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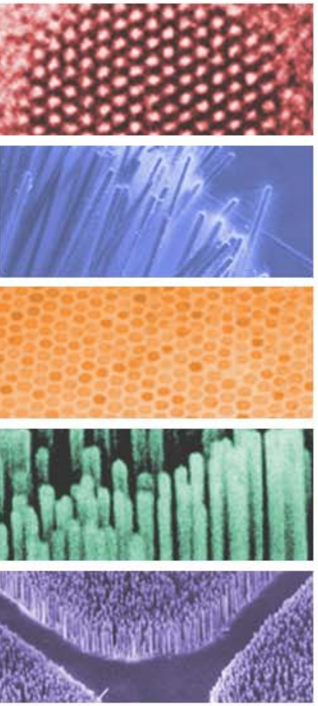
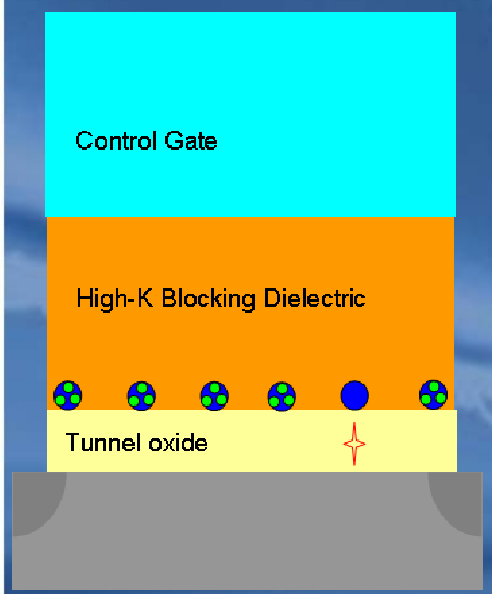
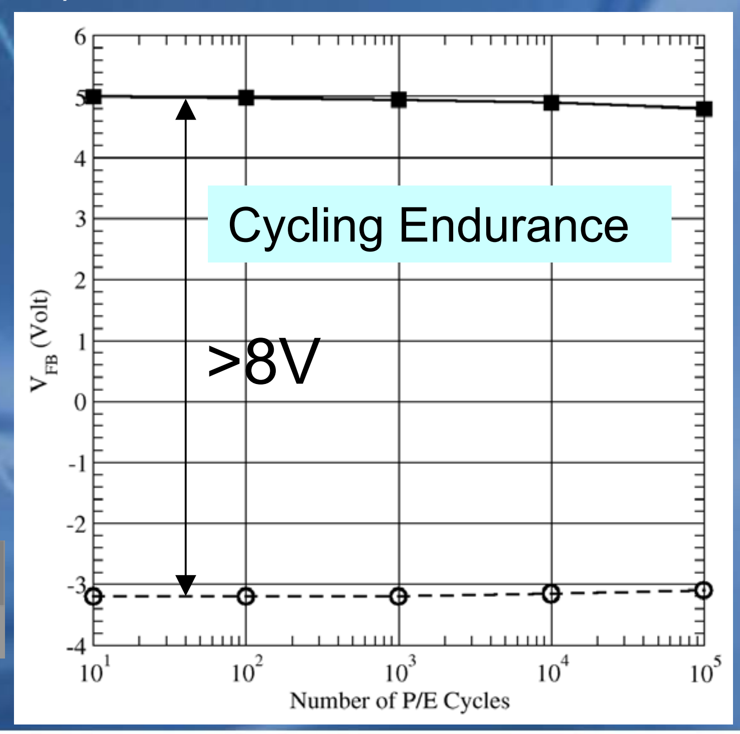
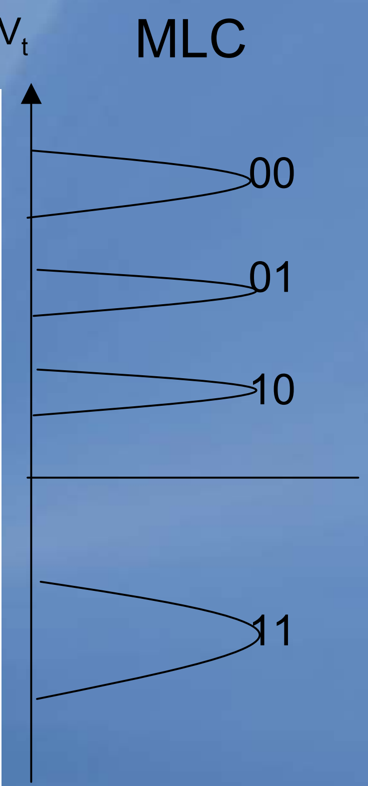
Colloidal Metal Nanocrystals for Multilevel Cell NAND Flash Memory with 100,000 Cycling Endurance

Jian Chen
Nanosys, Inc., Palo Alto, CA



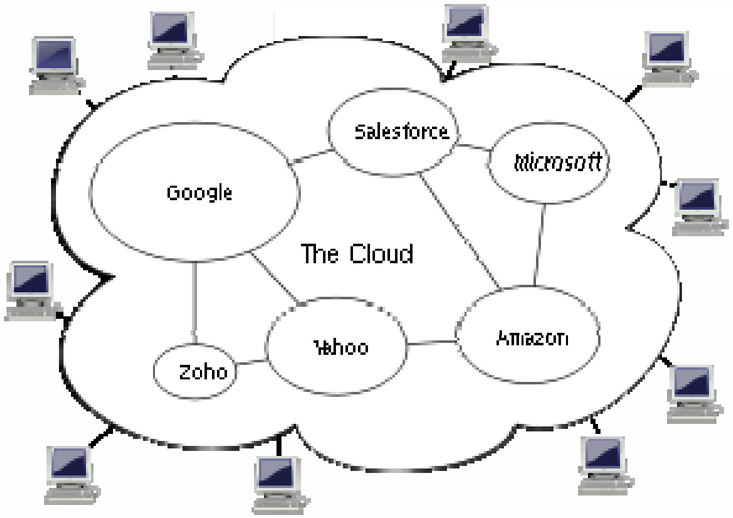


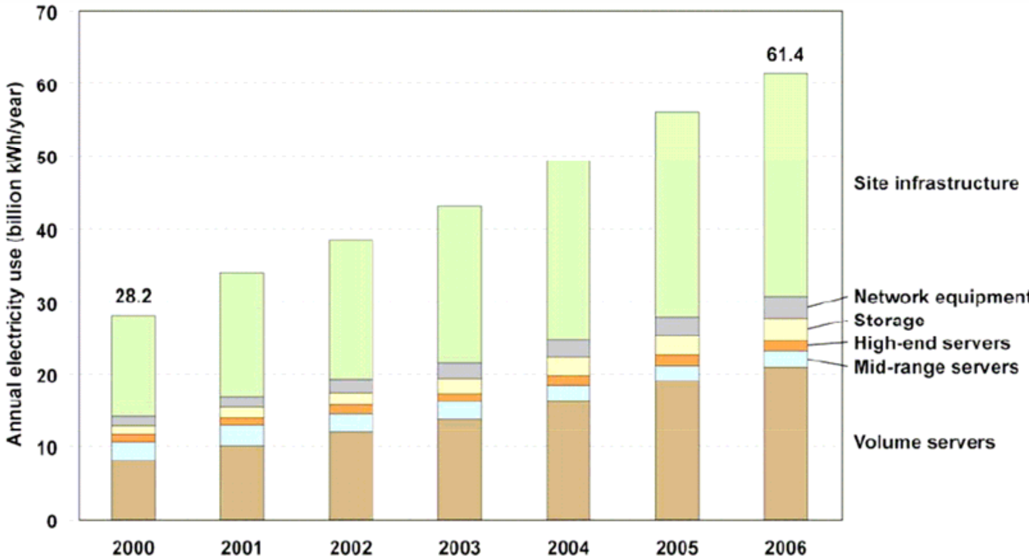




NCCAVS-TUG Meeting, San Jose, 10/14/2009

Electricity Consumption in Data Centers





- In 2006, US data centers consume 61 billion kWh electricity, 1.5% of total US demand
- By 2011, demand will double to more than 100 billion kWh

