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

- Parallel architecture
  - 10F²
- Serial architecture
  - 4F²
- Parallel architecture
  - 7F²
**NAND vs. NOR**

**Flash Memory**

<table>
<thead>
<tr>
<th>Random Access</th>
<th>Serial Access</th>
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**NOR**

- **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

**NAND**

- **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
• Need to transition to multi-bit technologies
Multi-level Cell Storage - NAND

- 4 bits/cell
- 3 bits/cell
- 2 bits/cell
- 1 bit/cell

Substrate

CG

FG

S

D

# of cells

1111 1110 1101 1100 1011 1010 1001 1000 0111 0110 0101 0100 0011 0010 0001 0000

# of cells

111 110 101 100 011 010 001 000

# of cells

111 110 101 100

# of cells

1 0
Multi-level Cell Storage - NROM

2 bits/cell

4 bits/cell

Santa Clara, CA  USA
August 2008
Multi-level Cell Storage Cost Advantage

Samsung

4Gb SLC NAND
70nm
156mm²

Hynix

4Gb SLC NAND
70nm
145mm²

Toshiba

8Gb MLC NAND
70nm
146mm²

Saifun

8Gb Quad NROM
75nm
120mm²

Toshiba

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**
  - BBHII
Read Mechanisms

NOR

NAND

NROM

Selected WL

Unselected WL

BL=0.8V 0.8V 0.8V 0.8V

4.5V

0V

4.5V

0V

4.5V

0V

Substrate
NOR Flash Technology Evolution

2000 - 180nm

2002 - 130nm

2004 - 90nm

2006 - 65nm

2008 - 45nm

Images: Intel Corp.
NROM Flash Technology Evolution

2002 - 230nm

2004 - 110nm

2006 - 90nm

2008 - 65nm

2009 - 45nm

Images: Spansion
• NROM code to be superseded by Eclipse
Data Flash Density Trend

- MLC NAND
- NORM QUAD

Source: Forward Insights
Code – Bit Size Trend

Volume Production

Bit size (µm²)


Mirrorbit MLC NOR
NAND - Bit Size Trend

![Graph showing the trend in bit size for SLC, MLC, 8LC, and 16LC NAND from 2003 to 2012.](image-url)
## Scaling Challenges

<table>
<thead>
<tr>
<th>NOR Flash</th>
<th>NAND Flash</th>
<th>NROM</th>
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</thead>
<tbody>
<tr>
<td>• Short channel effect</td>
<td>• Inter-cell interference</td>
<td>• Short channel effect</td>
</tr>
<tr>
<td>• Contact and isolation fill</td>
<td>• CG-FG coupling</td>
<td>• Bit disturbs</td>
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<tr>
<td>• Charge storage reduction</td>
<td>• Gap fill</td>
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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