CME 300 Properties of Materials

Homework 9 November 26, 2011

18.7 How does the electron structure of an isolated atom differ from that of a solid material?

18.8 In terms of electron energy band structure, discuss reasons for the difference in electrical conductivity between metals, semiconductors, and insulators.

18.19 For intrinsic semiconductors, the intrinsic carrier concentration n_i depends on temperature as follows:

$$n_i \propto \exp\left(-\frac{E_g}{2kT}\right) \qquad (18.35a)$$

or taking natural logarithms,

$$\ln n_i \propto -\frac{E_g}{2kT} \qquad (18.35b)$$

Thus, a plot of ln n_i versus $1/T\,(\mathrm{K})^{-1}$ should be linear and yield a slope of $-E_g/2k$. Using this information and the data presented in Figure 18.16, determine the band gap energies for silicon and germanium, and compare these values with those given in Table 18.3.

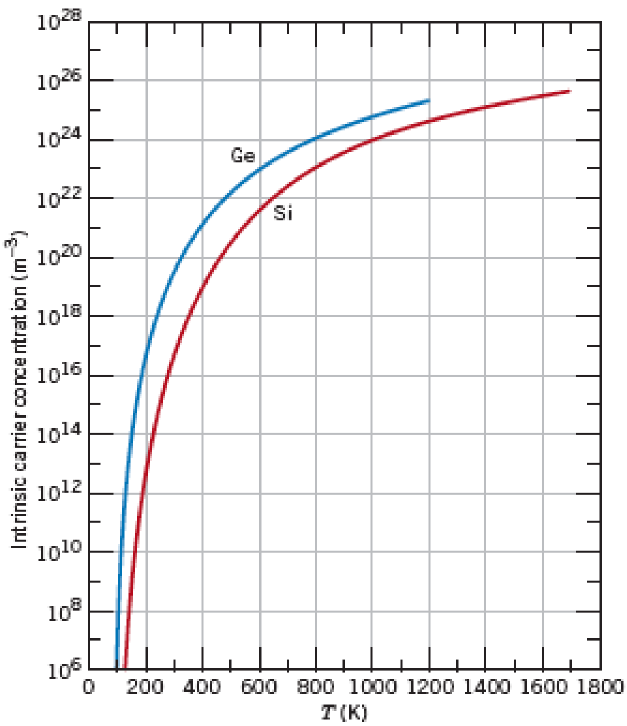


Figure 18.16 Intrinsic carrier concentration (logarithmic scale) as a function of temperature for germanium and silicon. (From C. D. Thurmond, "The Standard Thermodynamic Functions for the Formation of Electrons and Holes in Ge, Si, GaAs, and GaP," *Journal of The Electrochemical Society*, **122**, [8], 1139 (1975). Reprinted by permission of The Electrochemical Society, Inc.)

Table 18.3 Band Gap Energies, Electron and Hole Mobilities, and Intrinsic Electrical Conductivities at Room Temperature for Semiconducting Materials

Material	*Band Gap (eV)*	*Electrical Conductivity* $[(\Omega\text{-}m)^{-1}]$	*Electron Mobility* ($m^2/V\text{-}s$)	*Hole Mobility* ($m^2/V\text{-}s$)
		Elemental		
Si	1.11	4×10^{-4}	0.14	0.05
Ge	0.67	2.2	0.38	0.18
		III–V Compounds		
GaP	2.25	—	0.03	0.015
GaAs	1.42	10^{-6}	0.85	0.04
InSb	0.17	2×10^{4}	7.7	0.07
		II–VI Compounds		
CdS	2.40	—	0.03	—
ZnTe	2.26	—	0.03	0.01

18.24 Define the following terms as they pertain to semiconducting materials: intrinsic, extrinsic, compound, elemental. Now provide an example of each.

18.26 **(a)** In your own words, explain how donor impurities in semiconductors give rise to free electrons in numbers in excess of those generated by valence band–conduction band excitations. **(b)** Also explain how acceptor impurities give rise to holes in numbers in excess of those generated by valence band–conduction band excitations.

18.28 Will each of the following elements act as a donor or an acceptor when added to the indicated semiconducting material? Assume that the impurity elements are substitutional.

Impurity	*Semiconductor*
N	Si
B	Ge
S	InSb
In	CdS
As	ZnTe

18.36 Compare the temperature dependence of the conductivity for metals and intrinsic semiconductors. Briefly explain the difference in behavior.

and doped (extrinsic) semiconductors.

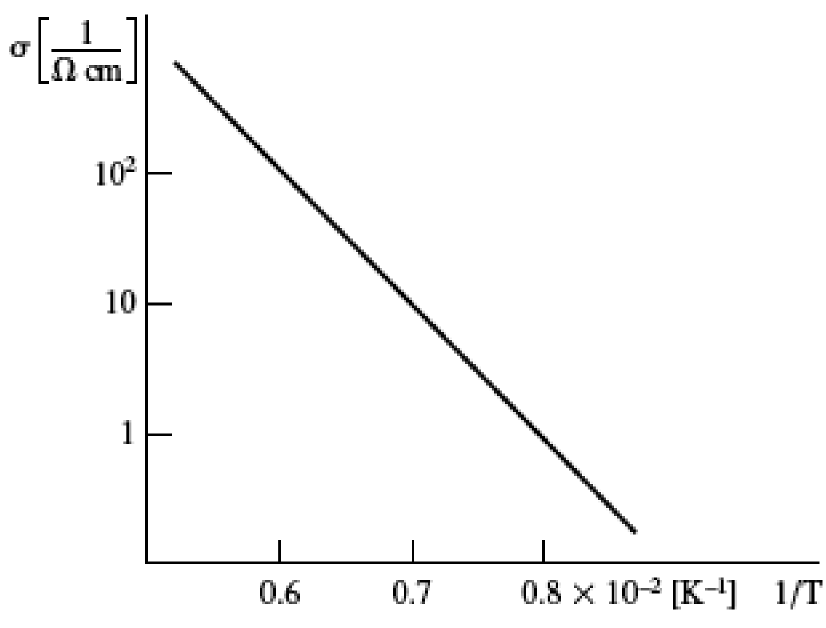
18.41 Some hypothetical metal is known to have an electrical resistivity of 3.3×10^{-8} (Ω-m). Through a specimen of this metal 15 mm thick is passed a current of 25 A; when a magnetic field of 0.95 tesla is simultaneously imposed in a direction perpendicular to that of the current, a Hall voltage of -2.4×10^{-7} V is measured. Compute **(a)** the electron mobility for this metal, and **(b)** the number of free electrons per cubic meter.

18.43 Briefly describe electron and hole motions in a *p–n* junction for forward and reverse biases; then explain how these lead to rectification.

18.45 What are the two functions that a transistor may perform in an electronic circuit?

18.46 Cite the differences in operation and application for junction transistors and MOSFETs.

11.7. In the figure below, σ is plotted as a function of the reciprocal temperature for an intrinsic semiconductor. Calculate the gap energy. (Hint: Combine (11.12) and (11.15) and take the ln from the resulting equation assuming $N_e \equiv N_h \cdot$ Why?).)



1) Define the Drude Model, Quantum Mechanics Model, Density of States, Fermi Energy, Extrinsic Semiconductor, Intrinsic Seimconductor, Indirect Band Gap Semiconductor, Direct Band Gap Semiconductor, Homo-Junction, Hetero-Junction.

2) How does a Laser Diode function?