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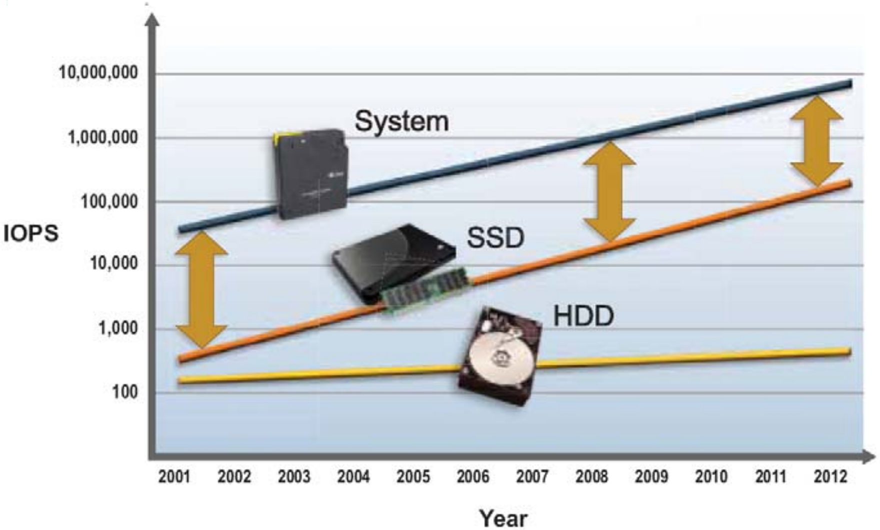
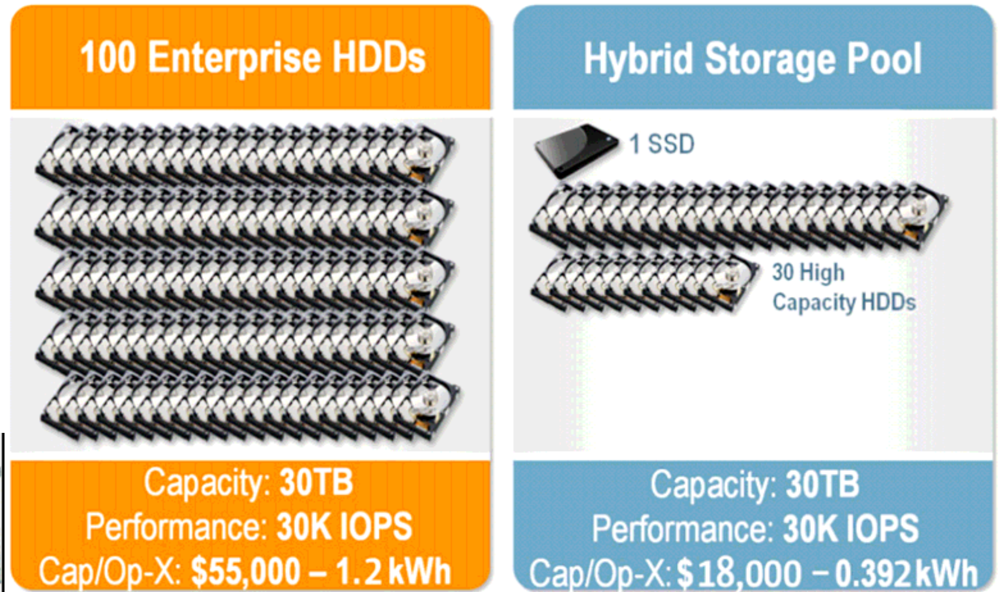
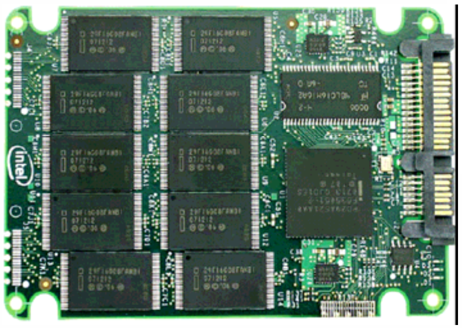
SSDs Entering Enterprise Data Storage

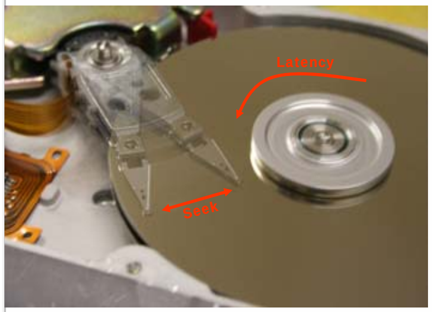
Much Lower Electricity Consumption





https://www.sun.com/offers/details/ssd_sun_servers.html





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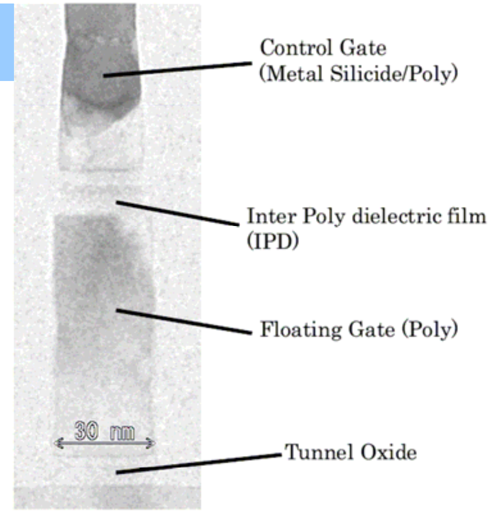
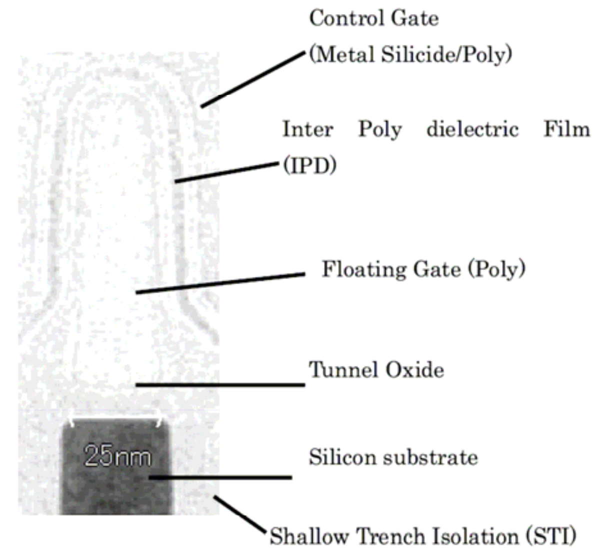
Progression of Poly-FG NAND Flash Technology

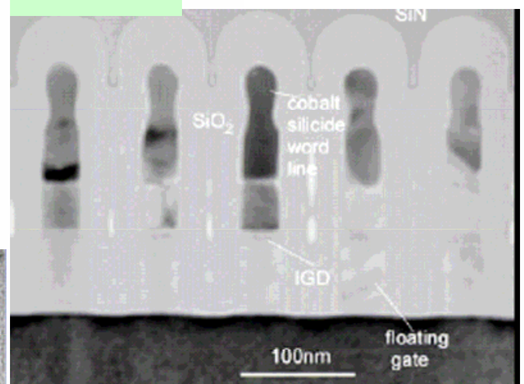
2xnm





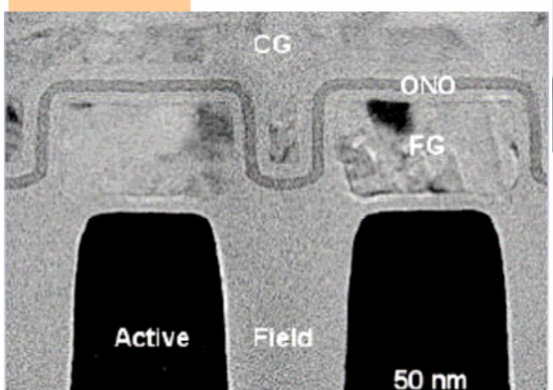
T. Kamigaichi, et. al., IEDM 2008.

