Embedded 28-nm Charge-Trap NVM Technology

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Outline

- Embedded NVM applications
- Charge-trap NVM at Cypress
- Scaling
- Key Flash macro specs
- 28-nm Flash memory reliability
- Conclusions

Embedded NVM Applications

- Focus on NVM monolithically integrated in a System-on-Chip (SoC)

Consumer
- Cost
- Endurance
- Ambient -25C to 85C
- 50-ns access
- 100k endurance

Industrial
- Low power
- Cost
- Ambient -40C to 105C
- 25-ns access
- 10k endurance

Automotive
- Performance
- Reliability
- Ambient -40C to 125C
- Code: 20-ns access
- Code: 1k endurance
- Data: 100k endurance

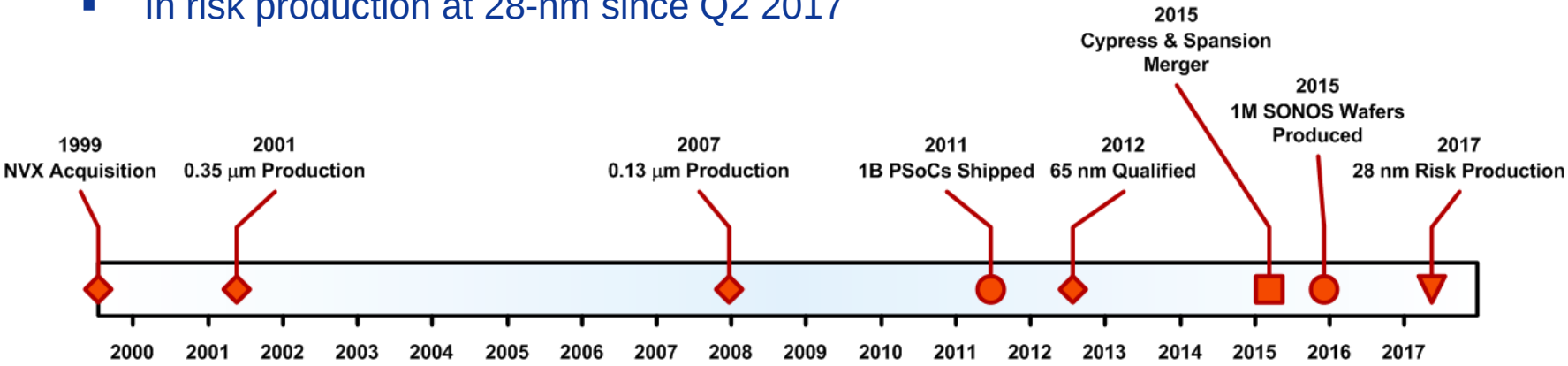
IoT Opportunity

- IoT device shipments will grow from 0.6 billion units in 2017 to 2.3 billion units in 2023[1]
  - eNVM is a key enabler of embedded processing and connectivity
  - eNVM costs are holding up adoption (process and test)
  - Low power read and write operations – active power
  - Secure program/data storage
  - No compromise on reliability; fast access time

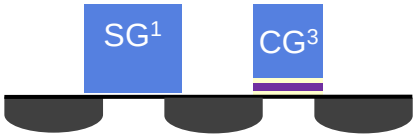
[1] Linley Group 2017

Charge-Trap NVM: Cypress History

- Acquired NVX and its Silicon Oxide Nitride Oxide Silicon (SONOS) IP in 1999
- Put SONOS into production at 0.35-μm node in 2001 and 0.13-μm node in 2007
- Shipped >2 billion PSoC units with SONOS eFlash
- Produced >1 million wafers with foundry partners HH-Grace, UMC, and HLMC
- In risk production at 28-nm since Q2 2017



Embedded Charge-Trap NVMs

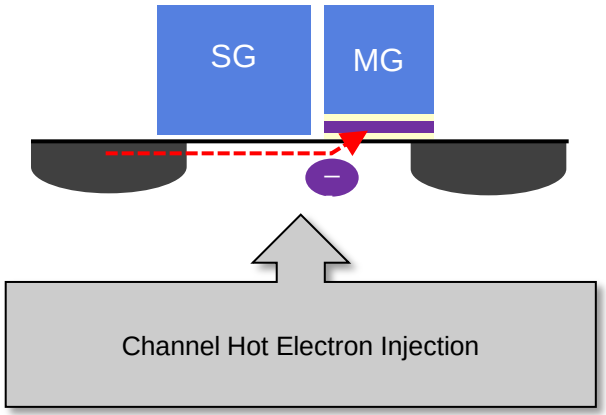


Feature	eCT	SONOS
Node	40-nm	40, 28-nm
Cell Architecture	1.5T, 1 bit/cell	2T, 1 bit/cell
Memory Device	ONO	ONO
Program/Erase Method	HEI/HHI	FN/FN
Ambient Operating Temperature	-40C to 125C	-40C to 105C
Speed/Random Access Time	8 ns	25 ns
Write Endurance	125k cycles	100k cycles
Data Retention	20 years	10 years
Extra Masks beyond Std CMOS	8	5
Applications	Embedded NOR Flash for automotive MCUs	Embedded NOR Flash for consumer and industrial MCUs

