The Many Flavors of NAND … and More to Come

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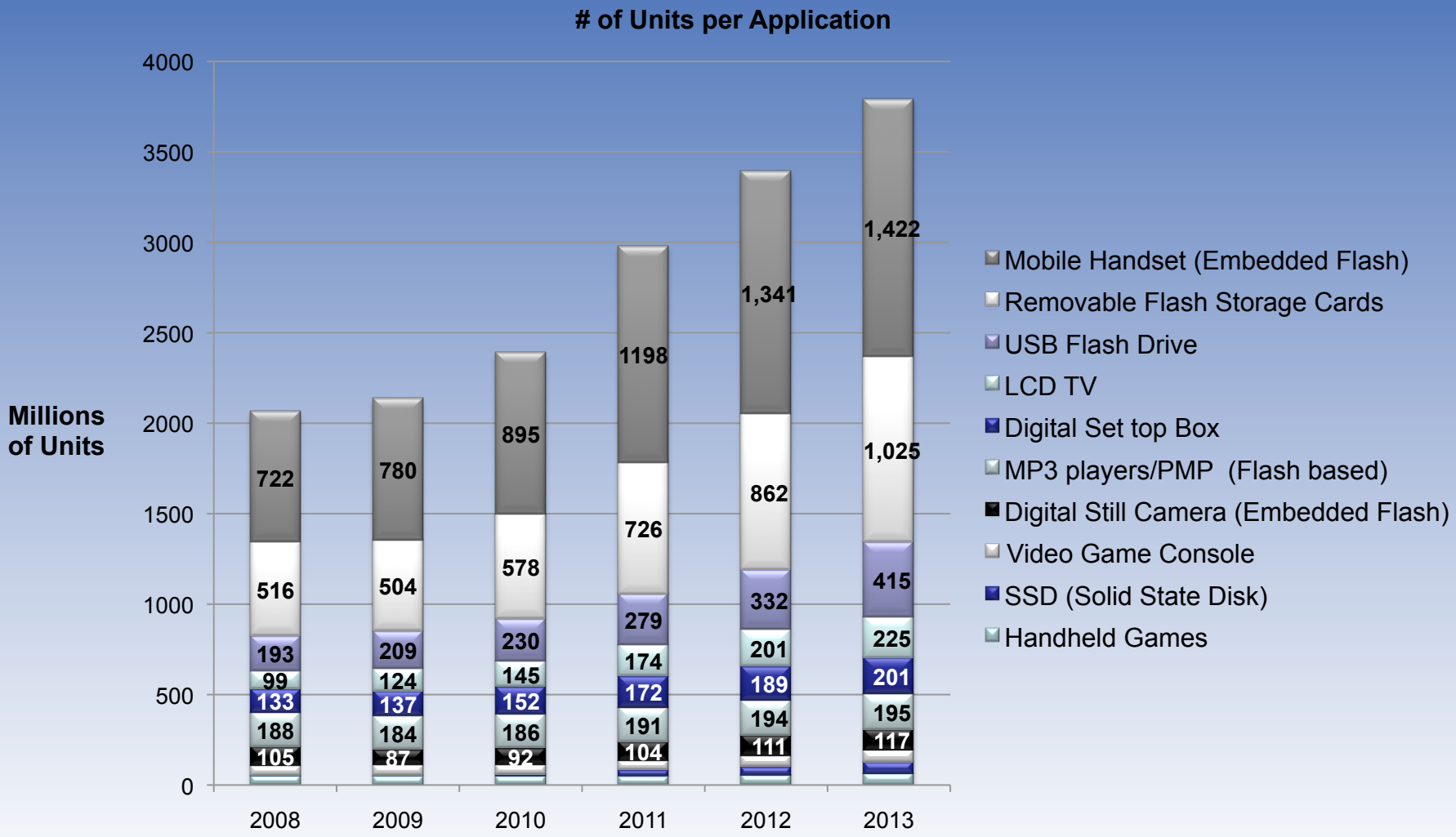
NAND Market Growth Drivers

