عندما تكون القوة باتجاه اعتباطي فان تعجيل الالكترون لا يكون دائما باتجاه هذه القوة ولكن يمكن تحليل التعجيل الى مركبتين الاولى موازية للمحال والاخرى عمودية . فالمركبة الموازية للمجال هي المسؤولة عن نقل الطاقة من المجال الى الالكترون ولكن الصعوبة في معرفة القيمة العددية للكتلة التي تنتجعن مركبة المجال الموازية (شاكر جابر 230)

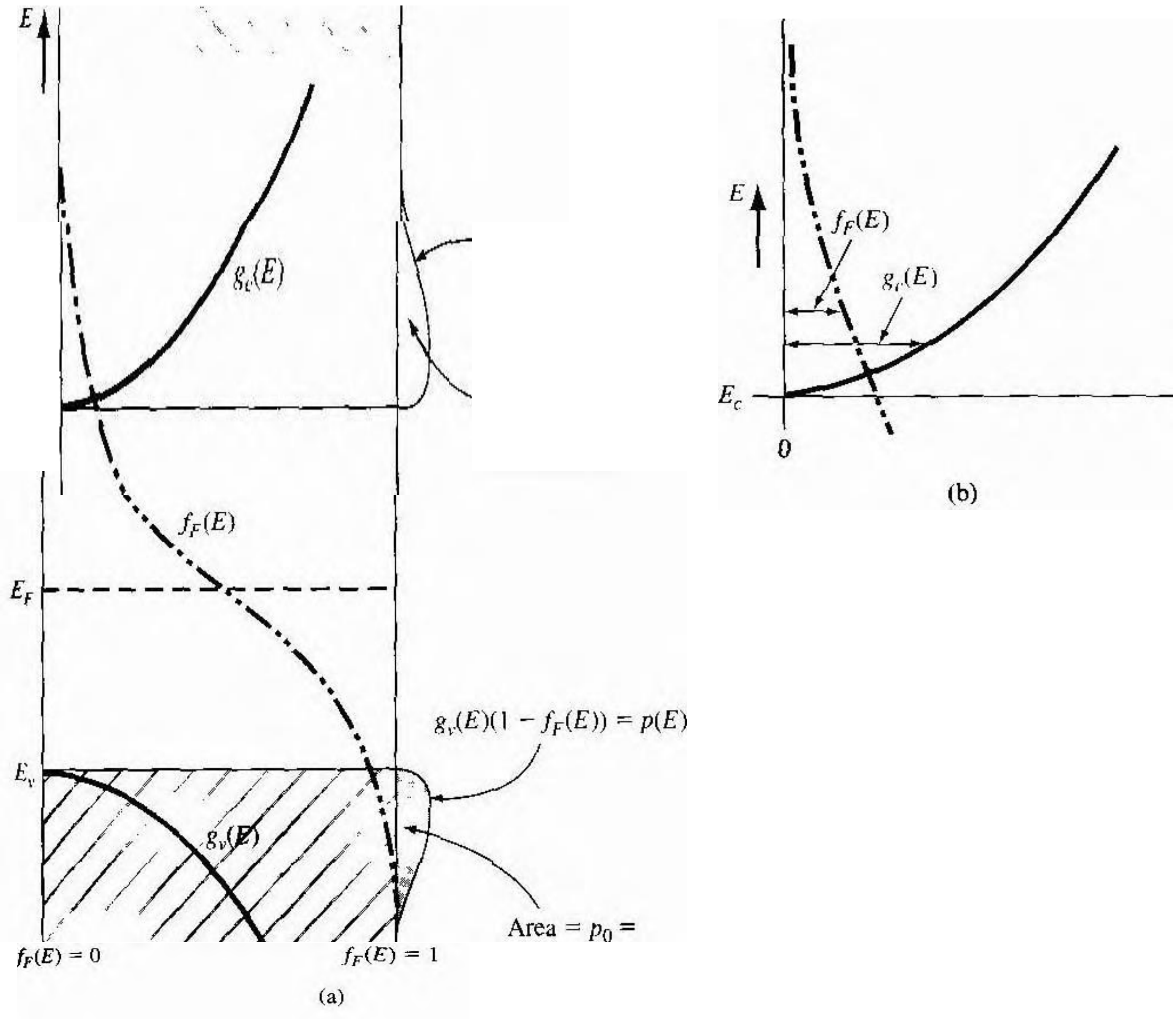

Figure 3: (a) Density of states functions, Fermi-Dirac probability function, and areas representing electron and hole concentrations for the case when E_f is near the midgap energy; **(b)** expanded view near the conduction band energy;and (c) expanded view near the valence band energy.

