

DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Faculty	Center/Institute/ Department
Physics and Technologies of Single-crystalline, Ceramic and Composite Materials (7,5 ECTS credits)	Materials Engineering N 002	Faculty of physics	Institute of Applied Electrodynamics and Telecommunications
Student's workload	Number of credits ECTS	Student's workload	Number of credits ECTS
Lectures		Consultations	up to 1
Individual study	7.5 without consultations; up to 6.5 with consultations	Seminars	

Course annotation

Single crystal growth.

Czochralski, Bridgman-Stockbarger, Verneuil, Kyropoulos, Zone melting methods.

Ceramics technologies.

Ceramics microstructure. Ceramic synthesis by solid phase reaction method. Formation of ceramics: uniaxial pressing, isostatic pressing, layer casting. Processes taking place during ceramics sintering. Hot pressing. Spark plasma sintering method. Glass ceramics.

Thin films technologies.

Evaporation, evaporation by electronic beam, pulsed laser deposition (PLD), magnetron sputtering of material, chemical vapor deposition (CVD), metalorganic chemical vapor deposition (MOCVD). Epitaxial layer growth, discrepancies between the crystal lattice parameters of the layer and the substrate. Molecular beam epitaxy.

Structure of solid materials. Point, linear and planar defects in crystals. Thermodynamics of defects. Thermally activated processes, diffusion.

Applications of ceramics materials.

Ohmic resistors. High temperature heating elements. Varistors, memristors. Fuel cells and batteries. Ceramic chemical sensors. High temperature superconductors. Ceramic capacitors. Pjzoceramics. Ferroelectric memory.

Metal-insulator composites. Electrical percolation. Its models. Models of dielectric properties of composites. Maxwell-Garnet model. Maxwell-Wagner relaxation. Methods of equivalent circuits. Electrical conductivity in composites: tunnelling, hopping.

Polymeric composites. Dielectric relaxation in polymeric composites. Phase transitions in polymeric composites. Positive and negative resistivity effects.

Polymeric composites preparation methods. Alloy mixing. Polymerization. Casting. Mixing the solution. Cold and hot presses. Influence of composite production methods on their properties.

Polymeric matrices and their properties. Epoxy resin, polydimethylsiloxane, plexiglass, polyvinylidene fluoride. Viscosity and glass transition of polymer matrices and their impact on composites properties. Chemical compatibility. Composites of different matrices.

Hybrid composites. Electrical percolation in hybrid composites. Electromagnetic, mechanical, thermal properties of hybrid composites. Synergy effects in hybrid composites. Electric transport in hybrid composites.

Fillers of composites. Carbon nanotubes, fullerenes, graphene, carbon soda. Metallic nanoparticles. Inorganic nanoparticles. Ferroelectric and ferromagnetic nanoparticles. Effects of nanoparticle size and shape on composite properties. Adhesion. Relationships between nanoparticles and composite properties.

Functionalization of nanoparticles. Defect functionalization. Covalent and noncovalent functionalization. Click functionalization.

Ceramics composites. Ceramics composites production: cold and hot pressing, chemical methods, infiltration. Grain size effects.

Carbon matrix composites. Carbon foams, carbon gels, carbon-carbon fibers composites, graphene-carbon nanotubes composites. Hybrid gels and synergy. Production methods and physical properties.

Investigations methods of composites and nanostructures.

Electron microscopy. Optical microscopy. Scanning tunnel microscopy. Atomic force microscopy. Determination of thin films thickness and texture.

Dielectric, impedans, Raman, Furje infrared, electron paramagnetic and nuclear magnetic resonance spectroscopies, differential scanning calorimetry, thermogravimetric analysis.

