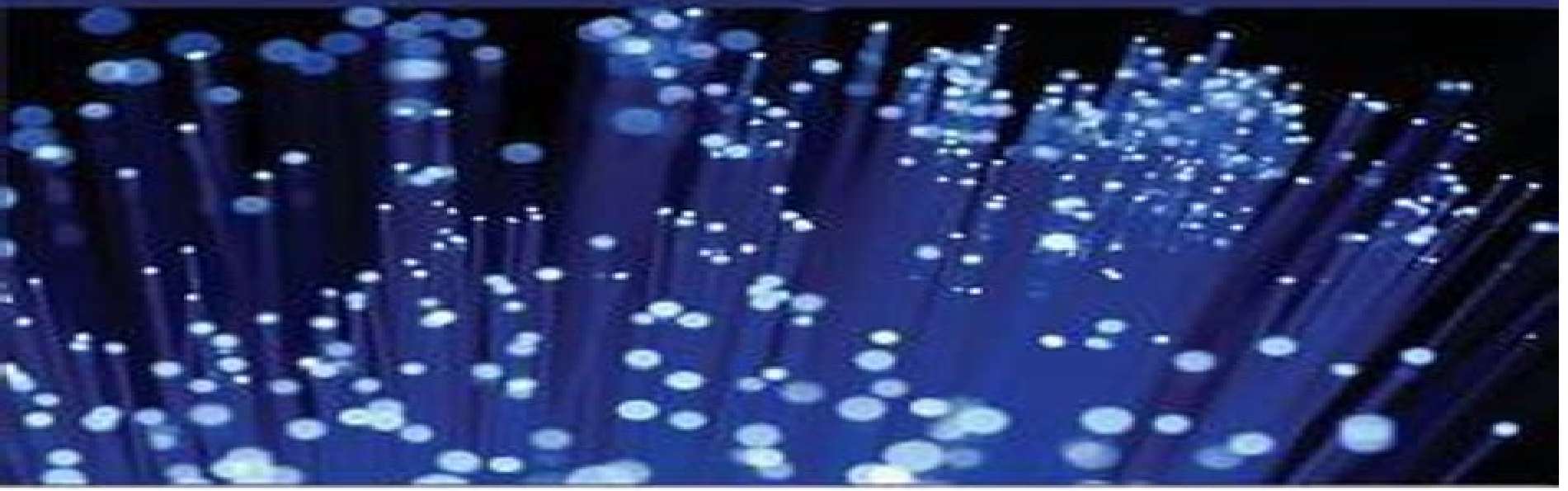

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High Speed Germanium-Silicon Modulators For Optical Interconnect

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High Speed Germanium-Silicon Modulators For Optical Interconnect Yiwen Rong,2014-11-28 Information processing requires interconnects to carry information from one place to another Optical interconnects between electronics systems have attracted significant attention and development for a number of years because optical links have demonstrated potential advantages for high speed low power and interference immunity With increasing system speed and greater bandwidth requirements the distance over which optical communication is useful has continually decreased to chip to chip and on chip levels Monolithic integration of photonics and electronics will significantly reduce the cost of optical components and further combine the functionalities of chips on the same or different boards or systems Modulators are one of the fundamental building blocks for optical interconnects **High Speed, Low Driving Voltage Vertical Cavity Germanium-silicon Modulators for Optical Interconnect** Yiwen Rong,2010 Information processing requires interconnects to carry information from one place to another Optical interconnects between electronics systems have attracted significant attention and development for a number of years because optical links have demonstrated potential advantages for high speed low power and interference immunity With increasing system speed and greater bandwidth requirements the distance over which optical communication is useful has continually decreased to chip to chip and on chip levels Monolithic integration of photonics and electronics will significantly reduce the cost of optical components and further combine the functionalities of chips on the same or different boards or systems Modulators are one of the fundamental building blocks for optical interconnects Previous work demonstrated modulators based upon the quantum confined Stark effect QCSE in SiGe p i n devices with strained Ge SiGe multi quantum well MQW structures in the i region While the previous work demonstrated the effect it did not examine the high speed aspects of the device which is the focus of this dissertation High speed modulation and low driving voltage are the keys for the device s practical use At lower optical intensity operation the ultimate limitation in speed will be the RC time constant of the device itself At high optical intensity the large number of photo generated carriers in the MQW region will limit the performance of the device through photo carrier related voltage drop and exciton saturation In previous work the devices consist of MQWs configured as p i n diodes The electric field induced absorption change by QCSE modulates the optical transmission of the device The focus of this thesis is the optimization of MQW material deposition minimization of the parasitic capacitance of the probe pads for high speed low voltage and high contrast ratio operation The design fabrication and high speed characterization of devices of different sizes with different bias voltages are presented The device fabrication is based on processes for standard silicon electronics and is suitable for mass production This research will enable efficient transceivers to be monolithically integrated with silicon chips for high speed optical interconnects We demonstrated a modulator with an eye diagram of 3 125GHz a small driving voltage of 2 5V and an f3dB bandwidth greater than 30GHz Carrier dynamics under ultra fast laser excitation

