NOR Flash from Greater China: From Follower to Leader

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GigaDevice Semiconductor Inc.
History of Flash Memory Technology

- **1984**: Flash Invent
  - Toshiba, Fujio Masuoka invented the Flash Memory

- **1988**: NOR
  - Intel 1st produced NOR Flash, 256Kbit

- **1989**: NAND
  - Toshiba 1st produced NAND Flash

- **2012**: 3D NAND
  - Samsung 1st produced 3D NAND Flash, 24-Layer

- **2016**: Toshiba/Sandisk, Micron/Intel, Hynix produced 3D NAND
NAND vs. NOR Flash

<table>
<thead>
<tr>
<th>Layout</th>
<th>NAND</th>
<th>NOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bit line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit Cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell Array</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell Size</td>
<td>4F²</td>
<td>10F²</td>
</tr>
</tbody>
</table>

- **Data**
  - USB/Cards
  - SSD

- **Code + Data**
  - Mobile
  - DVD
  - STB
  - Industrial
  - Automotive

- **Code + Parameter**
  - Modem
  - PC

- **Code Only**
  - HDD, Add-on boards, CD-ROM
  - Printer, DVD, PDA, OA, Games, TV

- **Standby Power**
  - Cost-per-bit
  - File Storage Use
  - Code Execution
  - Read Speed
  - Write Speed
  - Capacity

* (*): Depending on how memory is used, NOR is typically slower on writing and NAND for storing larger amount of data. NOR is typically fast on reads, which consume less power.
NAND dominates Flash landscape, yet NOR continues finding its niche...
• Downward of traditional Market slow down in 2015

• Now we have cross “V” wave and back to ramp

Turning around for NOR Flash Market

Source: Gartner 2017
NOR Flash in Growing Applications

NOR Flash Shipment by applications

(Mn 2Mb Equiv)

- Smart Phone(TDDI)
- Smart Phone(AMOLED)
- Feature Phone
- Smart Phone(AP)
- PC

Flash Memory Summit 2018
Santa Clara, CA
NOR Flash: Indispensable in every Embedded Systems

Boot code in system from shadowing to eXecution In Place

Finds new Applications

IoT

Feature Phone

Modules in Smart phone:
- OLED
- TDDI
- AP
- Camera

Embedded System

Automotive
Growing Presence from Greater China NOR Suppliers

Mainland + Taiwan ~8%

Macronix  Spansion  Micron
Samsung  SST  Others

Mainland + Taiwan ~60%

Macronix  Winbond  Gigadevice
Micron  Cypress  Others

Source: Webfeet Research, 2017
## Healthy NOR Supply Chain in Greater China

<table>
<thead>
<tr>
<th>Business Model</th>
<th>Design house</th>
<th>Fab/Foundry</th>
<th>OSAT</th>
<th>Programmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainland</td>
<td>Gigadevice, Dosilicon, Fudan Micro, ISSI</td>
<td>SMIC, XMC, HLMC</td>
<td>CJ, TFMicro, Huatian</td>
<td>Xelteck, ZLG</td>
</tr>
<tr>
<td>Taiwan</td>
<td>MXIC, Winbond, ESMT</td>
<td>MXIC, Winbond, Powerchip</td>
<td>PTI, ASE/SPIL</td>
<td>Deliprog</td>
</tr>
</tbody>
</table>
NOR is currently the only self-supplied memory in Mainland China

<table>
<thead>
<tr>
<th>System</th>
<th>Device</th>
<th>Core IC</th>
<th>Self Sufficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer System</td>
<td>Server</td>
<td>MPU</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>MPU</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
<td>MPU</td>
<td>2%</td>
</tr>
<tr>
<td>General Purpose System</td>
<td>Programmable Logic Device</td>
<td>FPGA/CPLD</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Digital Signal Processing</td>
<td>DSP</td>
<td>0%</td>
</tr>
<tr>
<td>Storage System</td>
<td>Semiconductor Memory</td>
<td>Application Processor</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communication Processor</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Embedded MPU</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Embedded DSP</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network Processor Unit</td>
<td>15%</td>
</tr>
<tr>
<td>Display System</td>
<td>TV</td>
<td>DRAM</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NAND Flash</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOR Flash</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Image Processor</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Display Driver</td>
<td>0%</td>
</tr>
</tbody>
</table>
New Applications Driving NOR Flash Market

