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|  | **Course Syllabus** |

**1.** **Course Title:**

Kinetic effects of electrons in semiconductors and nanostructures

**2. Academic Level:**

Bachelor

**3. ECTS Credits:**

3 ECTS

**4. Semester:**

7, autumn semester

**5. School/Department:**

Institute of Nanotechnologies, Electronics and Equipment Engineering / Department of Radio Engineering Electronics and Nanoelectronics

**6. Location:**

Taganrog Campus, 2 Shevchenko St., Taganrog

**7. Instructor:**

Prof. Igor Malyshev, PhD, email: [ivmalyshev@sfedu.ru](mailto:ivmalyshev@sfedu.ru)

**8. Language of Instruction:**

English

**9. Course Description:**

This course is designed for in-depth study of the kinetic processes of hot electrons, their drift and diffusion, which take place in the volumes of various crystal lattices of semiconductor structures and determine their output characteristics and parameters.

**10. Course Aims:**

* to obtain basic knowledge, skills and abilities about methods for calculating the parameters of processes occurring in modern semiconductor devices;
* to study main kinetic effects manifested by electrons in the structures of modern active elements.
* to increase the level of English proficiency,

**11. Specific entry requirements (if any):**

English B1

The course requires basic knowledge of energy and electronic structures of atoms and molecules in various semiconductors, as well as knowledge in specific areas of general physics, chemistry, physics of solids and mathematics.

**12. Course Content:**

The course is comprised of 5 units (and UNIT 0). Each unit ends with a capstone project worked by the students individually with guidance from the lecturer.

*Unit 0: Electron transfer in semiconductor structures. Basic relations*. Main crystal structures of semiconductors, their energy diagrams and band structures. States of electrons. Lagrangian and Hamiltonian. Distribution function, Schrеdinger equation and Boltzmann kinetic equation.

*Unit 1: Dielectric properties of semiconductors*. Semiconductor reaction to a disturbing potential. Physical nature issues of the dielectric constant. Components of intrinsic conductivity.

*Unit 2: General information about scattering in semiconductors*. Ideal crystals in equilibrium and associated elementary excitations with ionic and electronic degrees of freedom, phonons and plasmons, respectively. Effects of "collisions" between electrons and lattice structures.

*Unit 3: Electron-phonon interactions*. Two types of interactions. The first is the deformation potential, which is associated with the displacement of the potential near the atom. The second is (the interaction of Furlich), which is associated with the long-range electric field, caused by the displacement of atoms. Interactions with acoustic phonons.

*Unit 4: Energy dependence of the effective mass of charge carriers*. Types of dysperse in semiconductors. Two-valley representation of the band diagram and relations for the description of the effective mass for different semiconductors and nanostructures. Taylor series decomposition of a function for inverse effective mass.

*Unit 5: Drift-diffusion model of carrier transport in the bulk of semiconductors in strong electric and magnetic fields*. Phenomenological approach to the processes of drift and heating in the volume of semiconductors. Differential kinetic equations that take into account the drift and diffusion components of transport processes. The effects that are manifested in the output conductivity under the influence of strong constant electric and magnetic fields.

**13. Intended Learning Outcomes:**

Knowledge: basic principles of preparation and design of presentations and reports, basic knowledge in the field of kinetic processes in various semiconductors.

Abilities: to compose, to present reports in English, to prepare presentations; to use basic methods and techniques of communication in English to solve different problems of professional activities.

Skills: to think abstractly, to analyze, to synthesize the information received in English; to provide efficient and high-quality presentation in the field of kinetic processes in various semiconductors.

**14. Learning and Teaching Methods:**

**Passive:** lecture-visualization using presentation material, oral questioning.

**Active:** independent work with literature, scientific, educational and reference digital resources, performance of analytical tasks, individual assignments.

**Interactive:** participation in practical classes, participation in discussions, presentation of project assignments in English. The course can be carried out partly or as a whole using electronic and distant educational system of University.

**15. Methods of Assessment/Final assessment information:**

**16. Reading List:**

1. W. Borchardt-Ott. Crystallography: An Introduction (Springer, Berlin, 2011) – 216 P.
2. Massimo V. Fischetti, William G. Vandenberghe. Advanced Physics of Electron Transport in Semiconductors and Nanostructures- (Springer, Switzerland, 2016) - 474 P.
3. P. Yu, M. Cardona. Fundamentals of Semiconductors: Physics and Materials Properties, 3rd edn. (Springer, Berlin/Heidelberg, 2005) – 327 P.
4. S. Sze, M.K. Lee, Semiconductor Devices: Physics and Technology (Wiley, New York, 2012) - 276 P.
5. S. Jin, M.V. Fischetti, Ting-wei Tang, Theoretical study of carrier transport in silicon nanowire transistors based on the multisubband Boltzmann transport equation. // IEEE Trans. Electron Devices 55, 2886 (2008)

Assignments for this course consists of: 5 projects, a midterm exam, and an end of term paper and presentation

1. Structures of semiconductor lattices **Project**: one week after the end of unit 10%

2. Interactions with one type of phonons **Project**: one week after the end of unit 10%

3. m=f(W) for one type of dispersion **Projec**t one week after the end of unit 10%

4. In Class Midterm Exam 20%

4. Drift and diffusion parameters for one type of semiconductors

**Project:** one week after the end of unit 10%

5. Output conductivity of one from AIIIBV semiconductors

**Project:** one week after the end of unit 10%

6. Presentation in class 10 min pres. and 5 min Q&A 10%

7. End of term Paper during final exam Content and grammar 20%

A 10% per day late penalty will be applied to all assignments. 100%