Dawon Kahng and Simon M. Sze invent the Non-Volatile Memory Floating Gate at Bell Labs; this is published as “A Floating Gate and Its Application to Memory Devices” (Bell System Technical Journal). Simon M. Sze went on to receive the 2014 FMS Lifetime Achievement Award.

Dov Frohman-Bentchkowsky invents the Erasable Programmable Read-Only Memory (EPROM) at Intel; this is published as “Memory Behavior in a Floating-Gate Avalanche-Injection MOS (FAMOS) Structure” in April 1971 (Applied Physics Letters), which cited the 1967 Kahng/Sze Bell Labs Floating Gate publication.

Hughes Microelectronics files Eli Harari patent for first practical floating gate EEPROM using thin SiO$_2$ and Fowler-Nordheim tunneling for program and erase; Eli Harari went on to receive the 2012 FMS Lifetime Achievement Award.
1977


1978


1979


1980

Flash Memory Summit

Hughes Microelectronics introduces the 3108, first CMOS EEPROM 8Kb chip employing Fowler Nordheim tunneling

Intel introduces the 2816, 16Kb HMOS EEPROM employing Fowler Nordheim tunneling
1981

British scientist and inventor Kane Kramer designs first digital audio player (IXI) based on magnetic bubble memory chips.

1982

SEEQ Technology introduces the 5213, first EEPROM with on-chip charge pump for in-system write and erase, an invention used in all flash memory devices.

1983

Intel introduces 2817A 16Kb EEPROM.

1984

First paper describing flash EEPROM presented by Fujio Masuoka of Toshiba at IEEE International Electron Devices Meeting (IEDM) in San Francisco. Fujio Masuoka went on to receive the 2013 FMS Lifetime Achievement Award.

Intel begins flash process development.

ATMEL (Advanced Technology for Memory and Logic) is founded by George Perlegos, who went on to receive the 2017 Lifetime Achievement Award.
1985
Exel files patent for first NOR Flash cell

1986
Flash card concept introduced with ECC and on-card controller by Intel
Intel forms unit focusing on solid state drives

1987
First NAND-type flash memory technology presented by Fujio Masuoka of Toshiba at IEEE International Electron Devices Meeting (IEDM)
Intel invents first Flash File System concept
Intel introduces NOR flash chips

1988
SunDisk founded to develop new "System Flash" architecture combining embedded controller, firmware and flash memory to emulate disk storage
SunDisk files first two MLC (Multi-Level Cell) flash patents
JPEG and MPEG standards released allowing economical production of digital cameras
Intel samples 1Mb NOR flash
Intel and Psion design flash-based mobile PC
First flash-based digital camera, Fuji DS-1P, demonstrated
150mm wafers used

Annual Revenue > $1,600,000

$6,400,000

1985
Exel files patent for first NOR Flash cell
1989

- SunDisk files System Flash patent
- M-Systems founded and introduces Flash Disk concept (precursor to flash SSDs)
- M-Systems co-founders Dov Moran and Aryeh Mergi went on to receive 2018 FMS Lifetime Achievement Awards
- Intel ships 512Kb and 1Mb NOR flash
- Psion flash-based PC introduced
- Microsoft introduces Flash File System in joint effort with Intel
- DigiPro introduces 8MB NOR Flashdisk at Comdex
- Western Digital and SunDisk pioneer NOR-based SSD fully emulating ATA HDD
- Personal Computer Memory Card International Association (PCMCIA) founded

1990

- Sony introduces EReader using flash memory
- Kodak flash-based camera prototypes shown
- NOR flash pricing in parity with DRAM pricing
- PCMCIA sets standard on ATA PC Card form factor and pinout using SunDisk “System Flash” specification for full HDD compatibility
- Intel introduces 1MB and 4MB linear flash PCMCIA cards introduced
- Intel introduces 2Mb NOR chip
- SunDisk introduces world’s first NOR flash SSD: 20MB 2.5”, fully compatible with Conner peripherals 2.5” ATA HDD
- Toshiba develops world’s first 4Mb NAND flash
- Kodak ships DCS-100, its first DCS at $13,000
- Zenith, Poqet and HP palm-sized notebook computers using flash memory cards shown at Spring Comdex
- Information Storage Devices introduces flash-based voice recorder chip
- AMD introduces its first NOR product
- M-Systems introduces TrueFSS, the first flash memory card FTL, this was later adopted by the PCMCIA as its FTL
- Intel launches second-generation FFS2
- Intel introduces 8Mb flash chip and 4MB-20MB linear flash memory cards
- Intel introduces 1Mb “boot lock” NOR flash with sectors for BIOS applications—first use of internal write state machine to manage flash write algorithm
- SunDisk introduces first serial 9Mb NOR Flash chip for SSD applications
- PCs begin using flash for BIOS storage
- Toshiba ships first mass-produced NAND (4Mb)