4xnm

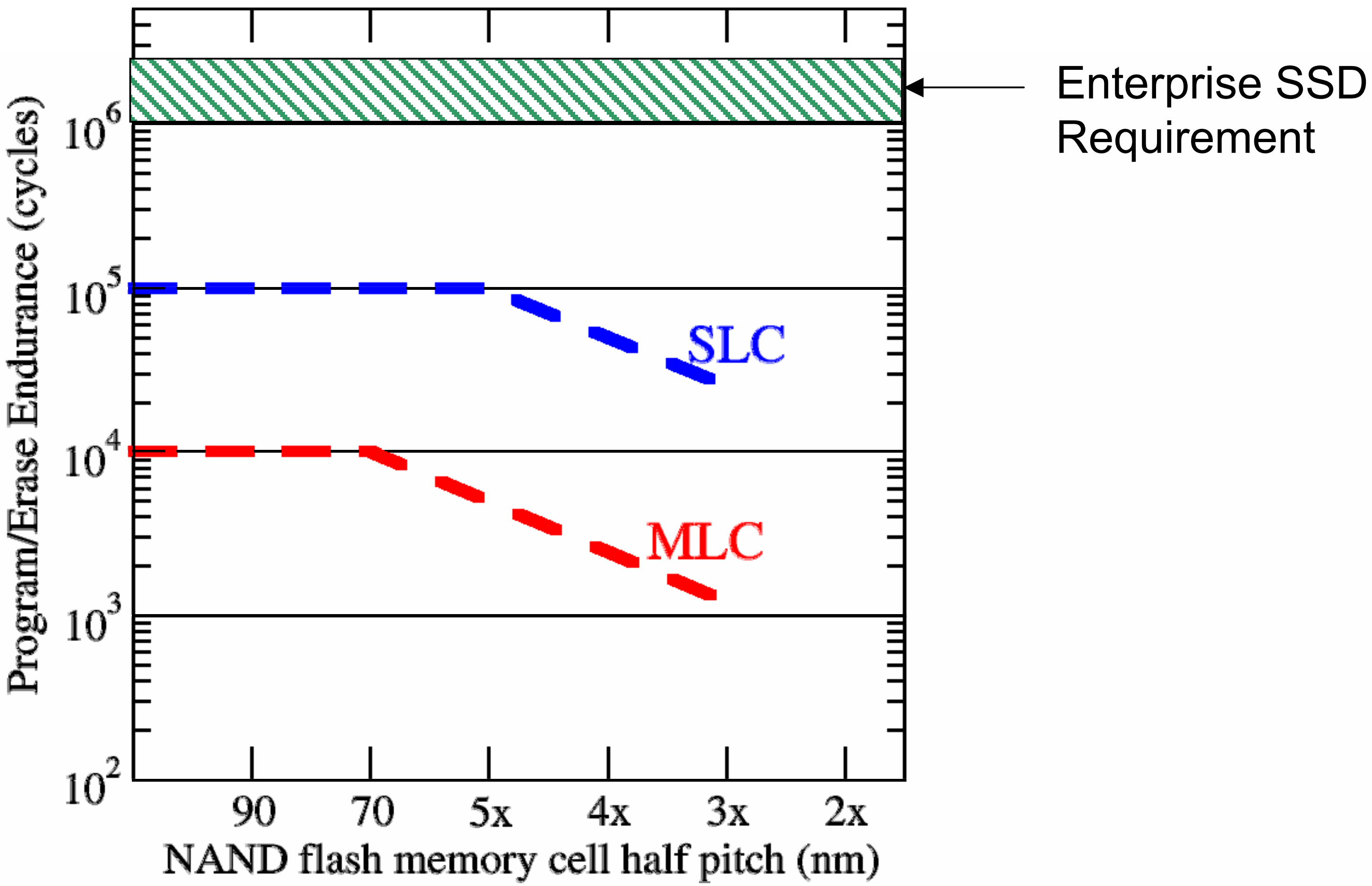


A. Fazio, Stanford, 11/2008

90nm

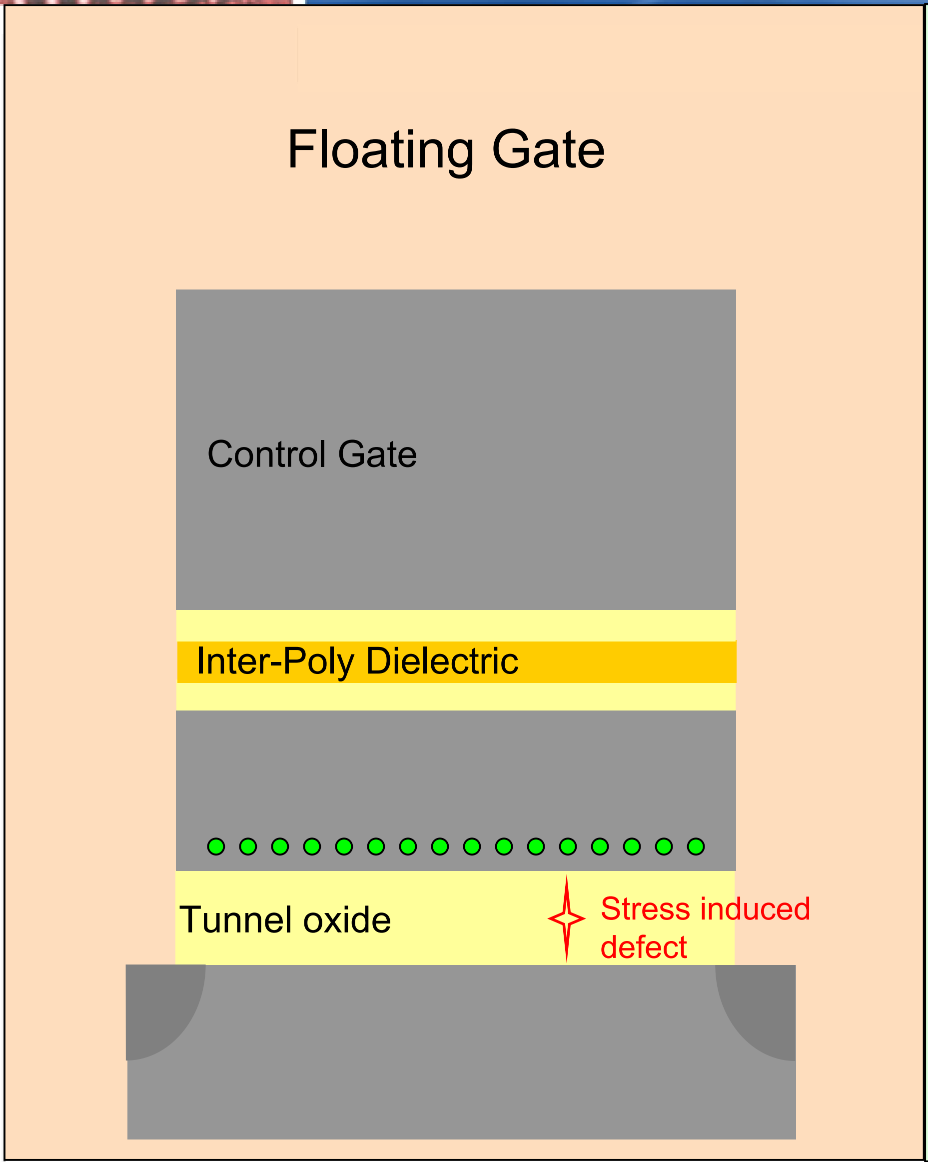


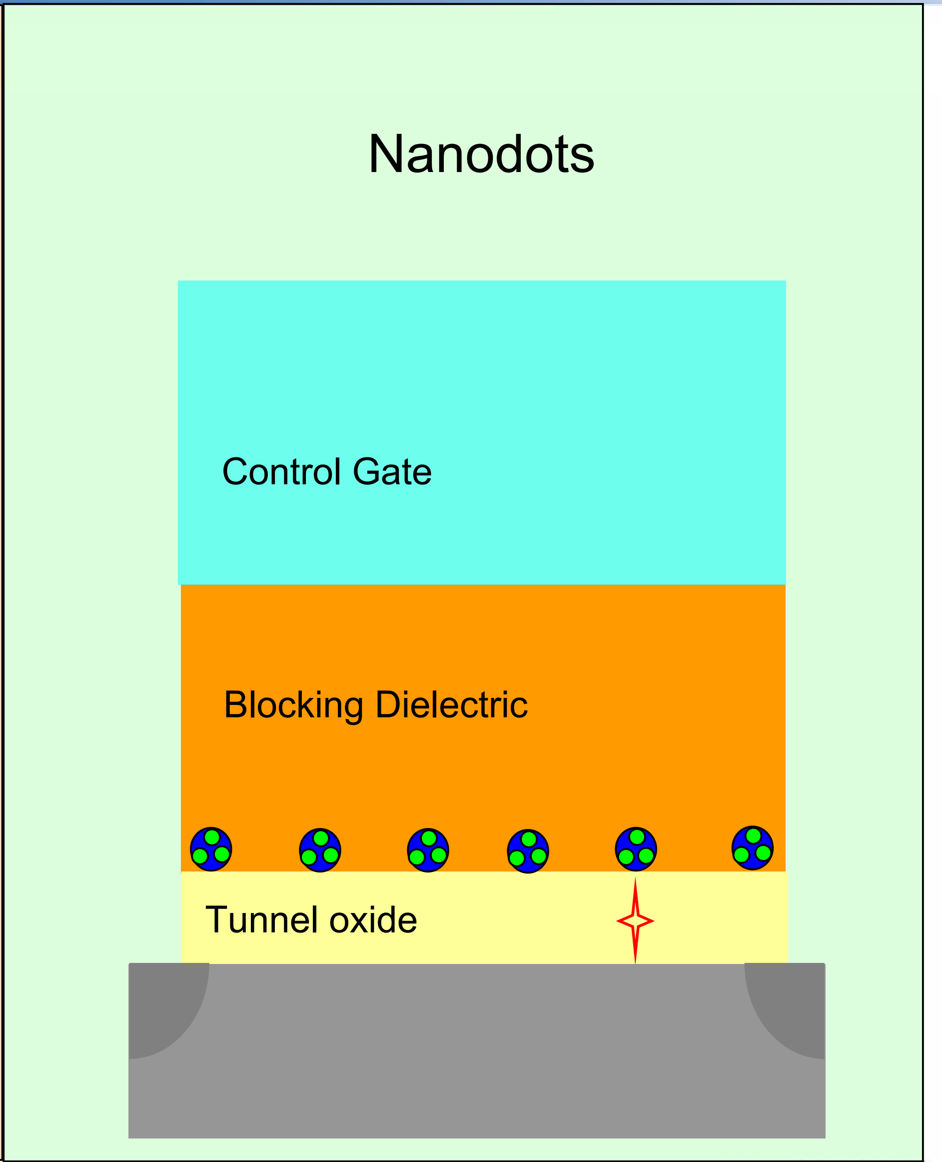
Degradation of Program/Erase Endurance at Smaller Technology Nodes



