



20 Years of NAND Innovation

3d Nand Flash Memory

Yasuo Cho



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NAND Flash Memory Technologies Seiichi Aritome, 2015-12-29 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

3D Flash Memories Rino Micheloni, 2016-05-26 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

3D IC Devices, Technologies, and Manufacturing Hong Xiao, 2016-04 This book discusses the advantages of 3D devices and their applications in dynamic random access memory DRAM 3D NAND flash and advanced technology node CMOS ICs Topics include the development of DRAM cell transistors and storage node capacitors the manufacturing process of advanced buried word line DRAM 3D FinFET CMOS IC devices scaling trends of CMOS logic devices that may be used in the post CMOS era and 3D technologies such as the 3D wafer process integration of silicon on ILD and TSV based 3D packaging

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

NAND Flash Memory Technologies Seiichi Aritome, 2015-11-30 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

Inside NAND Flash Memories Rino Micheloni, Luca Crippa, Alessia Marelli, 2010-07-27 Digital photography MP3 digital video etc make extensive use of NAND based Flash cards as storage media To realize how much NAND Flash memories pervade every aspect of our life just imagine how our recent habits would change if the NAND memories suddenly disappeared To take a picture it would be necessary to find a film as well as a traditional camera disks or even magnetic tapes would be used to record a video or to listen a song and a cellular phone would return to be a simple mean of communication rather than a multimedia console The development of NAND Flash memories will not be set down on the mere evolution of personal entertainment systems since a new killer application can trigger a further success the replacement of Hard Disk Drives HDDs with Solid State Drives SSDs SSD is made up by a microcontroller and several NANDs As NAND is the technology driver for IC circuits Flash designers and technologists have to deal with a lot of challenges Therefore SSD system developers must understand Flash technology in order to exploit its benefits and countermeasure its weaknesses *Inside NAND Flash Memories* is a comprehensive guide of the NAND world from circuits design analog and digital to Flash reliability including radiation effects from testing issues to high performance DDR interface from error correction codes to NAND applications like Flash cards and SSDs

Inside Solid State Drives (SSDs) Rino Micheloni, Alessia Marelli, Kam Eshghi, 2012-10-15 Solid State Drives SSDs are gaining momentum in enterprise and client applications replacing Hard Disk Drives HDDs by offering higher performance and lower power In the enterprise developers of data center server and storage systems have seen CPU performance growing exponentially for the past two decades while HDD performance has improved linearly for the same period Additionally multi core CPU designs and virtualization have increased randomness of storage I Os These trends have shifted performance bottlenecks to enterprise storage systems Business critical applications such as online transaction processing financial data processing and database mining are increasingly limited by storage performance In client applications small mobile platforms are leaving little room for batteries while demanding long life out of them Therefore reducing both idle and active power consumption has become critical Additionally client storage systems are in need of significant performance improvement as well as supporting small robust form factors Ultimately client systems are optimizing for best performance power ratio as well as performance cost ratio SSDs promise to address both enterprise and client storage requirements by drastically improving performance while at the same time reducing power Inside Solid State Drives walks the reader through all the main topics related to SSDs from NAND Flash to memory controller hardware and software from I O interfaces PCIe SAS SATA to reliability from error correction codes BCH and LDPC to encryption from Flash signal processing to hybrid storage We hope you enjoy this tour inside Solid State Drives

2019 IEEE 11th International Memory Workshop (IMW) IEEE Staff, 2019-05-12 The IMW is a unique forum for specialists in all aspects of memory nonvolatile volatile microelectronics and people with different backgrounds who wish to gain a better understanding of the field The morning and afternoon technical sessions are organized in a manner that provides ample time for informal exchanges amongst presenters and attendees The evening panel discussions will address hot topics in the memory and memory system field Papers are solicited in all aspects of semiconductor memory technology Flash DRAM SRAM PCRAM RRAM MRAM embedded memory and other NV memories

Vertical 3D Memory Technologies Betty Prince, 2014-10-06 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

Embedded Flash Memory for Embedded Systems: Technology, Design for Sub-systems, and Innovations Hideto

Hidaka, 2017-09-09 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

Flash Memory Devices Cristian Zambelli, Rino Micheloni, 2022-02-10 Flash memory devices have represented a breakthrough in storage since their inception in the mid 1980s and innovation is still ongoing The peculiarity of such technology is an inherent flexibility in terms of performance and integration density according to the architecture devised for integration The NOR Flash technology is still the workhorse of many code storage applications in the embedded world ranging from microcontrollers for automotive environment to IoT smart devices Their usage is also forecasted to be fundamental in emerging AI edge scenario On the contrary when massive data storage is required NAND Flash memories are necessary to have in a system You can find NAND Flash in USB sticks cards but most of all in Solid State Drives SSDs Since SSDs are extremely demanding in terms of storage capacity they fueled a new wave of innovation namely the 3D architecture Today 3D means that multiple layers of memory cells are manufactured within the same piece of silicon easily reaching a terabit capacity So far Flash architectures have always been based on floating gate where the information is stored by injecting electrons in a piece of polysilicon surrounded by oxide On the contrary emerging concepts are based on charge trap cells In summary flash memory devices represent the largest landscape of storage devices and we expect more advancements in the coming years This will require a lot of innovation in process technology materials circuit design flash management algorithms Error Correction Code and finally system co design for new applications such as AI and security enforcement

