IDF2012
INTEL DEVELOPER FORUM

Silicon Technology Leadership for the Mobility Era

Mark Bohr, Intel Senior Fellow

SPCS008

Sponsors of Tomorrow.

Agenda

- Transistor Scaling Trends
- 32 nm SoC Technology
- 22 nm CPU Technology
- 22 nm SoC Technology

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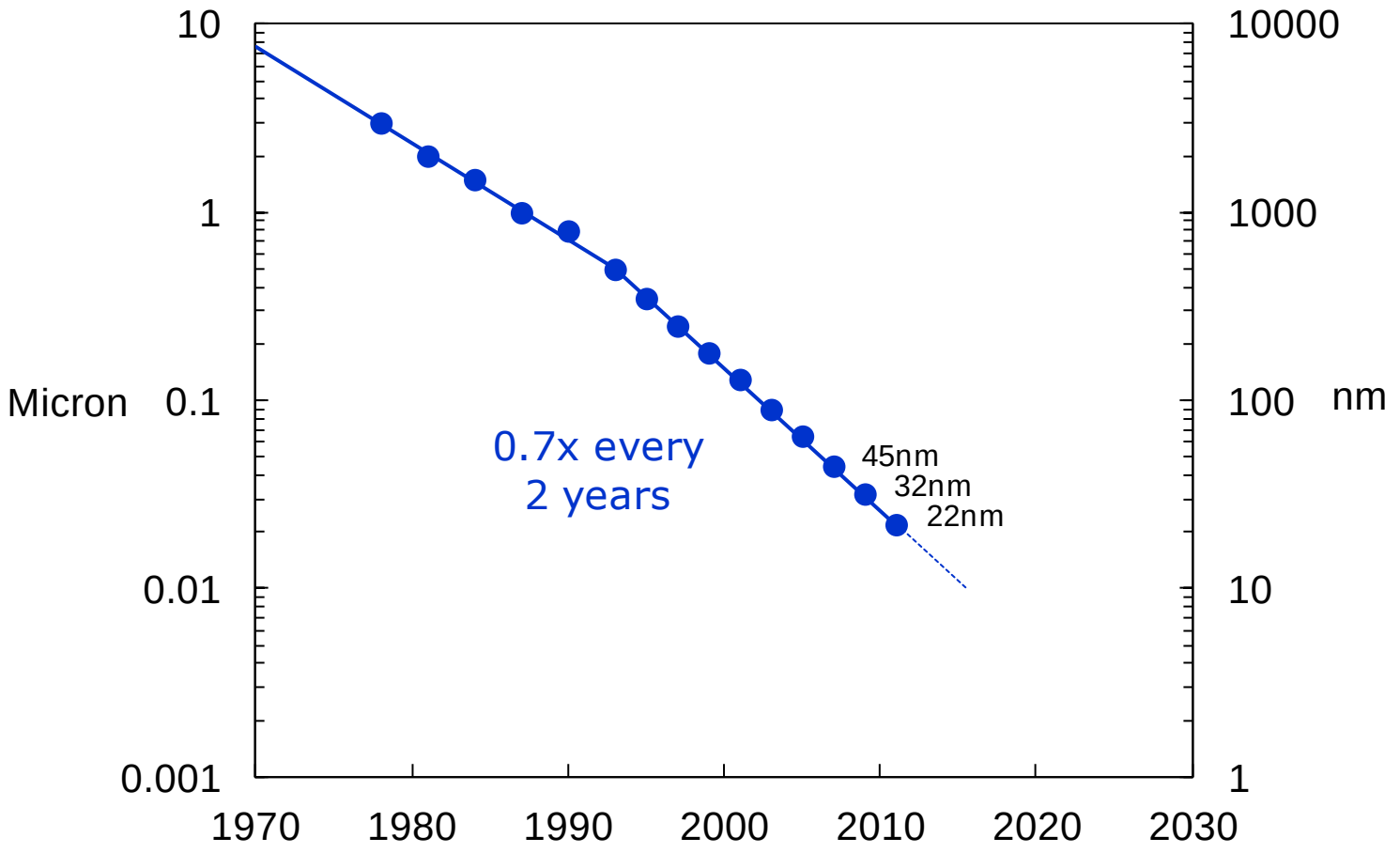
Agenda

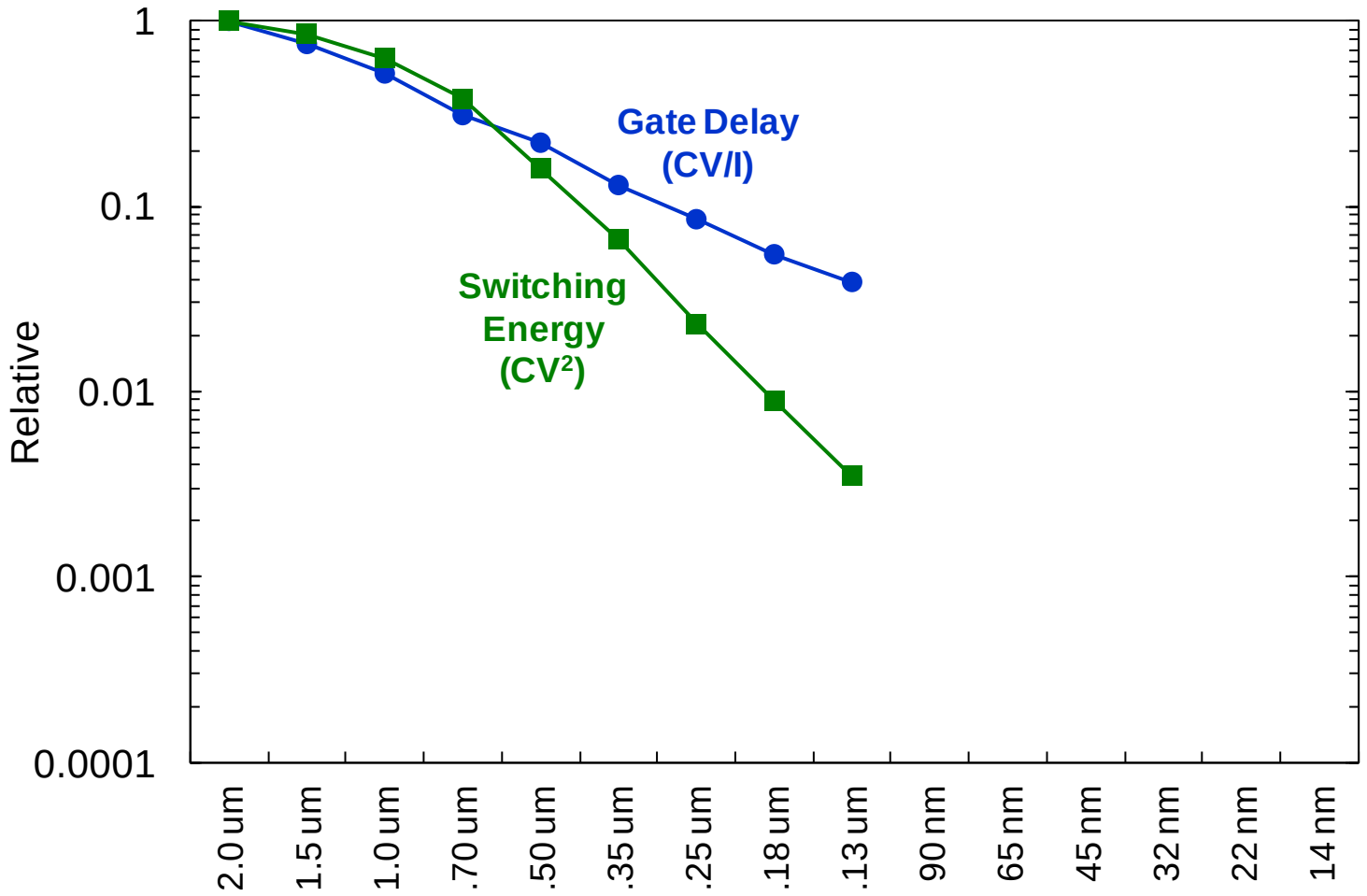
- Transistor Scaling Trends
- 32 nm SoC Technology
- 22 nm CPU Technology
- 22 nm SoC Technology

Transistor Scaling



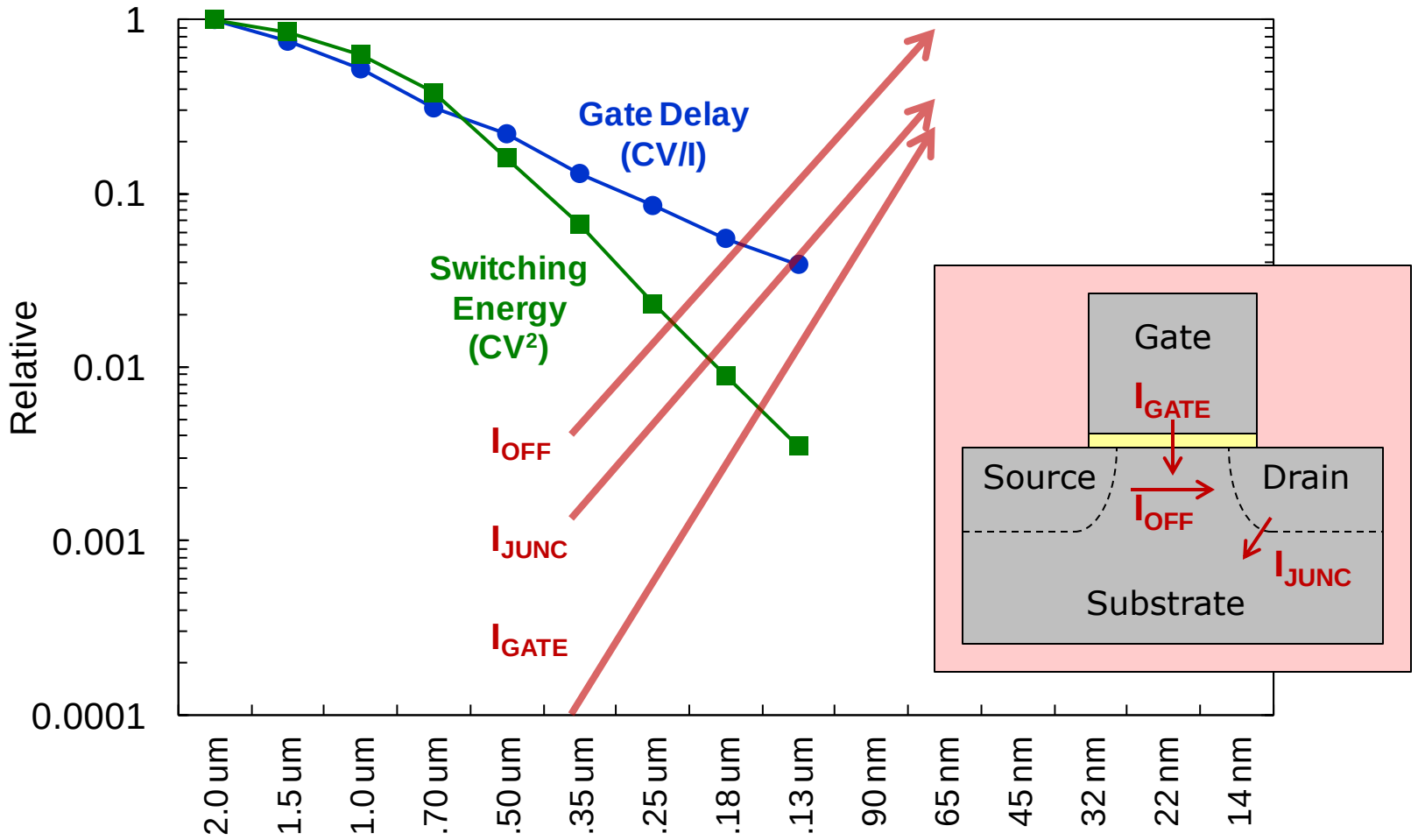
Transistor dimensions scale to improve performance, reduce power and reduce cost per transistor

Transistor Performance and Power



"Classical" transistor scaling provided improvements in performance (gate delay) and active power (switching energy)

Transistor Performance and Power



… but at the expense of increased leakage current

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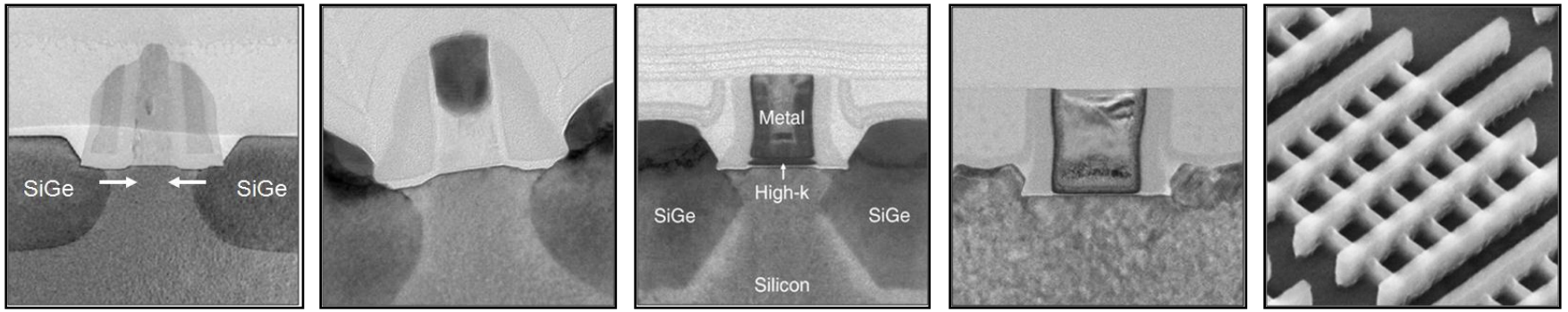
Non-Classical Scaling