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- Japanese companies:
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<th>Year</th>
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<tr>
<td>1993</td>
<td>Datalight introduces &quot;Card Trick&quot; flash management software. Apple introduces NOR flash-based Newton PDA. Intel introduces 16Mb and 52Mb NOR flash. Intel and Conner Peripherals introduce jointly-developed 5Mb/10Mb ATA flash disk drive. AMD introduces 5-volt-only NOR using negative gate erase.</td>
</tr>
<tr>
<td>1995</td>
<td>Casio introduces the QV-11 digital camera with flash rather than film or floppy. Mitsubishi introduces DiNOR. SunDisk introduces 34Mb Serial NOR flash chip for SSD applications. SunDisk changes name to SanDisk. Flash (NOR and NAND) revenues exceed $1B. CompactFlash Association (CFA) founded.</td>
</tr>
<tr>
<td>1996</td>
<td>Toshiba introduces SmartMedia Memory Card (also called Solid State Floppy Disk Card). Samsung starts shipping NAND flash. Kodak DC-25 is first DSC with CompactFlash card. Datalight introduces FlashFX flash management software supporting NOR and NAND in a single driver. SanDisk introduces first flash cards with MLC serial NOR. Palm introduces flash memory-based PDA. 0.35 micron process announced. $2.6B in flash memory revenues, 163.063% growth in 10 years. Lexar Media spins off from Cirrus Logic. USB Association (USBA) founded.</td>
</tr>
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<td>Year</td>
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</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td><strong>1997</strong></td>
<td></td>
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</table>
| | M-Systems introduces flash-based MPMan MP3 player  
| | Sandisk and Siemens introduce MultiMedia Card (MMC and MMCplus)  
| | Sony introduces the Memory Stick  
| | First cell phones ship with flash memory  
| | M-Systems introduces NAND-based DiskOnChip  
| | 200mm wafers begin production  
| | 500 million flash chips ship  
| | Intel introduces 2-bit/cell 64Mb MLC StrataFlash  
| | MultiMediaCard (MMC) unveiled by Sandisk and Siemens  
| | Toshiba and SanDisk create flash memory manufacturing joint venture  
| | Micron announces NOR products  
| | Over one billion flash chips ship  
| | Dov Moran of M-Systems applies for patent on USB-based flash drive  
| | NOR revenues exceed $4B  
| | Lexar Media introduces CompactFlash-to-USB JumpSHOT  
| | M-Systems (working with IBM) and Trek Technology introduce USB flash drives  
| | Intel ships its one-billionth flash unit  
| | 160nm process announced  
| | Flash (NOR and NAND) revenues exceed $10B  
| | SD Card Association founded  |
| **1998** |  |
| | 250nm process announced  
| | SaeHan Information Systems and licensee Eiger ship world’s first mass-produced MP3 player (MPMan) with 32Mb  
| | Diamond Rio introduces PMP300 MP3 player  
| | Panasonic, SanDisk and Toshiba launch SD card MultiMediaCard Association (MMCA) founded by 14 companies  
| | MultiMediaCard (MMC) unveiled by SanDisk and Siemens  
| | NOR revenues exceed $2B  
| | NOR revenues exceed $4B  
| | Semiconductor Technology International (STI) begins 180nm production  
| | 180nm process announced  
| | 200mm wafers begin production  
| | Intel ships its one-billionth flash unit  
| | 250nm process announced  
| | Intel introduces 2-bit/cell 64Mb MLC StrataFlash  
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2001
- Toshiba and SanDisk announce 1Gb MLC NAND
- SanDisk introduces first NAND System Flash product
- Hitachi introduces AG-AND
- Samsung begins mass production of 512Mb flash memory device
- NAND revenues exceed $1B

