



Flash Memory Trends

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Agenda

- Flash Memory Overview
 - Architecture
 - Multi-level Cell Storage

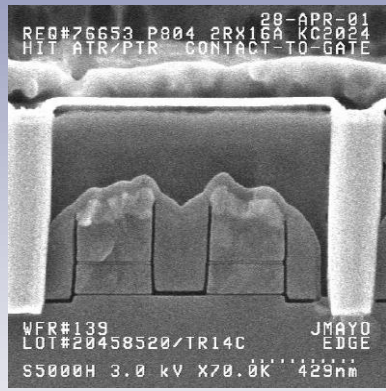
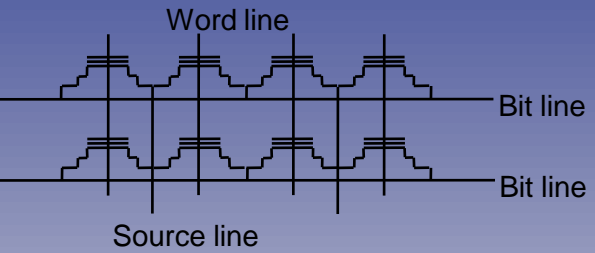
- Technology Overview
 - Technology Evolution
 - Roadmaps
 - Scaling Challenges

- Vendors

- Summary

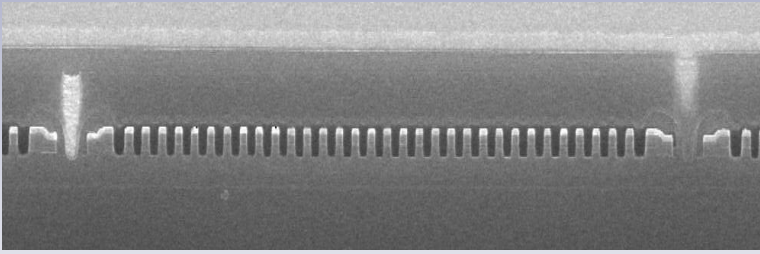
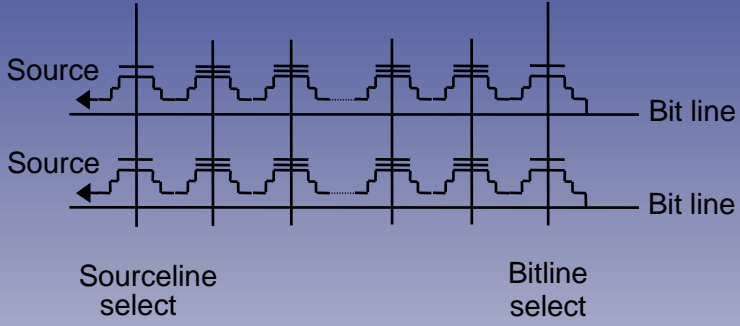
Array Architectures

NOR



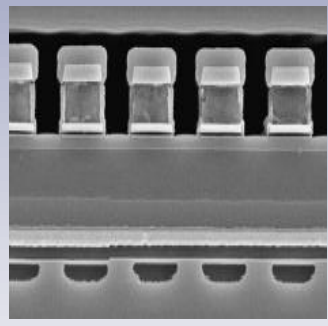
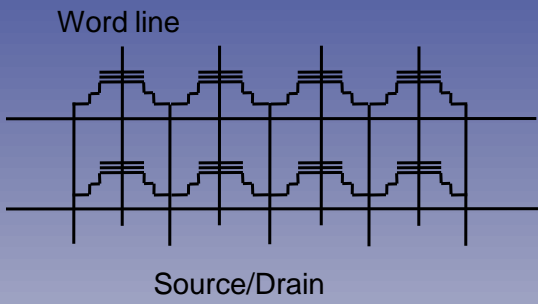
- Parallel architecture
- $10F^2$

NAND



- Serial architecture
- $4F^2$

NROM



- Parallel architecture
- $7F^2$

NAND vs. NOR

Flash Memory

random access

serial access

NOR

NAND

Access time:

Random: 60-120ns

page mode/burst mode:
30ns/15ns

write speed:

random: 10µs/byte or word

- High Performance optimized
 - fast random read
 - fast random write

Access speed:

Random: 10-50µs

serial (page mode): 25-50ns

write speed:

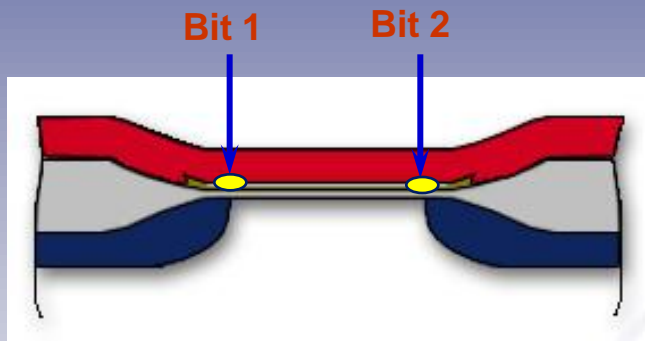
random: 200µs/byte

page: 200µs/page (0,4µs/byte)

