

# HOT CARRIERS IN SEMICONDUCTOR NANOSTRUCTURES

*Physics  
and  
Applications*



Edited by

**Jagdeep Shah**

# Hot Carriers In Semiconductor Nanostructures Physics And Applications

**Hari Singh Nalwa**



## **Hot Carriers In Semiconductor Nanostructures Physics And Applications:**

**Hot Carriers in Semiconductor Nanostructures** Jagdeep Shah, 2012-12-02 Nonequilibrium hot charge carriers play a crucial role in the physics and technology of semiconductor nanostructure devices This book one of the first on the topic discusses fundamental aspects of hot carriers in quasi two dimensional systems and the impact of these carriers on semiconductor devices The work will provide scientists and device engineers with an authoritative review of the most exciting recent developments in this rapidly moving field It should be read by all those who wish to learn the fundamentals of contemporary ultra small ultra fast semiconductor devices Topics covered include Reduced dimensionality and quantum wells Carrier phonon interactions and hot phonons Femtosecond optical studies of hot carrier Ballistic transport Submicron and resonant tunneling devices

**Hot Electrons in Semiconductors** N. Balkan, 1998 Since the arrival of the transistor in 1947 research in hot electrons like any field in semiconductor research has grown at a stunning rate From a physicist's point of view the understanding of hot electrons and their interactions with the lattice has always been a challenging problem of condensed matter physics Recently with the advent of novel fabrication techniques such as electron beam or plasma etching and the advanced growth techniques such as the molecular beam epitaxy MBE and metallo organic chemical vapour deposition MOCVD it has become possible to fabricate semiconductor devices with sub micron dimensions where the electrons are confined to two quantum well one quantum wire or zero quantum dot dimensions In devices of such dimensions a few volts applied to the device result in the setting up of very high electric fields hence a substantial heating of electrons Thus electronic transport in the device becomes non linear and can no longer be described using the simple equations of Ohm's law The understanding of the operations of such devices and the realisations of more advanced ones make it necessary to understand the dynamics of hot electrons There is an obvious lack of good reference books on hot electrons in semiconductors The few that exist either cover a very narrow field or are becoming quite outdated This book is therefore written with the aim of filling the vacuum in an area where there is much demand for a comprehensive reference book The book is intended for both established researchers and graduate students and gives a complete account of the historical development of the subject together with current research interests and future trends The contributions are written by leading scientists in the field They cover the physics of hot electrons in bulk and low dimensional device technology The material is organised into subject area that can be classified broadly into five groups 1 introduction and overview 2 hot electron phonon interactions and the ultra fast phenomena in bulk and two dimensional structures 3 hot electrons in both long and short quantum wires and quantum dots 4 hot electron tunnelling and hot electron transport in superlattices and 5 novel devices based on hot electron transport The chapters are grouped according to subject matter as far as possible However although there is much overlap of ideas and concepts each chapter is essentially independent of the others

Ultrafast Spectroscopy of Semiconductors and Semiconductor Nanostructures Jagdeep Shah, 2013-11-11 **Hot**

**Carriers in Semiconductors** Karl Hess, J.P. Leburton, U. Ravaioli, 2012-12-06 This volume contains invited and contributed papers of the Ninth International Conference on Hot Carriers in Semiconductors HCIS 9 held July 3 I August 4 1995 in Chicago Illinois In all the conference featured 15 invited oral presentations 60 contributed oral presentations and 105 poster presentations and an international contingent of 170 scientists As in recent conferences the main themes of the conference were related to nonlinear transport in semiconductor heterojunctions and included Bloch oscillations laser diode structures and femtosecond spectroscopy Interesting questions related to nonlinear transport size quantization and intersubband scattering were addressed that are relevant to the new quantum cascade laser Many lectures were geared toward quantum wires and dots and toward nanostructures and mesoscopic systems in general It is expected that such research will open new horizons to nonlinear transport studies An attempt was made by the program committee to increase the number of presentations related directly to devices The richness of nonlocal hot electron effects that were discussed as a result in our opinion suggests that future conferences should further encourage reports on such device research On behalf of the Program and International Advisory Committees we thank the participants who made the conference a successful and pleasant experience and the support of the Army Research Office the Office of Naval Research and the Beckman Institute of the University of Illinois at Urbana Champaign We are also indebted to Mrs Sara Starkey and Mrs

