

Quantum Dot Applications for Flash Memory, Semiconductor Lasers, and Photodetectors

Sanjay Banerjee

Department of Electrical and Computer Engineering
Microelectronics Research Center

Flash memory is failing to track with Moore's Law

- Current fabrication and materials have inherent size limitations which are becoming critical
 - Reduction in the tunneling oxide layer leads to fragility and cell failure beyond 80 angstroms
- Programming problems
 - Speed
 - High voltage and power required
 - Retention
 - Precision/distinguishability

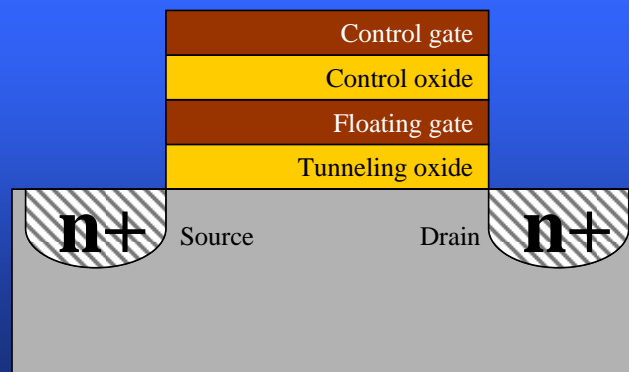
How do you save flash memory?

- Improve the tunneling oxide layer
 - Increase capacitance and reduce accidental quantum tunneling
- Replace the floating gate
 - Prevent accidental discharge
- Find methods to improve programmability
 - Increase channel mobility
 - Improve materials to increase speed, retention, lower voltage, lower power

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Failure rates increase as you shrink current tunneling oxide layers

Standard flash memory cell

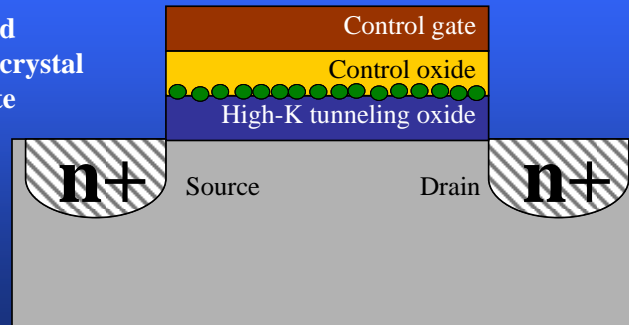


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Quantum dots and high-K tunneling oxide reduce size, increase stability

Adding a high-K tunneling oxide layer and quantum dots

Si-Ge-C and
metal nanocrystal
floating gate



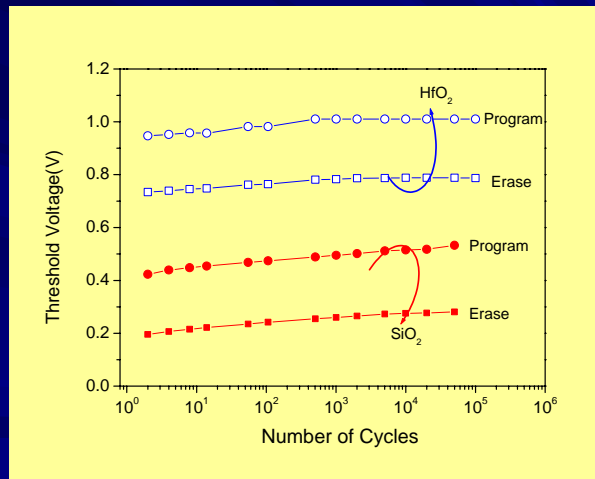
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High-K tunneling layer

- Replace current materials with a high-K tunneling oxide:
 - Lowers voltage and power to program
 - Improves retention of charge (thicker layers)
 - Increases capacitance
 - Can increase thickness without reducing programmability
 - Reduces quantum tunneling leakage

