Industry Overview

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Revision Date: 12-1-2008 INDUSTRY.PPT
OUTLINE

§ Terminology
§ History of the Semiconductor Industry
§ Worldwide Semiconductor Industry
§ New Technology
§ Semiconductor Manufacturing
§ What New in Microchips
§ SILICON
§ GERMANIUM
§ GALLIUM ARSENIDE
§ SINGLE CRYSTAL
§ SEMICONDUCTORS
§ WAFER
§ N-TYPE
§ P-TYPE
§ TRANSISTOR
§ INTEGRATED CIRCUIT
Pure silicon has only $1 / 1,000,000,000$ atoms of impurity (25 crabapple trees in a forest covering entire U.S. with trees every 50 ft.

n-type or p-type silicon has impurities intentionally introduced at the level of $1 / 1,000,000$ atoms (thus 99.9999% pure!!)
TERMINOLOGY

mil = 1 / 1000 inch = 25.4 μm
micrometer = 1 / 1,000,000 meter
Angstrom = 1 / 10,000,000,000 meter

1 MICROMETER IS TWO WAVELENGTHS OF GREEN LIGHT LONG

A 1 MICRON WIDE LINE ON A 4 INCH DIAMETER SILICON WAFER IS THE SAME SCALE AS A 100 FOOT WIDE ROAD ON NORTH AMERICA

A HAIR IS ~100 MICROMETERS
HISTORY OF THE SEMICONDUCTOR INDUSTRY

- 1942 Very Pure Silicon and Germanium
- 1947 pn Junction Diodes Invented
- 1947 The Junction Transistor is Invented at Bell Labs by Bardeen, Brattain and Schockley
- 1950 Single Crystal by Teal and Little at Bell Labs
- 1954 Texas Instruments Introduces Commercial Production of the Transistor
- 1958 Integrated Circuits Invented by Kilby at TI
- 1960 First Planer Integrated Circuits Invented by Noyce at Farichild Co.
- 1962 First Commercial Integrated Circuits

Transistor inventors (from left), Dr. Walter Brattain, Dr. William Shockley, and Dr. John Bardeen.
## WORLDWIDE INDUSTRY RANKINGS

<table>
<thead>
<tr>
<th>Industry</th>
<th>Value (in dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BANKS: COMMERCIAL &amp; SAVINGS</td>
<td>1,252,970,000,000</td>
</tr>
<tr>
<td>MOTOR VEHICLES AND PARTS</td>
<td>1,177,548,000,000</td>
</tr>
<tr>
<td>TRADING (STOCKS, ETC)</td>
<td>1,120,886,000,000</td>
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<tr>
<td>INSURANCE</td>
<td>1,199,445,000,000</td>
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<tr>
<td>PETROLEUM REFINING</td>
<td>991,388,000,000</td>
</tr>
<tr>
<td>ELECTRONICS</td>
<td>809,741,000,000</td>
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<tr>
<td>FOOD AND PHARMACEUTICALS</td>
<td>705,805,000,000</td>
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<tr>
<td>TELECOMMUNICATIONS</td>
<td>533,350,000,000</td>
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<tr>
<td>CHEMICALS</td>
<td>275,002,000,000</td>
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<tr>
<td>COMPUTERS (OFFICE EQUIPMENT)</td>
<td>251,575,000,000</td>
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<tr>
<td>BUILDING MATERIALS</td>
<td>199,916,000,000</td>
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<tr>
<td>INDUSTRIAL AND FARM EQUIPMENT</td>
<td>197,789,000,000</td>
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<tr>
<td>METAL PRODUCTS</td>
<td>193,277,000,000</td>
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<tr>
<td>AEROSPACE</td>
<td>166,558,000,000</td>
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</table>

*Source: Fortune Magazine August 4, 1997*
## WORLDWIDE ELECTRONICS INDUSTRY

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
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<tbody>
<tr>
<td>Consumer Electronics</td>
<td>$60.7</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>$247</td>
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<td>Measurement Equipment</td>
<td>$47.3</td>
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<tr>
<td>Medical Electronics</td>
<td>$16.9</td>
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<tr>
<td>Professional Electronics</td>
<td>$94.9</td>
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<tr>
<td>Telecommunications</td>
<td>$58.0</td>
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<tr>
<td>Automation</td>
<td>$46.6</td>
</tr>
<tr>
<td>Data Processing</td>
<td>$191.5</td>
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<tr>
<td>Software</td>
<td>$145.2</td>
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<tr>
<td>Office Automation</td>
<td>$26.0</td>
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</table>