90 nm	65 nm	45 nm	32 nm	22 nm
2003	2005	2007	2009	2011



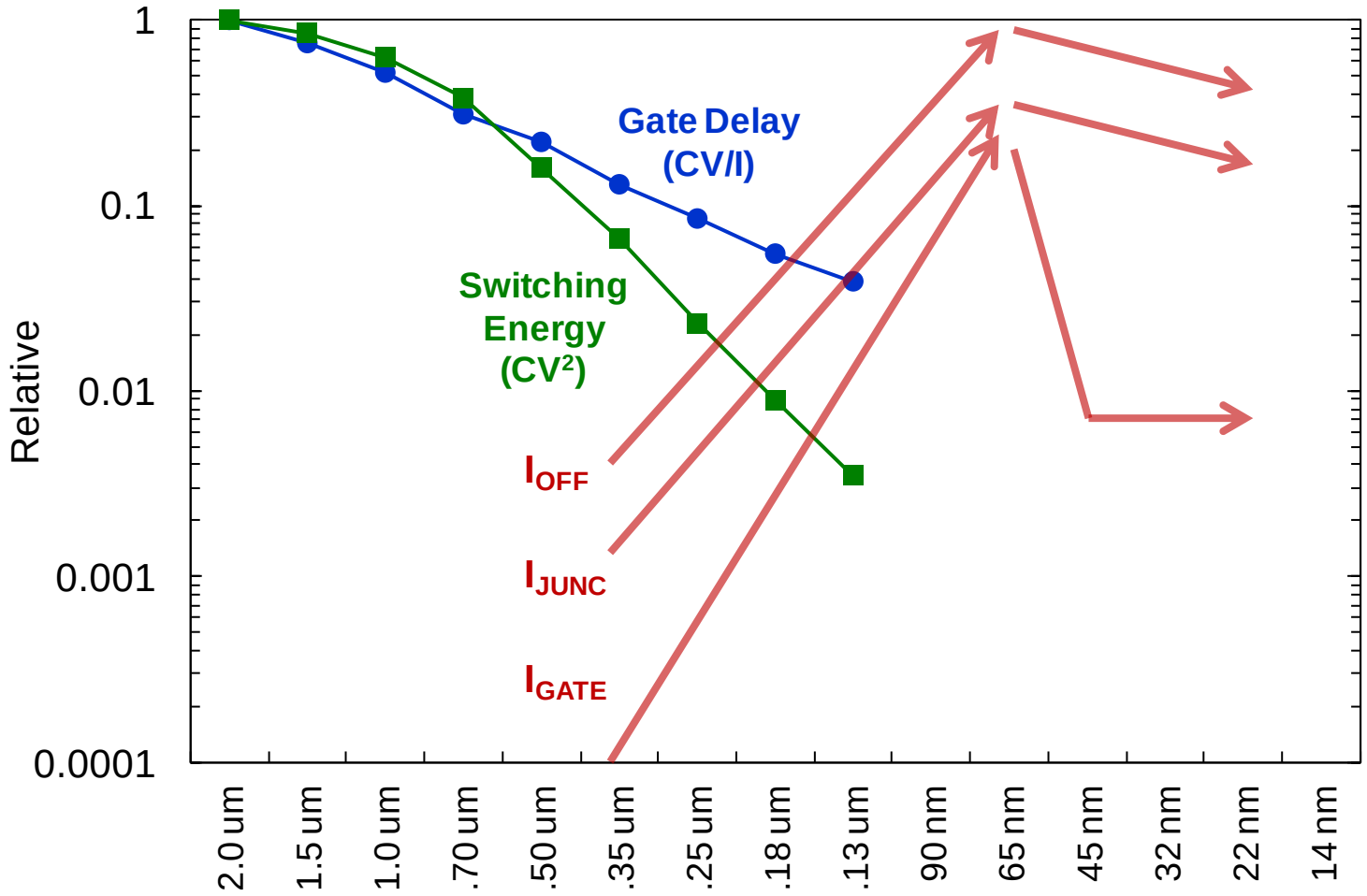
Strained Silicon

High-k Metal Gate

Tri-Gate

Scaling now requires continual innovations in transistor structure and materials

Transistor Performance and Power



Transistor scaling now focuses on reducing leakage

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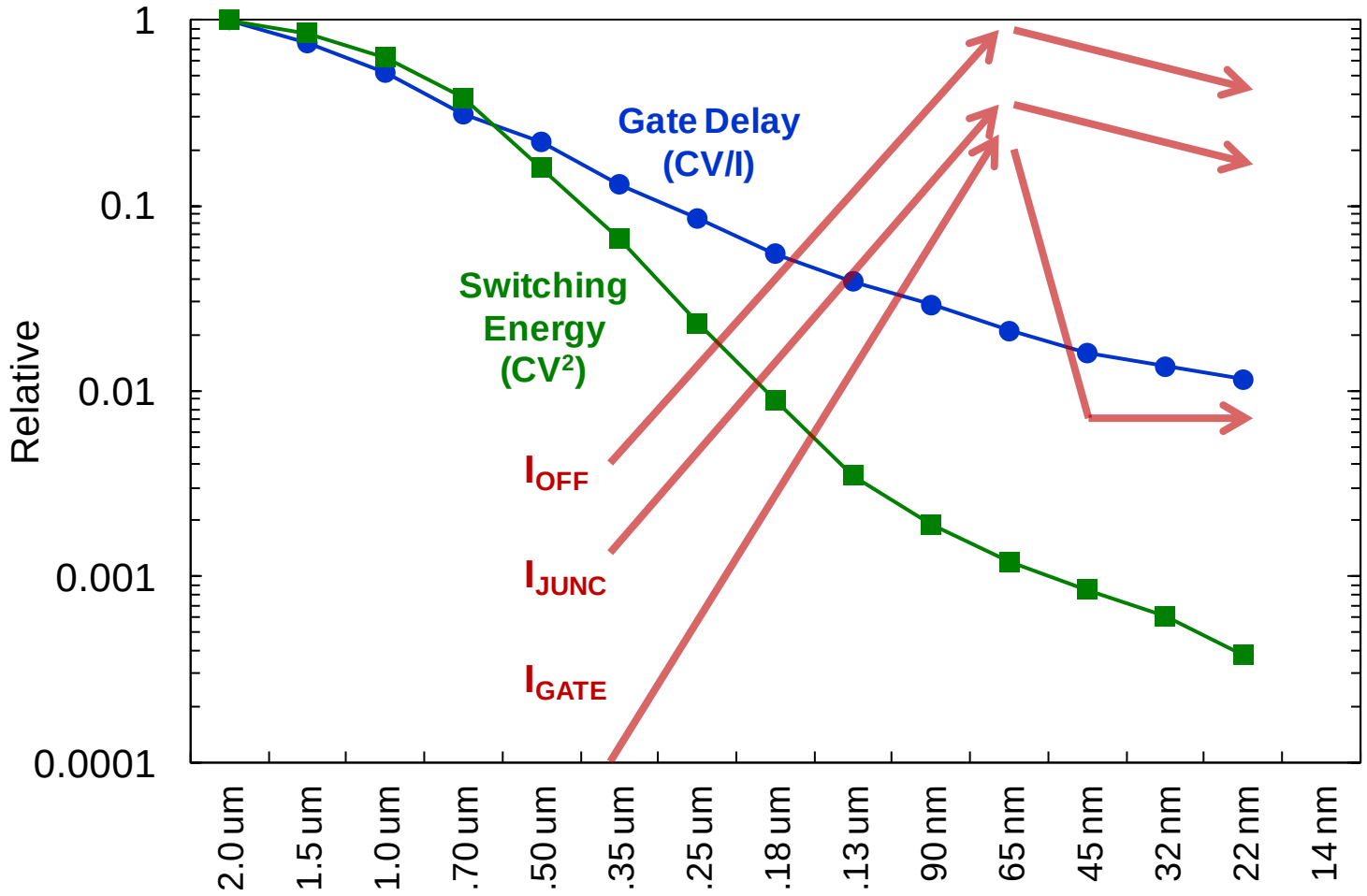
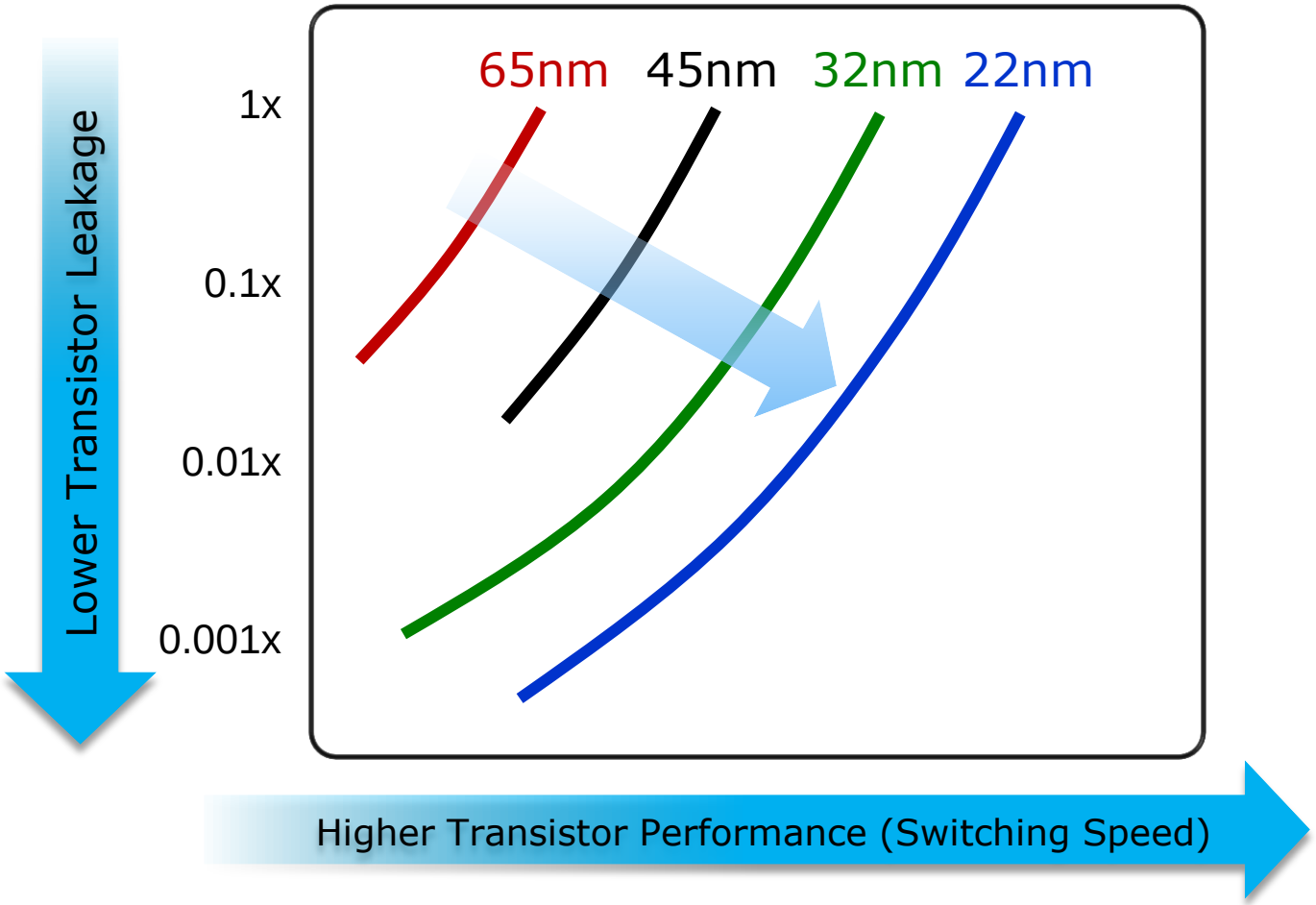
Transistor Performance and Power



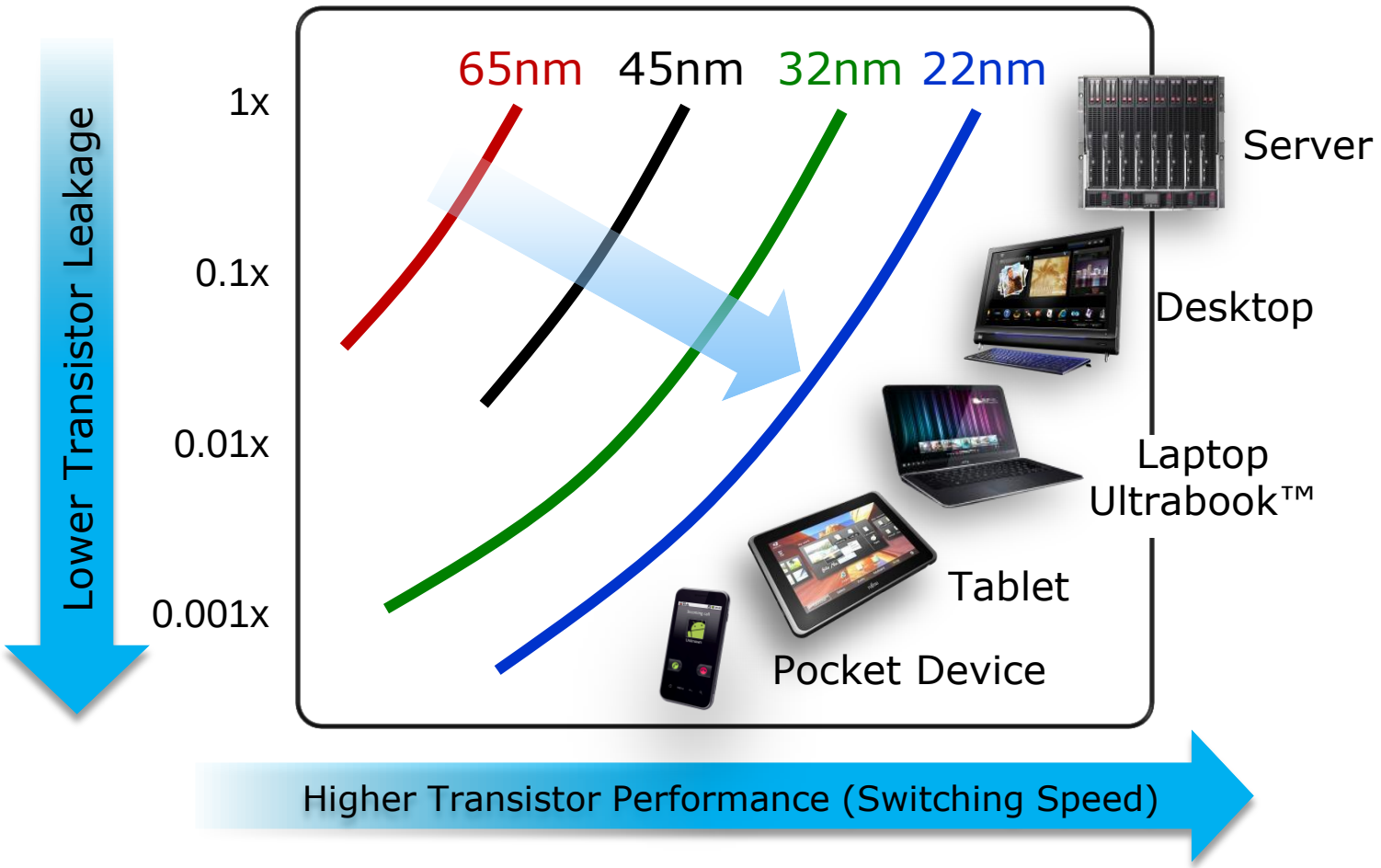
… and continues to improve performance and power

