semiconductor thin films (note that it does not cover the subject of metal thin films). It begins by examining the origins of MBE, first of all looking at the nature of molecular beams and considering their application to fundamental physics, to the development of nuclear magnetic resonance and to the invention of the microwave MASER. It shows how molecular beams of silane (SiH4) were used to study the nucleation of silicon films on a silicon substrate and how such studies were extended to compound semiconductors such as GaAs. From such surface studies in ultra-high vacuum the technique developed into a method of growing high quality single crystal films of a wide range of semiconductors. Comparing this with earlier evaporation methods of deposition and with other epitaxial deposition methods such as liquid phase and vapour phase epitaxy (LPE and VPE). The text describes the development of MBE machines from the early 'home-made' variety to that of commercial equipment and show how MBE was gradually refined to produce high quality films with atomic dimensions. This was much aided by the use of various in-situ surface analysis techniques, such as reflection high energy electron diffraction (RHEED) and mass spectrometry, a feature unique to MBE. It looks at various modified versions of the basic MBE process, then proceed to describe their application to the growth of so-called 'low-dimensional structures' (LDS) based on ultra-thin heterostructure films with thickness of order a few molecular monolayers. Further chapters cover the growth of a wide range of different compounds and describe their application to fundamental physics and to the fabrication of electronic and opto-electronic devices. The authors study the historical development of all these aspects and emphasise both the (often unexpected) manner of their discovery and development and the unique features which MBE brings to the growth of extremely complex structures with monolayer accuracy.

In this volume, the editor and contributors describe the use of molecular beam epitaxy (MBE) for a range of key materials systems that are of interest for both technological and fundamental reasons. Prior books on MBE have provided an introduction to the basic concepts and techniques of MBE and emphasize growth and characterization of GaAs-based structures. The aim in this book is somewhat different; it is to demonstrate the versatility of the technique by showing how it can be utilized to prepare and explore a range of distinct and diverse materials. For each of these materials systems MBE has played a key role both in their development and application to devices.

This subject is divided into two volumes. Volume I is on homoepitaxy with the necessary systems, techniques, and models for growth and dopant incorporation. Three chapters on homoepitaxy are followed by two chapters describing the different ways in which MBE may be applied to create insulator/Si stackings which may be used for three-dimensional circuits. The two remaining chapters in Volume I are devoted to device applications. The first three chapters of Volume II treat all aspects of heteroepitaxy with the exception of the epitaxial insulator/Si structures already treated in volume I.

Silicon Molecular Beam Epitaxy

Proceedings of the 3rd International Symposium on Silicon Molecular Beam Epitaxy, Symposium A of the 1989 E-MRS Conference, Strasbourg, France, 30 May-2 June 1989

Proceedings

Molecular Beam Epitaxy

Molecular Beam Epitaxy Growth and Characterization of ZnO-based Layers and Heterostructures

Covers both the fundamentals and the state-of-the-art technology used for MBE Written by expert researchers working on the frontlines of the field, this book covers fundamentals of Molecular Beam Epitaxy (MBE) technology and science, as well as state-of-the-art MBE technology for electronic and optoelectronic device applications. MBE applications to magnetic semiconductor materials are also included for future magnetic and spintronic device applications. Molecular Beam Epitaxy: Materials and Applications for Electronics and Optoelectronics is presented in five parts: Fundamentals of MBE; MBE technology for electronic devices application; MBE for optoelectronic devices; Magnetic semiconductors and spintronics devices; and Challenge of MBE to new materials and new researches. The book offers chapters covering the history of MBE; principles of MBE and fundamental mechanism of MBE growth; migration enhanced epitaxy and its application; quantum dot formation and selective area growth by MBE; MBE of III-nitride semiconductors for electronic devices; MBE for Tunnel-FETs; applications of III-V semiconductor quantum dots in optoelectronic devices; MBE of III-V and III-nitride heterostructures for optoelectronic devices with emission wavelengths from THz to ultraviolet; MBE of III-V semiconductors for mid-infrared photodetectors and solar cells; dilute magnetic semiconductor materials and ferromagnet/semiconductor heterostructures and their application to spintronic devices; applications of bismuth-containing III–V semiconductors in devices; MBE growth and device applications of Ga2O3; Heterovalent semiconductor structures and their device applications; and more. Includes chapters on the fundamentals of MBE Covers new challenging researches in MBE and new technologies Edited by two pioneers in the field of MBE with contributions from well-known MBE authors including three Al Cho MBE Award winners Part of the Materials for Electronic and Optoelectronic Applications series Molecular Beam Epitaxy: Materials and Applications for Electronics and Optoelectronics will appeal to graduate students, researchers in academia and industry, and others interested in the area of epitaxial growth.