- IOT& Module
  - Low Size
  - Low Power
  - Low Pin out
- Low Cost
- High Performance
  - Auto
  - Octal SPI/DDR
- Long product lifecycle
- High reliability ECC
GigaDevice Milestones

- Headquarter to Beijing, China
- Founded in Silicon Valley, US
- June 2004: SRAM Product
- April 2005: China's first SPI NOR Flash
- May 2008: China's first Cortex-M3 32-Bit MCU
- April 2005: China's first SPI NAND Flash
- May 2013: China's first NAND Flash Mass Production
- August 2015: World's first SPI NAND Flash
- August 2016: National IC Fund purchased 11% of GigaDevice shares, becoming GD's second largest shareholder
- October 2017: Purchased 1.02% share of SMIC, becoming SMIC's fifth largest shareholder
- September 2017: Signed co-development agreement with Hefei Industrial Investment Fund. Launched 19nm DRAM project in Hefei
- November 2017: Purchased 1.02% share of SMIC, becoming SMIC's fifth largest shareholder
- December 2017: Announced the acquisition of Silead
Rapid Growing of GigaDevice

- 2017 top 10 IC design companies in China
- Top 500 listed companies in China
- Current company market value at ~USD $5B
- Total employees: 450+, 60% in R&D, Revenue >USD $720K per employee
- Filed 800+ patents with 323 patents granted
No. 1 NOR Flash Supplier of Mainland China

Table 2. Flash Memory 2017 Vendor Market Shares

<table>
<thead>
<tr>
<th>Rank</th>
<th>Flash Vendor</th>
<th>$ in Millions</th>
<th>% Change</th>
<th>Market Share</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Samsung</td>
<td>10,080, 12,180, 18,047</td>
<td>48.2%</td>
<td>33.2%</td>
<td>33.8%</td>
</tr>
<tr>
<td>2</td>
<td>Toshiba</td>
<td>6,409, 6,473, 9,115</td>
<td>40.8%</td>
<td>17.7%</td>
<td>17.1%</td>
</tr>
<tr>
<td>3</td>
<td>WDC (SanDisk)</td>
<td>4,692, 5,193, 8,669</td>
<td>66.9%</td>
<td>14.2%</td>
<td>16.2%</td>
</tr>
<tr>
<td>4</td>
<td>Micron</td>
<td>4,431, 4,617, 6,241</td>
<td>35.2%</td>
<td>12.6%</td>
<td>11.7%</td>
</tr>
<tr>
<td>5</td>
<td>Hynix</td>
<td>3,230, 3,589, 5,198</td>
<td>44.8%</td>
<td>9.8%</td>
<td>9.7%</td>
</tr>
<tr>
<td>6</td>
<td>Intel</td>
<td>2,440, 2,528, 3,419</td>
<td>35.2%</td>
<td>6.9%</td>
<td>6.4%</td>
</tr>
<tr>
<td>7</td>
<td>Macronix</td>
<td>473, 521, 759</td>
<td>45.7%</td>
<td>1.4%</td>
<td>1.4%</td>
</tr>
<tr>
<td>8</td>
<td>Cypress</td>
<td>642, 635, 634</td>
<td>(0.1)%</td>
<td>1.7%</td>
<td>1.2%</td>
</tr>
<tr>
<td>9</td>
<td>Winbond</td>
<td>354, 397, 597</td>
<td>50.4%</td>
<td>1.1%</td>
<td>1.1%</td>
</tr>
<tr>
<td>10</td>
<td>GigaDevice</td>
<td>185, 166, 285</td>
<td>71.7%</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

- No. 3 SPI NOR Flash provider in the World
- The only company from Mainland China in top 10 Global Flash Memory Suppliers

Source: Webfeet Research, 2017
1. NOR was once the main Flash till feature phone years. As NAND Flash dominates in smart phone and SSD in data storage era, NOR continues to find its niche in various applications, as the indispensable code memory in every embedded system.

2. IoT, smart phone modules and automotive applications drive the NOR Flash ramping up again, both in revenue and in unit counts.

3. Suppliers from Greater China are leading the NOR Flash production and market share. GigaDevice is one of leading NOR Flash suppliers in the world and the largest NOR Flash supplier from mainland China.
Thank you