Nonvolatile Memory Technologies With Emphasis On Flash A Comprehensive Guide To Understanding And Using Flash Memory Devices

A timely text on the recent developments in data storage, from a materials perspective Ever-increasing amounts of data storage on hard disk have been made possible largely due to the immense technological advances in the field of data storage materials. Developments in Data Storage: Materials Perspective covers the recent progress and developments in recording technologies, including the emerging non-volatile memory, which could potentially become storage technologies of the future. Featuring contributions from experts around the globe, this book provides engineers and graduate students in materials science and electrical engineering a solid foundation for grasping the subject. The book begins with the basics of magnetism and recording technology, setting the stage for the following chapters on existing methods and related research topics. These chapters focus on perpendicular recording media to underscore the current trend of hard disk media; read sensors, with descriptions of their fundamental principles and challenges; and write head, which addresses the advanced concepts for writing data in magnetic recording. Two chapters are devoted to the highly challenging area in hard disk drives of tribology, which deals with reliability, corrosion, and wear-resistance of the head and media. Next, the book provides an overview of the emerging technologies, such as heat-assisted magnetic recording and bit-patterned media recording. Non-volatile memory has emerged as a promising alternative storage option for certain device applications; two chapters are dedicated to non-volatile memory technologies such as the phase-change and the magnetic random access memories. With a strong focus on the fundamentals along with an overview of research topics, Developments in Data Storage is an ideal reference for graduate students or beginners in the field of magnetic recording. It also serves as an invaluable reference for future storage technologies including non-volatile memories.

A Flash memory is a Non Volatile Memory (NVM) whose "unit cells" are fabricated in CMOS technology and programmed and erased electrically. In 1971, Frohman-Bentchkowsky developed a folating polysilicon gate tran sistor [1, 2], in which hot electrons were injected in the floating gate and removed by either Ultra-Violet (UV) internal photoemission or by Fowler Nordheim tunneling. This is the "unit cell" of EPROM (Electrically Pro grammable Read Only Memory), which, consisting of a single transistor, can be very densely integrated. EPROM memories are electrically programmed and erased by UV exposure for 20-30 mins. In the late 1970s, there have been many efforts to develop an electrically erasable EPROM, which resulted in EEPROMs (Electrically Erasable Programmable ROMs). EEPROMs use hot electron tunneling for program and Fowler-Nordheim tunneling for erase. The EEPROM cell consists of two transistors and a tunnel oxide, thus it is two or three times the size of an EPROM. Successively, the combination of hot carrier programming and tunnel erase was rediscovered to achieve a single transistor EEPROM, called Flash EEPROM. The first cell based on this concept has been presented in 1979 [3]; the first commercial product, a 256K memory chip, has been presented by Toshiba in 1984 [4]. The market did not take off until this technology was proven to be reliable and manufacturable [5].

Advances in Nonvolatile Memory and Storage Technology, Second Edition, addresses recent developments in the non-volatile memory spectrum, from fundamental understanding, to technological aspects. The book provides up-to-date information on the current memory technologies as related by leading experts in both academia and industry. To reflect the rapidly changing field, many new chapters have been included to feature the latest in RRAM technology, STT-RAM, memristors and more. The new edition describes the emerging technologies including oxide-based ferroelectric memories, MRAM technologies, and 3D memory. Finally, to further widen the discussion on the applications space, neuromorphic computing aspects have been included. This book is a key resource for postgraduate students and academic researchers in physics, materials science and electrical engineering. In addition, it will be a valuable tool for research and development managers concerned with electronics, semiconductors, nanotechnology, solid-state memories, magnetic materials, organic materials and portable electronic devices. Discusses emerging devices and research trends, such as neuromorphic computing and oxide-based ferroelectric memories Provides an overview on developing nonvolatile memory and storage technologies and explores their strengths and weaknesses Examines improvements to flash technology, charge trapping and resistive random access memory

In recent years, utilization of the abundant advantages of quantum physics, quantum dots, quantum wires, quantum wells, and nanocrystals has attracted considerable scientific attention in the field of nonvolatile memory. Nanocrystals are the driving element that have brought the nonvolatile flash memory technology to a distinguished height. However, new approaches are still required to strengthen this technology for future applications. This book details the methods of fabrication of nanocrystals and their application in baseline nonvolatile memory and emerging nonvolatile memory technologies. The chapters have been written by renowned experts of the field and will provide an in-depth understanding of these technologies. The book is a valuable tool for research and development sectors associated with electronics, semiconductors, nanotechnology, material sciences, solid state memories, and electronic devices.