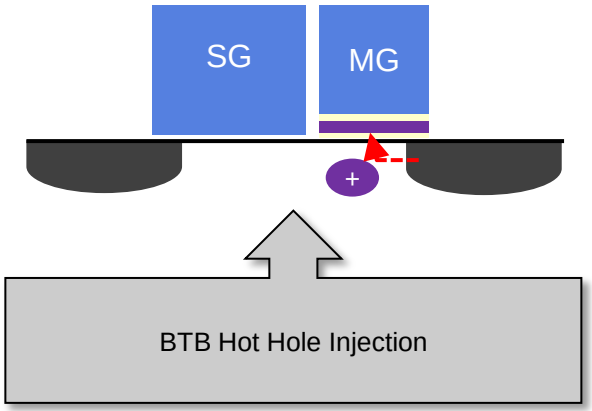
[1] SG: select gate
[2] MG: memory gate
[3] CG: control gate

eCT Program & Erase Operations

Program



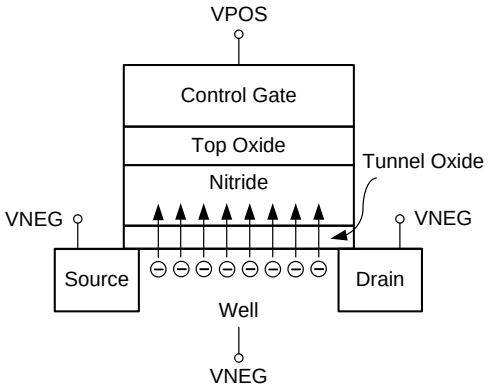
Erase



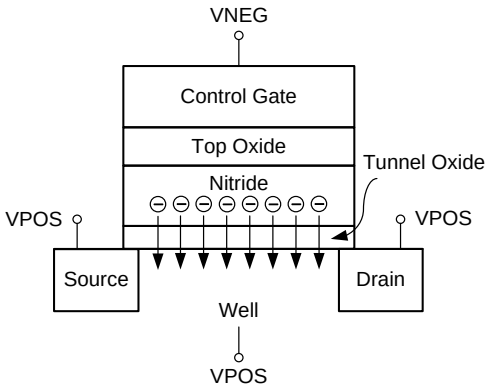
SONOS Program & Erase Operations

- Silicon Oxide Nitride Oxide Silicon (SONOS)
  - A SONOS transistor is a planar, scalable MOS transistor with an ONO stack as the gate dielectric
  - The basis of the NVM function is storage of captured charges in discrete traps in the nitride (N) layer
  - Program and erase operations use uniform channel FN tunneling
  - Requires only five extra masks beyond the standard CMOS process

Program

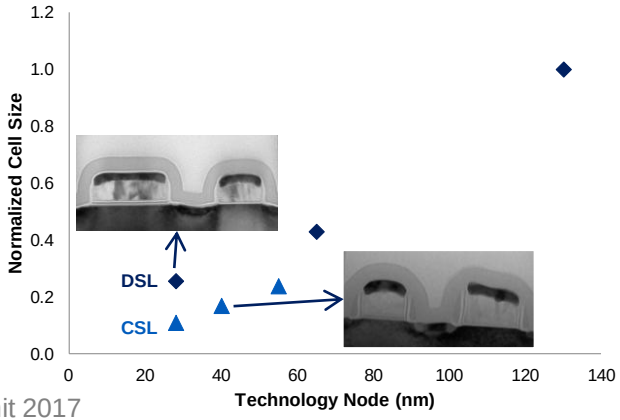


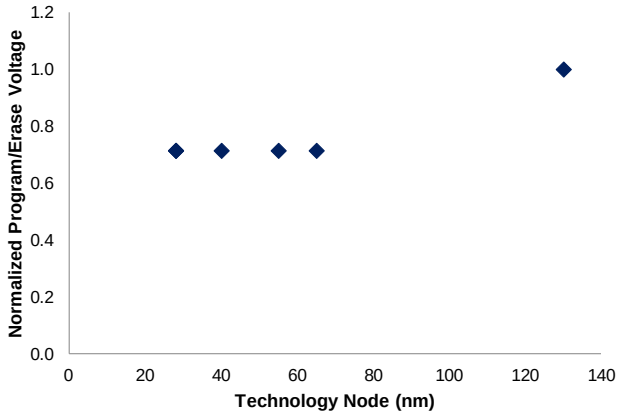
Erase



SONOS Scaling

- Cell area scales down
  - Program/erase voltages are held constant since 65-nm
  - Transition from dedicated (DSL) to common (CSL) source line array enables significant reduction in cell area at the same node
- Trade-off exists between the access time and cell area