- Low Cost
 - small cell size
- High sustained write
 - page write

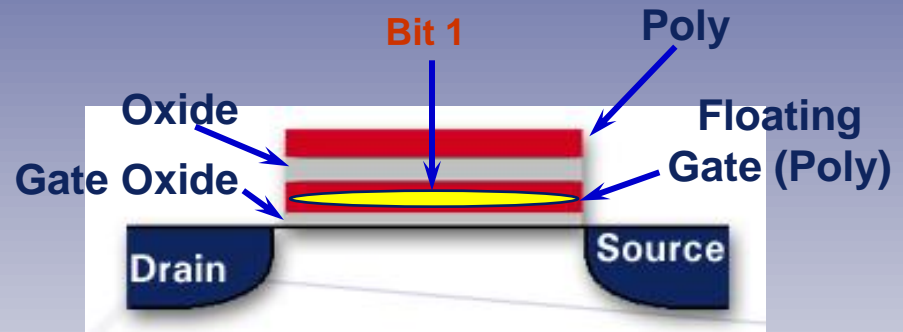
NROM vs. Floating Gate

NROM



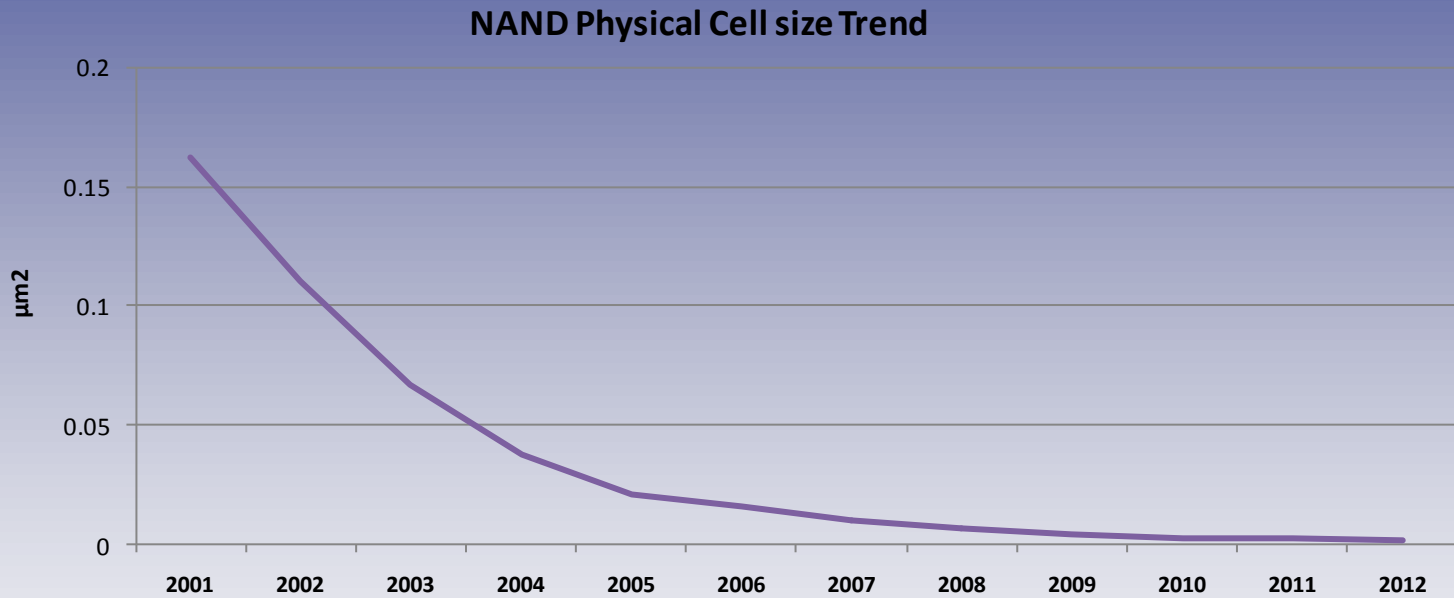
- localized storage in nitride traps
- 2 *physical* bits per cell
- multi-level cell storage allows storage of 2 *electrical* bits per cell

Floating Gate



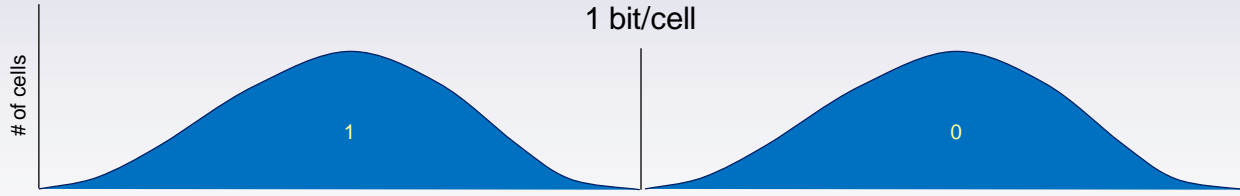
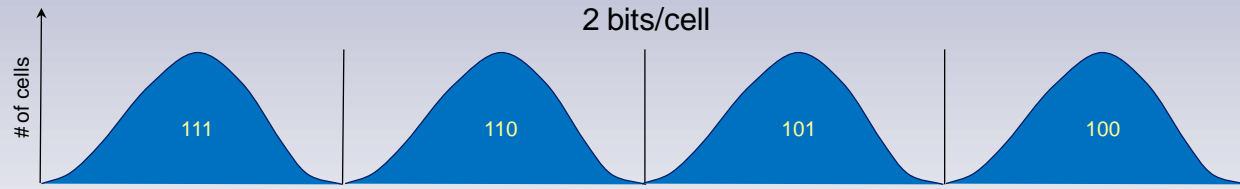
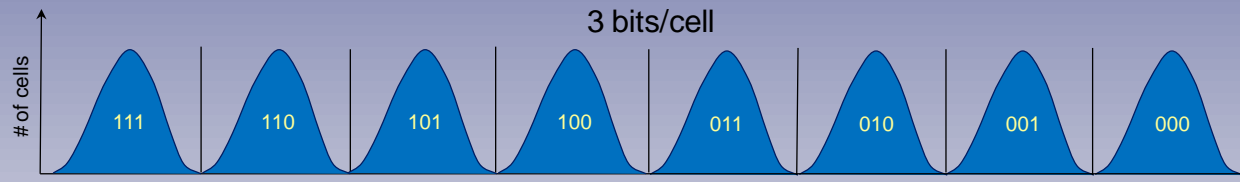
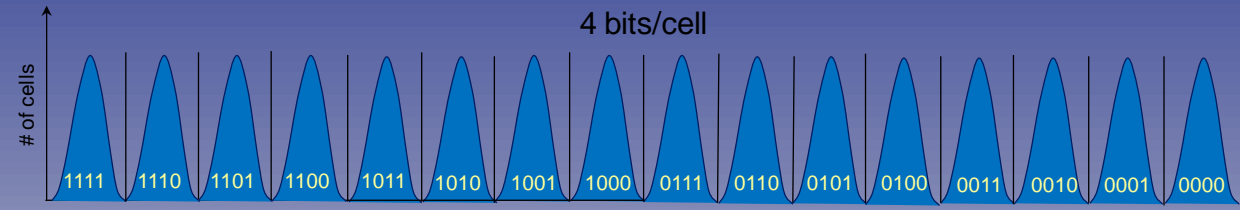
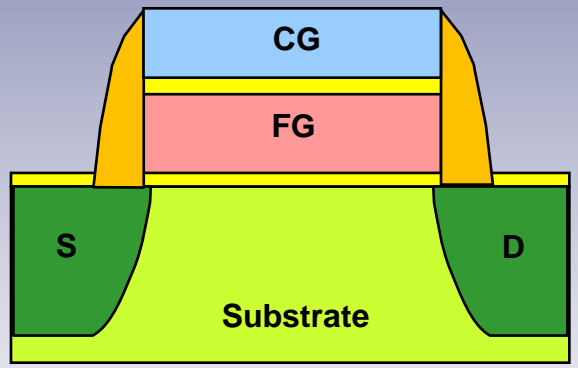
- physical storage of charge in floating gate
- multi-level cell storage allows storage of 2 or more *electrical* bits per cell

