Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Кафедра
Мікроелектроніки

Electronic materials: principles and applied science

Робоча програма навчальної дисципліни (Силабус)

Реквізитинавчальної дисципліни

Рівень вищої освіти	third (doctor of philosophy)
Галузь знань	17 Electronics, automation and electronic communications
Спеціальність	176 Micro- and Nano-System Engineering
Освітня програма	Micro- and Nano-System Engineering
Статус дисципліни	Selective
Форма навчання	Full time
Рік підготовки, семестр	2nd year, spring semester
Обсяг дисципліни	5 credits (150 hours)
Семестровий контроль/ контрольні заходи	Exam
Розклад занять	
Мова викладання	English
Інформація про керівника курсу / викладачів	Lecturer: Professor, Doctor of Physical and Mathematical Sciences Poplavko Yuri Mikhailovich Practical / Seminar: Poplavko Yuriy Mykhailovych yu.poplavko@kpi.ua
Розміщення курсу	Googleclassroom

Програманавчальної дисципліни

1. Описнавчальної дисципліни, її мета, предмет вивчення та результати навчання

Materials of electronic equipment occupy an important place not only in modern electronics, but also in information technologies. The use of electronics and equipment in the tropics, spacecraft and submarines, the development of computer technology and miniaturization of equipment, make new demands on these materials. The course ***studies*** the features of the structure and symmetry of dielectrics; mechanisms of various electrical processes in materials; connection of structure with electrical and magnetic properties of materials, etc. Students ***learn to***: determine the basic electronic mechanisms of materials; to establish for the main mechanisms the connection of parameters with the characteristics of the material; determine the main physical causes of the properties and effects used by microelectronics; calculate the parameters of anisotropic active materials; evaluate and calculate the electrical parameters of materials; establish for the main mechanisms the relationship of parameters with the characteristics of the material.

The ***purpose*** of the discipline is the formation of students' competencies:

General competencies:

Ability to apply knowledge in practical situations.

Ability to participate in the planning and execution of experiments and laboratory studies of the properties of physical systems, physical phenomena and processes, processing and presentation of their results.

Ability to participate in the manufacture of experimental samples, other objects of study.

Ability to participate in the implementation of research and development results.

Ability to constantly develop competencies in field of electronics materials, engineering and computer technology.

Ability to use modern theoretical ideas in the field of physics of materials for the analysis of physical systems.

Ability to use methods and tools of theoretical research and mathematical modeling in professional activities.

After mastering discipline, students must demonstrate the following ***learning outcomes***:

- knowledge of the structure and symmetry of solids, possible defects in the crystal structure and mechanisms of electrical and magnetic processes in dielectrics, the relationship of structure with the electrical properties of dielectrics, nanophysics and nanotechnology;

- ability to determine the basic mechanisms of electrical conductivity, polarization, magnetization, phase transformations in materials, etc .;

- experience in establishing a connection between the technological processes of obtaining and processing materials and their electrophysical parameters; practical determination of the main electrophysical parameters of electric charge transfer, dielectric polarization, magnetization, piezo and pyroeffects, optical effects, etc., used in micro- and nanoelectronics; calculations of basic electrophysical parameters of materials.

The course forms **general competencies** in the ability to abstract thinking, analysis and synthesis (GC1), to search, process and analyze information from different sources (GC2), to apply modern information technology (GC4), to carry out scientific and innovative activities (GC5) and **professional competencies**:

- Ability to independently carry out research activities in the field of knowledge "Automation and instrumentation" using modern theories, methods and information and communication technologies (PC1).
- Ability to conduct theoretical and experimental research, mathematical and computer modelling in the field of knowledge "Automation and Instrumentation" (PC4).
- Knowledge of construction, parameters and characteristics, element base, design principles and manufacturing technology of modern micro- and nanoelectronics devices (PC8).
- Ability to communicate in a multilingual scientific environment (PC10).

As a result of successful mastering of the course, applicants for higher education achieve the following **program learning outcomes**:

- Have advanced conceptual and methodological knowledge in micro- and nanosystem technology and at the boundaries of subject areas, as well as research skills sufficient for conducting scientific and applied research at the level of the latest world achievements in the relevant field, gaining new knowledge practice (PLO1).
- Systematically think and apply creative abilities to form fundamentally new ideas, build and study physical, mathematical and computer models of objects and processes of micro- and nanoelectronics, offer ways to solve problems when methods of solving them are not known (PLO4).
- Plan and perform experimental and / or theoretical research in the field of micro- and nanosystem technology, related interdisciplinary areas using modern theories, methods, specialized equipment and facilities, information and communication technologies, critically analyse the results of own research and the results of other researchers in the context of the whole complex modern knowledge about the researched problem (PLO5).
- Develop new methods and technologies, software and hardware of micro- and nanosystem technology, microelectronic information systems (PLO9).