2002
- Olympus and FujiFilm introduce xD-Picture Card
- MMCmobile card introduced by MMCA (MultiMediaCard Association)
- Sony and SanDisk jointly introduce Memory Stick PRO and half-size Memory Stick PRO Duo cards
- M-Systems introduces Mobile DiskOnChip, the first SSD in a chip; this was used in handsets by Nokia, Motorola and Ericsson
- AMD introduces MirrorBit charge trap flash
- 130nm process announced

2003
- SanDisk introduces miniSD card
- Sony and SanDisk jointly introduce Memory Stick PRO Micro
- Spansion spins out of AMD and Fujitsu
- NAND revenues exceed $5B

2004
- U3 software system for USB flash drives introduced by SanDisk and M-Systems
- NAND prices drop below DRAM prices
- SanDisk and Motorola introduce TransFlash card, now the microSD card
- DataLight introduces multi-threaded “FlashFX Pro” management software to support multimedia NAND devices
- Spansion announces MirrorBit Quad 4-bit NOR 90nm process announced
- Hynix and ST Micro form flash joint venture
- Hynix NAND product introduced
- Infineon NAND product introduced based on Saifun Charge Trap Flash
- Panasonic and Sanyo introduce first flash-based camcorders
- SanDisk introduces Flash Sansa MP3 players
Apple introduces first two flash-based iPads, iPod shuffle and iPod nano
Microsoft introduces Hybrid Hard Disk Drive concept
MMC micro card introduced by MMCA
70nm process announced
Micron introduces NAND product
Over three billion flash chips ship
NAND GB shipments overtake those of DRAM
NAND revenues exceed $10b

$ 4,560,493,000

2005

Apple introduces first two flash-based iPods, iPod shuffle and iPod nano
Microsoft introduces Hybrid Hard Disk Drive concept
MMC micro card introduced by MMCA
70nm process announced
Micron introduces NAND product
Over three billion flash chips ship
NAND GB shipments overtake those of DRAM
NAND revenues exceed $10b

$ 10,637,231,000

2006

Intel introduces Robson Cache Memory (now called Turbo Memory)
Microsoft introduces ReadyBoost
SanDisk announces 3-bit MLC NAND technology
M-Systems announces 4-bit MLC technology
SanDisk announces microSDHC card
SanDisk acquires Matrix Semiconductor
SanDisk acquires M-Systems
Samsung and Seagate demonstrate first Hybrid Hard Disk Drives
IMFT formed by Intel and Micron to manufacture NAND flash
STEC acquires Gnutech
Spansion acquires ORNAND flash
56nm process announced
300mm wafers begin production
Micron acquires Lexar Media
Flash revenues exceed $20b
First Flash Memory Summit held in San Jose

$ 22,182,405,000

2007

Toshiba introduces eMMC NAND
IMFT begins shipping 50nm NAND flash
Toshiba introduces first MLC SATA-based SSD
Apple introduces the iPhone
Fusion-io announces 640GB ioDrive MLC NAND-based PCIe X4 board
BiTMICRO launches 3.5" SSD with capacity of 1.6TB (for military applications)
Spansion acquires Salfun
Several laptop MLC SSDs introduced with up to 128GB storage
Dell introduces SSD option for laptop models
Sub-$200 netbook computers introduced with flash memory storage
Microsoft introduces flash-based Zune Player
NAND revenues exceed $14.5b
Flash revenues exceed $22b, almost 9 times 1997 revenues
Seagate announces Hybrid Storage Alliance
Seagate introduces first hybrid HDD, the Momentus 550
MMCA JEDEC jointly release eMMC spec