and high speed photocurrent response are also investigated *High Speed, Low Driving Voltage Vertical Cavity Germanium-silicon Modulators for Optical Interconnect* Yiwen Rong,2010 Information processing requires interconnects to carry information from one place to another Optical interconnects between electronics systems have attracted significant attention and development for a number of years because optical links have demonstrated potential advantages for high speed low power and interference immunity With increasing system speed and greater bandwidth requirements the distance over which optical communication is useful has continually decreased to chip to chip and on chip levels Monolithic integration of photonics and electronics will significantly reduce the cost of optical components and further combine the functionalities of chips on the same or different boards or systems Modulators are one of the fundamental building blocks for optical interconnects Previous work demonstrated modulators based upon the quantum confined Stark effect QCSE in SiGe p i n devices with strained Ge SiGe multi quantum well MQW structures in the i region While the previous work demonstrated the effect it did not examine the high speed aspects of the device which is the focus of this dissertation High speed modulation and low driving voltage are the keys for the device s practical use At lower optical intensity operation the ultimate limitation in speed will be the RC time constant of the device itself At high optical intensity the large number of photo generated carriers in the MQW region will limit the performance of the device through photo carrier related voltage drop and exciton saturation In previous work the devices consist of MQWs configured as p i n diodes The electric field induced absorption change by QCSE modulates the optical transmission of the device The focus of this thesis is the optimization of MQW material deposition minimization of the parasitic capacitance of the probe pads for high speed low voltage and high contrast ratio operation The design fabrication and high speed characterization of devices of different sizes with different bias voltages are presented The device fabrication is based on processes for standard silicon electronics and is suitable for mass production This research will enable efficient transceivers to be monolithically integrated with silicon chips for high speed optical interconnects We demonstrated a modulator with an eye diagram of 3 125GHz a small driving voltage of 2 5V and an f3dB bandwidth greater than 30GHz Carrier dynamics under ultra fast laser excitation and high speed photocurrent response are also investigated *Ge/SiGe Quantum Well Waveguide Modulator for Optical Interconnect Systems* Ren Shen,2011 Thanks to the development of silicon VLSI technology over the past several decades we can now integrate far more transistors onto a single chip than ever before However this also imposes more stringent requirements in terms of bandwidth density and power consumption on the interconnect systems that link transistors The interconnect system is currently one of the major hurdles for the further advancement of the electronic technology Optical interconnect is considered a promising solution to overcome the interconnect bottleneck The quantum confined Stark effect in Ge SiGe quantum well system paves the way to realize efficient optical modulation on Si in a fully CMOS compatible fashion In this dissertation we investigate the integration of Ge SiGe quantum well waveguide modulators with silicon on insulator