List of literature

1. Joel I. Gersten, Frederick W. Smith, The Physics and Chemistry of Materials, 2001, John Wiley & Sons
2. Milton Ohring, Materials Science of Thin Films Deposition and Structure, Second Edition, 2002, Academic Press
3. A. J. Moulson, J. M. Herbert, Electroceramics, Second Edition, 2003, John Wiley & Sons
4. Charles Kittel, Introduction to Solid State Physics, Eight Edition, 2005, John Wiley & Sons
5. Vytautas Grivickas, Antanas Feliksas Orliukas, Aloyzas Žindulis, Sigita Tamliavičius, Medžiagų mokslas, 2008, Progreus
6. R. Z. Taherian, A. Kausar, Electrical conductivity in polymer-based composites, Elsevier 2018.
7. X. Huang, Ch. Zhi, Polymer nanocomposites, Springer, 2016.
8. K. K. Chavla, Composite Materials. Science and engineering, Springer, 2019 (ketvirtas leidimas).
9. B. Reddy, Advances in diverse industrial applications of nanocomposites, IntechOpen, 2011.
10. J. P. Davim, C. A. Chartridis, Nanocomposites. Materials, manufacturing and engineering, Walter de Gruyter, 2013.
11. A. Y. C. Nee, Handbook of manufacturing engineering and technology, Springer, 2015.
12. L. Hollaway, Handbook of polymer composites for engineers, Woodhead Publishing Limited, 1994.
13. M. Hosokawa, M. Naito, Nanoparticle technology handbook, Elsevier, 2008.
14. L. Bowman, Carbon nanotubes handbook, NY research press, (2015).
15. R. Vaitaj, Springer handbook of nanomaterials, Springer, 2013.

Subject submission and evaluation

PhD student should prepare about 20 min. presentation about topic relevant for PhD work. Exam assesment consist of 25 % preztentation and 75 % exam grade.

Consulting teachers	Scientific degree	Pedagogical name	Main scientific works published in a scientific field in last 5 year period
Tomas Šalkus (tomas.salkus@ff.vu.lt)	Dr.	Doc.	1. M. Mosialek, A. Mechna, M. Dziubaniuk, E. Bielanska, A. Kežionis, T. Šalkus, E. Kazakevičius, B. Bozek, A. Krawczyk, J. Wyrwa, A.F. Orliukas, Composite cathode material LSCF-Ag for solid oxide fuel cells

		obtained in one step sintering procedure, <i>Electrochimica Acta</i> 282, 427 (2018). 2. I.P. Studenyak, A.I. Pogodin, O.P. Kokhan, V. Kavaliukė, T. Šalkus, A. Kežionis, A.F. Orliukas, Crystal growth, structural and electrical properties of $(\text{Cu}_{1-x}\text{Ag}_x)_7\text{GeS}_5\text{I}$ superionic solid solutions, <i>Solid State Ionics</i> 329, 119 (2019). 3. M. Dudek, B. Lis, R. Lach, S. Daugėla, T. Šalkus, A. Kežionis, M. Mosialek, R.P. Socha, J. Morgiel, M. Gajek, M. Sitarz, M. Ziabka, $\text{Ba}_{0.95}\text{Ca}_{0.05}\text{Ce}_{0.9}\text{Y}_{0.1}\text{O}_3$ as an electrolyte for proton-conducting ceramic fuel cells, <i>Electrochimica Acta</i> 304 (2019) 70-79. 4. M. Mosialek, R.P. Socha, B. Bozek, D. Wilgocka-Slezak, E. Bielanska, A. Kežionis, T. Šalkus, E. Kazakevičius, A.F. Orliukas, M. Dziubaniuk, J. Wyrwa, J. Wojewoda-Budka, M. Faryna, B. Lis, M. Dudek, R. Lach, Changes in properties of scandia-stabilised ceria-doped zirconia ceramics caused by silver migration in the electric field, <i>Electrochimica Acta</i> 338 (2020) 135866. 5. M. Dudek, B. Lis, R. Lach, S. Daugėla, T. Šalkus, A. Kežionis, M. Mosialek, M. Sitarz, A. Rapacz-Kmita, Samples of $\text{Ba}_{1-x}\text{Sr}_x\text{Ce}_{0.9}\text{Y}_{0.1}\text{O}_3$, $0 < x < 0.1$, with Improved Chemical Stability in $\text{CO}_2\text{-H}_2$ Gas-Involving Atmospheres as Potential Electrolytes for a Proton Ceramic Fuel Cell, <i>Materials</i> 13 (2020) 1874.
Jan Macutkevič	Dr.	1. D. Meisak, J. Macutkevici, A. Plyushch, P. Kuzhir, A. Selskis, J. Banys, Dielectric relaxation in hybrid Epoxy/MWCNT/MnFe₂O₄ composites, <i>Polymers</i> 12, 697 (2020). 2. P. Bertasius, D. Meisak, J. Macutkevici, P. Kuzhir, A. Selskis, E. Volnyanko, K. Banys, Fine tuning of electrical transport and dielectric properties of epoxy/carbon nanotubes composites via magnesium oxide additives, <i>Polymers</i> 11, 2044 (1-14) (2019). 3. E. Palaimiene, J. Macutkevici, J. Banys, A. Winiarski, I. Gruszka, J. Kopierski, A. Molak, Crossover from ferroelectric to relaxor behavior in $\text{Ba}_{1-x}\text{Ca}_x\text{TiO}_3$ ($x=0.17$) system, <i>Materials</i> 13, 2854 (2020).