NAND Flash Cell Size

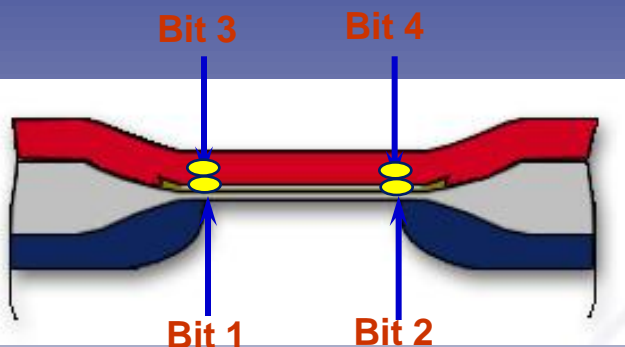


- Need to transition to multi-bit technologies

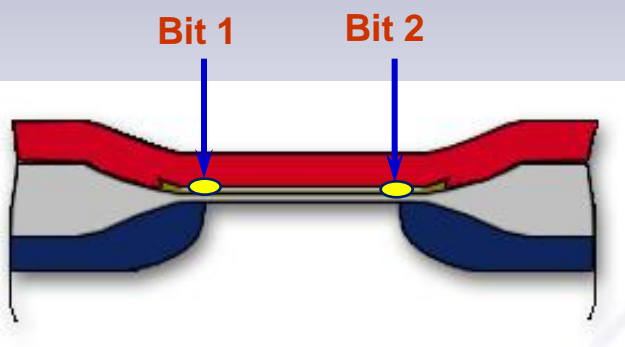
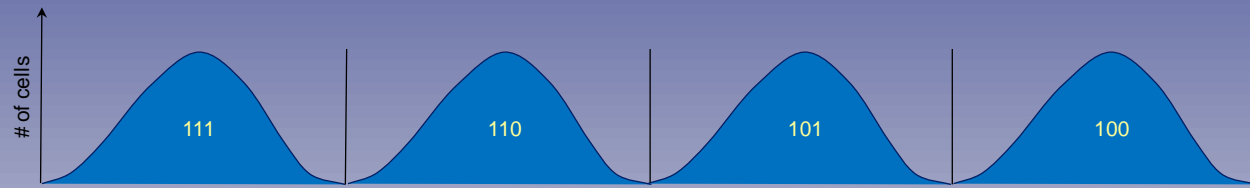
Multi-level Cell Storage - NAND



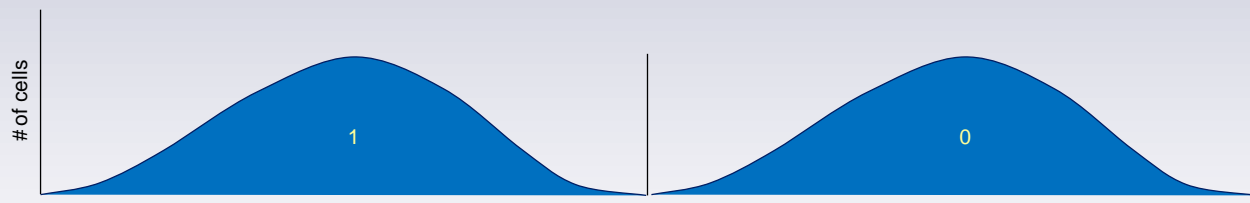
Multi-level Cell Storage - NROM



4 bits/cell



2 bits/cell



Multi-level Cell Storage Cost Advantage

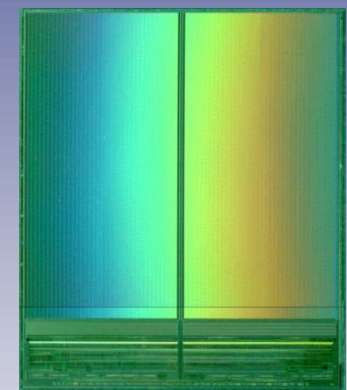
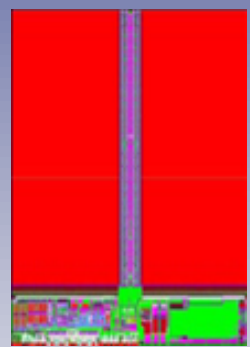
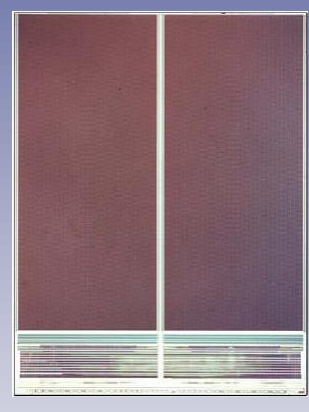
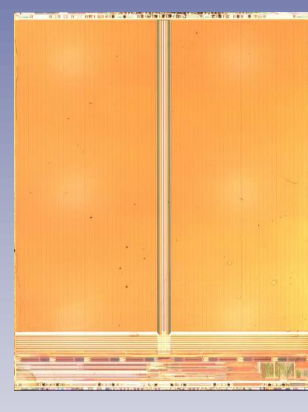
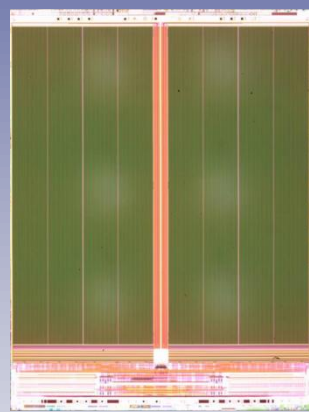
Samsung

