Basic Circuit Design

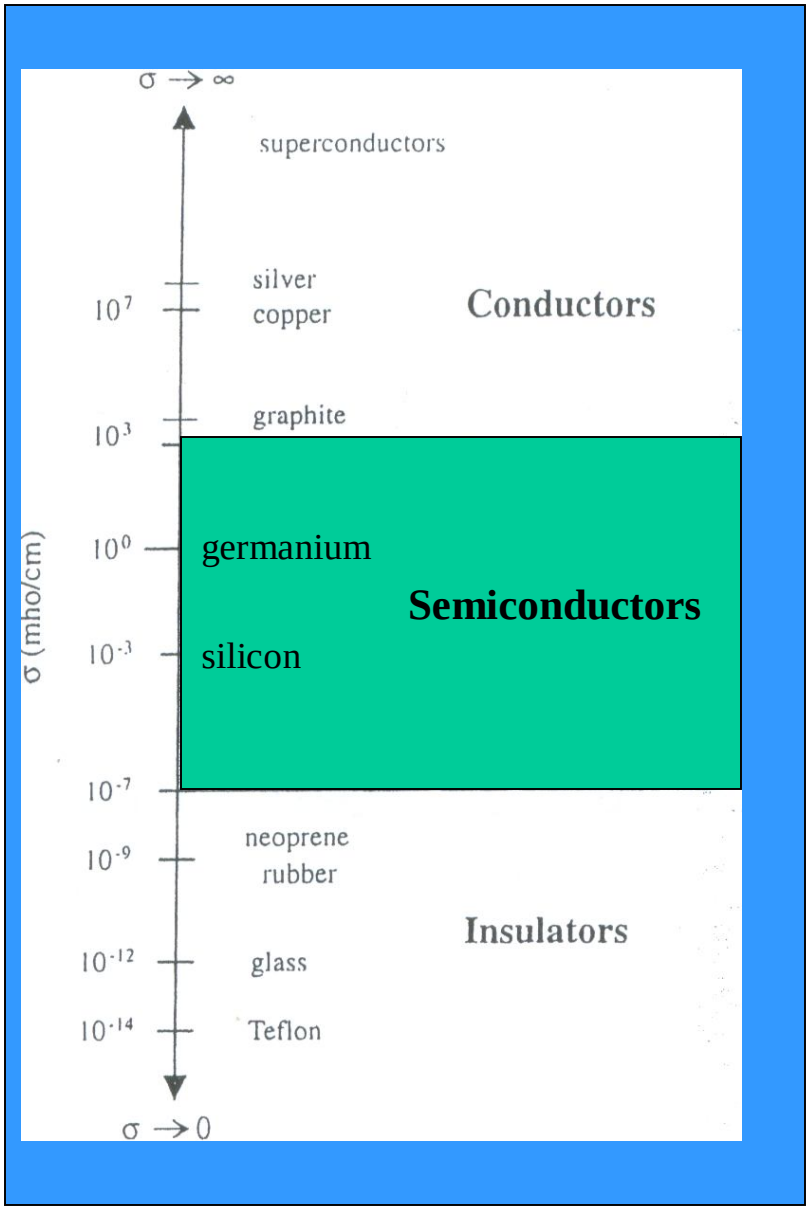
Lecture Notes 2

By

Elisephane Irankunda

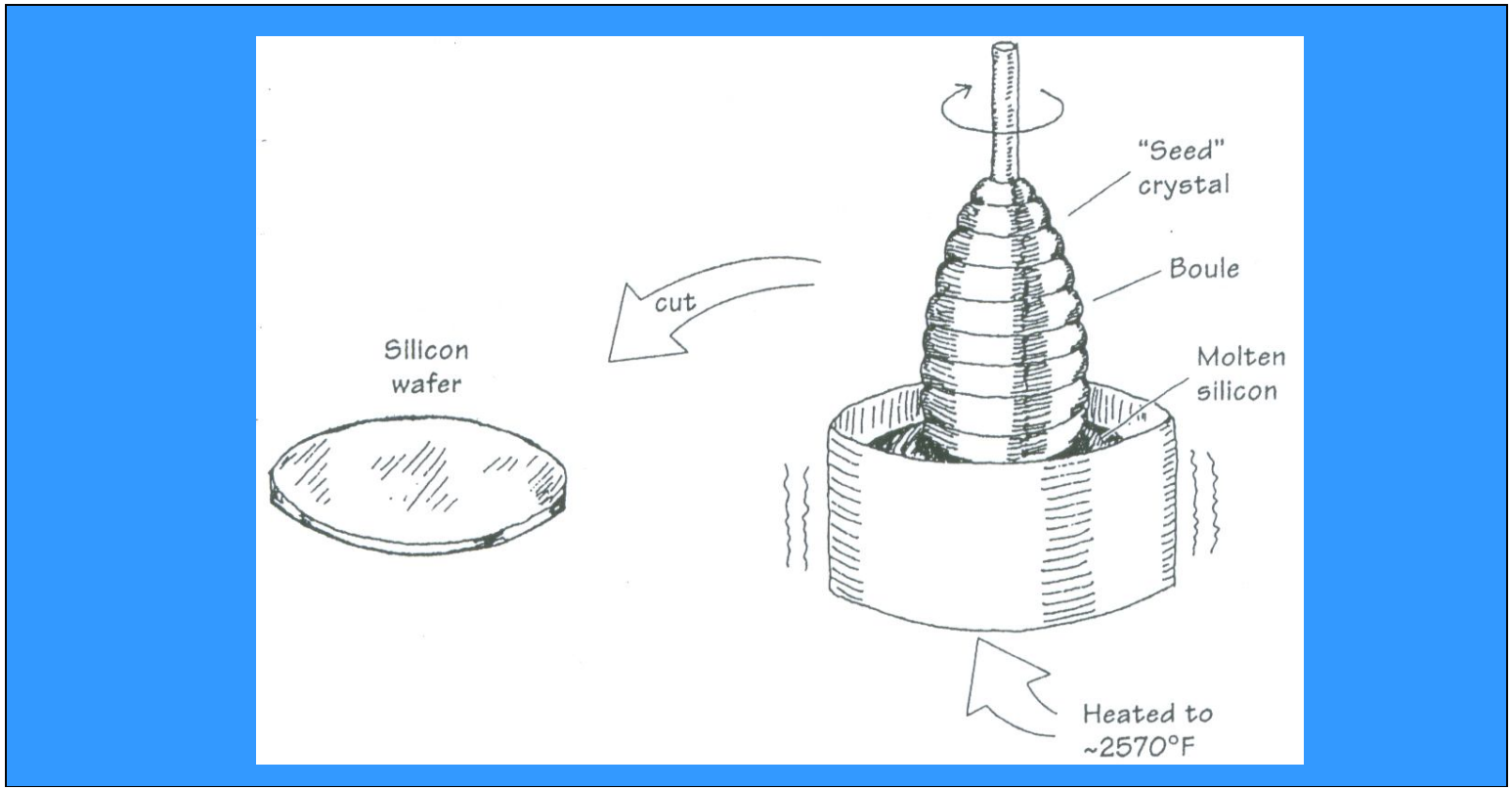
Semiconductor —I

- Materials that permit flow of electrons are called conductors (e.g., gold, silver, copper, etc.).
- Materials that block flow of electrons are called insulators (e.g., rubber, glass, Teflon, mica, etc.).
- Materials whose conductivity falls between those of conductors and insulators are called semiconductors.
- Semiconductors are “part-time” conductors whose conductivity can be controlled.



