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STUDY AND ANALYSIS OF ENERGY BANDS WITH VARIOUS TYPES OF CRYSTAL STRUCTURES

Prof. G. R. Kumrey [1], Dr. S. K. Mahobia [2]
[1] Assistant Professor, Department of Electrical Engineering, Rewa Engineering College, Rewa (M.P.), INDIA
[2] Assistant Professor, Department of Physics, Rewa Engineering College, Rewa (M.P.), INDIA

Abstract:
The difference between conductors, insulators and semiconductors is to plot the available energies for electrons in the materials. Instead of having discrete energies as in the case of free atoms, the available energy states form bands. Energy bands occur in solids where the discreet energy levels of the individual atoms merge into bands which contain a large number of closely spaced energy levels.

Keywords:
Band Theory, Metals, insulators, crystal structures.

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1. INTRODUCTION

In insulators the electrons in the valence band are separated by large gap from the conduction band, in conductors like metals the valence band overlaps the conduction band, and in semiconductors there is a small gap between the valence and conduction bands. A small gap, the presence of some percentage of a doping material can increase conductivity dramatically. The important parameter in the band theory is the Fermi level, the top of the available electron energy levels at low temperatures. The position of the Fermi level with the relation to the conduction band is a crucial factor in determining electrical properties.

Figure 1: Energy bands

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2. ENERGY BANDS

The crystal structure of common semiconductors to illustrate the fact that most semiconductors have an ordered structure in which atoms are placed in a periodic lattice. We then consider the Kronig-Penney model. This one dimensional model illustrates how a periodic potential yields a set of energy bands and energy band gaps. It is the detailed band structure of a given material which can be directly linked to its conducting, insulating or semiconducting behavior.

3. CRYSTALS AND CRYSTAL STRUCTURES

Semiconductors are consisting of atoms which are placed in an ordered form which is called a crystal. Crystals are identified based on their lattice structure. For instance the crystal structure of silicon is like that of diamond and referred to as the diamond lattice, which are shown in figure. Each atom in the diamond lattice has a covalent bond with four adjacent atoms which together form a tetrahedron. This lattice can also be formed from two face-centered-cubic lattices which are displaced along the body diagonal of the larger cube in the figure by one quarter of that body diagonal.

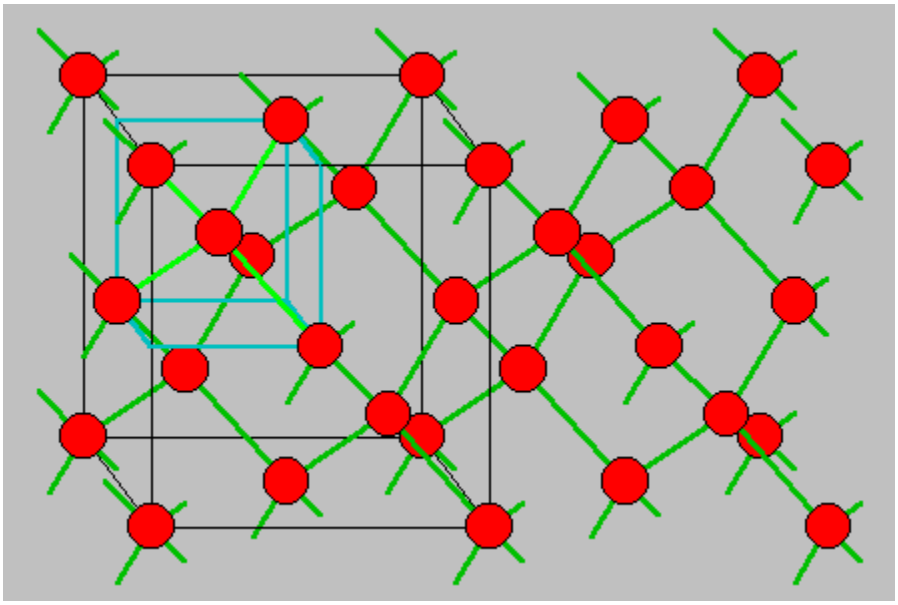

Figure 2: The diamond lattice of silicon and germanium

Compound semiconductors such as GaAs and InP have a lattice structure which is similar to that of diamond. However the lattice contains two different types of atoms. Each atom still has four covalent bonds, but they are bonds with atoms of the other type. This structure is referred to as the zinc-blende lattice as shown below.

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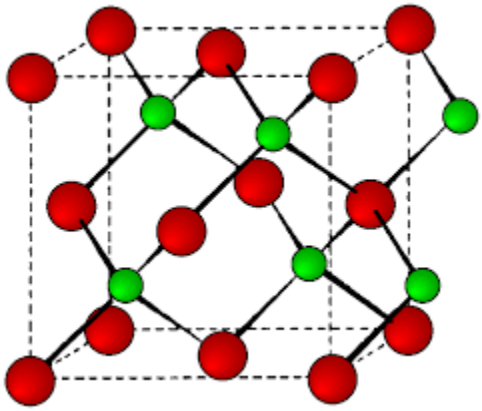

Figure 3: The zinc-blende lattice of GaAs and InP

4. METALS, INSULATORS AND SEMICONDUCTORS

The band structure of material we still need to find out which energy levels are actually occupied and whether specific bands are empty, partially filled or completely filled.

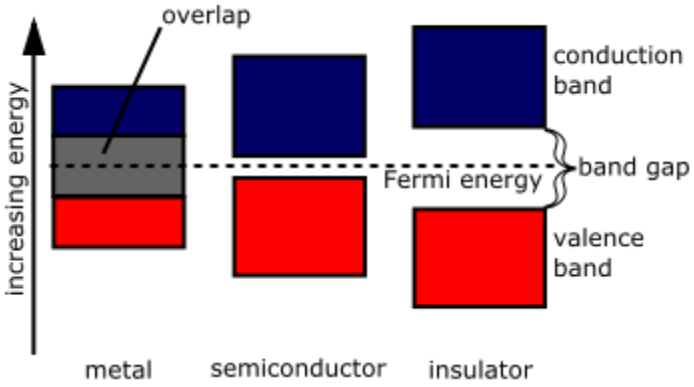

Figure 4: Metals, semiconductors and insulators

5. ENERGY BANDS OF SEMICONDUCTORS

As semiconductors are of primary interest in this text, we now introduce a simplified energy band diagram for semiconductors and define some key parameters.

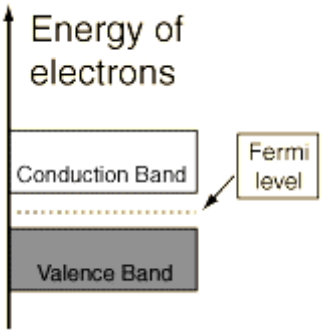

Figure 5: Energy bands of semiconductors

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