Computer Memory and the Future of NVM

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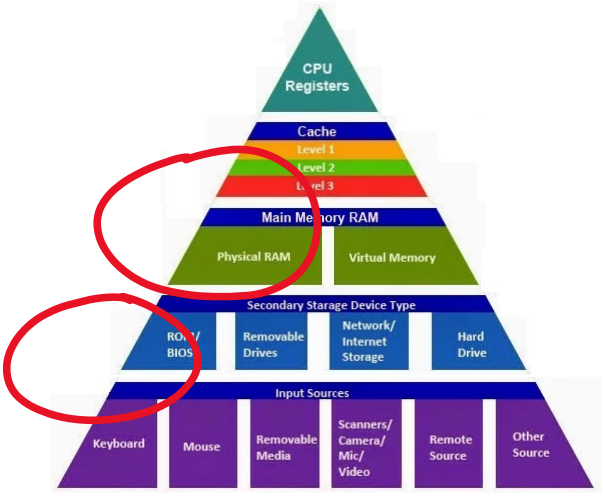
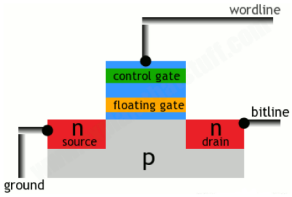
Computer Memory Hierarchy



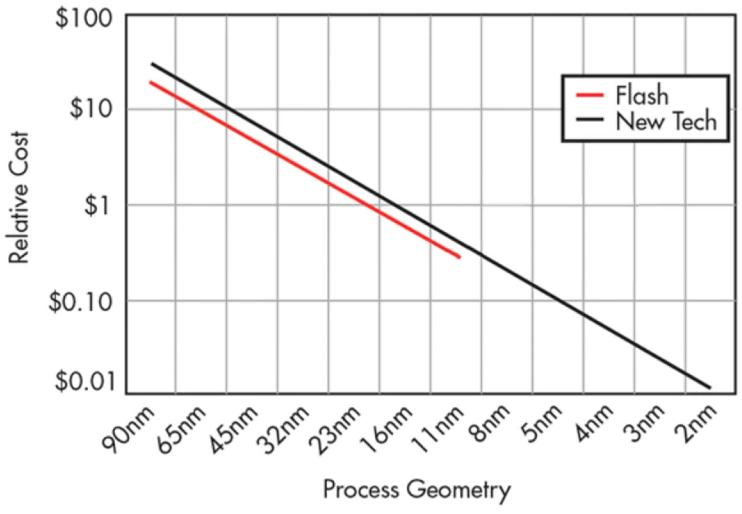
Memory Market Overview

- **Volatile:**
  - (1964) – SRAM is used for limited, fast working memory – expensive and power-hungry.
  - (1967) – DRAM is used for high volumes of working memory – complex and slower than SRAM.
- **Non-Volatile:**
  - (1956) – PROM is used for storage of permanent data, usually low-level programs – data cannot be erased or changed.
  - (1972) – EEPROM can be erased and re-programmed. Still utilized today in modem, video cards and many electronic gadgets.
  - **(1981) – Flash memory is invented!** – A *universal* non-volatile memory type that is used in most computers as a storage medium.
    - Utilizes floating gate transistors.
    - MUCH, much faster.
    - Ability to clear and rewrite chunks of data.

"the number of transistors in a dense integrated circuit doubles about every two years"

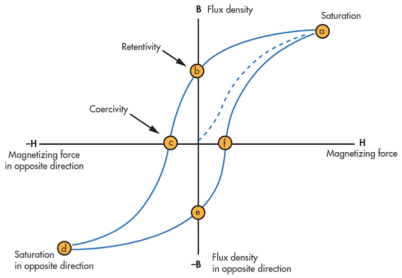


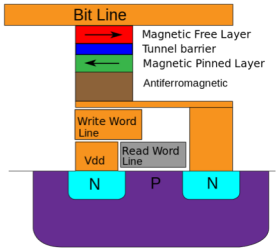
What's the problem?



Emerging Developments in NVM

- Ferroelectric Memory (FRAM):
  - Uses materials that exhibit magnetic-like properties:
    - Low power consumption – 1.5v compared to 10-14v for Flash.
    - Performs well across a wide spectrum of temperatures.
    - SPEED – write time is less than 50ns. 1000x faster than Flash/EEPROM

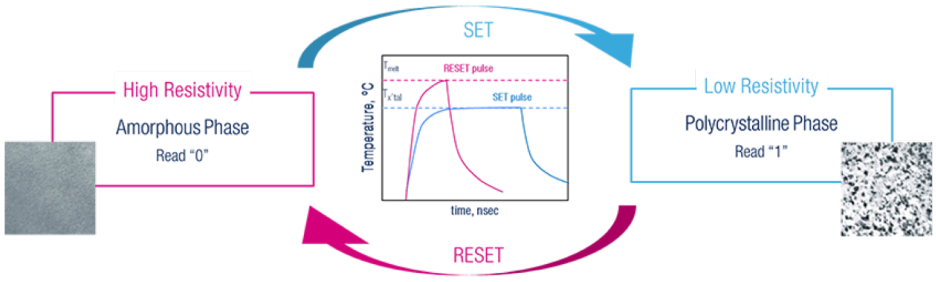




- Magnetoresistive Memory (MRAM):
  - Uses a magnetic layer to store a bit.
    - Denser than SRAM which results in a net less expensive chip.
    - Simpler to access than Flash memory and DRAM.
    - Faster and utilizes less power than other NVM.

