Will Phase Change Memory (PCM) Replace DRAM or NAND Flash?

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Flash Memory Summit

Phase Change Memory (PCM)

- “New memory” motivation (recognized ~1999)
- Current NVM (and DRAM) are becoming electrostatics limited
  - MOS transistor-based cell
  - Charge storage memory effect
- Starting to encounter physical scaling limitations
- Limitations manifesting first as degradation in reliability (endurance/retention)

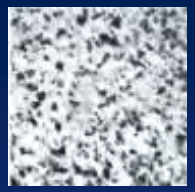
Phase Change Memory (PCM)

- Realization
  - Next-generation NVM will exploit new storage physics
  - Significant innovation will take time (history says ~10-year “gestation”)
- Response
  - PCM identified as the best candidate
  - Research efforts validated the assumptions and initiated development
  - PCM moving into production today
- We believe features of PCM will enable new usage models

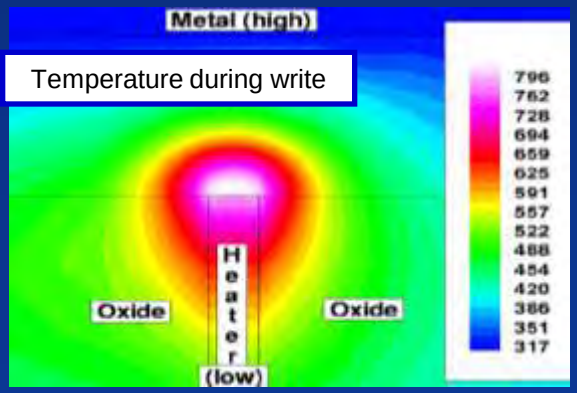
PCM Mechanisms

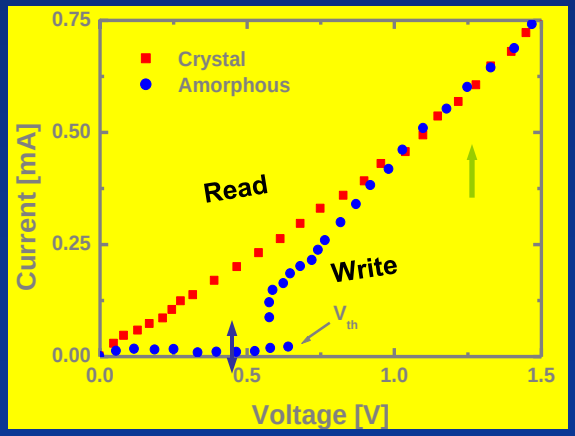
- Storage
  - GST: germanium-antimony-tellurium chalcogenide glass
  - Cell states varying from amorphous (high resistance) to crystalline (low resistance) states
- Read operation
  - Measure resistance of the GST
- Write operation
  - Heat GST via current flow (Joule effect)
  - Time at critical temperature determines cell state