RRAM technology has made significant progress in the past decade as a competitive candidate for the next generation non-volatile memory (NVM). This lecture is a comprehensive tutorial of metal oxide-based RRAM technology from device fabrication to array architecture design. State-of-the-art RRAM device performances, characterization, and modeling techniques are summarized, and the design considerations of the RRAM integration to large-scale array with peripheral circuits are discussed. Chapter 2 introduces the RRAM device fabrication techniques and methods to eliminate the forming process, and will show its scalability down to sub-10 nm regime. Then the device performances such as programming speed, variability control, and multi-level operation are presented, and finally the reliability issues such as cycling endurance and data retention are discussed. Chapter 3 discusses the RRAM physical mechanism, and the materials characterization techniques to observe the conductive filaments and the electrical characterization techniques to study the electronic conduction processes. It also presents the numerical device modeling techniques for simulating the evolution of the conductive filaments as well as the compact device modeling techniques for circuit-level design. Chapter 4 discusses the two common RRAM array architectures for large-scale integration: one-transistor-one-resistor (1T1R) and cross-point architecture with selector. The write/read schemes are presented and the peripheral circuitry design considerations are discussed. Finally, a 3D integration approach is introduced for building ultra-high density RRAM array. Chapter 5 is a brief summary and will give an outlook for RRAM's potential novel applications beyond the NVM applications.

A detailed, practical review of state-of-the-art implementations of memory in IoT hardware As the Internet of Things (IoT) technology continues to evolve and become increasingly common across an array of specialized and consumer product applications, the demand on engineers to design new generations of flexible, low-cost, low power embedded memories into IoT hardware becomes ever greater. This book helps them meet that demand. Coauthored by a leading international expert and multiple patent holder, this book gets engineers up to speed on state-of-the-art implementations of memory in IoT hardware. Memories for the Intelligent Internet of Things covers an array of common and cutting-edge IoT embedded memory implementations. Ultra-low-power memories for IoT devices-including plastic and polymer circuitry for specialized applications, such as medical electronics-are described. The authors explore microcontrollers with embedded memory used for smart control of a multitude of Internet devices. They also consider neuromorphic memories made in Ferroelectric RAM (FeRAM), Resistance RAM (ReRAM), and Magnetic RAM (MRAM) technologies to implement artificial intelligence (AI) for the collection, processing, and presentation of large quantities of data generated by IoT hardware. Throughout the focus is on memory technologies which are complementary metal oxide semiconductor (CMOS) compatible, including embedded floating gate and charge trapping EEPROM/Flash along with FeRAMS, FeFETs, MRAMs and ReRAMs. Provides a timely, highly practical look at state-of-the-art IoT memory implementations for an array of product applications Synthesizes basic science with original analysis of memory technologies for Internet of Things (IoT) based on the authors' extensive experience in the field Focuses on practical and timely applications throughout Features numerous illustrations, tables, application requirements, and photographs Considers memory related security issues in IoT devices Memories for the Intelligent Internet of Things is a valuable working resource for electrical engineers and engineering managers working in the electronics system and semiconductor industries. It is also an indispensable reference/text for graduate and advanced undergraduate students interested in the latest developments in integrated circuit devices and systems.

This book provides a comprehensive introduction to embedded flash memory, describing the history, current status, and future projections for technology, circuits, and systems applications. The authors describe current main-stream embedded flash technologies from floating-gate 1Tr, floating-gate with split-gate (1.5Tr), and 1Tr/1.5Tr SONOS flash technologies and their successful creation of various applications. Comparisons of these embedded flash technologies and future projections are also provided. The authors demonstrate a variety of embedded applications for auto-motive, smart-IC cards, and low-power, representing the leading-edge technology developments for eFlash. The discussion also includes insights into future prospects of application-driven non-volatile memory technology in the era of smart advanced automotive system, such as ADAS (Advanced Driver Assistance System) and IoE (Internet of Everything). Trials on technology convergence and future prospects of embedded non-volatile memory in the new memory hierarchy are also described. Introduces the history of embedded flash memory technology for micro-controller products and how embedded flash innovations developed; Includes comprehensive and detailed descriptions of current main-stream embedded flash memory technologies, sub-system designs and applications; Explains why embedded flash memory requirements are different from those of stand-alone flash memory and how to achieve specific goals with technology development and circuit designs; Describes a mature and stable floating-gate 1Tr cell technology imported from stand-alone flash memory products - that then introduces embedded-specific split-gate memory cell technologies based on floating-gate storage structure and charge-trapping SONOS technology and their eFlash sub-system designs; Describes automotive and smart-IC card applications requirements and achievements in advanced eFlash beyond 4 0nm node.

