SYLLABUS

1. Information regarding the programme

1.1 Higher education institution	Babeş-Bolyai University
1.2 Faculty	Faculty of Physics
1.3 Department	Doctoral School of Physics
1.4 Field of study	Physics
1.5 Study cycle	Doctorate
1.6 Study programme / Qualification	Doctoral training/PhD in Physics

2. Course data

2.1 **Name of the discipline**	Advanced experimental methods in solid state physics						
2.2 **Teacher responsible for lectures**	Prof. dr. Romulus Tetean, Prof. dr. Viorel Pop, Prof. dr. Iosif Deac, Prof. dr. Coriolan Tiuşan						
2.3 **Teacher responsible for seminars**	Prof. dr. Romulus Tetean, Prof. dr. Viorel Pop, Prof. dr. Iosif Deac, Prof. dr. Coriolan Tiuşan						
2.4. Year of study	I	**2.5 Semester**	1	**2.6. Type of evaluation**	E	**2.7 Course framework**	DS

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	3	Of which: 3.2 Lectures	2	3.3 Seminars / Laboratory classes	1
3.4 Total hours in the curriculum	36	Of which: 3.5 Lectures	24	3.6 Seminars / Laboratory classes	12
Time allotment:					**89**
Learning using manual, course support, bibliography, course notes					34
Additional documentation (in libraries, on electronic platforms, field documentation)					24
Preparation for seminars/labs, homework, papers, portfolios and essays					15
Tutorship					12
Evaluations					4
Other activities:					-

3.7 Total individual study hours	89
3.8 Total hours per semester	125
3.9 Number of ECTS credits	10

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Solid State Physics, Statistical physics, Magnetism, Material Science.
4.2. competencies	- manipulating basic fundamental knowledge in magnetism, quantum mechanics and material science. - basic experimental skills for in Solid State Physics.

5. Conditions (if necessary)

5.1. for the course	• Course hall with blackboard, projector and software
5.2. for the seminar /lab activities	• Course hall with blackboard, projector, internet access and dedicated software

6. Specific competencies acquired

Professional competencies	**C1.** Using of advanced knowledge of physics, mathematics and chemistry of solids for study in Solid State Physics and Materials Science. Capacity for analysis and synthesis of physical data, the ability to model complex phenomena. **C2.** Capitalization of physical fundamentals, of methods and tools of solid state physics and materials science for specific production activities, expertise and monitoring. Mindset multi- and interdisciplinary. **C3.** Planning and conducting experiments to assess the uncertainty and interpretation of the results. Use basic research laboratory equipment and industrial laboratory for conducting research experiments. Planning and implementation independently experiments or experimental investigations and evaluating the uncertainty of the results **C4.** Communicating complex scientific ideas, conclusions or results of a scientific project experiments. Ability to obtain and argue scientific results, the ability to produce scientific papers and to relate to the editorial board of scientific journals of the field.
Transversal competencies	**CT1.** Fulfil the professional tasks effectively and responsibly with respect for law and ethics under qualified assistance. Responsible execution of professional duties in terms of autonomy and decision-making based on self-assessment. **CT2.** Effective work in multidisciplinary team on different hierarchical levels. Implementation of activities and fulfilling specific teamwork roles on different hierarchical levels, showing initiative and entrepreneurial leadership based on promoting dialogue, cooperation positive attitudes, mutual respect, diversity and multiculturalism and continuous improvement of their activities. **CT3.** Effective use of information sources and communication resources and training assistance, both in Romanian and in a foreign language. Objective self-evaluation of the need for continues training to labour market insertion and the adaptation to dynamic requirements of labour market.