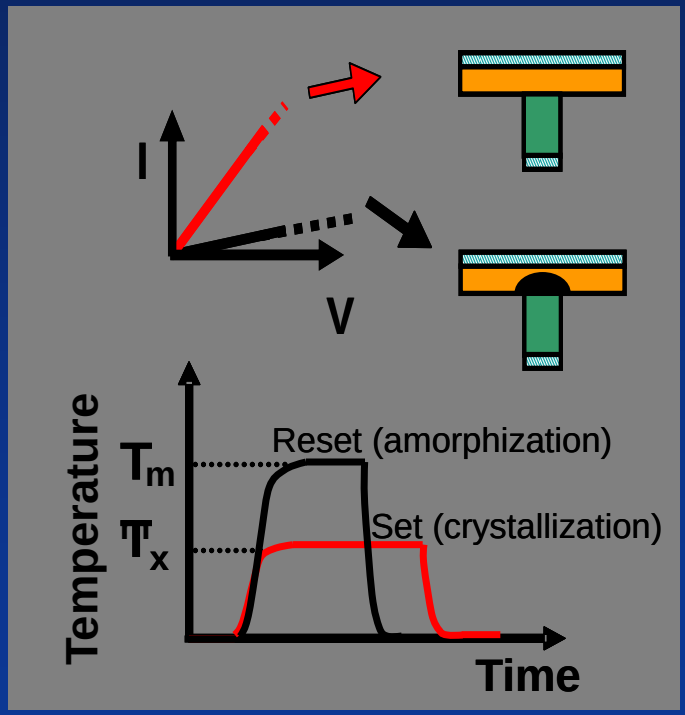
Crystalline



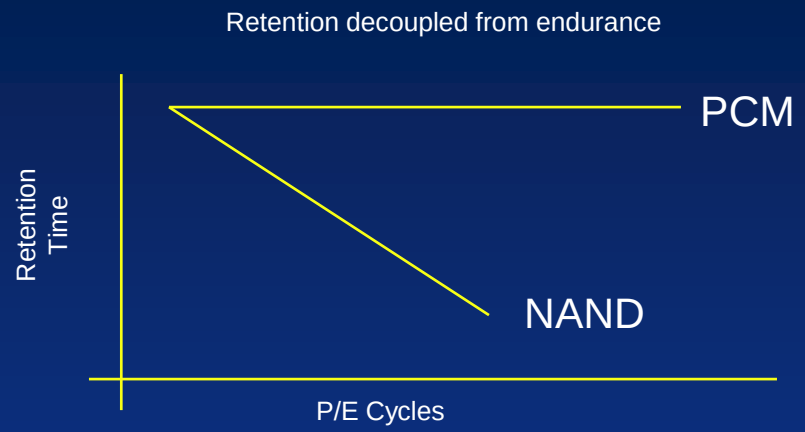
Amorphous

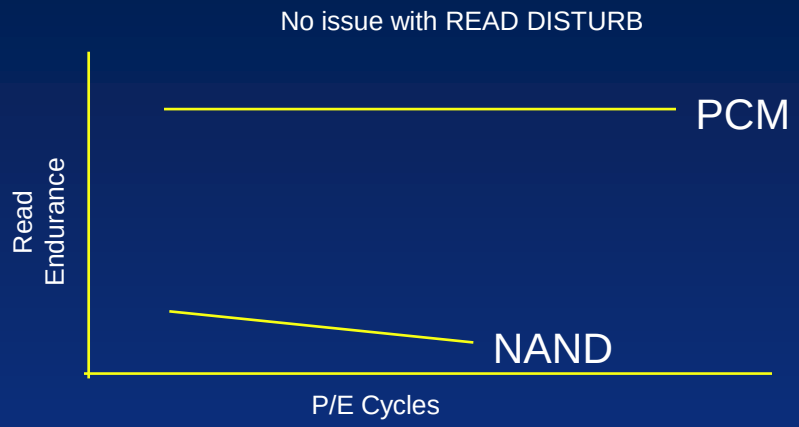






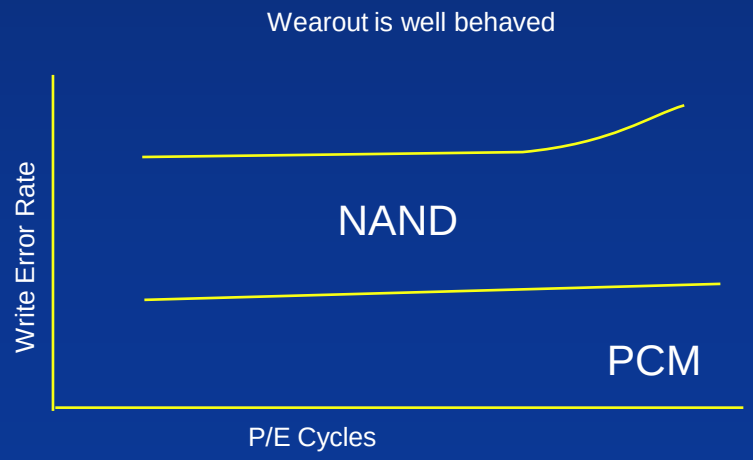
Summary of Key PCM Reliability Metrics





Result:

- Management greatly simplified; no software overhead for some apps
- Post-stress shelf life problem solved
- Endurance can be increased significantly through management of bit errors; data is stable when successfully written



PCM Key Attributes

Attribute	PCM	EEPROM	NOR	NAND	DRAM
Nonvolatile	Yes	Yes	Yes	Yes	No
Granularity	Small/Byte	Small/Byte	Large	Large	Small/Byte
Erase	No	No	Yes	Yes	No
Software	Easy	Easy	Moderate	Hard	Easy
Power	~Flash	~Flash	~Flash	~Flash	High
Write Bandwidth	1–15+ MB/s	13–30 KB/s	0.5–2 MB/s	10+ MB/s	100+ MB/s
Read Latency	50–100ns	200–200ns	70–100ns	15–50µs	20–80ns
Endurance	10^{6+}	10^{5}–10^{6}	10^{5}	10^{4-5}	Unlimited

PCM provides an new set of features combining components of NVM with DRAM

PCM Application Opportunities

Wireless systems

- Direct code execution, semi-static data and file storage
- ➢ Bit alterability allows direct-write memory

Solid state storage subsystems

- Frequently accessed pages and elements easily managed when manipulated in place
- ➢ Caching with PCM will improve performance and reliability

Computing platforms

- Taking advantage of nonvolatility to reduce the power
- ➢ PCM offers endurance and write latency that are compelling for a number of novel solutions

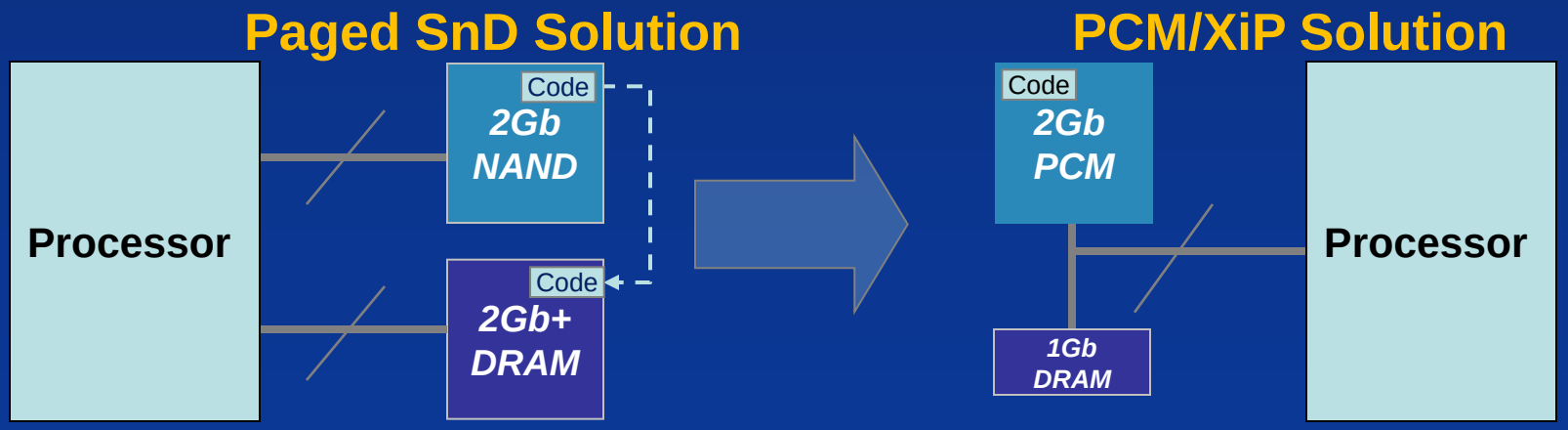
Wireless Systems: LPDDR2-PCM Architecture Evolution

Paged SnD Solution

- Code stored in NVM
- Code shadowed or paged to DRAM to execute
- Reliability is a significant concern
- Significant performance variability

PCM/XiP Solution

- Code stored in PCM
- Code executed from PCM
- No reliability concerns for code
- Limited or no performance variability