Nonvolatile Memory Technologies with Emphasis on FlashA Comprehensive Guide to Understanding and Using Flash Memory DevicesJohn Wiley & Sons

Kevin Zhang Advancement of semiconductor technology has driven the rapid growth of very large scale integrated (VLSI) systems for increasingly broad applications, incl- ing high-end and mobile computing, consumer electronics such as 3D gaming, multi-function or smart phone, and various set-top players and ubiquitous sensor and medical devices. To meet the increasing demand for higher performance and lower power consumption in many different system applications, it is often required to have a large amount of on-die or embedded memory to support the need of data bandwidth in a system. The varieties of embedded memory in a given system have alsobecome increasingly more complex, ranging fromstatictodynamic and volatile to nonvolatile. Among embedded memories, six-transistor (6T)-based static random access memory (SRAM) continues to play a pivotal role in nearly all VLSI systems due to its superior speed and full compatibility with logic process technology. But as the technology scaling continues, SRAM design is facing severe challenge in mainta- ing suf?cient cell stability margin under relentless area scaling. Meanwhile, rapid expansion in mobile application, including new emerging application in sensor and medical devices, requires far more aggressive voltage scaling to meet very str- gent power constraint. Many innovative circuit topologies and techniques have been extensively explored in recent years to address these challenges.

The manufacture of flash memory, which is the dominant nonvolatile memory technology, is facing severe technical barriers. So much so, that some emerging technologies have been proposed as alternatives to flash memory in the nano-regime. Nonvolatile Memory Design: Magnetic, Resistive, and Phase Changing introduces three promising candidates: phase-change memory, magnetic random access memory, and resistive random access memory. The text illustrates the fundamental storage mechanism of these technologies and examines their differences from flash memory techniques. Based on the latest advances, the authors discuss key design methodologies as well as the various functions and capabilities of the three nonvolatile memory technologies.

Would you like to add the capabilities of the Non-Volatile Memory (NVM) as a storage element in your silicon integrated logic circuits, and as a trimming sector in your high voltage driver and other silicon integrated analog circuits? Would you like to learn how to embed the NVM into your silicon integrated circuit products to improve their performance?This book is written to help you.It provides comprehensive instructions on fabricating the NVM using the same processes you are using to fabricate your logic integrated circuits. We at our eMemory company call this technology the embedded Logic NVM. Because embedded Logic NVM has simple fabrication processes, it has replaced the conventional NVM in many traditional and new applications, including LCD driver, LED driver, MEMS controller, touch panel controller, power management unit, ambient and motion sensor controller, micro controller unit (MCU), security ID setting tag, RFID, NFC, PC camera controller, keyboard controller, and mouse controller. The recent explosive growth of the Logic NVM indicates that it will soon dominate all NVM applications. The embedded Logic NVM was invented and has been implemented in users' applications by the 200+ employees of our eMemory company, who are also the authors and author-assistants of this book.This book covers the following Logic NVM products: One Time Programmable (OTP) memory, Multiple Times Programmable (MTP) memory, Flash memory, and Electrically Erasable Programmable Read Only Memory (EEPROM). The fundamentals of the NVM are described in this book, which include: the physics and operations of the memory transistors, the basic building block of the memory cells and the access circuits.All of these products have been used continuously by the industry worldwide. In-depth readers can attain expert proficiency in the implementation of the embedded Logic NVM technology in their products.

This book first provides the basics of magnetism that electrical engineering students in the semiconductor curriculum can easily understand. Then, it goes one step forward to discuss electron spin. Following the above background discussion, readers are taught the physics of magnetic tunnel junction device (MTJ), the work horse of MRAM, for memory applications. At the end of this book, the author gives a comparison of emerging non-volatile memories (PCM, ReRAM, FeRAM and MRAM). The author also explores MRAM’s unique quality among emerging memories, in that is the only one in which the atoms in the device do not move when switching states. This property makes it the most reliable and low power.