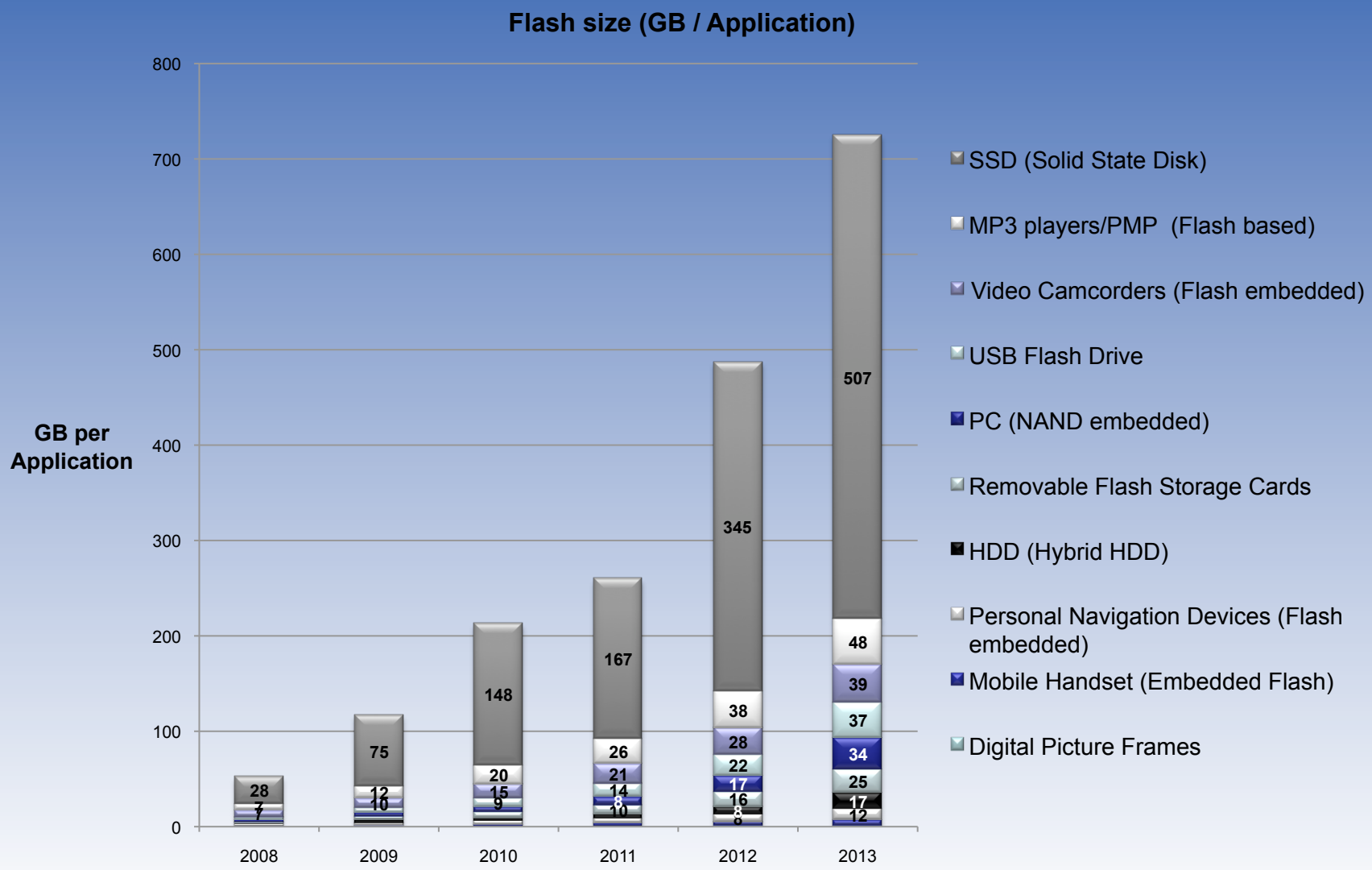
Santa Clara, CA USA
August 2009

Top 10 Applications by Units Shipped



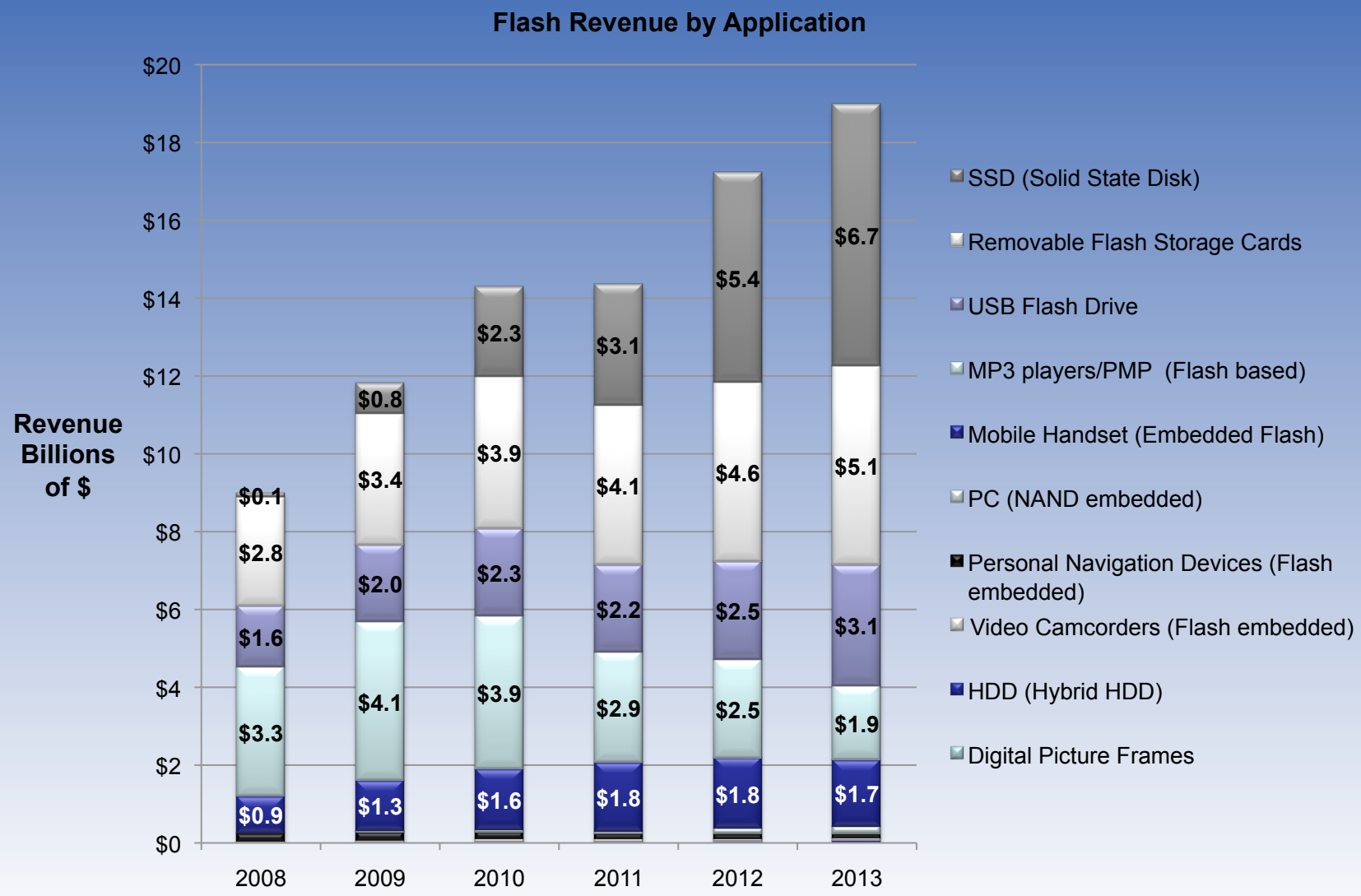
Source: iSuppli

Top 10 Applications by Gigabytes



Source: iSuppli

Top 10 Applications by Revenue



Source: iSuppli

Matching NAND to the Application

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August 2009

Quality & Reliability
Small Form Factor
High Density
Low Power
High Performance
High Endurance
NAND Management
NAND Market Requirements