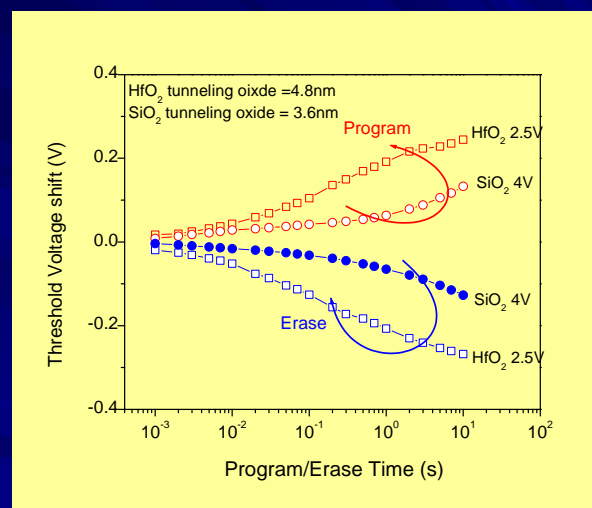
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High-K devices have high endurance



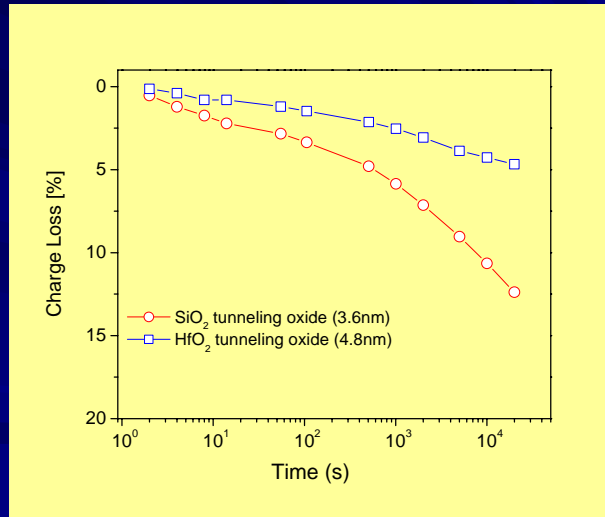
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High-K layer makes programming and erase faster



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High-K layer improves charge retention



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Quantum dots avoid failure problems

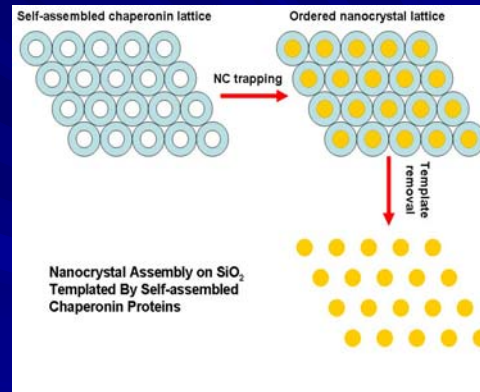
- Use of independently charged quantum dot nanocrystals replacing the floating gate later
 - With current continuous layers, one flaw discharges the entire cell
 - With quantum dots, flaw only discharges dots immediately above the flaw, cell maintains charge



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Protein templates fix quantum dot arrangement problems

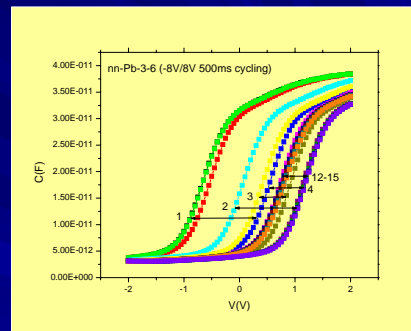
- Quantum dots as used today are not optimally distributed
- Currently randomly laid on top of the tunneling layer
- Using self-assembled chaperonin proteins to template nanocrystals



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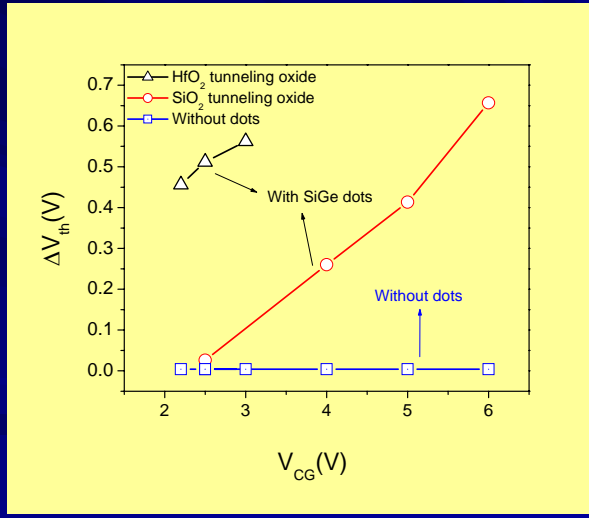
High-K layer and quantum dot gate features