This book introduces readers to the latest advances in sensing technology for a broad range of non-volatile memories (NVMs). Challenges across the memory technologies are highlighted and their solutions in mature technology are discussed, enabling innovation of sensing technologies for future NVMs. Coverage includes sensing techniques ranging from well-established NVMs such as hard disk, flash, Magnetic

RAM (MRAM) to emerging NVMs such as ReRAM, STTRAM, FeRAM and Domain Wall Memory will be covered.

This book is an introduction to the fundamentals of emerging non-volatile memories and provides an overview of future trends in the field. Readers will find coverage of seven important memory technologies, including Ferroelectric Random Access Memory (FeRAM), Ferromagnetic RAM (FMRAM), Multiferroic RAM (MFRAM), Phase-Change Memories (PCM), Oxide-based Resistive RAM (RRAM), Probe Storage, and Polymer Memories. Chapters are structured to reflect diffusions and clashes between different topics. Emerging Non-Volatile Memories is an ideal book for graduate students, faculty, and professionals working in the area of non-volatile memory. This book also: Covers key memory technologies, including Ferroelectric Random Access Memory (FeRAM), Ferromagnetic RAM (FMRAM), and Multiferroic RAM (MFRAM), among others. Provides an overview of non-volatile memory fundamentals. Broadens readers’ understanding of future trends in non-volatile memories.

For the technological progress in communication technology it is necessary that the advanced studies in circuit and software design are accompanied with recent results of the technological research and physics in order to exceed its limitations. This book is a guide which treats many components used in mobile communications, and in particular focuses on non-volatile memories. It emerges following the conducting line of the non-volatile memory in the wireless system: On the one hand it develops the foundations of the interdisciplinary issues needed for design analysis and testing of the system. On the other hand it deals with many of the problems appearing when the systems are realized in industrial production. These cover the difficulties from the mobile system to the different types of non-volatile memories. The book explores memory cards, multichip technologies, and algorithms of the software management as well as error handling. It also presents techniques of assurance for the single components and a guide through the Datasheet lectures.

Magnetic random-access memory (MRAM) is poised to replace traditional computer memory based on complementary metal-oxide semiconductors (CMOS). MRAM will surpass all other types of memory devices in terms of nonvolatility, low energy dissipation, fast switching speed, radiation hardness, and durability. Although toggle-MRAM is currently a commercial product, it is clear that future developments in MRAM will be based on spin-transfer torque, which makes use of electrons’ spin angular momentum instead of their charge. MRAM will require an amalgamation of magnetics and microelectronics technologies. However, researchers and developers in magnetics and in microelectronics attend different technical conferences, publish in different journals, use different tools, and have different backgrounds in condensed-matter physics, electrical engineering, and materials science. This book is an introduction to MRAM for microelectronics engineers written by specialists in magnetic materials and devices. It presents the basic phenomena involved in MRAM, the materials and film stacks being used, the basic principles of the various types of MRAM (toggle and spin-transfer torque; magnetized in-plane or perpendicular-to-plane), the back-end magnetic technology, and recent developments toward logic-in-memory architectures. It helps bridge the cultural gap between the microelectronics and magnetics communities.

This book describes the basic technologies and operation principles of charge-trapping non-volatile memories. The authors explain the device physics of each device architecture and provide a concrete description of the materials involved as well as the fundamental properties of the technology. Modern material properties used as charge-trapping layers, for new applications are introduced.

The primary focus of this book is on basic device concepts, memory cell design, and process technology integration. The first part provides in-depth coverage of conventional nonvolatile memory devices, stack structures from device physics, historical perspectives, and identifies limitations of conventional devices. The second part reviews advances made in reducing and/or eliminating existing limitations of NVM device parameters from the standpoint of device scalability, application extendibility, and reliability. The final part proposes multiple options of silicon based unified (nonvolatile) memory cell concepts and stack designs (SUMs). The book provides Industrial R&D personnel with the knowledge to drive the future memory technology with the established silicon FET-based establishments of their own. It explores application potentials of memory in areas such as robotics, avionics, health-industry, space vehicles, space sciences, bio-imaging, genetics etc.

This comprehensive reference book provides electronics engineers with the technical data and perspective necessary for the intelligent selection, specification, and application of nonvolatile semiconductor memory devices. A "one-stop shopping" tool for the working engineer, this book presents the fundamental aspects of nonvolatile semiconductor memory technologies, devices, reliability, and applications.