- SLC NAND with endurance >~100,000 can meet the demand of enterprise SSD with the help from controllers (wear leveling, ECC, etc).

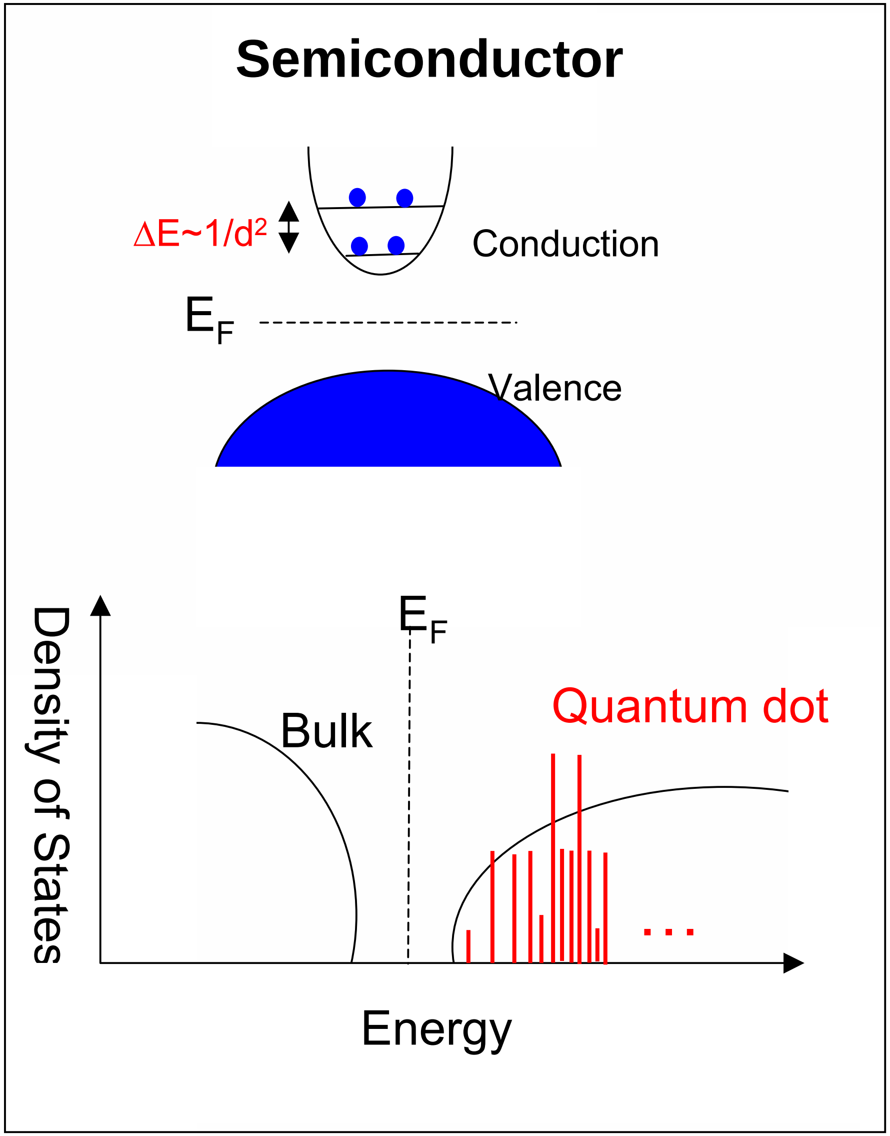
Discrete Charge Storage in Nanodots Offers Better P/E Cycling Endurance

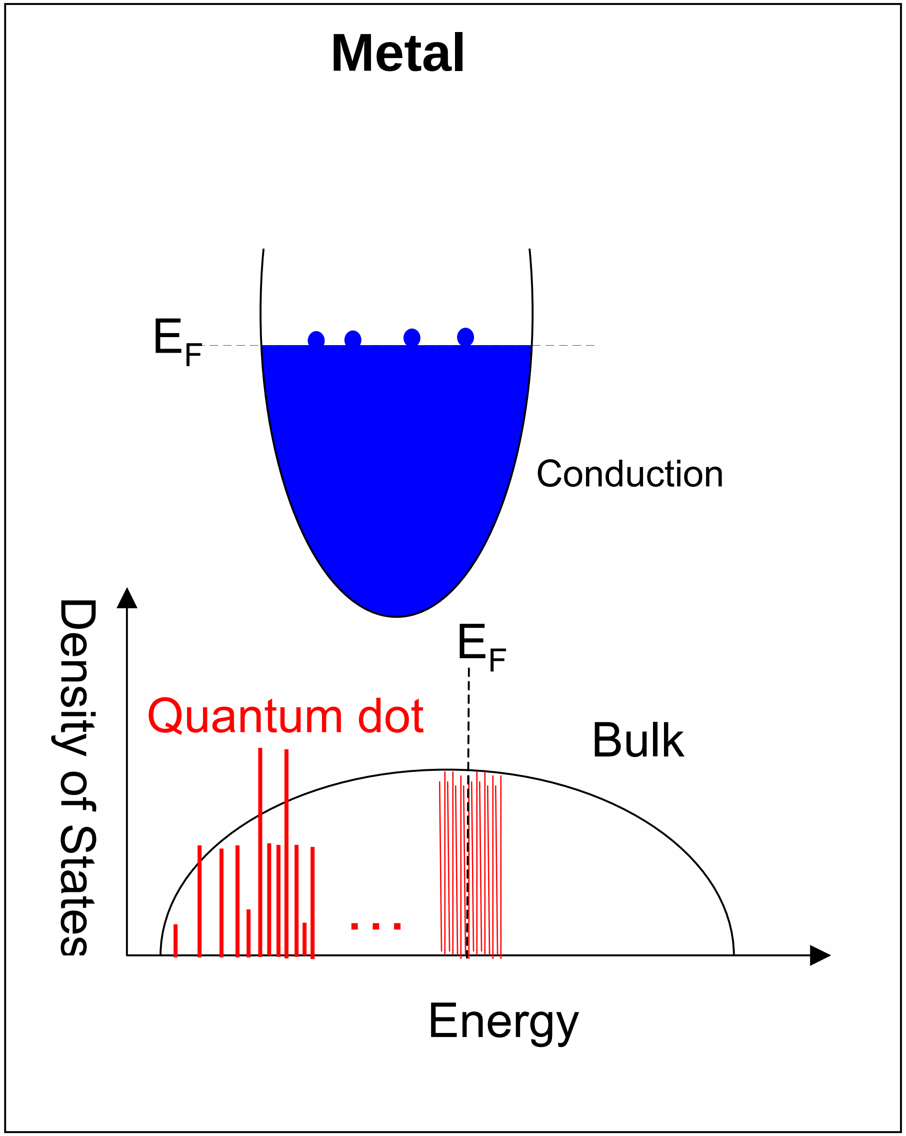




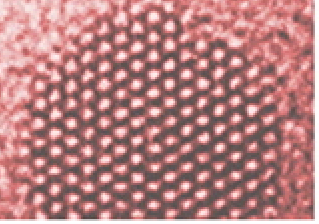
Why Metal Nanodots?

