Bonding model
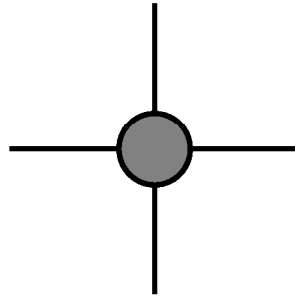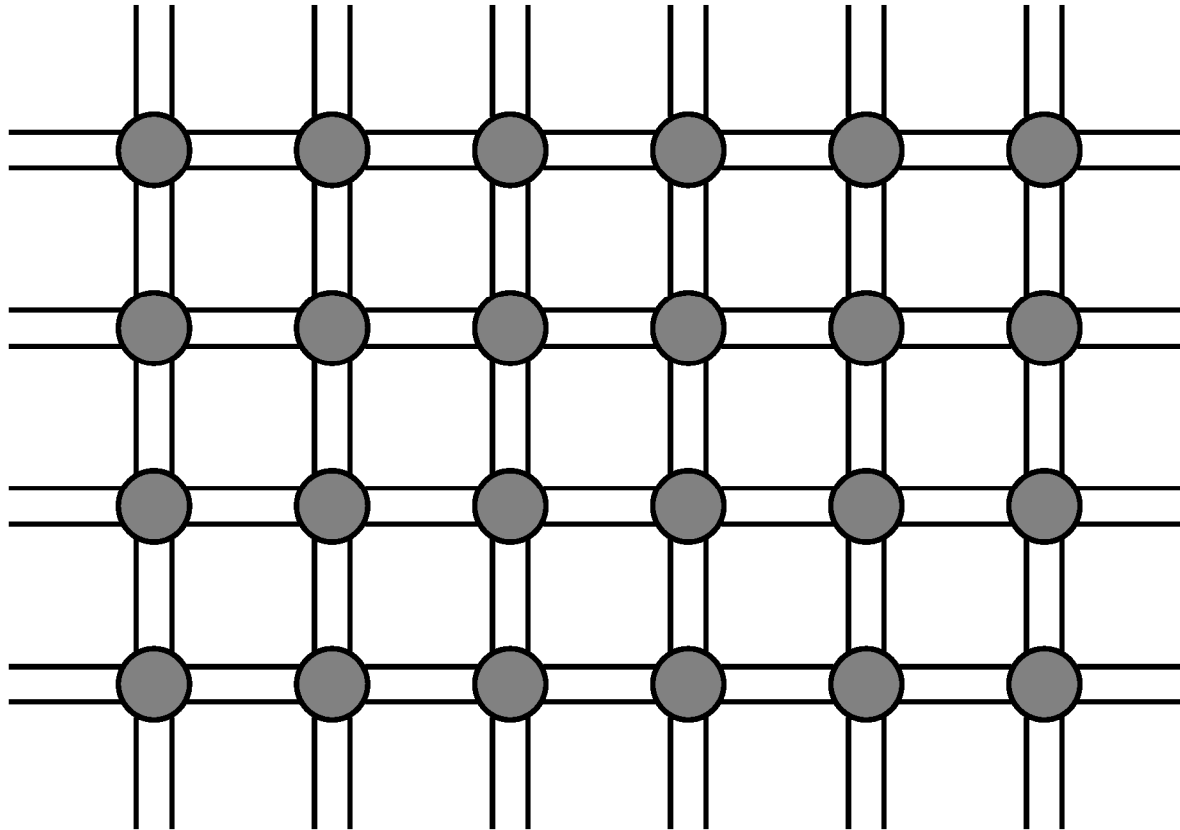
- **Lines represent valence electrons**