This book explores the implications of non-volatile memory (NVM) for database management systems (DBMSs). The advent of NVM will fundamentally change the dichotomy between volatile memory and durable storage in DBMSs. These new NVM devices are almost as fast as volatile memory, but all writes to them are persistent even after power loss. Existing DBMSs are unable to take full advantage of this technology because their internal architectures are predicated on the assumption that memory is volatile. With NVM, many of the components of legacy DBMSs are unnecessary and will degrade the performance of data-intensive applications. We present the design and implementation of DBMS architectures that are explicitly tailored for NVM. The book focuses on three aspects of a DBMS: (1) logging and recovery, (2) storage and buffer management, and (3) indexing. First, we present a logging and recovery protocol that enables the DBMS to support near-instantaneous recovery. Second, we propose a storage engine architecture and buffer management policy that leverages the durability and byte-addressability properties of NVM to reduce data duplication and data migration. Third, the book presents the design of a range index tailored for NVM that is latch-free yet simple to implement. All together, the work described in this book illustrates that rethinking the fundamental algorithms and data structures employed in a DBMS for NVM improves performance and availability, reduces operational cost, and simplifies software development.

Beginning and experienced programmers will use this comprehensive guide to persistent memory programming. You will understand how persistent memory brings together several new software/hardware requirements, and offers great promise for better performance and faster application startup times—a huge leap forward in byte-addressable capacity compared with current DRAM offerings. This revolutionary new technology gives applications significant performance and capacity improvements over existing technologies. It requires a new way of thinking and developing, which makes this highly disruptive to the IT/computing industry. The full spectrum of industry sectors that will benefit from this technology include, but are not limited to, in-memory and traditional databases, AI, analytics, HPC, virtualization, and big data. Programming Persistent Memory describes the technology and why it is exciting the industry. It covers the operating system and hardware requirements as well as how to create development environments using emulated or real persistent memory hardware. The book explains fundamental concepts; provides an introduction to persistent memory programming APIs for C, C++, JavaScript, and other languages; discusses RMDA with persistent memory; reviews security features; and presents many examples. Source code and examples that you can run on your own systems are included. What You'll Learn Understand what persistent memory is, what it does, and the value it brings to the industry Become familiar with the operating system and hardware requirements to use persistent memory Know the fundamentals of persistent memory programming: why it is different from current programming methods, and what developers need to keep in mind when programming for persistence Look at persistent memory application development by example using the Persistent Memory Development Kit (PMDK)Design and optimize data structures for persistent memoryStudy how real-world applications are modified to leverage persistent memoryUtilize the tools available for persistent memory programming, application performance profiling, and debugging Who This Book Is For C, C++, Java, and Python developers, but will also be useful to software, cloud, and hardware architects across a broad spectrum of sectors, including cloud service providers, independent software vendors, high performance compute, artificial intelligence, data analytics, big data, etc.

This book offers a balanced and comprehensive guide to the core principles, fundamental properties, experimental approaches, and state-of-the-art applications of two major groups of emerging non-volatile memory technologies, i.e. spintronics-based devices as well as resistive switching devices, also known as Resistive Random Access Memory (RRAM). The first section presents different types of spintronic-based devices, i.e. magnetic tunnel junction (MTJ), domain wall, and skyrmion memory devices. This section describes how their developments have led to various promising applications, such as microwave oscillators, detectors, magnetic logic, and neuromorphic engineered systems. In the second half of the book, the underlying device physics supported by different experimental observations and modelling of RRAM devices are presented with memory array level implementation. An insight into RRAM desired properties as synaptic element in neuromorphic computing platforms from material and algorithms viewpoint is also discussed with specific example in automatic sound classification framework.