The first book to present a unified treatment of hybrid source MBE and metalorganic MBE. Since metalorganic MBE permits selective area growth, the latest information on its application to the INP/GaInAs(P) system is presented. This system has been highlighted because it is one of rising importance, vital to optical communications systems, and has great potential for future ultra-highspeed electronics. The use of such analytical methods as high resolution x-ray diffraction, secondary ion mass spectroscopy, several photoluminescence methods, and the use of active devices for materials evaluation is shown in detail.

The objective of the research supported by the grant to grow epitaxial III-V semiconductor films using gaseous source materials for molecular beam epitaxy (MBE). The grant provides the critical equipment items needed to customize an existing commercial MBE system and allow growth of heteroepitaxial structures that can not be fabricated by other existing techniques.

Optoelectronic Devices

Molecular Beam Epitaxy of Three Dimensional Topological Insulator Bi?se? Thin Films

Molecular Beam Epitaxy of Aluminum Gallium Arsenide on Channeled Substrates

Proceedings of the Second International Symposium on Silicon Molecular Beam Epitaxy

Fundamentals and Current Status

The atomic arrangement and subsequent properties of a material are determined by the type and conditions of growth leading to epitaxy, making control of these conditions key to the fabrication of higher quality materials. Epitaxial Growth of Complex Metal Oxides reviews the techniques involved in such processes and highlights recent developments in fabrication quality which are facilitating advances in applications for electronic, magnetic and optical purposes. Part One reviews the key techniques involved in the epitaxial growth of complex metal oxides, including growth studies using reflection high-energy electron diffraction, pulsed laser deposition, hybrid molecular beam epitaxy, sputtering processes and chemical solution deposition techniques for the growth of oxide thin films. Part Two goes on to explore the effects of strain and stoichiometry on crystal structure and related properties, in thin film oxides. Finally, the book concludes by discussing selected examples of important applications of complex metal oxide thin films in Part Three. Provides valuable information on the improvements in epitaxial growth processes that have resulted in higher quality films of complex metal oxides and further advances in applications for electronic and optical purposes Examines the techniques used in epitaxial thin film growth Describes the epitaxial growth and functional properties of complex metal oxides and explores the effects of strain and defects

The NATO Advanced Study Institute on "Molecular Beam Epitaxy (MBE) and Heterostructures" was held at the Ettore Majorana Center for Scientific Culture, Erice, Italy, on March 7-19, 1983, the second course of the International School of Solid-State Device Re search. This volume contains the lectures presented at the Institute. Throughout the history of semiconductor development, the coupling between processing techniques and device structures for both scientific investigations and technological applications has time and again been demonstrated. Newly conceived ideas usually demand the ultimate in existing techniques, which often leads to process innova tions. The emergence of a process, on the other hand, invariably creates opportunities for device improvement and invention. This intimate relationship between the two has most recently been witnessed in MBE and heterostructures, the subject of this Institute. This volume is divided into several sections. Chapter 1 serves as an introduction by providing a perspective of the subject. This is followed by two sections, each containing four chapters, Chapters 2-5 addressing the principles of the MBE process and Chapters 6-9 describ ing its use in the growth of a variety of semiconductors and heteros tructures. The next two sections, Chapters to-II and Chapters 12-15, treat the theory and the electronic properties of the heterostructures, respectively. The focus is on energy quantization of the two dimensional electron system. Chapters 16-17 are devoted to device structures, including both field-effect transistors and lasers and detec tors.