7. Course objectives (based on the acquired competencies grid)

7.1 The general objective of the discipline	Acquiring notions on the experimental and theoretical techniques and methods concerning the study of condensed matter.
7.2 Specific objectives	Acquiring the notions related to: - Determining the crystal structure of different classes of materials, both massive and nanostructured. - Determination of thermal properties of materials. - Determination of magnetic structures, of the respective magnetic moments, determination of the local magnetic properties - Analysis of surface defects

	- Knowledge of the specific properties of surfaces and their role in practical applications - Studying the effect of intense magnetic fields on electrical conductivity; magnetoresistance measurement - Determination of the Fermi surface (by De Haas van Alphen effect) and the electronic structure (XPS and ARPES), - Measurement of magnetic susceptibility in alternating current for determining the dynamic magnetic properties, of the phase transformations, using the nonlinear components of the complex susceptibility. - Knowledge of most common lithography techniques used in micro and nanostructuration. -Knowledge of various magnetometry and micromagnetic imaging techniques commonly used in characterization of low dimensional systems: thin films and nanostructures. - Processing and interpretation of experimental results. - Valorization of data obtained through publications. - Analysis of possible technological applications.

8. Content

8.1 Lectures	**Teaching methods**	**Comments**
Determination of the crystalline structure with X-rays: X-ray diffraction. X-ray sources. High and small angle diffraction. Crystalline and non-crystalline materials. Particular aspects of small dimensional systems.	Lecture, demonstration, debate, Case-based learning, the experiment demonstration and presentations on the computer	2 hours
X-ray absorption spectroscopy. XANES, EXAFS. EXAFS signal extraction. XPS. TEM, SEM		2 hours
Thermal measurements. Differential thermal analysis Electron diffraction. Neutron diffraction, mu-SR.		2 hours
Magnetic nanostructures: specific magnetic properties of magnetic systems with dimensions comparable to the characteristic lengths in magnetism (domain wall, exchange length, etc.)		3 hours
Production, characterizing and applications of magnetic nanostructures.		3 hours
AC magnetic susceptibility and the magnetic properties of solids. The principles of the method. Implementation. Calibration. Characterization of the magnetic order of solids by ac susceptibility measurements. Frequency and magnetic field dependence of the ac susceptibility. Non- linear ac susceptibility. Ac susceptibility study of superconducting materials.		2 hours
Experimental techniques and principles of structure-related phenomena. Experimental study of the Fermi surface in metals. Electrons in high magnetic fields. Quantum oscillation and the topology of Fermi surface. De Haas-van Alphen		2 hours

Effect. Photoemission spectroscopy. Angle Resolved Photo Emission Spectroscopy (ARPES).		
Transport phenomena in high magnetic fields (Focus on colossal magnetoresistance). Magnetoresistance. Introductory remarks. Ordinary MR, AMR, Giant MR, Tunel MR, CMR. Colossal Magnetoresistance. Mixed valence manganites. Phase diagrams. Electrons' interaction. Double exchange interaction. Jahn-Teller distortion. Polarons. Charge/orbital ordering. Phase separation. Examples. Cryostats for magneto-transport measurements.		2 hours
Elaboration and characterisation of thin film heterostructures by ultra-high vaccum techniques: sputtering, Molecular Beam Epitaxy, Laser Ablation, CVD/ALD techniques.		2 hours
Micro and nanosctructuration by self-assambling and lithography patetrining.		2 hours
Magnetometry techniques and micromagnetic imaging: VSM, SQUID, susceptometry, MOKE, AHE, torque magnetometry, XMCD, XPM, STXM, SPM, MFM, Lorentz microscopy, SPLEEM, SEMPA,...		2 hours

Bibliography

Compulsory:

1. C. Kittel, Introduction to Solid State Physics (7ed., Wiley, 1996).
2. N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, Saunders, 1976.
3. U. Mizutani, Introduction to the Electron Theory of Metals,Cambridge University Press 2001.
4. E.Burzo, "Fizica Fenomenelor Magnetice" vol. 1-3, Editura Academiei Române 198-1987, 1255 pag.
5. H. Alloul, Introduction to the Physics of Electrons in Solids, Springer-Verlag Berlin Heidelberg 2
6. Z. L. Wang (editor), Characteriyation of Nanophase Materials, Ed. Wiley-VCH, Weinheim, New York, Chichester, Brisbane, Singapore, Toronto, 2000.
7. F.J.Himpsel, J.E.Ortega, G.J.Mankey, R.F.Willis, Magnetic nanostructures, Advances in Phys, Vol.47, Nr. 4, 511-597, 1998.
8. Z.I.Wang, Elastic and Inelastic Scattering in Electron Diffraction and Imaging, Plenum Pub.Co, New York, 1995.
9. Coey J.M.D., Magnetism and Magnetic Materials, Cambridge University Press, New York 2010.
10. Alex Hubert, Rudolf Schäfer, Magnetic Domains, The Analysis of Magnetic Microstructures, Springer Berlin Heidelberg New York 2009, ISBN 978-3-540-64108-7.
11. J. A. Veneables, Introduction to surfaces and thin film processes, Cambridge University Press 2003, ISBN 0 511 01273 X.
12. Cui B (editor), Recent Advances in Nanofabrication Techniques and Applications, Intech, 2011.