waveguides For the first time we demonstrate the selective epitaxial growth of Ge SiGe quantum well structures on patterned Si substrates The selective epitaxy exhibits perfect selectivity and minimal pattern sensitivity Compared to their counterparts made using bulk epitaxy the p i n diodes from selective epitaxy demonstrate very low reverse leakage current and high reverse breakdown voltage Strong quantum confined Stark effect QCSE is for the first time demonstrated in this material system in the telecommunication C band at room temperature A 3 dB optical modulation bandwidth of 2 8 THz is measured covering more than half of the C band We propose analyze and experimentally demonstrate a novel approach to realize butt coupling between a SOI waveguide and a selectively grown Ge SiGe quantum well waveguide modulator using a thin dielectric spacer Through numerical simulation we show that the insertion loss penalty for a thin 20 nm thick spacer can be as low as 0 13 dB Such a quantum well waveguide modulator with a footprint of 8 Mu m2 has also been fabricated demonstrating 3 2 dB modulation contrast with merely 1V swing at a speed of 16 Gpbs **Optical Interconnects** Lorenzo Pavesi,Gérard Guillot,2007-05-17 Optical Interconnects provides a fascinating picture of the state of the art in optical interconnects and a perspective on what can be expected in the near future It is composed of selected reviews authored by world leaders in the field and these reviews are written from either an academic or industrial viewpoint An in depth discussion of the path towards fully integrated optical interconnects in microelectronics is presented This book will be useful not only to physicists chemists materials scientists and engineers but also to graduate students who are interested in the fields of microelectronics and optoelectronics CMOS-Compatible Key Engineering Devices for High-Speed Silicon-Based Optical Interconnections Jing Wang,2018-11-23 This book discusses some research results for CMOS compatible silicon based optical devices and interconnections With accurate simulation and experimental demonstration it provides insights on silicon based modulation advanced multiplexing polarization and efficient coupling controlling technologies which are widely used in silicon photonics Researchers scientists engineers and especially students in the field of silicon photonics can benefit from the book This book provides valuable knowledge useful methods and practical design that can be considered in emerging silicon based optical interconnections and communications And it also give some guidance to student how to organize and complete an good dissertation *Integrated Optical Interconnect Architectures for Embedded Systems* Ian O'Connor,Gabriela Nicolescu,2012-11-07 This book provides a broad overview of current research in optical interconnect technologies and architectures Introductory chapters on high performance computing and the associated issues in conventional interconnect architectures and on the fundamental building blocks for integrated optical interconnect provide the foundations for the bulk of the book which brings together leading experts in the field of optical interconnect architectures for data communication Particular emphasis is given to the ways in which the photonic components are assembled into architectures to address the needs of data intensive on chip communication and to the performance evaluation of such architectures for specific applications **Silicon Photonics for High-Performance Computing and**

Beyond Mahdi Nikdast,Sudeep Pasricha,Gabriela Nicolescu,Ashkan Seyedi,Di Liang,2021-11-16 Silicon photonics is beginning to play an important role in driving innovations in communication and computation for an increasing number of applications from health care and biomedical sensors to autonomous driving datacenter networking and security In recent years there has been a significant amount of effort in industry and academia to innovate design develop analyze optimize and fabricate systems employing silicon photonics shaping the future of not only Datacom and telecom technology but also high performance computing and emerging computing paradigms such as optical computing and artificial intelligence Different from existing books in this area Silicon Photonics for High Performance Computing and Beyond presents a comprehensive overview of the current state of the art technology and research achievements in applying silicon photonics for communication and computation It focuses on various design development and integration challenges reviews the latest advances spanning materials devices circuits systems and applications Technical topics discussed in the book include Requirements and the latest advances in high performance computing systems Device and system level challenges and latest improvements to deploy silicon photonics in computing systems Novel design solutions and design automation techniques for silicon photonic integrated circuits Novel materials devices and photonic integrated circuits on silicon Emerging computing technologies and applications based on silicon photonics Silicon Photonics for High Performance Computing and Beyond presents a compilation of 19 outstanding contributions from academic and industry pioneers in the field The selected contributions present insightful discussions and innovative approaches to understand current and future bottlenecks in high performance computing systems and traditional computing platforms and the promise of silicon photonics to address those challenges It is ideal for researchers and engineers working in the photonics electrical and computer engineering industries as well as academic researchers and graduate students M S and Ph D in computer science and engineering electronic and electrical engineering applied physics photonics and optics **High-Speed Photonics Interconnects** Lukas Chrostowski,Krzysztof Iniewski,2017-12-19 Dramatic increases in processing power have rapidly scaled on chip aggregate bandwidths into the Tb s range This necessitates a corresponding increase in the amount of data communicated between chips so as not to limit overall system performance To meet the increasing demand for interchip communication bandwidth researchers are investigating the use of high speed optical interconnect architectures Unlike their electrical counterparts optical interconnects offer high bandwidth and negligible frequency dependent loss making possible per channel data rates of more than 10 Gb s High Speed Photonics Interconnects explores some of the groundbreaking technologies and applications that are based on photonics interconnects From the Evolution of High Speed I O Circuits to the Latest in Photonics Interconnects Packaging and Lasers Featuring contributions by experts from academia and industry the book brings together in one volume cutting edge research on various aspects of high speed photonics interconnects Contributors delve into a wide range of technologies from the evolution of high speed input output I O circuits to recent trends in

