Status of the Memory Industry

Market and Technology Report 2020
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Simone is a Technology & Market analyst at Yole Développement (Yole) working with the Semiconductor & Software division. He is member of the Yole’s memory team and he contributes on a day-to-day basis to the analysis of memory markets and technologies, their related materials and fabrication processes. Previously, Simone carried out experimental research in the field of nanoscience and nanotechnology, focusing on emerging semiconducting materials and their device applications. He (co-) authored more than 15 papers in high-impact scientific journals and was awarded the prestigious Marie Curie Intra-European Fellowship. Simone obtained a PhD in physics in 2015 from Ecole Polytechnique Fédérale de Lausanne (Switzerland), where he developed novel flash memory cells based on heterostructures of 2D materials and high-κ dielectrics. Simone earned a double M. A. Sc. degree from Polytechnique de Montréal (Canada) and Politecnico di Milano (Italy), graduating cum laude.

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Walt Coon

Walt Coon joins Yole Développement’s memory team as VP of NAND and Memory Research, part of the Semiconductor & Software division. Walt is leading the day-to-day production of both market updates, Market Monitors and Pricing Monitors, with a focus on the NAND market and semiconductor industries. In addition, he is deeply involved in the business development of these activities. Walt has significant experience within the memory & semiconductor industry. He spent 16 years at Micron Technology, managing the team responsible for competitor benchmarking, and industry supply, demand, and cost modeling. His team also supported both corporate strategy and Mergers & Acquisitions analysis. Previously, he spent time in Information Systems, developing engineering applications to support memory process and yield enhancement. Walt Coon earned a Master of Business Administration from Boise State University (Idaho, United-States) and a Bachelor of Science in Computer Science from the University of Utah (United-States).

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Mike Howard

Mike Howard is member of the memory team at Yole Développement (Yole) as VP of DRAM and Memory Research. Mike’s mission at Yole is to deliver a comprehensive understanding of the entire memory and semiconductor landscape (with special emphasis on DRAM) via market updates, Market Monitors, and Pricing Monitors. Mike is also deeply involved in the business development of all memory activities. Mike has a deep understanding of the DRAM and memory markets with a valuable combination of industry and market research experience. For the decade prior to joining Yole, Mike was the Senior Director of DRAM and Memory Research at IHS. Before IHS, Mike worked at Micron Technology where he had roles in corporate development, marketing, and engineering. Mike earned a Master of Business Administration at The Ohio State University (United-States), a Bachelor of Science in Chemical Engineering and a Bachelor of Arts in Finance at the University of Washington (Washington, United-States).

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ABOUT THE AUTHORS

Biographies & contacts

Ivan Donaldson
Ivan Donaldson is the VP of financial market development at Yole Développement (Yole). He is responsible for managing services and client relationships in the global financial segment including institutional investors, research firms, private equity funds, venture capital funds, and investment bankers. Prior to Yole, as VP of Corporate Strategy at Micron Technology, Ivan’s responsibilities included corporate strategic planning, M&A and business development, and generating strategic intelligence. In addition, he represented the company externally with key counterparties, business partners, and government officials. He was also previously the head of Micron Technology’s Investor Relations team, representing the company with investors worldwide. In addition to the memory industry, Ivan has developed expertise in imaging and compound semiconductor markets, all of which are a focus in his position with Yole.

Ivan earned a Bachelor of Business Administration degree in Finance from Boise State University (Idaho, United-States), graduating Magna Cum Laude.

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Emilie Jolivet
Emilie Jolivet is Director of the Semiconductor & Software Division at Yole Développement (Yole), part of Yole Group of Companies. Emilie manages the expansion of the technical and market expertise of her team. In addition, Emilie’s mission focusses on the management of business relationships with semiconductor leaders and the development of market research and strategy consulting activities. With its previous collaborations at Freescale and EV Group, Emilie developed a core expertise dedicated to package & assembly, semiconductor manufacturing, memory and software & computing.

Emilie Jolivet holds a Master’s degree in Applied Physics specializing in Microelectronics from INSA (Toulouse, France) and graduated with an MBA from IAE (Lyon, France).

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Santosh Kumar
Santosh Kumar is working as Principal Analyst and Director Packaging, Assembly & Substrates, Yole Korea, part of Yole Développement (Yole). Based in Seoul, Santosh is strongly involved in the market, technology and strategic analysis of the microelectronic assembly & packaging technologies and present his vision of the industry in numerous conferences as well as through papers and patents publication.

His main interest areas are advanced IC packaging technology including equipment & materials. He is the author of several reports on fan-out / fan-in WLP, flip chip, and 3D/2.5D packaging.

