Pathways Presentation: Solid State Electronics

Power  Radar, antennas, communications  Computers  Feedback, control, systems
My path to ASU, engineering

Physics, Electron transport in amorphous silicon

Mechanical Engineering, Germanium nanocrystal solar cells

Electrical, computer, and Energy Engineering

Microelectronics Engineering, High-efficiency silicon heterojunction solar cells
Where we’ve come from

Vacuum tubes (pre-solid-state)

First transistor

First integrated circuit

UNIVAC mainframe

Mac 128k

Mac Powerbook 100
Where we are
Transistor production

- Transistor number/chip has increased from 1 to $10^9$ in 40 years!
Semiconductor Progress in Perspective

- Semiconductor progress in device size, circuit speed, power consumption, memory storage capability, and cost has been enormous since 1960.
- How a model 1970 automobile would perform, had it improved at the same rate as integrated circuits.

<table>
<thead>
<tr>
<th></th>
<th>1970</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (mph)</td>
<td>100</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Power (mpg)</td>
<td>20</td>
<td>1,750,000</td>
</tr>
<tr>
<td>Cost (1995 $)</td>
<td>20,000</td>
<td>40</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>1,500</td>
<td>0.06</td>
</tr>
<tr>
<td>Luggage (ft³)</td>
<td>20</td>
<td>80,000</td>
</tr>
</tbody>
</table>
Solid State Electronics

- Electronic systems are driven by semiconductor chips
- These chips perform analog and digital circuit functions
- Semiconductor chips contain semiconductor devices
- Semiconductor devices have to be designed, fabricated, measured, modeled, marketed, and sold
- Need to know:
  - Device physics
  - Circuit design
  - Fabrication techniques
  - Modeling
  - Measurements
Courses

- **EEE 434 – Quantum Mechanics for Engineers**
  - Basic physics describing the behavior of electrons and atoms

- **EEE 435 – Fundamentals of CMOS and MEMS**
  - Fabrication of semiconductor devices/circuits. *Important!*

- **EEE 436 – Fundamentals of Solid State Devices**
  - Introduces the physics of the most common semiconductor devices, *i.e.*, how do these device work. *Important!*

- **EEE 437 – Optoelectronics**
  - Light emitting/detecting devices (lasers, photodetectors, etc.)

- **EEE 439 – Semicond. Facilities/Cleanroom Practices**
  - Facilities/cleanrooms to make semiconductors

- **EEE 465 – Photovoltaic Energy Conversion**
  - The science, manufacturing and economics of producing electricity from solar energy
Faculty and research at ASU

First white lasers
(Ning)

World-class solar research
(Bertoni, Bowden, Goodnick, Holman, Honsberg, King, Tao, Vasileska, Zhang, ...)

Nanofabrication facility
(Thornton, Kozicki, Chae, ...)

III-N LEDs power devices
(Zhao)
Semiconductor Industry

*What do engineers in the semiconductor industry do?*

- **Circuit design**
  - Design and lay out circuits to be manufactured
- **Simulation/modeling**
  - Simulate semiconductor device, circuit, and systems behavior (simulation is faster and cheaper than manufacturing)
- **Fabrication**
  - Fabricate these circuits, maintain yield
- **Measurement/characterization**
  - Characterize the performance of the devices/circuits/chips
- **Sales/marketing**
  - Sell and market devices, chips, systems, equipment, services
In which industries do semiconductor engineers work?

- Devices
- Optics
- Circuits
- Communications
- Equipment
- Energy
Job Opportunities

- **Chip Manufacturers**
  - Freescale, Intel, IBM, Texas Instruments, National Semiconductor, ST Semiconductors, Global Foundries, Microchip, Micron ...

- **Equipment Manufacturers**
  - Applied Materials, KLA/Tencor, Chemical Cos., Digital Instruments, Lam, Agilent, Keithley ...

- **Services**
  - Companies producing simulation software, other services
Graduate school?

- **BS**
  - Entry-level degree
  - For technical work you’ll be at the lower end of the range of engineers
  - For less technical work, good

- **MS**
  - Good degree
  - Valued by industry
  - More advanced knowledge, but not overly specialized
  - Most useful degree for most cases

- **PhD**
  - Specialized
  - Good for those interested in more advanced, more interesting work
  - Necessary for academic or R&D careers
Graduate school?

**Median Annual Income**

<table>
<thead>
<tr>
<th>Education Level</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School</td>
<td>0</td>
</tr>
<tr>
<td>Some College</td>
<td>1</td>
</tr>
<tr>
<td>Associate Degr.</td>
<td>2</td>
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<td>MS</td>
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<tr>
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**Lifetime Income**

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*Arizona Republic, Oct. 20, 2004*
Graduate school?