



Band Gaps and Lattices

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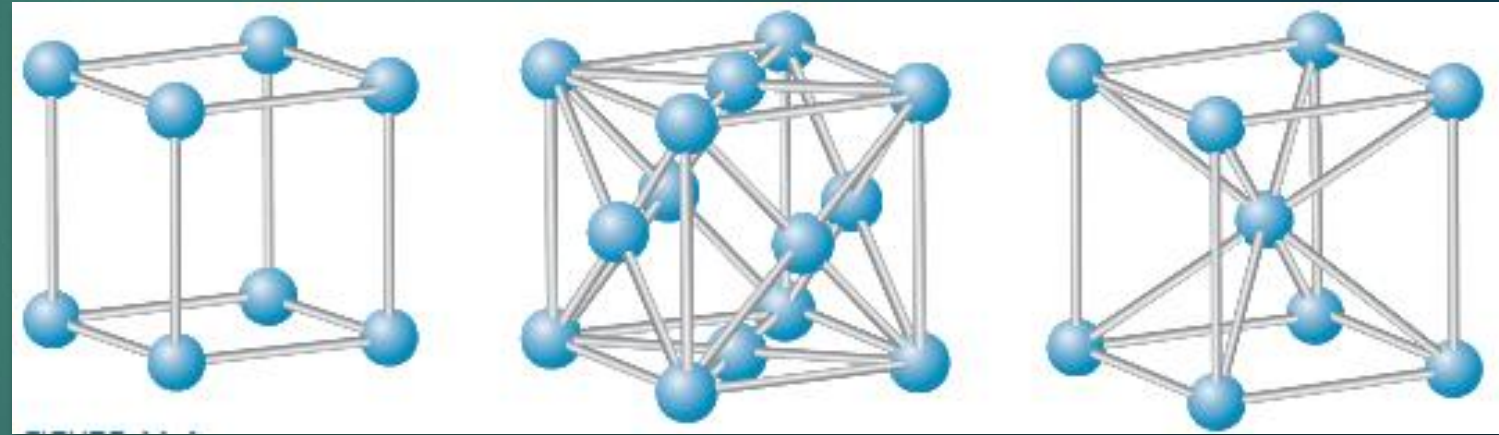
Semiconductors

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

Lattices

Crystal structures:

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



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

| | | | | | | | | | | | | | | | | | |
|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 H | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | 57 La | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | 89 Ac | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Nh | 114 Fl | 115 Mc | 116 Lv | 117 Ts | 118 Og |
| | | | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu | |
| | | | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr | |

Hail the Graph:

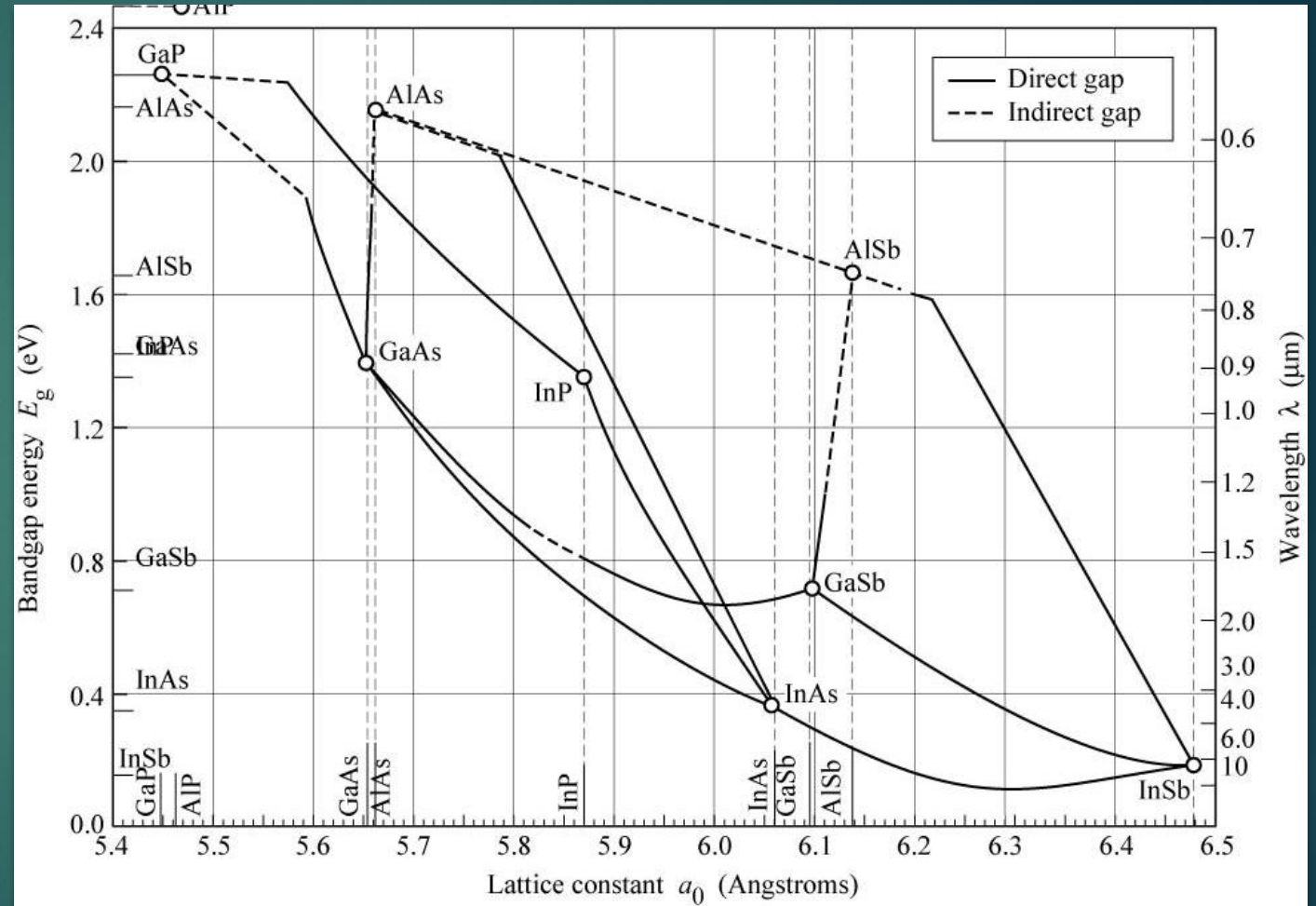
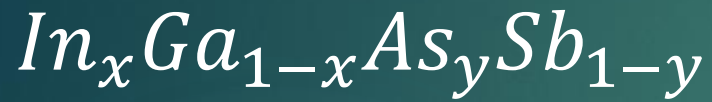