Santosh Kumar received the bachelor and master degree in engineering from the Indian Institute of Technology (IIT), Roorkee and University of Seoul respectively.

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COMPANIES CITED IN THE REPORT

METHODOLOGIES & DEFINITIONS

Yole’s market forecast model is based on the matching of several sources:

- **Comparison with existing data**
- **Monitoring of corporate communication**
- **Using other market research data**
  - Yole analysis (consensus or not)

- **Comparison with prior Yole reports**
  - Recursive improvement of dataset
  - Customer feedback

- **Top-to-bottom approach**
  - Aggregate of market forecasts
    - @ System level

- **Bottom-up approach**
  - Ecosystem analysis
    - Aggregate of all players’ revenue
      - @ System level

- **Top-to-bottom approach**
  - Aggregate of market forecast
    - @ Semiconductor device level

- **Bottom-up approach**
  - Ecosystem analysis
    - Aggregate of key players’ revenues
      - @ Semiconductor device level

Market

- **Volume (in Munits)**
- **ASP (in $)**
- **Revenue (in $M)**

- **Semiconductor foundry activity**
  - Capacity investments and equipment needs

Preexisting information

Primary data
- Reverse costing
- Patent analysis
- Annual reports
- Direct interviews

Secondary data
- Press releases
- Industry organization reports
- Conferences

Information Aggregation
SCOPE OF THE REPORT

Stand-Alone Memory Markets and Technologies

(NV)SRAM/FRAM  Emerging NVM
NOR
NAND
DRAM

Other (EEPROM, ROM, etc.)

Key End-Markets and End-Systems

Datacenters - Servers and Enterprise
Mobile – Smartphones
Client – PC, client SSD
Automotive – Vehicles (incl. ADAS systems)

 Yours needs are out of the report’ scope?
Contact us for a custom:
COMPARISON WITH THE 2019 REPORT
What we saw, what we missed

What we saw:
  o **Market:**
    • As expected, the NAND market started reaching a balanced condition at the end of 2019 with ASPs rising again in Q4. DRAM took a bit longer: prices/revenues started rising moderately (QoQ) in Q1 2020.
  o **Players:**
    • YMTC introduced its 64L 3D NAND into the market in 2020. CXMT is the most advanced DRAM player in China; however, its first-generation DRAM will not be broadly available by 2020.

What we missed:
  o **Market:**
    • DRAM revenue and ASP declines in 2019 were worst than expected. 2019 forecast: ASP -36%, revenue -26%. 2019 actual: ASP -49%, revenue -38%.
    • In line with trends of the overall memory market, NOR revenues went through a 12% decline. We noticed also that NOR replacement is a potential target for stand-alone emerging NVM by 2025.
  o **Technologies:**
    • The memory market leader Samsung will be introducing storage products based on 136L single-stack 3D NAND in 2020. Intel plans to introduced an FG-based 144L 3D NAND technology.
  o **Players:**
    • Micron has lost significant NOR market share in 2019, as it is not focusing on NOR as in the past, the priority is given to the more profitable NAND and DRAM businesses.
STAND-ALONE MEMORY MARKET - OVERVIEW

- NAND and DRAM account for ≈XX% of the overall stand-alone memory market.
- Combined NAND and DRAM revenue was ≈ $XXX billion in 2019, down XX% from 2018.

2019 Memory Market - Breakdown by Technology

Total Stand-Alone Market in 2019 ≈ $XXXB
IMPACT OF COVID-19 ON THE BIT SHIPMENTS IN 2020

• H1 shipments slightly higher due strong Q1 datacenter and PC SSD demand & buyaheads due to supply chain concerns.
• H2 growth driven by datacenter and new gaming console releases.

• H1 2020 shipments higher due to strong server segment and buyaheads due to supply chain concerns.
• H2 shipments lower due to reduced capex and softer demand.
STAND-ALONE MEMORY MARKET OVERVIEW - FOCUS ON NAND

NAND Market Revenue

Revenue ($M) - % Change

-80% -40% 0% 40% 80% 120%

$0 $20 000 $40 000 $60 000 $80 000


Total NAND Market in 2019 ~ $XXB

NAND Market Shares by Revenue

Macronix Cypress Winbond Other

Samsung SK hynix Micron Western Digital Kioxia

Market shares are based on actual market results for CY-2019
Source: “NAND Market Monitor Q2 2020” by Yole

