Drohobych Ivan Franko State Pedagogical University

APPROVED
Vice-Rector for Scientific, Pedagogical Work and Informatization
Voloodymyr HALYK
15 листопада 2023

SYLLABUS

SOLID-STATE ELECTRONICS AND OPTOELECTRONICS

Field of Study:	10 Natural sciences
Progrmme Subject Area:	105 Applied physics and nanomaterials
Educational Programme	Applied physics and nanomaterials
Discipline status:	Obligatory
Faculty of	Physics, Mathematics, Economics and Innovative Technologies
Department of	Physics and Information Technologies
Language of instruction:	English

Information on the Study of the Discipline

Mode of study	Year of study	Semester	Total scope of the discipline: hours/ECTS credits	Number of hours						Term paper	Type of semester control	
				Auditory classes					Individual work			
				Total	Lectures	Laboratory work	Practical classes	Seminars			Credit	Exam
Full-time	2	3	90/3	30	14	16	-	-	60	-	-	+
Part-time	2	4	90/3	8	4	4	-	-	82	-	-	+

The Sullabus is based of the Educational Programme and the Curriculum for the specialists of the third (Educational and Scientific) level of higher education (3 Credit)

Autor:
________ **Ihor VIRT,** Doctor of Physical and Mathematics Sciences, Professor;

Approved by the guarantor of the Education Programme : ________ Ihor VIRT,
Doctor of Physical and Mathematics Sciences, Professor.

Approved at the meeting of the Departament of Physics and Information a Technologies
Protocol № 3 dated 26 10 2023.
Head of the Departament ________ Vitaly HOLSKYI

Approved at the meeting of the Scientific and Methodical Council of the Faculty of Physics, Mathematics, Economics and Innovative Technologies.
Protocol № 3 dated 31 жовтня 2023.

Approved at the meeting of the Scientific and Methodical Council of the University
Protocol № 9 dated 14 листопада 2023.

1. THE PURPOSE OF STUDYING THE EDUCATIONAL DISCIPLINE

Purpose: formation of future specialists in-depth knowledge about the physical basis of the principle of operation of solid-state devices and the technological processes used in their construction.

Subject: solid-state devices, technological processes and materials of electronic equipment.

Tasks mastering the basics of the theory of electron-hole transitions, homo- and heterostructures and contacts of the "metal-semiconductor" type; principles of construction of various electronic devices and solid-state electronics devices; principles of construction of transistors and multilayer devices; principles of construction of microelectronic devices and solid-state optoelectronic devices.

2. PREREQUISITES FOR STUDYING THE EDUCATIONAL DISCIPLINE

The educational discipline is taught after studying the disciplines "Higher Mathematics", "Physics", "Materials Science TCM", "Electrical Engineering and Electronics", "Fundamentals of Heat Engineering and Hydraulics", "Modern Materials Science in Engineering" and is the basis for studying the disciplines of the cycle of professional training of specialists of the third (educational and scientific) level of higher education.

3. EXPECTED LEARNING OUTCOMES

According to the educational programme, higher education applicants must

know: basic principles and regularities of solid-state electronics and optoelectronics; physical principles of operation of microelectronic devices and the connection of their parameters with structural features; technology of devices and materials used for their creation; the main technological processes of creating microstructures.

be able:

Integral competence: to solve complex problems in the field of professional, including research and innovation activities, which involves a deep rethinking of existing and the creation of new integral knowledge and professional practice.

General competences: to operate with scientific terminology and to build a hierarchy of scientific concepts according to the levels of their generalization; to navigate in the modern regulatory framework of education development, educational policy trends in Ukraine; to generalize innovative pedagogical experience in one's own scientific research; to prepare, plan, organize one's own scientific and pedagogical activities; to adequately apply scientific methods to fulfill the tasks of one's own research; to implement information and communication technologies to implement the scientific research plan; psychological readiness for scientific activity, development of scientific thinking; readiness for emotional self-regulation, development of willpower, self-organization and self-actualization; readiness for self-analysis of the results of scientific activity.