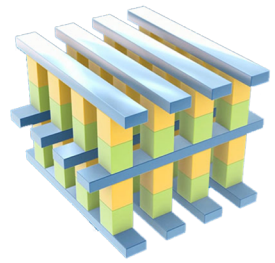
Emerging Developments in NVM

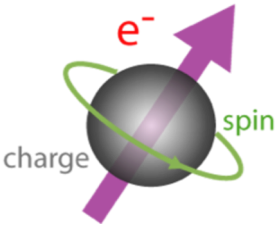
- Phase-Change Memory (PCM)
  - PCM works by changing the phase of a special kind of glass (Chalcogenide glass) within the bit cell.
    - Faster than Flash – significantly better read and write times. No erase cycle required.
    - Lower power consumption.
    - Not susceptible to scaling difficulties.
    - Not yet commercially viable.



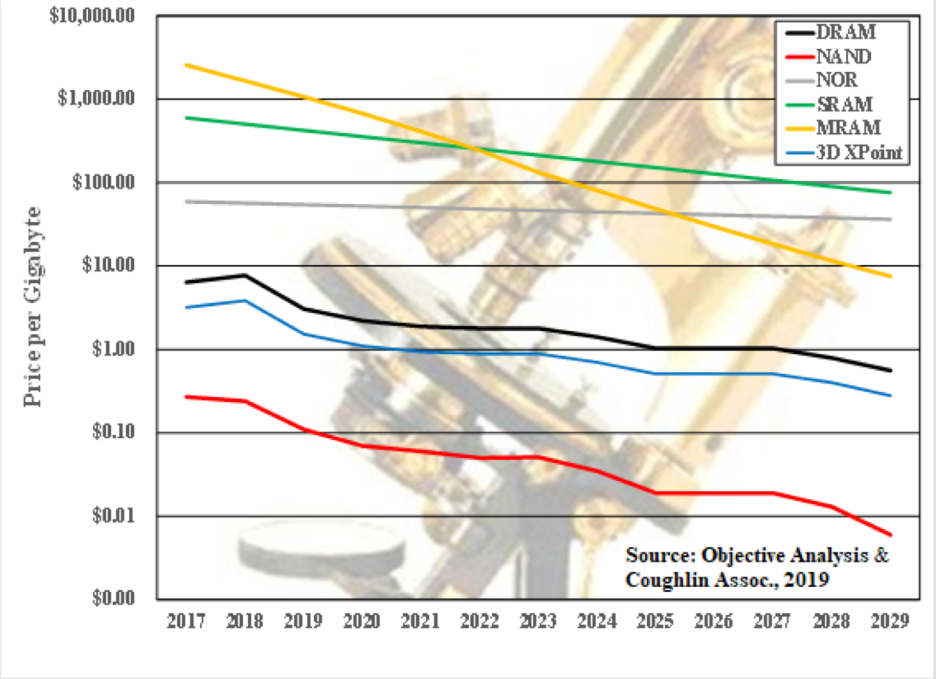
Future of NVM

- 3-D XPoint:
  - Transistor-less with memory cells at the intersection of a massive amount of perpendicular wires.
    - A type of PCM.
    - Faster than NAND with greater endurance.
    - Twice as dense as DRAM.
- Spin Transfer Torque RAM (STT-RAM):
  - Uses electron spins to create a current that changes the magnetic orientation of a bit stored in an Magnetic Tunnel Junction (MTJ).
    - The BEST of all worlds!
    - Higher density, better scalability than CMOS technology.
    - Comparable performance to SRAM.
    - Low power consumption.
- Goals for the future:
  - NVM memory becomes embedded.
  - Reduce size below Flash's scalability limit.
  - Replace levels 2 and 3 cache with NVM.
  - Reduce cost of emerging memory to increase competitiveness.





	SRAM	DRAM	Flash (NOR)	Flash (NAND)	FRAM	MRAM	PCM	STT-RAM
Non-Volatile	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Cell size (F^2)	50-120	6-10	10	5	15-34	16-40	6-12	6-20
Read time (ns)	1-100	30	10	50	20-80	3-20	20-50	2-20
Write/Erase time (ns)	1-100	50 / 50	10 ms / 100 ms	1 ms / 0.1 ms	50 / 50	3-20	50 / 120	2-20
Endurance	10^{56}	10^{16}	10^{5}	10^{6}	10^{12} 1	$> 10^{25}$	10^{10} 1	$> 10^{25}$
Voltage required	No	2 V	6-8 V	16-20 V	2-3 V	3 V	1.5-3.5 V	<1.5 V
Cost	$$$$	$$$	$	$	$$$	$$$	$$$	?



Sources

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