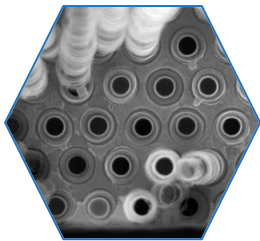
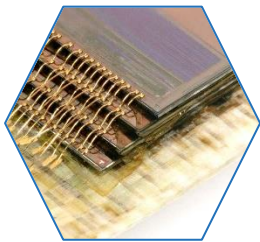
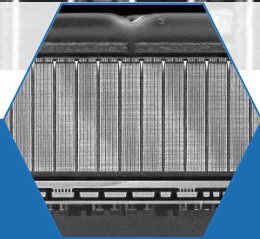


3D NAND Memory Comparison 2021

Physical analysis and cost comparison of three leading-edge 3D NAND technologies: Samsung's 128-layer, SK Hynix's 128-layer, and Intel's 144-layer.



NAND revenue is expected to expand over time as cost reductions enable further penetration of NAND-based storage. Revenue is expected to increase from \$56 billion in 2020 to \$70 billion in 2021, a huge increase of 25%. By 2026, NAND market revenue is expected to exceed \$90 billion.

NAND is the most common and widely used type of non-volatile memory technology because it offers a combination of high storage capacity and low cost per bit. Demand for this memory technology continues to grow (2020-2026 NAND bit growth CAGR of 29%), led by important megatrends such as mobility, cloud computing, AI, and the Internet of Things (IoT).

This report focuses on technologies from Samsung, SK Hynix, and Intel, who respectively held market shares of 34%, 11%, and 9% in 2020.

3D NAND technology continues to rapidly develop. NAND memory improves device capacity by stacking memory cells into vertical layers. In 2015, commercialized 3D NAND memory used 32-layers, while in 2021 most manufacturers are mass producing 128-layer 3D NAND memory. The progressive addition of wordline layers results in significant changes in the manufacturing processes of memory devices. Storing multiple bits per memory cell equates to improved capacity without any additional manufacturing process steps.

In this report, three memories taken from solid-state drives are analyzed: Samsung's 128-layer, SK Hynix's 128-layer, and Intel's 144-layer. This report presents a detailed study of Samsung's latest 128-layer V-NAND using charge trap flash and triple-

level cell NAND memory cells; SK Hynix's 128-layer (also referred to as the '4D NAND' by SK Hynix) using periphery under cell technology (PuC); and Intel's unique technology, which combines floating gate architecture with CMOS under array (CuA). Also included in this report is a full analysis and comparison of the NAND memories. Details on package teardown are provided as well, accompanied by optical and high-resolution SEM images of the memory dies that show the dies' features and process. The die cross-section reveals Samsung's single deck, SK Hynix's double deck, and Intel's wordlines in three decks. The cross-section images disclose the memory floating gate or charge trap technology used by each memory. Also furnished is the manufacturing process of the 3D NAND memory and the cost analysis and comparison. Finally, this comparison report includes the manufacturing process comparison and the cost comparison detailing the NAND array wafer cost, CMOS cost, die cost, and cost per gigabit of the three memories.

Title: 3D NAND Memory Comparison 2021

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COMPLETE TEARDOWN WITH:

- Detailed photos
- Precise measurements
- Materials analysis
- Manufacturing process flow
- Supply chain evaluation
- Manufacturing cost analysis
- Physical analysis, manufacturing process, and cost analysis comparison

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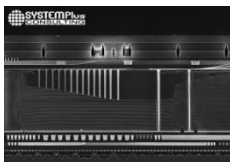


Belinda Dube is working for System Plus Consulting as an Engineer & Analyst, Semiconductor Memories, especially DRAM and 3D NAND flash memory. At the same time, she also investigates IC technologies as well as advanced packaging. Belinda is also engaged in the development of reverse engineering & costing analyses with the power electronics and compound semiconductors team.



Véronique Le Troadec has joined System Plus Consulting as a laboratory engineer. Coming from Atmel Nantes, she has extensive knowledge in failure analysis of components and in deprocessing of integrated circuits.

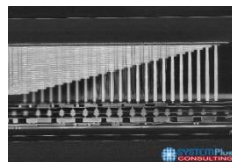
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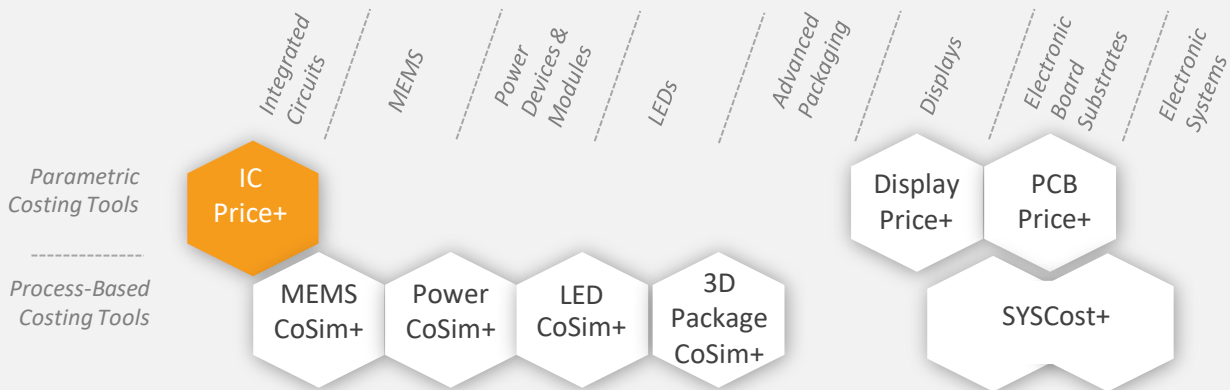


NAND Quarterly Market Monitor

After a difficult finish to 2020, the NAND market outlook improves in early 2021.

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Our analysis is performed with our costing tool IC Price+.

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ABOUT SYSTEM PLUS CONSULTING

WHAT IS A REVERSE COSTING®?

Reverse Costing® is the process of disassembling a device (or a system) in order to identify its technology and calculate its manufacturing cost, using in-house models and tools.



CONTACTS

Headquarters
22, bd Benoni Goullin
Nantes Biotech
44200 Nantes
France
+33 2 40 18 09 16
sales@systemplus.fr

Europe Sales Office
Lizzie LEVENEZ
Frankfurt am Main
Germany
+49 151 23 54 41 82
lizzie.levenez@yole.fr

America Sales Office
Hal LEVY
Western USA & Canada
+1 408 334 0554
hal.levy@yole.fr

Chris YOUMAN
Eastern USA & Canada
+1 919-607-9839
chris.youman@yole.fr

Asia Sales Office
Takashi ONOZAWA
Japan & Rest of Asia
+81 80 4371 4887
onozawa@yole.fr

Mavis WANG
Greater China
TW +886 979 336 809
CN +8613661566824
wang@yole.fr

Peter OK
Korea
+82 10 4089 0233
peter.ok@yole.fr

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