Professional competencies of the specialty: the ability to study and modernize existing industrial technologies, understanding the processes of the innovation environment, problems of modern electronics; the ability to introduce the known physical properties of the research object and the physico-chemical phenomena occurring in it into modern technological processes.

Programme learning outcomes: knowledge of physical laws and known facts to describe the qualitative physical interpretation of the results of experimental measurements; knowledge of regularities of researched phenomena and physical objects in the knowledge system of this field of applied physics, assessment of their scientific novelty; knowledge of modern methods of interpretation of raw data for the synthesis of new materials, in particular nano-sized products and technological processes; the ability to evaluate the mechanical, technological, physical properties, structure and phase composition of substances and materials being studied or obtained using modern technical means and methods; the ability to effectively use standard devices, equipment and materials for the analysis of researched objects; the ability to master operations of analysis, synthesis, comparison, comparison of physical and chemical phenomena and processes to solve various scientific and research tasks; the ability to apply scientific methods to perform the tasks of one's own research.

4. CRITERIA FOR ASSESSMENT OF LEARNING OUTCOMES

Assessment is carried out according to the scales: ECTS, 100-point and national.

Grade "A" (90 - 100 points) - "excellent" (*excellent knowledge and skills with only a small number of minor errors*): accepts an acquirer who demonstrates deep system knowledge of software material; competently formulate the tasks facing solid-state electronics in the modern world; is able to use the acquired knowledge for the correct description of physical processes in solid-state devices, taking into account their design features; to be able to analyze the operation of modern solid-state electronics and optoelectronic devices, determine their parameters and characteristics; knows how to use acquired knowledge, skills and abilities to solve practical tasks; all types of educational work have been completed.

Grade "B" (82 - 89 points) - "good" (*above average with few errors*): receives an acquirer who demonstrates good system knowledge of software material; is able to formulate the problems facing solid-state electronics in the modern world; is able to use the acquired knowledge for the correct description of physical processes in solid-state devices, taking into account their design features; to be able to analyze the operation of modern solid-state electronics and optoelectronic devices, determine their parameters and characteristics; is able to use the acquired knowledge, skills and abilities to solve practical tasks, with few significant errors; all types of educational work have been completed.

Grade "C" (75-81 points) - "good" (*in general, thorough system knowledge with a small number of significant errors*): accepts an applicant who has a good command of the program material; tries to formulate the problems facing solid-state electronics in the modern world; mostly knows how to use the acquired knowledge for the correct description of physical processes in solid-state devices, taking into account their design features; to be able to analyze the operation of modern solid-state electronics and optoelectronic devices, determine their parameters and characteristics; with a small number of significant errors, is able to use the acquired knowledge, the ability to solve practical tasks; all types of educational work have been completed.

Grade "D" (67 - 74 points) - "satisfactory" (*not bad, but with a significant number of shortcomings*): awarded for knowledge and understanding of the main program material; reproduces the material in a simplified form; can demonstrate the connection between individual theoretical patterns and solve simple applied problems; with the difficulties of formulating the problems facing solid-state electronics in the modern world; analyzes the operation of modern devices of solid-state electronics and optoelectronics, which have a significant number of shortcomings, determines their parameters and characteristics; all types of educational work have been completed.

Grade "E" (60 - 66 points) - "satisfactory" (*knowledge and skills meet the minimum criteria*): awarded to an applicant whose knowledge and skills meet the minimum criteria according to the program; who can reproduce more than half of the educational material at the reproductive level with elements of logical connections; has elementary skills and abilities; can perform the simplest applied task; does not know how to independently formulate the tasks facing solid-state electronics in the modern world, analyze the operation of modern solid-state electronics and optoelectronics devices, determine their parameters and characteristics; all types of educational work were completed, but with significant shortcomings.