**Coherent Optical Interactions in Semiconductors** R.T. Phillips, 2013-06-29 The NATO Advanced Research Workshop on Coherent Optical Processes in Semiconductors was held in Cambridge England on August 11 14 1993 The idea of holding this Workshop grew from the recent upsurge in activity on coherent transient effects in semiconductors The development of this field reflects advances in both light sources and the quality of semiconductor structures such that tunable optical pulses are now routinely available whose duration is shorter than the dephasing time for excitonic states in quantum wells It was therefore no surprise to the organisers that as the programme developed there emerged a heavy emphasis on time resolved four wave mixing particularly in quantum wells Nevertheless other issues concerned with coherent effects ensured that several papers on related problems contributed some variety The topics discussed at the workshop centred on what is a rather new field of study and benefited enormously by having participants representing many of the principal groups working in this area Several themes emerged through the invited contributions at the Workshop One important development has been the careful examination of the two level model of excitonic effects a model which has been remarkably successful despite the expected complexities arising from the semiconductor band structure Indeed modest extensions to the two level model have been able to offer a useful account for some of the complicated polarisation dependence of four wave mixing signals from GaAs quantum wells This work clearly is leading to an improved understanding of excitons in confined systems

**Theory of Transport Properties of Semiconductor Nanostructures** Eckehard Schöll, 2013-11-27 Recent advances in the fabrication of semiconductors have created almost unlimited possibilities to design structures on a nanometre scale with extraordinary electronic and

optoelectronic properties The theoretical understanding of electrical transport in such nanostructures is of utmost importance for future device applications This represents a challenging issue of today's basic research since it requires advanced theoretical techniques to cope with the quantum limit of charge transport ultrafast carrier dynamics and strongly nonlinear high field effects This book which appears in the electronic materials series presents an overview of the theoretical background and recent developments in the theory of electrical transport in semiconductor nanostructures It contains 11 chapters which are written by experts in their fields Starting with a tutorial introduction to the subject in Chapter 1 it proceeds to present different approaches to transport theory The semiclassical Boltzmann transport equation is in the centre of the next three chapters Hydrodynamic moment equations Chapter 2 Monte Carlo techniques Chapter 3 and the cellular automaton approach Chapter 4 are introduced and illustrated with applications to nanometre structures and device simulation A full quantum transport theory covering the Kubo formalism and nonequilibrium Green's functions Chapter 5 as well as the density matrix theory Chapter 6 is then presented

**Semiconductor Quantum Bits** Fritz Henneberger, Oliver Benson, 2016-04-19 This book highlights state of the art qubit implementations in semiconductors and provides an extensive overview of this newly emerging field Semiconductor nanostructures have huge potential as future quantum information devices as they provide various ways of qubit implementation electron spin electronic excitation as well as a way to transfer

**Compound Semiconductors 1995, Proceedings of the Twenty-Second INT Symposium on Compound Semiconductors held in Cheju Island, Korea, 28 August-2 September, 1995** Institute of Physics Conference, 2020-10-28 Compound Semiconductors 1995 focuses on emerging applications for GaAs and other compound semiconductors such as InP GaN GaSb ZnSe and SiC in the electronics and optoelectronics industries The book presents the research and development work in all aspects of compound semiconductors It reflects the maturity of GaAs as a semiconductor material and the rapidly increasing pool of research information on many other compound semiconductors Covering the full breadth of the subject from growth through processing to devices and integrated circuits this volume provides researchers in materials science device physics condensed matter physics and electrical and electronic engineering with a comprehensive overview of developments in this well established research area

*Transport in Nanostructures* David Ferry, Stephen Marshall Goodnick, 1999-10-28 A comprehensive detailed description of the properties and behaviour of mesoscopic devices

**Handbook of Raman Spectroscopy** Ian R. Lewis, Howell Edwards, 2001-08-08 This work covers principles of Raman theory analysis instrumentation and measurement specifying up to the minute benefits of Raman spectroscopy in a variety of industrial and academic fields and how to cultivate growth in new disciplines It contains case studies that illustrate current techniques in data extraction and analysis as well as over 500 drawings and photographs that clarify and reinforce critical text material The authors discuss Raman spectra of gases Raman spectroscopy applied to crystals applications to gemology in vivo Raman spectroscopy applications in forensic science and collectivity of vibrational

modes among many other topics      **Quantum Transport in Ultrasmall Devices** David K. Ferry, Harold L. Grubin, Carlo Jacoboni, A.-P. Jauho, 2012-12-06 The operation of semiconductor devices depends upon the use of electrical potential barriers such as gate depletion in controlling the carrier densities electrons and holes and their transport Although a successful device design is quite complicated and involves many aspects the device engineering is mostly to devise a best device design by defining optimal device structures and manipulating impurity profiles to obtain optimal control of the carrier flow through the device This becomes increasingly difficult as the device scale becomes smaller and smaller Since the introduction of integrated circuits the number of individual transistors on a single chip has doubled approximately every three years As the number of devices has grown the critical dimension of the smallest feature such as a gate length which is related to the transport length defining the channel has consequently declined The reduction of this design rule proceeds approximately by a factor of 1.4 each generation which means we will be using 0.1015  $\mu\text{m}$  rules for the 4 Gb chips a decade from now If we continue this extrapolation current technology will require 30 nm design rules and a cell 3.2 size      **Quantum**