Hynix

Toshiba

Saifun

Toshiba



4Gb SLC NAND
70nm
156mm²

4Gb SLC NAND
70nm
145mm²

8Gb MLC NAND
70nm
146mm²

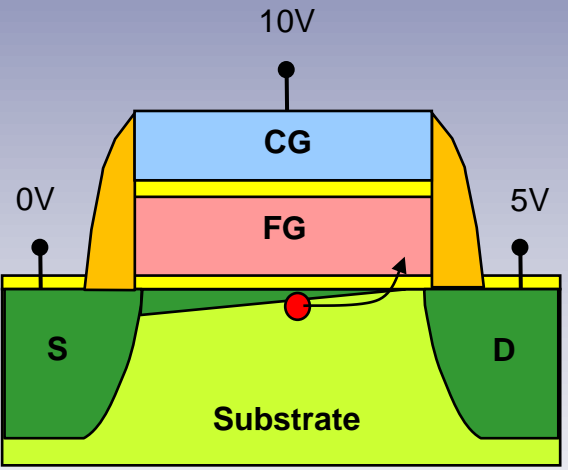
8Gb Quad NROM
75nm
120mm²

16Gb 4b/c NAND
70nm
168mm²

Images: Semiconductor Insights, Inc., Saifun Semiconductors, Toshiba

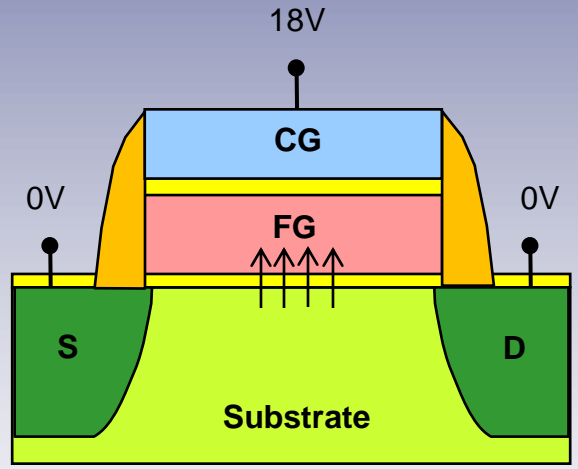
Programming Mechanisms

NOR



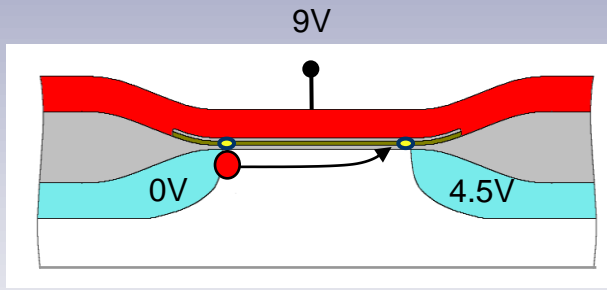
• CHE

NAND



• FN tunneling

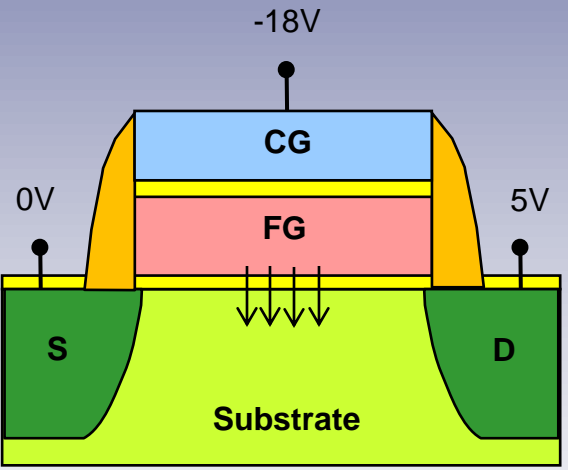
NROM



• CHE

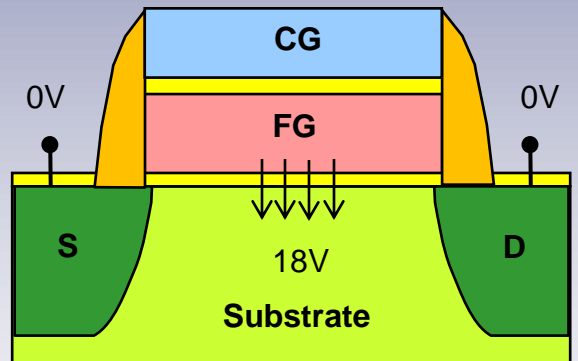
Erase Mechanisms

NOR



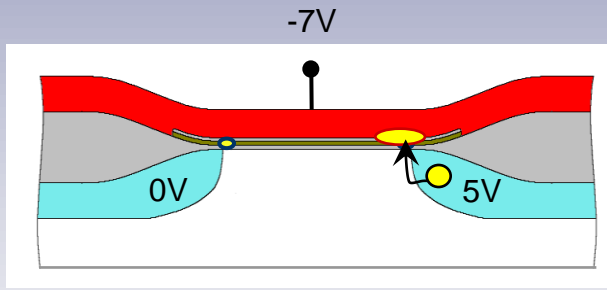