Grade "FX" (35 - 59 points) - "unsatisfactory" (*unsatisfactory knowledge with the possibility of retaking the exam*): the recipient receives for superficial knowledge and understanding of the main program material; inconsistent presentation of material with significant errors; does not know how to make generalizations and conclusions; does not know how to apply theoretical knowledge when solving applied problems; cannot formulate the problems facing solid-state electronics in the modern world; cannot analyze the operation of modern solid-state electronics and optoelectronics devices, determine their parameters and characteristics; did not complete all types of educational work.

Grade "F" (1-34 points) - "unsatisfactory" (*with a mandatory repeat course*): presented in the case when the acquirer possesses only separate concepts, fragmentary knowledge of the software material without any connection between them; does not know how to apply theoretical knowledge when solving applied problems; cannot formulate the problems facing solid-state electronics in the modern world; are unable to analyze the operation of modern solid-state electronics and/or optoelectronics devices, determine their parameters and characteristics; did not complete all types of educational work.

5. MEANS OF DIAGNOSIS OF LEARNING OUTCOMES

1) admission to protection and performance of laboratory work;
2) final control work;
3) interview with the lecturer;
4) exam.

6. CONTENT OF EDUCATIONAL DISCIPLINE

1. Physics of electron-hole (*p-n*) transition

1.1. Electron-hole transition. Formation and parameters of electron-hole transitions.
1.2. Energy diagram of the *p-n* transition in the equilibrium state.
1.3. Contact potential difference. The width of the *p-n*-transition.
1.4. Externally biased *p-n* junction operation. Injection and extraction of charge carriers.
1.5. Types of p-n transitions: symmetric, asymmetric, linear.
1.6. The volt-ampere characteristic of an ideal *p-n* junction.
1.7. Equivalent diagram of the *p-n*-transition.
1.8. Special contact designs. *p-i-n*-structures.
1.9. Heterojunctions. Contacts of the "metal-semiconductor" type. Other types of contacts.

2. Functional properties of diode structures

2.1. Diodes and their classification. Semiconductor diodes.
2.2. Rectifier diodes. High-frequency and pulse diodes.
2.3. Zener diodes and stabilizers.
2.4. Tunnel and inverted diodes. Energy diagrams and IUC.
2.5. Avalanche-transition diodes.
2.6. Non-linear elements. Varicaps.
2.7. Schottky diodes.

3. Bipolar transistors

3.1. Physical principles of operation of transistors and thyristors. Structure and main modes Work.
3.2. Switching circuits of bipolar transistors. Static characteristics.
3.3. A bipolar transistor as an active quadrupole.
3.4. Temperature and frequency properties of transistors.
3.5. Four-layer structures. Dinistors and trinistors. Triacs
3.6. Field-effect transistors with a controlling p-n junction, structure, principle of operation, characteristics and parameters.
3.7. MIS transistor with the specified channel. MIS transistor with a built-in channel.
3.8. Transistors with static induction.

4. Integrated microcircuits

4.1. Integrated microcircuits as a special type of solid-state electronic devices.
4.2. Basic terms and definitions.
4.3. Structural and technological types of integrated microcircuits and their classification.
4.4. Integrated microcircuit as a special type of solid-state electronic devices.
4.5. Elements of integrated circuits.

5. Functional electronic with charge-coupled device (CCD)

5.1. Ways of creating a charge in a semiconductor.
5.2. Charge movement along the semiconductor surface.
5.3. Diagnostics of the presence of a charge.
5.4. Image conversion devices on CCD.
5.5. Digital and analog devices on CCD.