- Accidental quantum tunnel discharges reduced
- Programmability maintained



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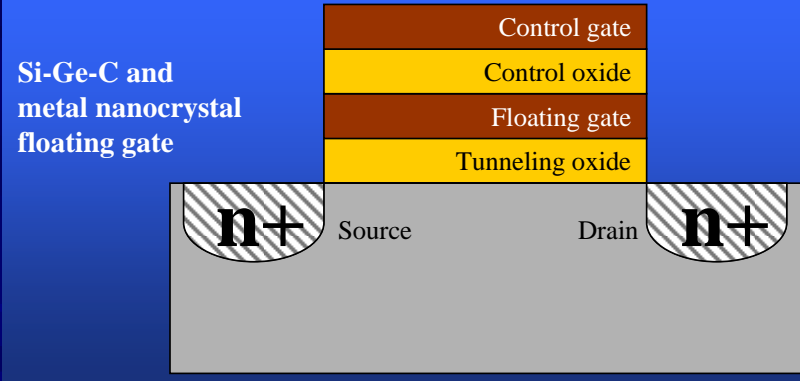
High-K and quantum dots create better distinction of states



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How do you improve programmability?

Standard flash memory cell

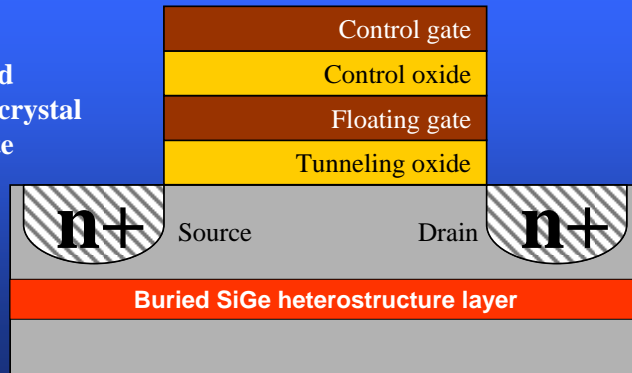


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Mobility layer improves programming speed and reduces power needed

Flash memory cell with high-mobility channel

Si-Ge-C and metal nanocrystal floating gate

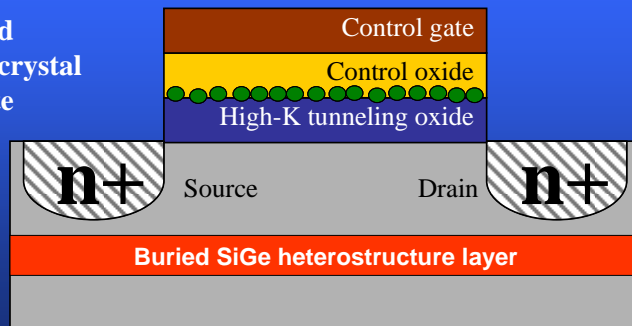


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We have invented a vastly improved memory cell

Completed cell: high-K tunneling oxide layer, quantum dots, and mobility layer

Si-Ge-C and metal nanocrystal floating gate



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Technology overview

- Specialty proteins enable precise distribution and size control of nanoparticles on a surface
 - Improves performance, reliability
 - Reduces potential size
- Changing materials of tunneling layer:
 - Improves reliability
 - Increases capacity
 - Improves programming
- Adding mobility layer
 - Faster programming at lower voltages

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Benefits and applications

- New technologies improve non-volatile flash memory
 - Increased speed
 - Reduced size of memory cell for portable devices
 - Lower leakage currents for low-power portable and handheld applications
 - Low-voltage/power, high-speed, high-reliability flash memory for digital cameras, cell phones, etc.
- Protein template method has a variety of other applications
 - Semiconductor lasers
 - Photodetectors

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Next steps

- Current status
 - 3 patent applications filed
 - Bench prototype complete
- Next steps to commercialization
 - Prototype it in a memory circuit (as opposed to individual cells)
 - Start-up opportunity!
- Follow-up meeting:
 - Thursday, June 9, 2:30-3:30pm