Transistor Performance vs. Leakage



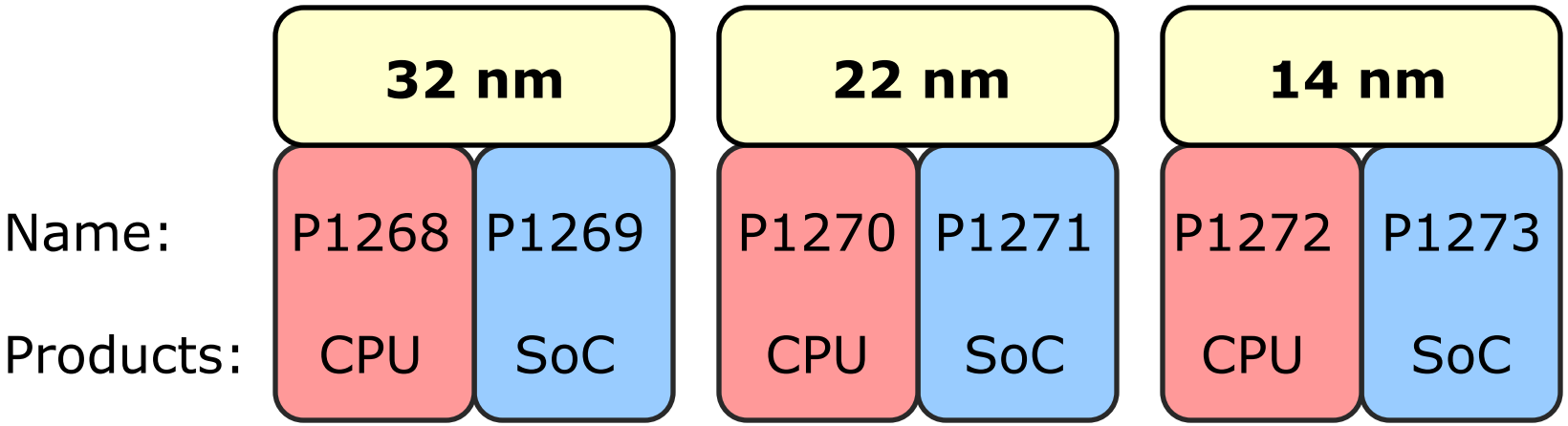
Transistors now improve on both performance and leakage vectors

Transistor Performance vs. Leakage



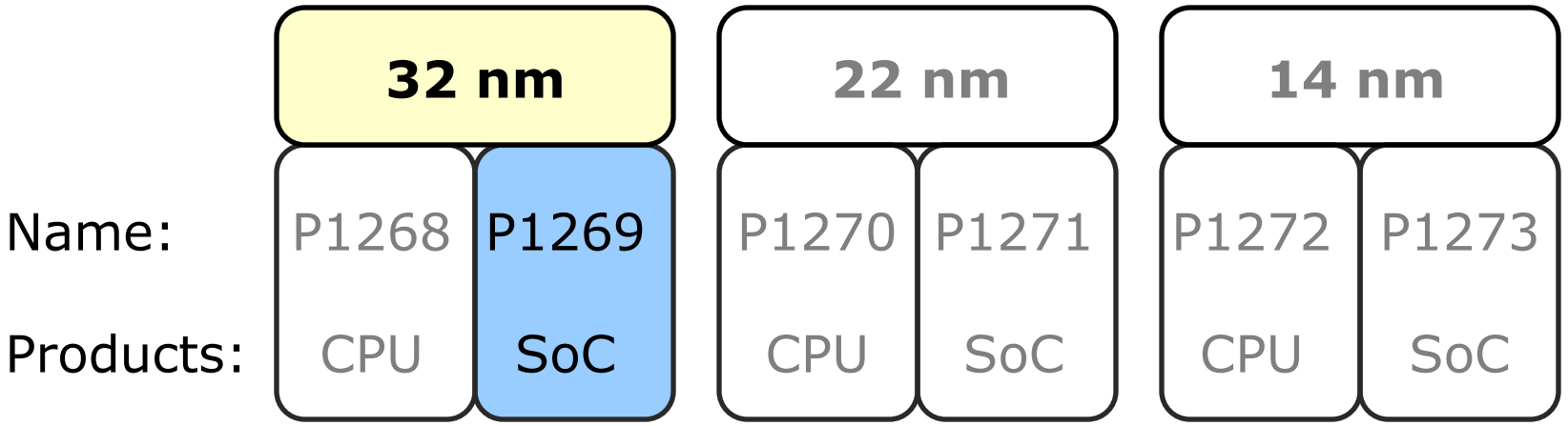
Wider range of transistors to support a wider range of products

Intel® Technology Roadmap



Intel develops both CPU and SoC versions of each generation

Intel® Technology Roadmap



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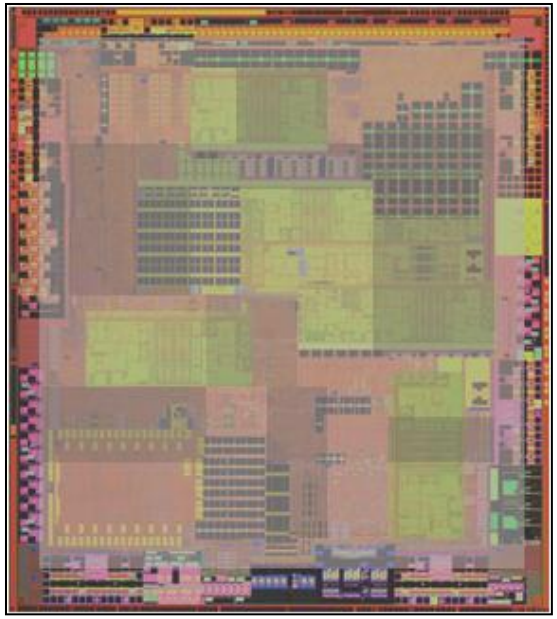
Low Power Smartphone Products

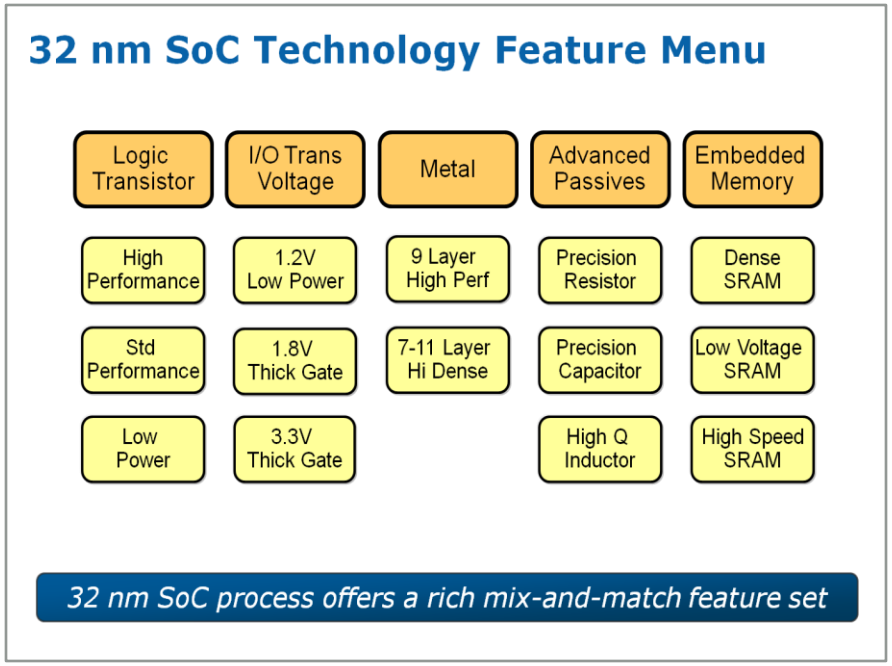
Medfield Phone



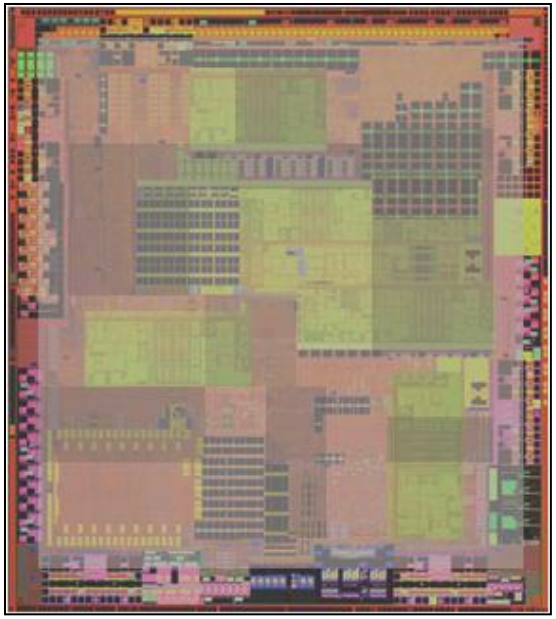
32 nm Intel® Atom™ processor (Medfield) SoC

432 million transistors, 64 mm^2

Low Power Smartphone Products



Intel Developer Forum, Sep. 2009



32 nm SoC Technology

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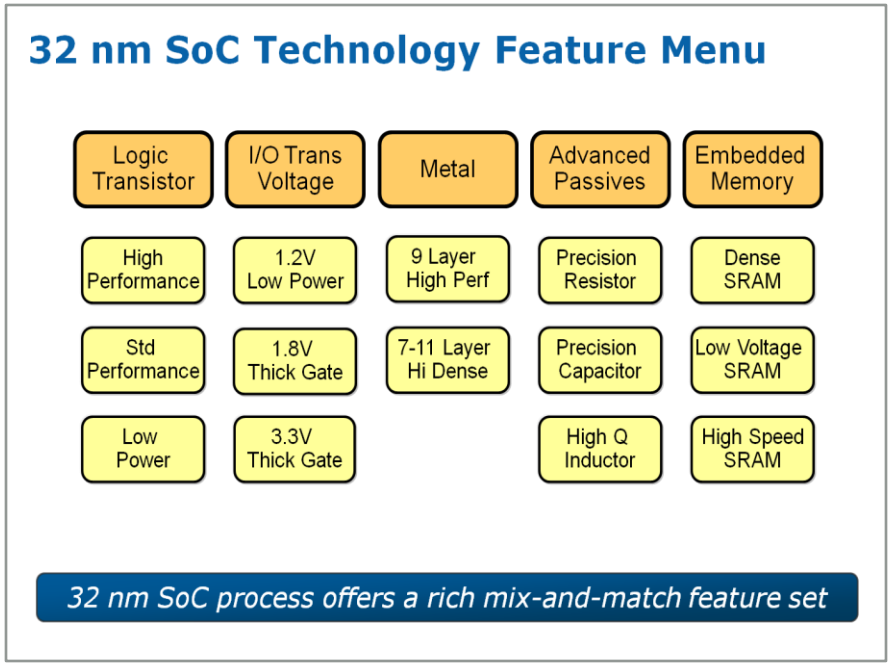
Low Power Smartphone Products



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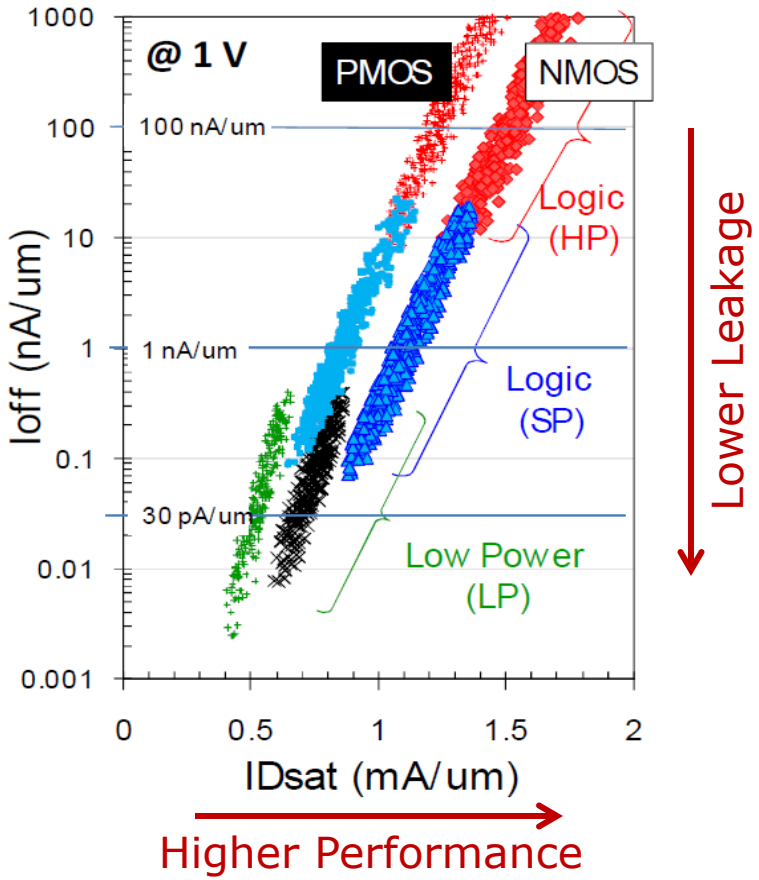

