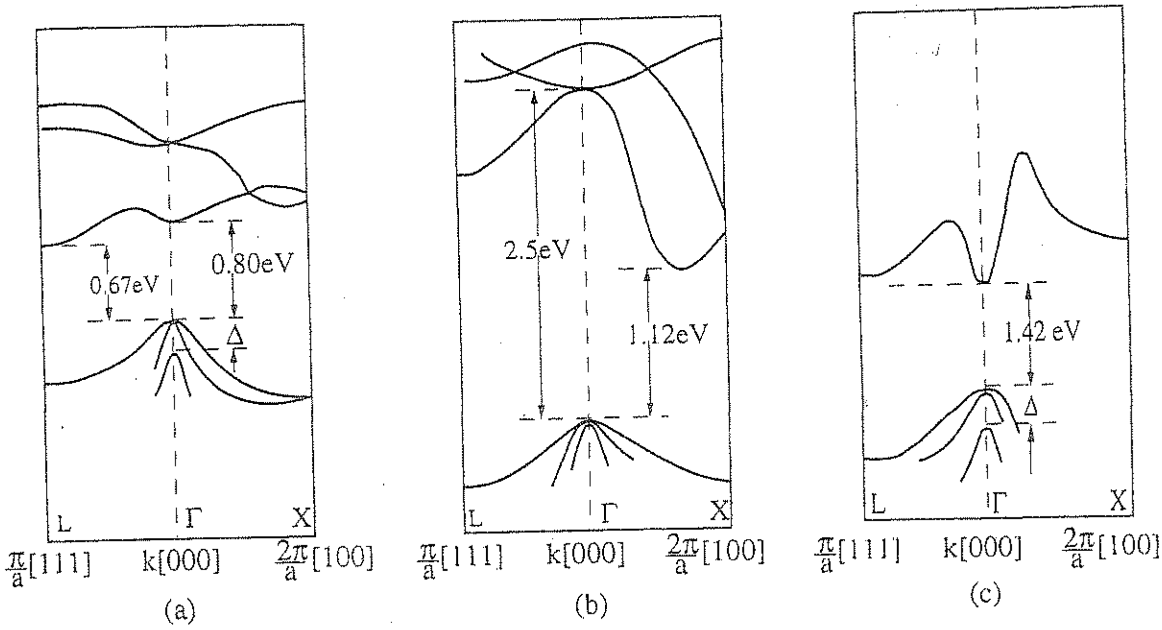

Figure 1.1 Diagrams showing the variations of electron energy with wave number (momentum) in (a) Ge, (b) Si, and (c) GaAs along the [100] and [111] directions in *k* space. Electrons are located near the minimum of the conduction band, whereas holes are located near the maximum of the valence band. The band structures of Ge and Si are examples of indirect-gap semiconductors, whereas that of GaAs represents a direct bandgap semiconductor. Δ is the spin-orbit splitting (from S. Wang, *Fundamentals of Semiconductor Theory and Device Physics*, Prentice Hall, Englewood Cliffs, NJ, 1989).