photonics interconnects packaging The book discusses the challenges associated with scaling I O data rates and current design techniques It also describes the major high speed components channel properties and performance metrics The book exposes readers to a myriad of applications enabled by photonics interconnects technology Learn about Optical Interconnect Technologies Suitable for High Density Integration with CMOS Chips This richly illustrated work details how optical interchip communication links have the potential to fully leverage increased data rates provided through complementary metal oxide semiconductor CMOS technology scaling at suitable power efficiency levels Keeping the mathematics to a minimum it gives engineers researchers graduate students and entrepreneurs a comprehensive overview of the dynamic landscape of high speed photonics interconnects Advanced Interconnects for ULSI Technology Mikhail Baklanov,Paul S. Ho,Ehrenfried Zschech,2012-04-02 Finding new materials for copper low k interconnects is critical to the continuing development of computer chips While copper low k interconnects have served well allowing for the creation of Ultra Large Scale Integration ULSI devices which combine over a billion transistors onto a single chip the increased resistance and RC delay at the smaller scale has become a significant factor affecting chip performance Advanced Interconnects for ULSI Technology is dedicated to the materials and methods which might be suitable replacements It covers a broad range of topics from physical principles to design fabrication characterization and application of new materials for nano interconnects and discusses Interconnect functions characterisations electrical properties and wiring requirements Low k materials fundamentals advances and mechanical properties Conductive layers and barriers Integration and reliability including mechanical reliability electromigration and electrical breakdown New approaches including 3D optical wireless interchip and carbon based interconnects Intended for postgraduate students and researchers in academia and industry this book provides a critical overview of the enabling technology at the heart of the future development of computer chips *Neuromorphic Photonics* Paul R. Prucnal,Bhavin J. Shastri,2017-05-08 This book sets out to build bridges between the domains of photonic device physics and neural networks providing a comprehensive overview of the emerging field of neuromorphic photonics It includes a thorough discussion of evolution of neuromorphic photonics from the advent of fiber optic neurons to today s state of the art integrated laser neurons which are a current focus of international research Neuromorphic Photonics explores candidate interconnection architectures and devices for integrated neuromorphic networks along with key functionality such as learning It is written at a level accessible to graduate students while also intending to serve as a comprehensive reference for experts in the field **Optical Fiber Telecommunications Volume VIA** Ivan Kaminow,Tingye Li,Alan E Willner,2013-05-03 Optical Fiber Telecommunications VI A B is the sixth in a series that has chronicled the progress in the R D of lightwave communications since the early 1970s Written by active authorities from academia and industry this edition brings a fresh look to many essential topics including devices subsystems systems and networks A central theme is the enabling of high bandwidth communications in a cost effective manner for the development of customer applications These

volumes are an ideal reference for R D engineers and managers optical systems implementers university researchers and students network operators and investors Volume A is devoted to components and subsystems including photonic integrated circuits multicore and few mode fibers photonic crystals silicon photonics signal processing and optical interconnections