5.6. Negative resistance and negative conductivity.
5.7. Principles of using negative resistance in electronic devices.

6. Solid-state radiation sources

6.1. Sources of incoherent radiation.
6.2. Luminescence and its types. Injection luminescence.
6.3. Materials and radiation spectra. LEDs on heterojunctions.
6.4. LED matrices. Electroluminescent elements. Internal modulation.
6.5. Semiconductor lasers with electronic and optical pumping.
6.6. Injection lasers, structure and principle of operation. Threshold pumping current and efficiency.
6.7. Laser heterostructures, strip lasers.
6.8. Lasers on superlattices.
6.9. A distributed-feedback laser (DFB) and a distributed Bragg reflector laser (DBR).
6.10. Powerful injection lasers, laser lines and grids.
6.11. Cascade lasers at intraband transitions.
6.12. Radiation receivers. Characteristics of photoreceivers.

7. Solid-state heterostructural nanoelements and nanodevices

7.1. The main types of heterostructures of semiconductor devices.
7.2. Optical modulators, photosensitive p-i-n-i structures.
7.3. Photoreceivers on quantum wells.
7.4. Heterostructural field effect transistors.
7.5. The structure of modern nanotransistors of the HEMT (High Electron Mobility Transistor) type based on AB compounds.
7.6, Resonance-tunnel transistor on a quantum dot.
7.7. Transistors on "hot" electrons.
7.8. Integrated microcircuits on heterostructural field-effect transistors (FinFET).
7.9. Acoustoelectronic devices. Conversion of an acoustic signal into an electrical signal and the reverse conversion.
7.10. Surface acoustic waves (SAW) and methods of their excitation. Magnetoelectronic devices.
7.11. Magnetic recording of information. Magnetoacoustic devices. Magneto-optical devices.
7.12. Dielectric electronics. Dielectric devices of electronics.

Approximate topics of laboratory works

1. Determination of rectifier characteristics of diodes.
2. Study of an amplifier based on bipolar transistors.
3. Study of an amplifier based on field-effect transistors.
4. Studying the characteristics of logical integrated circuits.
5. Study of the emitting characteristics of LEDs.
6. Determination of the characteristics of photodiodes and photoresistors.

7. TASKS FOR INDEPENDENT WORK

The student's independent work in the discipline involves studying theoretical material in preparation for laboratory classes, writing a test paper, an interview with a lecturer and a semester exam.

Approximate topics of independent work

1. Reveal the essence of the charging (barrier) capacity of the *p-n* junction.
2. Describe the dynamic operation mode of the transistor.
3. Give examples of devices with an *S*-shaped characteristic.
4. Characterize functional electronic devices based on volume negative resistance.
5. Find out the conditions of inversion and amplification in semiconductors.
6. Describe injection lasers with quantum-sized layers. quantum wells and dots.
7. Give examples and describe devices based on ballistic transport.

8. Describe integrated microcircuits on resonance-tunnel heterostructures.
9. Perform the conversion of an acoustic signal into an electrical signal and vice versa.
10. Give examples of magneto-acoustic and magneto-optical devices.

8. FORMS OF CURRENT AND FINAL CONTROL

Current control of knowledge is carried out in laboratory classes, control work and an interview with a lecturer.

Performing laboratory work involves theoretical preparation for work (working on theoretical material), the ability to analyze the researched processes and explain their physical essence, the structure and operation of the researched objects; writing a report for laboratory work, quality design of the report; defense of the report (interview with the teacher). Each laboratory work is valued at 10 points - 5 points for admission and 5 points for drawing up a report and defense. The student must make up the missed laboratory session within the set time.

The test is performed in a written form and is valued at 20 points.

The interview with the lecturer is held in the second half of the semester on the topics of the material covered according to the pre-announced schedule.

Final control is conducted in the form of a written exam. Examination tickets contain two theoretical questions and two practical tasks.

The generalized number of points in the discipline is defined as the total score of the current performance with a weighting factor of 0.6 and grades for the exam in a 100-point scale with a weighting factor of 0.4. The assessment of the discipline is given according to the assessment scales: 100-point, national and ECTS.

Distribution of 100 points between types of works:

CURRENT PERFORMANCE			SUM OF POINTS	EXAMINATION
Performing laboratory work	Final control work	Interview with the lecturer	$S_{current}$	S_{final}
60 (6×10)	20	20	100	100
Weight factor			0,6	0,4
				$S_{summary} = 0{,}6 \cdot S_{current} + 0{,}4 \cdot S_{final}$.