32 nm SoC Technology

32 nm SoC transistors range from high performance to low power

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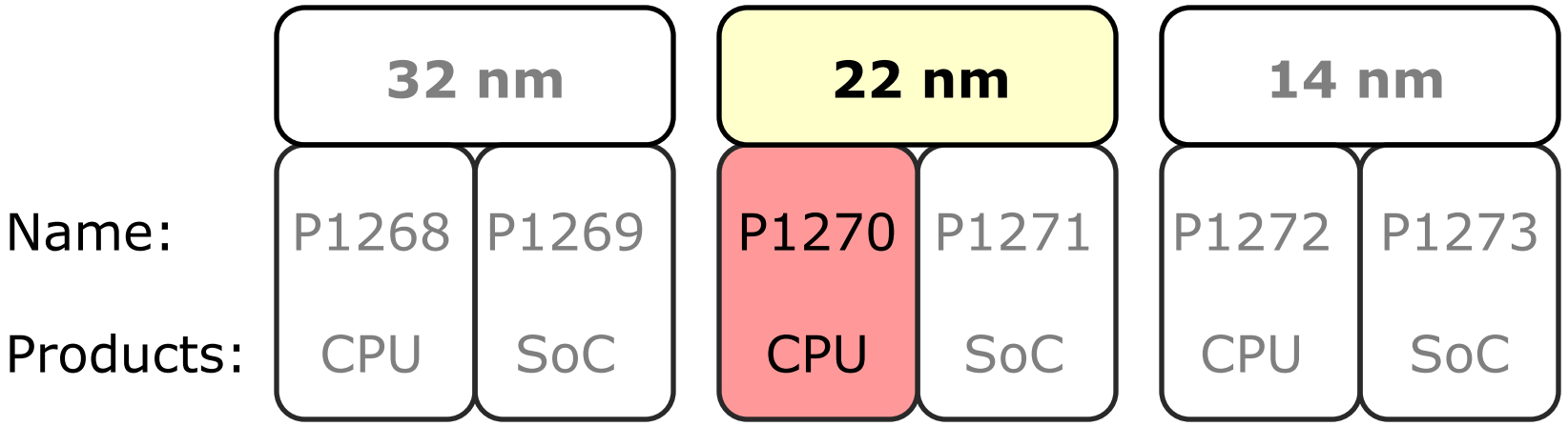
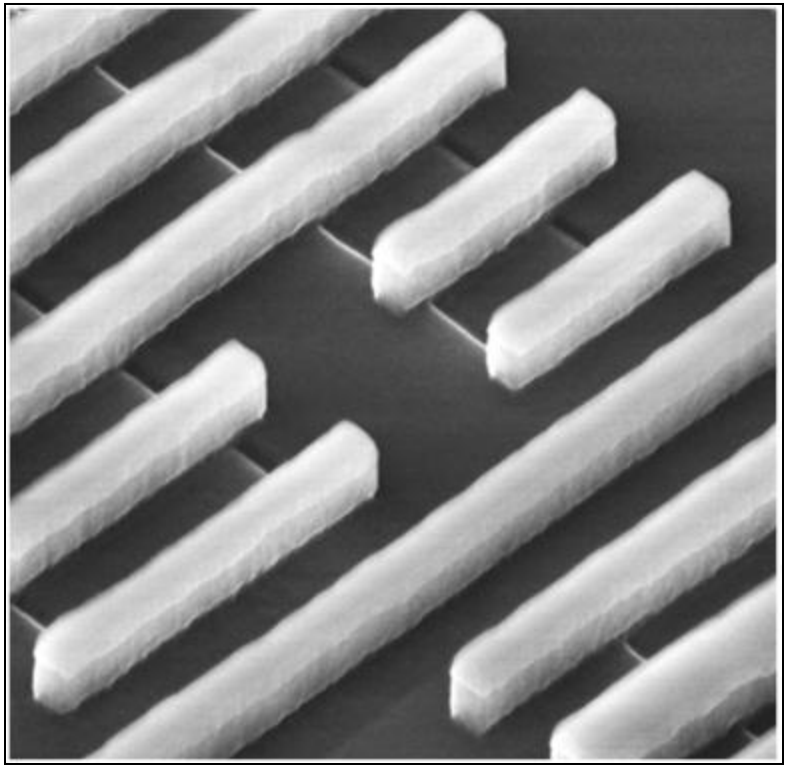
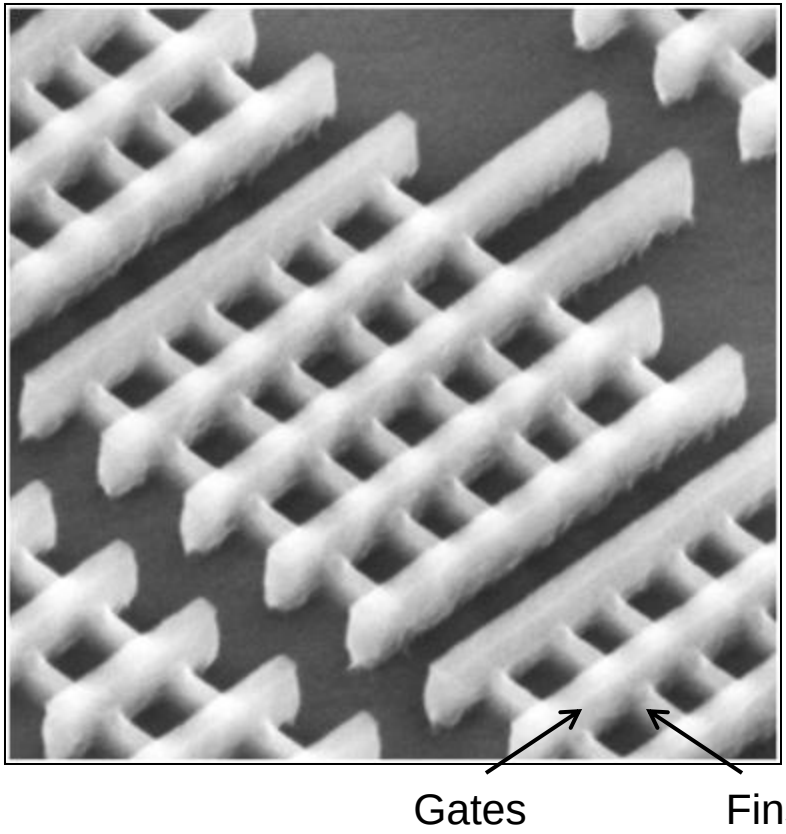
Intel® Technology Roadmap



32 nm Planar Transistors

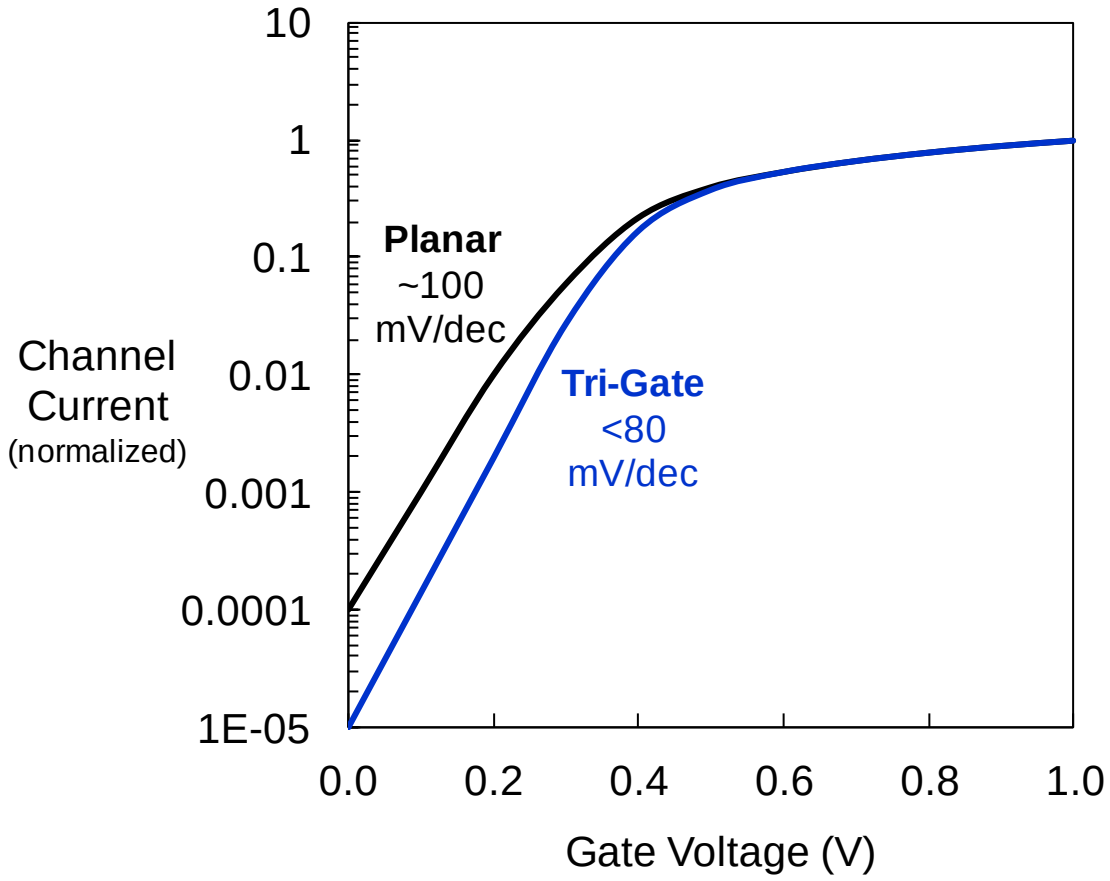


22 nm Tri-Gate Transistors



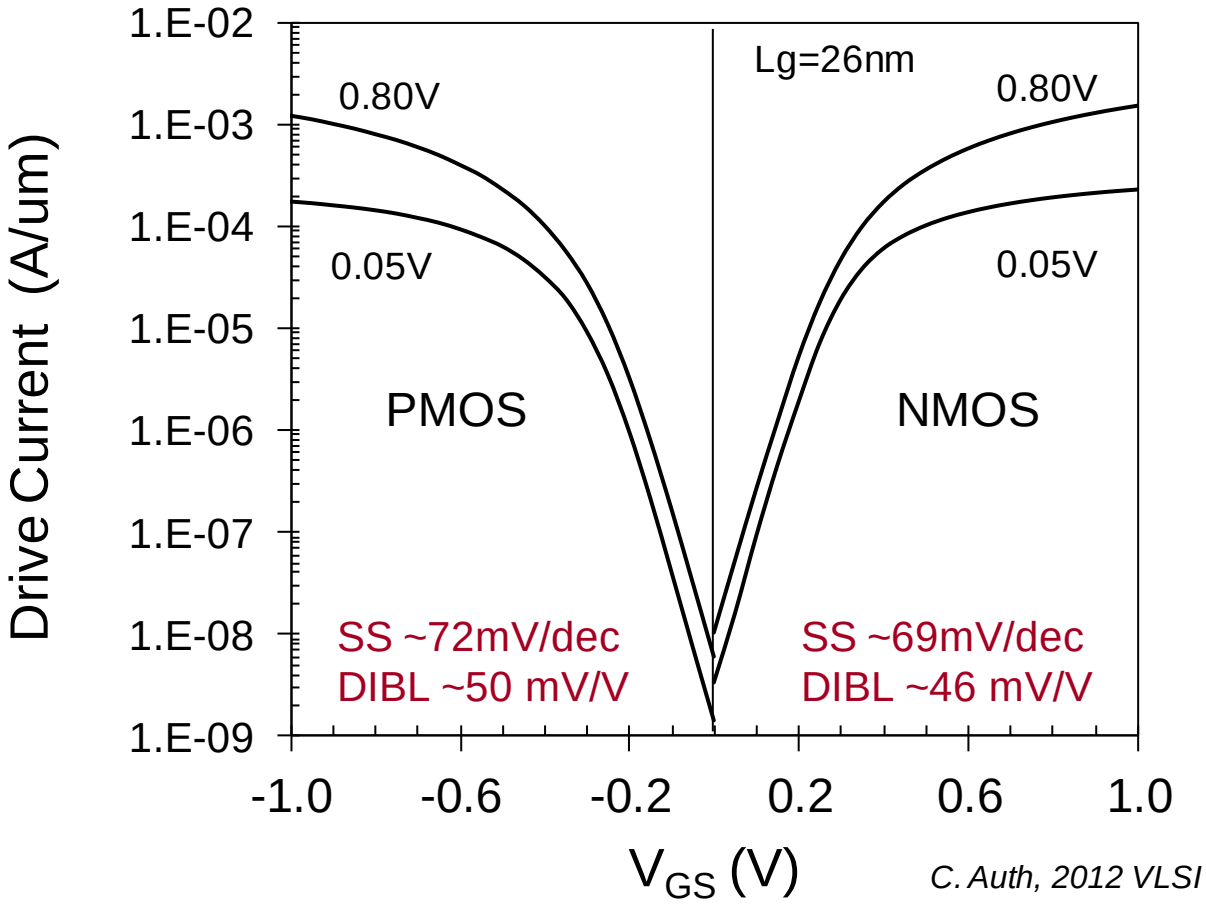
22 nm generation introduces revolutionary 3-D Tri-Gate transistors

Fully Depleted Device



Tri-Gate transistors are fully depleted devices offering a steeper sub-threshold slope

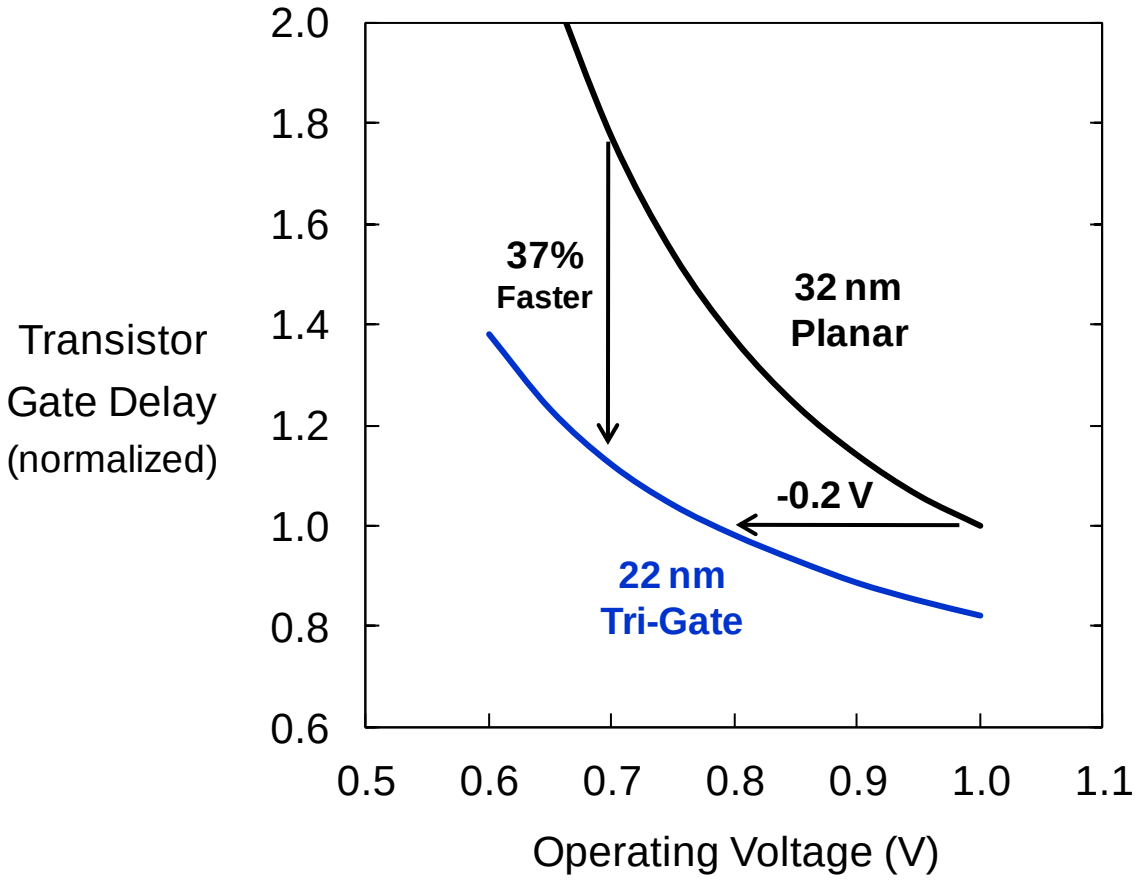
22 nm Tri-Gate I-V Curves



C. Auth, 2012 VLSI

Tri-Gate provides steepest sub-threshold slope and best short channel (DIBL) values of any technology in manufacturing

