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CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication

Lecture 4
Single-Crystal Silicon

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Reading:
Chapter 2, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

 (some images obtained from Wikimedia Commons)

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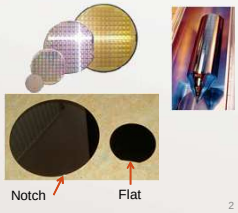
Silicon Wafer Growth

- The vast majority of integrated circuits (ICs) are made on single-crystal silicon wafers
- Wafers are grown in large ingots, then sliced and polished

Wafer Diameter	Wafer Thickness
4-inch (100 mm)	525 μm
5-inch (125 mm)	625 μm
150 mm	675 μm
200 mm	725 μm
300 mm	775 μm
450 mm	925 μm (expected)



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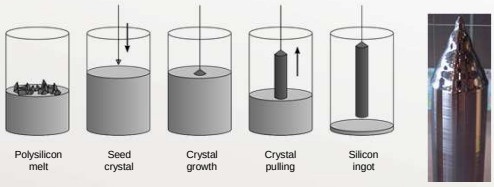
Silicon Wafer Growth



The Czochralski Growth Process

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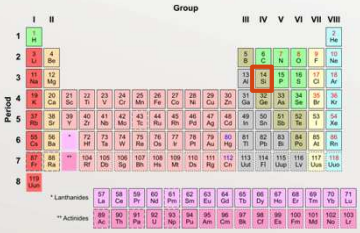
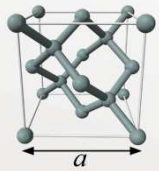
Silicon Crystal

- Silicon is a Group IV material, and forms a tetrahedral crystal





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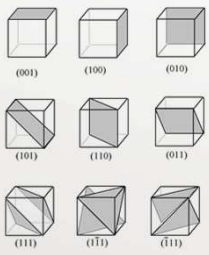
Silicon Wafers

- Wafer are pre-doped to a certain level (p-type or n-type: we'll explain what that means later)
- Wafers are sliced along different crystallographic planes: (100), (110), and (111) wafers are used



Miller indices

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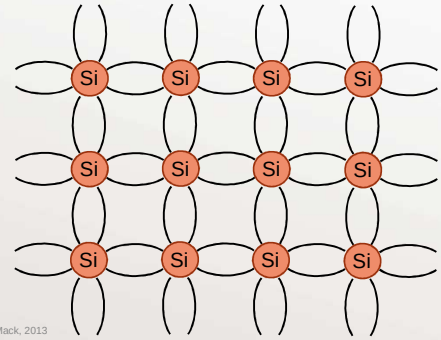
Intrinsic Silicon



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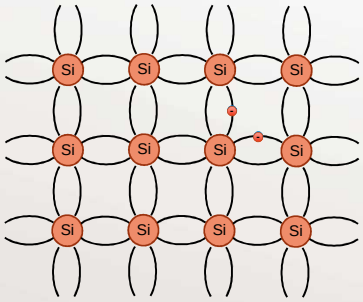
Electron-Hole Pair Generation/Recombination



- Thermal energy can occasionally allow a bond electron to escape
- The free electron is mobile charge carrier
- The missing spot in the bond acts like a mobile + charge: a **hole**.
- When a mobile electron finds a mobile hole, they can recombine

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Electron-Hole Pairs

- At room temperature, the intrinsic silicon equilibrium charge carrier concentration is

$$n_i = p_i = 1.5 \times 10^{10}\ cm^{-3}$$

$$n = mobile\ electron\ concentration$$

$$p = mobile\ hole\ concentration$$

Note that the density of silicon atoms in the crystal is 5 X 10^{22} cm^{-3}

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Lecture 4: What have we learned?

- Describe the Czochrolski growth process
- Why do Goup IV materials often act as semiconductors?
- Define “intrinsic semiconductor”
- Explain the processes of electron-hole generation and recombination
- What are the two charge carriers in semiconductor devices?