**Total $809.7 Billion**


EETIMES.COM December 2006
### WORLD’S TOP 20 ELECTRONICS COMPANIES

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Revenues</th>
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</thead>
<tbody>
<tr>
<td>GENERAL ELECTRIC</td>
<td>U.S.</td>
<td>$79,179</td>
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<tr>
<td>IBM CORP</td>
<td>U.S.</td>
<td>$75,947</td>
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<tr>
<td>HITACHI CORP</td>
<td>JAPAN</td>
<td>$75,669</td>
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<td>MATSUSHITA</td>
<td>JAPAN</td>
<td>$68,148</td>
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<tr>
<td>SIEMENS AG</td>
<td>GERMANY</td>
<td>$63,705</td>
</tr>
<tr>
<td>SONY CORP</td>
<td>JAPAN</td>
<td>$50,278</td>
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<tr>
<td>TOSHIBA CORP</td>
<td>JAPAN</td>
<td>$48,416</td>
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<td>NEC CORP</td>
<td>JAPAN</td>
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<td>PHILIPS NV</td>
<td>NETHERLANDS</td>
<td>$41,037</td>
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<td>FUJITSU LTD</td>
<td>JAPAN</td>
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<td>HP</td>
<td>U.S.</td>
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<td>ABB</td>
<td>SWITZERLAND</td>
<td>$34,574</td>
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<td>MITSUBISHI</td>
<td>JAPAN</td>
<td>$33,073</td>
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<tr>
<td>ALCATEL ALSTHOM</td>
<td>FRANCE</td>
<td>$31,684</td>
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<tr>
<td>MOTOROLA</td>
<td>U.S.</td>
<td>$27,973</td>
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<td>SAMSUNG</td>
<td>KOREA</td>
<td>$24,710</td>
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<tr>
<td>INTEL</td>
<td>U.S.</td>
<td>$20,847</td>
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<td>CONPAQ COMPUTER</td>
<td>U.S.</td>
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<td>DIGITAL EQUIPMENT</td>
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<td>ELECTROLUX</td>
<td>SWEDEN</td>
<td>$16,399</td>
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**SOURCE:** FORTUNE AUGUST 1997
## WORLD’S TOP 20 SEMICONDUCTOR MANUFACTURERS

<table>
<thead>
<tr>
<th>Company</th>
<th>Revenue</th>
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<tbody>
<tr>
<td>INTEL</td>
<td>$31,359 MILLION</td>
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<tr>
<td>SAMSUNG ELECTRONICS</td>
<td>$19,207</td>
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<tr>
<td>TEXAS INSTRUMENTS</td>
<td>$12,832</td>
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<tr>
<td>TOSHIBA</td>
<td>$10,166</td>
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<tr>
<td>STMICROELECTRONICS</td>
<td>$9,931</td>
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<tr>
<td>RENESAS TECHNOLOGY</td>
<td>$8,221</td>
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<tr>
<td>ADVANCED MICRO DEVICES</td>
<td>$7,471</td>
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<td>HYNIX</td>
<td>$7,365</td>
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<tr>
<td>NXP</td>
<td>$6,221</td>
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<tr>
<td>FREESCALE SEMICONDUCTOR</td>
<td>$6,059</td>
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<tr>
<td>NEC</td>
<td>$5,696</td>
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<td>QIMONDA</td>
<td>$5,549</td>
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<tr>
<td>MICRON TECHNOLOGY</td>
<td>$5,290</td>
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<tr>
<td>INFINEON TECHNOLOGIES</td>
<td>$5,195</td>
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<td>SONY</td>
<td>$4,875</td>
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<tr>
<td>QUALCOMM</td>
<td>$4,466</td>
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<tr>
<td>MATSUSHITA ELECTRIC</td>
<td>$4,124</td>
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<tr>
<td>BROADCOM</td>
<td>$3,657</td>
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<tr>
<td>SHARP ELECTRONICS</td>
<td>$3,476</td>
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<tr>
<td>ELPIDA MEMORY</td>
<td>$3,354</td>
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<tr>
<td>IBM MICROELECTRONICS</td>
<td>$3,151</td>
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</tbody>
</table>

10 of these have manufacturing sites in the U.S.A.