The large scale integration and planar scaling of individual system chips is reaching an expensive limit. If individual chips now, and later terrabyte memory blocks, memory macros, and processing cores, can be tightly linked in optimally designed and processed small footprint vertical stacks, then performance can be increased, power reduced and cost contained. This book reviews for the electronics industry engineer, professional and student the critical areas of development for 3D vertical memory chips including: gate-all-around and junction-less nanowire memories, stacked thin film and double gate memories, terrabit vertical channel and vertical gate stacked NAND flash, large scale stacking of Resistance RAM cross-point arrays, and 2.5D/3D stacking of memory and processor chips with through-silicon-via connections now and remote links later. Key features: Presents a review of the status and trends in 3-dimensional vertical memory chip technologies. Extensively reviews advanced vertical memory chip technology and development Explores technology process routes and 3D chip integration in a single reference

This book describes the technology of charge-trapping non-volatile memories and their uses. The authors explain the device physics of each device architecture and provide a concrete description of the materials involved and the fundamental properties of the technology. Modern material properties, used as charge-trapping layers, for new applications are introduced. Provides a comprehensive overview of the technology for charge-trapping non-volatile memories; Details new architectures and current modeling concepts for non-volatile memory devices; Focuses on conduction through multi-layer gate dielectrics stacks.

This book explores the design implications of emerging, non-volatile memory (NVM) technologies on future computer memory hierarchy architecture designs. Since NVM technologies combine the speed of SRAM, the density of DRAM, and the non-volatility of Flash memory, they are very attractive as the basis for future universal memories. This book provides a holistic perspective on the topic, covering modeling, design, architecture and applications. The practical information included in this book will enable designers to exploit emerging memory technologies to improve significantly the performance/power/reliability of future, mainstream integrated circuits.

This book describes computing innovation, using non-volatile memory for a sustainable world. It appeals to both computing engineers and device engineers by describing a new means of lower power computing innovation, without sacrificing performance over conventional low-voltage operation. Readers will be introduced to methods of design and implementation for non-volatile memory which allow computing equipment to be turned off normally when not in use and to be turned on instantly to operate with full performance when needed.

The book intends to bring under one roof research work of leading groups from across the globe working on advanced applications of emerging memory technology nanodevices. The applications dealt in the text will be beyond conventional storage application of semiconductor memory devices. The text will deal with material and device physical principles that give rise to interesting characteristics and phenomena in the emerging memory device that can be exploited for a wide variety of applications. Applications covered will include system-centric cases such as - caches, NVSRAM, NVTCAM, Hybrid CMOS-RRAM circuits for: Machine Learning, In-Memory Computing, Hardware Security - RNG/PUF, Biosensing and other misc beyond storage applications. The book is envisioned for multi-purpose use as a textbook in advanced UG/PG courses and a research text for scientists working in the domain.

With its comprehensive coverage, this reference introduces readers to the wide topic of resistance switching, providing the knowledge, tools, and methods needed to understand, characterize and apply resistive switching memories. Starting with those materials that display resistive switching behavior, the book explains the basics of resistive switching as well as switching mechanisms and models. An in-depth discussion of memory reliability is followed by chapters on memory cell structures and architectures, while a section on logic gates rounds off the text. An invaluable self-contained book for materials scientists, electrical engineers and physicists dealing with memory research and development.

This book provides students and practicing chip designers with an easy-to-follow yet thorough, introductory treatment of the most promising emerging memories under development in the industry. Focusing on the chip designer rather than the end user, this book offers expanded, up-to-date coverage of emerging memories circuit design. After an introduction on the old solid-state memories and the fundamental limitations soon to be encountered, the working principle and main technology issues of each of the considered technologies (PCRAM, MRAM, FeRAM, ReRAM) are reviewed and a range of topics related to design is explored: the array organization, sensing and writing circuitry, programming algorithms and error correction techniques are reviewed comparing the approach followed and the constraints for each of the technologies considered. Finally the issue of radiation effects on memory devices has been briefly treated. Additionally some considerations are entertained about how emerging memories can find a place in the new memory paradigm required by future electronic systems. This book is an up-to-date and comprehensive introduction for students in courses on memory circuit design or advanced digital courses in VLSI or CMOS circuit design. It also serves as an essential, one-stop resource for academics, researchers and practicing engineers.