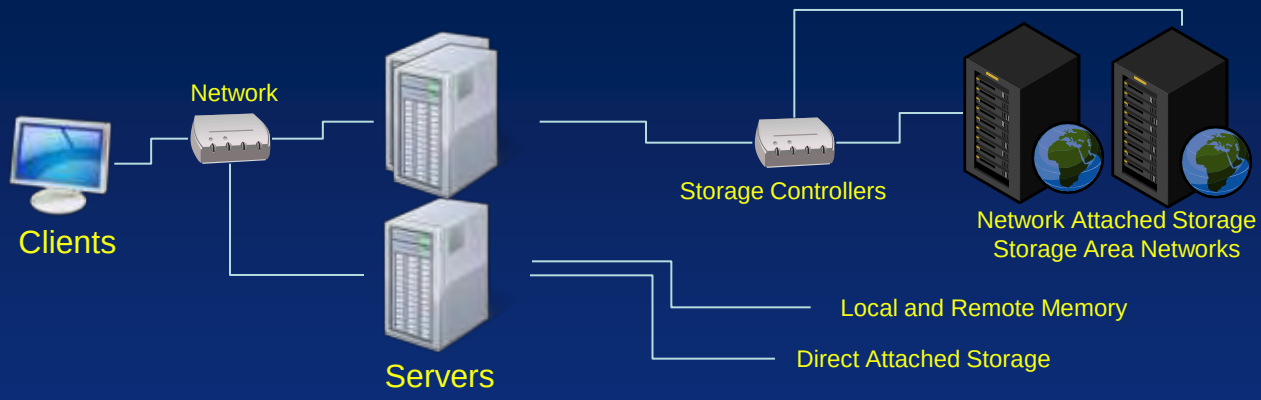
System Benefits of LPDDR2-PCM

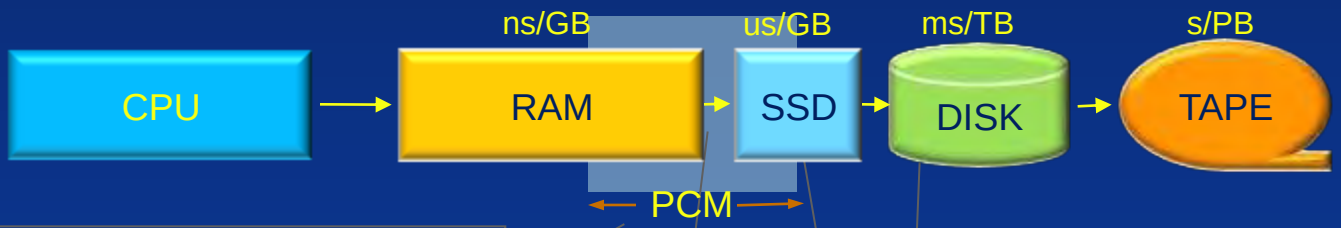
- LPDDR2-PCM system architecture saves DRAM and power
- Performance mostly equivalent to DRAM
- PCM system architecture simplifies software
- Endurance and data retention are fundamentally decoupled, improving TTM
- PCM opens new usage models
- Persistent-RAM model (NV + bit alterability) changes application operation

System Benefits of LPDDR2-PCM

- PCM file system performance close to spec (NAND/NOR lose performance due to erase)
- PCM user improvements
  - Instant on
  - Boot time
  - Application launch
  - Application concurrency
  - Power
- PCM reliability improvements
- PCM overcomes DRAM scaling and NAND reliability concerns