**Heterostructures** Vladimir Vasil'evich Mitin, Viacheslav Kochelap, Michael A. Stroscio, 1999-07-13 Quantum Heterostructures provides a detailed description of the key physical and engineering principles of quantum semiconductor heterostructures Blending important concepts from physics materials science and electrical engineering it also explains clearly the behavior and operating features of modern microelectronic and optoelectronic devices The authors begin by outlining the trends that have driven development in this field most importantly the need for high performance devices in computer information and communications technologies They then describe the basics of quantum nanoelectronics including various transport mechanisms In the latter part of the book they cover novel microelectronic devices and optical devices based on quantum heterostructures The book contains many homework problems and is suitable as a textbook for undergraduate and graduate courses in electrical engineering physics or materials science It will also be of great interest to those involved in research or development in microelectronic or optoelectronic devices      **Superlattice to**

**Nanoelectronics** Raphael Tsu, 2010-10-22 Written by one of the founders in this field this edition provides a historical overview of the invention of superlattice one of the most important devices of the second half of the 20th century In addition to describing the fundamental concepts this completely revised and updated edition provides new insights in the field of man made solids      **Tunneling And Its Implications: Proceedings Of The Adriatico Research Conference D**

Mugnai, Anedio Ranfagni, Lawrence S Schulman, 1997-04-19 The motion of a particle undergoing quantum tunneling has long been an open and debated problem in several aspects One of the most discussed is the determination of the time spent in such processes but many other features deserve consideration In this volume both theoretical and experimental aspects such as quantum measurement optical analogy experimental tests solid state devices and time scale for anomalies quantum Zeno effect and superluminal evanescence are explored      **Wide Bandgap Semiconductors** Kiyoshi Takahashi, Akihiko

Yoshikawa, Adarsh Sandhu, 2007-04-12 The p n junction was invented in the first half of the twentieth century and the latter half saw the birth of light emitting diodes red and yellow green in the 1960s and yellow in the 1970s However theoretical predictions of the improbability of synthesizing p type wide bandgap semiconductors cast a long shadow over hopes for devices emitting in the elusive blue part of the electromagnetic spectrum which would complete with red and green the quest for the primary colors making up white light At a time when many researchers abandoned their efforts on nitrides Professor Isamu Akasaki of Nagoya University at this time remained committed to his belief that synthesis of high quality GaN crystals would eventually enable p type doping and in 1989 he succeeded in fabricating the world's first GaN p n junction light emitting diode Professor Isamu Akasaki kindly accepted our invitation to contribute to this book and describes his journey from the nitride wilderness to the first experimental results of blue emission from GaN p n junctions Japan's major contribution to the development of wide bandgap semiconductor devices The discovery of blue emission from GaN p n junctions in 1989 was the major technological turning point during the development of wide bandgap emission devices with wide reaching scientific industrial and social implications Tunneling And Its Implications Adriatico Research Conference on Tunneling and Its Implications 1996, Trieste, Italy, D. Mugnai, 1997 The motion of a particle undergoing quantum tunneling has long been an open and debated problem in several aspects One of the most discussed is the determination of the time spent in such processes but many other features deserve consideration In this volume both theoretical and experimental aspects such as quantum measurement optical analogy experimental tests solid state devices and time scale for anomalies quantum Zeno effect and superluminal evanescence are explored Publisher's website Nanoelectrodynamics Hitoshi Nejo, 2013-03-14 Many books on mesoscopic systems have been published as progress has continued in the fields of nanoscience and nanotechnology The focus in these books is mainly on quantum mechanical behavior in artificial electronic systems fabricated by nanometer scale structuring Such quantum mechanical behavior is projected to macroscopic observers and the quantum nature can be utilized in practical devices Quantum computers another hot topic nowadays are characterized by excitation coherence properties among nanostructures and the ability to maintain excitations is very important when using the characteristics as information In that sense the device is described as a microscopic system and some processes occur before being projected to macroscopic observers In this book the authors try to describe not only the techniques for fabricating nanostructures but also new directions as regards exciting systems and understanding how energy is dissipated through observation The idea of nanoelectrodynamics underlying the book is an analogy with the well established classical electrodynamics In contrast to the latter nanoelectrodynamics is still in its infancy and far from well established When a structure is miniaturized as a device it is essential to have control over energy excitation and dissipation Otherwise when a device is squeezed down beyond a certain size and the energy dissipation becomes overwhelmed the device will eventually collapse It is our aim in this book to provide some thoughts on the task of making devices out of small structures Time in