2. Пререквізити та постреквізити дисципліни (місце в структурно-логічній схемі навчання за відповідною освітньою програмою)

Перереквізити: Physics, solid state physics, materials and components of micro- and nanosystem technology

Постреквізити: Dissertation defense

Зміст навчальної дисципліни (перелік розділів і тем)

1. Electronics materials structure
2. Mechanical properties of solids
3. Thermal properties of solids
4. Quasi-particles in solids
5. Metals
6. Magnetics
7. Semiconductors
8. Dielectrics-insulators
9. Active dielectrics
10. Phase transitions

3. Навчальні матеріали та ресурси

1. Yuriy M. Poplavko. Electronic materials. Principles and applied science. 2019, 683 pages. Edited by ELSEVIER, **USA**.
2. Yu.M. Poplavko. Solid state elementary electrophysics, Vol. 1 Symmtry, quasi-particles, metals, magnetics. Kyiv, Edited by Igor Sicorsky Polytechnic Institute, 2016, 364 pages. Tutorial approved by Academic Council of Igor Sicorsky Polytechnic Institute (protocol №11 of November 7, 2016).
3. Yu.M. Poplavko. Solid state elementary electrophysics, Vol. 2 Semiconductors, dielectrics, phase transitions. Kyiv, Edited by Igor Sicorsky Polytechnic Institute, 2016, 364 pages. Tutorial approved by Academic Counsil of Igor Sicorsky Polytechnic Institute (protocol №11 of November 7, 2016).
4. Yuriy Poplavko. Polar crystals. Physical nature and new effects. LAMBERT, Saarbrucen, Academic Publishing, 2014. 84 pages.
5. Yuriy M. Poplavko. Physics of active dielectrics. Volume 1. Polarization, conduction, losses, breakdown. 349 pages. LAMBERT Academic Publishing. 2015. Навчальний посібник: Гриф «КПІ» - рішення Наукової Ради НТУУ Протокол №6 від 30 червня 2015 р.
6. Yuriy M. Poplavko. Physics of active dielectrics. Volume 2. Piezoelectrics, pyroelectrics, ferroelectrics, phase transitions. 251 pages. LAMBERT Academic Publishing. 2015. Навчальний посібник: Гриф «КПІ» - рішення Наукової Ради НТУУ Протокол №6 від 30 червня 2015 р.
7. Yu.M. Poplavko, Yu.I. Yakymenko. Functional dielectrics for electronics. Fundamentals of conversion properties. 2020, 294 pages. Edited by ELSEVIER, **USA**.
8. Yuriy M. Poplavko. Dielectric spectroscopy of electronic materials. Applied physics of dielectrics. 2021, 425 pages. Edited by ELSEVIER, USA.

Навчальний контент

4. Методика опанування навчальної дисципліни(освітнього компонента)

Information is provided (by sections, topics) about all-educational classes (lectures, practical, seminar, laboratory) and recommendations are given for their mastering. Independent student's work. Preparation for classroom classes, calculations based on primary data, problem solving, essay writing, calculation work, homework, etc.)

Політика та контроль

5. Політика навчальної дисципліни (освітнього компонента)

Encouraging answers to tasks using English is encouraged.
The following types of training sessions are planned within the discipline:
- lectures;
- practical training;
- ndependent work.

The topics of the discipline are interrelated, the material is studied in a logical sequence. The classes reveal the most important theoretical issues that allow students to provide deep independent study of all program material. Topics and the order of practical classes are formed in a logical sequence and are fully consistent with the lecture material. Theoretical and practical knowledge is deepened by independent work using the recommended literature and information resources of the Internet.

The classes use a personal computer, commonly used computer programs and operating systems, a projector, an interactive whiteboard, and Internet resources.Control of learning material is carried out by individual survey (testing), homework and credit.

6. Додаткова інформація з дисципліни (освітнього компонента)

Electronics materials science is a part of “Solid state physics" but accommodated to electrical engineering. In general, modern materials science covers a very wide range of issues, but in this book mainly *electrical properties* of metals, semiconductors, dielectrics, and magnets are described, in particular those that are of importance for specialists in electronics.

Electronics is a science and engineering discipline concerning study and application of electrical phenomena inherent in substances (mainly, solids). Based on these studies, electronic devices are created, as well as the art of electronic circuits and systems construction is developed. It is also possible to define electronics as the science of electrons interaction with electromagnetic fields or as a science and methodology of creating electronic materials, instruments, and devices. Theoretical problems of electronics are concerned with the study of electrons interaction with macroscopic fields inside the workspace of an electronic device as well as with the study of interaction of electrons with microscopic fields of ions, atoms, molecules or crystal lattice. Practical problems of electronics boil down to the design of electronic devices that perform various functions, such as conversion and transmission of information, control, computing, as well as the energy supplying.