Tremendous progress has been made in the last few years in the growth, doping and processing technologies of the wide bandgap semiconductors. As a result, this class of materials now holds significant promis for semiconductor electronics in a broad range of applications. The principal driver for the current revival of interest in III-V Nitrides is their potential use in high power, high temperature, high frequency and optical devices resistant to radiation damage. This book provides a wide number of optoelectronic applications of III-V nitrides and covers the entire process from growth to devices and applications making it essential reading for those working in the semiconductors or microelectronics. Broad review of optoelectronic applications of III-V nitrides

Molecular Beam Epitaxy ...
Volume I
Proceedings of the Molecular Beam Epitaxy Workshop ; 5
Molecular Beam Epitaxy of III-V Compounds
A Short History

Molecular Beam Epitaxy (MBE): From Research to Mass Production, Second Edition, provides a comprehensive overview of the latest MBE research and applications in epitaxial growth, along with a detailed discussion and 'how to' on processing molecular or atomic beams that occur on the surface of a heated crystalline substrate in a vacuum. The techniques addressed in the book can be deployed wherever precise thin-film devices with enhanced and unique properties for computing, optics or photonics are required. It includes new semiconductor materials, new device structures that are commercially available, and many that are at the advanced research stage. This second edition covers the advances made by MBE, both in research and in the mass production of electronic and optoelectronic devices. Enhancements include new chapters on MBE growth of 2D materials, Si-Ge materials, AIN and GaN materials, and hybrid ferromagnet and semiconductor structures. Condenses the fundamental science of MBE into a modern reference, speeding up literature review Discusses new materials, novel applications and new device structures, grounding current commercial applications with modern understanding in industry and research Includes coverage of MBE as mass production epitaxial technology and how it enhances processing efficiency and throughput for the semiconductor industry and nanostructured semiconductor materials research community

Molecular Beam Epitaxy introduces the reader to the use of molecular beam epitaxy (MBE) in the generation of III-V and IV-VI compounds and alloys and describes the semiconductor and integrated optics reasons for using the technique. Topics covered include semiconductor superlattices by MBE; design considerations for MBE systems; periodic doping structure in gallium arsenide (GaAs); nonstoichiometry and carrier concentration control in MBE of compound semiconductors; and MBE techniques for IV-VI optoelectronic devices. The use of MBE to fabricate integrated optical devices and to study semiconductor surface and crystal physics is also considered. This book is comprised of eight chapters and opens with an overview of MBE as a crystal growth technique. The discussion then turns to the deposition of semiconductor superlattices of GaAs by MBE; important factors that must be considered in the design of a MBE system such as flux uniformity, crucible volume, heat shielding, source baffling, and shutters; and control of stoichiometry deviation in MBE growth of compound semiconductors, along with the effects of such deviation on the electronic properties of the grown films. The following chapters focus on the use of MBE techniques for growth of IV-VI optoelectronic devices; for fabrication of integrated optical devices; and for the study of semiconductor surface and crystal physics. The final chapter examines a superlattice consisting of a periodic sequence of ultrathin p- and n-doped semiconductor layers, possibly with intrinsic layers in between. This monograph will be of interest to chemists, physicists, and crystallographers.

