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ELECTRICAL CONDUCTIVITY OF SEMICONDUCTORS

АННОТАЦИЯ. Основная цель данной статьи - изучить структуру и свойства полупроводников на молекулярном уровне.

В тексте рассматриваются условия для возникновения проводимости, влияние внешних факторов на связи в кристаллической решётке. Описана работа p-n перехода.

КЛЮЧЕВЫЕ СЛОВА: полупроводники, проводимость, диоды, электроны, дырки, p-n-переход.

ABSTRACT. The main purpose of this article is to study the structure and properties of semiconductors at the molecular level.

The conditions for the occurrence of conductivity and the influence of external factors on the bonds in the crystal lattice are considered in the text. The work of p-n transition is described.

KEY WORDS: semiconductors, conductivity, diodes, electrons, holes, p-n junction.

The substances capable of conducting or not conducting electric current are not limited to strict separation only into conductors and dielectrics. There are also semiconductors, such as silicon, selenium, germanium, and other minerals and alloys, worthy of being isolated in a separate group.

These substances conduct electric current better than dielectrics, but worse than metals, and their specific conductivity increases with temperature or light. This feature of semiconductors makes them applicable in light and temperature sensors, but their main application is still electronics.

If we look, as an example, at the silicon crystal, we can find that silicon has a valence of four, that is, on the outer shell of its atom there are 4 electrons, which are associated with four neighboring silicon atoms in the crystal. If to act with heat or light on such a crystal, the valence electrons will receive an increase in energy, and leave their atoms, turning into free electrons — in the semiconductor volume exposed to the electronic gas — as in metals, that is, there will be a condition for conductivity.

But unlike metals, semiconductors are characterized by electron and hole conductivity. Why does this happen and what is it? When the valence electrons leave their places, these former places are formed areas with a lack of negative charge - "holes", now having an excess positive charge.

As the result, the “hole" will easily jump to a neighboring electron, and once that hole will be filled by leaping over it with an electron, the electron leaping over a place again formed a hole.

It turns out that the hole is a positively charged mobile region of the semiconductor. When the semiconductor is included in the circuit with the EMF source, the electrons will move to the positive terminal of the source, and the holes to the negative terminal. This is how the conductivity of a semiconductor is realized.

The movement in semiconductor holes and conduction electrons without the applied electric field will be chaotic. If an external electric field is applied to the crystal, then the electrons inside it will move against the field, and the holes will move along the field, that is, in the semiconductor there will be a phenomenon of its own conductivity, which will be caused not only by electrons, but also by holes.

In the semiconductor conductivity always occurs only under the influence of some external factors: due to the irradiation of photons, the action of temperature, the imposition of electric fields, etc.

The Fermi level in the semiconductor falls in the middle of the band gap. For the transition of the electron from the upper valence band to the lower conduction band, the activation energy is needed, which is equal to the width of the band gap delta E. And as soon as an electron appears in the conduction band, a hole is born immediately in the valence band. Thus, the energy expended is divided equally in the formation of a pair of current carriers.

Half of the energy (corresponds to half of the forbidden zone) is spent on the transfer of the electron, and half — on the formation of a hole, as a result, the beginning of the reference corresponds to the middle of the forbidden zone. The Fermi energy in a semiconductor is the energy at which electrons and holes are excited. The position that the Fermi level is located for the semiconductor in the middle of the band gap can be confirmed by mathematical calculations, but here the mathematical calculations are omitted.

Under the influence of external factors, such as increasing temperature, thermal vibrations of the crystal lattice of the semiconductor lead to the destruction of some valence bonds, so that some electrons become free charge carriers.

In semiconductors, along with the process of formation of holes and electrons, the process of recombination works: electrons pass into the valence band from the conduction zone, giving their energy to the crystal lattice and radiating quanta of electromagnetic radiation. Thus, each temperature corresponds to the equilibrium concentration of holes and electrons, depending on the temperature.

There is still an impurity conductivity of semiconductors when a little other substance which differs in higher or lowered valence, in comparison with the basic substance, enters in a crystal of the pure semiconductor.

If in pure, say, in the same silicon, the number of holes and free electrons is equal, that is, they are formed all the time in pairs, then in the case of an admixture added to the silicon, for example arsenic, having a valence of 5, the number of holes will be less than the number of free electrons, that is, a semiconductor with a large number of free electrons, negatively charged, it will be a semiconductor of n-type (negative). If you mix in India, which has a valence of 3, that is, less than silicon, then there will be more holes — this will be a semiconductor of p-type (positive).

Now, if we bring semiconductors of different conductivity into contact, then at the contact point we get a p-n junction. The electrons moving from the n-region and the hole moving from the p-region will move to each other for a meeting, and on different sides of the contact will be the region with opposite charges (on different sides of the p-n-transition): in the n-region will accumulate a positive charge, and in the p-region — negative. Different parts of the crystal with respect to the transition will be charged oppositely. This position is very important for all semiconductor devices.

The simplest example of such a device is a semiconductor diode, where only one p-n junction is used, which is enough to achieve the task-to conduct current only in one direction.

The electrons from the n-region move towards the positive pole of the power supply, and holes from the p-region move towards the negative pole. Near the transition enough positive and negative charges will accumulate, the resistance of the transition will be greatly reduced, and the circuit will be current.

In the reverse inclusion of the diode, the current will go tens of thousands of times smaller, since electrons and holes will simply be carried by the electric field in different directions from the transition. The diode rectifier works on this principle.

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