

**AGH**AGH UNIVERSITY OF SCIENCE
AND TECHNOLOGY

Module name: Experimental methods in solid state chemistry

Academic year: 2019/2020 Code: CIMT-1-071-s ECTS credits: 3

Faculty of: Materials Science and Ceramics

Field of study: Materials Science Specialty: —

Study level: First-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 0

Course homepage: —

Responsible teacher: dr inż. Prażuch Janusz (prazuch@agh.edu.pl)

Description of learning outcomes for module

| MLO code | Student after module completion has the knowledge/ knows how to/is able to | Connections with FLO | Method of learning outcomes verification (form of completion) |
|----------------|---|----------------------|---|
| Skills: he can | | | |
| M_U001 | Students will gain information of methods of crystallography and diffraction: X-Ray (powder (XRD), single crystals), electron and neutron diffraction. Understanding and analysis of structural data acquired using diffraction methods from polycrystalline materials, texture analysis by a pole figure method will be discussed. | IMT1A_U04, IMT1A_U02 | |
| M_U002 | Students will gain information of classes of possible reactions of solid-state synthesis and routes of preparation of solids with the required properties. Basic knowledge of students concerning bonding in solids and structure and properties of solids. | IMT1A_U04 | |
| M_U003 | Students will gain information of different microscopic and related techniques: reflected light microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM) combined with chemical microanalysis (EDS and WDS), selected area diffraction (SAD) and their application for topography, morphology, microstructure, texture, particle size and shape, surface details, precipitations presence, chemical and structure analysis. | IMT1A_U01, IMT1A_U02 | Examination |

| | | | |
|-------------------------------------|---|---------------------------------------|-------------|
| M_U004 | Students will gain information of the most frequently used surface analytical methods: AES, XPS, SIMS, SNMS, GDOES and also related spectroscopies like SEXAFS, EELS, and LEED regarding their application, possibilities and limitations. | IMT1A_U06, IMT1A_U02 | Test |
| M_U005 | Students will gain information of experimental determining transport properties of solids; understanding the determined transport properties in relation to the nature of the bonding and the dynamical properties of the lattice, point defect and electronic structure. | IMT1A_U04, IMT1A_U02 | Test |
| M_U006 | Students will gain information of measuring the magnetic properties of solids and obtaining chemical information from magnetic measurements (response of materials to magnetic fields). | IMT1A_U02 | Test |
| M_U007 | Students will gain a basic information of techniques of absorption, reflection, and emission of light and their application for characterization of solids. | IMT1A_U02 | Test |
| M_U008 | Students will gain a good knowledge of thermal analysis techniques: measurement of certain physical and chemical properties as a function of temperature (enthalpy, heat capacity, mass and coefficient of thermal expansion) using thermogravimetry (TG), differential thermal analysis (DTA), differential scanning calorimetry (DSC), thermomechanical analysis (TMA). | IMT1A_U01, IMT1A_U02 | Test |
| M_U009 | Students will be familiar with the selected methods important in the study of defects in solids, solid solutions and mechanisms of film growth and interpretation of their results. | IMT1A_U01, IMT1A_U02 | |
| Knowledge: he knows and understands | | | |
| M_W001 | Providing knowledge of types of solids and synthesis methods of solid-state materials. | IMT1A_W01, IMT1A_W03 | Examination |
| M_W002 | Providing knowledge of diffraction methods for structure determination: X-ray, neutron, and electron diffraction. | IMT1A_U02 | Test |
| M_W003 | Providing knowledge of electron microscopy imaging and diffraction methods; scanning electron microscopy (SEM), transmission electron microscopy (TEM). Combination of electron imaging and chemical microanalysis (EDS and WDS); Electron microscopy sample preparation methods; Focused Ion Beam (FIB) technique. | IMT1A_W04, IMT1A_W01, IMT1A_W03 | Examination |

