Intel Demonstrates
High-k + Metal Gate Transistor Breakthrough
on 45 nm Microprocessors

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Risk Factors

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If we use any non-GAAP financial measures during the presentations, you will find on our website, intc.com, the required reconciliation to the most directly comparable GAAP financial measure.
Key Messages

- Intel has achieved a significant breakthrough in transistor technology by developing high-k + metal gate transistors for its 45 nm process that significantly reduce leakage power.

- High-k + metal gate transistors are the biggest advancement in transistor technology since the introduction of polysilicon gate MOS transistors in the late 1960s.

- Working 45 nm microprocessors have been made using these revolutionary high-k + metal gate transistors.

- These new 45 nm multi-core microprocessors will deliver higher performance and greater energy efficiency.

- Intel’s 45 nm products are on track to begin production in 2H ’07 with three factories scheduled to be manufacturing 45 nm by 1H ‘08.
# Intel's Logic Technology Evolution

<table>
<thead>
<tr>
<th>Process Name:</th>
<th>P1262</th>
<th>P1264</th>
<th><strong>P1266</strong></th>
<th>P1268</th>
<th>P1270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithography:</td>
<td>90 nm</td>
<td>65 nm</td>
<td><strong>45 nm</strong></td>
<td>32 nm</td>
<td>22 nm</td>
</tr>
</tbody>
</table>

*Moore's Law continues!*

Intel continues to develop a new technology generation every 2 years.
45 nm Technology Benefits

• Compared to today’s 65 nm technology, Intel’s 45 nm technology will provide the following product benefits:

  ~2x improvement in transistor density, for either smaller chip size or increased transistor count

  ~30% reduction in transistor switching power

  >20% improvement in transistor switching speed or
  >5x reduction in source-drain leakage power

  >10x reduction in gate oxide leakage power

• These performance and leakage improvements would not be possible without high-k + metal gate

• This process technology will provide the foundation to deliver improved performance/watt that will enhance the user experience
High-k + Metal Gate Transistors

High-k + metal gate transistors provide significant performance increase and leakage reduction, ensuring continuation of Moore’s Law.
High-k + Metal Gate Transistors

**Metal Gate**
- Increases the gate field effect

**High-k Dielectric**
- Increases the gate field effect
- Allows use of thicker dielectric layer to reduce gate leakage

**HK + MG Combined**
- Drive current increased >20% (>20% higher performance)
- Or source-drain leakage reduced >5x
- Gate oxide leakage reduced >10x

![Diagram of HK+MG Transistor](image)
High-k + Metal Gate Transistors

✓ Integrated 45 nm CMOS process
✓ High performance
✓ Low leakage
✓ Meets reliability requirements
✓ Manufacturable in high volume

Low Resistance Layer
Work Function Metal Different for NMOS and PMOS
High-k Dielectric Hafnium based
Silicon Substrate

“The implementation of high-k and metal gate materials marks the biggest change in transistor technology since the introduction of polysilicon gate MOS transistors in the late 1960s”

Gordon Moore
High-k + Metal Gate Transistors

• Specific metal gate and high-k dielectric materials are not being disclosed at this time

• There are hundreds of material options for metal gate electrodes and high-k dielectrics

• Identifying the HK+MG material combination that meets high performance, low leakage, reliability and manufacturing requirements is a very significant accomplishment

• No other company has reached this level of success and they are not expected to have HK+MG until the 32 nm generation or later
Intel’s Components Research group announced first working high-k + metal gate transistors in 2003
2006 45 nm SRAM Announcement

45 nm SRAM Chip

- 0.346 μm² cell
- 153 Mbit density
- 119 mm² chip size
- >1 billion transistors
- Functional silicon in Jan ‘06

45 nm SRAM test vehicle includes all transistor and interconnect features to be used on 45 nm microprocessors

January 2006

153 Mbit SRAM in Jan ‘06 used same process features as today’s 45 nm CPU, including high-k + metal gate transistors and cost effective 193 nm dry lithography
Penryn Die Photo

45 nm next generation Intel® Core™2 family processor
410 million transistors for dual core, 820 million for quad core

*World’s first working 45 nm CPU*
Penryn Family Processors

Grows the performance and energy efficiency lead established by Intel® Core™2 family and Intel® Xeon™ family processors

- Next step in Intel’s rapid technology cadence with second generation quad core in production 2H ’07
- Family codename Penryn with server, workstation, desktop, and mobile optimized versions
- New microarchitecture features for even greater performance and new capabilities
- New Intel® SSE4 instructions expand capabilities and performance for media/HPC applications
- Higher core speeds and larger caches
- Leading energy efficiency through design, new power management modes and Intel’s 45 nm silicon process

*Design is out of fab and working*
Penryn First Silicon Boots
Windows* Vista*, Mac OS X*, Windows* XP and Linux

* Other names and brands may be claimed as the property of others.
45 nm Yield Improvement Trend

45 nm defect reduction trend at expected 2 year offset from 65 nm
45 nm on track for production ramp in 2H ‘07
45 nm Manufacturing Fabs

D1D
Oregon
Ramp in 2H ‘07

Fab 32
Arizona
Ramp in 2H ‘07

Fab 28
Israel
Ramp in 1H ‘08

Three 300 mm factories are planned to be manufacturing 45 nm products by 1H ‘08
Summary

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*Intel is pulling further ahead of the competition*
Risk Factors

This presentation contains forward-looking statements that involve a number of risks and uncertainties. These statements do not reflect the potential impact of any mergers, acquisitions, divestitures, investments or other similar transactions that may be completed in the future. The information presented is accurate only as of today’s date and will not be updated. In addition to any factors discussed in the presentation, the important factors that could cause actual results to differ materially include the following: 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, significant pricing pressures, and product demand that is highly variable and difficult to forecast. 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Background Information
High-k + Metal Gate Transistor Tutorial

Transistors consist of these key structures:

- Silicon substrate
- Silicon channel
- Gate electrode
- Gate dielectric
- Source-drains
Since the late 1960’s transistors have been made with these basic materials.
A low resistance capping layer was added in the 1980’s to help improve transistor performance.
High-k + Metal Gate Transistor Tutorial

Transistors act as an electrical switch
In the “on” state current flow from source to drain should be high
High-k + Metal Gate Transistor Tutorial

Transistors act as an electrical switch
In the “off” state current flow from source to drain should be low
High-k + Metal Gate Transistor Tutorial

Thinning the gate dielectric increases gate electrode coupling to the Si channel (increases gate field effect) and helps to increase “on” current and reduce “off” current.
Thinning the gate dielectric too much can cause leakage current to flow through the normally insulating gate dielectric.
During normal operation a thin region depleted of conducting carriers is formed at the bottom of polysilicon gates, resulting in an undesired increase in the effective thickness of the gate dielectric.
The thicker effective gate dielectric results in degraded “on” current and increased “off” current.
Converting the polysilicon gate electrode to metal eliminates the depleted region and increases the gate field effect resulting in increased “on” current and decreased “off” current.
Converting SiO₂ gate dielectric to high-k allows thickening the dielectric layer while also increasing the gate field effect resulting in increased “on” current, decreased “off” current and significantly decreased gate leakage.