

# Resistive Random Access Memory

**Alex James**

**Resistive Switching** Daniele Ielmini, Rainer Waser, 2016 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.

*Advances in Non-volatile Memory and Storage Technology* Yoshio Nishi, 2014-06-24 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)

*Resistive Switching: Oxide Materials, Mechanisms, Devices and Operations* Jennifer Rupp, Daniele Ielmini, Ilia Valov, 2021-10-15 This book provides a broad examination of redox-based resistive switching memories (ReRAM), a promising technology for novel types of nanoelectronic devices, according to the International Technology Roadmap for Semiconductors, and the materials and physical processes used in these ionic transport-based switching devices. It covers defect kinetic models for switching, ReRAM deposition/fabrication methods, tuning thin film microstructures, and material/device characterization and modeling. A slate of world-renowned authors address the influence of type of ionic carriers, their mobility, the role of the local and chemical composition and environment, and facilitate readers' understanding of the effects of composition and structure at different length scales (e.g., crystalline vs amorphous phases, impact of extended defects such as dislocations and grain boundaries). ReRAMs show outstanding potential for scaling down to the atomic level, fast operation in the nanosecond range, low power consumption, and non-volatile storage. The book is ideal for materials scientists and engineers concerned with novel types of nanoelectronic devices such as memories, memristors, and switches for logic and neuromorphic computing circuits beyond the von Neumann concept.

*Resistive Random Access Memory (RRAM)* Shimeng Yu, 2022-06-01 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.

**Nonvolatile Memory Design** Hai Li, Yiran Chen, 2017-12-19 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.

**Compact Modeling** Gennady Gilenblat, 2010-06-22 Most of the recent texts on compact modeling are limited to a particular class of semiconductor devices and do not provide comprehensive coverage of the field. Having a single comprehensive reference for the compact models of most commonly used semiconductor devices (both active and passive) represents a significant advantage for the reader. Indeed, several kinds of semiconductor devices are routinely encountered in a single IC design or in a single modeling support group. *Compact Modeling* includes mostly the material that after several years of IC design applications has been found both theoretically sound and practically significant. Assigning the individual chapters to the groups responsible for the definitive work on the subject assures the highest possible degree of expertise on each of the covered models.

*Perovskite Materials, Devices and Integration* He Tian, 2020-06-10 Perovskites have attracted great attention in the fields of energy storage, pollutant degradation as well as optoelectronic devices due to their excellent properties. This kind of material can be divided into two categories; inorganic perovskite represented by perovskite oxide and organic-inorganic hybrid perovskite, which have described the recent advancement separately in terms of catalysis and photoelectron applications. This book systematically illustrates the crystal structures, physic-chemical properties, fabrication process, and perovskite-related devices. In a word, perovskite has broad application prospects. However, the current challenges cannot be ignored, such as toxicity and stability.

**Noise in Nanoscale Semiconductor Devices** Tibor Grasser, 2020-04-26 This book summarizes the state-of-the-art, regarding noise in nanometer semiconductor devices. Readers will benefit from this leading-edge research, aimed at increasing reliability based on physical microscopic models. Authors discuss the most recent developments in the understanding of point defects, e.g. via ab initio calculations or intricate measurements, which have paved the way to more physics-based noise models which are applicable to a wider range of materials and features, e.g. III-V materials, 2D materials, and multi-state defects. Describes the state-of-the-art, regarding noise in nanometer semiconductor devices; Enables readers to design more reliable semiconductor devices; Offers the most up-to-date information on point defects, based on physical microscopic models.

**Emerging Non-volatile Memory Technologies** Wen Siang Lew, Gerard Joseph Lim, Putu Andhita Dananjaya, 2021-01-09 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.

**Nanoscience And Technology: A Collection Of Reviews From Nature Journals** Peter Rodgers, 2009-08-21 This book contains 35 review articles on nanoscience and nanotechnology that were first published in Nature Nanotechnology, Nature Materials and a number of other Nature journals. The articles are all written by leading authorities in their field and cover a wide range of areas in nanoscience and technology, from basic research (such as single-molecule devices and new materials) through to applications (in, for example, nanomedicine and data storage).