7 of these are Affiliates of the Microelectronic Engineering Program at RIT.

SOURCE: global-electronics.net 2006
## Semiconductor Revenue Leaders

<table>
<thead>
<tr>
<th>2006 Rank</th>
<th>2005 Rank</th>
<th>Company</th>
<th>Country of origin</th>
<th>Revenue (million $ USD)</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Intel</td>
<td>US</td>
<td>31 542</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Samsung</td>
<td>South Korea</td>
<td>19 842</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Texas Instruments</td>
<td>US</td>
<td>12 600</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Toshiba Semiconductors</td>
<td>Japan</td>
<td>10 141</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>STMicroelectronics</td>
<td>France-Italy</td>
<td>9 854</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Renesas Technology (merger of Mitsubishi and Hitachi Semiconductors)</td>
<td>Japan</td>
<td>7 900</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>Hynix</td>
<td>US</td>
<td>7 865</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>AMD (1)</td>
<td>US</td>
<td>7 506</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Freescale (3)</td>
<td>US</td>
<td>5 988</td>
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<tr>
<td>10</td>
<td>9</td>
<td>NXP (spin-off from Philips Semiconductors) (2)</td>
<td>US</td>
<td>5 874</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>NEC Semiconductors</td>
<td>Japan</td>
<td>5 679</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>Qimonda (4) (spin-off from Infineon)</td>
<td>Germany</td>
<td>5 413</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>Micron Technology</td>
<td>US</td>
<td>5 210</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>Infineon (4)</td>
<td>Germany</td>
<td>5 119</td>
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<td>15</td>
<td>13</td>
<td>Sony</td>
<td>Japan</td>
<td>4 852</td>
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<td>16</td>
<td>16</td>
<td>Qualcomm</td>
<td>US</td>
<td>4 529</td>
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<tr>
<td>17</td>
<td>14</td>
<td>Matsushita Electric</td>
<td>Japan</td>
<td>4 022</td>
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<tr>
<td>18</td>
<td>20</td>
<td>Broadcom</td>
<td>US</td>
<td>3 668</td>
</tr>
<tr>
<td>19</td>
<td>18</td>
<td>Elpida Memory</td>
<td>US</td>
<td>3 527</td>
</tr>
<tr>
<td>20</td>
<td>17</td>
<td>Sharp Electronics</td>
<td>Japan</td>
<td>3 341</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other companies</td>
<td>Other companies</td>
<td>81 912</td>
</tr>
</tbody>
</table>

**Total Revenue**: 260 194
The Semiconductor Industry has grown from $14 Billion in 1983 to $66 Billion in 1993 (10 years) and then to $123 Billion in 1997 (4 years) and $247 Billion in 2006 and is Predicted to top $400 Billion in 2011
LONDON — Samsung, TSMC, Intel, Toshiba, and UMC had the five largest shares of the world's chip manufacturing capacity at the end of 2006, with a combined capacity of just over 2.9 million 200-mm equivalent wafer per month. They accounted for 32 percent of total wafer capacity as of year-end 2006, according to market research company IC Insights.

At the same time, nearly 48 percent of the world's capacity was represented by the combined capacity of the top ten chip companies, the researcher said. Geographically, the top-10 capacity leaders represent a diverse group with three based in Taiwan, two in South Korea, two in the United States, two in Japan, and one in Europe. Two of the largest capacity holders are the pure-play foundries, TSMC and UMC.
INTERNATIONAL LINKAGES

THE SEMICONDUCTOR MARKET IS WORLDWIDE
AS A RESULT MANY
INTERNATIONAL LINKAGES ARE BEING FORMED

<table>
<thead>
<tr>
<th></th>
<th>MOTOROLA</th>
<th>TI</th>
<th>INTEL</th>
<th>NATIONAL</th>
<th>AMD</th>
<th>SIGNETICS</th>
<th>HARRIS</th>
<th>LSILOGIC</th>
<th>IBM</th>
<th>SIEMENS</th>
<th>SGS</th>
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<td>NEC</td>
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<td>MATSUSHITA</td>
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</tr>
</tbody>
</table>
MARKET SHARE

The U.S. leads the world in semiconductor market share, but ....

