

DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Faculty	Center/Institute/ Department
Selected Topics of Condensed Matter Physics (10 ECTS credits)	Physics N 002	Faculty of Physics	Institute of Photonics and Nanotechnology
Student's workload	Hours	Student's workload	Hours
Lectures	25	Consultations	25
Individual study	200	Seminars	

Course annotation

The goal of this course to provide thorough understanding of selected topics in solid state physics. The course will consist of three main parts: a) Description and characterization of crystalline state using X-ray and other diffraction methods, b) charge transport in materials with different crystallinity, c) polarization phenomena in solid state and phase transitions.

Crystals and crystal structures. Bravais lattices and crystal systems. Miller indexes and zone axis. Reciprocal lattice. Bragg's law. X-ray diffraction. Ewald's sphere. Possible diffraction geometries and scans. Determination of crystal phase, structure, orientation, composition, strain, thickness, dislocation density of crystalline materials. Electron diffraction in TEM, RHEED, EBSD techniques.

Transport of charge carriers: high and low conductivity materials, conductivity relaxation time, space charge limited current, influence of trapping, ambipolar mobility. Charge carriers transport in mesoscopic structures, ballistic transport, quantization of conductivity, single electron transistor. Transport in amorphous materials, forbidden gap of mobility, Anderson's localization criteria. Models of the charge carriers transport in organic materials, hopping of charge carriers, movement through the Gaussian density of states. Experimental techniques for estimation of the charge carriers mobility.

Electric polarization in condensed matter. Interaction between electromagnetic radiation and electric dipoles, nanoclusters and phonons. Phase transitions in condensed matter, thermodynamic and statistical theory of phase transitions, models describing static and dynamic properties of phase transitions. Metastable states and self-organizing systems. Experimental methods to study phase transitions. Ferroelectric and related materials.

List of literature

1. The Basics of Crystallography and Diffractions, Christopher Hammond Oxford university press (2015).
2. High resolution X-ray Diffractometry and Topography, D. K. Bowen and B.K. Tanner, Taylor&Frabcus (2005).
3. Current Injection in Solids, M. A. Lampert, P. Mark, Academy Press (1970).
4. Charge transport in DisorderedSolids with Application in Electronics, S. Baranovski, John Wiley & Sons (2006).
5. Photophysics of Molecular Materials: From Single Molecules to Single Crystals, G. Lanzani, Wiley (2005).
6. Electronic Quantum Transport in Mesoscopic Semiconductor Structures, T. Ihn, Springer (2004).

7. J.Grigas. Microwave dielectric spectroscopy of ferroelectrics and related materials, Gordon and Breach, (1996). 8. Malcolm E. Lines, Alastair M. Glass. Principles and applications of ferroelectrics and related materials, Clarendon Press, (1977).			
Consulting teachers	Scientific degree	Pedagogical name	Main scientific works published in a scientific field in last 5 year period
Tadas Malinauskas	Dr.	Doc.	1. I. Reklaitis , L. Krencius, T. Malinauskas, S. Yu. Karpov , H. J. Lugauer, I. Pietzonka, M. Strassburg, P. Vitta and R Tomašiūnas “Time of carrier escape and recombination coefficients in InGaN quantum-well active regions of blue, cyan, and green lightemitting diodes” Semicond. Sci. Technol. 34, 015007 (2019) 2. J. Mickevičius, D. Dobrovolskas, T. Malinauskas, M. Kolenda, A. Kadys, G. Tamulaitis “Improvement of luminescence properties of InN by optimization of multistep deposition on sapphire”, Thin Solid Films 680, 89-93 (2019) 3. Ž. Podlipskas, J. Jurkevičius, A. Kadys, S. Miasojedovas, T. Malinauskas, R. Aleksiejūnas „The detrimental effect of AlGaN barrier quality on carrier dynamics in AlGaN/GaN interface“ Scientific Reports 9, 17346 (2019). 4. M. Kolenda, D. Kezys, I. Reklaitis, E. Radiunas, R. Ritasalo, A. Kadys, T. Grinys, T. Malinauskas, S. Stanionyte, M. Skapas, R. Petruškevičius, and R.Tomašiūnas “Development of polarity inversion in a GaN waveguide structure for modal phase matching” J Mater Sci (2020) 55:12008–12021. 5. I. Reklaitis, E. Radiunas, T. Malinauskas, S. Stanionytė, G. Juška, R. Ritasalo, T. Pilvi, S. Taeger, M. Strassburg, R. Tomašiūnas, “A comparative study on atomic layer deposited oxide film morphology and their electrical breakdown” Surface & Coatings Technology 399 (2020) 126123. 6. P. Onufrijevs, P. Ščajev, A. Medvids, M. Andrulevicius, S. Nargelas, T. Malinauskas, S. Stanionytė, M. Skapas, L. Grase, A. Pludons, M. Oehme, K.Lyutovich, E. Kasper, J. Schulze, H. H. Cheng “Direct-indirect GeSn band structure formation by laser Radiation: The enhancement of Sn solubility in Ge”, Optics and Laser Technology 128 (2020) 106200). 7. P. Ščajev, V. Soriūtė, G. Kreiza, T. Malinauskas, S. Stanionytė, P. Onufrijevs, A. Medvids, H.-H. Cheng “Temperature dependent carrier lifetime, diffusion coefficient, and diffusion length in Ge_{0.95}Sn_{0.05} epilayer” Journal of Applied Physics 128, 115103 (2020)

