Samsung
NAND Flash Memory

Memory Product &
Technology Division

2000.3.15
NAND Flash Memory
Technology for Mass-Storage

- Non-volatile and Low Power Operation
- Lowest Bit Cost Solid-State Memory
Various Flash Memory Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>NOR</th>
<th>DINOR</th>
<th>T-Poly</th>
<th>AND</th>
<th>NAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td><img src="image" alt="NOR Structure" /></td>
<td><img src="image" alt="DINOR Structure" /></td>
<td><img src="image" alt="T-Poly Structure" /></td>
<td><img src="image" alt="AND Structure" /></td>
<td><img src="image" alt="NAND Structure" /></td>
</tr>
<tr>
<td>Program Method</td>
<td>CHE</td>
<td>F-N</td>
<td>CHE</td>
<td>F-N</td>
<td>F-N</td>
</tr>
<tr>
<td>Erase Method</td>
<td>F-N</td>
<td>F-N</td>
<td>F-N</td>
<td>F-N</td>
<td>F-N</td>
</tr>
<tr>
<td>Layers</td>
<td>2P2M</td>
<td>3P2M</td>
<td>3P1M</td>
<td>3P2M</td>
<td>2P1M</td>
</tr>
<tr>
<td>Company</td>
<td>Intel, AMD</td>
<td>Mitsubishi</td>
<td>SanDisk</td>
<td>Hitachi</td>
<td>Samsung Toshiba</td>
</tr>
</tbody>
</table>

Reference: ISSCC 94, 95, 96 Flash Session
## Unit Cell Comparison

<table>
<thead>
<tr>
<th>Item</th>
<th>NOR TYPE</th>
<th>NAND TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical View</strong></td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>
| Features | • One Tr. NMOS Floating Gate Device  
• Program : Hot - Electron  
• Erase : F-N Tunneling (BTBT Effect) | • One Tr. NMOS Floating Gate Device  
• Program : F-N Tunneling  
• Erase : F-N Tunneling (No BTBT)  
• Low Vcc Possible |
Cell Architecture Comparison

NOR TYPE
- Large cell and fast random access

NAND TYPE
- Small cell, but fast sequential access

- Contact is the limiting factor for scale-down.
- Easy to Scale Down.

Contact
NOR Flash Erase Method

Key Factors: Device Scalability, Voltage Scalability (Vcc, Charge Pump), Maximum High Voltage, Current Consumption (BTBT), Reliability (P/E Endurance, Retention)

Reference:
BTBT (Band To Band Tunneling) Effect

- During Erase Operation
- Gate Potential Assisted BTBT Phenomena
- Increased Vs Current
- Reliability Issues due to Hot-hole Trapping

--> DD Structure for Source

References:
## NOR Flash Program Method & Endurance

<table>
<thead>
<tr>
<th>Program Method</th>
<th>Typical Endurance Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
</tbody>
</table>

- **Hot Electron Injection**
- **Advantages**
  - Fast Program Speed (~us)
- **Disadvantages**
  - Large Program Current (~500uA/cell)
  - Difficult Voltage Scaling
  - Strong Charge Pump Circuit for Low Vcc

### Typical Endurance Characteristics

- $V_{cg} = 12V$; $t_{e} = 4E-3s$
- $V_{d} = 8V$; $t_{w} = 1E-3s$

![Graph](image)
NAND Flash Program/ Erase Method

<table>
<thead>
<tr>
<th>Program</th>
<th>Erase</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 ~ 20V</td>
<td>0V</td>
</tr>
<tr>
<td>Float</td>
<td>Float</td>
</tr>
<tr>
<td></td>
<td>0V</td>
</tr>
<tr>
<td></td>
<td>Float</td>
</tr>
<tr>
<td></td>
<td>19 ~ 21V</td>
</tr>
<tr>
<td>● Use F-N Tunneling</td>
<td>● Use F-N Tunneling</td>
</tr>
<tr>
<td>● Channel Inversion</td>
<td>● Channel Accumulation</td>
</tr>
</tbody>
</table>

- No DD Source (Easy Device Scaling)
- No BTBT Current (Easy Voltage Scaling)
NAND Flash Endurance vs. Characteristics