			4. A. Plyushch, J. Macutkevicius, S. Svirskas, J. Banys, V. Plausinaitiene, D. Bychanok, S. A. Maksimenko, A. Selskis, A. Sokal, K. N. Lapko, P. P. Kuzhir, Silicon carbide/phosphate ceramics composite for electromagnetic shielding applications whiskers vs particles, Applied Physics Letters 114, 183105 (2019). 5. J. Castro-Gutierrez, E. Palaimiene, J. Macutkevicius, J. Banys, P. Kuzhir, S. Schaefer, V. Fierro, A. Celzard, Electromagnetic properties of carbon gels, Materials 12, 4143 (2019).
Renata Butkutė	Dr.	Doc.	1. T. Paulauskas, V. Pačebutas, R. Butkutė, B. Čechavičius, A. Naujokaitis, M. Kamarauskas, M. Skapas, J. Devenson, M. Čaplovičová, V. Vretenár, X. Li, M. Kociak and A. Krotkus, Atomic-Resolution EDX, HAADF, and EELS Study of GaAs_{1-x}Bi_x Alloys, Nanoscale Research Letters, 15:121 (2020), https://doi.org/10.1186/s11671-020-03349-2 2. S. Pūkienė, M. Karaliūnas, A. Jasinskas, E. Dudutienė, B. Čechavičius, J. Devenson, R. Butkutė, A. Udal and G. Valušis, Enhancement of photoluminescence of GaAsBi quantum wells by parabolic design of AlGaAs barriers, Nanotechnology, Vol. 30, 455001 (11pp) (2019); https://doi.org/10.1088/1361-6528/ab36f3 3. I. Nevinskas, F. Kadlec, C. Kadlec, R. Butkutė and A. Krotkus, Terahertz pulse emission from epitaxial n-InAs in a magnetic field, J. Phys. D: Appl. Phys., Vol. 52, 365301 (2019); https://doi.org/10.1088/1361-6463/ab28e7 4. Justinas Glemža, Vilius Palenskis, Andrejus Geižutis, Bronislovas Čechavičius, Renata Butkutė, Sandra Pralgauskaitė and Jonas Matukas, Low-Frequency Noise Investigation of 1.09 μm GaAsBi Laser Diodes, Materials, 12, 673 (2019); doi:10.3390/ma12040673. 5. Martynas Skapas, Sandra Stanionytė, Tadas Paulauskas, and Renata Butkutė, HRTEM Study of Size-Controlled Bi Quantum Dots in Annealed GaAsBi/AlAs Multiple Quantum Well Structure, Phys. Stat. Sol. b, 1800365 (1-6) (2019), DOI: 10.1002/pssb.20180036.

Certified by the Doctoral Committee of Material Engineering (T 008) on 09/02/2023, protocol No. (7.17 E) 15600-KT-39

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