9. TOOLS, EQUIPMENT, SOFTWARE

Multimedia presentations in Microsoft PowerPoint, posters, and demonstration samples are used in lectures. In laboratory classes, students acquire skills in research work and practical application of theoretical knowledge. The performance of laboratory work requires the presence of a laboratory equipped with specialized laboratory equipment and the necessary measuring 1 control instrument. Consumables - specially prepared samples are provided for conducting research in laboratory classes. Excel, MatLab, GNU-Octave, Mathcad software are used for calculations, data processing, and diagram construction.

10. RECOMMENDED SOURCES OF INFORMATION

a) main

1. Sze S.M., Ng K.K. Physics of Semiconductor Devices. – Wiley-Interscience, 2006. – 832 p.
2. Dugaev V., Litvinov V. Modern Semiconductor Physics and Device Applications. – CRC Press, 2021. – 382 p.
3. Evstigneev M. Introduction to Semiconductor Physics and Devices. – Springer, 2022. –462 p.
4. B. Raj, A. Raman: Nanoscale Semiconductors; Materials, Devices and Circuits. – CRC Press, 2022. – 259 p.
5. Kasap S. Optoelectronics and Photonics: Principles and Practices. – Pearson, 2012. –528.
6. Jena D. Quantum Physics of Semiconductor Materials and Devices. – Oxford University Press, 2022. – 897 p.

7. Nano-Semiconductors Devices and Technology.– Edi. Iniewski K.– CRC Press, 2017.– 599p.
8. Singh J., Mishra U. K. Semiconductor Device Physics and Design.– Springer, 2008.– 320 p.
9. Mitin V.V., Kochelap V. A., Stroscio M. A. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications.– Cambridge University Press, 2008.– 347p.

b) additional

1. Krishnaswamy J.A., Ramamurthy P.C., Hegde G., Mahapatra D.R. Modelling and Design of Nanostructured Optoelectronic Devices. – Springer, 2022. –293 p.
2. Nanomaterials for Optoelectronic Applications. –Edit.: Shkir M., Kaushik A. K., Alfaify S. – Apple Academic Press, 2022. – 314p.
3. Optoelectronic Devices: Advanced Simulation and Analysis. – Edit.: Piprek J. – Springer, 2005. –452 p.
4. Sub-Micron Semiconductor Devices : Design and applications. – Edit.: Raman A., Shekhar D., Kumar N.. – Taylor & Francis Group, 2022. – 671 p.
5. Mishra U., Singh J.Semiconductor Device Physics and Design. – Springer, 2008. –583p.
6. Новгородцев А.І., Борисенко О.А., Кобяков О.М. Курс лекцій з дисципліни «Твердотільна електроніка». Суми: Вид-во СумДУ, 2008 . – 205 с.
7. Хорунжий В.А. Функціональна мікроелектроніка. Опто- і акустоелектроніка. Харків: Основа, 1995. – 131 с.

c) Information resources

1. https://www.numerade.com/books/semiconductor-devices-physics-and-technology/?gclid=EAIaIQobChMIsbqq-ca_-gIVywN7Ch3N5QI7EAMYASAAEgLjD_D_BwE
2. https://www.udemy.com/course/semiconductor-device-physics-an-introduction/?utm_source=adwords&utm_medium=udemyads&utm_campaign=LongTail_la.EN_cc.ROW&utm_content=deal4584&utm_term=_._ag_119586862319_._ad_535397279676_._kw__._de_c_._dm__._pl__._ti_dsa-1212271230479_._li_1011463_._pd__._&matchtype=&gclid=EAIaIQobChMIgcW3ise_-gIVb0aRBR2a3QfnEAMYASAAEgJye_D_BwE
3. https://visic-tech.com/on-board-chargers/