$ 18,435,970,000

2008

SanDisk introduces ABL to enable high speed MLC, TLC and X4 NAND
34nm process announced by Intel and Micron
Toshiba introduces first 9120GB MLC SATA-based SSD
Intel and ST Micro spin off Numonyx
IBM demos first “Million IOPS” array
EMC announces use of flash-based SSDs for enterprise SAN applications
Apple introduces MacBook Air
Micron, Samsung and Sun Microsystems announce high-endurance flash memory
Violin introduces first fully flash-based storage appliance
Samsung announces 330GB 2.5" MLC SSD with SATA II Interface
Several companies announce MLC flash SSDs with up to 256GB for notebook apps
Micron introduces first serial NAND flash
Toshiba develops 3D NAND structure, BiCS
Apple sells one million flash-based iPhones in 3 days
MMCA merges into JEDEC
SNIA Solid State Storage Initiative (SSSI) formed
Intel and Micron introduce 34nm TLC NAND
Samsung introduces first full HD camcorder with 64GB SSD
Seagate enters SSD market
SandForce introduces first compression-based SSD controller
Vivident and Schooner introduce first flash-based application appliances for the data center
Pillar Data converts Axiom SANs to SSD
Pliant introduces first SAS SSD
SanDisk and Toshiba present 4-bit/cell flash at ISSCC
WD acquires SiliconSystems and gets into SSD business
NVEO introduces first PC flash caching software “Dataplex”
SanDisk introduces 100-year flash storage vault
Aigiga ships NAND-backed DIMM
LSI acquires SandForce
SanDisk acquires Plint
IMFT introduces 20nm NAND flash
Intel announces Smart Response SSD caching for PCs
Seagate announces second generation Momentum XT hybrid HDD with 8GB NAND flash and 750GB HDD storage
Apple acquires Anobit
Fusion-io acquires IIO Turbine
NVM Express organization established and NVMe Rev. 1.0 published
Richard Pashley, Stefan Lai, Bruce McCormick and Niles Kynett formerly of Intel receive FMS Lifetime Achievement Awards
SanDisk and Toshiba announce 19nm flash memory enabling 128Gb chips
Ultrabooks begin to ship with Smart Response SSD cache
Macronix and Winbond enter NAND flash business
Seagate Technology introduces SSHD combining flash memory with an HDD
Elpida introduces ReRAM
Micron and Intel introduce 20nm 128Gb NAND chip using hi-k planar cell
SK hynix formed upon SK Telecom’s acquisition of controlling interest in Hynix Semiconductor
MOSAID samples 333GB/s HL-NAND
Adesto acquires ATME’s Serial NOR business
Spanisnion introduces 8Gb NOR chip
Denbhis Technologies introduces Memory Modem
Proximal Data introduces AutoCache
SanDisk acquires FlashSoft
EMC acquires XtremeIO
OCZ acquires Sanrad
Samsung acquires NVEO
Intel acquires Nevex and introduces CacheWorks
LSI introduces Nytro flash with MegaRAID CacheCade caching software
Micron introduces 2.5” PCIe enterprise SSD
IBM acquires Texas Memory Systems
SanDisk founder Eli Haran receives FMS Lifetime Achievement Award

Email your suggested additions and changes to timeline@FlashMemorySummit.com
Samsung announces availability of 24-layer 3D V-NAND and demonstrates 1TB SSD at FMS
Diablo Technologies announces Memory Channel Storage technology
SMART Storage Systems incorporates Diablo Technologies designs into ULLtraDIMM
SNIA NVDIMM SIG formed, many flash-based NVDIMM products introduced
Western Digital and SanDisk introduce SSDs using (SSD) combined with an SSD
Toshiba introduces line of SSDs
EverSpin Technologies announces shipments of STT MRAM
Micron and other companies sample 16nm flash memory
SanDisk releases CFast 2.0 memory card, fastest memory card for professional video
M.2 PCIe interface formalized
Western Digital acquires sTec, Vinent and Velobit
SanDisk acquires SMART Storage Systems
NVMurance introduces software to extend flash endurance
Micron acquires Elpida
Intel acquires Intel Cache Acceleration Software
First NVMe devices from Samsung and SanDisk
Fujio Masuoka, formerly of Toshiba, receives FMS Lifetime Achievement Award

2014

Samsung, SanDisk and Toshiba announce 3D NAND production facilities
SanDisk introduces 4TB Enterprise SSD
SanDisk announces 128GB microSD card, a 1000x increase in capacity on device's 10th anniversary
IBM announces eFlash DIMMs using SanDisk ULLtraDIMMs' implementation of Diablo Memory-Channel Storage technology
Samsung rolls out second generation 3D V-NAND with 32 layers
Spanxion introduces HyperFlash NQR with 333 MB/s HyperBus
Toshiba acquires OCZ
EverSpin introduces and ramps production of STT-MRAM
Samsung introduces 3-bit/cell 3D NAND SSDs
Adesto ships one-millionth CRAM
SK hynix acquires Violin's PCIe SSD business
Seagate acquires LSI/Avago storage business
SanDisk acquires Fusion-io
HGST acquires Skyera
SanDisk acquires Proximal Data
Simon Sez, former of Bell Labs, receives FMS Lifetime Achievement Award