			8. D. Dobrovolskas, A. Kadys, A. Usikov, T. Malinauskas, K. Badokas, I. Ignatjev, S. Lebedev, A. Lebedev, Y. Makarov, G. Tamulaitis “Luminescence of structured InN deposited on graphene interlayer” Journal of Luminescence 232, 117878 (2021). 9. S Nargelas, J Mickevičius, A Kadys, K Jarašiūnas, T Malinauskas “Stimulated emission threshold in thick GaN epilayers: interplay between charge carrier and photon dynamics” Optics & Laser Technology 134, 106624 (2021). 10. K. Badokas, A. Kadys, J. Mickevicius, I. Ignatjev, M. Skapas, S. Stanionytė, E. Radiunas, G. Juška, T. Malinauskas “Remote epitaxy of GaN via graphene on GaN/sapphire templates” J. Phys. D: Appl. Phys. 54 205103 (2021).
Kristijonas Genevičius	Dr.		1. A. Aukštuolis, N. Nekrašas, K. Genevičius, G. Juška “Investigation of charge carrier mobility and recombination in PBDTTPD thin layer structures”, Organic Electronics 90, 106066 (2021). 2. A. Aukštuolis, N. Nekrašas, K. Genevičius, J. Jonikaitė-Švėgždienė “Anisotropy of charge carrier transport in PCPDTBT field-effect transistor structures”, Synthetic Metals 264, 116382 (2020). 3. G. Juška, K. Genevičius “Investigation of recombination in organic heterostructures by i-CELIV” Applied Physics Letters 113 (12), 123301 (2018). 4. Artiom Magomedov, Ernestas Kasparavičius, Kasparas Rakstys, Sanghyun Paek, Natalia Gasilova, Kristijonas Genevičius, Gytis Juška, Tadas Malinauskas, Mohammad Khaja Nazeeruddin, Vytautas Getautis “Pyridination of hole transporting material in perovskite solar cells questions the long-term stability” Journal of Materials Chemistry C 6 (33), 8874-8878 (2018). 5. Kasparas Rakstys, Sanghyun Paek, Peng Gao, Paul Gratia, Tomasz Marszalek, Giulia Grancini, Kyung Taek Cho, Kristijonas Genevicius, Vygintas Jankauskas, Wojciech Pisula, Mohammad Khaja Nazeeruddin “Molecular engineering of face-on oriented dopant-free hole transporting material for perovskite solar cells with 19% PCE” Journal of Materials Chemistry A 5 (17), 7811-7815 (2017).
Mantas Šimėnas	Dr.	Doc.	1. M. Ptak, A. Sieradzki, M. Šimėnas, M. Maczka. Molecular spectroscopy of hybrid organic-inorganic

			perovskites and related compounds. Coord. Chem. Rev. 448, 214180 (2021). 2. K. H. Richardson, J. J. Wright, M. Šimėnas, J. Thiemann, W. K. Myers, G. McGuire, A. M. Esteves, J. J. L. Morton, M. Hippler, M. M. Nowaczyk, G. T. Hanke, M. M. Roessler. Functional basis of electron transport within photosynthetic complex I. Nat. Comm. 12, 5387 (2021). 3. A. Gonzalez-Nelson, S. Mula, M. Šimėnas, S. Balčiūnas, A. R. Altenhof, C. S. Vojvodin, S. Canossa, J. Banys, R. W. Schurko, F.-X. Coudert, M. A. van der Veen. Emergence of coupled rotor dynamics in metal–organic frameworks via tuned steric interactions. JACS 143, 12053 (2021). 4. M. Šimėnas, S. Balčiūnas, S. Svirskas, M. Kinka, M. Ptak, V. Kalendra, A. Gağor, D. Szewczyk, A. Sieradzki, R. Grigalaitis, A. Walsh, M. Mączka, J. Banys. Phase Diagram and Cation Dynamics of Mixed $MA_{1-x}FA_xPbBr_3$ Hybrid Perovskites. Chem. Mater. 33, 5926 (2021). 5. M. Šimėnas, S. Balčiūnas, J. N. Wilson, S. Svirskas, M. Kinka, A. Garbaras, V. Kalendra, A. Gağor, A. Szewczyk, A. Sieradzki, M. Maczka, V. Samulionis, A. Walsh, R. Grigalaitis, J. Banys. Suppression of phase transitions and glass phase signatures in mixed cation halide perovskites. Nat. Comm. 11, 5103 (2020). 6. M. Šimėnas, D. Klose, M. Ptak, K. Aidas, M. Mączka, J. Banys, A. Pöpl, G. Jeschke. Magnetic excitation and readout of methyl group tunnel coherence. Sci. Adv. 6, eaba1517 (2020).
Certified during Doctoral Committee session 02/02/2022, protocol No. (7.17 E) 15600-KT-32			
Committee Chairman prof. S. Juršėnas			