SIGNIFICANCE OF SEMICONDUCTORS IN MODERN USE

Adilova Xalida Shamshetdin qızı
Nukus State Pedagogical Institute named after Azhiniyaz
(Nukus, Republic of Karakalpakstan)

Akimbaev Ruslan Farxodovich
Vocational school of Shoykhontokhur district of Tashkent city
E-mail: xalida-2015@mail.ru

ABSTRACT

This article deals with the importance of semiconductors and its in the modern world.

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INTRODUCTION

Semiconductors are substances in solid and liquid states of aggregation, the electrical conductivity of which at direct current increases when heated or illuminated. M. Faraday in 1833 discovered that the electrical conductivity of silver sulfide increases both when heated externally and when heated by a current excited in it. The positive photoconductivity of selenium, that is, an increase in its electrical conductivity when illuminated, was discovered by W. Smith in 1873. Later, the semiconductor properties of cuprous oxide and other substances were revealed. Research on the physics and technology of semiconductor materials led to the creation of micro-, opto- and acoustoelectronics, which largely led to progress in the entire technosphere. In addition, these materials definitely played the role of photocatalysts in the processes of origin and evolution of wildlife on Earth.

The most widely used semiconductor materials in the form of single and polycrystals. When a semiconductor is heated or illuminated, its atoms are quite easily ionized, resulting in both mobile electrons and mobile holes. In general, a hole is an elementary excitation of the electronic subsystem of a crystal, a quasiparticle, that is, an imaginary particle. The electric charge of the hole is equal in magnitude and opposite in sign to the charge of the electron, and its spin is equal in magnitude to the spin of the electron. The bound state of an electron and a hole in a crystal that transfers energy, but not electric charge, is called an exciton.

According to the band theory, the spectrum of allowed and forbidden values of electron energy in three-dimensional crystals consists of alternating bands - energy bands. The zones are formed by a quasi-continuous set of atomic energy levels "split" as a result of the aggregation of free atoms into a crystalline structure. In crystalline semiconductors, the states of the valence band filled with electrons are separated from the vacant states of electrons in the conduction band by a band gap. Electrons fill the allowed energy bands in accordance with the Pauli principle: at Q energy levels of a quantum system, there can be no more than 2Q electrons, since each level corresponds to two states of the electron spin. The band theory of the states of electrons in crystals is based on the use of the adiabatic and one-electron approximations in solving the Schrödinger equation: the average velocity of atomic nuclei around equilibrium positions is much less than the average velocity of electrons; each electron moves in a spatially periodic field created by nuclei and other electrons.

Almost all properties of a semiconductor depend on the type and concentration of defects in the crystal structure, as well as on temperature, illumination, deformation, and other types of influence. Like the cells of living organisms, semiconductors are sensitive to the effects of radiation: ultraviolet, x-ray and gamma radiation, fast electrons, protons, neutrons, ions. The energy transferred to an atom of the crystalline matrix by radiation can cause it to shift from the position of thermodynamic equilibrium with the formation of a primary radiation defect - an interstitial atom and an atomic vacancy. The accumulation of single primary radiation defects and their associates with each other or with impurity atoms leads to the fact that crystals lose transparency, increase volume, etc. If nuclear reactions occur under the action of radiation, the composition of nuclides in the substance changes. In general, semiconductors optimally combine both susceptibility to external influences and manufacturability of operations for forming stable devices from them.

Research into semiconductor materials and devices in Belarus was started by I. G. Nekrashevich, N. N. Sirota, V. D. Tkachev, and V. P. Gribkovsky in the early 1960s. Among the achievements in this area at the Department of Semiconductor Physics and Nanoelectronics, Belarusian State University, the following should be noted:

■ development of radiation physics of covalent crystals and discrete semiconductor devices based on them;

■ detection of radiative recombination of electrons and holes at dislocations in plastically deformed silicon crystals;

■ registration of infra-low-frequency self-oscillations of electric current in boron-doped micron-thick polycrystalline silicon films;

■ discovery of the effect of absorption of microwave electromagnetic radiation by electrons "levitating" over the surface of a natural diamond crystal during its interband photoexcitation;

■ implementation of manufacturing technologies for a number of semiconductor device structures.