Donors and Acceptors

Adding donor or acceptor impurity atoms to a semiconductor will change the distribution of electrons and holes in the material. Since the Fermi energy is related to the distribution function, the Fermi energy will change as dopant atoms are added. If the Fermi energy changes from near the mid gap value, the density of electrons in the conduction band and the density of holes in the valence band will change. These effects are shown in Figures 4.8 and 4.9. Figure 4.8 shows the case for $\boldsymbol{E_F} > \boldsymbol{E_{Fi}}$ and Figure 4.9 shows the case for $E_F < E_{Fi}$. When $E_f > \boldsymbol{E_{fi}}$ the electron concentration is larger than the hole concentration, and when $E_F < E_{fi}$ the hole concentration

Figure 1. shows schematically the doping of a silicon crystal with an arsenic atom. The arsenic atom forms covalent bonds with its four adjacent silicon atoms, and the fifth electron becomes a conduction electron, thereby giving rise to a positively charged arsenic atom. As a consequence, the silicon crystal becomes n-type and arsenic is called a donor. Boron, on the other hand, has only three outer shell electrons and is an acceptor in silicon. Impurities such as arsenic and boron have energy levels very close to the conduction band and valence band, respectively, as indicated in ***Figure 1***. Shallow donors or acceptors such as these exist in ionized form at room temperature because thermal energy is sufficient to ionize them. This condition is called complete ionization, that is, $n = N_A$ or N_D.

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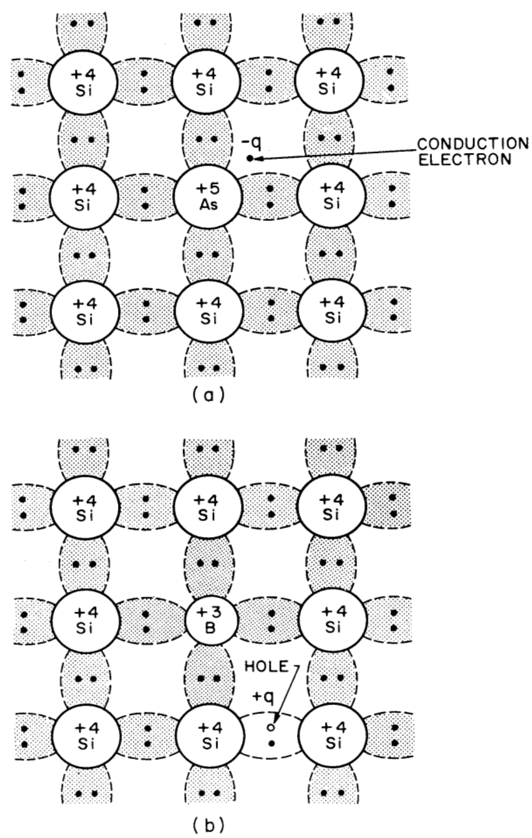

Figure 1.: Schematic bond pictures of (a) n-type Si with donor (arsenic) and (b) p-type Si
with acceptor (boron

Since $n = N_C \exp\{-(E_C - E_F)/kT\}$, $N_D = N_C \exp\{-(E_C - E_F)/kT\}$ and
$E_C - E_F = kT \ln[N_C/N_D]$ *(Equation 1.4)*

One of the implications of *Equation 1.4* is that (E_C-E_F) becomes smaller with increasing N_D, or in other words, the Fermi level moves closer to the bottom of the conduction band. Similarly, for p-type semiconductors, the Fermi level moves towards the top of the valence band with increasing acceptor concentration.
When both donors and acceptors are present simultaneously, the impurity present at a higher concentration determines the type of conductivity in the semiconductor. The electron in an n-type semiconductor is called the majority carrier, whereas the hole in n-type semiconductor is termed the minority carrier. Conversely, in a p-type semiconductor, holes are majority carriers and electrons are minority carriers show fig (2) and fig(3)
we have been discussing the donor and acceptor impurities in a group **IV** semiconductor, such as silicon. The situation in the group Ill-V compound semiconductors, such as gallium arsenide, is more complicated. Group elements, such as beryllium, zinc, and cadmium, can enter the lattice as substitutional impurities, replacing the group I11 gallium element to become acceptor impurities. Similarly, group VI elements, such as selenium and tellurium, can enter the lattice substitutionally, replacing the group V arsenic element to become donor impurities.