Source: SIA
NEW SEMICONDUCTOR PLANTS IN U.S. 2000-2006

$1.5 Billion Each

Atmel, Colorado Springs, Co  
DEC, Hudson, Mass  
Fujitsu, Gresham, Oregon  
AMD, Austin, Texas  
Motorola, Austin, Texas  
Motorola, Chandler, AZ  
Motorola, Richmond, VA  
SGS-Thompson, Carlton, TX  
HP, Corvallis, Oregon  
Toshiba, Hillsboro, Oregon  
Zilog, Nampa, Idaho  
NEC, Roseville, CA  
Intel Albuquerque, NM  
Intel, Chandler, AZ  
Intel, Seattle, WA  
IBM, Manassas, VA  
Samsung, Austin, TX  
Harris Semiconductor, Mt.top, PA
EXTERNAL FACTORS DETERMINE WHERE TO BUILD

TARIFFS, TRADE AGREEMENTS
TAXES, GOVERNMENT INCENTIVES
RESTRICTIONS/CONTROL/GOVERNMENT REPORTING
CAPITAL AVAILABILITY AND COST
ENVIRONMENTAL CONCERNS
WORKFORCE, EDUCATION
INDUSTRY IS WORLD WIDE

More than $5.3 billion revenues in FY 06/07

§ 12,000 employees worldwide
§ 1,700 engineers in R&D
§ Global footprint in R&D: five major R&D facilities on three continents
  Munich, Dresden, Raleigh, Burlington and Xi'an
§ Global footprint in manufacturing with access to five 300mm
  manufacturing sites on three continents:
  - Fully owned: Dresden (Germany) and Richmond (USA)
  - Joint Venture: Inotera (Taiwan)
  - Foundries: SMIC (China) and Winbond (Taiwan)
QIMONDA, RICHMOND VIRGINIA

§ Grand opening April 1998
§ $2.9B Qimonda investment
§ The plant operates 24x7x365
§ Employ ~2400

§ Manufacture various DRAMs for the computing, infrastructure, graphics and consumer/mobile applications
§ Product designs are being manufactured on leading edge technology
§ 200mm (8”) clean room 80,000 sq. ft.
§ 300mm (12”) clean room 120,000 sq. ft.
§ Total site 1,350,000 sq. ft.
QIMONDA, RICHMOND VIRGINIA

Don Koszelak, Engineering Manager
New plant planned for Albany, NY
## Employers of Graduates and Co-ops

<table>
<thead>
<tr>
<th>Digital Equipment Corporation</th>
<th>Motorola</th>
<th>Seattle Silicon</th>
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</thead>
<tbody>
<tr>
<td>Fairchild</td>
<td>Texas Instruments</td>
<td>Western Digital</td>
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<tr>
<td>National Semiconductor</td>
<td>VLSI Technology</td>
<td>Bell Aerospace</td>
</tr>
<tr>
<td>Delco</td>
<td>Lockheed</td>
<td>NCR</td>
</tr>
<tr>
<td>CIA, NSA, NIST</td>
<td>Silicon Systems</td>
<td>Micron Technology</td>
</tr>
<tr>
<td>U.S. Army, Navy, Air Force</td>
<td>Xerox</td>
<td>AT&amp;T Bell Labs</td>
</tr>
<tr>
<td>Johns Hopkins Applied Physics Lab</td>
<td>GCA Tropel</td>
<td>Olin Hunt</td>
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<tr>
<td>AT&amp;T International</td>
<td>Honeywell</td>
<td>MIT</td>
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<tr>
<td>StepperSematech</td>
<td>Rockwell</td>
<td>SONY</td>
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<td>Allied Signal</td>
<td>TRW</td>
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<td>Hughes Aircraft Company</td>
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<tr>
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<td>Toppan Printing</td>
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<td>Samsung</td>
<td>Matshshita</td>
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</tbody>
</table>