Thus, electronics materials sciences are important for specialists in electronics. It should also be noted that at present not only educational, but also monographic literature cannot keep pace with the rapid development of the materials science, in other words, of the applied solid state physics. This includes many areas of knowledge and technology – from preparation of materials to electronics. In this context, nanophysics and nanotechnology are particularly fast growing areas, and it is clear that they were never mentioned in the books on solid state physics published 20-30 years ago.

The present book uses considerably simplified mathematical treatment of theories, while emphasis is made on the basic concepts of physical phenomena in electronic materials and their relatively simple explanation. Most chapters are devoted to the advanced scientific and technological problems of electronic materials; in addition, some new insights into theoretical facts relevant to technical devices are presented. This approach is used due to the contemporary tendency for mutual penetration and synthesis of different fields that at the first glance belong to different areas of science.

The *first chapter* presents general information about the structure and the symmetry of solids. In addition to traditional subjects this book includes the description of symmetry of composite materials and nanomaterials.

In the *second chapter* the main mechanical properties of solids are examined. Among highlights of mechanical properties, the preference is given to elastic characteristics, both static and dynamic ones. As volume so surface elastic waves are considered important in acoustoelectronics and optoelectronics.

In the *third chapter* the thermal properties of electronics materials are presented, such as specific heat, thermal conductivity and thermal expansion. The concept of phonons is introduced and their role in thermal properties of solids is discussed.

The *fourth chapter* is devoted to the concept of quasi-particles. The fundamentals of classical and quantum statistics (fermions and bosons concepts) are briefly discussed, as well as the main properties of photons, phonons, magnons and electrons in atoms and in crystals. The basics of band theory are given.

In the *fifth chapter* the properties of metals are analysed. The most important conducting materials used in the electronics and instrumentation are described. Mechanisms of electrical conductivity, thermal conductivity, thermoelectric power and thermal expansion in conductors are considered. Some special phenomena are studied, such as heavy fermions in metals, crioconductivity, superconductivity, and more. Both the classical and the band theories of electrons in metals are expounded, such as quantum distribution of electronic gas, the effect of magnetic field, and Fermi surface. Special attention is paid to mechanisms of electrical charge and heat transfer in metals, as well as to charge carrier mobility, Hall's effect and magnetoresistance. The features of magnetic nanomaterials are also studied.

The ***sixth chapter*** is devoted to one of the complex problems of solid state physics, namely, magnetism. Following the traditional approach, the disordered and slightly ordered magnetic materials are considered, and in this connection the physical basis of the "weak magnetism" – diamagnetism and paramagnetism – is presented. Diamagnetism in fullerenes and semimetals is examined, as well as paramagnetism in rare earth elements compounds. This chapter also considers the physical basis of "strong magnetics", also known as spin-ordered ferromagnetics, as well as of the ferrimagnetic structures, which are very important for technical applications.

In addition to the traditional presentation of magnetism, some latest findings in this area are discussed, including magnetostriction, termostriction and recently discovered giant magnetocaloric effect in rare earth elements, their compounds, and other materials. Much attention is paid to modern scientific and technical achievements in the field of magnetism that have not yet been reflected in textbooks. To some extent, it relates also to new effects in magnetic semiconductors and magnetooptics, but mostly to properties of nanostructured magnetic materials (magnetic glass, super-paramagnetism, etc.).

The *seventh chapter,* which deals with basic properties and characteristics of semiconductors, can be considered as the central section for professionals in electronics. Elementary band theory of semiconductors is discussed, kinetic processes and optical phenomena in the semiconductors are explained. Main properties of semiconductors in the magnetic fields are described.

The *eighth chapter* is devoted to the physics of crystalline dielectrics. The determinant features of polarization mechanisms in dielectrics are described, as well as dielectrics interaction with electromagnetic waves. The mechanisms of electrical charge transfer in dielectrics, the mechanisms of dielectric loss, and the nature of electrical breakdown are also discussed.

In the *ninth chapter*, the special features of so-called *active dielectrics* – i.e., piezoelectrics, pyroelectrics, ferroelectrics and electrets – are described; especially because they are widely used in modern electronics, and have great prospects in future.

The *tenth chapter* is devoted to the phase transitions in solids. Based on Landau theory, phase transitions of second-type are considered, both in the crystals and in the liquid crystals. The physical meaning of the *ordering parameter*, introduced by Landau, is explained in the context of ferroelectrics, ferromagnetics, ferroelastics, liquid-crystals, superconductors, etc. More detail the metal-insulator, metal-superconductor, paraelectric-ferroelectric phase transitions are discussed, which involve critical change of electrical parameters – conductivity, permittivity or permeability, optical and other properties of the materials. External control by these parameters is widely used in modern electronic devices.

Робочу програму навчальної дисципліни (силабус):

Складено професором, докт. фіз.-мат. наук Поплавко Юрієм Михайловичем

Ухвалено кафедрою мікроелектроніки (протокол № 27 від 21.06.2024)

Погоджено Методичною комісією факультету (протокол № 06/2024 від 27.06.2024)