NAND Application Requirements

Mobile & Consumer Electronics	• Small Form Factor • Low Power
Notebook (SSDs & Embedded)	• High Density • Low Power
Enterprise Storage	• High Endurance • High Performance • Quality & Reliability

NAND management is increasingly critical to all

NAND Technologies

SLC NAND

- **Target apps:** Enterprise storage & code storage
- **Features:** High-Performance, High-Endurance

2-bit/cell NAND

- **Target apps:** Notebook SSDs & consumer applications
- **Features:** High-Density, Lower-Cost than SLC

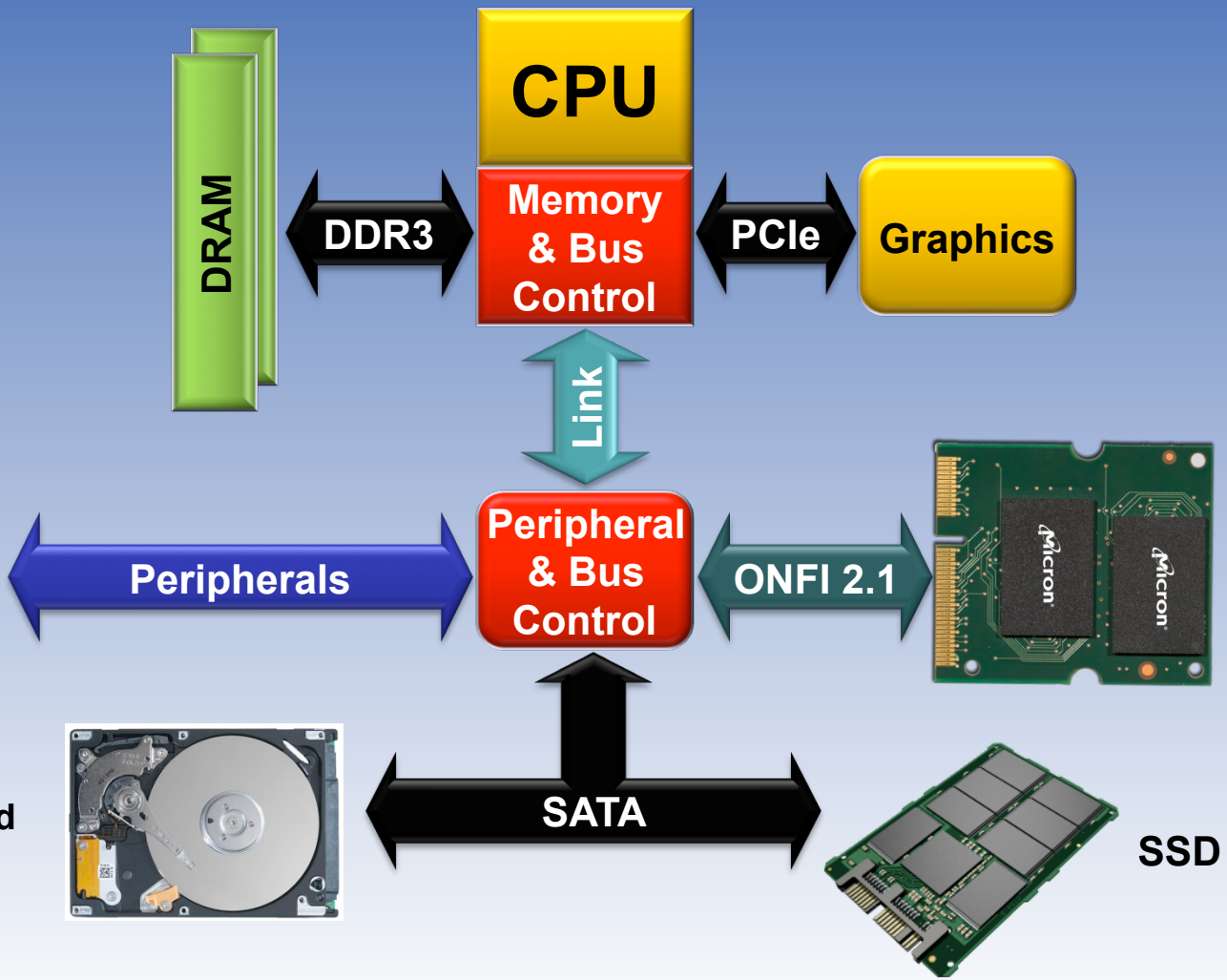
3-bit/cell NAND

- **Target apps:** Flash cards & USB drives
- **Features:** Highest Density, Lowest Cost