Quantum Mechanics J.G. Muga, R. Sala Mayato, I.L. Egusquiza, 2003-07-01 Time and quantum mechanics have each of them separately captivated scientists and laymen alike as shown by the abundance of popular publications on time or on the many quantum mysteries or paradoxes. We too have been seduced by these two topics and in particular by their combination. Indeed the treatment of time in quantum mechanics is one of the important and challenging open questions in the foundations of quantum theory. This book describes the problems and the attempts and achievements in defining formalizing and measuring different time quantities in quantum theory such as the parametric clock time tunneling times decay times dwell times delay times arrival times or jump times. The theoretical analysis of several of these quantities has been controversial and is still subject to debate. For example there are literally hundreds of research papers on the tunneling time. In fact the standard recipe to link the observables and the formalism does not seem to apply at least in an obvious manner to time observables. This has posed the challenge of extending the domain of ordinary quantum mechanics. *Handbook of*

*Nanostructured Materials and Nanotechnology, Five-Volume Set* Hari Singh Nalwa, 1999-10-29 Nanostructured materials is one of the hottest and fastest growing areas in today's materials science field along with the related field of solid state physics. Nanostructured materials and their based technologies have opened up exciting new possibilities for future applications in a number of areas including aerospace automotive x ray technology batteries sensors color imaging printing computer chips medical implants pharmacy and cosmetics. The ability to change properties on the atomic level promises a revolution in many realms of science and technology. Thus this book details the high level of activity and significant findings are available for those involved in research and development in the field. It also covers industrial findings and corporate support. This five volume set summarizes fundamentals of nano science in a comprehensive way. The contributors enlisted by the editor are at elite institutions worldwide. **Key Features** Provides comprehensive coverage of the dominant technology of the 21st century. Written by 127 authors from 16 countries making this truly international. First and only reference to cover all aspects of nanostructured materials and nanotechnology.

**Quantum Information II, Proceedings Of The Second International Conference** Takeyuki Hida, Kimiaki Saito, 2000-07-31 Contents The Quantum Filtering Problem as a Dynamical Covariance Condition L. Accardi CKS Space in Terms of Growth Functions N. Asai et al Large Deviation Principle for Catalytic Processes Associated with Nonlinear Catalytic Noise Equations I. D. Ku The Estimation of Tunneling Time by the Use of Nelson's Quantum Stochastic Process Towards a Comparison with a Neutron Interference Experiment T. Hashimoto T. Tomomura Complexity in White Noise Analysis T. Hida Cauchy Problems in White Noise Analysis and an Application to Finite Dimensional PDEs U. C. Ji It Formula for Generalized Levy Functionals Y. J. Lee H. H. Shih Rhythmic Contraction and Its Fluctuations in an Amoeboid Organism of the Physarum Plasmodium T. Nakagaki H. Yamada Quantum Computation and NP Complete Problems T. Nishino A Note on Coherent State Representations of White Noise Operators N. Obata Complexity in Quantum System and Its Application to Brain Function M. Ohya NP Complete Problems with Chaotic Dynamics M. Ohya I. V.

Volovich Field Fluctuation and Signal Generation in Living Cells F Oosawa Stochastic Processes Generated by Functions of the L vy Laplacian K Sait A H Tsoi Gaussian Processes and Gaussian Random Fields S Si An Approach to Synthesize Filters with Reduced Structures Using a Neural Network K Suzuki et al Study for Modeling the Spontaneous Fluctuation in Biological System M Yamanoi et al Readership Pure and applied probabilists functional analysts mathematical physicists theoretical physicists and mathematical biologists Keywords

## Reviewing **Hot Carriers In Semiconductor Nanostructures Physics And Applications**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is actually astonishing. Within the pages of "**Hot Carriers In Semiconductor Nanostructures Physics And Applications**," an enthralling opus penned by a highly acclaimed wordsmith, readers set about an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve to the book is central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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