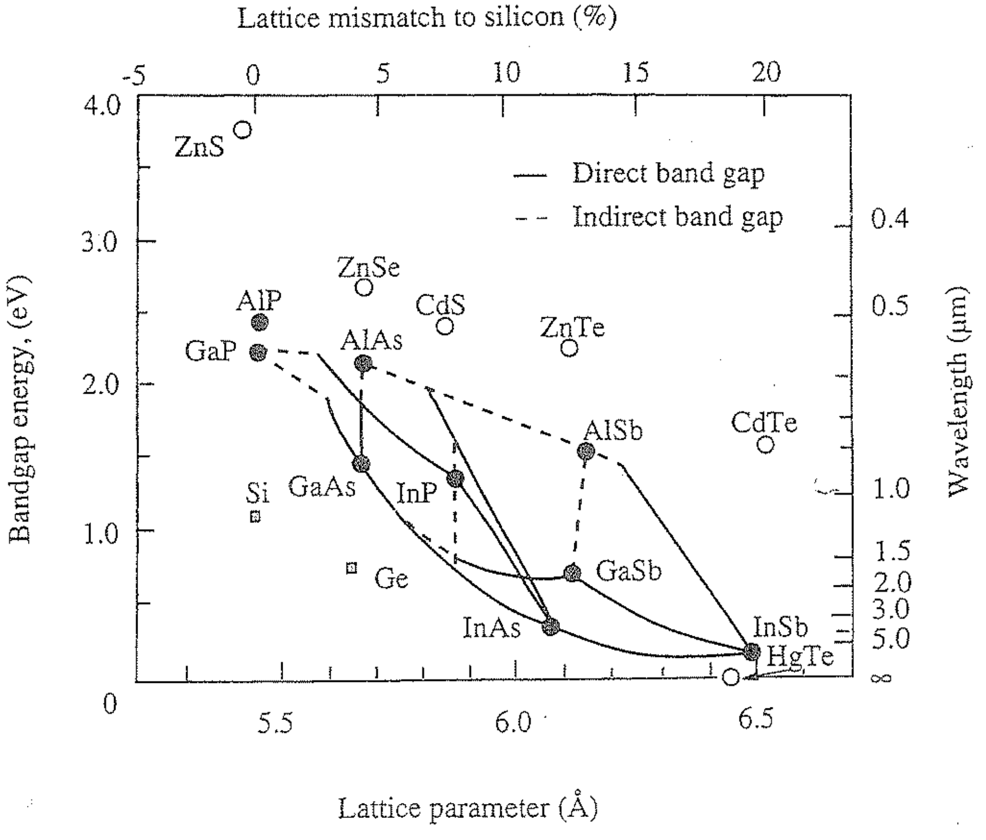

Figure 1.2 Energy bandgap versus lattice constant for common elemental and compound semiconductors. The tie lines joining the binaries represent ternary compositions. The dashed lines represent indirect bandgap material. The vertical dashed line passing through the point representing InP contains the bandgaps for the lattice-matched InGaAlAs and InGaAsP quaternary systems.

TABLE 1.2 LATTICE CONSTANTS, NEAREST-NEIGHBOR DISTANCES AND COVALENT RADII OF ELEMENTAL AND COMPOUND SEMICONDUCTORS (adapted from M. Shur, *Physics of Semiconductor Devices*, Prentice Hall, Englewood Cliffs, NJ, 1990).

Material	Lattice constant, a (Å) at 25°C	Distance between nearest neighbors, $a\sqrt{3/4}$ (Å)	Sum of covalent radii (Å)
Si	5.4309	2.353	2.34
Ge	5.6461	2.450	2.44
$A_{III}B_V$			
AlAs	5.6611	2.430	2.44
AlP	5.451	2.360	2.36
AlSb	5.136	2.224	2.62
BAs	4.776	2.068	2.06
BN	3.615	1.565	1.58
BP	4.538	1.965	1.98
BSb	5.170	2.239	2.24
GaAs	5.6532	2.448	2.44
GaP	5.4495	2.360	2.36
GaSb	6.095	2.639	2.62
InAs	6.0584	2.623	2.62
InP	5.8687	2.540	2.54
InSb	6.479	2.805	2.80
$C_{II}D_{VI}$			
CdTe	6.482	2.807	2.95
HgS	5.841		
HgSe	6.084		
HgTe	6.462	2.798	2.95
ZnS	5.415		
ZnSe	5.653		
ZnTe	6.101	2.642	2.78