Cell Vth Shift

Programmed Cell
Erased Cell

Program/ Erase Time Variation

Program Time
Erase Time

Number of P/E Cycles

Cell Vth (V)

Number of P/E Cycles

Time (µS)
NAND Flash Operation

128+4Mb ARRAY

1 Block (=32 Page) (16K+512) Byte

128Mb : 32KRow (1024 Block)

512 Column 16 Column

Page Register (512+16Byte)

1 Slow Row access

2 Fast Page Access

Command, address and data multiplexed into I/O port

• Address map

<table>
<thead>
<tr>
<th>Cycle</th>
<th>A0</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>A0</td>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
<td>A6</td>
<td>A7</td>
</tr>
<tr>
<td>2nd</td>
<td>A9</td>
<td>A10</td>
<td>A11</td>
<td>A12</td>
<td>A13</td>
<td>A14</td>
<td>A15</td>
<td>A16</td>
</tr>
<tr>
<td>3rd</td>
<td>A17</td>
<td>A18</td>
<td>A19</td>
<td>A20</td>
<td>A21</td>
<td>A22</td>
<td>A23</td>
<td>*X</td>
</tr>
</tbody>
</table>

A0 ~ A7 : Selects the starting address of the 1st half of the register
A9 ~ A13 : Selects 1 page of 1 block (32 pages)
A14 ~ A23 : Selects 1 of 1024 blocks

• Read Operation

CLE
CE
WE
ALE
RE
I/O0
I/O1
I/O2
I/O3
I/O4
I/O5
I/O6
I/O7

1st 2nd 3rd

1 downloaded from array to page register

2 downloaded from page register

amsung ELECTRONICS

The Leader in Memory Technology

Product Planning & Application Engineering
NAND Flash Performance Analysis

Time calculation for updating 160KB file

- Erase time: 119 ms
- Program time: 140 ms
- Read time: 260 ms

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Page size</th>
<th>Block size</th>
<th>Read/page</th>
<th>Program/page</th>
<th>Erase/block</th>
</tr>
</thead>
<tbody>
<tr>
<td>8Mb</td>
<td>256Byte</td>
<td>4KByte</td>
<td>10 us</td>
<td>250us</td>
<td>2ms</td>
</tr>
<tr>
<td>16Mb</td>
<td>256Byte</td>
<td>4KByte</td>
<td>10 us</td>
<td>250us</td>
<td>2ms</td>
</tr>
<tr>
<td>32/64Mb</td>
<td>512Byte</td>
<td>8KByte</td>
<td>10/7us</td>
<td>250/200us</td>
<td>2ms</td>
</tr>
<tr>
<td>128Mb</td>
<td>512Byte</td>
<td>16KByte</td>
<td>10 us</td>
<td>200us</td>
<td>2ms</td>
</tr>
</tbody>
</table>

- Page size: 256 Byte, 4K Byte, 256 Byte, 4K Byte, 512 Byte, 8K Byte, 512 Byte, 16K Byte
- Block size: 256 Byte, 4K Byte, 512 Byte, 8K Byte, 512 Byte, 16K Byte
- Read/page: 10 us, 10 us, 10/7 us, 10 us
- Program/page: 250us, 250us, 250/200us, 200us
- Erase/block: 2ms, 2ms, 2ms, 2ms
Bit cost continues to be dropped as the memory density grows.
# Flash Memory Application Segment

<table>
<thead>
<tr>
<th>Applications</th>
<th>Chip Storage (Mbit)</th>
<th>Key Features</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>EPROM Replacement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- PC BIOS Firmware</td>
<td></td>
<td></td>
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<tr>
<td>- OS/APPS Software</td>
<td></td>
<td></td>
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<tr>
<td>- D.Cellular Phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Boot Code Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Mass Storage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- PCMCIA ATA Card</td>
<td></td>
<td></td>
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<tr>
<td>- Solid-State Disk</td>
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<tr>
<td>- Digital Still Camera</td>
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<tr>
<td>- Digital Audio Recorder</td>
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<td></td>
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<tr>
<td>- Music Player</td>
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</tbody>
</table>

- **Random Access**
  - Separate Addr./Data Line
  - Chip or Large Erase Block
  - 1 piece/system

- **Low Cost**
  - High Speed Sequential Access
  - Mid./Small Block Size
  - Single Voltage (3V)