Band Gaps and Lattices

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Semiconductors

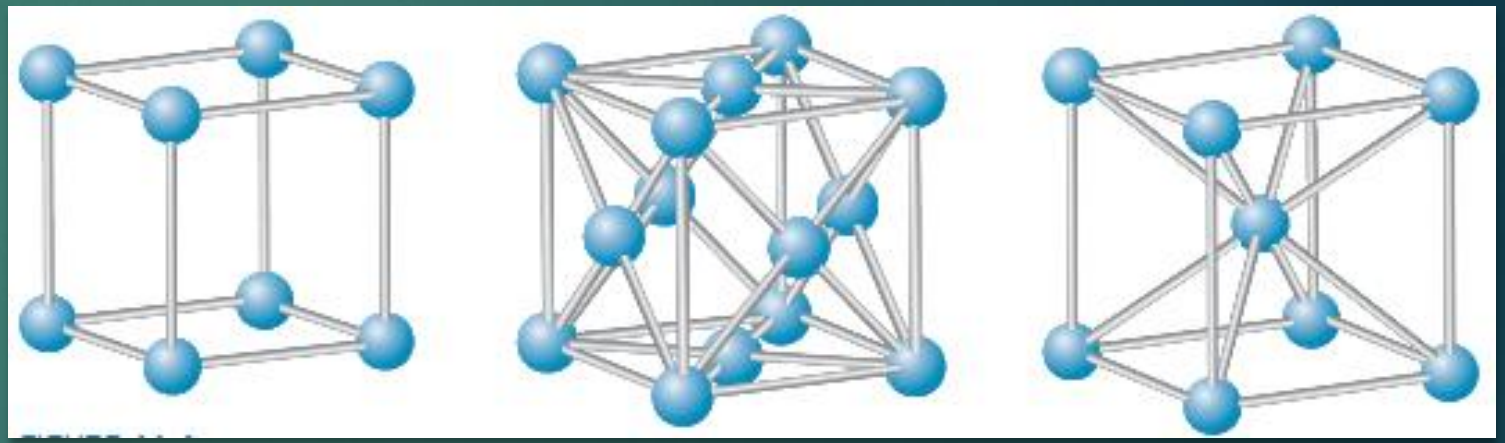
- A semiconductor is a material with an energy gap (E_g) of order 1 eV between the valence band and the conduction band.

Krane, Kenneth S. *Modern Physics*. 3rdrd ed., John Wiley & Sons, Inc., 2012.

Lattices

Crystal structures:

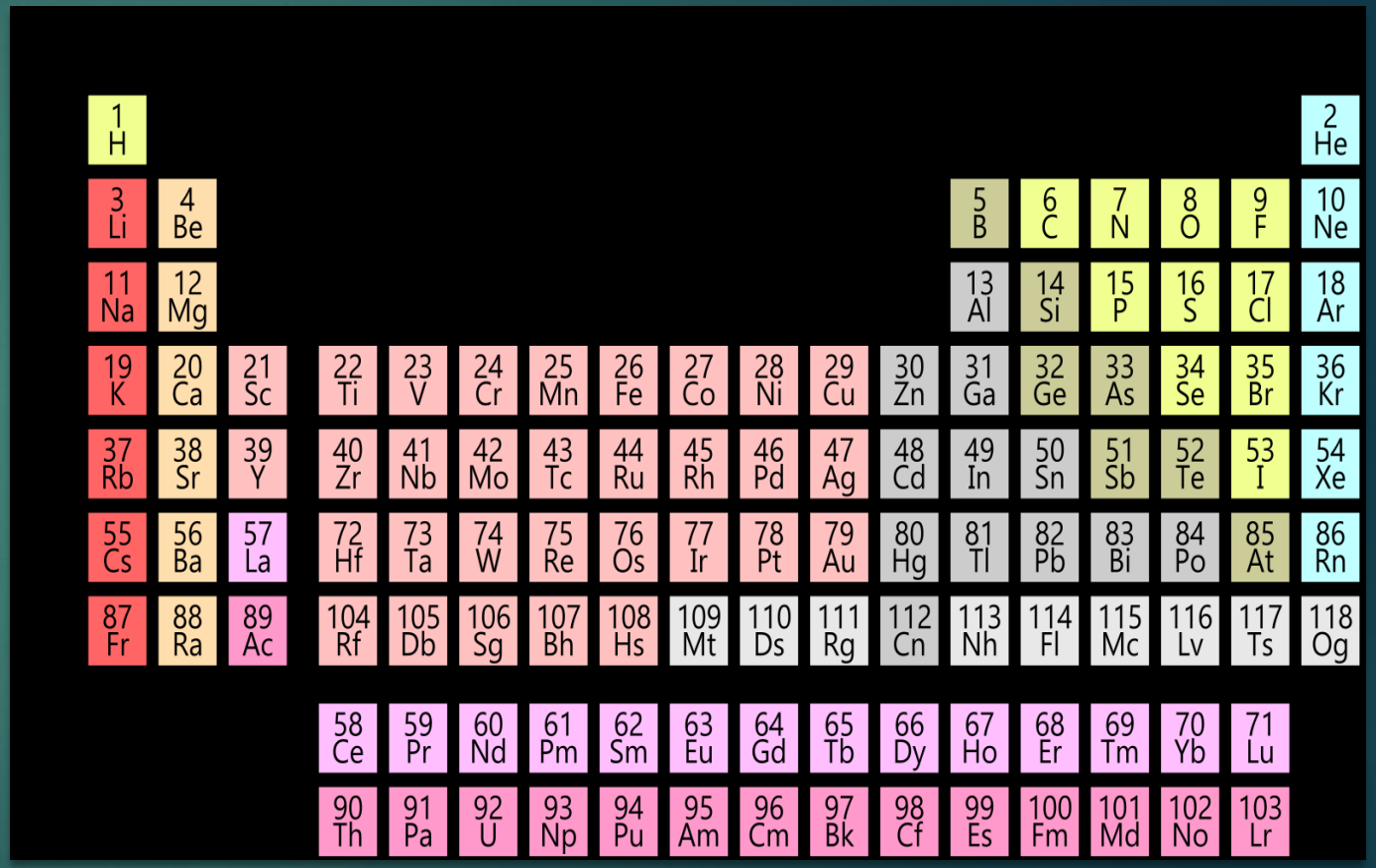
1. Simple
2. Face-Centered (unique)
3. Body-Centered



Krane, Kenneth S. *Modern Physics*. 3rdrd ed., John Wiley & Sons, Inc., 2012.

Ga, In, As, and Sb

- Ga and In are post-transition metals, III
- As and Sb are metalloids, V
- They form a full outer shell, III-V fill outer shells
- Mixed bond: covalent & polarized
- Covalent: electron is shared
- Polarized: permanent displacement of electrons in a covalent bond



Hail the Graph:

$In_xGa_{1-x}As_ySb_{1-y}$

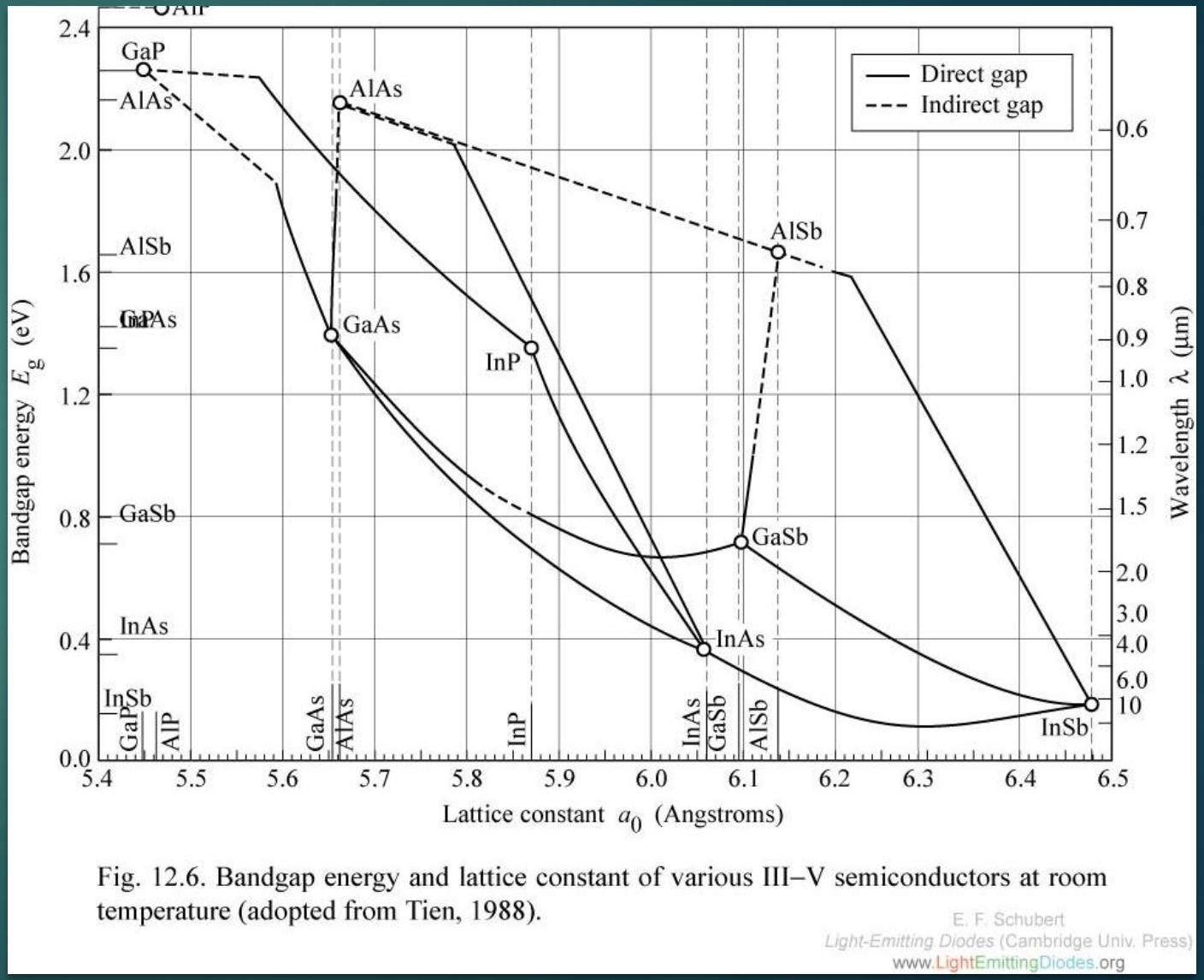


Fig. 12.6. Bandgap energy and lattice constant of various III–V semiconductors at room temperature (adopted from Tien, 1988).

The Goal

Given a lattice constant and a band gap, what is the composition we need to grow?

The Goal, cont'd...

- Binary Alloys, GaAs
- Ternary Alloys, GaInAs
- Quaternary Alloys, InGaAsSb

- Molecular Beam Epitaxy (MBE)