NAND Average Selling Price

ASP ($/Gb) - % Change

-80% -40% 0% 40% 80%

$0 $0.02 $0.04 $0.06


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STAND-ALONE MEMORY MARKET OVERVIEW - FOCUS ON DRAM

**DRAM Market Revenue**

- Revenue ($M)
- % Change

**DRAM Average Selling Price**

- ASP ($/Gb)
- % Change

**Total DRAM Market in 2019 ~ $XXB**

**DRAM Market Shares by Revenue**

Market shares are based on actual market results for CY-2019
Source: “DRAM Market Monitor Q2 2020” by Yole
NAND MEMORY - LEADING PLAYERS BY MARKET SEGMENTS

- Samsung is the undisputed leader in the SSD and Mobile segments (largest markets) followed by the Kioxia-Western Digital alliance.
- Samsung does not focus on the Removable & Consumer segment, which is dominated by Toshiba and Western Digital with a combined market share of ~XX%.

Total 2019 NAND market
~$XXB

NAND Revenue Market Share 2019 by Application

- SSD
- Mobile
- Removable & Consumer
- Other

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• Samsung is leading the largest market segments - Datacenter and Mobile - as well as Graphics and Consumer segments.

• SK hynix and Samsung are the top players for PC DRAM, whereas Micron leads the Automotive DRAM market.

Total 2019 DRAM market
~$XXB

DRAM Revenue Market Share 2019 by Application
MEMORY WAFER DEMAND - FORECAST FOR COMBINED NAND AND DRAM

Datacenter and mobile will be the dominant categories, automotive is the fastest growing segment.

NAND & DRAM wafer demand (12” wafers out per year)

Yole Développement

‘19-’25 CAGR ~ XX%
Most of the NAND bits produced in the coming years will be used in enterprise SSDs for data center applications.

Automotive is the fastest growing segment for NAND-bit demand with a CAGR of 19–25~ XX%.

**NAND demand from different systems (in GB)**
• Servers for data centers and smartphones will be the major consumers of DRAM bits.
• Automotive is the fastest growing segment for NAND-bit demand with a CAGR_{19-25} \sim XX\%
STAND-ALONE MEMORY TECHNOLOGIES AND MARKETS

• DRAM and NAND together represent ~XX% of the stand-alone memory market.

• The remaining ~XX% of the market (~$XX) consists of:
  - Flash NOR (~$XX)
  - EEPROM, EPROM, Mask PROM/ROM, etc. (~$XX)
  - Volatile RAM (~$XX)
    • Asynchronous SRAM
    • Synchronous SRAM
  - Non-Volatile RAM (~$XXM)
    • nvSRAM
    • BBSRAM
    • FeRAM
  - Stand-alone emerging NVMs (~$XX)

• Compared to NAND and DRAM, these markets are much less volatile and relatively more stable.
OTHER STAND-ALONE MEMORIES

STAND-ALONE NOR FLASH MEMORY - MARKET OVERVIEW

- Since its peak at smartphones to smart TVs and wearables, the stand-alone memory market has been in decline.
- Several applications that used to rely on stand-alone memories, such as touch-display drivers, have been replaced by flash memories.
- Despite some consolidation and business and technology stakeholders being established in the market, the overall market was $5.5B in 2019.

STAND-ALONE (NV)SRAM - MARKET EVOLUTION

Volatile and Non-Volatile SRAM market forecast

- The stand-alone SRAM market has been in decline since its peak in 2011, when it was $12.5B.
- The decline in the market is due to the rise of other memory technologies, such as flash, and ASOs are already declining because of the market shift.
- The average business growth was 4-5% in 2018 and is expected to decline to 3-4% in 2019.
- Cypress is currently the leader in the SRAM market, accounting for 20% of the market.
- The main applications are in consumer electronics, medical, and automotive.

EMERGING MEMORY - TECHNOLOGIES AND KEY PLAYERS

- PCM: Phase-Change Memory
  - Micron
  - Intel
  - SK Hynix
  - IBM
- RRAM: Resistive Random-Access Memory
  - Panasonic
  - Fujitsu
  - addesto
  - Crossbar
- STT-MRAM: Spin-Transfer Torque Magnetic RAM
  - Everspin
  - GlobalFoundries
  - IBM
  - Intel
- Non-exhaustive lists!
NOR MEMORY – AVERAGE SELLING PRICE AND DENSITY

2019 NOR shipments (units) - Breakdown by Density

- ≤ 2Mb
- > 2Mb and ≤ 4Mb
- > 4Mb and ≤ 8Mb
- > 8Mb and ≤ 16Mb
- > 16Mb and ≤ 32Mb
- > 32Mb and ≤ 64Mb
- > 64b and ≤ 128Mb
- > 128Mb