Optional:

1. Journals on condensed matter physics
2. http://xxx.lanl.gov/archive/cond-mat

8.2 Seminar / laboratory	Teaching methods	Remarks
Particular aspects of X-ray diffraction in small dimensional systems.	Presentations. Correlations between experimental results and	2 hours
Sample preparation for X-ray measurements.		1 hour
Case studies prepared with the doctoral students, based on their individual doctoral research topics.		2 hours
New magnetic behaviors at the nanometer level.		1 hours

Case studies: band structure origin and analysis in special classes of solid-state compounds. Interpretation of the results of complex susceptibility measurements.	theoretical models. Discussions.	3 hours
Lithography techniques for micro and nanostructuration of planar and perpendicular spintronic devices.		2 hours
Case study: micromagnetic analysis by magnetic force microscopy in thin film heterostructures and patterned media.		1 hour

Bibliography

1. E.Burzo, "Fizica Fenomenelor Magnetice" vol. 1-3, Editura Academiei Române 198-1987, 1255 pag.
2. H. Alloul, Introduction to the Physics of Electrons in Solids, Springer-Verlag Berlin Heidelberg 2
3. Z. L. Wang (editor), Characteriyation of Nanophase Materials, Ed. Wiley-VCH, Weinheim, New York, Chichester, Brisbane, Singapore, Toronto, 2000
4. F. Gömöry, Characterization of High-Temperature Superconductors by AC Susceptibility Measurements, Superconductor Science and Technology 10(8):523 · January 1999.
5. Handbook of Magnetism and Advanced magnetic materials, Willey : volume 1: Fundamentals and Theory; volume 2: Micromagnetism; volume 3: Novel Techniques for Characterizing and Preparing Samples; volume 4: Novel Materials; volume 5: Spintronics and Magnetoelectronics.
6. Chris A. Mack, Fundamental Principles of Optical Lithography - The Science of MicrofabricationJohn Wiley & Sons Inc, 2007
7. Cui B (editor), Recent Advances in Nanofabrication Techniques and Applications, Intech, 2011.

9. Aligning the contents of the discipline with the expectations of the epistemic community, representatives, professional associations and standard employers operating in the program field

The content of the discipline is in accordance with the subjects which are studied in the same field in Romanian and foreign universities and with the specific demands of research institutes, economy and labour market.

10. Evaluation

Activity type	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Weight in the final grade
10.4 Course	Understanding of the physical phenomena in condensed matter physics and capacity to make connexion between the results obtained by different techniques.	Participation, discussions and answers to questions	25 %
10.5 Seminar/lab activities	Preparation and presentation on a subject related to advanced methods in condensed matter physics.The quality of the presentation.	Direct evaluation	75%
10.6 Minimum performance standards			

- Main techniques used for characterization
- Choosing, planning and carrying out an experimental method for a certain kind of elaboration and characterization.

Signature of course coordinator	Signature of seminar coordinator
Prof.dr. Romulus Tetean	Prof.dr. Romulus Tetean
Prof.dr. Viorel Pop	Prof.dr. Viorel Pop
Conf.dr. Iosif Grigore Deac	Conf.dr. Iosif Grigore Deac
Prof.dr. Coriolan Tiusan	Prof.dr. Coriolan Tiusan

Date	Signature Head of department
21.09.2024	Prof. dr. Vasile Chiș