There are ~1500 locations in the world that manufacture microchips.
Fairchild
National Semiconductor
Delco
CIA, NSA, NIST
AT&T
Sohio
Ultratech Stepper
Precision Monolithics
ASM Lithography
Dupont Photomasks
Analog Devices
Tektronix
Siemens
Hughes Aircraft Company
Chartered Semiconductor
U.S. Army, Navy, Air Force
Johns Hopkins Applied Physics
Digital Equipment Corporation

Motorola
Texas Instruments
VLSI Technology
Lockheed
Silicon Systems
Xerox
Tropel
Honeywell
Rockwell International
Sematech

Allied Signal
Cypress Semiconductor
Advanced Micro Devices
Eastman Kodak Co.
Harris Semiconductor
Applied Materials
Varian
Phillips
Chartered Semiconductor

Seattle Silicon
NCR
Micron Technology
AT&T Bell Labs
Olin Hunt
MIT
SONY
Phillips
TRW
ETEC
IBM
Hewlett Packard
Intel
Sanders
Toppan Printing
Matshshita
TOP 10 EMPLOYERS
(cumulative number hired by 2006)

§ Intel (126)
§ Freescale (Motorola) (108)
§ IBM (92)
§ Micron (64)
§ Advanced Micro Devices (59)
§ National Semiconductor (53)
§ Texas Instruments (28)
§ Analog Devices (25)
§ Cypress Semiconductor (11)
§ Qimonda (Infion) (10)
**TOP 15 EQUIPMENT MAKERS**

<table>
<thead>
<tr>
<th>Company</th>
<th>Revenue (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPLIED MATERIALS</td>
<td>$11,159</td>
</tr>
<tr>
<td>TOKYO ELECTRON</td>
<td>$2,943</td>
</tr>
<tr>
<td>NIKON</td>
<td>$2,350</td>
</tr>
<tr>
<td>ASM LITHOGRAPHY</td>
<td>$2,121</td>
</tr>
<tr>
<td>KLA-TENCOR</td>
<td>$1,885</td>
</tr>
<tr>
<td>LAM RESEARCH</td>
<td>$1,611</td>
</tr>
<tr>
<td>NOVELLUS SYSTEMS</td>
<td>$1,265</td>
</tr>
<tr>
<td>CANON</td>
<td>$950</td>
</tr>
<tr>
<td>SILICON VALLEY GROUP</td>
<td>$950</td>
</tr>
<tr>
<td>DAI NIPPON SCREEN</td>
<td>$850</td>
</tr>
<tr>
<td>EATON (AXCELIS)</td>
<td>$805</td>
</tr>
<tr>
<td>HITACHI</td>
<td>$582</td>
</tr>
<tr>
<td>MATTSON</td>
<td>$480</td>
</tr>
<tr>
<td>KOKUSAI</td>
<td>$361</td>
</tr>
<tr>
<td>EBARA</td>
<td>$355</td>
</tr>
</tbody>
</table>

**Source:** ELECTRONIC NEWS JULY 2000
APPLICATION SPECIFIC INTEGRATED CIRCUITS


NUMBER OF TRANSISTORS PER INTEGRATED CIRCUIT

1
10
100
1,000
10,000
100,000
1,000,000
10,000,000

STANDARD IC’S

ASIC’S

1997 Top Ten

NEC $1,863,000
IBM $1,541,000
Lucent $1,486,000
Fujitsu $1,248,000
LSI Logic $1,182,000
Texas Instruments $886,000
VLSI Technology $667,000
Toshiba $660,000
Altera $631,000
Xilinx $612,000
NEW MEMS COMBINE TINY MOVING MECHANICAL PARTS AND ELECTRONICS ON A SINGLE MICROCHIP

LIKE THE CHIP IN YOUR CAR THAT FIRES OFF THE AIR BAG
MICROMACHINES

100 µm

Analog Devices, Co.
Texas Instruments
Freescale
A VARIETY OF SEQUENTIAL STEPS WHICH RESULTS IN HUNDREDS OF THOUSANDS OF TRANSISTORS BEING MADE AT THE SAME TIME ON EACH CHIP