**Nanocrystals in Nonvolatile Memory** Writam Banerjee, 2024-08-09 In recent years, the abundant advantages of quantum physics, quantum dots, quantum wires, quantum wells, and nanocrystals in various applications have attracted considerable scientific attention in the field of nonvolatile memory (NVM). Nanocrystals are the driving elements that have helped nonvolatile flash memory technology reach its distinguished height, but new approaches are still needed to strengthen nanocrystal-based nonvolatile technology for future applications. This book presents comprehensive knowledge on nanocrystal fabrication methods and applications of nanocrystals in baseline NVM and emerging NVM technologies and the chapters are written by experts in the field from all over the globe. The book presents a detailed analysis on nanocrystal-based emerging devices by a high-level researcher in the field. It has a unique chapter especially dedicated to graphene-based flash memory devices, considering the importance of carbon allotropes in future applications. This updated edition covers emerging ferroelectric memory device, which is a technology for the future, and the chapter is contributed by the well-known Ferroelectric Memory Company, Germany. It includes information related to the applications of emerging memories in sensors and the chapter is contributed by Ajou University, South Korea. The book introduces a new chapter for emerging NVM technology in artificial intelligence and the chapter is contributed by University College London, UK. It guides the readers throughout with appropriate illustrations, excellent figures, and references in each chapter. It is a valuable tool for researchers and developers from the fields of electronics, semiconductors, nanotechnology, materials science, and solid-state memories.

Emerging Non-Volatile Memories Seungbum Hong, Orlando Auciello, Dirk Wouters, 2014-11-18 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.

**Resistive RAM and Peripheral Circuitry** John Reuben, 2024-05-18 This book is written as an introductory textbook on Resistive Random Access Memory (ReRAM). ReRAM is a prominent emerging memory among other competing Non-Volatile Memories (NVM) seeking to replace flash memory. This book is based on the author's peer-reviewed research conducted at the Chair of Computer Architecture, FAU, Germany. Referring to his research and the most relevant research from the literature, the author presents the developments in this field concisely. The purpose is to clarify basic concepts and introduce the reader to ReRAM with an emphasis on circuit design. Hence, this book is written for university students considering a career in the semiconductor industry. Since the author's research was conducted in collaboration with a silicon foundry, hardware engineers will find this book practical and industry-relevant. Researchers in the field of In-Memory Computing will also benefit from this book since the NVM array is the basic substrate for such computing paradigms. This three-part book condenses the research and development of the last decade into eight chapters. In Part I, a good foundation is laid for understanding the individual device structure, its electrical characteristics, and modeling methodology. The different array configurations in which these memory devices are fabricated are also discussed. In Part II, the peripheral circuits -the CMOS circuits around the ReRAM array are discussed. They include sense amplifiers, programming circuits, and row/column access circuits. Recent developments such as the possibility to perform certain computing tasks in the ReRAM array are discussed in Part III.

**Normally-Off Computing** Takashi Nakada, Hiroshi Nakamura, 2017-01-18 As a step toward ultimate low-power computing, this book introduces normally-off computing, which involves inactive components of computer systems being aggressively powered off with the help of new non-volatile memories (NVMs). Because the energy consumption of modern information devices strongly depends on both hardware and software, co-design and co-optimization of hardware and software are indispensable to improve energy efficiency. The book discusses various topics including (1) details of low-power

technologies including power gating, (2) characteristics of several new-generation NVMs, (3) normally-off computing architecture, (4) important technologies for implementing normally-off computing, (5) three practical implementations: healthcare, mobile information devices, and sensor network systems for smart city applications, and (6) related research and development. Bridging computing methodology and emerging memory devices, the book is designed for both hardware and software designers, engineers, and developers as comprehensive material for understanding normally-off computing.

**Polymer Nanocomposite Materials** Ye Zhou, Guanglong Ding, 2021-03-24 Polymer Nanocomposite Materials Discover an authoritative overview of zero-, one-, and two-dimensional polymer nanomaterials Polymer Nanocomposite Materials: Applications in Integrated Electronic Devices delivers an original and insightful treatment of polymer nanocomposite applications in energy, information, and biotechnology. The book systematically reviews the preparation and characterization of polymer nanocomposites from zero-, one-, and two-dimensional nanomaterials. The two distinguished editors have selected resources that thoroughly explore the applications of polymer nanocomposites in energy, information, and biotechnology devices like sensors, solar cells, data storage devices, and artificial synapses. Academic researchers and professional developers alike will enjoy one of the first books on the subject of this environmentally friendly and versatile new technology. Polymer Nanocomposite Materials discusses challenges associated with the devices and materials, possible strategies for future directions of the technology, and the possible commercial applications of electronic devices built on these materials. Readers will also benefit from the inclusion of: A thorough introduction to the fabrication of conductive polymer composites and their applications in sensors An exploration of biodegradable polymer nanocomposites for electronics and polymer nanocomposites for photodetectors Practical discussions of polymer nanocomposites for pressure sensors and the application of polymer nanocomposites in energy storage devices An examination of functional polymer nanocomposites for triboelectric nanogenerators and resistive switching memory Perfect for materials scientists and polymer chemists, Polymer Nanocomposite Materials: Applications in Integrated Electronic Devices will also earn a place in the libraries of sensor developers, electrical engineers, and other professionals working in the sensor industry seeking an authoritative one-stop reference for nanocomposite applications.