| | | | |
|--------|--|---------------------------------|-------------|
| M_W004 | Providing knowledge of surface analysis techniques; X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), Secondary Ion Mass Spectrometry (SIMS), Secondary Neutral Mass Spectrometry (SNMS), tracer methods, Rutherford Backscattering Analysis (RBS) and Glow Discharge Optical Emission Spectroscopy (GDOES), Surface Extended X-Ray Absorption Fine Structure (SEXAFS), Electron energy loss spectroscopy (EELS), Low-Energy Electron Diffraction (LEED). | IMT1A_W04, IMT1A_W01, IMT1A_W03 | Test |
| M_W005 | Providing knowledge of techniques of transport measurement of a solid material: d.c.conductivity (electrical resistivity), a.c. conductivity (impedance), thermopower, Hall effect, photoconductivity, thermal conductivity. Relation of the determined transport properties of solids with electronic structure. | IMT1A_W04, IMT1A_W01, IMT1A_W03 | Examination |
| M_W006 | Providing knowledge of magnetic measurements of materials and correlation of magnetic susceptibility with chemistry of substances. | IMT1A_W04, IMT1A_W01, IMT1A_W03 | Examination |
| M_W007 | Providing knowledge of optical techniques used for characterization of solids: absorption, reflectivity, and luminescence. | IMT1A_W04, IMT1A_W03 | Examination |
| M_W008 | Providing knowledge of thermal analysis investigation methods: thermogravimetry (TG), differential thermal analysis (DTA), and differential scanning calorimetry (DSC). | IMT1A_W04 | Examination |
| M_W009 | Providing collective information on experimental methods for investigating defects in solids, solid solutions and film growth mechanisms. | IMT1A_W04, IMT1A_W03 | Examination |

Number of hours for each form of classes

| Suma | Form of classes | | | | | | | | | | |
|------|-----------------|--------------------|--------------------|-----------------|----------------------|-----------------|-------------------|-------------------|-----------|-------------------------------|----------|
| | Lectures | Auditorium classes | Laboratory classes | Project classes | Conversation seminar | Seminar classes | Practical classes | Fieldwork classes | Workshops | Prace kontrolne i przejściowe | Lektorat |
| 30 | 15 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 |

FLO matrix in relation to forms of classes

| MLO code | Student after module completion has the knowledge/ knows how to/is able to | Form of classes |
|----------|--|-----------------|
| | | |

| | | Lectures | Auditorium classes | Laboratory classes | Project classes | Conversation seminar | Seminar classes | Practical classes | Fieldwork classes | Workshops | Prace kontrolne i przejściowe | Lektorat |
|----------------|---|----------|--------------------|--------------------|-----------------|----------------------|-----------------|-------------------|-------------------|-----------|-------------------------------|----------|
| Skills: he can | | | | | | | | | | | | |
| M_U001 | Students will gain information of methods of crystallography and diffraction: X-Ray (powder (XRD), single crystals), electron and neutron diffraction. Understanding and analysis of structural data acquired using diffraction methods from polycrystalline materials, texture analysis by a pole figure method will be discussed. | + | - | - | - | - | - | - | - | - | - | - |
| M_U002 | Students will gain information of classes of possible reactions of solid-state synthesis and routes of preparation of solids with the required properties. Basic knowledge of students concerning bonding in solids and structure and properties of solids. | + | - | - | - | - | - | - | - | - | - | - |
| M_U003 | Students will gain information of different microscopic and related techniques: reflected light microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM) combined with chemical microanalysis (EDS and WDS), selected area diffraction (SAD) and their application for topography, morphology, microstructure, texture, particle size and shape, surface details, precipitations presence, chemical and structure analysis. | + | - | - | - | - | + | - | - | - | - | - |
| M_U004 | Students will gain information of the most frequently used surface analytical methods: AES, XPS, SIMS, SNMS, GDOES and also related spectroscopies like SEXAFS, EELS, and LEED regarding their application, possibilities and limitations. | + | - | - | - | - | - | - | - | - | - | - |
| M_U005 | Students will gain information of experimental determining transport properties of solids; understanding the determined transport properties in relation to the nature of the bonding and the dynamical properties of the lattice, point defect and electronic structure. | + | - | - | - | - | + | - | - | - | - | - |

