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PROPERTIES AND STRUCTURES OF NANOMATERIALS IN TEACHING THE COURSE OF MODERN GENERAL PHYSICS IN UNIVERSITIES

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ABSTRACT

In this work the experience of teaching course in general physics, taking into account the structure and properties of nanomaterials are presented. The experience of teaching course in general physics, taking into account the properties of nanomaterials, showed increased interest of students in the chosen specialty. These features pose methodological problem that must be solved in the process of publishing educational literature.

KEYWORDS: - Structure and properties of nanomaterials, teaching course in general physics, methodological problem, increased interest of students

INTRODUCTION

At present, huge amount of material has been accumulated on the physical properties of nanomaterials. Nanostructures are one of the most interesting condensed phase states. They have many peculiarities and physical and chemical properties not previously observed.

In this work the experience of teaching course in general physics, taking into account the structure and properties of nanomaterials are presented. An analysis of existing courses in general physics for universities shows that the latest advances in physics, especially the properties of nanomaterials and nanoparticles, are not actually reflected, with the exception of work [6]. So far, this is the only textbook for the course of general physics, intended as a teaching aid for students of higher educational institutions studying in technical and natural science specialties.

The Commission on Nanotechnologies under the President of the Russian Academy of Sciences, headed by the Nobel Prize laureate Academician

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Zh.Alferov, has developed a large general academic research program, which includes six main sections [1,2]:

1) physics of nanostructures;

2) nanoelectronics;

3) nanomaterials;

4) nanobiotechnology;

5) nanodiagnostics;

6) education.

In this work, we will focus on the physical properties of nanoparticles:

1. Nanomaterials and nanostructures as objects of molecular physics. Nanomaterials usually consist of nanofragments (nanoparticles) with an ordered structure. It is customary to call nanoparticles objects ranging in size from 1 to 100 nm, which occupy an intermediate position between molecules and microparticles. The properties of nanoparticles and the way they are organized into ordered structures determine the unusual properties of nanomaterials. By changing the size and configuration of the constituent nanoelements or the way they are connected to each other, it is possible to change the properties of nanomaterials and even control them.

According to modern concepts, nanomaterials are divided into types as follows:

1. Nanoporous structures;

2. Nanoparticles;

3. Nanotubes and nanofibers;

4. Nanodispersions (nanocolloids);

5. Nanostructured surfaces and films;

6. Nanocrystals and nanoclusters.

This list shows that these nanomaterials are objects of molecular and atomic physics. This fact should be reflected in the course of molecular physics. Now let's dwell on other properties of nanomaterials:

1. Mechanical properties. In terms of their mechanical properties, CNTs differ sharply from bulk materials. CNTs combine high strength and rigidity with high elasticity. The tube bends but does not break. Young's modulus is almost 10 times that of steel. And the strength is almost 20 times higher. These properties make it possible to use CNTs as an indenter for determining microhardness.

2. Thermophysical properties. The largest number of results was obtained in the study of thermal conductivity. The thermal conductivity of carbon nanomaterials differs markedly from other allotropic properties of carbon. While it is large for diamond and graphite, it is much lower for CNT fullerenes [3]. Thus, at room temperature, the absolute value of the thermal conductivity of sample filled with nanotubes is about 60 times less than for graphite. The main mechanism of heat transfer in the bulk of nanotubes is phonon. The phonon mean free path at temperatures below 30 K is 0.5–1.5 μm. The low thermal conductivity of materials with fullerenes and CNTs is explained by the weak intermolecular bond between fullerene molecules in the crystal and the disordered structure of samples with CNTs. The following table shows the thermophysical properties of high-temperature superconductors (HTSC) widely used in electronics.

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Thermophysical parameters of materials of HTSC structures

Options	Materials				
	$Y_1Ba_2Cu_3O_7$	$Zr(Y)O_2$	Al_2O_3	MgO	$SrTiO_3$
Density, kg / m^3	6350	3980	5850	3580	5110
Specific heat, J / kg·K	150	70	80	100	200
Thermal conductivity, W / Km	2,1 10,	2000	1.5	700	10

Electrical and magnetic properties

These properties for CNTs have been studied most fully. In accordance with the temperature dependence, the resistance of all CNTs can be divided into two groups: metallic and semiconducting. In the former, the resistance is insignificant and increases almost linearly with temperature. In the latter, almost linear dependence of the logarithm of resistance on the reciprocal temperature is observed. In this case, the characteristic activation energies are 0.1-0.3 eV.

In metal nanotubes, ballistic conductivity is observed, which is characterized by the absence of temperature dependence and is explained by the ballistic transfer of electrons without scattering and energy loss. in this case, the conductivity does not depend on the length of the nanotube and is equal to the quantum conductivity e2 / h = (25813 Ohm)-1, recall that the conductivity of an ordinary conductor is directly proportional to its cross section and inversely proportional to its length.

CNTs have a pronounced magnetoresistance. When an external magnetic field is applied in the direction of the nanotube axis, depending on the magnetic field strength, oscillations of the electrical resistance are observed, which is explained by the quantum-mechanical Aharonov-Bohm effect. The oscillation amplitude is comparable to quantum resistance.

High-temperature superconductors in nanoelectronics

At present, both theoretically and experimentally, the possibility of creating electronic elements and devices with unique characteristics based on superconductors has been demonstrated. The prospects for the commercial use of such devices have expanded significantly with the discovery of the phenomenon of high-temperature superconductivity.

The practical results of using high-temperature superconductors in nanoelectronics are associated with the development of effective methods for the formation of structures with submicron dimensions. In this case, it is possible to create cheap electronic devices based on the Josephson and Meyer effects. These phenomena occur only in superconductors, and the best technical characteristics are achieved when the core size is less than 10 nm. This is due to the fact that the correlation length of current carriers in high-temperature superconductors is very small and amounts, depending on the direction, from 0.1 to 1.5 nm. The emergence and intensive development of methods for the formation of structures with volume of several nanometers

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opens up new prospects for using the phenomenon of high-temperature superconductivity in electronics.

Optical properties

The optical properties of CNTs are similar to crystalline solids. The specificity of the object is manifested only in the frequency characteristics of the spectra. The Raman scattering technique makes it possible to analyze the dynamics of the CNT lattice. in Raman scattering of group of lines with frequencies 1590 and 1551 s \ T corresponds to tangential vibrations of carbon atoms. Optical absorption spectra in the energy range of 0.75 eV – 2.0 eV are also Raman spectra, which makes it possible to determine the average diameter of nanotubes and their size distribution [4].

The emission of electrons from nanotubes is accompanied by the appearance of luminescence in the wavelength range of 0.6-0.75 μm, and heating of nanotube imitators causes noticeable thermal radiation.

The optical properties also include the ability of single-layer tubes to explode under intense illumination, for example, with a photographic flash).

Materials science

One of the most important applications of nanotechnology is the creation of new materials that can lead to fundamental change in industrial technology. The main directions of work in this area are as follows.

- Creation of a device for information technology. With this technology, the recording density can be increased up to 1000 times.
- Obtaining nanoscale metal composites (cermets)
- Manufacturing of flame retardant plastics and fillers in the form of dispersed nanoparticles.

One of the main disadvantages of plastics is their flammability, which is accompanied by the release of toxic and harmful substances. The fire resistance of plastic can be significantly increased by introducing dispersed inorganic fillers from nanosized powders into them.

Conclusion

The experience of teaching course in general physics, taking into account the properties of nanomaterials, showed increased interest of students in the chosen specialty.

These features pose methodological problem that must be solved in the process of publishing educational literature.

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