Sample

Problem 5

I. Answer the following questions regarding an electron in a solid. Assume that the Schrödinger equation for an electron in a solid can be expressed by

$$\left(-\frac{\hbar^2}{2m^*}\frac{\partial^2}{\partial x^2}+V\right)\Psi = i\hbar\frac{\partial}{\partial t}\Psi \ ,$$

where Ψ is the wave function of an electron, m^* is an effective mass of an electron, $\hbar$ is the reduced Planck constant, and V is a potential for an electron. x is the position and t is time.

(1) The wave function of an electron with an energy E can be expressed by $\Psi = A\varphi(x)e^{-i\omega t}$, where A is a constant, and $E = \hbar\omega$. When a potential V is assumed to be a constant that is independent of time and position, derive the Schrödinger equation for $\varphi(x)$.

(2) Assuming that $\varphi(x) = e^{ikx}$ in Question (1), derive the dispersion relationship between an energy E and a wavenumber k.

(3) Consider an electron with a constant energy E_0 in Question (2). Show the necessary condition of E_0 for the wave function to become a traveling wave.

(4) Assume that $V = 0$ at $|x| \leq W/2$, and $V = \infty$ at $|x| > W/2$, where W is a constant. When an electron is confined in the range of $|x| \leq W/2$, show the minimum energy of an electron and its wave function in a steady state.

Sample

II. Answer the following questions.

(1) Choose the appropriate illustration from Figs. 1(a) - (c) which indicates positions of conduction band, valence band and Fermi level in an n-type semiconductor.

(2) Consider that a d.c. voltage is applied to a p-n junction whose matrix is an identical semiconductor as illustrated in Fig. 2.

(2-i) Draw a schematic band diagram of the p-n junction when V is null.

(2-ii) Draw a schematic current-voltage (I-V) characteristics of the p-n junction, where sign of current I flowing in a direction of an arrow in Fig. 2 is positive.

(3) Consider that a monochromatic light irradiates a p-n junction whose matrix is an identical semiconductor as illustrated in Fig. 3.

(3-i) Describe what kind of relationship is required between a bandgap energy of the semiconductor matrix and a photon energy of this light so that the semiconductor can absorb the light.

(3-ii) Choose the sign (positive or negative) which appears at Terminal A by the light absorption when Terminals A and B are open. On the other hand, give a direction of current flowing by the light absorption when Terminals A and B are closed.

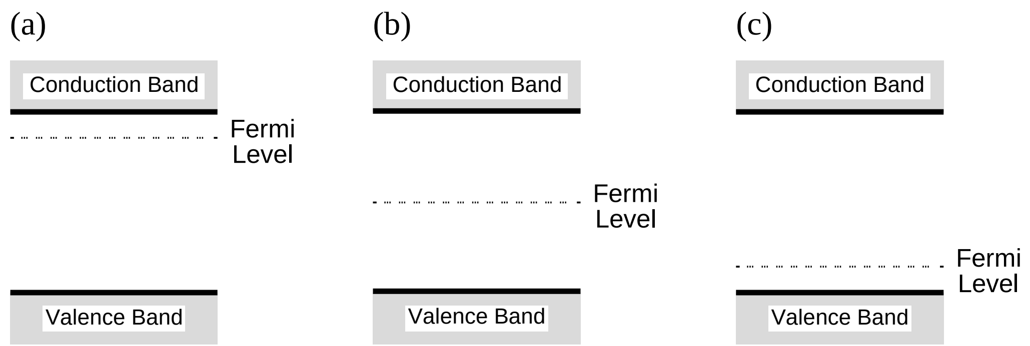

Fig. 1

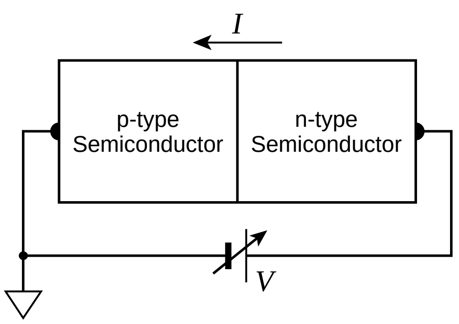

Fig. 2

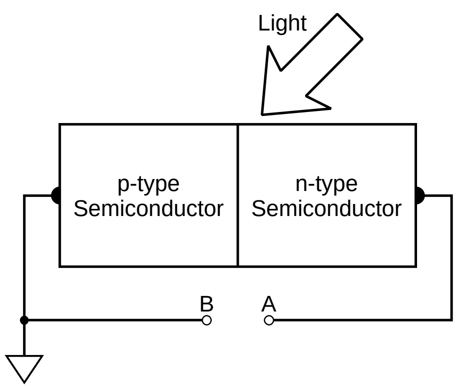

Fig. 3