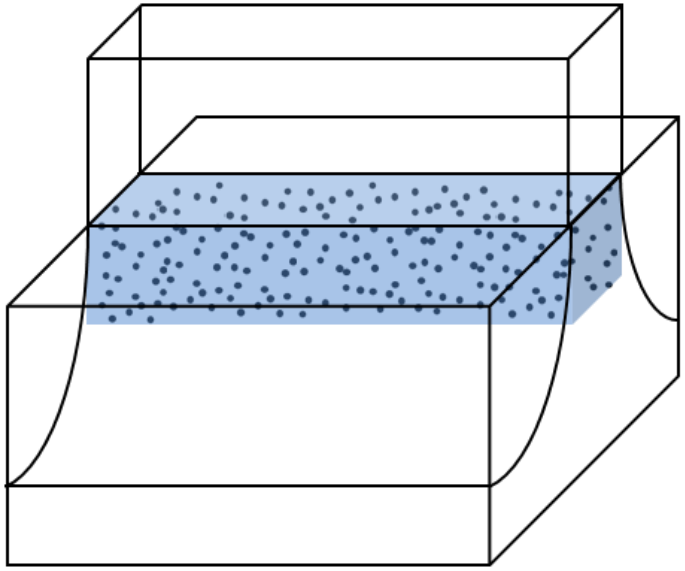
Performance/Power Benefits



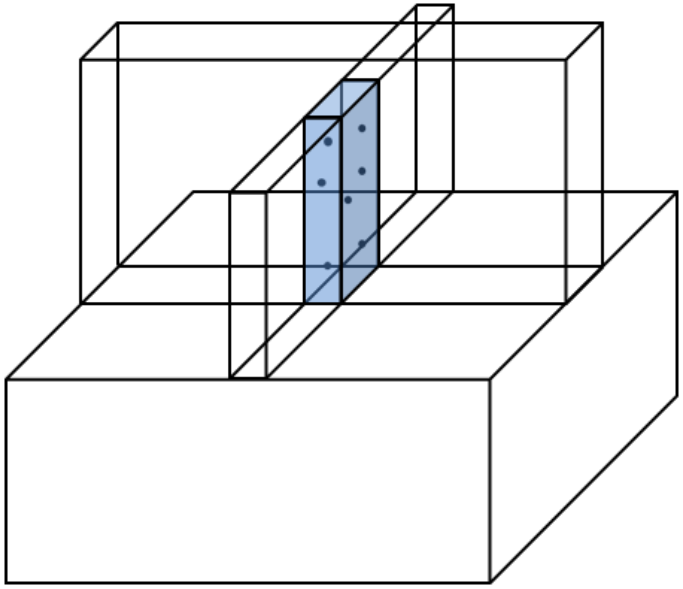
Tri-Gate provides 37% speed up at low voltage or 50% active power reduction at same performance

Reduced Channel Doping

Planar

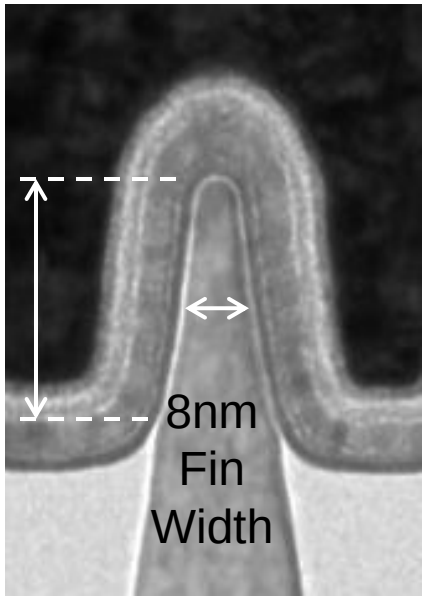


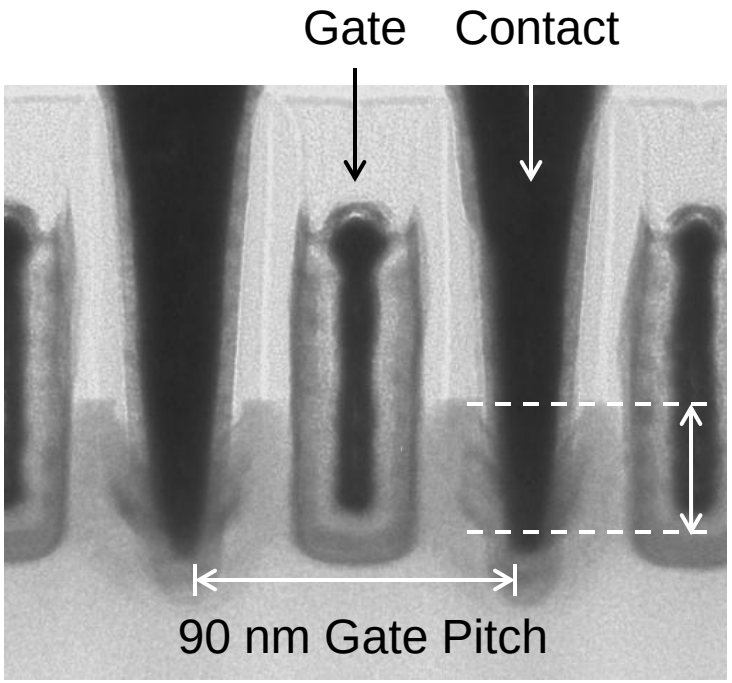
Tri-Gate



Fully depleted Tri-Gate structure has reduced channel doping, providing improved performance and reduced variability

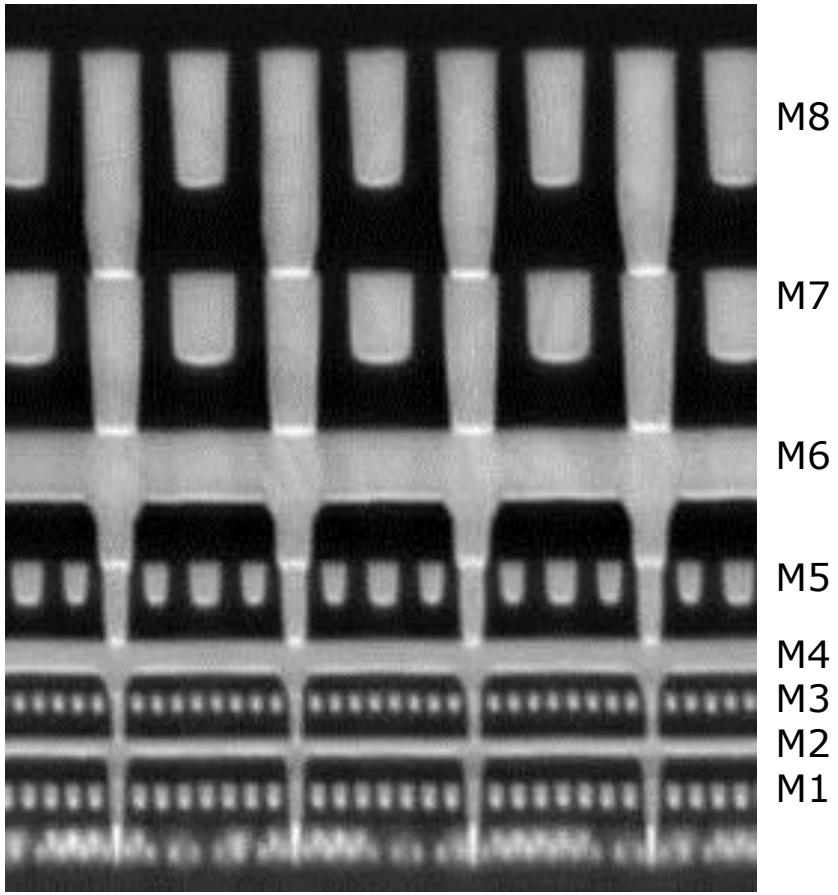
22 nm Tri-Gate Transistors





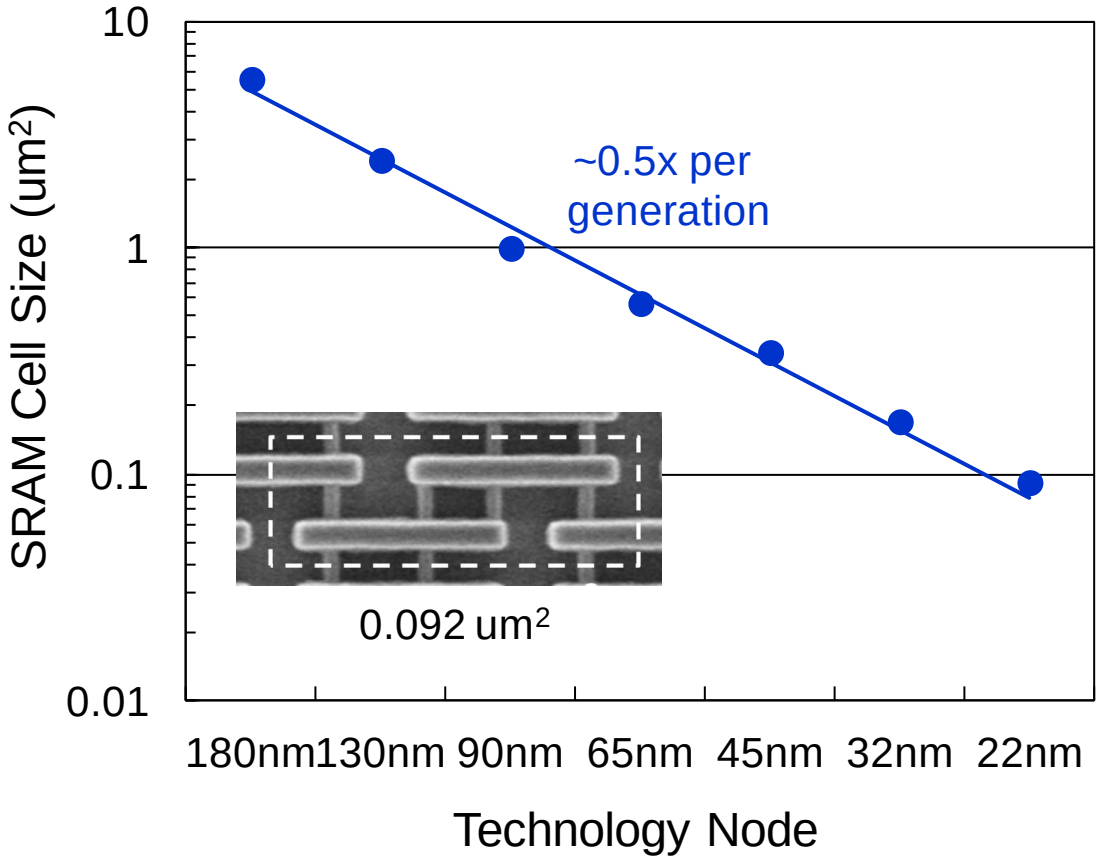
22 nm Interconnects

Layer	Pitch
TM	14 um
M8	360 nm
M7	320 nm
M6	240 nm
M5	160 nm
M4	112 nm
M3	80 nm
M2	80 nm
M1	90 nm



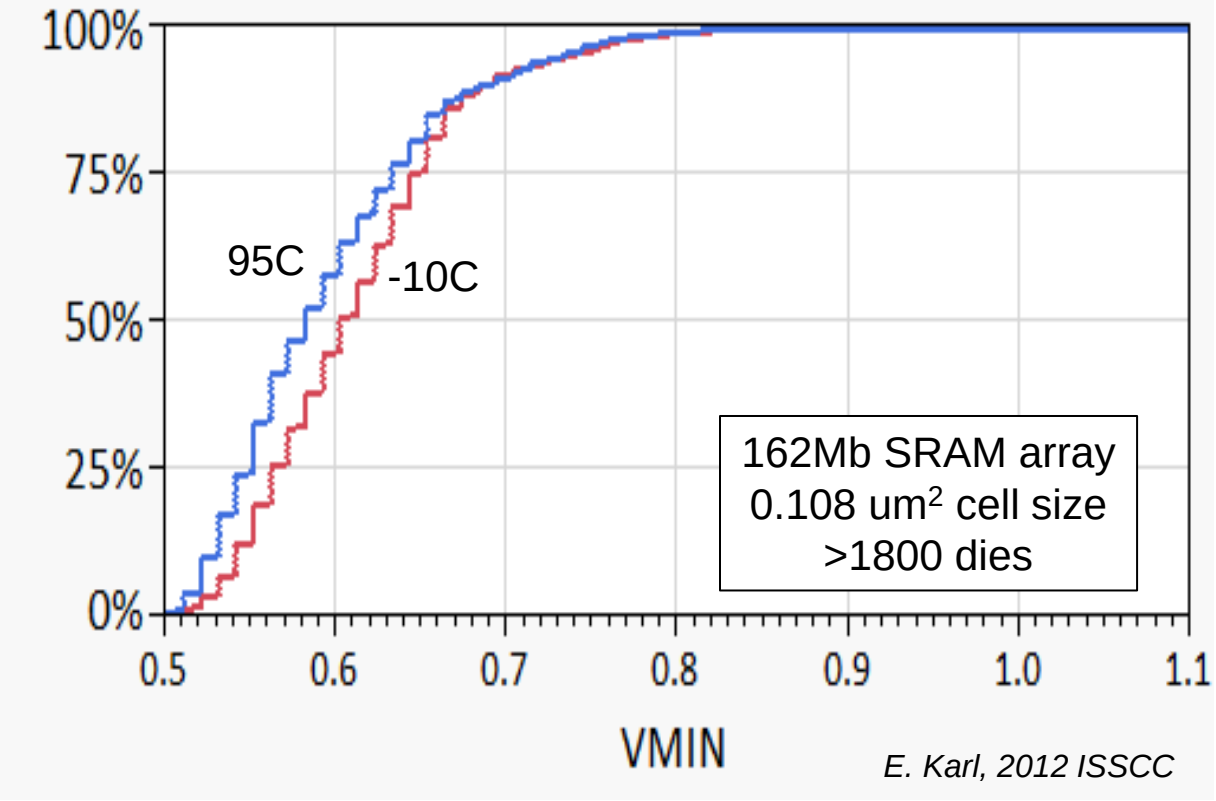
Minimum pitch scaled ~0.7x from 32 nm for ~2x transistor density improvement