2018 IEEE International Solid State Circuits Conference (ISSCC) IEEE Staff, 2018-02-11 ISSCC is the foremost global forum for solid state circuits and systems on a chip The Conference offers 5 days of technical papers and educational events related to integrated circuits including analog digital data converters memory RF communications imagers medical and MEMS ICs

Memory Mass Storage Giovanni Campardo, Federico Tiziani, Massimo Iaculo, 2011-02-04 Memory Mass Storage describes the fundamental storage technologies like Semiconductor Magnetic Optical and Uncommon detailing the main technical characteristics of the storage devices It deals not only with semiconductor and hard disk memory but also with different ways to manufacture and assembly them and with their application to meet market requirements It also provides an introduction to the epistemological issues arising in defining the process of remembering as well as an overview on human memory and an interesting excursus about biological memories and their organization to better understand how the best memory we have our brain is able to imagine and design memory

The Cache Memory Book Jim Handy, 1998-01-13 The Second Edition of The Cache Memory Book introduces systems designers to the concepts behind cache design The book teaches the basic cache concepts and more exotic techniques It leads readers through some of the most intricate protocols used in complex multiprocessor caches Written in an accessible informal style this text demystifies cache memory design by translating cache concepts and jargon into practical methodologies and real life examples It also provides adequate detail to serve as a reference book for ongoing work in cache memory design The Second Edition includes an updated and expanded glossary of cache memory terms and buzzwords The book provides new real world applications of cache memory design and a new chapter on cachetricks Illustrates detailed example designs of caches Provides numerous examples in the form of block diagrams timing waveforms state tables and code traces Defines and discusses more than 240 cache specific buzzwords comparing in detail the relative merits of different design methodologies Includes an extensive glossary complete with clear definitions synonyms and references to the appropriate text discussions

Semiconductor Memory Devices and Circuits Shimeng Yu, 2022-04-19 This book covers semiconductor memory technologies from device bit cell structures to memory array design with an emphasis on recent industry scaling trends and cutting edge technologies The first part of the book discusses the mainstream semiconductor memory technologies The second part of the book discusses the emerging memory candidates that may have the potential to change the memory hierarchy and surveys new applications of memory technologies for machine deep learning applications This book is intended for graduate students in electrical and computer engineering programs and researchers or industry professionals in semiconductors and microelectronics Explains the design of basic memory bit cells including 6 transistor SRAM 1 transistor 1 capacitor DRAM and floating gate charge trap FLASH transistor Examines the design of the peripheral circuits including the sense amplifier and array level organization for the memory array Examines industry trends of memory technologies such as FinFET based SRAM High Bandwidth Memory HBM 3D NAND Flash and 3D X point array Discusses the prospects and challenges of emerging memory technologies such as PCM RRAM STT MRAM SOT MRAM and FeRAM FeFET Explores the new applications such as in memory computing for AI hardware acceleration

NAND Flash Memory Technologies Seiichi Aritome, 2015-12-01 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

Scanning Nonlinear Dielectric Microscopy Yasuo Cho, 2020-05-21 Scanning Nonlinear Dielectric Microscopy Investigation of Ferroelectric Dielectric and Semiconductor Materials and Devices is the definitive reference on an important tool to characterize ferroelectric dielectric and semiconductor materials Written by the inventor the book reviews the methods for applying the technique to key materials applications including the measurement of ferroelectric materials at the atomic scale and the visualization and measurement of semiconductor materials and devices at a high level of sensitivity Finally the book reviews new insights this technique has given to material and device physics in ferroelectric and semiconductor materials The book is appropriate for those involved in the development of ferroelectric dielectric and semiconductor materials devices in academia and industry

Flash Memories Paulo Cappelletti, Carla Golla, Piero Olivo, Enrico Zanoni, 1999-06-30 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 floating polysilicon gate transistor 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 Programmable 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

Semiconductor Memories and Systems Andrea Redaelli, Fabio Pellizzer, 2022-06-07 Semiconductor Memories and Systems provides a comprehensive overview of the current state of semiconductor memory at the technology and system levels After an introduction on market trends and memory applications the book focuses on mainstream technologies illustrating their current status challenges and opportunities with special attention paid to scalability paths Technologies discussed include static random access memory SRAM dynamic random access memory DRAM non volatile memory NVM and NAND flash memory Embedded memory and requirements and system level needs for storage class memory are also addressed Each chapter covers physical operating mechanisms fabrication technologies and the main challenges to scalability Finally the work reviews the emerging trends for storage class memory mainly focusing on the advantages and opportunities of phase change based memory technologies Features contributions from experts from leading companies in semiconductor memory Discusses physical operating mechanisms fabrication technologies and paths to scalability for current and emerging semiconductor memories Reviews primary memory technologies including SRAM DRAM NVM and NAND flash memory Includes emerging storage class memory technologies such as phase change memory

Convergence of More Moore, More than Moore and Beyond Moore Simon Deleonibus, 2021-02-16 The era of Sustainable and Energy Efficient Nanoelectronics and Nanosystems has come The research and development on Scalable and 3D integrated Diversified functions together with new computing architectures is in full swing Besides data processing data storage new sensing modes and communication capabilities need the revision of process architecture to enable the Heterogeneous co integration of add on devices with CMOS the new defined functions and paradigms open the way to Augmented Nanosystems The choices for future breakthroughs will request the study of new devices circuits and computing architectures and to take new unexplored paths including as well new materials and integration schmes This book reviews in two sections including seven chapters essential modules to build Diversified Nanosystems based on Nanoelectronics and finally how they pave the way to the definition of Nanofunctions for Augmented Nanosystems

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