Optical Fiber Telecommunications VIA Radhakrishnan Nagarajan,Christopher Doerr,Fred Kish,2013-05-03 This chapter covers the field of semiconductor photonic integrated circuits PIC used in access metro long haul and undersea telecommunication networks Although there are many variants to implementing optical integration the focus is on monolithic integration where multiple semiconductor devices up to many hundreds in some cases are integrated onto the same substrate Monolithic integration poses the greatest technical challenge and the biggest opportunity for bandwidth and size scaling The PICs discussed here are based on the two most popular semiconductor material systems Groups III V indium phosphide based devices and Group IV silicon based devices The chapter also covers the historical evolution of the technology from the decades old original proposal to the current day terabit s class coherent PICs **Optical Interconnects for Future Data Center Networks** Christoforos Kachris,Keren Bergman,Ioannis Tomkos,2012-11-07 Optical Interconnects in Future Data Center Networks covers optical networks and how they can be used to provide high bandwidth energy efficient interconnects for future data centers with increased communication bandwidth requirements This contributed volume presents an integrated view of the future requirements of the data centers and serves as a reference work for some of the most advanced solutions that have been proposed by major universities and companies Collecting the most recent and innovative optical interconnects for data center networks that have been presented in the research community by universities and industries this book is a valuable reference to researchers students professors and engineers interested in the domain of high performance interconnects and data center networks Additionally Optical Interconnects in Future Data Center Networks provides invaluable insights into the benefits and advantages of optical interconnects and how they can be a promising alternative for future data center networks **Electroabsorption Mechanisms in Germanium Quantum Well Material** Rebecca Kayla Schaevitz,2011 One possible solution to make viable optoelectronic modulators that meet strict targets down to the scale of on chip communication is to use germanium rich materials Ge SiGe quantum wells grown on silicon substrates provide the strongest mechanism the quantum confined Stark effect QCSE and thereby can meet the strictest requirements for optical interconnects including CMOS compatibility Using such a strong effect Ge based modulators can be ultra compact ultralow power large bandwidth and high speed making them a strong contender for the future of optoelectronic device integration to solve the bottleneck problem In this thesis we will discuss the physical properties of the Ge and SiGe material system then present designs of optoelectronic modulators at the important 1310 nm and 1550 nm communication wavelengths using a program we developed called the Simple Quantum Well Electroabsorption Calculator SQWEAC SQWEAC takes the important physical mechanisms present such as QCSE and indirect absorption to

predict the electroabsorption profile of Ge based quantum wells QCSE was experimentally determined on a wide range of samples to show the predictive powers of SQWEAC Additionally indirect absorption was also experimentally determined to optimize the physical model for these Ge quantum well devices In being able to design both 1310 nm and 1550 nm devices using this Ge material system we provide a platform for designing optoelectronic devices that are Si CMOS compatible and operate over a wide range of wavelengths These modulators have the capability of providing the large density of information at very low energies per bit required for future interconnect technologies Conjugated Polymers John R. Reynolds,Barry C. Thompson,Terje A. Skotheim,2019-03-25 This book covers properties processing and applications of conducting polymers It discusses properties and characterization including photophysics and transport It then moves to processing and morphology of conducting polymers covering such topics as printing thermal processing morphology evolution conducting polymer composites thin films *Handbook of Conducting Polymers, Fourth Edition - 2 Volume Set* John R. Reynolds,Barry C. Thompson,Terje A. Skotheim,2019-11-14 In the last 10 years there have been major advances in fundamental understanding and applications and a vast portfolio of new polymer structures with unique and tailored properties was developed Work moved from a chemical repeat unit structure to one more based on structural control new polymerization methodologies properties processing and applications The 4th Edition takes this into account and will be completely rewritten and reorganized focusing on spin coating spray coating blade slot die coating layer by layer assembly and fiber spinning methods property characterizations of redox interfacial electrical and optical phenomena and commercial applications **SiGe, Ge, and Related Compounds: Materials, Processing, and Devices 8** Q. Liu,J.-M. Hartmann,A. Thean,S. Miyazaki,A. Ogura,X. Gong,M. Caymax,A. Schulze,G. Masini,A. Mai,M. Östling,G. Niu,D. Harame,2018-09-21 **Silicon Photonics Design** Lukas Chrostowski,Michael Hochberg,2015-03-12 From design and simulation through to testing and fabrication this hands on introduction to silicon photonics engineering equips students with everything they need to begin creating foundry ready designs In depth discussion of real world issues and fabrication challenges ensures that students are fully equipped for careers in industry Step by step tutorials straightforward examples and illustrative source code fragments guide students through every aspect of the design process providing a practical framework for developing and refining key skills Offering industry ready expertise the text supports existing PDKs for CMOS UV lithography foundry services OpSIS ePIXfab imec LETI IME and CMC and the development of new kits for proprietary processes and clean room based research Accompanied by additional online resources to support students this is the perfect learning package for senior undergraduate and graduate students studying silicon photonics design and academic and industrial researchers involved in the development and manufacture of new silicon photonics systems *Handbook of Silicon Photonics* Laurent Vivien,Lorenzo Pavesi,2016-04-19 The development of integrated silicon photonic circuits has recently been driven by the Internet and the push for high bandwidth as well as the need to reduce power dissipation induced by high data rate signal transmission To reach these

goals efficient passive and active silicon photonic devices including waveguide modulators photodetectors

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