Much Higher DOS Than Semiconductor Dots





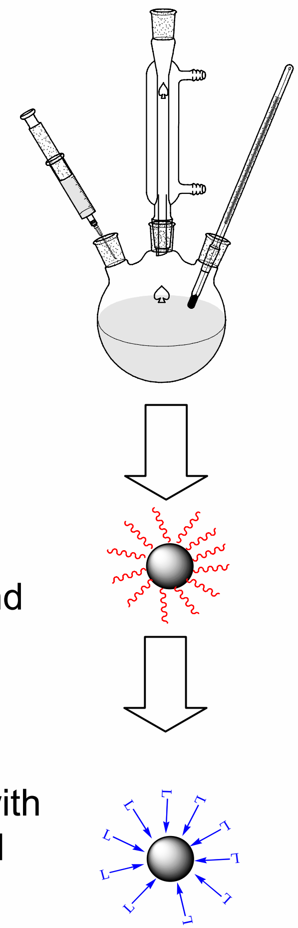
Highly Uniform and Tunable Nanodots Synthesized with Solution Chemistry

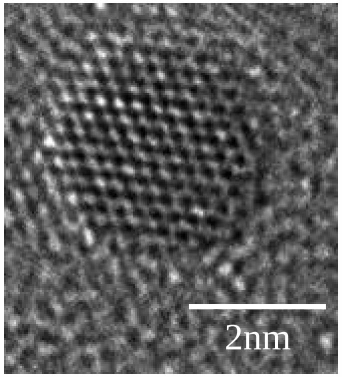


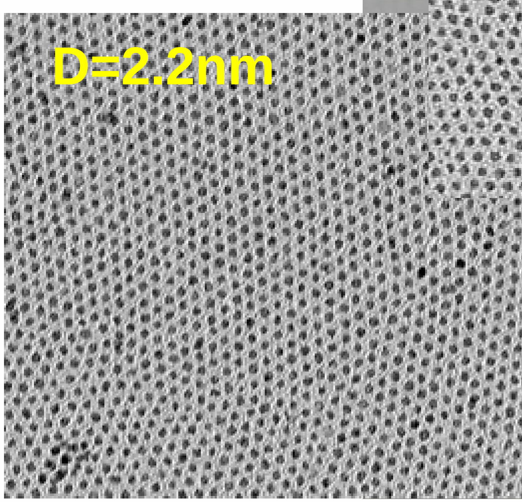
Dot Synthesis

Dot with Growth Ligand

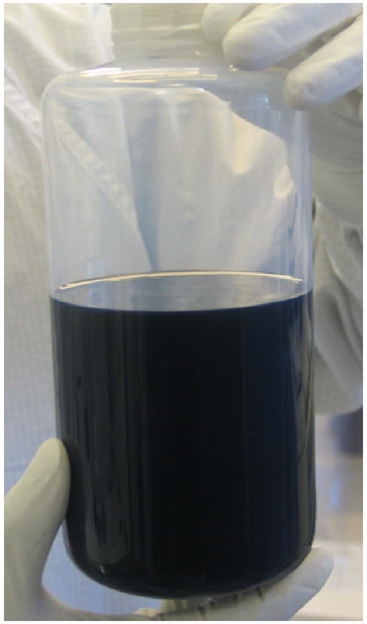
Exchanged with new Ligand







Nanodot Deposition using Spin-Coating



TEL Spin Coater Track

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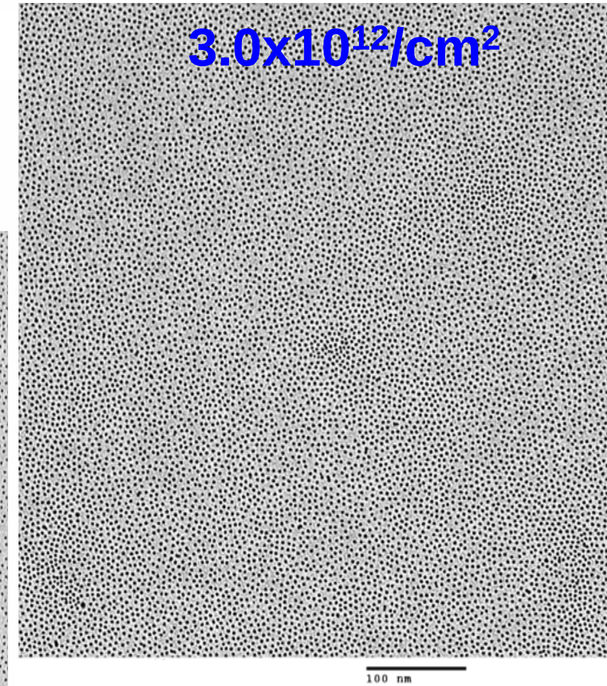
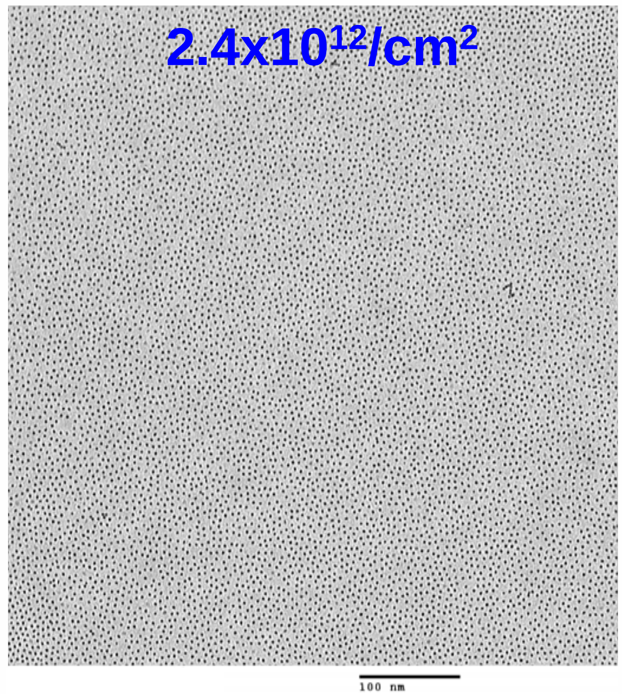
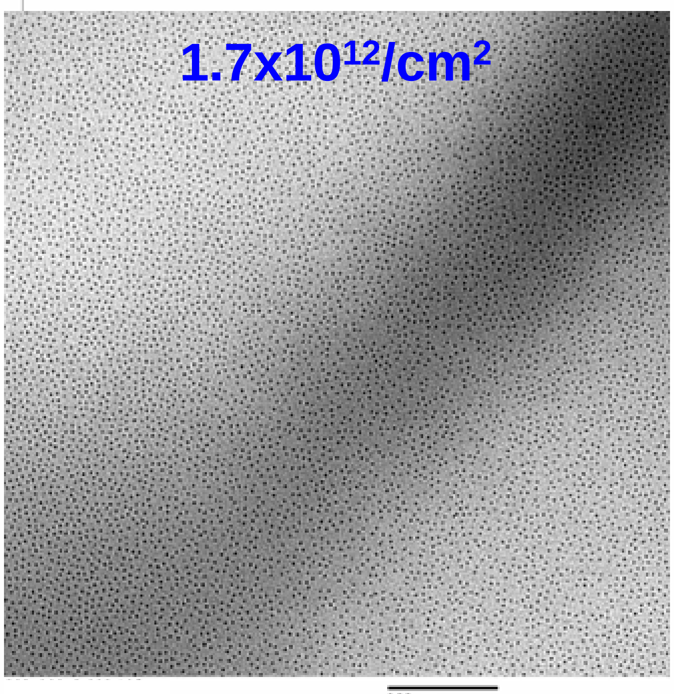
Adjustable Dot Density