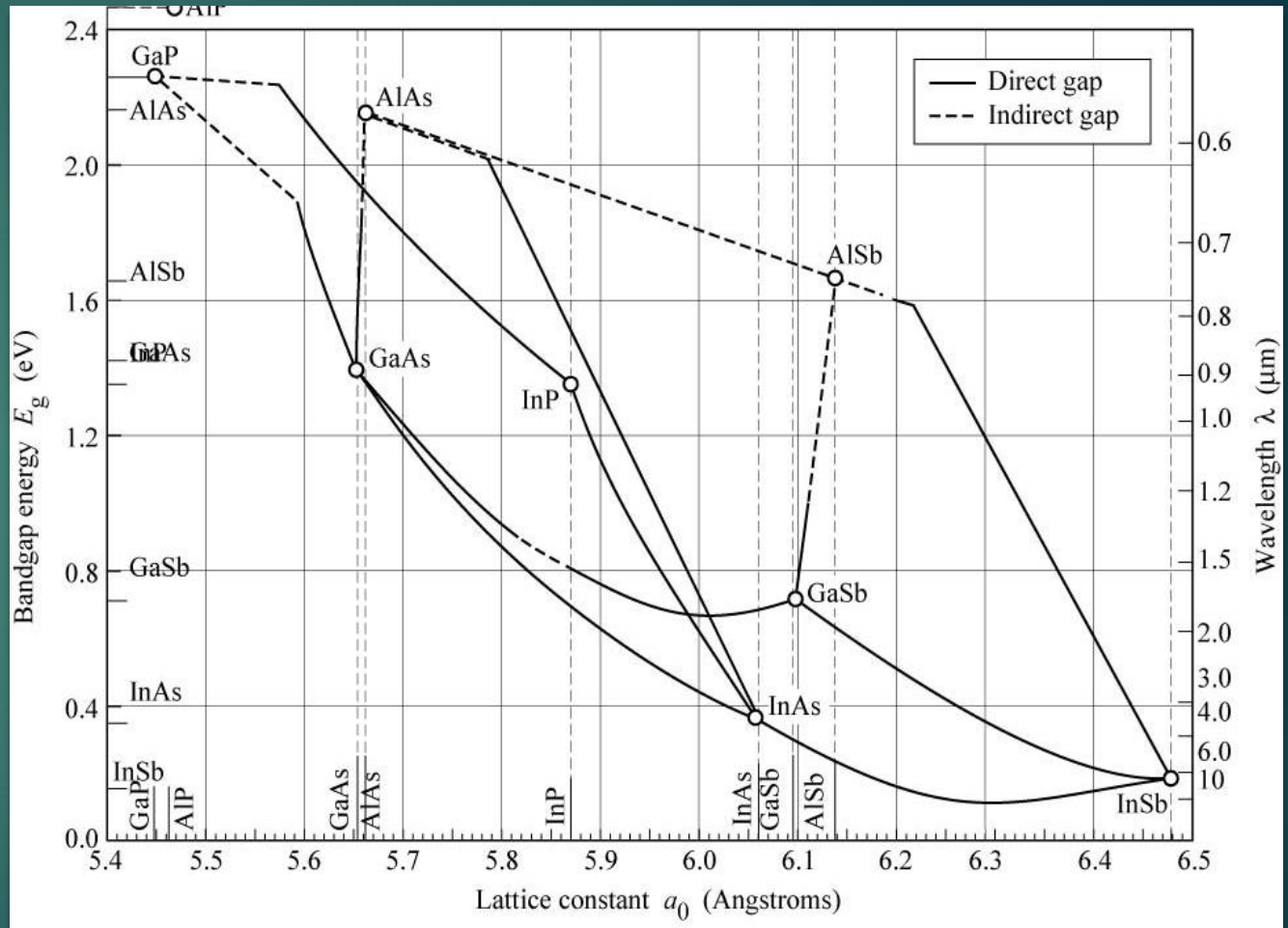


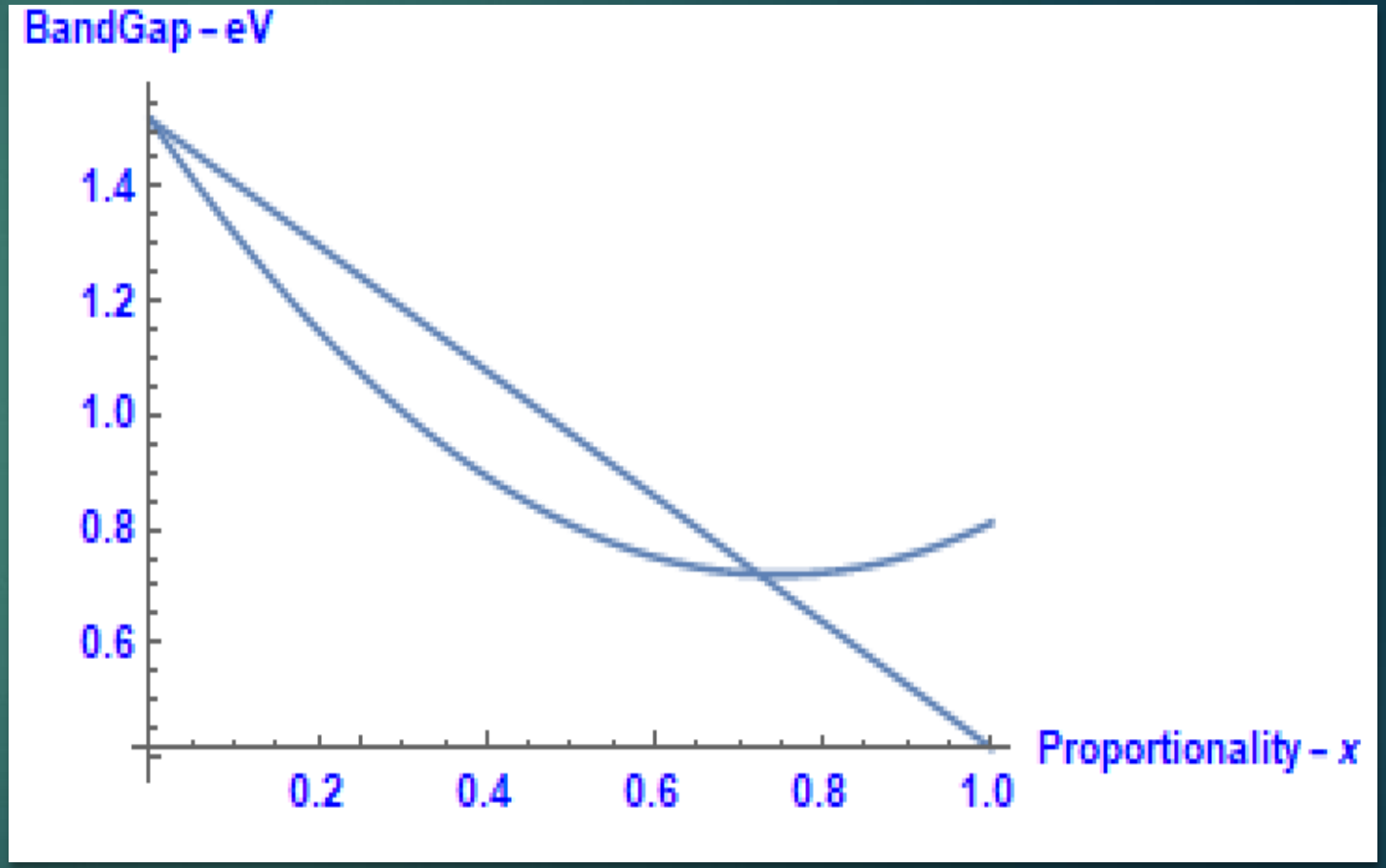
Fig. 12.6. Bandgap energy and lattice constant of various III–V semiconductors at room temperature (adopted from Tien, 1988).

The Equation:

$$E_g(A_xB_{1-x}) = xE_A + (1-x)E_B + x(1-x)\mathrm{C}$$

Bowing Parameters

- Graph: GaInAs



Lattice Constants

- Linear combination: ABCD material
- (z) is the proportionality

$$a_{AC} = a_A z + a_C(1 - z)$$
$$a_{AD} = a_A z + a_D(1 - z)$$
$$a_{BC} = a_B z + a_C(1 - z)$$
$$a_{BD} = a_B z + a_D(1 - z)$$

Applications

- Infrared detectors (photo diodes) for pollution monitoring
- CO_2, 4.23 microns, 0.293 eV