GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Solid state physics, PG_00049429		
Field of study	Corrosion		
Date of commencement of studies	February 2023	Academic year of realisation of subject	2022/2023
Education level	second-cycle studies	Subject group	Obligatory subject group in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish
Semester of study	1	ECTS credits	5.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Solid State Physics -> Faculty of Applied Physics and Mathematics		
Name and surname of lecturer (lecturers)	Subject supervisor	prof. dr hab. inż. Jarosław Rybicki	
	Teachers	prof. dr hab. inż. Jarosław Rybicki dr inż. Natalia Wójcik	

Lesson types and methods of instruction

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	30.0	0.0	30.0	0.0	0.0	60
E-learning hours included: 0.0						

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	60	15.0	50.0	125

Subject objectives

Presentation and discussion of basic principles of materials physics with a particular attention payed to relations among the structure at the atomic level and macroscopic physical properties of materials.

Learning outcomes

Course outcome	Subject outcome	Method of verification
K7_K01	During the lectures new trends in materials' physics and applications will be highlighted. Understanding of new achivements in the field requires continuous following the literature.	[SK5] Assessment of ability to solve problems that arise in practice
K7_U01	The student performs a number of experiments, presents and discusses the measurement results and critically compares them with the published data.	[SU1] Assessment of task fulfilment
K7_W01	Understanding the interrelationships between molecular sturcture of matter and microscopic properties of materials.	[SW1] Assessment of factual knowledge

Subject contents	Crystalline and glassy materials (short-range, medium-range and long-range order, radial and angular distribution functions); thermodynamics of phase transitions; glass transition; gels (classification and applications); quasicrystals; liquid crystals; auxetics. The basic concepts of crystallography (Bravais lattice, primitive and elementary cell, simple and complex lattice, Miller indices, etc.); symmetry operations; crystallographic point groups and space groups; the models of amorphous bodies (CRN, RCP, random-coil); the reciprocal lattice and its properties; conditions for Braggs diffraction and Laue diffraction. Crystalline bonds (ionic, covalent, metallic, molecular and hydrogen); binding energies (lattice sums, the Madelung energy, the Evjen method and Ewald method); fluctuation-dissipation effects. Structural defects: point defects (Schottky, Frenkel, substitutions, vacancies, intercalations); line defects (screw and edge dislocations, Frank network, mechanisms of dislocation generation, relationship with the strength of materials), planar defects (low-angle boundaries, stacking faults, twinning). Defects in the electronic structure (plasmons, excitons, polarons, magnons, F-centers). Lattice vibrations (mono- and diatomic chain, optical and acoustic branches, dispersion relations); normal vibrations; the models of lattice heat capacity (classical, Einstein, Debye); as well as the most significant anharmonic effects. The principles of the Drude model, the electrical conductivity of metals, magnetoresistive effect and the Hall effect. The Fermi gas of free electrons, the Fermi-Dirac distribution, Fermi level and chemical potential, degenerate and non-degenerate gas, the density of states, Wiedemann-Franz law. Thermoemission and cold emission from metal to vacuum; contact voltage. The model principles of the band theory; Blochs theorem; classification of solids on the basis of the band theory; effective mass and quasi-momentum. The dependence of electrical conductivity on the temperature in semiconductors and metals (due to changes in the carrier densities and in the relaxation time). Deviations from Ohms law (collisional ionisation, Zener effect, Poole-Frenkel effect, field dependence of relaxation time).
Prerequisites and co-requisites	A course in physics at the level of the first two years of studies.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Written test in theory	51.0%	50.0%
Preparation of written reports on laboratory exercises	100.0%	50.0%

Recommended reading		
	Basic literature	C. Kittel, Introduction to Solid State Physics, John Willey & Sons, NY 1966 N W Ashcroft, N D Mermin, Solid State Physics, Holt 1976
	Supplementary literature	W A Harrison, Solid State Theory, McGraw Hill, NY 1970
	eResources addresses	

