Minimizing Static Power Dissipation

Alessandro Yamhure
Outline

• What is Static Power?
• Multiple Threshold Voltages
• Ammonium-Sulfide Treated Gates
• Novel Transistor Structures
Power has been increasing rapidly

[ Source: Intel ]
Many other types of power consumption in addition to dynamic power:

- **Subthreshold Leakage**: Approaching 10-40% of active power.
- **Gate Leakage**: Was negligible, increasing due to thin gate oxides.
- **Short Circuit Current**: Fast edges keep to <10% of cap charging current.

![Diagram showing electrical components and their relationships]
Multiple Threshold Voltages

• Assign low threshold voltage to a few performance-critical transistors.
  – High subthreshold leakage for the performance critical transistors.

• Assign high threshold voltages to the majority of less timing-critical transistors.
  – Significantly reduce the overall leakage.
Multiple Threshold Voltages Cont’d…….

Future technologies are likely to offer three threshold voltages – or even more!

For example:

– High $V(\text{th})$: address-decoder and bus-driver circuits in a cache.
– Extra-high $V(\text{th})$: numerous cache bit-cells
– Low $V(\text{th})$: speed critical parts of processor core.
Ammonium-Sulfide Surface Treated Gates
(Purdue University)

GaAs MESFETs with Ammonium-Sulfide treated gates demonstrate a greater than 100-fold reduction in drain current minimum due to a decrease in Schottky gate leakage.
Reverse-biased Schottky gate diode conduction is dominant source of leakage.
Reverse-biased Schottky gate conduction

- Mainly thermionic emission of carriers over the junction potential barrier
- Increasing the Schottky barrier height would decrease number of carriers getting over the potential barrier.
Fig. 1. XPS Ga3d, As3d, and S2p core-level spectra for a succession of Au depositions on S-exposed n-type GaAs (100): (a) clean surface, (b) S exposed surface, (c) ~ 4 Å Au, (d) ~ 7 Å Au, (e) ~ 12 Å Au, (f) ~ 20 Å Au, (g) ~ 35 Å Au, and (h) ~ 50 Å Au.
Results

100-fold reduction in the drain current minimum – directly attributable to the reduction in leakage current of the ammonium-sulfide treated Schottky gates

\[ V_{ds} = 0.5V \]
\[ V_t = 0.2V \]
Use of Novel Transistor Structures
(Department of EE&CS, UC Berkeley)

Continued scaling of transistor gate lengths may require the adoption of novel transistor structures.
Advanced device structures

a) Bulk MOSFET

b) Double-Gate MOSFET

c) Ultra-Thin Body MOSFET
Reduced Vertical Electric Field

- Control of short channel effects and threshold voltage is achieved w/o dopants.
- no impurities means no depletion charge.
- Smaller average vertical electric field.
Gate leakage in UTB MOSFET is reduced by up to 3X.
Gate leakage in DG MOSFET is reduced up to 4X.
In Summary…

- Static power is starting to catch up with dynamic power
- Much research is going into reducing static power
  - On the architecture/circuit level
  - On the transistor level