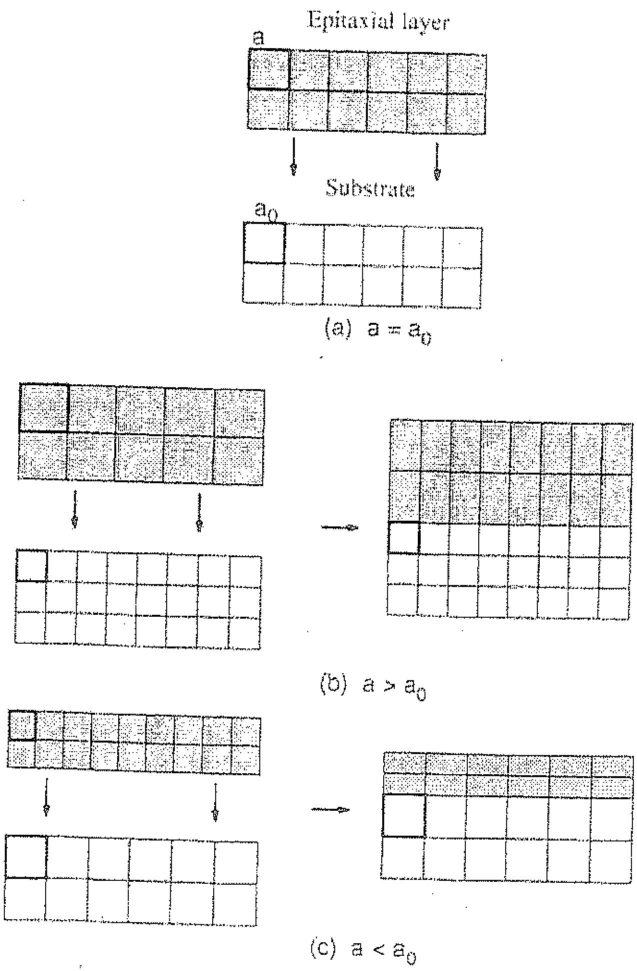

Figure 1.15 Accommodation of lattice of epitaxial layer with that of substrate for different cases: (a) lattice-matched growth ($a = a_0$), (b) biaxial compressive strain ($a > a_0$), and (c) biaxial tensile strain ($a < a_0$).

TABLE 1.5 COMPOSITIONAL DEPENDENCE OF THE ENERGY GAP OF TERNARY III–V SEMICONDUCTORS AT 300°K[a] (from H. C. Casey and M. B. Panish, *Heterostructure Lasers*, Academic Press, New York, 1978).

Compound	Direct energy gap $\mathcal{E}_g$ (eV)	Indirect energy gap, $\mathcal{E}_g$ (eV)	
		X minima	L minima
$Al_xIn_{1-x}P$	$1.351 + 2.23x$	—	—
$Al_xGa_{1-x}As$	$1.425 + 1.247x + 1.147 \times (x - 0.45)^2$	$1.900 + 0.125x + 0.143x^2$	$1.708 + 0.642x$
$Al_xIn_{1-x}As$	$0.360 + 2.012x + 0.698x^2$	—	—
$Al_xGa_{1-x}Sb$	$0.726 + 1.129x + 0.368x^2$	$1.020 + 0.492x + 0.077^2$	$0.799 + 0.746x + 0.334x^2$
$Al_xIn_{1-x}Sb$	$0.172 + 1.621x + 0.43x^2$	—	—
$Ga_xIn_{1-x}P$	$1.351 + 0.643x + 0.786x^2$	—	—
$Ga_xIn_{1-x}As$	$0.36 + 1.064x$	—	—
$Ga_xIn_{1-x}Sb$	$0.172 + 0.139x + 0.415x^2$	—	—
GaP_xAs_{1-x}	$1.424 + 1.150x + 0.176x^2$	—	—
$GaAs_xSb_{1-x}$	$0.726 - 0.502x + 1.2x^2$	—	—
InP_xAs_{1-x}	$0.360 + 0.891x + 0.101x^2$	—	—
$InAs_xSb_{1-x}$	$0.18 - 0.41x + 0.58x^2$	—	—