- **Silicon**
  - **4   valence electrons**
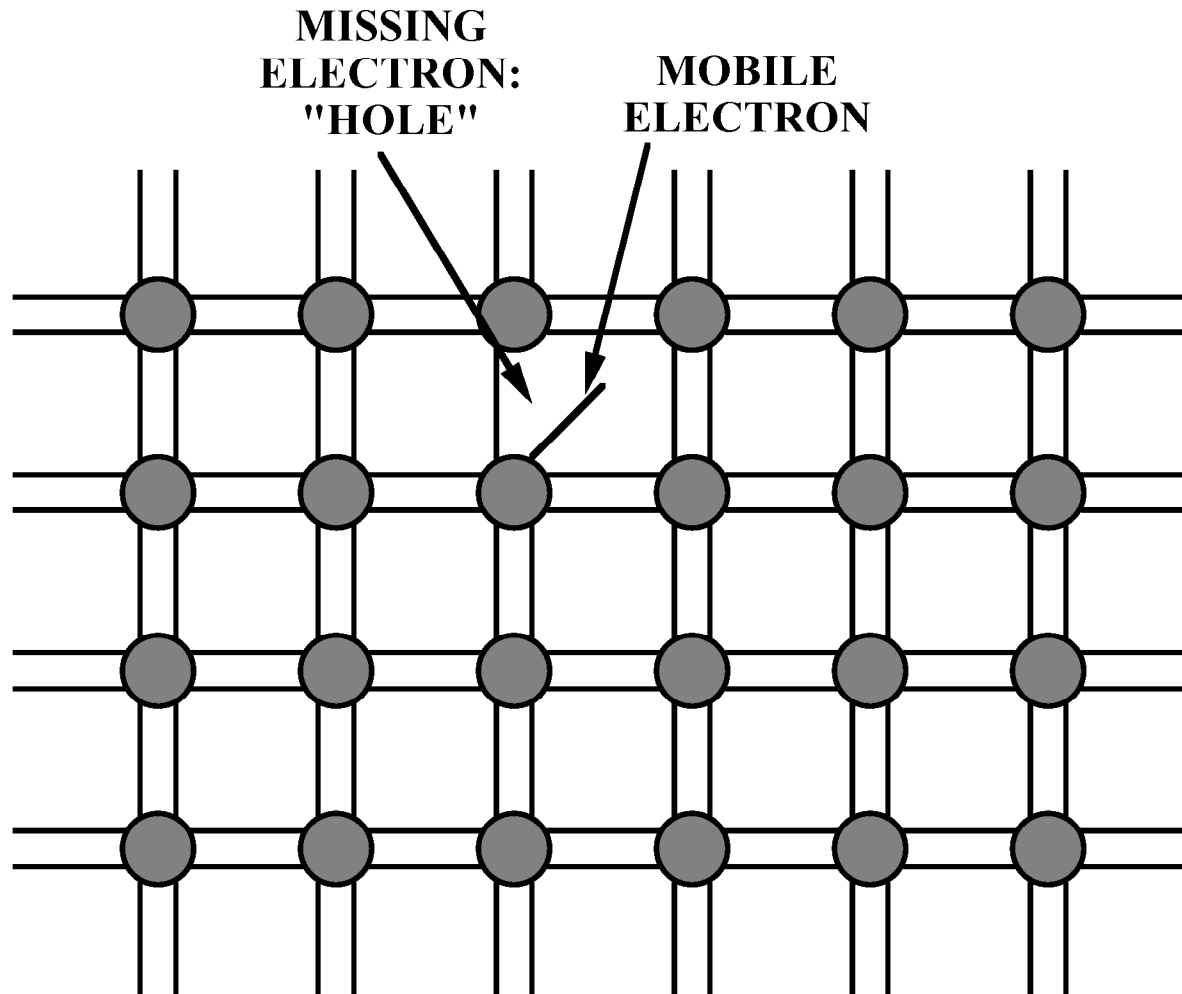
Pure (Intrinsic) Silicon, T = 0 $^\circ$K (Absolute Zero)