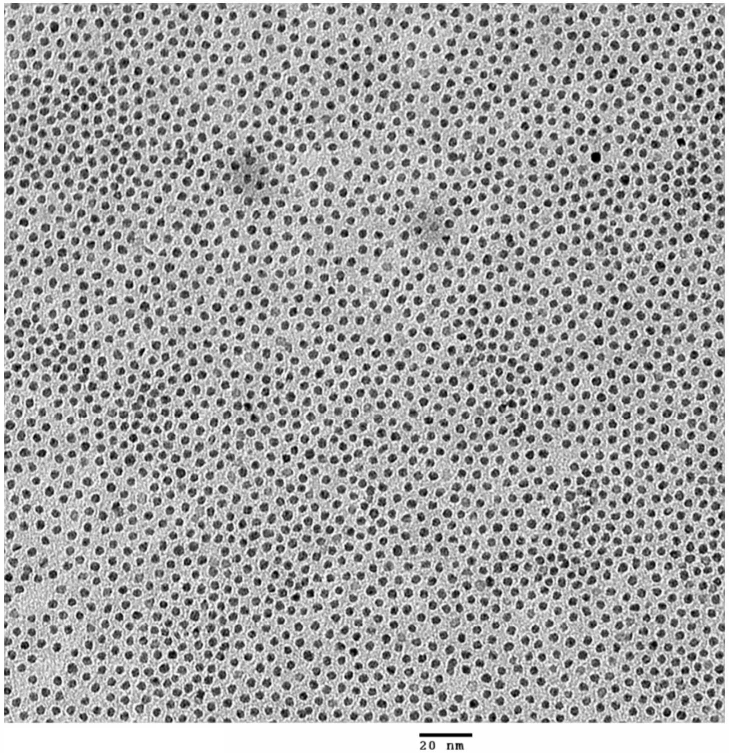




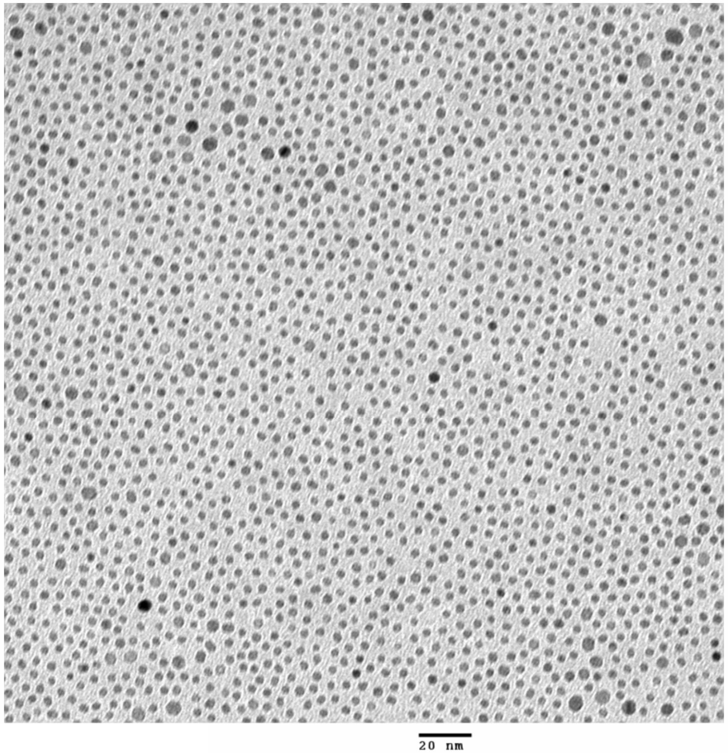
- By varying nanodot concentration and spin-coating conditions (e.g., wafer rotation speed), different nanodot densities on wafers can be obtained