NAND Solutions

High-Speed NAND	• **Target apps:** SSDs, USB 3.0 & Disc Caching • **Features:** ONFI 2.1 synchronous (DDR) interface, reaching speeds of up to 200 MB/s
Enterprise NAND	• **Target apps:** Servers, Storage & Networking • **Features:** Achieves 10x improvement in endurance compared to standard NAND
Managed NAND	• **Target apps:** Mobile and Consumer Electronics • **Features:** On-board controller handles NAND management functions
Serial NAND	• **Target apps:** Lower Density Embedded & Consumer • **Features:** Compatible with SPI interface

NAND in the PC



NAND Process Trends

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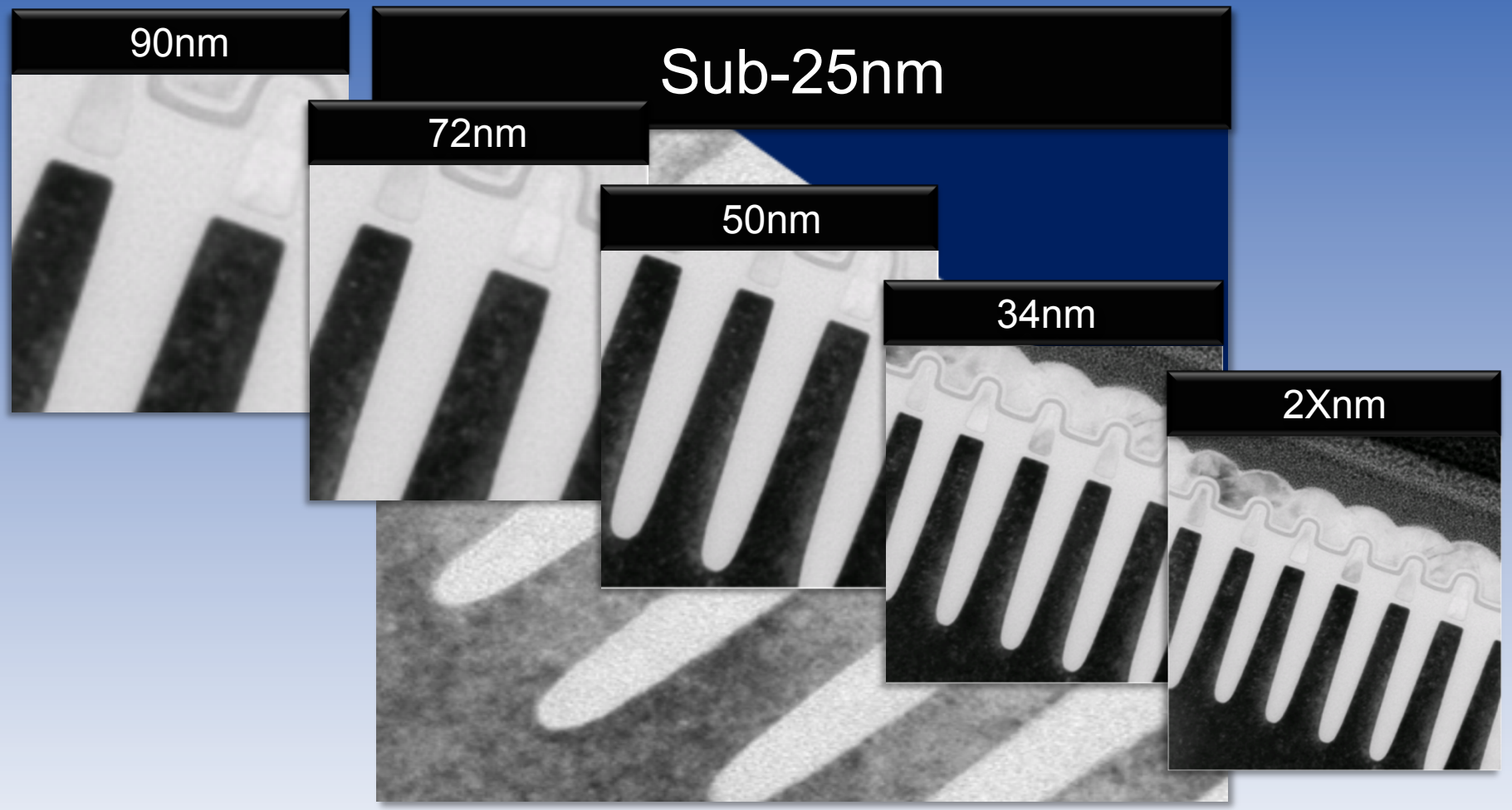
Flash Memory SUMMIT