All valence electrons tightly bound

Pure Silicon, T = 300 °K (Room Temperature)

Thermal energy frees some valence electrons

Pure Silicon, T = 300 °K (Room Temperature)

- **Thermal energy frees some valence electrons**
  - "electron": mobile negative charge
  - Missing electrons ("holes") behaves as mobile positive charge
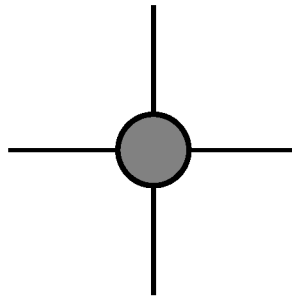- **Equal number of holes, electrons**
- **Relatively poor conductor**

Doping

- **Intentionally introduce impurity atoms to unbalance number of holes, electrons**
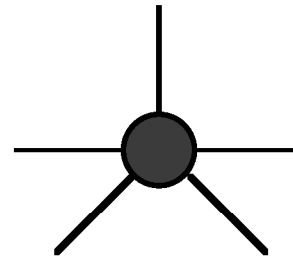- **Adjacent columns in periodic table**
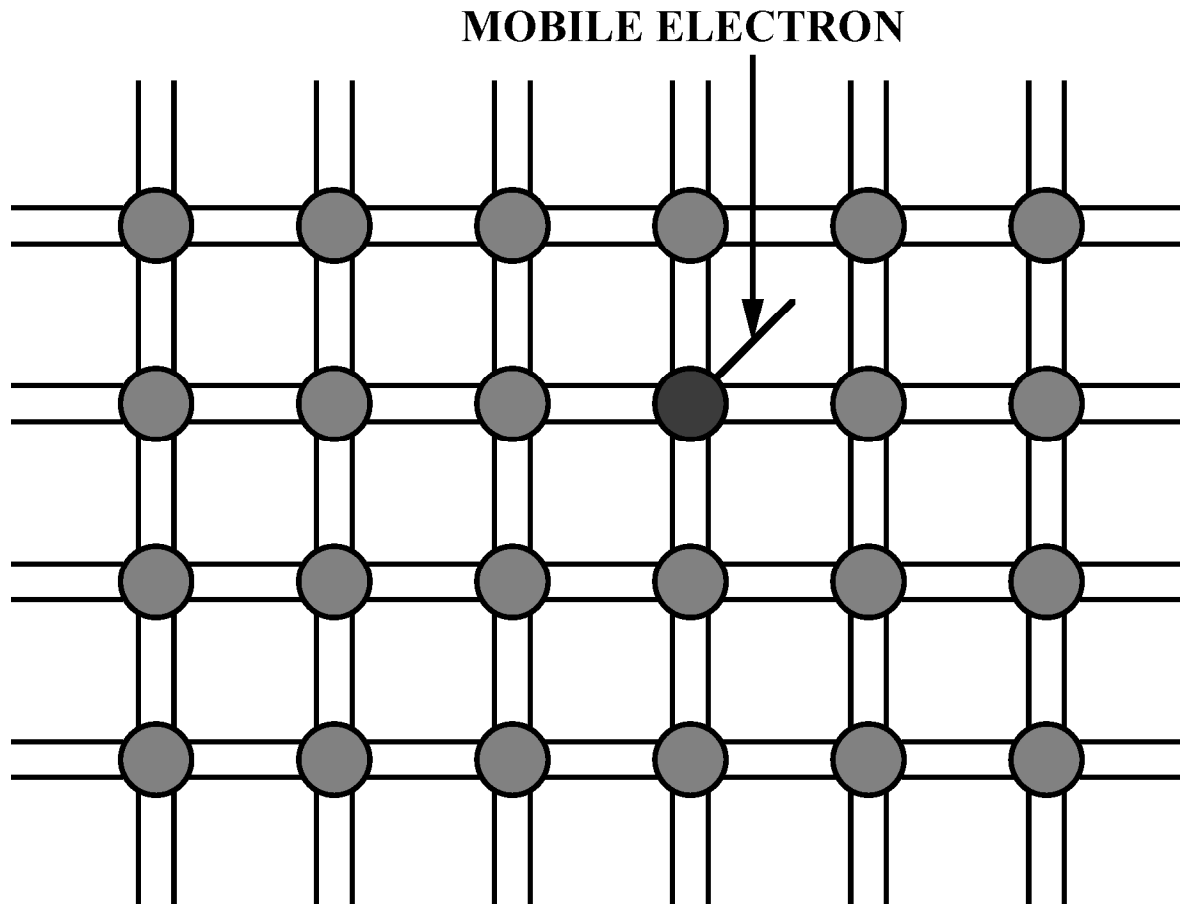
<div align="center">
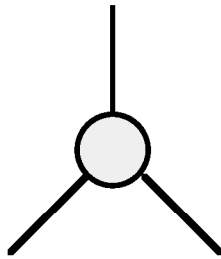
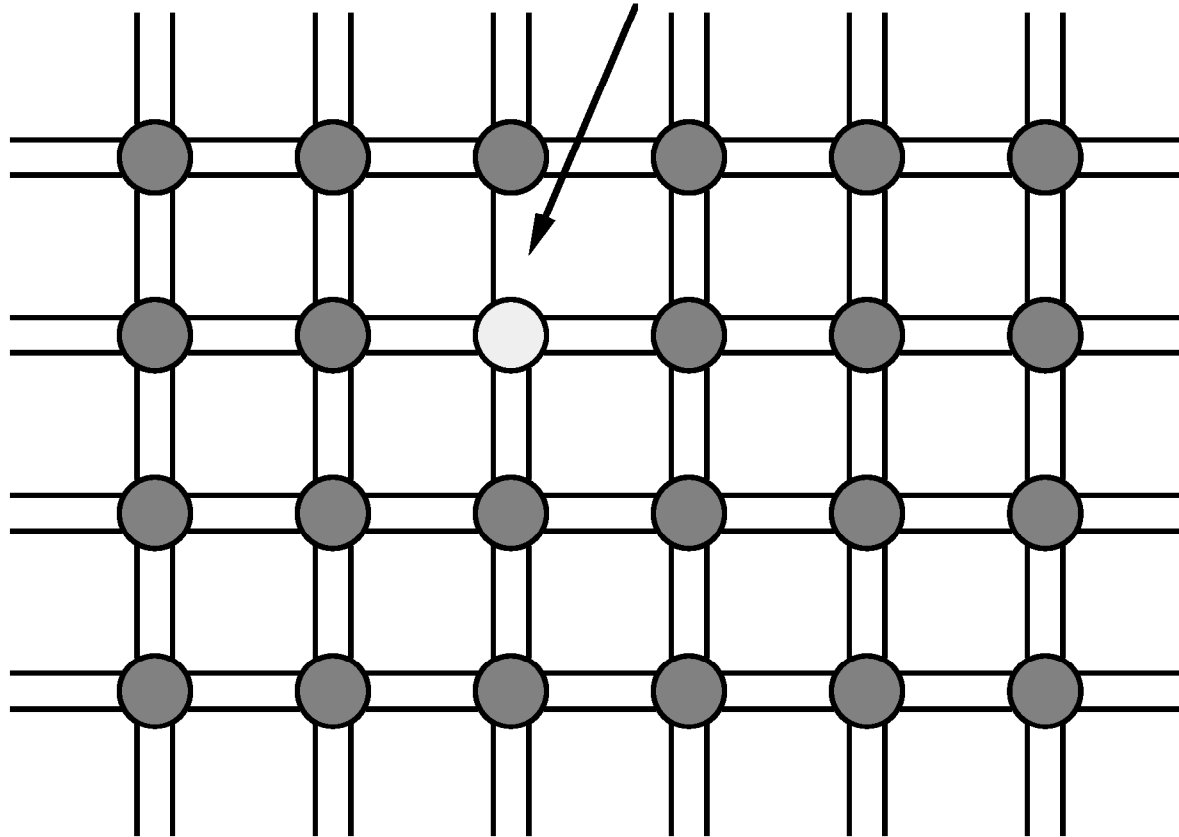**Boron**   **Silicon**   **Phosphorous**

</div>

Donor: Phosphorous

- **Donates extra electron**
- **More mobile _n_egative charges: n-type**

MOBILE ELECTRON

Acceptor: Boron

- **Vacancy ("hole") that can accept an electron**
- **More mobile positive charges: p-type**

MISSING ELECTRON: "HOLE"

Caution

- **Entire semiconductor is electrically neutral**
- **Donor: extra proton in nucleus**
- **Acceptor: missing proton in nucleus**

(for both, <u>relative to Si</u>)