Semiconductor Nanotechnology Stephen M. Goodnick, Anatoli Korin, Robert Nemanich, 2018-07-26 This book presents research dedicated to solving scientific and technological problems in many areas of electronics, photonics and renewable energy. Energy and information are interconnected and are essential elements for the development of human society. Transmission, processing and storage of information requires energy consumption, while the efficient use and access to new energy sources requires new information (ideas and expertise) and the design of novel systems such as photovoltaic devices, fuel cells and batteries. Semiconductor physics creates the knowledge base for the development of information (computers, cell phones, etc.) and energy (photovoltaic) technologies. The exchange of ideas and expertise between these two

technologies is critical and expands beyond semiconductors. Continued progress in information and renewable energy technologies requires miniaturization of devices and reduction of costs, energy and material consumption. The latest generation of electronic devices is now approaching nanometer scale dimensions, new materials are being introduced into electronics manufacturing at an unprecedented rate, and alternative technologies to mainstream CMOS are evolving. Nanotechnology is widely accepted as a source of potential solutions in securing future progress for information and energy technologies. Semiconductor Nanotechnology features chapters that cover the following areas: atomic scale materials design, bio- and molecular electronics, high frequency electronics, fabrication of nanodevices, magnetic materials and spintronics, materials and processes for integrated and subwave optoelectronics, nanoCMOS, new materials for FETs and other devices, nanoelectronics system architecture, nano optics and lasers, non-silicon materials and devices, chemical and biosensors, quantum effects in devices, nano science and technology applications in the development of novel solar energy devices, and fuel cells and batteries.

Memristor and Memristive Neural Networks Alex James,2018-04-04 This book covers a range of models, circuits and systems built with memristor devices and networks in applications to neural networks. It is divided into three parts: (1) Devices, (2) Models and (3) Applications. The resistive switching property is an important aspect of the memristors, and there are several designs of this discussed in this book, such as in metal oxide/organic semiconductor nonvolatile memories, nanoscale switching and degradation of resistive random access memory and graphene oxide-based memristor. The modelling of the memristors is required to ensure that the devices can be put to use and improve emerging application. In this book, various memristor models are discussed, from a mathematical framework to implementations in SPICE and verilog, that will be useful for the practitioners and researchers to get a grounding on the topic. The applications of the memristor models in various neuromorphic networks are discussed covering various neural network models, implementations in A/D converter and hierarchical temporal memories.

*Introduction to Magnetic Random-Access Memory* Bernard Dieny,Ronald B. Goldfarb,Kyung-Jin Lee,2016-11-14 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.

VLSI Tomasz Wojcicki, 2017-12-19 Recently the world celebrated the 60th anniversary of the invention of the first transistor. The first integrated circuit (IC) was built a decade later, with the first microprocessor designed in the early 1970s. Today, ICs are a part of nearly every aspect of our daily lives. They help us live longer and more comfortably, and do more, faster. All this is possible because of the relentless search for new materials, circuit designs, and ideas happening on a daily basis at industrial and academic institutions around the globe. Showcasing the latest advances in very-large-scale integrated (VLSI) circuits, VLSI: Circuits for Emerging Applications provides a balanced view of industrial and academic developments beyond silicon and complementary metal-oxide-semiconductor (CMOS) technology. From quantum-dot cellular automata (QCA) to chips for cochlear implants, this must-have resource: Investigates the trend of combining multiple cores in a single chip to boost performance of the overall system Describes a novel approach to enable physically unclonable functions (PUFs) using intrinsic features of a VLSI chip Examines the VLSI implementations of major symmetric and asymmetric key cryptographic algorithms, hash functions, and digital signatures Discusses nonvolatile memories such as resistive random-access memory (Re-RAM), magneto-resistive RAM (MRAM), and floating-body RAM (FB-RAM) Explores organic transistors, soft errors, photonics, nanoelectromechanical (NEM) relays, reversible computation, bioinformatics, asynchronous logic, and more VLSI: Circuits for Emerging Applications presents cutting-edge research, design architectures, materials, and uses for VLSI circuits, offering valuable insight into the current state of the art of micro- and nanoelectronics.

Nanoscale Semiconductor Memories Santosh K. Kurinec, Krzysztof Iniewski, 2017-07-28 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.

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