Memory Hierarchy in Servers and Storage Where PCM Can Fit





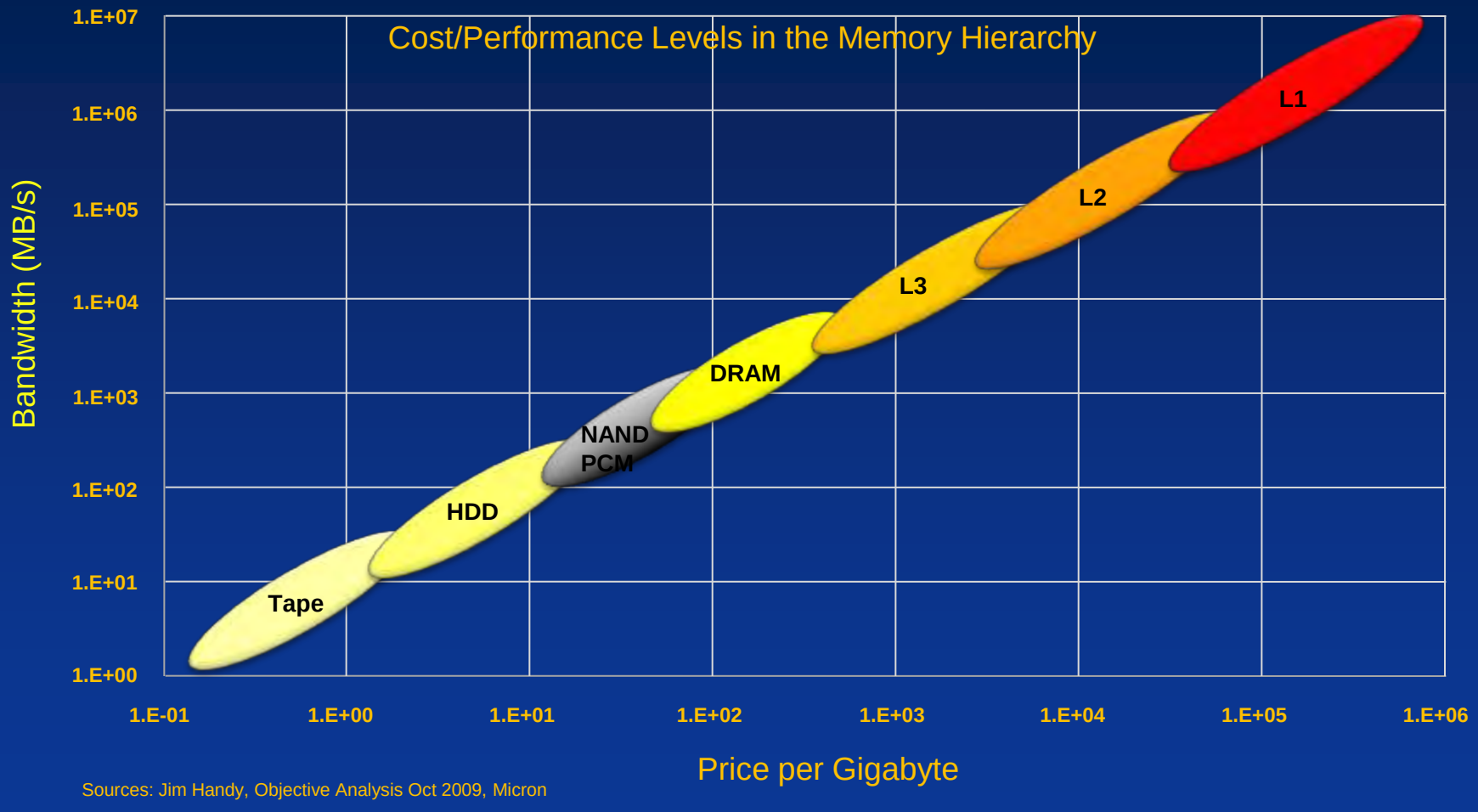
PCM replaces battery backed up RAM-cache at cabinet and rack levels

PCM improves reliability and performance in HDD/SSD

PCM for performance-high IOPs and low latency

PCM enables improved endurance for logging applications

Memory Hierarchy



Sources: Jim Handy, Objective Analysis Oct 2009, Micron

Summary

- Phase change memory (PCM) technology is demonstrating the capability to enter the broad memory market and to become a mainstream memory
- PCM provides a new set of features for novel applications, combining components of NVM and DRAM, while at the same time being a sustaining and a disruptive technology
- Our prediction is that with PCM achieving technology maturity, having a scaling perspective, and having a broad application range, it will play a key role in the memory market for the next decade