R&D in the Semiconductor Industry
What does the Future Hold?

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Semiconductor Technology is how computer chips are made
At 1976 transistor prices: an iPod would cost $3.4B and be as big as a football field.
How small are transistors today?

2010: 1/3000\textsuperscript{th} of a human hair (32 nm) . . . and shrinking
Moore’s Law sets the pace

Doubling every 2-3 years since 1970

http://www.wikipedia.org
The SIA Roadmap
Semiconductor Industry Association

The pace of computer advancement will continue:

<table>
<thead>
<tr>
<th>Year of Production</th>
<th>2010</th>
<th>2013</th>
<th>2016</th>
<th>2019</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feature Size [nm]</td>
<td>45</td>
<td>32</td>
<td>23</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Memory Chip Size</td>
<td>4 G</td>
<td>8 G</td>
<td>16 G</td>
<td>32 G</td>
<td>64 G</td>
</tr>
<tr>
<td><strong>Microprocessors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transistors per chip</td>
<td>2.2 B</td>
<td>4.4 B</td>
<td>9 B</td>
<td>18 B</td>
<td>35 B</td>
</tr>
</tbody>
</table>
How can this rate of progress be sustained?
Part 1:
The Technology
How does it work?

**Photolithography** is the technique for creating circuit patterns and is very similar to darkroom photography.
Smaller wavelengths of light create smaller patterns on the chip.
EUV photolithography enables another decade of progress for computer chips.

A great place to do advanced EUV research is at a Synchrotron, like the ALS at Lawrence Berkeley National Lab, a DOE Office of Science-supported lab.

This research supports the commercialization of nanotechnology.
Eleven Nobel Laureates

Ernest Orlando Lawrence
Melvin Calvin
Owen Chamberlain
Steven Chu
Donald A. Glaser

Luis W. Alvarez
Yuan T. Lee
Edwin M. McMillan
Glenn T. Seaborg
Emilio G. Segrè
George F. Smoot
Serving the National Scientific Community – Industry and Academic: Berkeley Lab’s Major Scientific Facilities

- Advanced Light Source
- National Energy Research Scientific Computing Center
- Molecular Foundry
- Joint Genome Institute
- National Center for Electron Microscopy
The Advanced Light Source

20 October 2010

[Diagram of the Advanced Light Source (ALS)]

[Graph showing brightness (photons/sec / mm² / mrad² / 0.1% BW)]

- **ALS Bend Magnet**
- **ALS Undulator**
- **The ALS**

[^1]: [The Advanced Light Source](https://www.lbl.gov/Science-Area/Lines-of-Research/)
Chipmaking starts with a mask

You have to hunt for defects. . .
Uhhh...not quite
We find defects that could ruin the mask.

The AIT EUV mask microscope.
Defects detected with the EUV microscope
The SEMATECH Berkeley Microfield Exposure Tool (MET)

The highest resolution EUV printing tool in the world
World-record patterning demonstrates the future of lithography
World-record patterning demonstrates the future of lithography
Part 2: The Economics
Why Moore’s Law?
The Virtuous Cycle

R&D (Innovation) → Lower Cost / Function (Moore’s Law)

$’s

Increasing Semiconductor Revenue → Expanding Applications (more products)
Innovation is Key to Semiconductor Industry Revenue

$10-20 Billion
R&D investment

Technology innovation is the driver

$250 Billion
semiconductor devices revenue

$2 Trillion
consumer electronics + related services

SIA, IBM
Companies work together for pre-competitive research.
One Example: SEMATECH and Lawrence Berkeley Lab (LBNL)

SEMATECH invested over $20M in equipment placed at LBNL to support semiconductor industry R&D

SEMATECH funds EUV research at LBNL over $4M/year

SEMATECH plans another round ($15M) of investment in LBNL from 2010-12
Semiconductor Technology: A United States Strength

Semiconductor devices are the second largest export good in the US

US based companies have 51% of the world market share in semiconductors

The semiconductor/electronic component industry (manufacturing, research, and development) employed 493,000 people in the United States in ‘08

That number dropped to 430,000 in ‘09

SIA and Bureau of Labor Statistics
Industry-Government Partnerships

• Funding research and partnerships with industry boosts US companies and promotes our unique competitive edge
• The DOE Labs, like Lawrence Berkeley, are a national resource
• Industry partnerships with government apply the expertise resident in the DOE labs to today’s problems
• What’s at stake?
  – If DOE funding is cut or these relationships are not encouraged, jobs can easily go elsewhere
  – US dominance in semiconductor technology
• What is required?
  – Increase DOE and other funding for basic research with industry partners
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