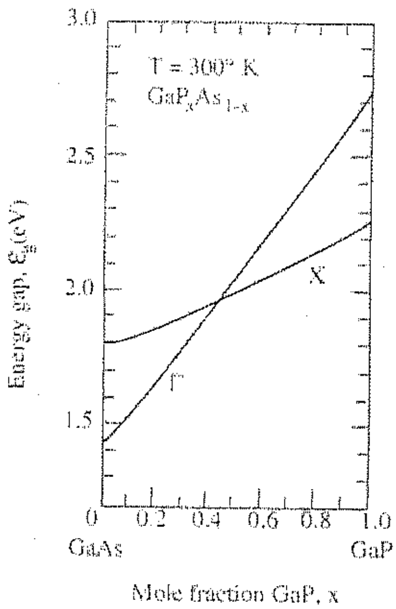

Figure 1.20 Compositional dependence of the direct-energy gap Γ and indirect-energy gap X for GaP_xAs_{1-x} (from M. R. Lorenz and A. Onton, *Proc. Int. Conf. Phys. Semiconduct.*, 10th, Cambridge, MA (S. P. Keller, J. C. Hensel, and F. Stern, eds.), 444, U.S. Atomic Energy Comm., Washington, D.C., 1970).

TABLE 2.1 ENERGY GAPS AND TRANSVERSE AND LONGITUDINAL ELECTRON EFFECTIVE MASSES FOR SOME IMPORTANT III-V BINARY COMPOUNDS.

	$\mathcal{E}_\Gamma$ (eV)	$\mathcal{E}$ (eV)	$\mathcal{E}_X$ (eV)	$m_e^{\Gamma *}(m_o)^a$	$m_e^{L*}(m_o)^a$	$m_e^{X*}(m_o)^a$	$m_{hh}^*(m_o)^b$	$m_{lh}^*(m_o)^b$	$m_{sh}^*(m_o)^c$
GaP	2.24	2.75	2.38	0.126	1.493(l)	1.993(l)	0.79	0.14	0.24
					0.142(t)	0.250(t)			
GaAs	1.42	1.71	1.91	0.063	1.538(l)	1.987(l)	0.48	0.09	0.15
					0.127(t)	0.229(t)			
AlAs	2.95	2.67	2.20	0.149	1.386(l)	0.813(l)	0.76	0.15	
InAs	0.35	1.45	2.14	0.031	1.565(l)	3.619(l)	0.60	0.03	0.089
					0.124(t)	0.271(t)			
InP	1.35	2.0	2.3	0.082	1.878(l)	1.321(l)	0.85	0.09	0.17
					0.153(t)	0.273(t)			

[a] M. V. Fischetti, *IEEE Trans. Electron Devices*, **38** (3), 634–649, 1991.

[b] M. Shur, *Physics of Semiconductor Devices*, Prentice Hall, Englewood Cliffs, NJ, 1990.

[c] Split-off hole mass, from G. P. Agrawal and N. K. Dutta, *Long Wavelength Semiconductor Lasers*, Van Nostrand Reinhold, New York, 1986.

(l) and (t) denote longitudinal and transverse effective masses, respectively.

TABLE 1.3 ELECTRON EFFECTIVE MASSES IN $In_xGa_{1-x}As$ GROWN PSEUDOMORPHICALLY ON GaAs AND $In_{0.53+x}Ga_{0.47-x}AS$ GROWN PSEUDOMORPHICALLY ON InP (from M. Jaffe and J. Singh, *Journal of Applied Physics*, **65**(1), 329, 1989).

