SYLLABUS

1. Information regarding the programme

1.1 Higher education institution	Babes-Bolyai University
1.2 Faculty	Physics
1.3 Department	Solid State Physics and Advanced Technologies
1.4 Field of study	Physics
1.5 Study cycle	Master
1.6 Study programme / Qualification	Solid State Physics

2. Information regarding the discipline

2.1 Name of the discipline				Physics of thin films			
2.2 Course coordinator				Prof. Dr. Coriolan TIUȘAN			
2.3 Seminar coordinator				Prof. Dr. Coriolan TIUȘAN			
2.4. Year of study	**I**	2.5 Semester	**II**	2.6. Type of evaluation	**E**	2.7 Type of discipline	**DA**

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

3.1 Hours per week	3	Of which: 3.2 course	2	3.3 seminar/laboratory	1
3.4 Total hours in the curriculum	42	Of which: 3.5 course	28	3.6 seminar/laboratory	14

Time allotment:	hours
Learning using manual, course support, bibliography, course notes	30
Additional documentation (in libraries, on electronic platforms, field documentation)	32
Preparation for seminars/labs, homework, papers, portfolios and essays	40
Tutorship	3
Evaluations	3
Other activities:	0

3.7 Total individual study hours	102
3.8 Total hours per semester	150
3.9 Number of ECTS credits	6

4. Prerequisites (if necessary)

4.1. curriculum	Solid state Physics, Magnetism, Thermodynamics, and molecular physics
4.2. competencies	Valorisation of physical fundamentals, of methods and tools of solid-state physics and material science for specific applications. Use and development of research laboratory equipment and industrial laboratory for conducting research experiments.

5. Conditions (if necessary)

5.1. for the course	Classroom equipped with blackboard and projector
5.2. for the seminar /lab activities	Access to the research laboratory of Babes-Bolyai University

6. Specific competencies acquired

Professional competencies	• Extensive understanding of solid-state physics. • Specific Competence in thin film Physics, vacuum and Ultra High Vacuum techniques, pressure measurement techniques • Methods for thin films deposition and characterization of physical properties • Acquisition, processing, and interpretation of experimental data.
Transversal competencies	• Materials of technical interest with tailored specific properties. • Experimental methods for synthesis and for study in material science: Physical Vapor and Chemical Vapor and Chemical Solution deposition tools • Characterization tools and techniques, specific for thin films, surfaces, and interfaces.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	This course is designed: - to provide an overview to the physics and methods used in elaboration and characterization of thin films - to illustrate applications of thin films and related devices
7.2 Specific objective of the discipline	Valorisation of physical fundamentals, of theoretical and practical knowledge We will examine what thin films are, their important properties, how they are produced, and how we can characterize them.

8. Content

8.1 Course	Teaching methods	Remarks
1. From nanoscopic Physics to nanotechnologies. Thin films, continuous and patterned media, technological applications.	Lecture combined with debates. The video projector and the blackboard will be used. For online teaching, specific platforms: MsTeams, Zoom, Skype will be used.	2 hours
2. Specific Solid-State Physics elements for thin films. Structure of surfaces, interfaces, classes of defects. Surface thermodynamics and kinetics: bonding, surface energy, wetting, nucleation, and growth. Equilibrium shape of a crystal and thin film nanostructures.		2 hours
3. Epitaxy of thin films. Film structure. Types and sources of defects in epitaxial films. Structure-zone modes. Amorphous metal alloy films.		2 hours
4. Surfaces in vacuum. Ultra-high vacuum techniques and processes. Kinetic theory concepts. Vacuum theory and concepts. Vacuum/UHV hardware: pumps, pressure gauges and RGA, specific materials for UHV equipment.		2 hours
5. *Physical Deposition Tools* (I): Molecular Beam Epitaxy Sputtering. Ion Beam Sputtering.		2 hours
Physical Deposition Tools: (II) Pulsed Laser Deposition (PLD). Chemical vapor deposition (MOCVD). Atomic Layer Deposition (ALD). *Chemical Solution deposition tools*: Sol-gel, Spin coating		2 hours
7. *Specific characterization tools for thin films (I).* General overview. In-situ and ex-situ thickness measuring tools. Structural/chemical characterization: SEM, TEM, diffraction		2 hours

techniques XRD, RHEED, LEED.		
8. *Specific characterization tools for thin films* (II). Chemical characterization techniques SEM/ED(A)X TEM/EELS. Auger electron Spectroscopy AES. X-Ray/UV photoelectron spectroscopy XPS/UPS. Angular resolved Photoemission. Secondary ion mass spectrometry (SIMS).		2 hours
9. *Specific characterization tools for thin films* (III). Surface imaging techniques: Atomic force Microscopy: multimodes, Scanning Tunnelling Microscopy/Spectroscopy. Electric and magnetic characterization SQUID, VSM, XMCD, etc.		2 hours
10. *Specific properties of thin film systems* (I). Electric properties of metallic, insulating and superconducting films. 2D and topologic thin film materials and applications.		2 hours
11. *Specific properties of thin film systems* (II). Magnetic properties. Optic properties. Tribological applications, metallurgic and protective coatings.		2 hours
12. Design of thin film deposition equipment: basic concepts of vacuum, materials for UHV chambers, pumping and vacuum measurement tools, deposition sources, specific CAD software tools.		2 hours
13. Emerging applications of thin film materials.		2 hours
14. Thin films, nanostructures and nanodevices for emerging applications: e.g. nano and optoelectronics, neuromorphic and quantum technologies.		2 hours

Bibliography

(1) Milton Ohring, “*The materials science of thin films*”, Academic Press Limited,London 1992.