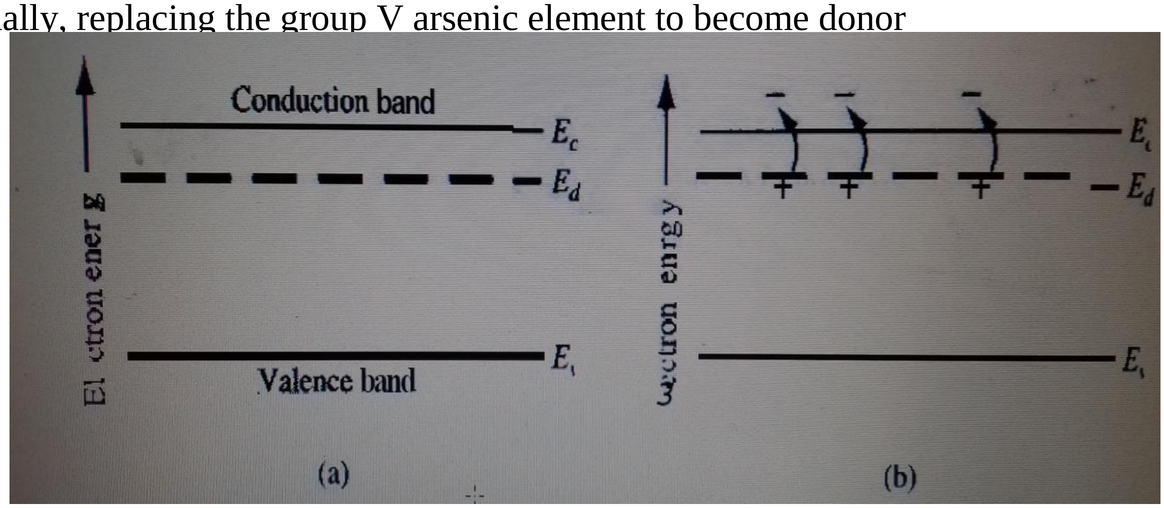

Figure 2.: The energy-hand diagram showing (a) the discrete donor energy state and (b) the effect of a donor state being ionized

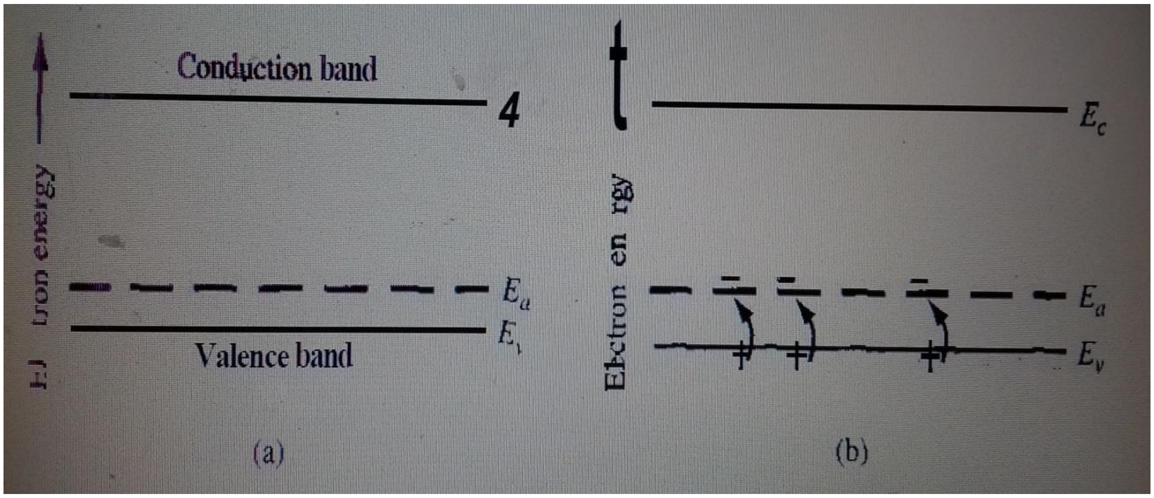

Figure *3.* The energy-band diagram showing (a) the discrete acceptor energy state and **(b)** the effect of an acceptor state being ionizcd

The corresponding ionization energies for these impurities are smaller than for the impurities in silicon. The ionization energies for the donors in gallium arsenide are also smaller than the ionization energies for the acceptors, because of the smaller effective mass of the electron compared to that of the hole .