SRAM Cells



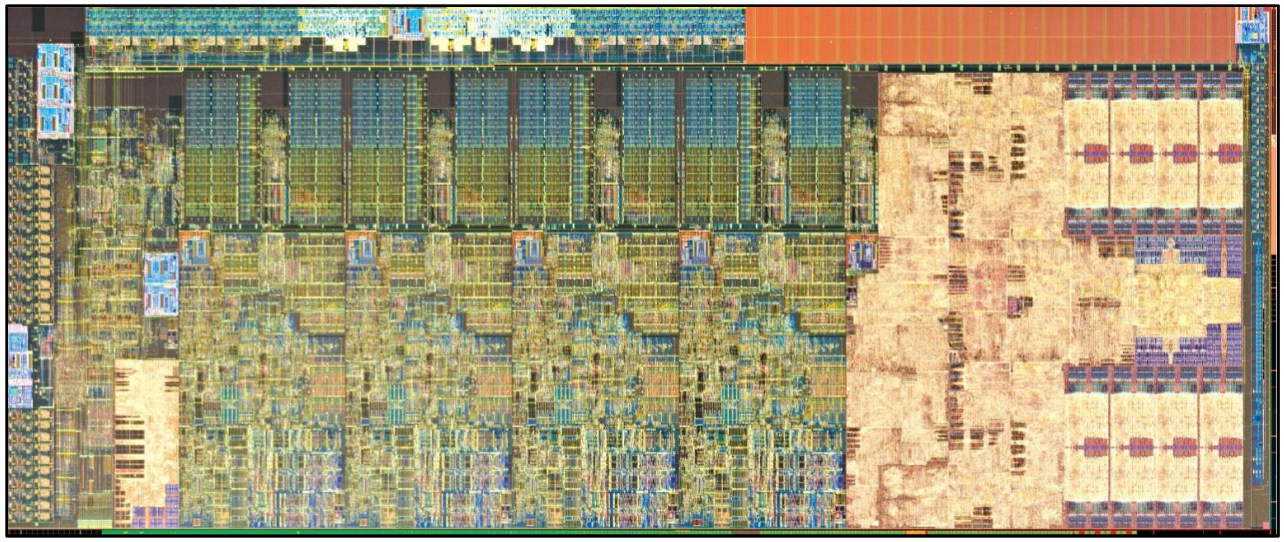
0.092 um² and 0.108 um² SRAM cells optimized for density and performance/power

SRAM Array V_{MIN}



0.60V medium active V_{MIN} for low power applications

3RD Generation Intel® Core™ Processor

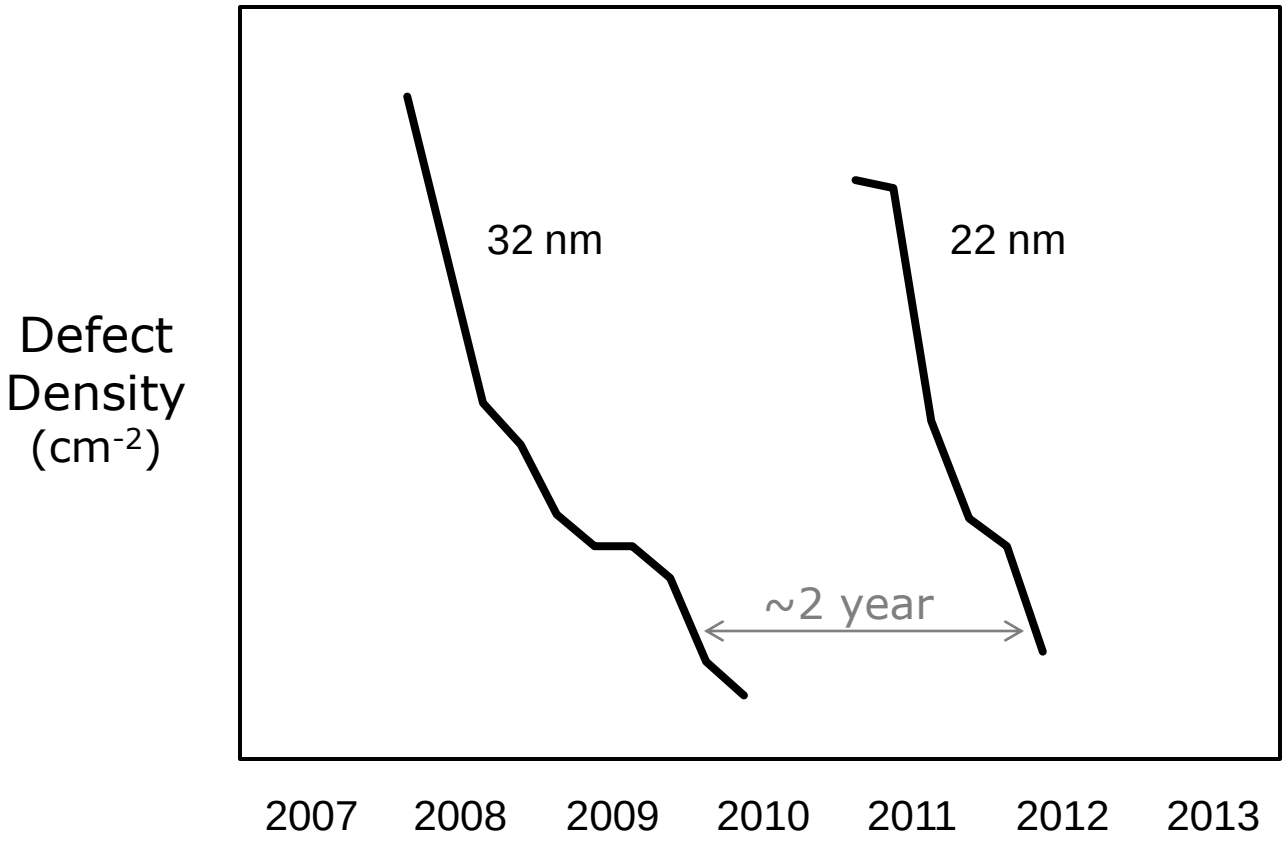


22 nm Tri-Gate Technology

4 Cores + Integrated Graphics

1.4 Billion Transistors, 160 mm^2

22 nm Defect Density Trend



22 nm defect density now at low levels needed for volume manufacturing

22 nm Manufacturing Fabs

D1D Oregon ✓

D1C Oregon

Fab 32 Arizona ✓

Fab 28 Israel ✓

Fab 12 Arizona

✓ In production 2Q ’12

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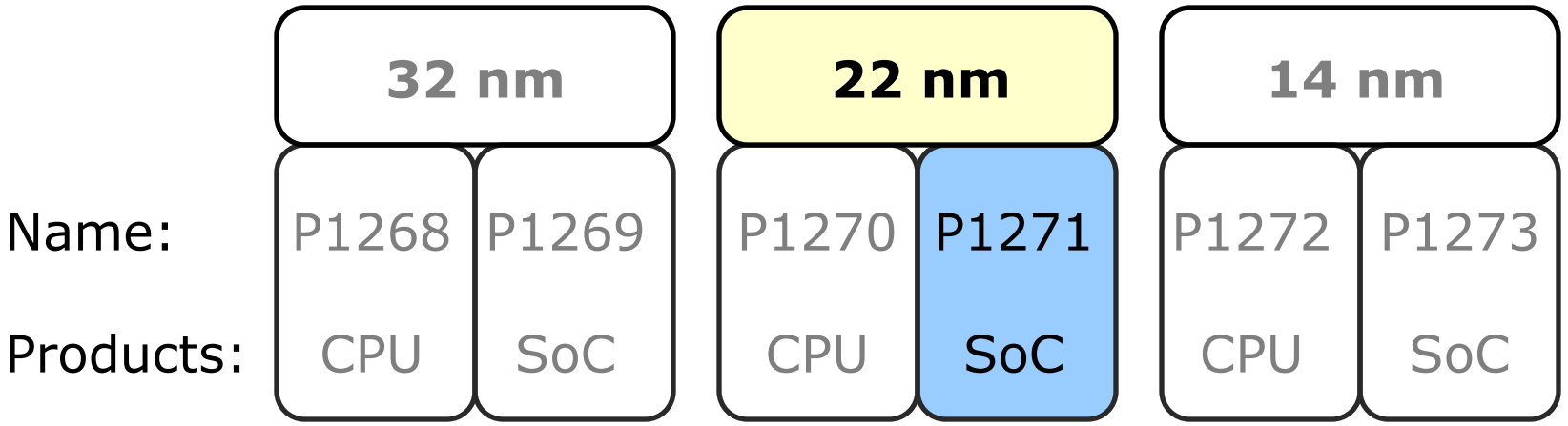
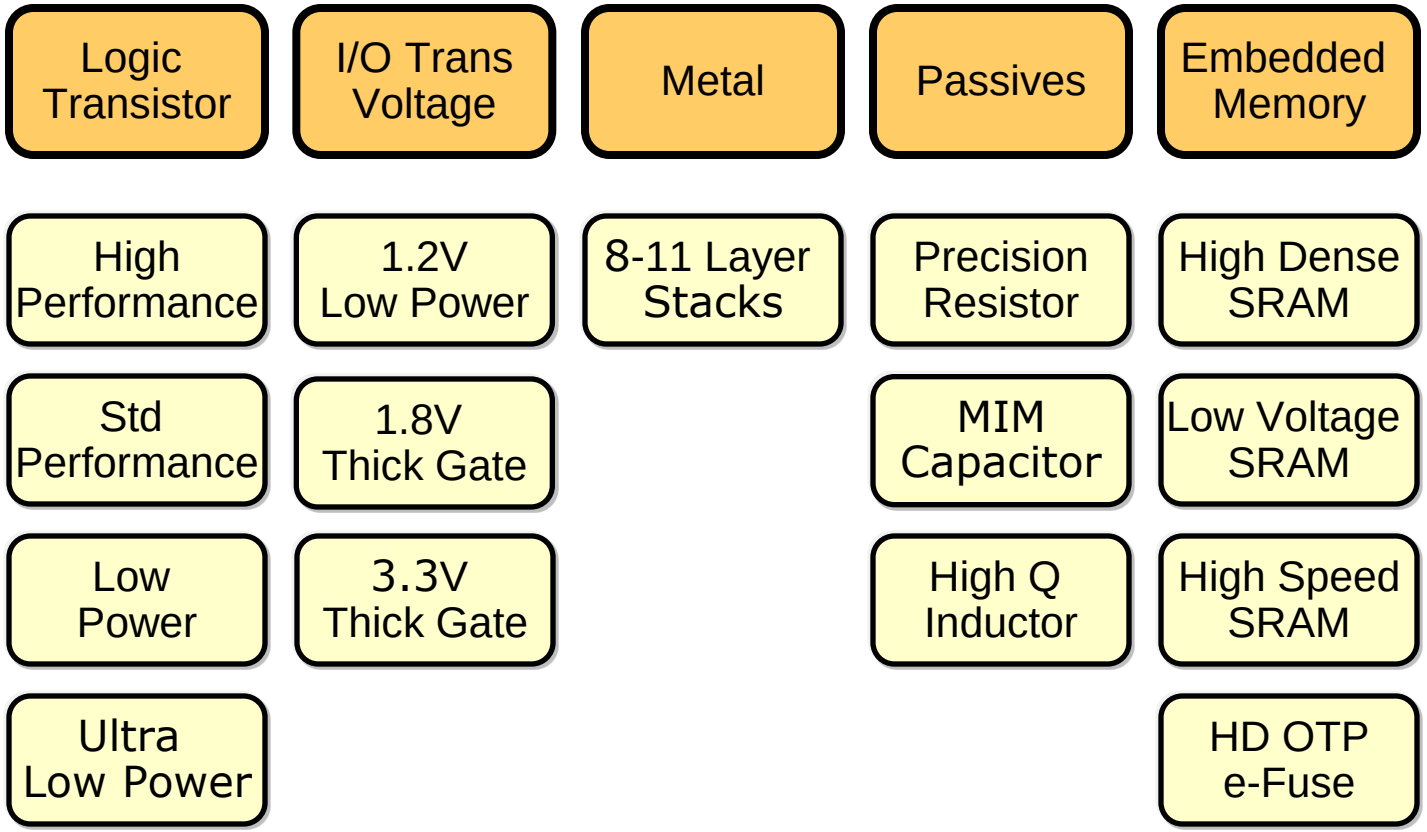
Intel® Technology Roadmap



CPU vs. SoC Technology Comparison

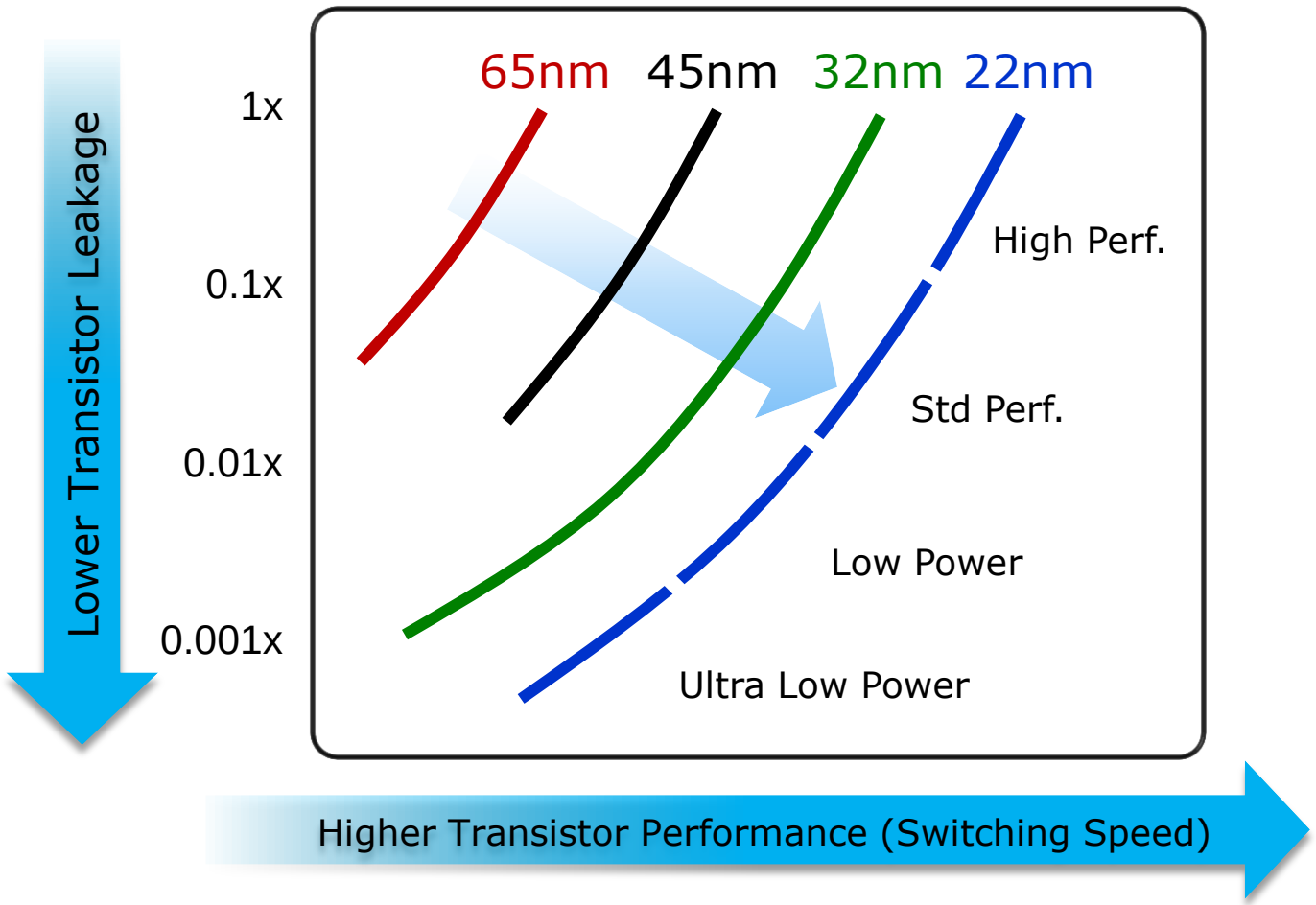
	CPU (P1270)	SoC (P1271)
Similarities		
Tri-Gate Structure	Same	Same
Tight Transistor Pitch	Same	Same
Dense SRAM Cell	Same	Same
Lower Level Interconnects	Same	Same
Fab Process Equipment	Same	Same
Differences		
Logic Transistors	High Speed	Low Leakage
I/O Transistors	Std Voltage	Std and High Volt
Upper Level Interconnects	High Speed	Dense
Precision Passives	None	R, C and L