• FN tunneling

NAND



• FN tunneling

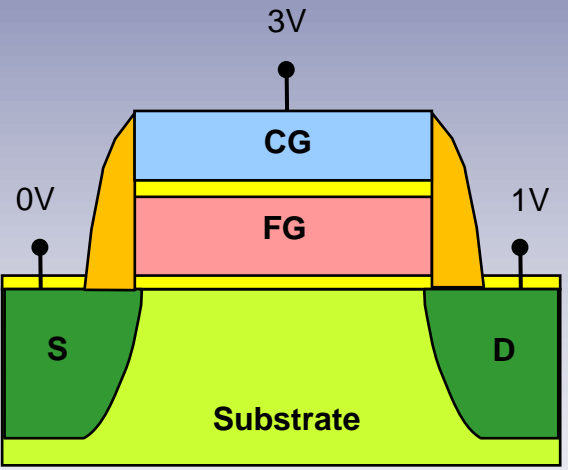
NROM



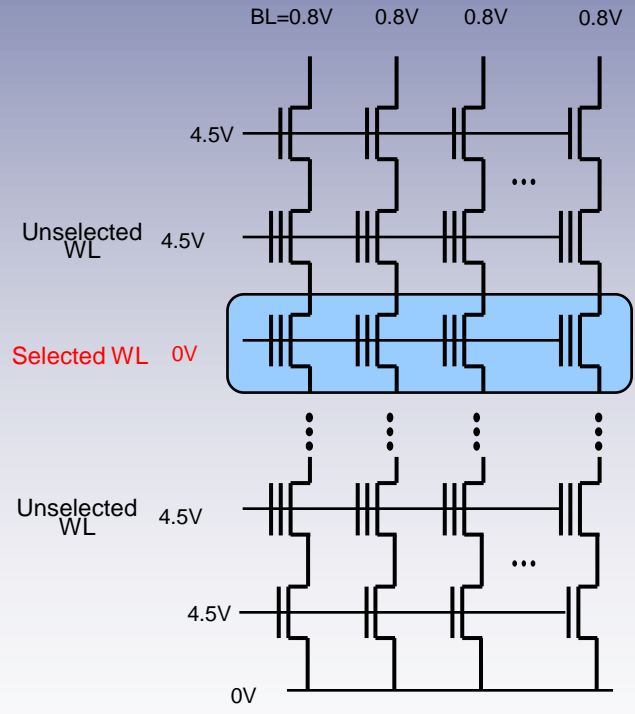
• BBHFI

Read Mechanisms

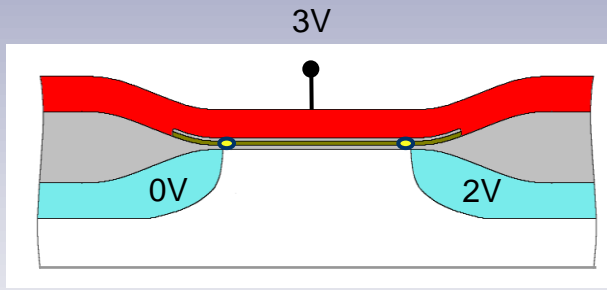
NOR



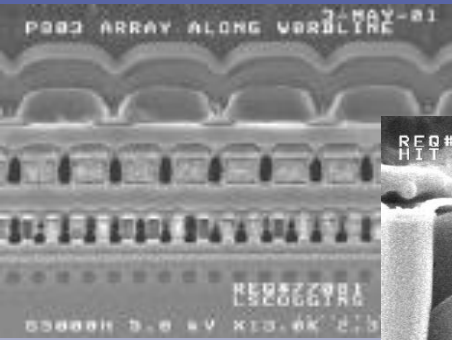
NAND



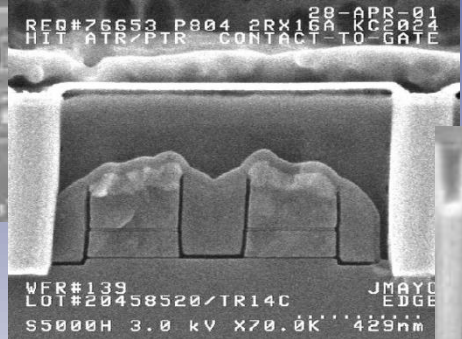
NROM



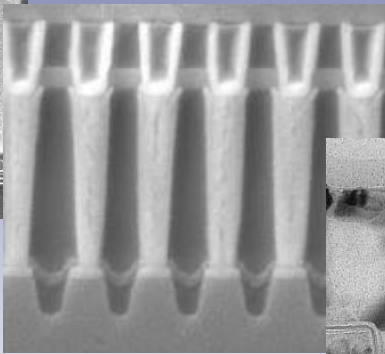
NOR Flash Technology Evolution



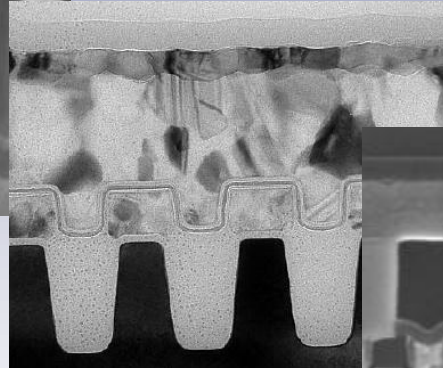
2002 - 130nm



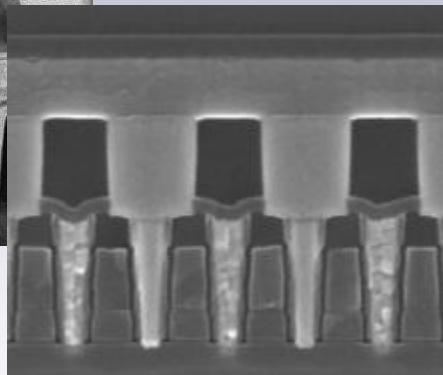
2004 - 90nm



2006 - 65nm



2008 - 45nm

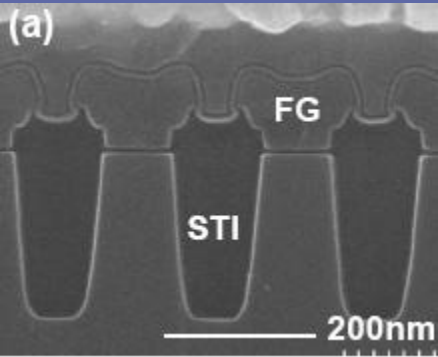


Images: Intel Corp.