ASP ($/Gb) Evolution

NOR ASP ($/Gb) vs. Density (Gb)

Data collected in Q1 2020
### OTHER STAND-ALONE MEMORY: SRAM AND FRAM

<table>
<thead>
<tr>
<th>Volatile and Non-Volatile SRAM</th>
<th>FRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td></td>
</tr>
<tr>
<td>Includes different types of stand-alone products: synchronous, asynchronous, NVSRAM (combinations of SRAM and EEPROM) and BBSRAM (a special NVSRAM based on an internal battery),</td>
<td>Non-volatile ferroelectric memory</td>
</tr>
<tr>
<td><strong>Players</strong></td>
<td></td>
</tr>
<tr>
<td>Cypress, Maxim, STMicroelectronics, Texas Instruments</td>
<td>Ramtron (Cypress), Fujitsu, Texas Instruments, Lapis (Rohm), IBM, Infineon</td>
</tr>
<tr>
<td>GSI Technology, Alliance Memory, Lyontek, Fidelix</td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td></td>
</tr>
<tr>
<td>Industrial and enterprise storage</td>
<td>Industrial and enterprise storage</td>
</tr>
<tr>
<td><strong>Market size</strong></td>
<td></td>
</tr>
<tr>
<td>~$XX in 2019</td>
<td>~$XXM in 2019</td>
</tr>
<tr>
<td>(SRAM <del>$XX, NVSRAM</del>$XX and BBSRAM~$XX )</td>
<td>(static market, CAGR_{19-25} &lt; XX% )</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td></td>
</tr>
<tr>
<td>High-cost (in particular for NVSRAM), and need for battery in the case of BBSRAM</td>
<td>Limited scalability (130nm, 4MB today), high cost</td>
</tr>
</tbody>
</table>

**Source:** Cypress

**Source:** Maxim/Dallas

**Source:** Texas Instruments
FINANCIAL ANALYSIS

FINANCIAL ANALYSIS - ASP, OPERATING COST AND MARGIN

FINANCIAL ANALYSIS - RESEARCH AND DEVELOPMENT

FINANCIAL ANALYSIS - TOP 10 PLAYERS BY REVENUE

FINANCIAL ANALYSIS - TOP 10 PLAYERS BY REVENUE

FINANCIAL ANALYSIS – CAPEX

Combined NAND and DRAM CAPEX in $M
**2019 - 2025 MARKET FORECAST**

**NAND MARKET REVENUE - FORECAST**

**NAND MARKET AVERAGE SELLING PRICE (ASP) - FORECAST**

**NAND MARKET BIT SHIPMENTS - FORECAST**

**NAND BIT DEMAND - FORECAST BY APPLICATIONS**

**NAND WAFER PRODUCTION - FORECAST**

**NAND TECHNOLOGY - PROCESS MIX FORECAST**

**DRAM MARKET AVERAGE SELLING PRICE (ASP) - FORECAST**

**DRAM MARKET REVENUE - FORECAST**

**DRAM TECHNOLOGY - PROCESS MIX FORECAST**

- 1znm will begin in 2020 and will become the dominant technology process by 2022 (~47% share).
- The average node is scaling with a CAGR of ~9% from 2019 to 2025.
CHINA MEMORY MARKET, PLAYERS AND ACTIVITIES

CHINA’S MEMORY LANDSCAPE

China is a key market for all leading memory suppliers

- In 2019, Samsung, SK hynix and Micron have sold more than 30% of their NAND and DRAM production to companies located in China. Besides, Kioxia, Western Digital and Intel have also been key suppliers of NAND memory to the Chinese market.

EMERGING NON-VOLATILE MEMORY ACTIVITIES IN CHINA

Overview of Emerging Non-Volatile Memory Activities in China

Company

- Shanghai Xinchu Integrated Circuit Co.
- Jiangua Advanced Memory Technology (JAMT) Corporation
- SPIC
- Crossbar Asia-Pacific
- HLMC
- Reliance (TV GigaDevice and Ramtron)

CHINA’S MEMORY EXPANSION - PLAYERS

Multiple Chinese players worth watching

- China has been researching for long on its own domestic IC industry. It also has invested in various multinational chipmakers to add memory and foundry bills.
YOLE GROUP OF COMPANIES RELATED REPORTS

Yole Développement

- NAND and DRAM Quarterly Market Monitors
- Emerging Non-Volatile Memory 2020
- MRAM Technology and Business 2019
- Neuromorphic Sensing and Computing 2019