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Today’s News

The world’s first 3-D Tri-Gate transistors on a production technology

New 22nm transistors have an unprecedented combination of power savings and performance gains.

These benefits will enable new innovations across a broad range of devices from the smallest handheld devices to powerful cloud-based servers.

The transition to 3-D transistors continues the pace of technology advancement, fueling Moore’s Law for years to come.

The world’s first demonstration of a 22nm microprocessor -- code-named Ivy Bridge -- that will be the first high-volume chip to use 3-D Tri-Gate transistors.
Energy-Efficient Performance Built on Moore’s Law

- Lower Transistor Leakage
- Higher Transistor Performance (Switching Speed)

Active Power per Transistor (normalized)

- 65nm Planar
- 45nm Planar
- 32nm Planar
- 22nm Tri-Gate

22 nm Tri-Gate transistors increase the benefit from a new technology generation

Source: Intel
Transistor Innovations Enable Technology Cadence

- **2003**: Invented SiGe Strained Silicon
- **2005**: 2nd Gen. SiGe Strained Silicon
- **2007**: Invented Gate-Last High-k Metal Gate
- **2009**: 2nd Gen. Gate-Last High-k Metal Gate
- **2011**: First to Implement Tri-Gate

**Strained Silicon**

**High k Metal gate**

**Tri-Gate**
Transistor Innovations Enable Cost Benefits of Moore’s Law to Continue

Source: Intel
22 nm Manufacturing Fabs

22nm upgrades to be completed 2011-12
Tri-Gate Achievement Results from Long Term Commitment to Research

Internal Research

Pathfinding

Development

Manufacturing

Tri-Gate Invented

Tri-Gate Selected for 22nm node

Single-fin transistor demonstrated
Multi-fin transistor demonstrated
Tri-gate SRAM cells demonstrated
Tri-gate RMG process flow developed

Tri-gate optimized for HVM

Bringing innovative technologies to HVM is the result of a highly coordinated internal research-development-manufacturing pipeline
“For years we have seen limits to how small transistors can get,” said Gordon E. Moore. “This change in the basic structure is a truly revolutionary approach, and one that should allow Moore’s Law, and the historic pace of innovation, to continue.”
3-D Tri-Gate transistors form conducting channels on three sides of a vertical fin structure, providing “fully depleted” operation.

*Transistors have now entered the third dimension!*

Source: Intel
22 nm 3-D Tri-Gate Transistor

Source: Intel
32 nm Planar Transistors

22 nm Tri-Gate Transistors

Source: Intel
Substrate voltage exerts some electrical influence on the inversion layer (where source-drain current flows). The influence of substrate voltage degrades electrical sub-threshold slope (transistor turn-off characteristics). NOT fully depleted.

Source: Intel
Std vs. Fully Depleted Transistors

Partially Depleted SOI (PDSOI)

Floating body exerts some electrical influence on inversion layer, degrading sub-threshold slope

NOT fully depleted

Not used by Intel

Source: Intel
Floating body eliminated and sub-threshold slope improved
Requires expensive extremely thin SOI wafer, which adds ~10% to total process cost
Not used by Intel

Source: Intel
Std vs. Fully Depleted Transistors

Fully Depleted Tri-Gate Transistor

Gate electrode controls silicon fin from three sides providing improved sub-threshold slope.

Inversion layer area increased for higher drive current.

Process cost adder is only 2-3%.

Source: Intel
Maximize current in “on” state (for improved performance)
Minimize current in “off” state (for lower power)
Switch very quickly between the two states (for performance)

Source: Intel
The “fully depleted” characteristics of Tri-Gate transistors provide a steeper sub-threshold slope that reduces leakage current.

Source: Intel
Transistor Operation

The steeper sub-threshold slope can also be used to target a lower threshold voltage, allowing transistors to operate at lower voltage to reduce power and/or improve switching speed.
Transistor gate delay (switching speed) slows down as operating voltage is reduced.

Source: Intel
22 nm planar transistors could provide some performance improvement, but would still have poor gate delay at low voltage.
Transistor Gate Delay

22 nm 3-D Tri-Gate transistors provide improved performance at high voltage and an unprecedented performance gain at low voltage.

Source: Intel
22 nm 3-D Tri-Gate transistors can operate at lower voltage with good performance, reducing active power by >50%
3-D Tri-Gate Transistor Benefits

- Dramatic performance gain at low operating voltage, better than Bulk, PDSOI or FDSOI
  - 37% performance increase at low voltage
  - >50% power reduction at constant performance
- Improved switching characteristics (On current vs. Off current)
- Higher drive current for a given transistor footprint
- Only 2-3% cost adder (vs. ~10% for FDSOI)

3-D Tri-Gate transistors are an important innovation needed to continue Moore’s Law

Source: Intel
22nm Product Update

Dadi Perlmutter
Executive Vice President
General Manager,
Intel Architecture Group
New 22nm 3-D transistors deliver unprecedented performance improvement and power reduction for Intel’s product portfolio

- This benefits smallest handhelds to powerful cloud-based servers
- 37% performance increase at low voltage vs. 32nm planar transistors*
- Consumes only half the power at the same performance level as 2-D transistors on 32nm planar chips*

* Based on Intel Internal Data
Intel Architecture Spans The Compute Continuum

- Desktops
- Laptops
- Embedded
- Smart TVs
- Netbooks
- Tablets
- Smartphones
- Servers / Cloud
Newest Manufacturing Technology Delivers Ivy Bridge

45 nm Process Technology
- Penryn
  - Intel® Core™ Microarchitecture
  - TICK

32 nm Process Technology
- Nehalem
  - NEW Intel® Microarchitecture
  - TOCK
- Westmere
  - NEW Intel® Microarchitecture (Nehalem)
  - TICK
- Sandy Bridge
  - NEW Intel® Microarchitecture
  - TOCK

22 nm Process Technology
- Ivy Bridge
  - NEW Intel® Microarchitecture (Sandy Bridge)
  - TICK
  - Intel's First 22 nm Processor

Cadence of Innovation Delivers New Microprocessor Efficiency on the 22 nm Process
Ivy Bridge
Sandy Bridge Migrated to 22nm Process Technology

Client: Efficient performance for thin and light form factors
• Increased performance vs. today’s 2nd generation Intel® Core™ product family
• Enhanced media and graphics performance with processor graphics
• Enhanced security features

Server: Increased performance and improved efficiency
• Integrated Storage Features

Further Demonstrating Intel Product and Process Leadership
IA Platforms for Low Power Segments
Optimized Performance for Phones, Tablets, and Consumer Electronics

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