This two-volume work covers recent developments in the single crystal growth, by molecular beam epitaxy, of materials compatible with silicon, their physical characterization, and device application. Papers are included on surface physics and related vacuum synthesis techniques such as solid phase epitaxy and ion beam epitaxy. A selection of contents: Volume I. SiGe Superlattices. SiGe strained layer superlattices (G. Abstreiter). Optical properties of strained GeSi superlattices grown on (001)Ge (T.P. Pearsall et al.). Growth and characterization of SiGe atomic layer superlattices (J.-M. Baribeau et al.). Optical properties of perfect and imperfect SiGe superlattices (K.B. Wong et al.). Confined phonons in stained short-period (001) Si/Ge superlattices (W. Bacsa et al.). Calculation of energies and Raman intensities of confined phonons in SiGe strained layer superlattices (J. White et al.). Rippled surface topography observed on silicon molecular beam epitaxial and vapour phase epitaxial layers (A.J. Pidduck et al.). The 698 meV optical band in MBE silicon (N. de Mello et al.). Silicon Growth Doping. Dopant incorporation kinetics and abrupt profiles during silicon molecular beam epitaxy (J.-E. Sundgren et al.). Influence of substrate orientation on surface segregation process in silicon-MBE (K. Nakagawa et al.). Growth and transport properties of SimSb1 (H. Jorke, H. Kibbel). Author Index. Volume. II. In-situ electron microscope studies of lattice mismatch relaxation in GexSi1-x/Si heterostructures (R. Hull et al.). Heterogeneous nucleation sources in molecular beam epitaxy-grown GexSi1-x/Si strained layer superlattices (D.D. Perovic et al.). Silicon Growth. Hydrogen-terminated silicon substrates for low-temperature molecular beam epitaxy (P.J. Grunthaner et al.). Interaction of structure with kinetics in Si(001) homoepitaxy (S. Clarke et al.). Surface step structure of a lens-shaped Si(001) vicinal substrate (K. Sakamoto et al.). Photoluminescence characterization of molecular beam epitaxial silicon (E.C. Lightowlers et al.). Doping. Boron doping using compound source (T. Tatsumi). P-type delta doping in silicon MBE (N.L. Mattey et al.). Modulation-doped superlattices with delta layers in silicon (H.P. Zeindell et al.). Steep doping profiles obtained by low-energy implantation of arsenic in silicon MBE layers (N. Djebbar et al.). Alternative Growth Methods. Limited reaction processing: growth of Si/Si1-xGex for heterojunction bipolar transistor applications (J.L. Hoyt et al.). High gain SiGe heterojunction bipolar transistors grown by rapid thermal chemical vapor deposition (M.L. Green et al.). Epitaxial growth of single-crystalline Si1-xGex on Si(100) by ion beam sputter deposition (F. Meyer et al.). Phosphorus gas doping in gas source silicon-MBE (H. Hirayama, T. Tatsumi). Devices. Narrow band gap base *heterojunction bipolar transistors using SiGe alloys (S.S. Iyer et al.). Silicon-based millimeter-wave integrated circuits (J-F. Luy). Performance and processing line integration of a silicon molecular beam epitaxy system (A.A. van Gorkum et al.). Silicides. Reflection high energy electron diffraction study of Cosi2/Si multilayer structures (Q. Ye at al.). Epitaxy of metal silicides (H. von Kanel et al.). Epitaxial growth of ErSi2 on (111)si (D. Loretto et al.). Other Material Systems. Oxygen-doped and nitrogen-doped silicon films prepared by molecular beam epitaxy (M. Tabe et al.). Properties of diamond structure SnGe films grown by molecular beam epitaxy (A. Harwit et al.). Si-MBE: Prospects and Challenges. Prospects and challenges for molecular beam epitaxy in silicon very-large-scale integration (W. Eccleston). Prospects and challenges for SiGe strained-layer epitaxy (T.P. Pearsall). Author Index.*

III-nitrides

Growth Processes and Surface Phase Equilibria in Molecular Beam Epitaxy

Papers from the 16th North American Conference on Molecular Beam Epitaxy

Gas-source Molecular Beam Epitaxy Growth of GaN with a Nitrogen Radical Beam and Ammonia

The Epitaxial Growth of CaF2/Si Heterostructures by Molecular Beam Epitaxy

This dissertation, "Molecular Beam Epitaxy of Three Dimensional Topological Insulator Bi_2Se_3 Thin Films" by Xin, Guo, □□, was obtained from The University of Hong Kong (Pokfulam, Hong Kong) and is being sold pursuant to Creative Commons: Attribution 3.0 Hong Kong License. The content of this dissertation has not been altered in any way. We have altered the formatting in order to facilitate the ease of printing and reading of the dissertation. All rights not granted by the above license are retained by the author. Abstract: In this thesis, molecular-beam epitaxy (MBE) of three-dimensional (3D) topological insulator (TI) Bi_2 Se_3 thin films on different substrates is presented. The substrates experimented include InP(111)A, GaAs(111)A, InP(001) and GaAs(001). Multiple characterization techniques are employed to investigate the film's structural, morphological and electrical properties. To facilitate growth of high quality epitaxial Bi_2 Se_3, thermal treatment of the substrate surfaceturnsout to be crucial for both InP(001) and InP(111). On the other hand, for high-index epitaxial Bi_2 Se_3 growth on GaAs(001), the In_2 Se_3 buffer layer has to be employed. Twin defects in epitaxial Bi_2 Se_3 (111) thin films on hexagonal substrates have been found inevitable in the past. In this study, however, such defects are successfully suppressed on InP(111)A and GaAs(111)Asubstrates, as evidenced in electron diffraction and morphological measurements. The prerequisite for the twin-free Bi_2 Se_3 (111) epitaxy appears to be the step-flow growth mode on the purposely treated stepped substrate surfaces, where deposits incorporate in film at step edges. The lattice of InP or GaAs substrate then plays a guiding role for epitaxial Bi_2 Se_3. Twin suppression is also seen to occur for growth on vicinal and islanded InP(111)A substrate, where a high density of steps inherently exists on surface. Transport studies on such single-domain Bi2Se3epifilms show superior electronic characteristics when compared to those of twinned films grown on, e.g., Si(111). The Shubnikov-de Haas (SdH)oscillations due to bulk state Landau quantization are observed in the magnetoresistance (MR) measurements of Bi_2 Se_3films grown on InP(111)A. So far, a majority of experimental work of 3D TIs is exclusively on the (111) surfaces, primarily due to the ease to obtain such a surface by cleavage or by growth. On the other hand, for strong topological insulator, nontrivial surface states are expected to exist on other surfaces as well, which remain to be experimentally confirmed. In this study, a high-index epitaxial Bi_2 Se_3is achieved by epitaxial growth on facetted InP(001) substrate. The latter is obtained by a cautious thermal treatment of the substrate wafer under Se flux, where the rhombohedral In_2 Se_3buffer layer forms, facilitating the growth of Bi_2 Se_3 (221) film.Such a high index Bi_2 Se_3 film is evidenced by low-energy electron diffraction (LEED), reflection high-energy electron diffraction (RHEED) and x-ray diffraction (XRD) measurements. The unique strapped morphology on Bi_2 Se_3 (221) surface is revealed by scanning tunneling microscopy (STM). Angle-resolved photoemission spectroscopy (ARPES) measurements unambiguously show the Dirac surface states elucidating the 3D topological nature ofBi_2 Se_3. Significantly, constant energy plot shows an anisotropic Fermi surface, being ofellipticalshape, which qualitatively agrees with the theoretical calculation. Transport studies of such Bi_2 Se_3(221) films reveal the ratio of conductivities along directions parallel and transverse the van der Waals (vdW) gaps to be as high as 4.4. DOI: 10.5353/th_b5153683 Subjects: Molecular beam epitaxy Thin films