Nanoscale memories are used everywhere. From your iPhone to a supercomputer, every electronic device contains at least one such type. With coverage of current and prototypical technologies, Nanoscale Semiconductor Memories: Technology and Applications presents the latest research in the field of nanoscale memories technology in one place. It also covers a myriad of applications that nanoscale memories technology has enabled. The book begins with coverage of SRAM, addressing the design challenges as the technology scales, then provides design strategies to mitigate radiation induced upsets in SRAM. It discusses the current state-of-the-art DRAM technology and the need to develop high performance sense amplifier circuitry. The text then covers the novel concept of capacitorless 1T DRAM, termed as Advanced-RAM or A-RAM, and presents a discussion on quantum dot (QD) based flash memory. Building on this foundation, the coverage turns to STT-RAM, emphasizing scalable embedded STT-RAM, and the physics and engineering of magnetic domain wall "racetrack" memory. The book also discusses state-of-the-art modeling applied to phase change memory devices and includes an extensive review of RRAM, highlighting the physics of operation and analyzing different materials systems currently under investigation. The hunt is still on for universal memory that fits all the requirements of an "ideal memory" capable of high-density storage, low-power operation, unparalleled speed, high endurance, and low cost. Taking an interdisciplinary approach, this book bridges technological and application issues to provide the groundwork for developing custom designed memory systems.

Presented here is an all-inclusive treatment of Flash technology, including Flash memory chips, Flash embedded in logic, binary cell Flash, and multilevel cell Flash. The book begins with a tutorial of elementary concepts to orient readers who are less familiar with the subject. Next, it covers all aspects and variations of Flash technology at a mature engineering level: basic device structures, principles of operation, related process technologies, circuit design, overall design tradeoffs, device testing, reliability, and applications.

Offers a comprehensive overview of NAND flash memories, with insights into NAND history, technology, challenges, evolutions, and perspectives Describes new program disturb issues, data retention, power consumption, and possible solutions for the challenges of 3D NAND flash memory Written by an authority in NAND flash memory technology, with over 25 years' experience

This book walks the reader through the next step in the evolution of NAND flash memory technology, namely the development of 3D flash memories, in which multiple layers of memory cells are grown within the same piece of silicon. It describes their working principles, device architectures, fabrication techniques and practical implementations, and highlights why 3D flash is a brand new technology. After reviewing market trends for both NAND and solid state drives (SSDs), the book digs into the details of the flash memory cell itself, covering both floating gate and emerging charge trap technologies. There is a plethora of different materials and vertical integration schemes out there. New memory cells, new materials, new architectures (3D Stacked, BiCS and P-BiCS, 3D FG, 3D VG, 3D advanced architectures); basically, each NAND manufacturer has its own solution. Chapter 3 to chapter 7 offer a broad overview of how 3D can materialize. The 3D wave is impacting emerging memories as well and chapter 8 covers 3D RRAM (resistive RAM) crosspoint arrays. Visualizing 3D structures can be a challenge for the human brain: this is way all these chapters contain a lot of bird's-eye views and cross sections along the 3 axes. The second part of the book is devoted to other important aspects, such as advanced packaging technology (i.e. TSV in chapter 9) and error correction codes, which have been leveraged to improve flash reliability for decades. Chapter 10 describes the evolution from legacy BCH to the most recent LDPC codes, while chapter 11 deals with some of the most recent advancements in the ECC field. Last but not least, chapter 12 looks at 3D flash memories from a system perspective. Is 14nm the last step for planar cells? Can 100 layers be integrated within the same piece of silicon? Is 4 bit/cell possible with 3D? Will 3D be reliable enough for enterprise and datacenter applications? These are some of the questions that this book helps answering by providing insights into 3D flash memory design, process technology and applications.

In response to tremendous growth and new technologies in the semiconductor industry, this volume is organized into five, information-rich sections. Digital Design and Fabrication surveys the latest advances in computer architecture and design as well as the technologies used to manufacture and test them. Featuring contributions from leading experts, the book also includes a new section on memory and storage in addition to a new chapter on nonvolatile memory technologies. Developing advanced concepts, this sharply focused book— Describes new technologies that have become driving factors for the electronic industry Includes new information on semiconductor memory circuits, whose development best illustrates the phenomenal progress encountered by the fabrication and technology sector Contains a section dedicated to issues related to system power consumption Describes reliability and testability of computer systems Pinpoints trends and state-of-the-art advances in fabrication and CMOS technologies Describes performance evaluation measures, which are the bottom line from the user’s point of view Discusses design techniques used to create modern computer systems, including high-speed computer arithmetic and high-frequency design, timing and clocking, and PLL and DLL design

VLSI-Design for Non-Volatile Memories is intended for electrical engineers and graduate students who want to enter into the integrated circuit design world. Non-volatile memories are treated as an example to explain general design concepts. Practical illustrative examples of non-volatile memories, including flash types, are showcased to give insightful examples of the discussed design approaches. A collection of photos is included to make the reader familiar with silicon aspects. Throughout all parts of this book, the authors have taken a practical and applications-driven point of view, providing a comprehensive and easily understood approach to all the concepts discussed. Giovanni Campardo and Rino Micheloni have a solid track record of leading design activities at the STMicroelectronics Flash Division. David Novosel is President and founder of Intelligent Micro Design, Inc., Pittsburg, PA.