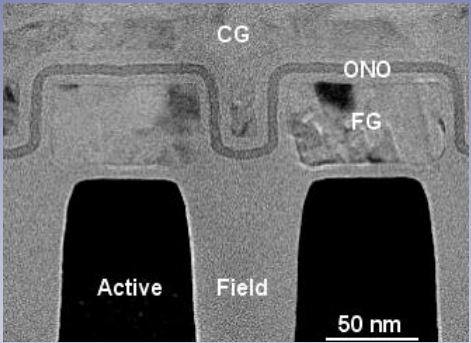
Santa Clara, CA USA
August 2008

NAND Flash Technology Evolution

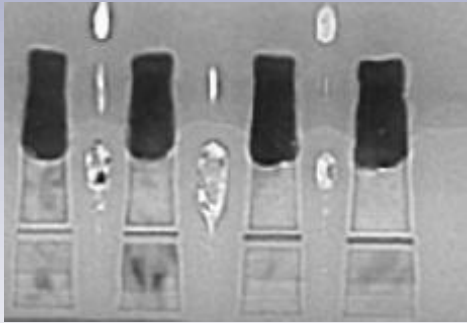
2004 - 90nm



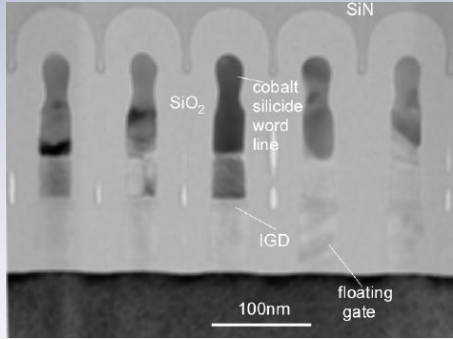
2006 - 60nm



2007 - 50nm



2008 - 40nm

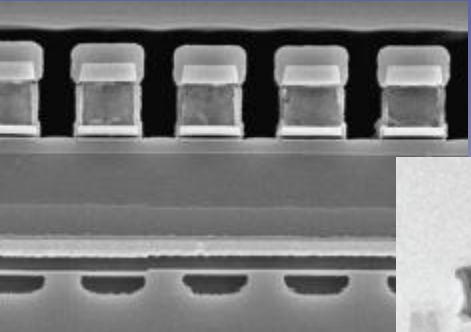


Images: Samsung, Semiconductor Insights, Toshiba

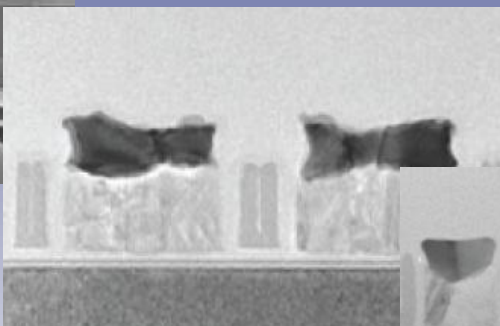
Santa Clara, CA USA
August 2008

NRROM Flash Technology Evolution

2002 - 230nm



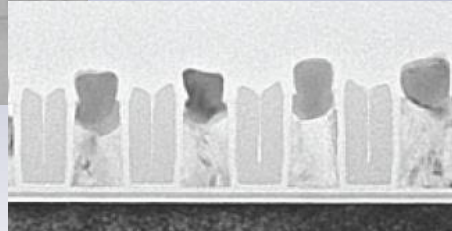
2004 - 110nm



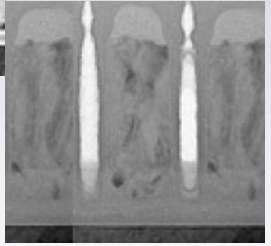
2006 - 90nm



2008 - 65nm

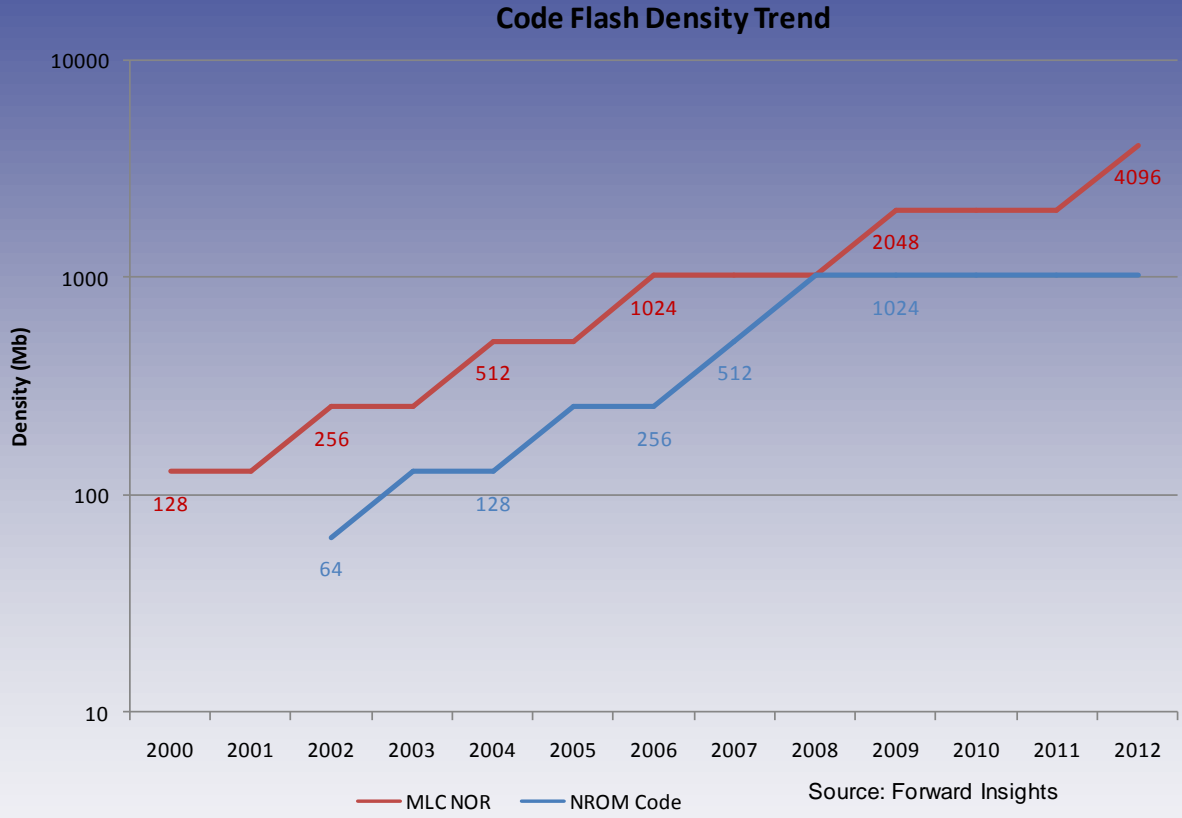


2009 - 45nm



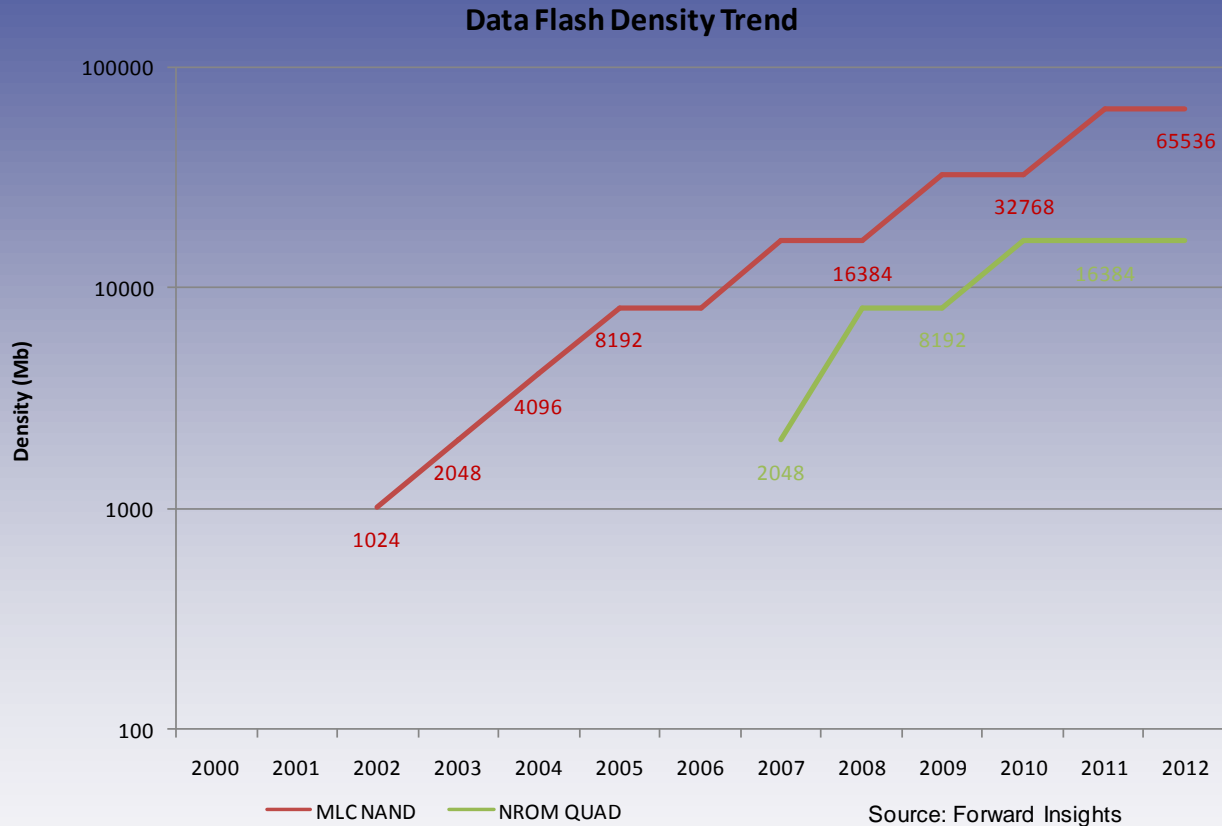
Images: Spansion

Code Flash Roadmap

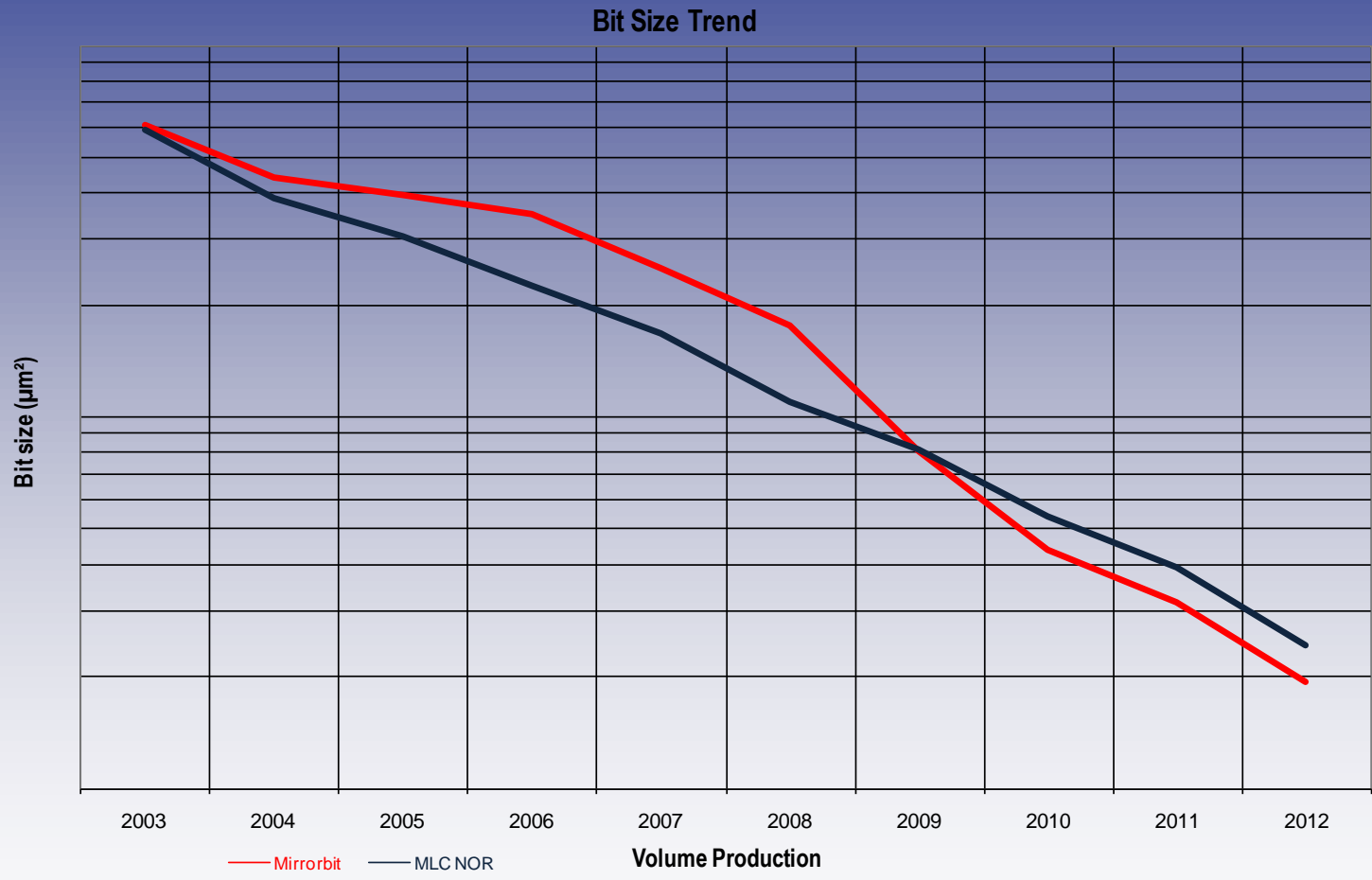


- NROM code to be superseded by Eclipse

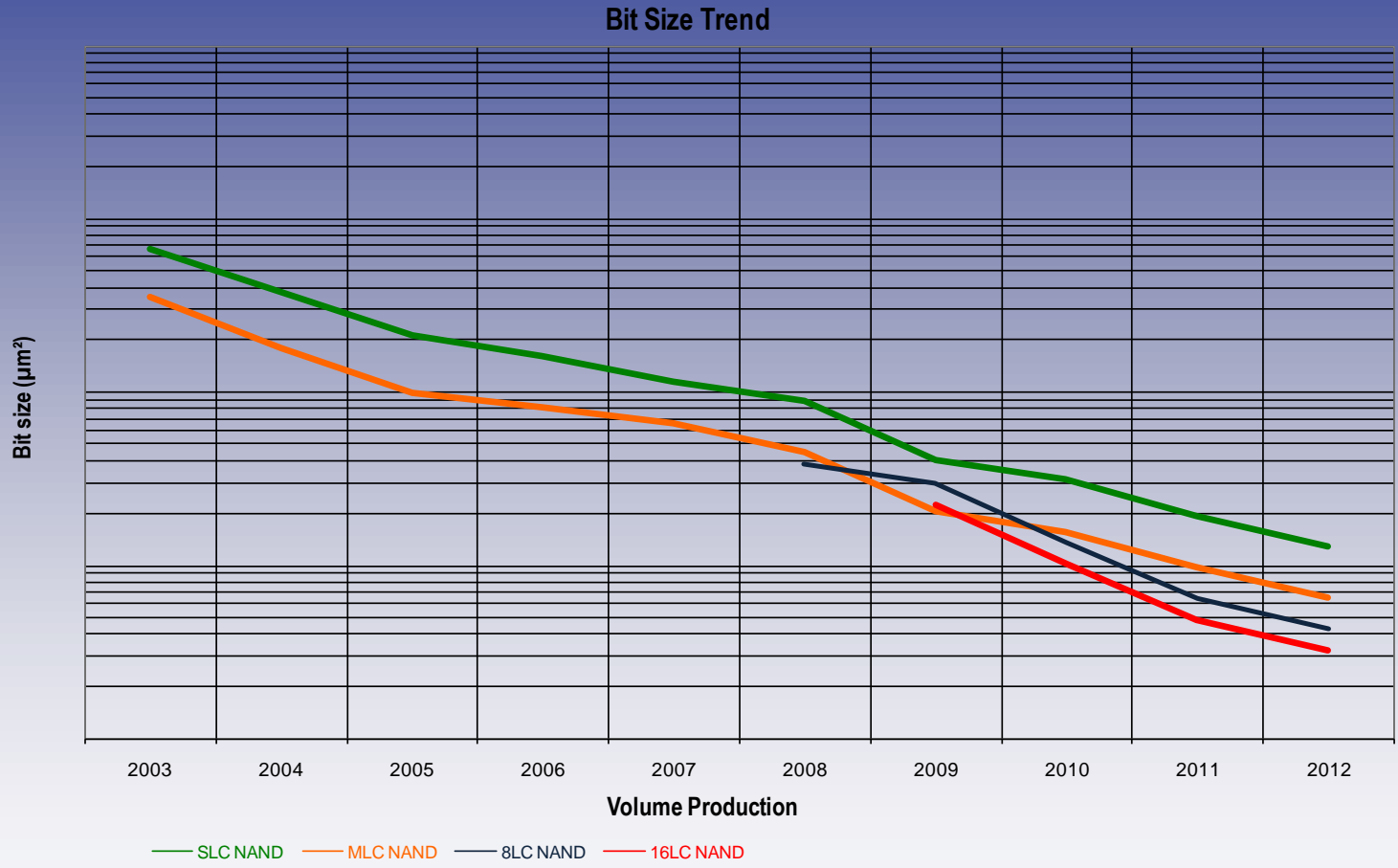
Data Flash Roadmap



Code – Bit Size Trend



NAND - Bit Size Trend



Scaling Challenges

NOR Flash	NAND Flash	NROM