22 nm SoC Technology Features



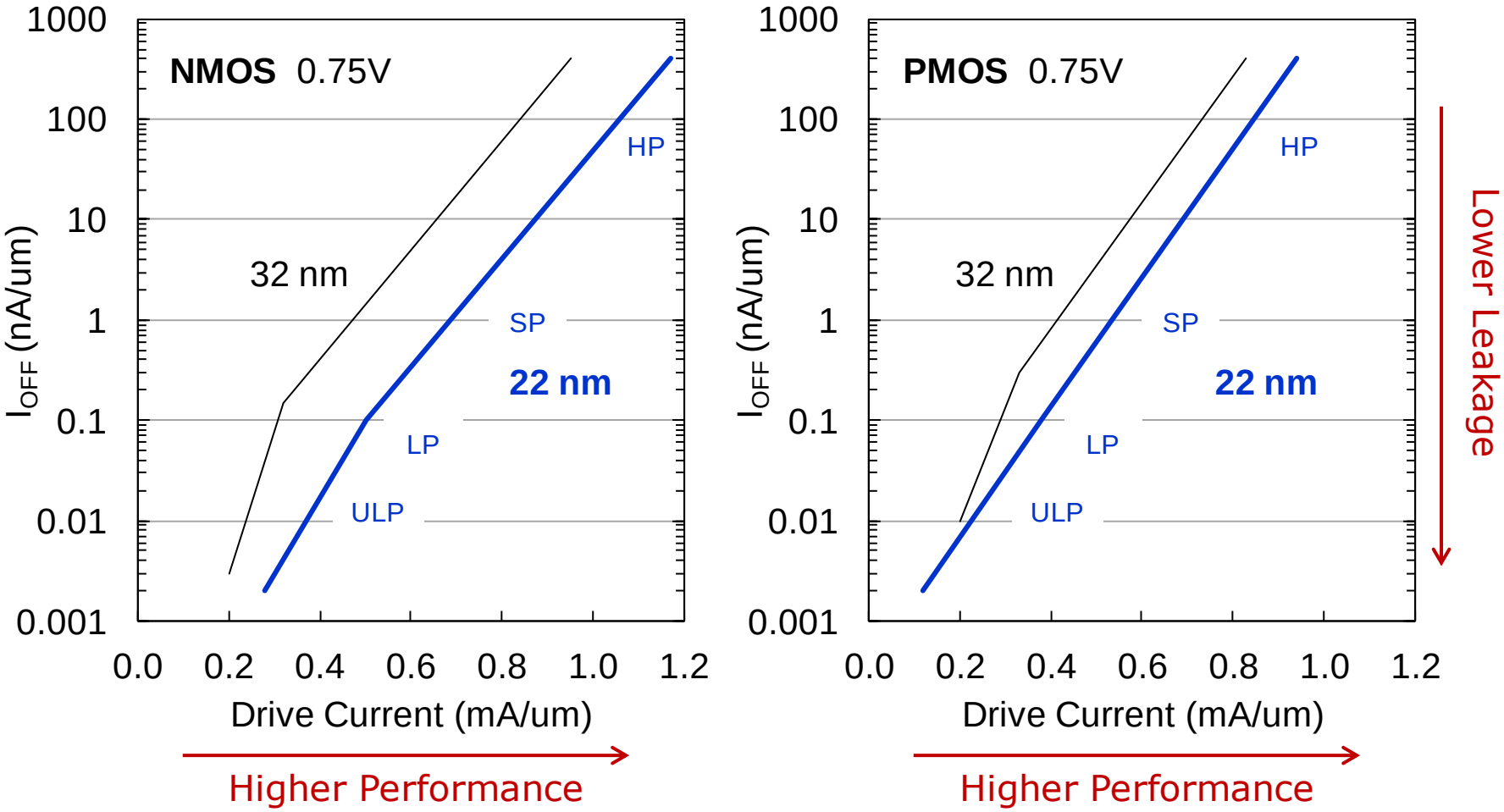
22 nm SoC technology offers a rich menu of feature options

Transistor Performance vs. Leakage



22 nm SoC technology offers a wide range of transistors

Transistor Performance vs. Leakage



22 nm SoC technology offers a wide range of transistors

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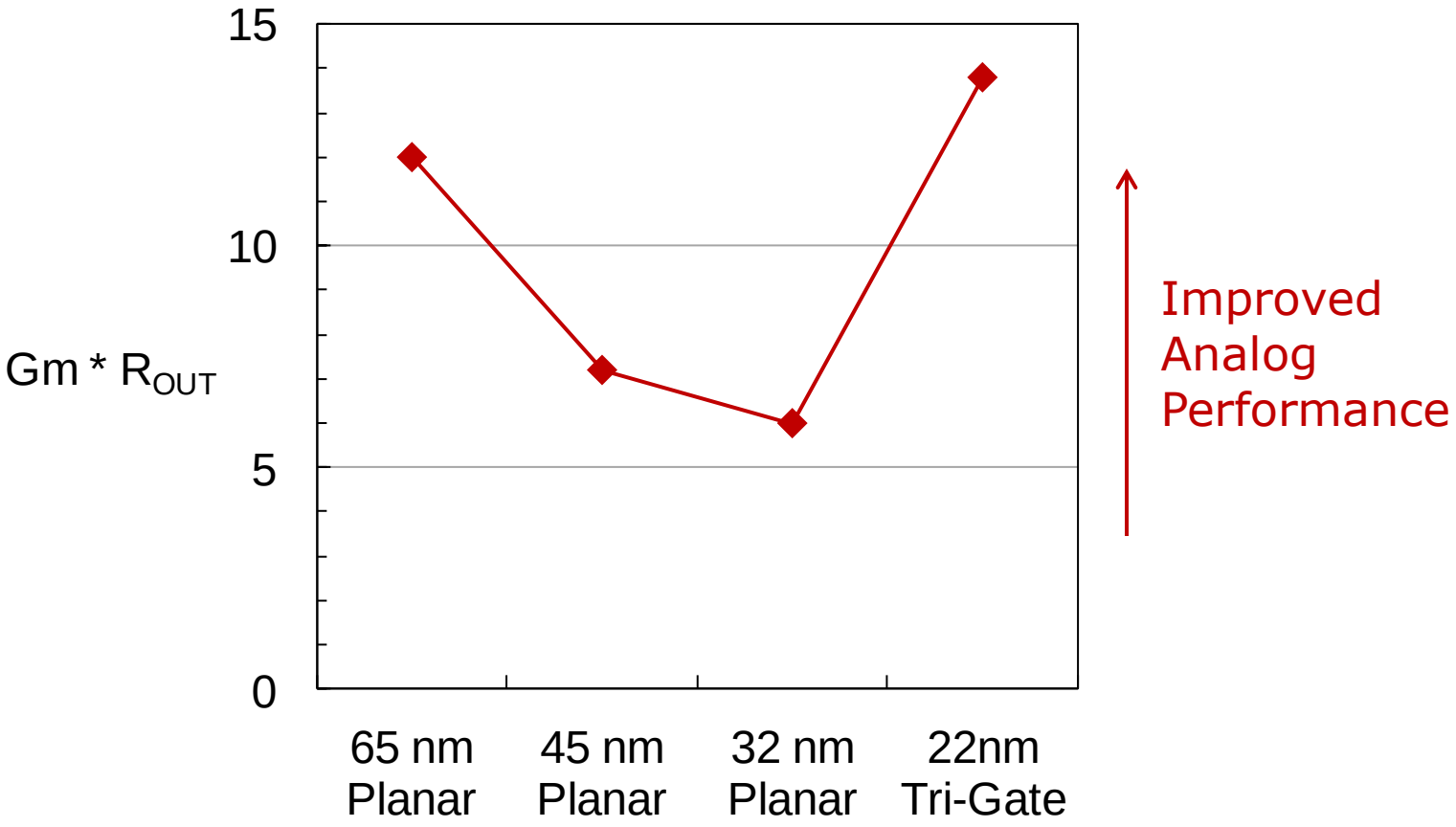
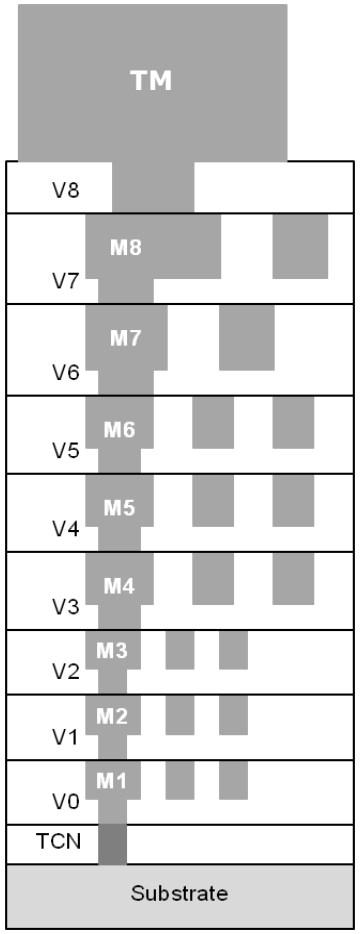
Analog Device Characteristics



22 nm Tri-Gate transistors provide improved Gm * R_{OUT} for improved analog circuit performance

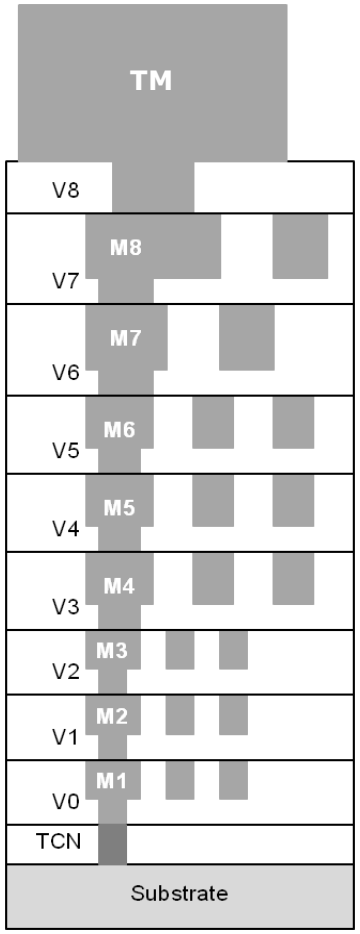
22 nm SoC Interconnect Options



Layer	A	B	C	
TM	14	14	14	um
M10	-	-	360	nm
M9	-	360	360	nm
M8	360	240	160	nm
M7	240	160	108	nm
M6	160	108	80	nm
M5	108	80	80	nm
M4	80	80	80	nm
M3	80	80	80	nm
M2	80	80	80	nm
M1	90	90	90	nm

Range of SoC interconnect options for low cost or high density

22 nm SoC Interconnect Options



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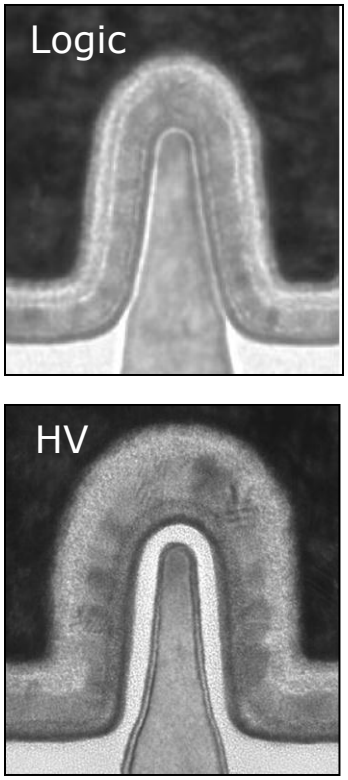
M6	160	108	80	nm
M5	108	80	80	nm
M4	80	80	80	nm
M3	80	80	80	nm
M2	80	80	80	nm
M1	90	90	90	nm

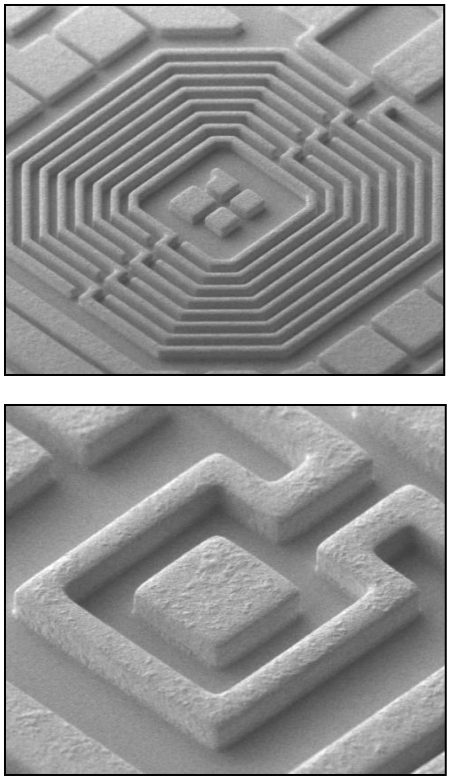
80 nm pitch is done with single patterning, thus an optimal pitch to use for this generation