| | | | | | | | | | | | | |
|-------------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|
| M_U006 | Students will gain information of measuring the magnetic properties of solids and obtaining chemical information from magnetic measurements (response of materials to magnetic fields). | - | - | - | - | - | + | - | - | - | - | - |
| M_U007 | Students will gain a basic information of techniques of absorption, reflection, and emission of light and their application for characterization of solids. | + | - | - | - | - | + | - | - | - | - | - |
| M_U008 | Students will gain a good knowledge of thermal analysis techniques: measurement of certain physical and chemical properties as a function of temperature (enthalpy, heat capacity, mass and coefficient of thermal expansion) using thermogravimetry (TG), differential thermal analysis (DTA), differential scanning calorimetry (DSC), thermomechanical analysis (TMA). | + | - | - | - | - | + | - | - | - | - | - |
| M_U009 | Students will be familiar with the selected methods important in the study of defects in solids, solid solutions and mechanisms of film growth and interpretation of their results. | + | - | - | - | - | + | - | - | - | - | - |
| Knowledge: he knows and understands | | | | | | | | | | | | |
| M_W001 | Providing knowledge of types of solids and synthesis methods of solid-state materials. | + | - | - | - | - | - | - | - | - | - | - |
| M_W002 | Providing knowledge of diffraction methods for structure determination: X-ray, neutron, and electron diffraction. | - | - | - | - | - | - | - | - | - | - | - |
| M_W003 | Providing knowledge of electron microscopy imaging and diffraction methods; scanning electron microscopy (SEM), transmission electron microscopy (TEM). Combination of electron imaging and chemical microanalysis (EDS and WDS); Electron microscopy sample preparation methods; Focused Ion Beam (FIB) technique. | + | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | | |
|--------|--|---|---|---|---|---|---|---|---|---|---|---|
| M_W004 | Providing knowledge of surface analysis techniques; X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), Secondary Ion Mass Spectrometry (SIMS), Secondary Neutral Mass Spectrometry (SNMS), tracer methods, Rutherford Backscattering Analysis (RBS) and Glow Discharge Optical Emission Spectroscopy (GDOES), Surface Extended X-Ray Absorption Fine Structure (SEXAFS), Electron energy loss spectroscopy (EELS), Low-Energy Electron Diffraction (LEED). | + | - | - | - | - | - | - | - | - | - | - |
| M_W005 | Providing knowledge of techniques of transport measurement of a solid material: d.c.conductivity (electrical resistivity), a.c. conductivity (impedance), thermopower, Hall effect, photoconductivity, thermal conductivity. Relation of the determined transport properties of solids with electronic structure. | + | - | - | - | - | - | - | - | - | - | - |
| M_W006 | Providing knowledge of magnetic measurements of materials and correlation of magnetic susceptibility with chemistry of substances. | + | - | - | - | - | - | - | - | - | - | - |
| M_W007 | Providing knowledge of optical techniques used for characterization of solids: absorption, reflectivity, and luminescence. | + | - | - | - | - | - | - | - | - | - | - |
| M_W008 | Providing knowledge of thermal analysis investigation methods: thermogravimetry (TG), differential thermal analysis (DTA), and differential scanning calorimetry (DSC). | + | - | - | - | - | - | - | - | - | - | - |
| M_W009 | Providing collective information on experimental methods for investigating defects in solids, solid solutions and film growth mechanisms. | + | - | - | - | - | - | - | - | - | - | - |

Student workload (ECTS credits balance)

| Student activity form | Student workload |
|--|------------------|
| Udział w zajęciach dydaktycznych/praktyka | 30 h |
| Realization of independently performed tasks | 40 h |
| Examination or Final test | 2 h |
| Contact hours | 3 h |
| Summary student workload | 75 h |
| Module ECTS credits | 3 ECTS |

Additional information

Module content

Lectures

Synthesis of solid-state materials.

Diffraction methods.

Electron microscopy.

Transmission Electron Microscopy. TEM sample preparation. Visit to IC-EM.

Surface and interface analysis methods.

Magnetic measurements.

Optical techniques.

Thermal analysis.

Seminar classes

Electron microscopy techniques and sample preparation.

Electrical resistance and impedance measurements.

Magnetic and optical techniques.

Thermogravimetry (TG) and Differential Thermal Analysis (DTA).

Experimental methods for investigating defects in solids and solid solutions.

Teaching methods and techniques:

Lectures: Treści prezentowane na wykładzie są przekazywane w formie prezentacji multimedialnej w połączeniu z klasycznym wykładem tablicowym wzbogaconymi o pokazy odnoszące się do prezentowanych zagadnień.

Seminar classes: Na zajęciach seminaryjnych podstawą jest prezentacja multimedialna oraz ustna prowadzona przez studentów. Kolejnym ważnym elementem kształcenia są odpowiedzi na powstałe pytania, a także dyskusja studentów nad prezentowanymi treściami.

Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:

Nie określono

Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:

Lectures:

- Attendance is mandatory: No

- Participation rules in classes: Studenci uczestniczą w zajęciach poznając kolejne treści nauczania zgodnie z sylabusem przedmiotu. Studenci winni na bieżąco zadawać pytania i wyjaśniać wątpliwości. Rejestracja audiowizualna wykładu wymaga zgody prowadzącego.

Seminar classes:

- Attendance is mandatory: Yes

- Participation rules in classes: Studenci prezentują na forum grupy temat wskazany przez prowadzącego oraz uczestniczą w dyskusji nad tym tematem. Ocenie podlega zarówno wartość merytoryczna prezentacji, jak i tzw. kompetencje miękkie.

Method of calculating the final grade

0,8 examination + 0,2 seminar activity.

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:

Nie określono

Prerequisites and additional requirements

Basic knowledge of physics and chemistry.

Recommended literature and teaching resources

1. Basic solid state chemistry / A.R. West.-2nd ed., John Wiley & Sons Ltd.
2. Introduction to solid state physics, / Charles Kittel.-7th ed.
3. Surfaces and Interfaces of Solid Materials / Hans Luth.-3rd ed.
4. Structure of crystals / Boris K. Vainshtein et al.-2nd ed.
5. The science and engineering of materials / Donal R. Askeland
6. Impedance spectroscopy. Theory, Experiment, and Applications / Evgenij Barsoukov, J. Ross Macdonald, eds.-2nd ed.
- 7 Reactions and Characterization of Solids / Sandra E. Dann
8. Optical properties of solids. An introductory textbook / Locharoenrat Kitsakorn
9. Introduction to thermal analysis of solids. Techniques and Applications / Michael E. Brown.-2nd ed.
10. Thermal analysis of Materials / Robert. F. Speyer
11. Electron Microscopy and Analysis/ Peter j. Goodhew at al.-3rd ed.
12. Transmission electron microscopy. Physics of Image Formation and Analysis / Ludwig Reimer.-4th ed.
13. High temperature oxidation and corrosion of metals / David John Young.-2nd ed.
- 14.Introduction to texture analysis. Macrotecture, microtexture and orientation mapping / Olaf Engler, Valerie Randle.-2nd ed.
14. Focused Ion Beam Systems. Basics and Applictions / Yao Nan
15. Scanning electron microscopy and X-ray microanalysis / Joseph I. Goldstein, Dale Newbury et al.-3rd ed.
16. Transmission Electron Microscopy. A textbook for Materials Science / David B. Williams, C. Barry Carter.-2nd ed.
17. Electron Backscatter Diffraction in Materials Science / Adam J. Schwartz et al. /eds/
- 17.Texture and Anisotropy / U. F. Kocks
18. The Chemistry and Physics of Coatings / Alastair R. Marrion
19. The Chemistry and Physics of Coatings / Alastair R. Marrion
20. The basics of crystallography and diffraction / Christopher Hammond.-4th ed.
21. Introduction to disloctaions / Derek Hull.-5th ed.
22. Refractory and ceramic materials / Luis F. Verdeja, Jose P. Sancho et al.
23. Imperfections in crystalline solids/ Wei Cai, William D. Nix
24. Thermodynamics in Materials Science / Robert DeHoff.-2nd ed.

25. Diffusion in Solids / Paul G. Shewmon.-2nd ed.
26. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry / Marc de Graef.-2nd ed.
27. Kinetics of materials / Robert W. Balluffi, Sam Allen, W.Craig Carter
28. Introduction to polymers / Robert J. Young
29. Phase transformations in metals and alloys / David A. Porter et al.
30. Materials Kinetics Fundamentals / Ryan O'Hayre

3. D.M. Adams, Inorganic Solids
4. A.K. Cheetham and P. Day, Solid State Chemistry : 1. Techniques and 2. Applications
5. P.A. Cox, The electronic structure and chemistry of solids
6. P.A. Cox, Transition metal oxides
7. R.C. Evans, An Introduction to crystal chemistry
8. A.F. Wells, Structural Inorganic Chemistry
9. N.N. Greenwood, Ionic crystal, lattice defect and non-stoichiometry
10. L. Smart and E. Moore, Solid state chemistry : An introduction
11. J.K. Burdett, Chemical bonding in solids
12. C.N.R. Rao and J. Gopalakrishnan, New directions in solid state chemistry
13. C.N.R. Rao, Chemical approaches to synthesis of inorganic materials

Scientific publications of module course instructors related to the topic of the module

Additional scientific publications not specified

Additional information

None