Compatibility with CMOS Processing

As Deposited

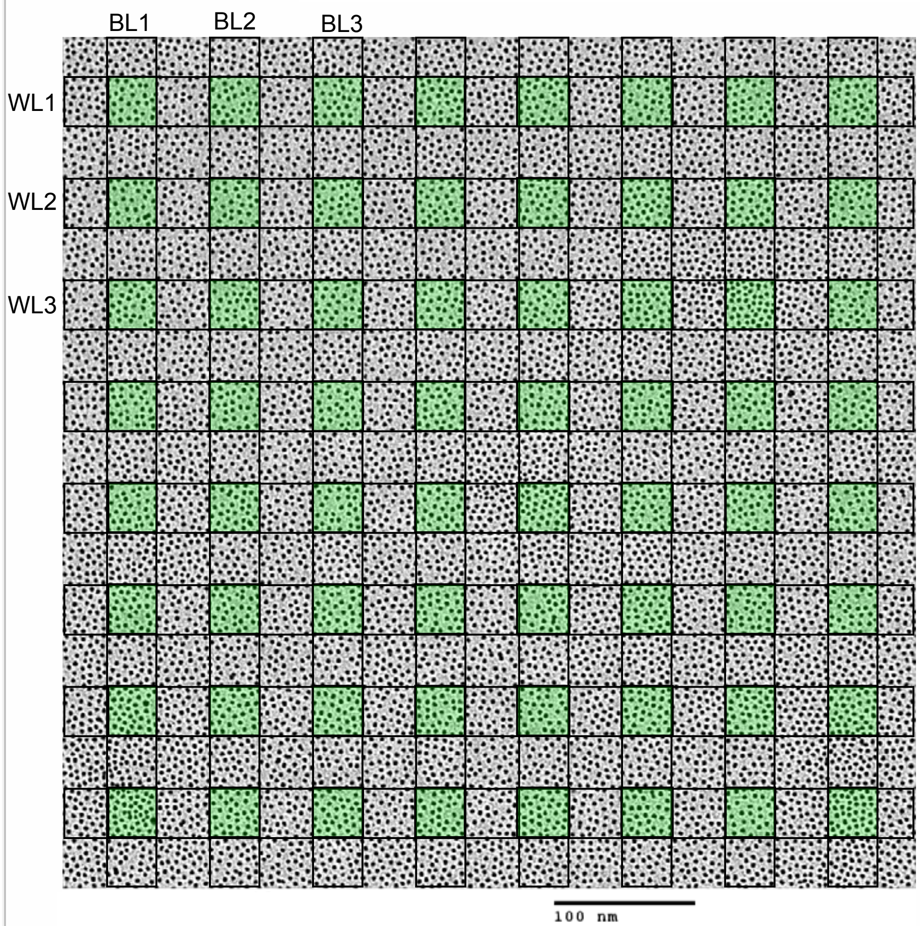


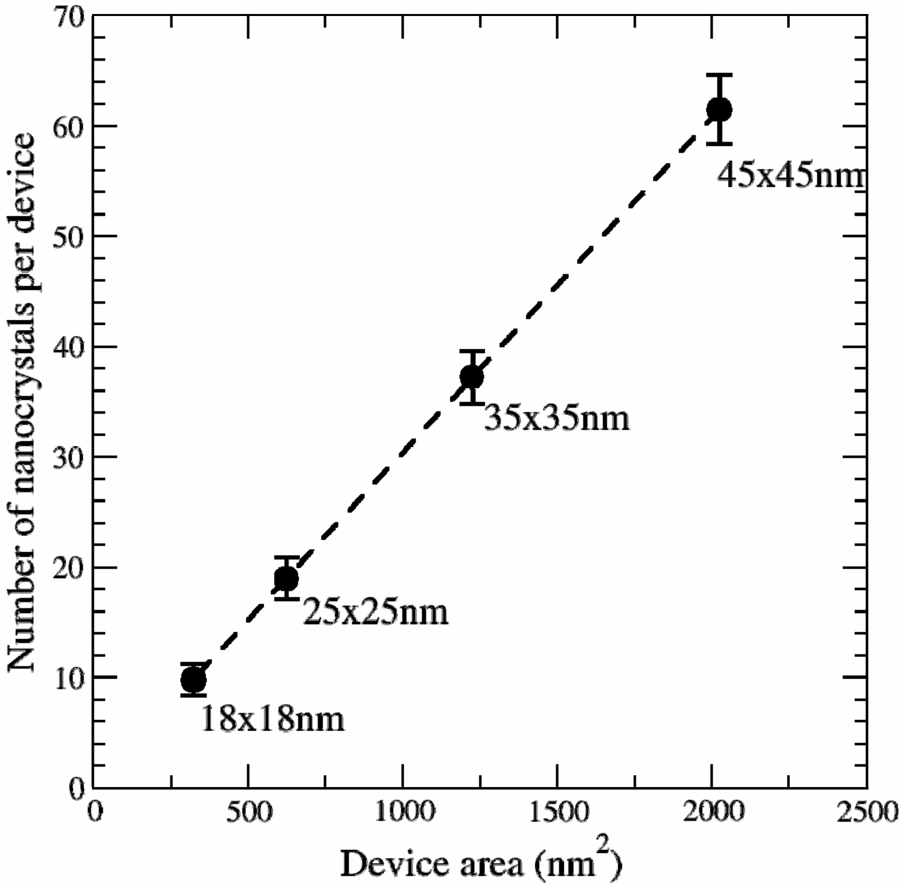
Post 950C RTP



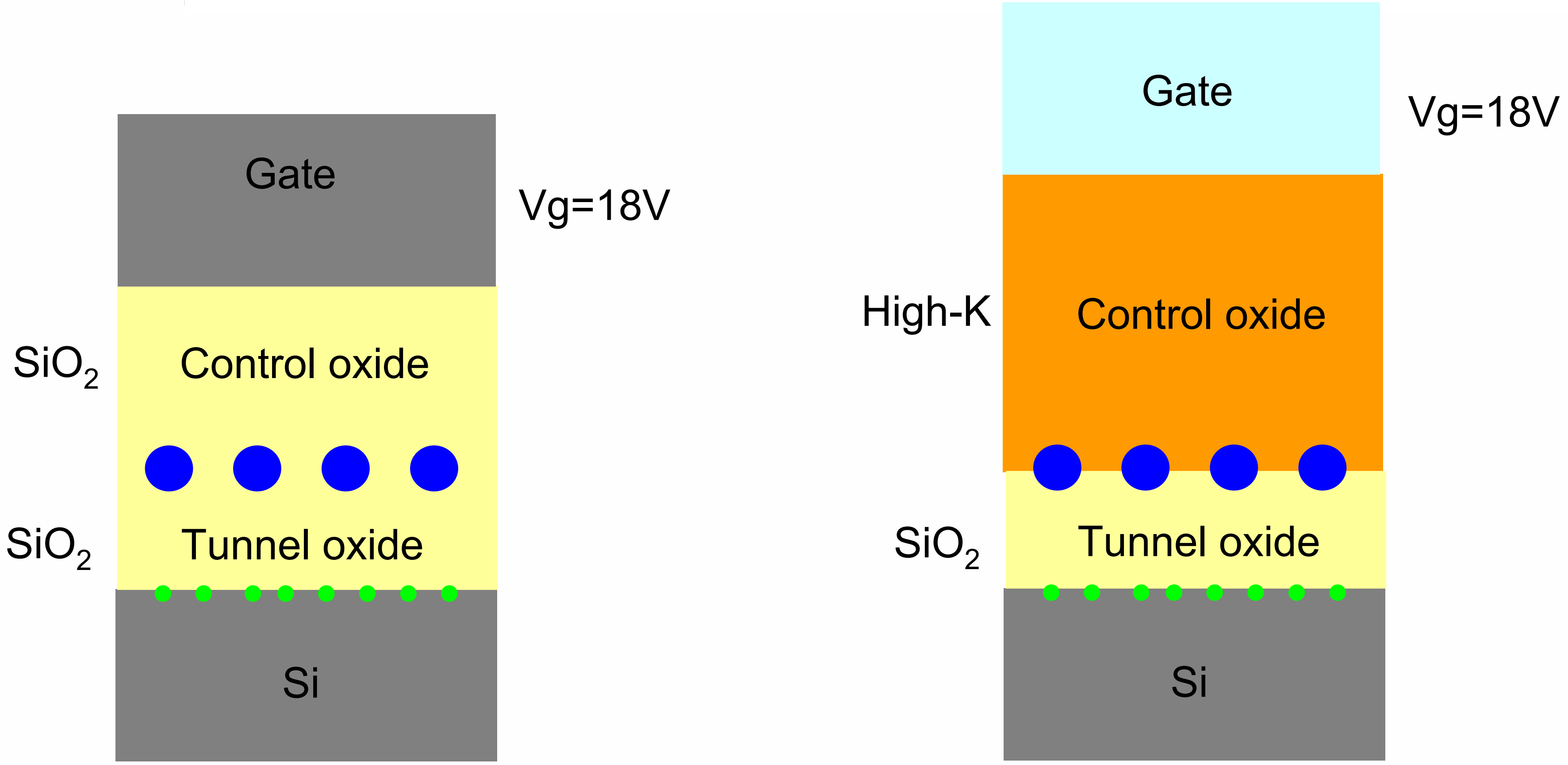
- High density of ~3×10^{12}dots/cm^2 obtained post 950C rapid thermal processing (source/drain implant activation)

Highly Uniform Monolayer of Nanodots

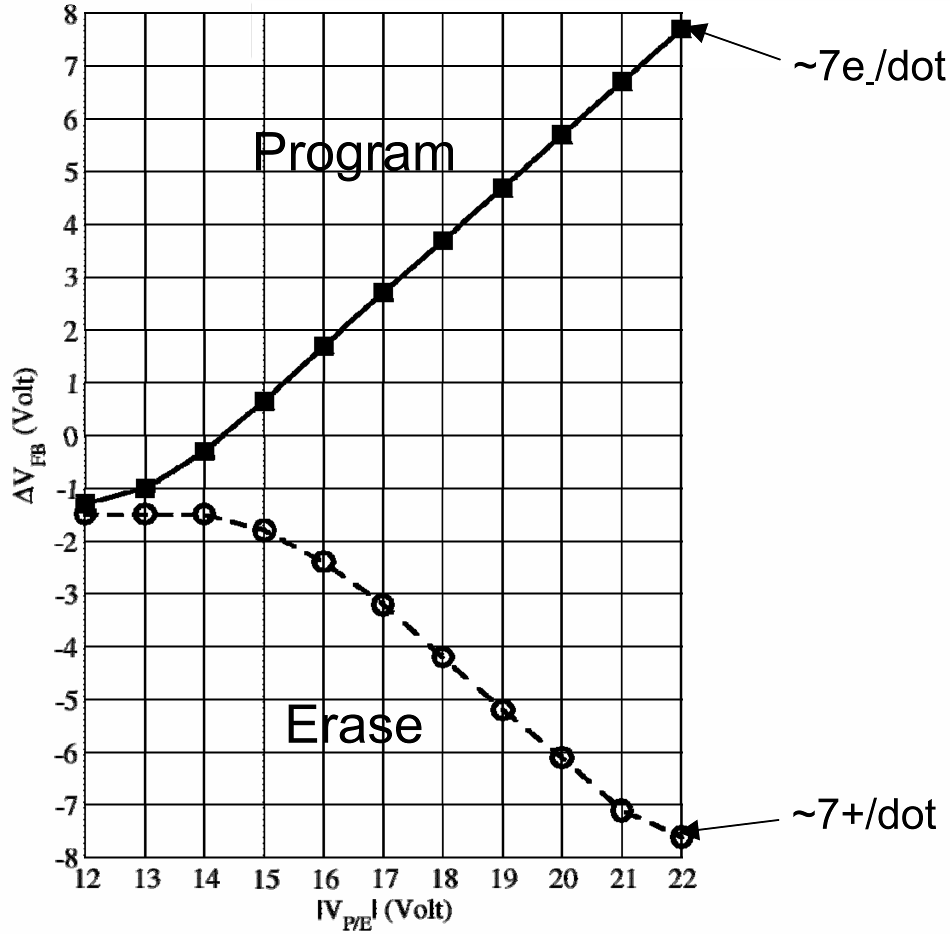


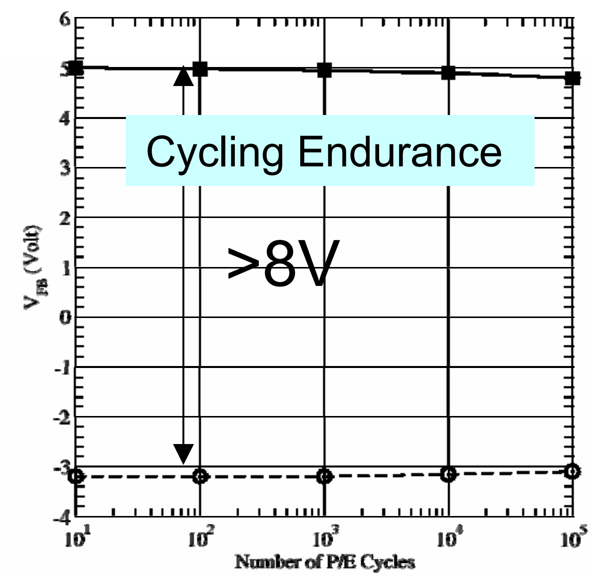


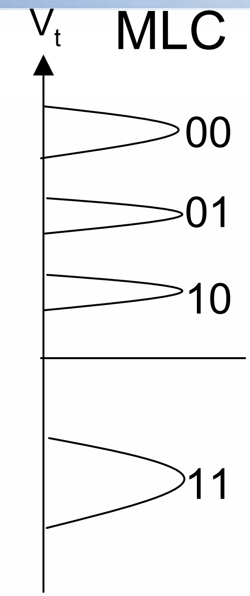
High-K Control Dielectric Increases Charge Storage Density for Nanodots