Fig. 12.6. Bandgap energy and lattice constant of various III-V semiconductors at room temperature (adopted from Tien, 1988).

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)

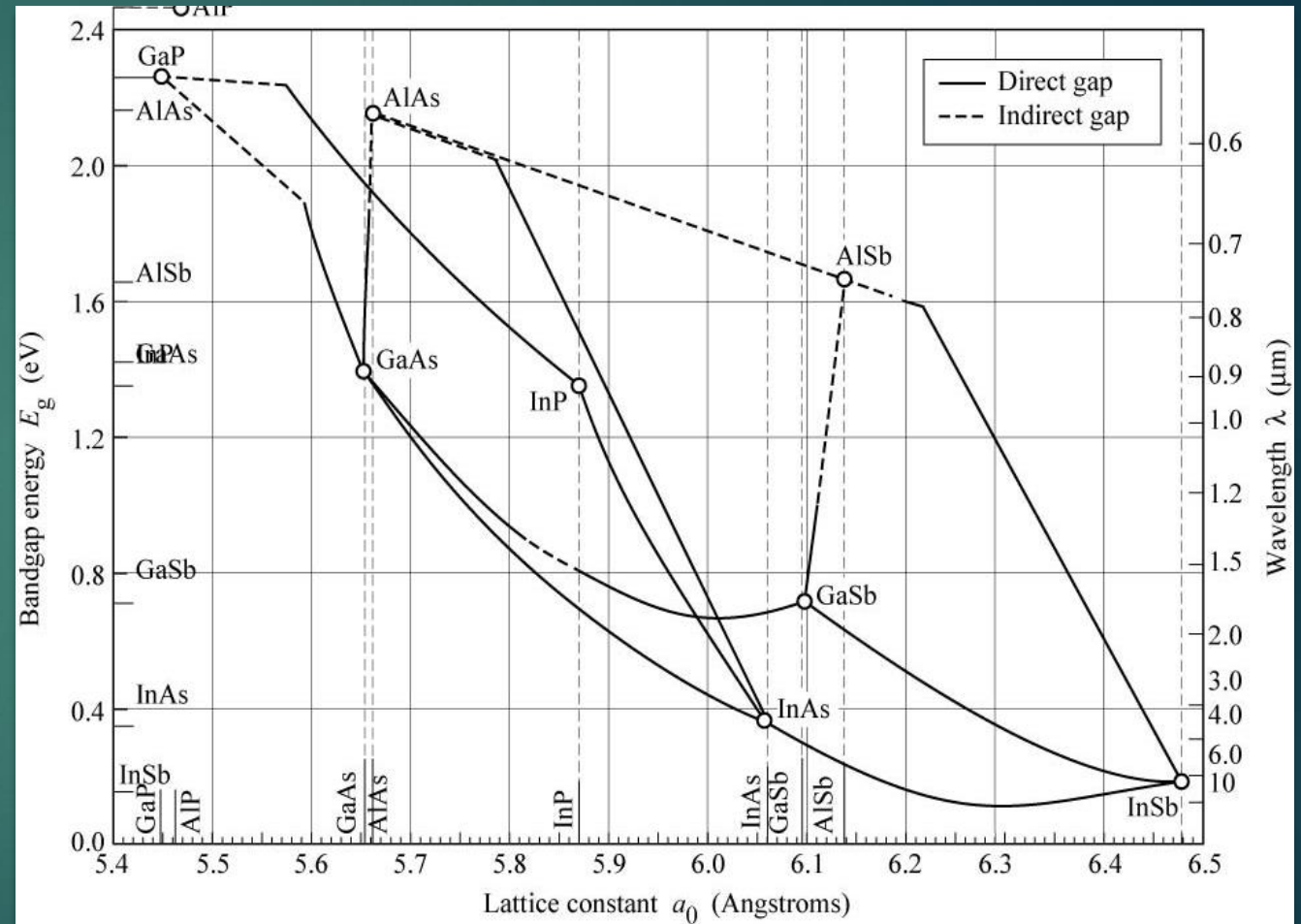