Example issues/ example questions/ tasks being completed

1. The properties of solids can be divided into structural and nonstructural. Explain the principle of this division and give two examples of a structural and nonstructural property.
2. What is the Bravais lattice? Name at least 7 Bravais lattices and characterize them by specifying the relation between parameters a, b, c, alpha, beta, gamma.
3. Define the Bravais lattice concepts, base, simple lattice, complex lattice and crystallographic axis.
4. Define the concept of primitive vectors, primitive cell and elementary cell.
5. What is crystal symmetry? Name at least 5 symmetry operations.
6. What are crystal symmetry groups? Give the classification and examples.
7. Present the liquid-glass and liquid-crystal phase transition in coordinates V-T. What is the glass transition temperature? How does it depend on the cooling rate?
8. Discuss the concept of close and medium range ordering in glasses.
9. Discuss the CRN glass structure model and give examples.
10. Discuss the RCP glass structure model and give examples.
11. Discuss the folded coil glass structure model and give examples.
12. Give two characterization methods for close and medium range ordering.
13. Discuss the concept of a reverse lattice, describe its main properties.
14. Formulate and derive Braggs condition for diffraction of crystals.
15. Formulate and derive the Laue condition for diffraction of crystals.
16. Discuss thermodynamically reversible point defects of crystals.
17. Describe an experiment showing formation of Schottky defects.
18. Why can a crystal with zero concentration of point defects not exist in nature? What are the two laws of nature that determine the equilibrium concentration of these defects?
19. Discuss the thermodynamically irreversible point defects in crystals, give examples
20. Derive the expression for the coefficient of diffusion of point defects.
21. Discuss two types of boundary dislocations (structure, Burgers vectors, etc.). What is the simplest way to estimate the energy of the dislocation core? How does it compare to the energy of the elastic strain?
22. Discuss the conservative and non-conservative motion of dislocation. What is the relation between the dislocation motion and the plastic deformation of crystal?
23. Describe the Frank-Read mechanism of generation of dislocation. What is the Frank lattice? How is it generated? How does the crystal strength depend on the concentration of dislocation?
24. Discuss the surface defects in crystals
25. Explain the essence of van der Waals bonding in noble gas crystals.
26. Discuss metallic bonding. Using the uncertainty principle explain how delocalization of electrons affects the total energy of a metal.
27. Discuss ionic bonds. What are lattice sums? What is the Madelung energy?
28. Discuss the Ewjena and Ewald methods of calculating electrostatic interaction energy in ionic crystals.
29. Discuss covalent and hydrogen bonds. In which materials do they occur?
30. Calculate and discuss the dispersion relation for the monatomic chain of atoms.
31. Calculate and discuss the dispersion relation for a two-atomic chain of atoms.
32. What are the normal vibrations of a crystal? What is their relation to vibrations of individual lattice atoms?
33. Why would a harmonic crystal (if it existed) have a zero coefficient of thermal expansion?
34. Express the total energy of a crystal as the sum of independent normal oscillators.
35. Discuss the specific lattice heat of materials and calculate its value within the frame of the classic model.
36. Discuss Einstein's model of lattice specific heat of crystals.
37. Discuss Debyes model of density of states. What is the Debye temperature and what is its physical meaning?
38. Discuss the Debye model of lattice specific heat of crystals.
39. Derive the expression for lattice thermal conductivity.
40. Formulate the Drude model assumptions and calculate the expression for electrical conductivity of metals within this framework.
41. Calculate the coefficient of electron thermal conductivity of metals under the Drude model.
42. Formulate and derive the Wiedemann-Franz law (with the accuracy up to a multiplicative constant).
43. What are plasmons? Calculate the dependence of their frequency on the carrier concentration.
44. Discuss at least two phenomena causing the dependence of electrical conductivity on an electric field through its effect on the carrier concentration.
45. Discuss the dependence of electrical conductivity on an electric field through its effect on the relaxation time.
46. Discuss the dependence of electrical conductivity on temperature through its effect on the carrier concentration.
47. Discuss the dependence of electrical conductivity on temperature through its effect on the relaxation time.
48. Calculate the density of states for a free electron gas with concentration n.
49. What is the Fermi level? What is the chemical potential? What is the relationship between these values?
50. What is the Fermi-Dirac distribution? Sketch a graph of the Fermi-Dirac distribution in two temperatures, T_1 and T_2, $T_1$2. What is its relation with the Boltzmann distribution?
51. Discuss the phenomenon of thermionic emission of electrons from metal to vacuum (Richardson's phenomenon).
52. Discuss the Schottky potential barrier lowering phenomenon with the thermionic emission of electrons from metal to vacuum.
53. Discuss the Fowler-Nordheim effect (cold emission).
54. Formulate the Bloch theorem (assumptions, thesis, explanation of indices). Sketch a typical Bloch state. What is the significance of the Bloch theorem in the physics of crystalline bodies?
55. Give the classification of solids within the band theory. Is there an energy gap in vitreous bodies? Give at least one experimental proof to justify your answer.
56. What is the electronic structure of solids? How does it depend on the external electric field? Justify your answer.
57. Discuss the concept of quasimomentum. Why should quasimomentum not be identified with the electron momentum?
58. Discuss the concept of the effective mass of carriers in semiconductors. In what region of the energy spectrum is it negative? How is it possible to physically interpret the negative effective mass?
59. Discuss the temperature dependence of the Fermi level and concentration of carriers in doped semiconductors (n-type).
60. Derive the self-agreed single-particle Schrödinger equation for electron gas in a crystal.
61. What are polarons? In which materials do they occur? Do they participate in electrical conductivity?

	62. What are small and large excitons? In which materials do they occur? What can be said about their binding energy? Do they take part in electric current conduction? 63. Calculate the complex propagation constant of an electromagnetic wave in a material characterized by continuous isotropic material constants. How do the refractive index and the weakening constant depend on the frequency? 64. Describe the resonant absorption of electromagnetic waves on bound electrons. 65. Discuss the concept of normal and anomalous absorption on bound electrons. 66. Discuss the issue of dispersion of electromagnetic waves in metals.
Work placement	Not applicable