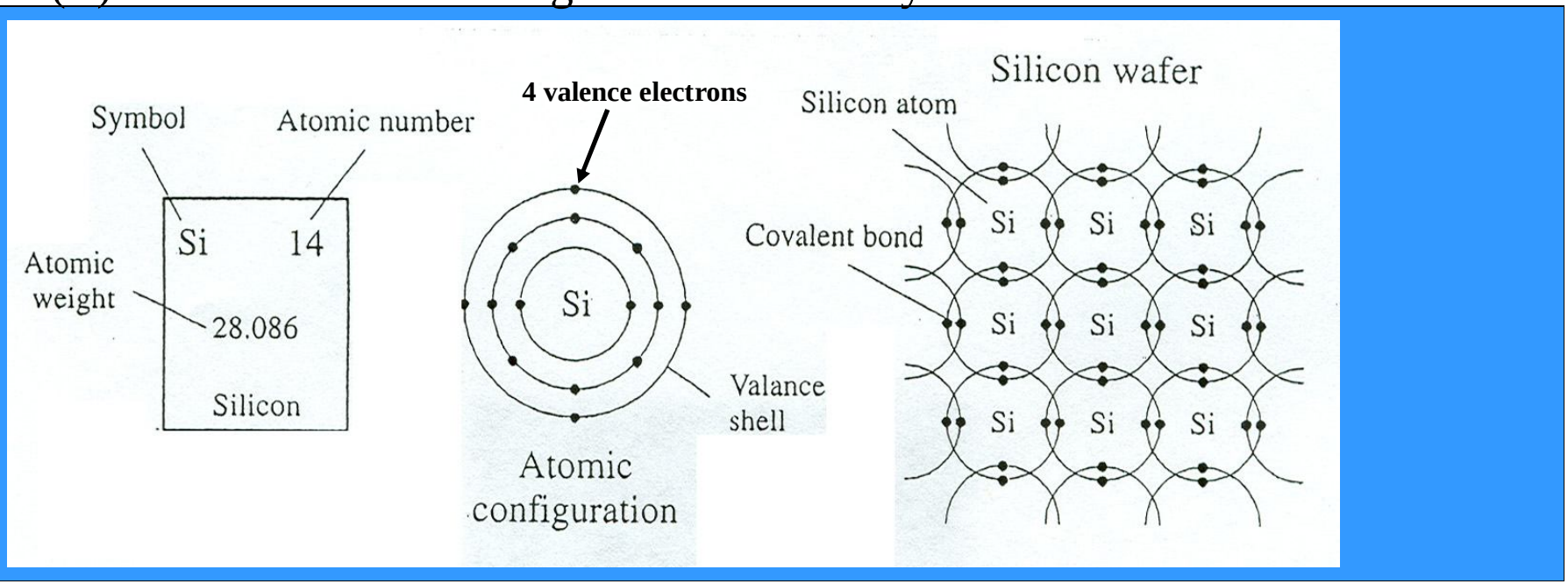
Semiconductor —II

- Silicon is the most common material used to build semiconductor devices.
- Si is the main ingredient of sand and it is estimated that a cubic mile of seawater contains 15,000 tons of Si.
- Si is spun and grown into a crystalline structure and cut into wafers to make electronic devices.



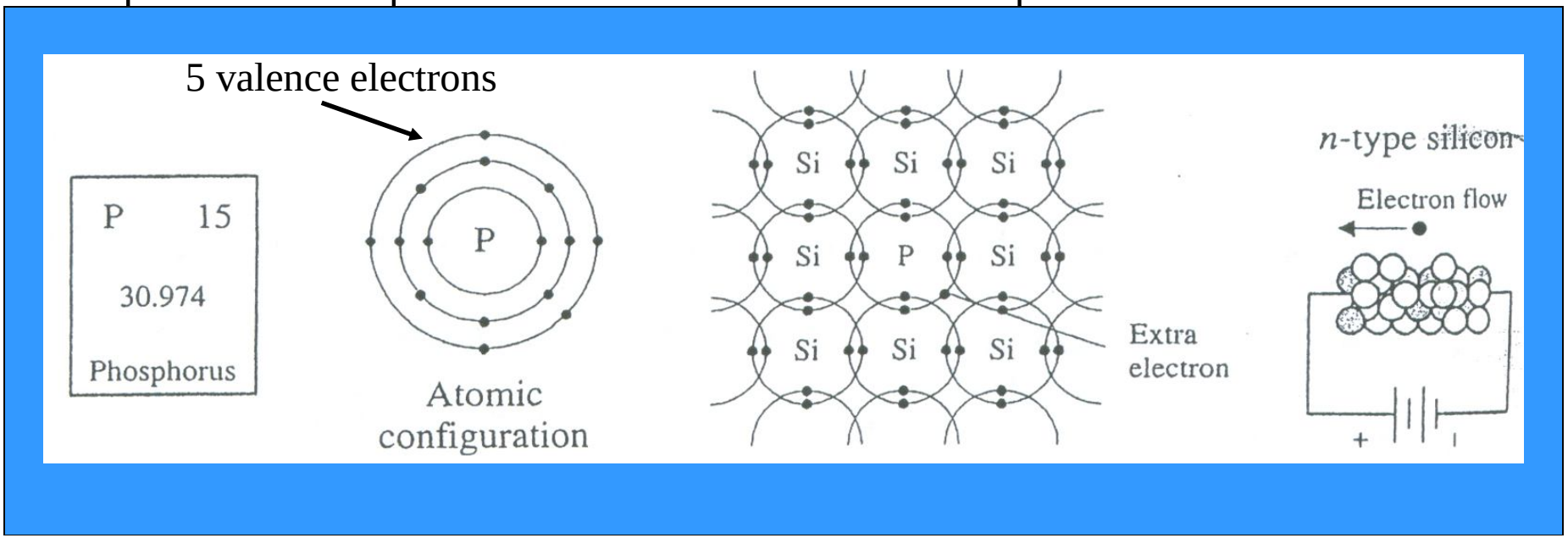
Semiconductor —III

- Atoms in a pure silicon wafer contains four electrons in outer orbit (called valence electrons).
  - Germanium is another semiconductor material with four valence electrons.
- In the crystalline lattice structure of Si, the valence electrons of every Si atom are locked up in covalent bonds with the valence electrons of four neighboring Si atoms.
  - In pure form, Si wafer does not contain any free charge carriers.
  - An applied voltage across pure Si wafer does not yield electron flow through the wafer.
  - A pure Si wafer is said to act as an insulator.
- In order to make useful semiconductor devices, materials such as phosphorus (P) and boron (B) are added to Si to change Si's conductivity.



