# Molecular Beam Epitaxy





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**Molecular Beam Epitaxy** GRIN Verlag
This volume describes the development of molecular beam epitaxy from its origins in the 1960s through to the present day. It begins with a short historical account of other methods of crystal growth, both bulk and epitaxial, to set the subject in context, emphasising the wide range of semiconductor materials employed. This is followed by an introduction to molecular beams and their use in the Stern-Gerlach experiment and the development of the microwave MASER--[Source inconnue].
**Molecular Beam Epitaxy** Springer Science & Business Media
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.
*Molecular Beam Epitaxy* William Andrew
The book "Nitride Semiconductor Technology" provides an overview of nitride semiconductors and their uses in optoelectronics and power electronics devices. It explains the physical properties of those materials as well as their growth methods. Their applications in high electron mobility transistors, vertical power devices, LEDs, laser diodes, and vertical-cavity surface-emitting lasers are discussed in detail. The book further examines reliability issues in these materials and puts forward perspectives of integrating them with 2D materials for novel high-frequency and high-power devices. In summary, it covers nitride semiconductor technology from materials to devices and provides the basis for further research.
**Growth of InP by Molecular Beam Epitaxy** Elsevier
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.
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 Cuvillier Verlag
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.
*Molecular Beam Epitaxy of HgCdTe* John Wiley & Sons
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
Proceedings of the Eighth International Conference on Molecular Beam Epitaxy, Toyonaka, Osaka, Japan, 28 August-2 September, 1994 Elsevier
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.
*Molecular Beam Epitaxy and Heterostructures* Elsevier
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.
**Materials Fundamentals of Molecular Beam Epitaxy** CRC Press
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 Springer Science & Business Media
Indium Phosphide MBE layers have been grown using a number of different phosphorus sources. Sources that produce a significant flux of P2 or atomic phosphorus yield much higher quality epitaxial films than sources which are predominantly P4. The best materials grown to date had room temperature mobilities greater than 3700 sq cm/V-ls-l and were grown using a small Inp phosphorus source. The geometry of the Inp phosphorus source is important. An incorrect choice can produce a source that produces predominately the P4 molecular species rather than the desired P2. (Author).
Gas Source Molecular Beam Epitaxy Springer Science & Business Media
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.
*Proceedings of the Second International Symposium on Silicon Molecular Beam Epitaxy* Academic Press
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.
**The Technology and Physics of Molecular Beam Epitaxy** Elsevier
Molecular Beam EpitaxyFrom Research to Mass ProductionElsevier
**Silicon-Molecular Beam Epitaxy** Springer
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.
*Growth and Properties of Phosphorus Containing III-V Heterostructures* Molecular Beam EpitaxyFrom Research to Mass Production
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
*A Short History* North Holland
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, AlN 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
*From Research to Mass Production* Elsevier
This dissertation, "Molecular Beam Epitaxy of Three Dimensional Topological Insulator $Bi_2Se_3$ Thin Films" by Xin, Guo, 郭欣, 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

*Molecular Beam Epitaxy* Springer Science & Business Media

This book contains full account of the advances made in the dilute nitrides, providing an excellent starting point for workers entering the field. It gives the reader easier access and better evaluation of future trends, Conveying important results and current ideas. Includes a generous list of references at the end of each chapter, providing a useful reference to the III-V-N based semiconductors research community. The high speed lasers operating at wavelength of 1.3 μm and 1.55 μm are very important light sources in optical communications since the optical fiber used as a transport media of light has dispersion and attenuation minima, respectively, at these wavelengths. These long wavelengths are exclusively made of InP-based material InGaAsP/InP. However, there are several problems with this material system. Therefore, there has been considerable effort for many years to fabricate long wavelength laser structures on other substrates, especially GaAs. The manufacturing costs of GaAs-based components are lower and the processing techniques are well developed. In 1996 a novel quaternary material GaInAsN was proposed which could avoid several problems with the existing technology of long wavelength lasers. In this book, several leaders in the field of dilute nitrides will cover the growth and processing, experimental characterization, theoretical understanding, and device design and fabrication of this recently developed class of semiconductor alloys. They will review their current status of research and development. Dilute Nitrides (III-N-V) Semiconductors: Physics and Technology organises the most current available data, providing a ready source of information on a wide range of topics, making this book essential reading for all post graduate students, researchers and practitioners in the fields of Semiconductors and Optoelectronics Contains full account of the advances made in the dilute nitrides, providing an excellent starting point for workers entering the field Gives the reader easier access and better evaluation of future trends, conveying important results and current ideas Includes a generous list of references at the end of each chapter, providing a useful reference to the III-V-N based semiconductors research community

*Molecular-beam-epitaxy Grown Channeled-substrate Multiple-quantum-well Lasers, Surface-emitting Laser Diodes, and Study of Dopant Effect on Disordering of Superlattice* Open Dissertation Press

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.

**Applications to Key Materials** Elsevier

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.