NAND Process Technology

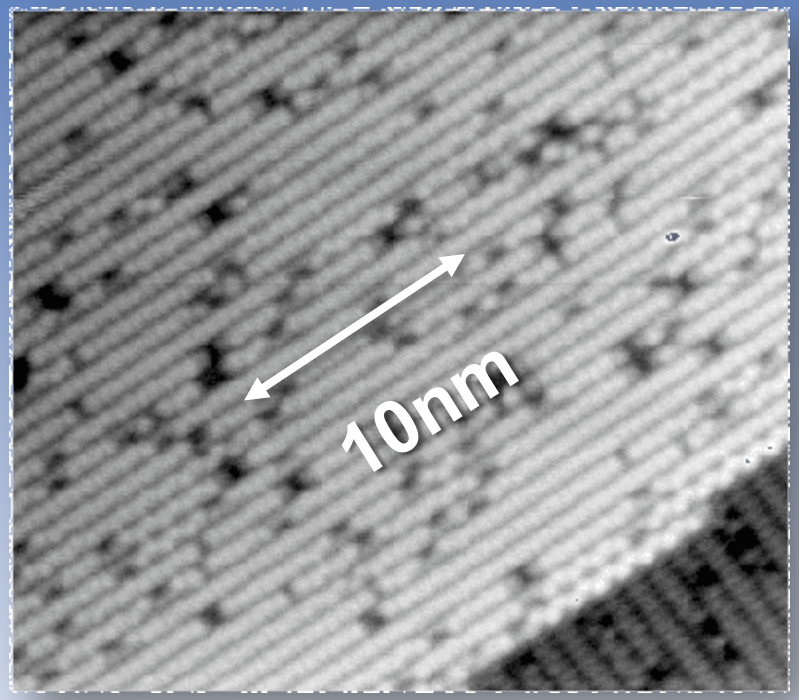


NAND Flash Cross-Sections

A Look at NAND Scaling

How long can floating gate tread water?

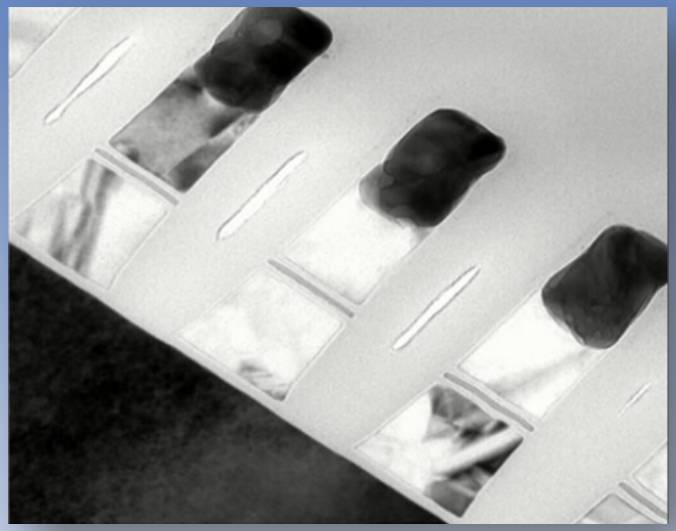
NAND Scaling: Approaching Atomic Dimensions