STEPS ARE:
- DEPOSITION - CVD, LPCVC, PVD
- SURFACE ALTERING - DIFFUSION, OXIDATION, ION IMPLANTATION
- PHOTOLITHOGRAPHY - G-LINE, I-LINE, EXCIMER LASER, X-RAY
- ETCHING - WET CHEMICAL ETCHING, PLASMA ETCHING, RIE
- CLEANING - RCA, MODIFIED RCA
TECHNOLOGY EVOLUTION: MICROPROCESSORS

INTEL 386 - 229,000 TRANSISTORS 1985

INTEL 486 - 1.2 MILLION TRANSISTORS 1989

INTEL CORE DUO-150 MILLION, 2006

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2004 – 110nm

256M DDR 110nm

2005 – 90nm

512M DDR 90nm

2007 – 75nm

512M DDR2 75nm
DRAM DEVELOPMENT/PRODUCTION MILESTONES

- Start of Development (ISSCC Paper)
- Engineering Samples
- Start of Production
- Volume Production
- Peak Volume
- 10% of Peak Volume

Sources: Toshiba, Mitsubishi, Nikkel Microdevices, MITI, Motorola, Texas Instruments, VLSI, Qtaquest, ICE


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Rochester Institute of Technology
Microelectronic Engineering
<table>
<thead>
<tr>
<th>Technology Evolution: Lithography</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0    0.7    0.5    0.35    0.25    0.17    0.10    0.07 μm</td>
</tr>
<tr>
<td>1M    4M    16M    64M    256M    1G    4G    16G    BITS</td>
</tr>
<tr>
<td>G    G/i    i    KrF    ArF</td>
</tr>
<tr>
<td>i+PS    KrF+PS    ArF+PS</td>
</tr>
<tr>
<td>i+PS    KrF+PS</td>
</tr>
</tbody>
</table>

**Phase Shift Mask (PS)**

G = 436, i = 365, KrF = 248, ArF = 193 nm

**Flex Composing, Biased Mask**
TECHNOLOGY TODAY

I.C. FACTORY COST $3 BILLION
300 MM WAFERS
GIGABIT DRAMS
150 MILLION TRANSISTOR I.C.’S
LESS THAN 0.045 MICRON FEATURES
LESS THAN 0.01 DEFECTS/CM²
2000 MHZ
2 BILLION INSTRUCTIONS/SEC
1.5 VOLT
1 INCH BY 1 INCH CHIPS
400 LEADS
25 WATTS/CHIP
NEW DESIGN TOOLS FOR
BILLION TRANSISTOR CIRCUITS

SOURCE: SRC
A 300mm wafer provides 2.46 times more good chips.
150 mm Wafers
Nsub = 1E15 cm-3 or 10 ohm-cm, n or p
Well Doping ~ 1E17 cm-3
Xjwell ~ 2.5 µm
Shallow Trench Isolation, Field Ox = 4000 Å
Dual Doped Gate n+ and p+
Xox < 100 Å
Lmin = 0.5 µm
LDD/Nitride Side Wall Spacers
TiSi2 Silicide
Tungsten Plugs, CMP, 2 Layers Aluminum
TECHNOLOGY CHALLENGES

TRANSISTOR DIMENSIONS ARE GETTING REALLY SMALL

A 45 NANOMETER TRANSISTOR IS ONLY 200 ATOMS LONG!!!

A 20 ANGSTROM THICK GATE OXIDE IS ONLY 4 MOLECULES THICK!!!
TECHNOLOGY CHALLENGES

Average human hair

~70 μm

DRAM Device “Bit Line”

0.10 μm

Structures 700 X thinner than a hair!

Require measurement precision 70,000 X thinner than a hair
A linear flow like that in automotive production would require much more equipment and reduce efficiency.

