Unit 8. Physical principles of semiconductors

CONTENTS

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The aim of this unit is to provide an introduction to different types of solids, the band theory, electrical properties of semiconductors, different types of conduction in semiconductors and semiconductor devices.

First we discuss the different types of molecular bonds and solids, distinguishing primarily between ionic, covalent and metallic solids, and introducing the free-electron model of metals, the concept of density of states and Fermi-Dirac's distribution.

We analyze the difference between conductors, insulators and semiconductors based on their energy band structure and the separation between the valence and conduction bands. When atoms are bonded together in condensed matter, their energy levels are divided into bands. At absolute zero, insulators and semiconductors have a completely filled valence band separated by an energy gap in an empty conduction band. However, in the case of semiconductors the gap range between these two bands is about 1 eV. Conductors have partially filled conduction bands. We also distinguish between intrinsic and extrinsic semiconductors. In the latter case, the addition of a small concentration of impurities can drastically change the semiconductor electrical properties. Added donor impurity yields an n-type semiconductor, while if added impurities receiving the result is a p-type extrinsic semiconductor At this point it is important to introduce the semiconductor equation or law of mass action, an essential equation in the study of semiconductors and semiconductor devices as well as the condition of electrical neutrality.

We describe the transport phenomena of electrical charges in semiconductors, as a consequence of the application of electric fields (drift current) or the existence of gradients of charge concentration (diffusion current). The concepts of drift velocity, current density and conductivity studied here are similar to those introduced in the case of metal conductors in the unit "Electrical current", with the difference that in the latter case the charges are free electrons, while in a semiconductor they can be electrons (negative charges) or holes (positive charges).

The last section of the unit is dedicated to semiconductor devices, with an introduction to the basic characteristics of the diode and the transistor. We start studying the *pn* junction, both in forward and reverse bias, because this type of junction is the basis for the construction of diodes and transistors. We include basic operating characteristics such as the electron and hole currents, voltage-current characteristics of a diode, and the voltages and currents in a transistor. Finally we briefly discuss some applications of these devices.