III-Nitride semiconductor materials OCo (Al, In, Ga)N OCo are excellent wide band gap semiconductors very suitable for modern electronic and optoelectronic applications. Remarkable breakthroughs have been achieved recently, and current knowledge and data published have to be modified and upgraded. This book presents the new developments and achievements in the field. Written by renowned experts, the review chapters in this book cover the most important topics and achievements in recent years, discuss progress made by different groups, and suggest future directions. Each chapter also describes the basis of theory or experiment. The III-Nitride-based industry is building up and new economic developments from these materials are promising. It is expected that III-Nitride-based LEDs may replace traditional light bulbs to realize a revolution in lighting. This book is a valuable source of information for engineers, scientists and students working towards such goals. Sample Chapter(s). Chapter 1: Hydride Vapor Phase Epitaxy of Group III Nitride Materials (540 KB). Contents: Hydride Vapor Phase Epitaxy of Group III Nitride Materials (V Dmitriev & A Usikov); Planar MOVPE Technology for Epitaxy of III-Nitride Materials (M Dauelsberg et al.); Close-Coupled Showerhead MOCVD Technology for the Epitaxy of GaN and Related Materials (E J Thrush & A R Boyd); Molecular Beam Epitaxy for III-N Materials (H Tang & J Webb); Growth and Properties of Nonpolar GaN Films and Heterostructures (Y J Sun & O Brandt); Indium-Nitride Growth by High-Pressure CVD: Real-Time and Ex-Situ Characterization (N Dietz); A New Look on InN (L-W Tu et al.); Growth and Optical/Electrical Properties of Al x Ga

1-x N Alloys in the Full Composition Range (F Yun); Optical Investigation of InGaN/GaN Quantum Well Structures Grown by MOCVD (T Wang); Clustering Nanostructures and Optical Characteristics in InGaN/GaN Quantum-Well Structures with Silicon Doping (Y-C Cheng et al.); III-Nitrides Micro- and Nano-Structures (H M Ng & A Chowdhury); New Developments in Dilute Nitride Semiconductor Research (W Shan et al.). Readership: Scientists; material growers and evaluators; device design, processing engineers; postgraduate and graduate students in electrical & electronic engineering and materials engineering.