22 nm SoC Device Features

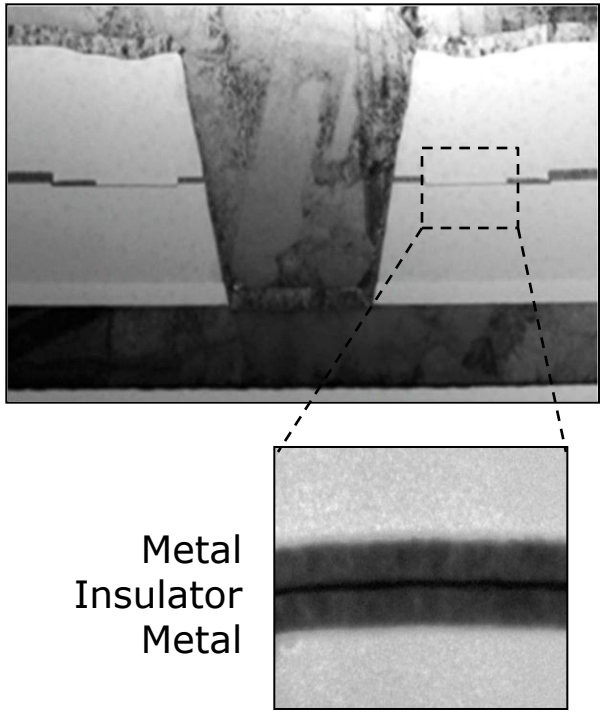
High Voltage I/O Transistors



Inductors



MIM Capacitor



2 Year Technology Cycles

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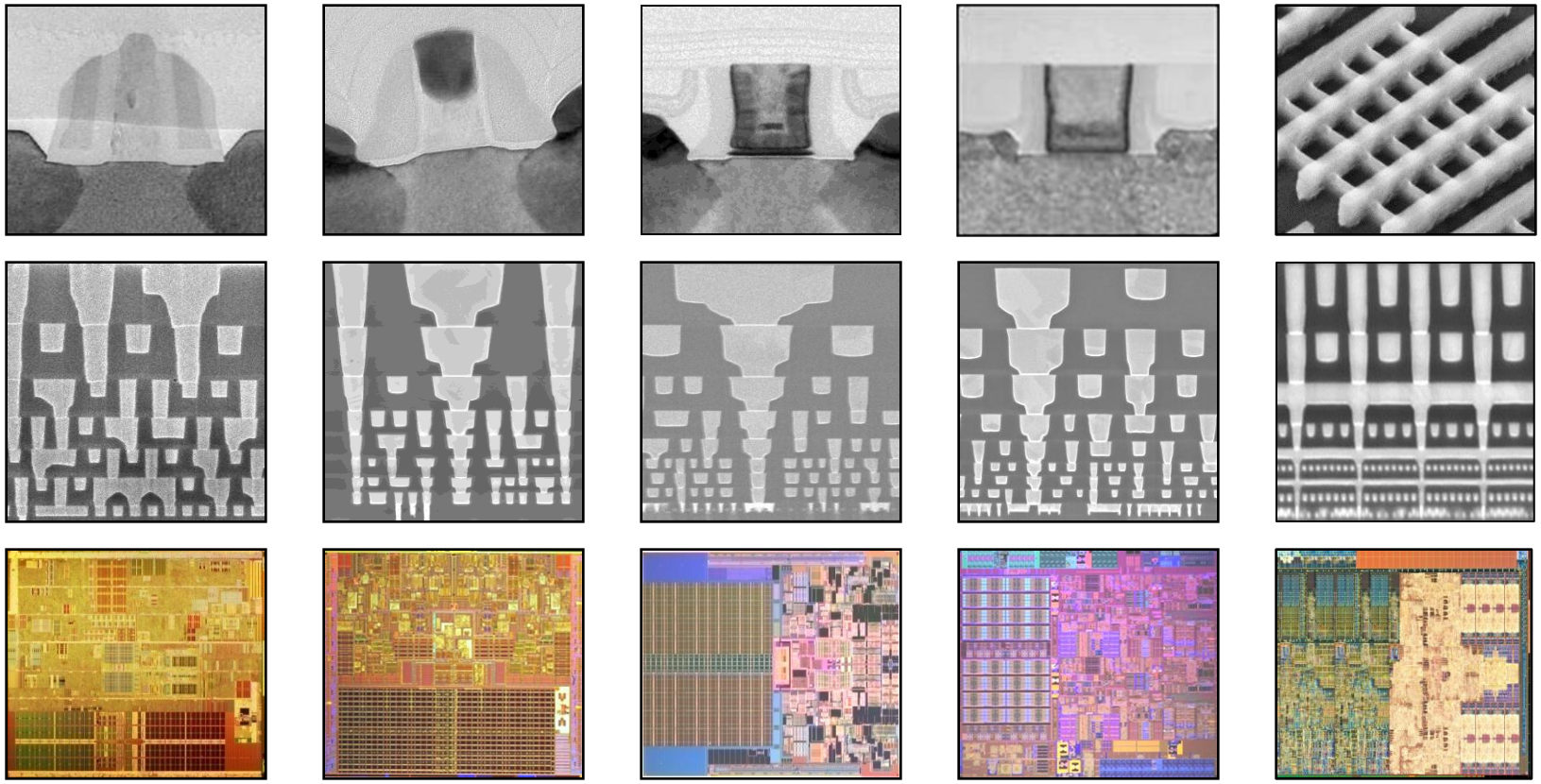
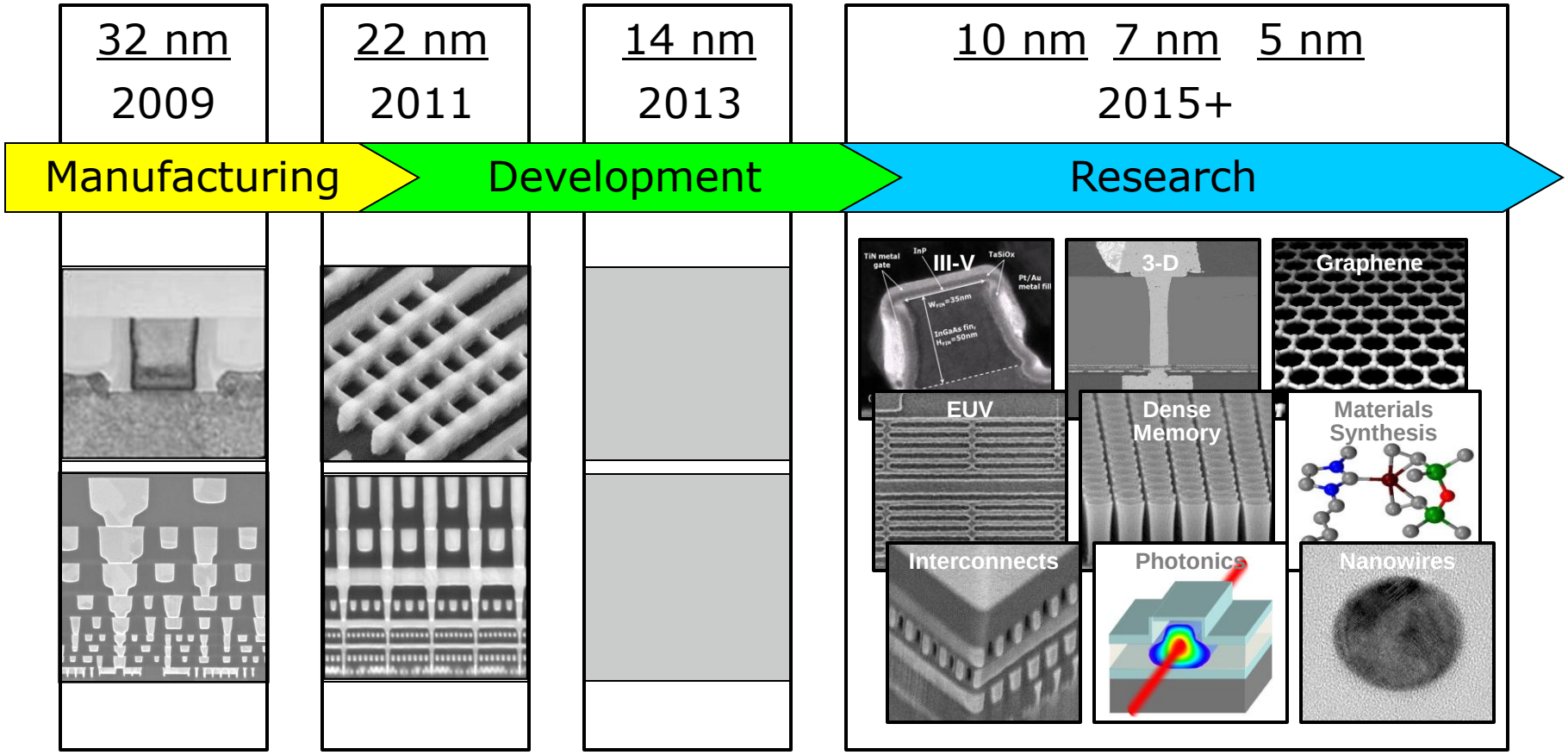
2003	2005	2007	2009	2011



Innovation Enabled Technology Pipeline



Future options subject to change

Advantage of an Integrated Device Manufacturer

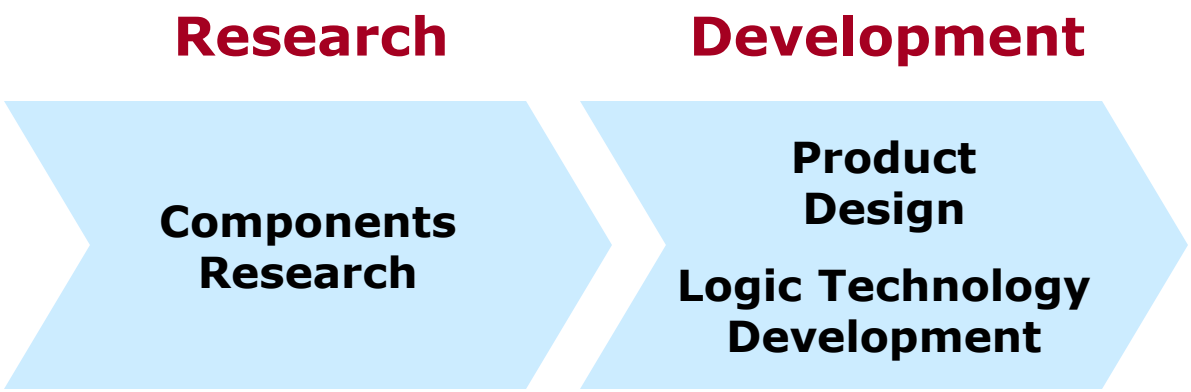
Research

Components Research

Equipment Vendors
Industry Consortia
Universities
Government Labs

- **Identify innovative technologies**

Advantage of an Integrated Device Manufacturer



- **Identify innovative technologies**

- **Co-optimize process+product**
- **Design for manufacturing**

Advantage of an Integrated Device Manufacturer

Research	Development	Manufacturing
Components Research	**Product Design** **Logic Technology Development**	**Wafer Manufacturing Fabs**
Equipment Vendors Industry Consortia Universities Government Labs	Design Tools Photo Masks Packaging	Oregon Arizona New Mexico Israel Ireland China
• **Identify innovative technologies**	• **Co-optimize process+product** • **Design for manufacturing**	• **Early product ramp** • **Rapid yield learning**

Summary

- Transistor scaling continues to provide improvements in performance, power and cost, but now with greater focus on power reduction
- Scaling no longer follows a “classical” path and requires continued innovations in materials and structures
- A highly integrated approach is needed to successfully bring innovative technologies from the research phase to high volume manufacturing
- Low power System-on-Chip technologies are increasingly important to support the wide range of features needed on mobile computing devices

Additional Sources of Information on This Topic:

More web based info:

www.intel.com/technology/architecture-silicon

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Risk Factors

The above statements and any others in this document that refer to plans and expectations for the second quarter, the year and the future are forward-looking statements that involve a number of risks and uncertainties. Words such as "anticipates," "expects," "intends," "plans," "believes," "seeks," "estimates," "may," "will," "should" and their variations identify forward-looking statements. Statements that refer to or are based on projections, uncertain events or assumptions also identify forward-looking statements. Many factors could affect Intel's actual results, and variances from Intel's current expectations regarding such factors could cause actual results to differ materially from those expressed in these forward-looking statements. Intel presently considers the following to be the important factors that could cause actual results to differ materially from the company's expectations. Demand could be different from Intel's expectations due to factors including changes in business and economic conditions, including supply constraints and other disruptions affecting customers; customer acceptance of Intel's and competitors' products; changes in customer order patterns including order cancellations; and changes in the level of inventory at customers. Uncertainty in global economic and financial conditions poses a risk that consumers and businesses may defer purchases in response to negative financial events, which could negatively affect product demand and other related matters. Intel operates in intensely competitive industries that are characterized by a high percentage of costs that are fixed or difficult to reduce in the short term and product demand that is highly variable and difficult to forecast. Revenue and the gross margin percentage are affected by the timing of Intel product introductions and the demand for and market acceptance of Intel's products; actions taken by Intel's competitors, including product offerings and introductions, marketing programs and pricing pressures and Intel's response to such actions; and Intel's ability to respond quickly to technological developments and to incorporate new features into its products. Intel is in the process of transitioning to its next generation of products on 22nm process technology, and there could be execution and timing issues associated with these changes, including products defects and errata and lower than anticipated manufacturing yields. The gross margin percentage could vary significantly from expectations based on capacity utilization; variations in inventory valuation, including variations related to the timing of qualifying products for sale; changes in revenue levels; segment product mix; the timing and execution of the manufacturing ramp and associated costs; start-up costs; excess or obsolete inventory; changes in unit costs; defects or disruptions in the supply of materials or resources; product manufacturing quality/yields; and impairments of long-lived assets, including manufacturing, assembly/test and intangible assets. The majority of Intel's non-marketable equity investment portfolio balance is concentrated in companies in the flash memory market segment, and declines in this market segment or changes in management's plans with respect to Intel's investments in this market segment could result in significant impairment charges, impacting restructuring charges as well as gains/losses on equity investments and interest and other. Intel's results could be affected by adverse economic, social, political and physical/infrastructure conditions in countries where Intel, its customers or its suppliers operate, including military conflict and other security risks, natural disasters, infrastructure disruptions, health concerns and fluctuations in currency exchange rates. Expenses, particularly certain marketing and compensation expenses, as well as restructuring and asset impairment charges, vary depending on the level of demand for Intel's products and the level of revenue and profits. Intel's results could be affected by the timing of closing of acquisitions and divestitures. Intel's results could be affected by adverse effects associated with product defects and errata (deviations from published specifications), and by litigation or regulatory matters involving intellectual property, stockholder, consumer, antitrust, disclosure and other issues, such as the litigation and regulatory matters described in Intel's SEC reports. An unfavorable ruling could include monetary damages or an injunction prohibiting Intel from manufacturing or selling one or more products, precluding particular business practices, impacting Intel's ability to design its products, or requiring other remedies such as compulsory licensing of intellectual property. A detailed discussion of these and other factors that could affect Intel's results is included in Intel's SEC filings, including the company's most recent Form 10-Q, Form 10-K and earnings release.

Rev. 5/4/12