(2) Milton Ohring , “*The Materials Science of Thin Films*”, 2nd edition, Academic Press Limited, London, 2001.

(3) John A. Venables “*Introduction to Surface and Thin Film Processes*”, 2003 PUBLISHED BY CAMBRIDGE UNIVERSITY PRESS.

(4) Hideaki Adachi and Kiyotaka Wasa, “*Thin Films and Nanomaterials*” in Handbook of Sputtering Technology (Second Edition), 2012.

(5) E.S. Machlin, “MATERIALS SCIENCE IN MICROELECTRONICS”, VOLUME 1- THE RELATIONSHIPS BETWEEN THIN FILM PROCESSING AND STRUCTURE, 2005, Elsevier

(6) M. C. Rao et al, International Journal of Modern Physics: Conference Series Vol. 22 (2013) 576–582. A BRIEF SURVEY ON BASIC PROPERTIES OF THIN FILMS FOR DEVICE APPLICATION.

(7) *Introduction to Nano Basics to Nanoscience and Nanotechnology*, Engineering Materials, A. Sengupta, C. K. Sarkar, Ed. Springer-Verlag GmbH (2015).

(8) *Handbook of Thin Film Deposition*, edited by K. Seshan, D. Schepis, Publisher: William Andrew; 4th edition (March 13, 2018).

(9) S. Andrieu, P. Muller, *Les surfaces solides : concepts et méthodes*, CNRS Editions, EDP Sciences 2005.

8.2 Seminar	Teaching methods	Remarks
1. General vacuum concepts. Main components of an UHV PVD chamber: structure, pumping, pressure control and monitoring, manipulations, sources, in-situ processing, and characterization	Frontal analysis of some complex laboratory equipment.	2 hours

tools. Case study on a UHV Sputtering/MBE equipment.	Interpretations, analysis, and conclusions on experimental data. Individual and group projects on the given assignments. The attendance to the presentation of colleagues is compulsory. The video projector and the blackboard (seminar) will be used. In case of online teaching, specific platforms: MsTeams, Zoom, Skype will be used.	
2. Specific *in-situ* and *ex-situ* characterization tools and techniques for thin films and surfaces. Underlying Physics, experimental and technical issues. Large equipment and large modular systems: concepts and specificities.		2 hours
3. Thin films applications in microelectronics: semiconductor CMOS devices, nanoelectronics.		2 hours
4. Optoelectronic devices and optic applications of thin films, energy conversion, solar cells.		2 hours
5. Superconductivity in thin film systems and applications.		2 hours
6. Magnetic thin films and multi-layered heterostructures for spintronics applications: sensors, data storage, emerging applications: neuromorphic and quantum technologies.		2 hours
7. Nanoscopic Physics, micro and nanofabrication tools, and concepts in modern electronic devices.		2 hours

Bibliography

(1) *Handbook of Thin-Film Technology*, Hartmut Frey Prof. Dr., Hamid R. Khan Prof. Dr. (eds.), Springer-Verlag Berlin Heidelberg, 2015.

(2) *Handbook of Thin Film Deposition*, edited by K. Seshan, D. Schepis, Publisher: William Andrew; 4th edition (March 13, 2018).

(3) *Handbook of Vacuum Science and Technology*, Dorothy Hoffman, Bawa Singh, John H. Thomas III, Academic Press, 1997

(3) Oxford Instruments. *Atomic layer deposition for quantum devices*.

(4) Web-resources, scientific reviews.

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

The content of the course is congruent to the similar matter studied in representative European and national universities. To better adapt to the work market requirements, the content of the course was related with the main trends from this field in the regional scientific research, industry and business environment.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	- Correctness and completeness of the knowledge. - Ability to use assimilated knowledge, to extrapolate and make correlation for explaining adjacent phenomena and problems. - Logical coherence. - The ability to use the scientific language. - Dutifulness, the interest for individual study.	Project evaluation and oral examination.	60 %
10.5 Seminar/lab activities	- The ability to explain and work with the gained knowledge. - Active presence in seminars. - Interactivity in presentation of colleagues, participation to dialogues after/ during the	Lecture on imposed theme with public presentation. The attendance to the presentation of	40 %

	lectures. - Interactivity during the case studies.	colleagues is compulsory.	
10.6 Minimum performance standards			
• Understanding of thin film paradigm in material science: capability to tailor functional properties by dimensionality. • Knowledge on main elaboration and characterisations tools and techniques in thin film materials. • Knowledge on main application of thin films and thin film-based patterned devices in modern technologies • Getting more than 50% of the total final mark.			

Date:
15.05.2023

Signature of course coordinator

Professor Dr. Coriolan V. Tiușan,

Signature of seminar coordinator

Professor Dr. Coriolan V. Tiușan

Date of approval:

22.05.2023

Signature of the head of department