This unique book covers the fundamental principle of electron diffraction, basic instrumentation of RHEED, definitions of textures in thin films and nanostructures, mechanisms and control of texture formation, and examples of RHEED transmission mode measurements of texture and texture evolution of thin films and nanostructures. Also presented is a new application of RHEED in the transmission mode called RHEED pole figure technique that can be used to monitor the texture evolution in thin film growth and nanostructures and is not limited to single crystal epitaxial film growth. Details of the construction of RHEED pole figures and the interpretation of observed pole figures are presented. Materials covered include metals, semiconductors, and thin insulators. This book also: Presents a new application of RHEED in the transmission mode Introduces a variety of textures from metals, semiconductors, compound semiconductors, and their characteristics in RHEED pole figures Provides examples of RHEED measurements of texture and texture evolution, construction of RHEED pole figures, and interpretation of observed pole figures RHEED Transmission Mode and Pole Figures: Thin Film and Nanostructure Texture Analysis is ideal for researchers in materials science and engineering and nanotechnology.

Materials Fundamentals of Molecular Beam Epitaxy

Chemical Beam, Gas-source Molecular Beam, and Molecular Beam Epitaxial Growth of III/V Compound Semiconductor Materials

MOLECULAR BEAM EPITAXY.

Semiconductor Materials

Proceedings of the Eighth International Conference on Molecular Beam Epitaxy, Toyonaka, Osaka, Japan, 28 August-2 September, 1994

A new and unique high vacuum crystal growth system has been developed. The gas source molecular beam/chemical beam epitaxial growth system features a 7000 l/s diffusion pumping system mounted directly beneath a molecular beam epitaxial growth chamber. After careful thermal cleaning of the new growth chamber, p-type GaAs of higher purity than previously reported has been grown by diffusion pumped molecular beam epitaxy. The purity of GaAs grown by this method increases directly from increased pumping. The system has also been used for growth of GaAs by gas-source molecular beam epitaxy and chemical beam epitaxy and the effects of a number of growth parameters on background carrier concentration are reported. High quality InGaP has been grown by gas-source molecular beam epitaxy. The differential thermal expansion coefficient of InGaP on GaAs has been determined directly from variable temperature x-ray measurements. InGaP has also been grown by chemical beam epitaxy. Although the quality of the layers is inferior to those grown by gas-source molecular beam epitaxy, the work presented here is one of the first reports of InGaP grown by chemical beam epitaxy. The results of these investigations are presented and the problems and advantages of the system are discussed.

One dimensional electronic materials are expected to be key components owing to their potential applications in nanoscale electronics, optics, energy storage, and biology. Besides, compound semiconductors have been greatly developed as epitaxial growth crystal materials. Molecular beam and metalorganic vapor phase epitaxy approaches are representative techniques achieving 0D–2D quantum well, wire, and dot semiconductor III-V heterostructures with precise structural accuracy with atomic resolution. Based on the background of those epitaxial techniques, high-quality, single-crystalline III-V heterostructures have been achieved. III-V Nanowires have been proposed for the next generation of nanoscale optical and electrical devices such as nanowire light emitting diodes, lasers, photovoltaics, and transistors. Key issues for the realization of those devices involve the superior mobility and optical properties of III-V materials (i.e., nitride-, phosphide-, and arsenide-related heterostructure systems). Further, the developed epitaxial growth technique enables electronic carrier control through the formation of quantum structures and precise doping, which can be introduced into the nanowire system. The growth can extend the functions of the material systems through the introduction of elements with large miscibility gap, or, alternatively, by the formation of hybrid heterostructures between semiconductors and another material systems. This book reviews recent progresses of such novel III-V semiconductor nanowires, covering a wide range of aspects from the epitaxial growth to the device applications. Prospects of such advanced 1D structures for nanoscience and nanotechnology are also discussed.

The technology of crystal growth has advanced enormously during the past two decades. Among, these advances, the development and refinement of molecular beam epitaxy (MBE) has been among the msot important. Crystals grown by MBE are more precisely controlled than those grown by any other method, and today they form the basis for the most advanced device structures in solid-state physics, electronics, and optoelectronics. As an example, Figure 0.1 shows a vertical-cavity surface emitting laser structure grown by MBE. * Provides comprehensive treatment of the basic materials and surface science principles that apply to molecular beam epitaxy * Thorough enough to benefit molecular beam epitaxy researchers * Broad enough to benefit materials, surface, and device researchers * Referenes articles at the forefront of modern research as well as those of historical interest

RHEED Transmission Mode and Pole Figures

Materials and Device Applications

Strained Layer Lasers Grown by Molecular Beam Epitaxy for High Speed Modulation

Proceedings of the ... International Conference on Molecular Beam Epitaxy

5 - 8 October 1997, University of Michigan, Ann Arbor, Michigan