Regarding the prospects for the development of the school of physics and technology of semiconductors in Belarus, the following can be noted. Recently, single and consolidated low-dimensional systems have gained practical importance, the extent of which along at least one direction in the coordinate space is comparable in value with one of the parameters of the length dimension characterizing the states and processes in these systems. Materials consisting mostly of such systems are called nanostructured or nanomaterials. By changing the size, shape, or mutual arrangement of low-dimensional systems as components of a nanomaterial, one can control its properties without changing the chemical composition.

To study, create and use low-dimensional systems, it is necessary to develop their theory. The fact is that the band theory is the basis for describing electrical, magnetic, optical, acoustic and thermal phenomena in three-dimensional crystalline dielectrics, semiconductors and metals with dimensions greater than or approximately equal to 0.1 μm. However, it is inapplicable for describing low-dimensional systems due to violations of point and translational symmetries, as well as the conditions for the applicability of the adiabatic and one-electron approximations. The quantum theory of solitary atoms, which is the basis for describing small molecules, cannot be used to adequately describe states and processes in systems with a size of about 0.1 μm. Therefore, it is necessary to develop a theory that considers the states and processes in individual molecules and atoms, taking into account their agglomeration into a low-dimensional system.

It seems that the improvement of the methods of creation and diagnostics, as well as the expansion of the areas of application of semiconductor systems of a new generation in electronics, photonics, spintronics and acoustics, will proceed traditionally: from idea to calculations, experiments and further to practical implementation. Based on this, we note some promising areas of research on this topic in their physical, chemical, biological and social aspects:

■ development of mathematical modeling methods and physical and chemical principles of molecular architecture of low-dimensional systems and device structures based on them. As a result, this will make it possible to implement "low-tonnage" technologies not by the method of "collective subcapture" and subsequent "direct stacking", but purposefully and economically;

■ development of the quantum theory of ionization equilibrium and migration of electrons, holes and ions in low-dimensional semiconductor systems for the purposes of hydrogen and solar energy. The solution of this problem will make it possible to create new materials for photoelectric converters and "non-poisonous" electrodes for water photolysis;

■ study of single and consolidated funnel-shaped macromolecules, curvilinear quantum-dimensional wires, as well as nanostructured "soft" materials to create functional elements of photonics, electromechanics, acoustics and bionics devices on their basis;

■ development of physical and technological methods for the formation of associates from impurity atoms or intrinsic atomic structural defects in crystalline semiconductors when creating solid-state analogs of inductors for power electronics;

■ integration of magnetism into semiconductor micro- and nano-electronics. The development of engineering of magnetic low-dimensional systems in silicon wafers will make it possible to extend their use within the framework of planar technology to spintronics;

■ establishing the dependence of the mechanical strength of wide-gap semiconductors on the position of the Fermi level in the energy band gap. This will make it possible to predict the destruction processes of these materials in devices of high-temperature electronics, optics, and mechanics;

■ study of hopping electron migration over multiply charged point defects in the crystal matrix of partially disordered semiconductors for the development of a hopping electric current rectifier and a Peltier element;

■ development of the concept of spin micro- and nanomechanics of dielectrics, semiconductors and metals with structural defects, which in the future will make it possible to predict sudden outbursts of hard coal in mines during its extraction;

■ transfer of knowledge, skills and developments from researchers to designers, from them to manufacturers and commercialization of science-intensive products.

CONCLUSION

It is clear that in scientific research and in the applications of their results, it is necessary to rely on theory, experiment, and practice, thanks to which the physics and technology of semiconductor materials have arisen and are developing.

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