<ul style="list-style-type: none">•Short channel effect•Contact and isolation fill•Charge storage reduction	<ul style="list-style-type: none">•Inter-cell interference•CG-FG coupling•Gap fill•Charge storage reduction	<ul style="list-style-type: none">•Short channel effect•Bit disturbs

NOR Flash Vendors

- Numonyx
 - \$2.4 billion merger of ST's (48.6%) and Intel's (45.1%) NOR businesses; Francisco Partners owns 6.3%
 - Includes ST's Catania and AMK8 fabs, stake in ST-Hynix Wuxi fab and Intel's fab 18
 - Intel contributed Pudong & Kiveta assembly & test facilities
 - Transitioning to 45nm
- Samsung
 - Focus on high density NOR for MCPs
 - NOR manufactured on legacy 200mm fabs
 - 65nm in volume
- Toshiba
 - NOR flash for MCPs
 - 1st MLC products on 70nm ramping

NOR Flash Vendors

- Macronix
 - Focus on serial flash and low density parallel NOR flash on 110nm

- Winbond
 - Focus on serial flash
 - 90nm NOR flash in 300mm fab ramping in 2H/08

NAND Flash Vendors

- Samsung
 - Fungible production capacity between NAND and DRAM
 - Volume production of 42nm
- Toshiba/SanDisk
 - NAND manufacturing JV: FlashPartners, FlashAlliance
 - Fundamental NAND and MLC patents
 - Volume production of 43nm
 - First to market with x3, x4 technology: 16Gb x3 in production
- Hynix/Numonyx
 - NAND joint development and manufacturing JV
 - Volume production of 48nm

NAND Flash Vendors

- Intel/Micron
 - NAND joint development and manufacturing JV
 - Sampling 34nm 32Gb MLC device
- Powerchip
 - 70nm in volume
 - 50nm in development

NROM Vendors

- Spansion
 - Acquired NROM patent owner, Saifun in E'07
 - Product and technology licensing agreement with SMIC for 65nm
 - Volume production of 65nm at SP1 300mm wafer fab
- Macronix
 - Code flash products based on 150nm NROM technology
 - 75nm XtraROM in production
- SMIC
 - Production of 2Gb NROM for data storage
 - Production of 8Gb NROM Quad in 2H/08

Summary

- NOR and NROM most suitable for code storage; NAND for data storage
- Move to multi-bit storage to drive further cost reductions as technology scaling slows
- Cost benefits of 3bit/cell & 4bit/cell to materialize in next two years

Acknowledgements

Special thanks for the use of material/images

- IEEE
- Intel
- Semiconductor Insights
- Spansion

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