x	$In_xGa_{1-x}As$			$In_{0.53+x}Ga_{0.47-x}As$		
	$m^*_{unstrained}$	$m^*_{\parallel strained}$	$m^*_{\perp strained}$	$m^*_{unstrained}$	$m^*_{\parallel strained}$*	$m^*_{\perp strained}$
0.00	0.066	0.066	0.066	0.045	0.045	0.045
0.05	0.064	0.065	0.064	0.044	0.044	0.045
0.10	0.062	0.064	0.063	0.042	0.043	0.045
0.15	0.060	0.063	0.063	0.040	0.041	0.044
0.20	0.058	0.062	0.062	0.037	0.039	0.044
0.25	0.056	0.061	0.061	0.035	0.037	0.044
0.30	0.054	0.060	0.061	0.033	0.035	0.043
0.35	0.052	0.058	0.060	0.031	0.033	0.043
0.40	0.050	0.057	0.060	0.028	0.030	0.043

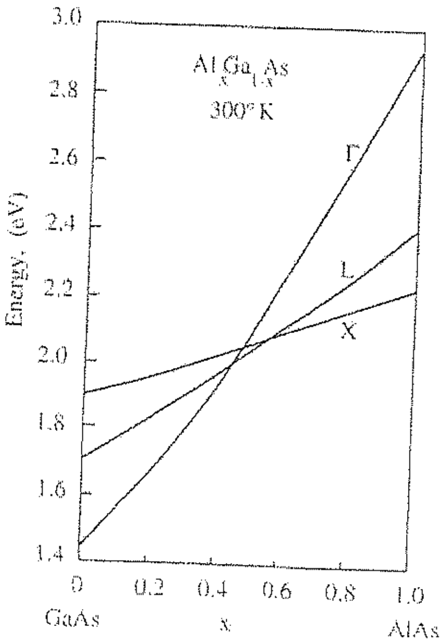

Figure 1.14 Compositional dependence of the direct (Γ) and indirect (X and L) conduction band minima in the $Al_xGa_{1-x}As$ mixed crystals.

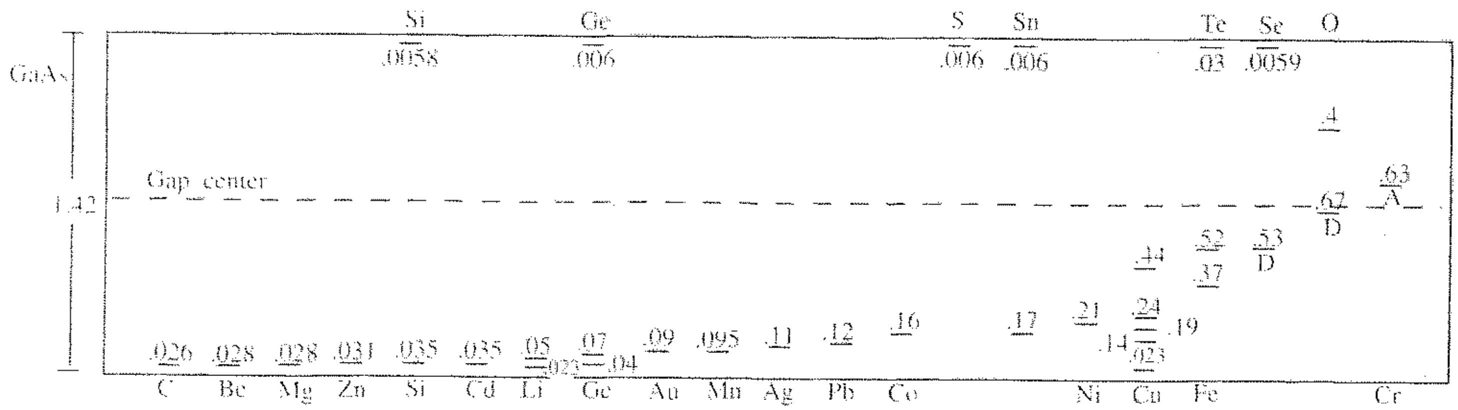

Figure 1.35 Energy levels of impurities in GaAs (from S. M. Sze, *Physics of Semiconductor Devices*, 2nd ed., Copyright © 1981. Reprinted by permission of Wiley, New York).