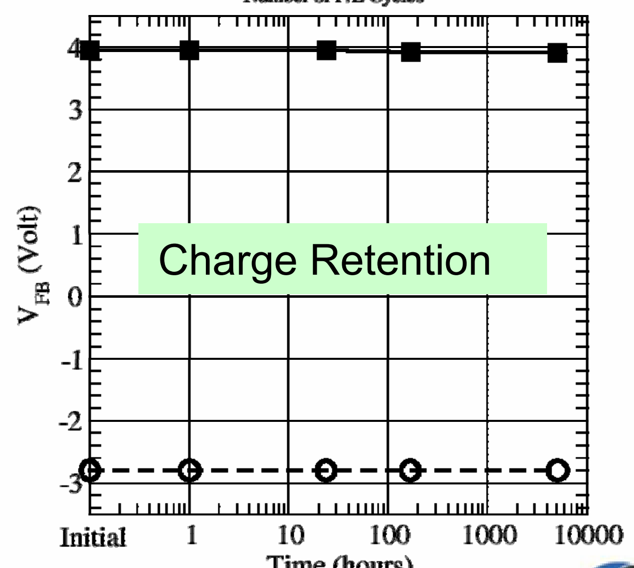


MOS Capacitor: Nanodot/High-K Offers Comparable Performance as FG/ONO









- >8V P/E window, sufficient for MLC
- Compatible with 100,000 P/E cycles
- Excellent charge retention

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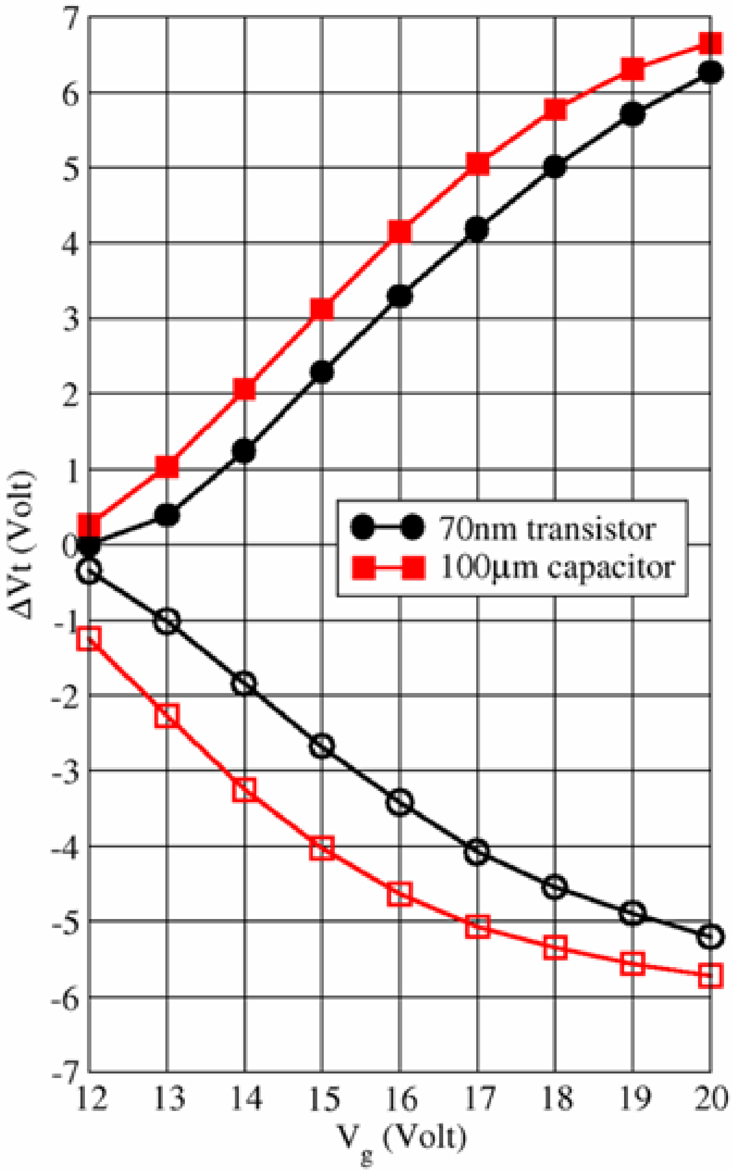
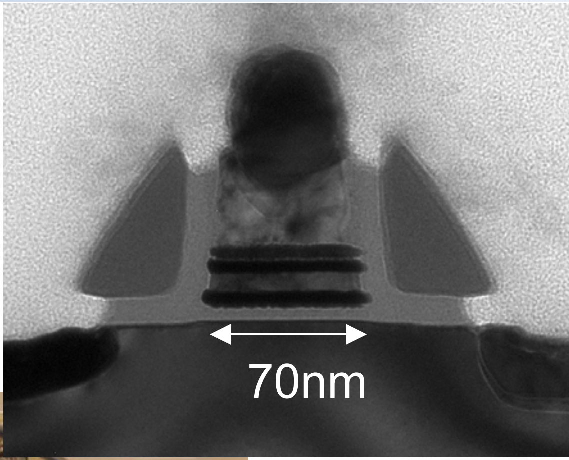
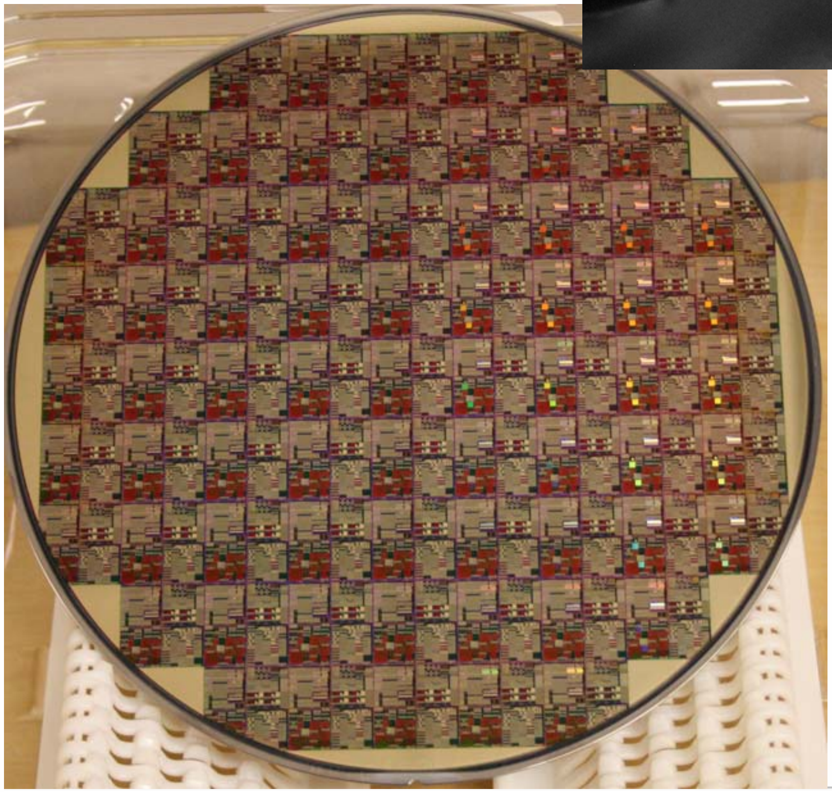
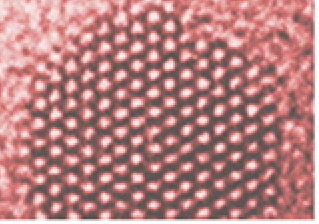
Nanodot Flash Transistors

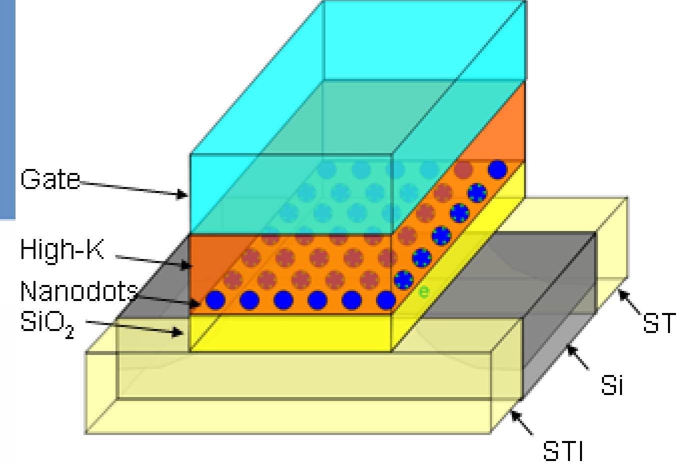








Conclusions



- Colloidal Metal Nanodots Combined with High-K Dielectric Offer an Alternative Charge-Storage NVM with Superior Endurance and Scalability
- Charge Storage: Poly FG→Metal Nanodots
  - Diameter: 2-3nm
  - Density: >3x10^{12}/cm^2
  - Fully Compatible with CMOS Processing
- Control Dielectric: ONO → High-k
- Control Gate: Poly → Metal
- Nanodot/High-K Electrical Performance Sufficient for MLC & SSD Requirements
  - Program/Erase Window >8V
  - Endurance 100,000 P/E Cycles