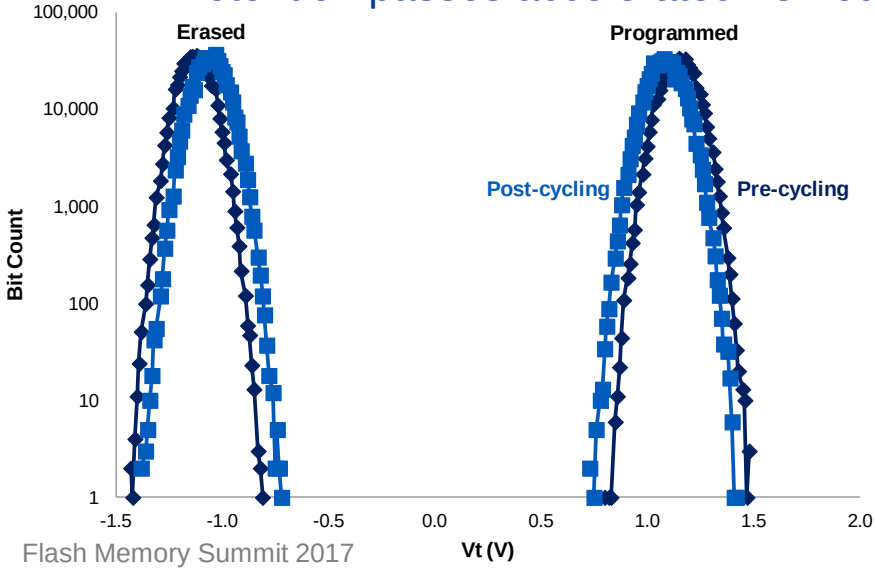


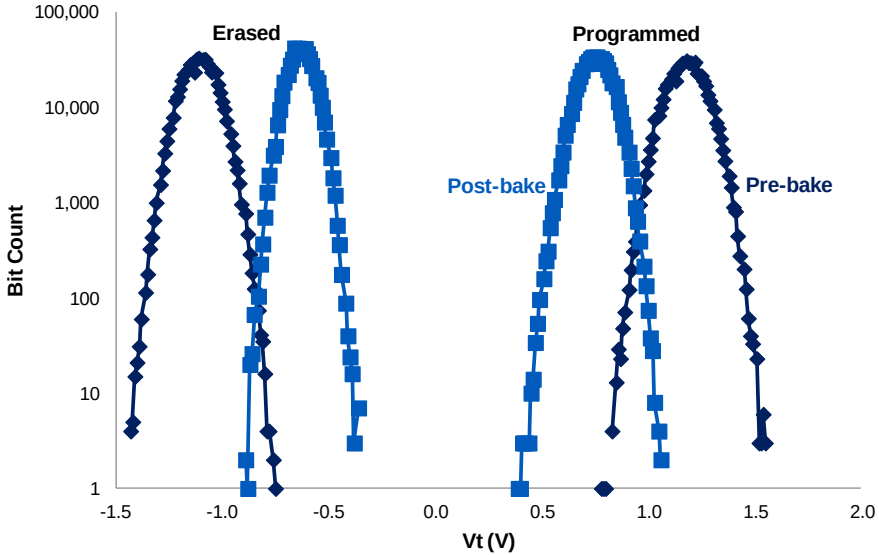
Key Flash Macro Specs

	28-nm SONOS	40-nm SONOS
Density	1Mb	1Mb-16Mb
Input data width	32-bit	32-bit
Output data width	64-bit	32-, 64- or 128-bit
Dual Power Supply	0.89 V-1.10V & 2.25 V-2.75 V	0.81 V-1.21 V & 1.62 V-3.63 V
Operating Temperature	-55C to 125C	-40C to 125C
Read access time	25 ns (1.05±0.05 V)	25 ns (1.10±0.11 V)
Read Current	75 μA/MHz per 64-bit	61 μA/MHz per 32-bit
Write Endurance	> 10k cycles	> 100k cycles
Data Retention	> 10 years at 110C	> 10 years at 100C

28-nm Flash Memory Reliability

- Write endurance easily passes 10,000 program/erase cycles at 125C
  - Vt window >1.4 V after cycling with single-pulse program/erase of constant amplitude and duration
- Retention passes accelerated 48-hour bake at 250C with > 0.7 V window left





Conclusions

- Charge-trap Flash technology has several advantages
  - Low cost: only five extra masks beyond the standard CMOS process
  - Low power: 0.9 V power supply, low-current FN/FN program/erase
  - Performance: 25-ns read access time in the standard power supply range
  - Resistant to de-processing; security features
- Cell is scalable even at constant program/erase voltages
- Cell and macro can be tuned to application
  - Consumer, e.g., smart cards: cost (CSL cell), 50 ns read, < 4 ms write time
  - Industrial: 25-ns read access with design techniques (smaller sectors, etc.)
  - Automotive: 8-ns eCT or robust DSL cell

Acknowledgments

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