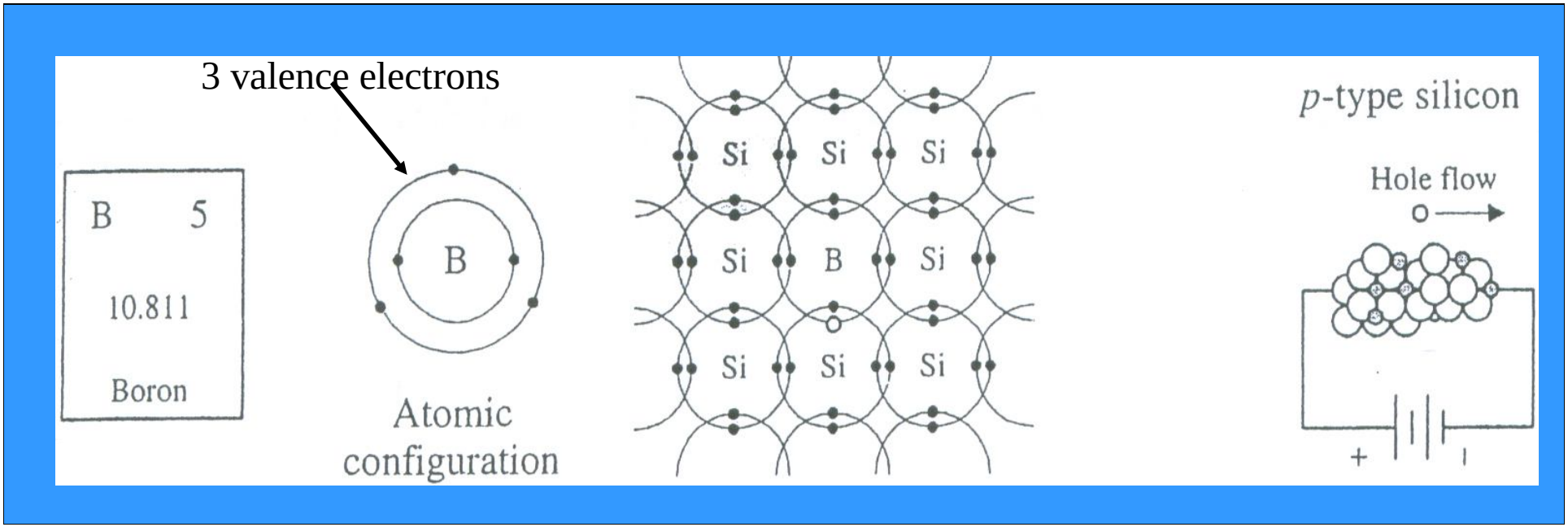
N-Type Silicon

- Pentavalent impurities such as phosphorus, arsenic, antimony, and bismuth have 5 valence electrons.
- When phosphorus impurity is added to Si, every phosphorus atom's four valence electrons are locked up in covalent bond with valence electrons of four neighboring Si atoms. However, the 5^{th} valence electron of phosphorus atom does not find a binding electron and thus remains free to float. When a voltage is applied across the silicon-phosphorus mixture, free electrons migrate toward the positive voltage end.
- When phosphorus is added to Si to yield the above effect, we say that Si is doped with phosphorus. The resulting mixture is called N-type silicon (N: negative charge carrier silicon).
- The pentavalent impurities are referred to as donor impurities.



P-Type Silicon —I

- Trivalent impurities e.g., boron, aluminum, indium, and gallium have 3 valence electrons.
- When boron is added to Si, every boron atom's three valence electrons are locked up in covalent bond with valence electrons of three neighboring Si atoms. However, a vacant spot "hole" is created within the covalent bond between one boron atom and a neighboring Si atom. The holes are considered to be positive charge carriers. When a voltage is applied across the silicon-boron mixture, a hole moves toward the negative voltage end while a neighboring electron fills in its place.
- When boron is added to Si to yield the above effect, we say that Si is doped with boron. The resulting mixture is called P-type silicon (P: positive charge carrier silicon).
- The trivalent impurities are referred to as acceptor impurities.



P-Type Silicon —II

- The hole of boron atom points towards the negative terminal.
- The electron of neighboring silicon atom points toward positive terminal.
- The electron from neighboring silicon atom falls into the boron atom filling the hole in boron atom and creating a “new” hole in the silicon atom.
- It appears as though a hole moves toward the negative terminal!