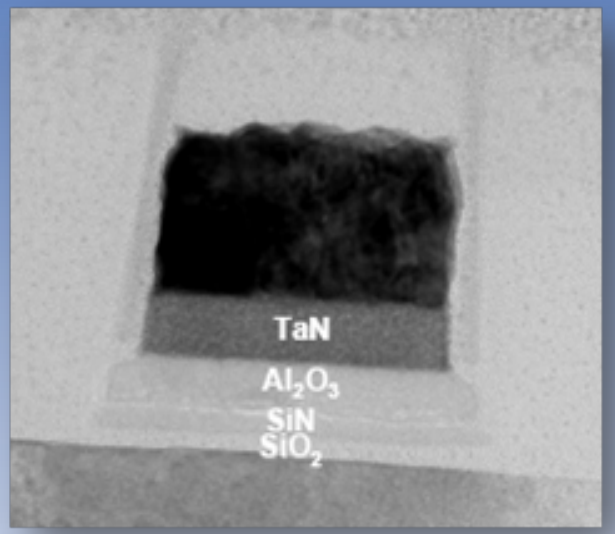


Scanning tunneling microscope image of a silicon surface showing 10nm is ~20 atoms across

- NAND production state of the art is ~34nm
- 2Xnm NAND development in progress

NAND Technology Transition





Floating Gate

Charge Trap Memory

Emerging Non-Volatile Memory Technologies

What are we going to call this conference in 5 years?

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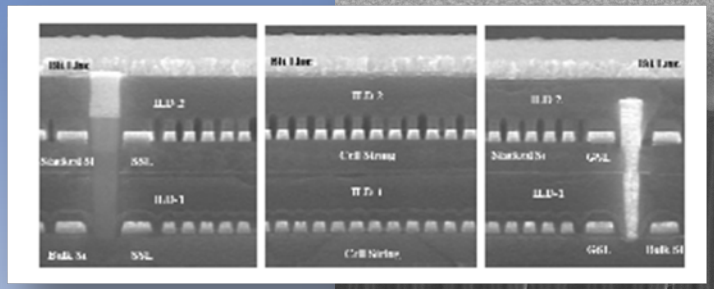
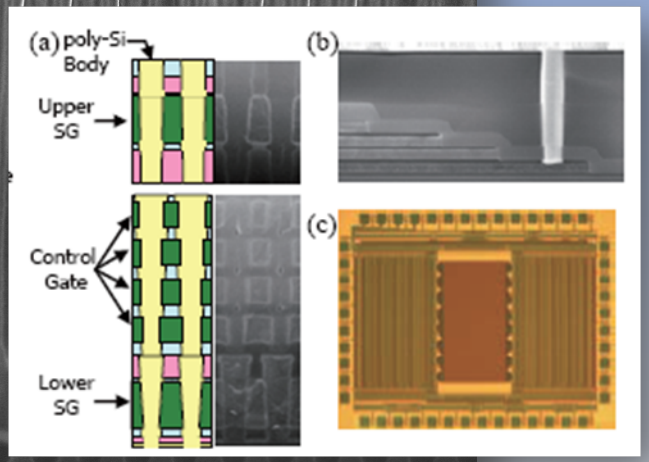
August 2009

Near-Term NAND Solution: 3D Cell

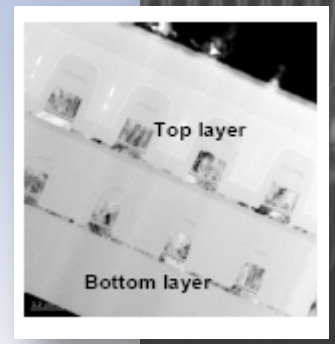
- 3D techniques already developed in DRAM
- Epitaxial TFT NAND



- Vertical NAND String



- Polysilicon TFT NAND



Emerging Non-Volatile (Non-NAND) Memory Technologies

- Ferroelectric RAM
- Magnetic RAM
- Phase Change RAM
- Resistive RAM
- Cross Point Memory

Summary

- NAND Market Continues to be Fueled by Consumer & Computing/SSD Applications
- Market Diversification: One Size Does Not Fit All
- NAND Scaling Will Become Increasingly Complex in the Coming Years
- In Five Years, We Are Still Going to Call this Conference the Flash Memory Summit