Information technology is essential to our daily life, and the limitations of silicone based memory systems mean a growing amount of research is focussed on finding an inexpensive alternative to meet our needs and allow the continued development of the industry. Inorganic silicone based technology is increasingly costly and complex and is physically limited by the problems of scaling down. Organic electrical memory devices are comparatively low cost, offer flexibility in terms of chemical structure, are compatible with flexible substrates and allow easy processing. For these reasons polymeric memory nanoscale materials are considered by many to be a potential substitute for conventional semiconductor memory systems. This edited book focusses solely on organic memory devices, providing a full background and overview of the area before bringing the reader up to date with the current and ongoing research in this area. The broad appeal of this book will be applicable to a wide range of researchers and those working in industry, in particular those working in materials, electrical and chemical engineering.

New solutions are needed for future scaling down of nonvolatile memory. Advances in Non-volatile Memory and Storage Technology provides an overview of developing technologies and explores their strengths and weaknesses. After an overview of the current market, part one introduces improvements in flash technologies, including developments in 3D NAND flash technologies and flash memory for ultra-high density storage devices. Part two looks at the advantages of designing phase change memory and resistive random access memory technologies. It looks in particular at the fabrication, properties, and performance of nanowire phase change memory technologies. Later chapters also consider modeling of both metal oxide and resistive random access memory switching mechanisms, as well as conductive bridge random access memory technologies. Finally, part three looks to the future of alternative technologies. The areas covered include molecular, polymer, and hybrid organic memory devices, and a variety of random access memory devices such as nano-electromechanical, ferroelectric, and spin-transfer-torque magnetoresistive devices. Advances in Non-volatile Memory and Storage Technology is a key resource for postgraduate students and academic researchers in physics, materials science, and electrical engineering. It is a valuable tool for research and development managers concerned with electronics, semiconductors, nanotechnology, solid-state memories, magnetic materials, organic materials, and portable electronic devices. Provides an overview of developing nonvolatile memory and storage technologies and explores their strengths and weaknesses Examines improvements to flash technology, charge trapping, and resistive random access memory Discusses emerging devices such as those based on polymer and molecular electronics, and nanoelectromechanical random access memory (RAM)

The subject of this book is to introduce a model-based quantitative performance indicator methodology applicable for performance, cost and reliability optimization of non-volatile memories. The complex example of flash memories is used to introduce and apply the methodology. It has been developed by the author based on an industrial 2-bit to 4-bit per cell flash development project. For the first time, design and cost aspects of 3D integration of flash memory are treated in this book. Cell, array, performance and reliability effects of flash memories are introduced and analyzed. Key performance parameters are derived to handle the flash complexity. A performance and array memory model is developed and a set of performance indicators characterizing architecture, cost and durability is defined. Flash memories are selected to apply the Performance Indicator Methodology to quantify design and technology innovation. A graphical representation based on trend lines is introduced to support a requirement based product development process. The Performance Indicator methodology is applied to demonstrate the importance of hidden memory parameters for a successful product and system development roadmap. Flash Memories offers an opportunity to enhance your understanding of product development key topics such as: · Reliability optimization of flash memories is all about threshold voltage margin understanding and definition; · Product performance parameter are analyzed in-depth in all aspects in relation to the threshold voltage operation window; · Technical characteristics are translated into quantitative performance indicators; · Performance indicators are applied to identify and quantify product and technology innovation within adjacent areas to fulfill the application requirements with an overall cost optimized solution; · Cost, density, performance and durability values are combined into a common factor – performance indicator - which fulfills the application requirements Semiconductor Memories provides in-depth coverage in the areas of design for testing, fault tolerance, failure modes and mechanisms, and screening and qualification methods including. * Memory cell structures and fabrication technologies. * Application-specific memories and architectures. * Memory design, fault modeling and test algorithms, limitations, and trade-offs. * Space environment, radiation hardening process and design techniques, and radiation testing. * Memory stacks and multichip modules for gigabyte storage.