2015

SanDisk introduces InfiniFlash storage system
Cypress Semiconductor acquires Spanxion
Toshiba, Samsung, and SanDisk announce 48-layer 3D NAND
Intel and Micron announce 256GB 3D NAND
Samsung introduces first NVMe m.2 SSDs
SanDisk introduces 200GB microSDXC UHS-I card
Cypress introduces 4MB serial FRAM
Intel and Micron announce 3D XPoint Memory
Intel announces 3D XPoint-based "Optane" DIMMs and SSDs
Micron introduces device with CMOS Under 3D NAND Array (CUA)
SanDisk introduces 200GB microSDXC card
Mellanox and partners demonstrate pre-standard NVMe over Fabrics (NVMe-oF)
Pure Storage has IPO
JEDEC publishes first NVDIMM-N standard for Persistent Memory Modules
Bob Normam, formerly of SanDisk and Micron, receives FMS Lifetime Achievement Award
Flash Memory Summit 10th Anniversary

2016

Micron, Intel, Toshiba, SanDisk and SK hynix ship 3D NAND
XMC breaks ground on first China-owned NAND flash lab
Micron introduces 768GB 3D NAND
Western Digital acquires SanDisk
EverSpin announces 256Gb MRAM chips
IBM adapts TLC to PCM
SanDisk ships 48-layer 3D NAND
NVMe-oF (NVM Express over Fabrics) Rev. 1.0 published
NVMe-of products demonstrated by at least 12 vendors
Toshiba introduces Through-Silicon Via (TSV) NAND
Spin Transfer Technologies delivers fully functional ST- MRAM samples
Micron launches Xccela Consortium
Toshiba ships industry's first NVMe BGA "SSD on a chip"
Western Digital demonstrates prototype of the world's first 1TB SDXC card
Kim Nam Kim, President of System LSI / Semiconductor Business at Samsung, receives FMS Lifetime Achievement Award
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<td>2017</td>
<td>Microchip ships its 75-billionth SST SuperFlash-based device</td>
</tr>
<tr>
<td>2018</td>
<td>Cypress introduces 16Mb FRAMs</td>
</tr>
<tr>
<td>2019</td>
<td>Toshiba completes $18B memory business sale</td>
</tr>
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<td>2019</td>
<td>Samsung launches high-speed 2-SSD</td>
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<td>2019</td>
<td>Micron ships Enterprise SSD using QLC and 1Tb 3D NAND die</td>
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<td>2019</td>
<td>Hyperstone introduces flash controllers with AI and Machine Learning</td>
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<td>2019</td>
<td>Intel samples Optane DC Persistent Memory</td>
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<td>2019</td>
<td>China’s “Big Fund” Phase 2 targets over $30B for semiconductor investments</td>
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<td>2019</td>
<td>NVMe/TCP Transport Binding spec ratified by NVMe WG</td>
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<td>NGD Systems ships industry’s first scalable ASiC-based Computational Storage NVMe SSD</td>
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<td>Samsung announces commercial production of eMRAM on 28nm FD-SOI process</td>
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<td>2019</td>
<td>Lightbits Labs ships industry’s first commercial NVMe/ TCP software-defined disaggregated storage solutions</td>
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<td>2019</td>
<td>YMTC samples 32-layer “Xtacking” NAND</td>
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<td>2019</td>
<td>Intel ships Optane (3D XPoint) memory on DIMMs</td>
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<td>Micron ships industry’s first QLC Enterprise SSDs</td>
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<td>2019</td>
<td>Intel ships SSDs with both Optane (3D XPoint) and QLC NAND</td>
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<td>2019</td>
<td>All major vendors ship 96-Layer NAND</td>
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<td>2019</td>
<td>All leading foundries produce embedded MRAM</td>
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<td>2019</td>
<td>Trade tensions brew between US and China</td>
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<td>2019</td>
<td>Open-Channel SSDs evolve to standardization as NVMe Zoned Namespaces (ZNS)</td>
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<td>2019</td>
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