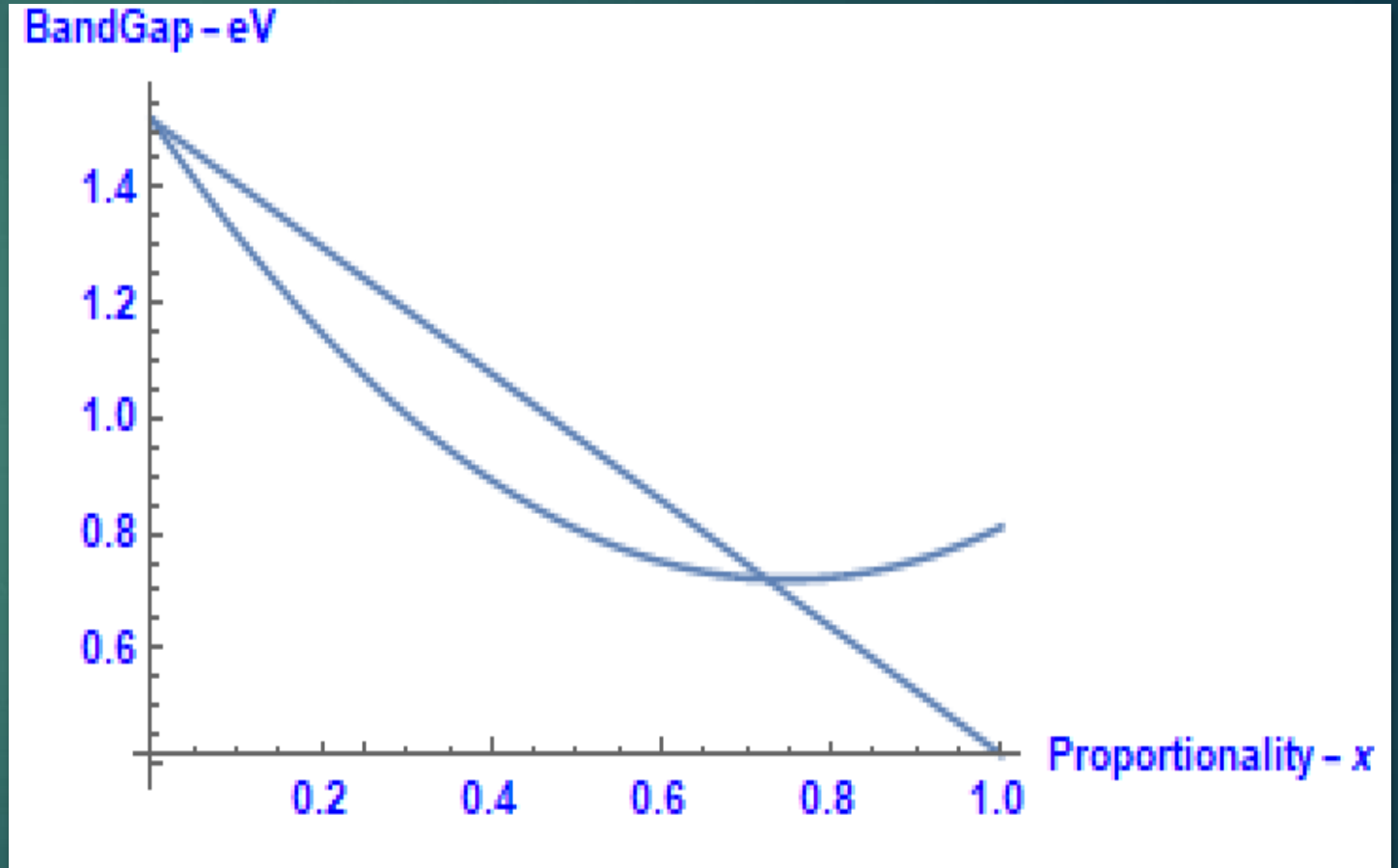
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The Equation:

$$E_g(A_x B_{1-x}) = xE_A + (1-x)E_B + x(1-x)C$$

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

