INTRODUCTION - Chapter 1 in the Text

• This course is basically about silicon chip fabrication, the technologies used to manufacture ICs.
• We will place a special emphasis on computer simulation tools to help understand these processes and as design tools.
• These simulation tools are more sophisticated in some technology areas than in others, but in all areas they have made tremendous progress in recent years.

• 1960 and 1990 integrated circuits.
• Progress due to: Feature size reduction - 0.7X/3 years (Moore’s Law).
  Increasing chip size - ≈ 16% per year.
  “Creativity” in implementing functions.
The era of “easy” scaling is over. We are now in a period where technology and device innovations are required. Beyond 2020, new currently unknown inventions will be required.
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<tbody>
<tr>
<td>Technology Node (half pitch)</td>
<td>250 nm</td>
<td>180 nm</td>
<td>130 nm</td>
<td>90 nm</td>
<td>65 nm</td>
<td>45 nm</td>
<td>32 nm</td>
<td>22 nm</td>
<td>18 nm</td>
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<tr>
<td>MPU Printed Gate Length</td>
<td>100 nm</td>
<td>70 nm</td>
<td>53 nm</td>
<td>35 nm</td>
<td>25 nm</td>
<td>18 nm</td>
<td>13 nm</td>
<td>10 nm</td>
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<tr>
<td>DRAM Bits/Chip (Sampling)</td>
<td>256M</td>
<td>512M</td>
<td>1G</td>
<td>4G</td>
<td>16G</td>
<td>32G</td>
<td>64G</td>
<td>128G</td>
<td>128G</td>
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<tr>
<td>MPU Transistors/Chip (x10⁶)</td>
<td></td>
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<tr>
<td>Min Supply Voltage (volts)</td>
<td>1.8-2.5</td>
<td>1.5-1.8</td>
<td>1.2-1.5</td>
<td>0.9-1.2</td>
<td>0.8-1.1</td>
<td>0.7-1.0</td>
<td>0.6-0.9</td>
<td>0.5-0.8</td>
<td>0.5-0.7</td>
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- Assumes CMOS technology dominates over entire roadmap.
- 2 year cycle moving to 3 years (scaling + innovation now required).

1990 IBM demo of Å scale “lithography”.
Technology appears to be capable of making structures much smaller than currently known device limits.
Historical Perspective

- Invention of the bipolar transistor - 1947, Bell Labs.
- Shockley’s “creative failure” methodology
- Grown junction transistor technology of the 1950s
- Alloy junction technology of the 1950s.

- Double diffused transistor technology of the 1950s.
• The planar process (Hoerni - Fairchild, late 1950s).
• First “passivated” junctions.

• Basic lithography process which is central to today’s chip fabrication.
• Lithographic process allows integration of multiple devices side by side on a wafer.

• Schematic cross-section of a modern silicon IC.
Computer Simulation Tools (TCAD)

• Most of the basic technologies in silicon chip manufacturing can now be simulated. Simulation is now used for:
  • Designing new processes and devices.
  • Exploring the limits of semiconductor devices and technology (R&D).
  • “Centering” manufacturing processes.
  • Solving manufacturing problems (what-if?)

• Actual cross-section of a modern microprocessor chip. Note the multiple levels of metal and planarization. (Intel website).
• Simulation of an advanced local oxidation process.

• Simulation of photoresist exposure.
Challenges For The Future

• Having a “roadmap” suggests that the future is well defined and there are few challenges to making it happen.

• The truth is that there are enormous technical hurdles to actually achieving the forecasts of the roadmap. Scaling is no longer enough.

• 3 stages for future development:

  “Technology Performance Boosters”

  Invention

  • Spin-based devices
  • Molecular devices
  • Rapid single flux quantum
  • Quantum cellular automata
  • Resonant tunneling devices
  • Single electron devices

Materials/process innovations
NOW

Device innovations
IN 5-15 YEARS??

Beyond Si CMOS
IN 15 YEARS??

Silicide
Poly
Gate
Sidewall
Spacer
Gate
Dielectric
Source
Drain
S/D Ext
S/D Ext
Substrate

S
S/D Ext
Dielectric
SiO₂
Si back gate

Silicon VLSI Technology
Fundamentals, Practice and Modeling
By Plummer, Deal & Griffin

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Upper Saddle River, NJ
Broader Impact of Silicon Technology

- Many other applications e.g. MEMs and many new device structures e.g. carbon nanotube devices, all use basic silicon technology for fabrication.
Summary of Key Ideas

• ICs are widely regarded as one of the key components of the information age.

• Basic inventions between 1945 and 1970 laid the foundation for today's silicon industry.

• For more than 40 years, "Moore's Law" (a doubling of chip complexity every 2-3 years) has held true.

• CMOS has become the dominant circuit technology because of its low DC power consumption, high performance and flexible design options. Future projections suggest these trends will continue at least 15 more years.

• Silicon technology has become a basic “toolset” for many areas of science and engineering.

• Computer simulation tools have been widely used for device, circuit and system design for many years. CAD tools are now being used for technology design.

• Chapter 1 also contains some review information on semiconductor materials and semiconductor devices. These topics will be useful in later chapters of the text.