The complex material flow needs to be managed.
TECHNOLOGY CHANGES QUICKLY

Wafer fabrication line

- Every 3 months new product
- Every 18 months new technology
- Cost driver: Equipment

Approach: Maximize usage of standard Equipment

2-8 machines
5-60 steps
USE OF AUTOMATION

Material Handling and Control Automation

Workflow Automation:
People monitor and manage exceptions

Process Automation:
Quality control based on machine data

Equipment Automation:
Hands-off processing

Goal:
All execution and control fully automated
FULLY AUTOMATED 250,000 TIMES PER DAY

1. Processing finished
2. Data to SPC and R2R uploaded
3. Transport to next area started

SPC: Statistical Process control
R2R: Run-to-run

Lithography
Metrology
Etch
Metrology

4. Lot for next tool reserved
5. Carrier transport to tool
6. Process parameter determined
7. Processing started
**Goal:** Automatically minimize process variations
RUN TO RUN CONTROL

Without R2R

With Automated R2R
CLEAN ROOM TECHNOLOGY

CLASS 100 HAS LESS THAN 100 PARTICLES OF SIZE GREATER THAN 1/2 MICROMETER PER CUBIC FOOT OF AIR

CLASS 10 CLEANER

CLASS 1 CLEANEST

PEOPLE ARE DIRTY:
PEOPLE GIVE OFF 200,000 PARTICLES PER MIN.
THE WHITE SUIT REDUCES THIS TO 10,000 PER MIN.
CLEAN ROOM CLOTHING
WAFER PODS (FOUP)
INTEGRATED CIRCUIT DESIGN

IF A 1 MICROMETER LINE IS REPRESENTED BY TWO PENCIL MARKS 1/10 INCH APART

THIS IS 2500 TIMES ACTUAL SIZE

THUS A 1/2 X 1/2 INCH CHIP DRAWN 2500 TIMES ACTUAL SIZE WILL BE MORE THAN 100 FEET BY 100 FEET

COMPUTER AIDED DESIGN STATIONS ARE REQUIRED TO MAKE NEW COMPUTERS

NEW CAD TOOLS WILL BE ABLE TO HANDLE 100 MILLION TRANSISTOR IC DESIGNS
6 INCH DIAMETER WAFER HAS A SURFACE AREA OF:

\[
\text{AREA} = \pi R^2 = \pi \times 9
\]

OR ABOUT 30 SQ. IN.

IF EACH CHIP WAS .1 INCH SQUARE THEN THERE WILL BE ABOUT 3000 CHIPS PER WAFER

INDUSTRY STARTS TYPICALLY 5000 WAFERS PER WEEK

THUS THERE ARE 15,000,000 CHIPS TO TEST PER WEEK

IF WE TEST EACH CHIP IN 1 SECOND IT WOULD TAKE 175 DAYS TO TEST ALL THE CHIPS MADE IN ONE WEEK USING ONE TESTER AT 24 HOURS/DAY
WHAT’S NEW

HOME VCR, TELEPHONE, COPIER, FAX, TELEVISION WILL BE COMBINED INTO ONE APPLIANCE

PICTURE TELEPHONE

WORLD WIDE WEB

ELECTRONIC STILL AND VIDEO CAMERA (ALBUMS)

INTELLIGENT HIGHWAY VEHICLE SYSTEMS

WIRELESS COMMUNICATIONS

VOICE AND BRAINWAVE INPUT TO COMPUTERS

MICROCHIPS IMPLANTED IN PEOPLE

SMART CREDIT CARDS

MICROELECTROMECHANICAL SYSTEMS (MEMS)
REFERENCES

1. Solid State Technology
2. Semiconductor International
3. Forbes
4. SRC
1. How old is the semiconductor industry?

2. How big is the semiconductor industry in terms of annual sales?

3. What is the major driving force behind the rapid growth?

4. Explain the DRAM Development/Production cycle?

5. List some job titles for people working in the semiconductor industry.

HOMEWORK - ANDY GROVE

These questions refer to the Time magazine, Dec. 29, 1997 issue. TIME “Man of the Year - Andrew Grove”. (see your CD/reading)

1. How many transistors are made each month?
2. Where did Andy Grove go to College? Graduate School?
3. Who started Intel and where did the name Intel come from?
4. What is the “branch predictor unit”?
5. Who makes the chip that sits in one of the cow’s four stomachs.
6. What is the Strider System?