# COURSE DESCRIPTION

*Functional Materials (in English)*

Academic year 2026-2027

**1. Programme-related data**

| | |
|---|---|
| 1.1. Higher Education Institution | Babeș-Bolyai University (BBU), Cluj-Napoca, Romania, in partnership with Technische Universität Chemnitz (TUC), Chemnitz, Germany |
| 1.2. Faculty | Chemistry and Chemical Engineering |
| 1.3. Department | Chemistry |
| 1.4. Field | Chemistry |
| 1.5. Level of study | Master |
| 1.6. Degree programme / Qualification | Advanced Chemistry / Master's Degree |
| 1.7. Form of education | Full-time education |

**2. Course-related data**

| | | | | | |
|---|---|---|---|---|---|
| 2.1. Course title | **Functional Materials (in English)** | | | Course code | **CME6140** |
| 2.2. Course coordinator | Prof. Dr. Cristian Silvestru (BBU), Lect. Dr. Eng. Lucian-Cristian Pop (BBU)<br>Prof. Dr. Michael Mehring (TUC) | | | | |
| 2.3. Seminar coordinator | Lect. Dr. Eng. Lucian-Cristian Pop (BBU)<br>Lect. Dr. Ionuț-Tudor Moraru (BBU) | | | | |
| 2.4. Year of study | 2 | 2.5. Semester | 2 | 2.6. Type of assessment | Exam |
| 2.7. Course status | Optional | | | 2.8. Course type | Specialisation subject |

**3. Total estimated time** (hours per semester of teaching activities)

| | | | | | |
|---|---|---|---|---|---|
| 3.1. Number of hours per week | **4** | of which: 3.2. course | **2** | 3.3. seminar/ laboratory/ project | **2** |
| 3.4. Total of hours in the curriculum | **56** | of which: 3.5. course | **28** | 3.6. seminar/ laboratory | **28** |
| **Time allocation for individual study (IS) and self-taught activities (ST)** | | | | | **hours** |
| Learning from textbooks, course materials, bibliography, and notes (IS) | | | | | 30 |
| Additional research in the library, on subject-specific electronic platforms, and on-site | | | | | 14 |
| Preparing seminars/ laboratories/ projects, assignments, reports, portfolios, and essays | | | | | 14 |
| Tutoring (professional guidance) | | | | | 7 |
| Examinations | | | | | 4 |
| Other activities | | | | | 0 |
| **3.7. Total hours of individual study (IS) and self-taught activities (ST)** | | | | **69** | |
| **3.8. Total hours per semester** | | | | **125** | |
| **3.9. Number of credits** | | | | **5** | |

**4. Prerequisites** (where applicable)

| | |
|---|---|
| 4.1. curriculum-related | • Not the case. |
| 4.2 skills-related | • Estimated personal level of English using Common European Framework of Reference for Languages (CEFR) should be minimum B1. |

**5. Specific conditions** (where applicable)

| | |
|---|---|
| 5.1. course-related | • Students will attend the courses having the materials (*e.g.* videos) made available prior to each course<br>• During the lecture students are asked to mute their mobile phones |
| 5.2. seminar/laboratory-related | • Students will attend the seminar with the course notes referring to the seminar topic<br>• During the seminar/practical work activities students are asked to mute their mobile phones |

**6.1. Competencies resulting from the completion of the degree programme** *(as referred to in the curriculum)*[1]

| **Professional competencies** | |
|---|---|
| **Competency code** | **Competency** |
| **PC1** | *Demonstrate disciplinary expertise* |
| **PC2** | *Perform scientific research* |
| **PC3** | *Apply scientific methods* |
| **PC4** | *Manage chemical testing procedures* |
| **PC5** | *Interact professionally in research and professional environments* |
| **Transversal competencies** | |
| **Competency code** | **Competency** |
| **TC1** | *Work independently* |
| **TC2** | Work in teams |
| **TC3** | *Think critically* |

**6.2. Learning outcomes relevant to the degree programme** *(as referred to in the curriculum)*[2]

| **Learning outcomes targeted by the subject** | | |
|---|---|---|
| **Competency code** | **Knowledge and comprehension** | **Specific academic skills** |
| **PC1, TC3** | *The graduate critically evaluates and integrates highly specialised knowledge from physical, inorganic, organic, analytical chemistry and biochemistry, including at disciplinary boundaries, as a basis for advanced reasoning.* | *The graduate analyses scientific concepts and evidence and synthesises coherent explanations for complex chemical systems, justifying conceptual choices.* |
| **PC2, TC1** | *The graduate demonstrates highly specialised knowledge as a basis for original thinking and/or research, including critical awareness of frontier knowledge.* | *The graduate formulates research questions/objectives, designs and implements an investigative approach, and critically evaluates the results obtained.* |
| **PC3, TC3** | *The graduate explains principles, limitations and validation criteria for advanced investigation and interpretation methods (experimental and/or computational) relevant to advanced chemistry.* | *The graduate applies, compares and validates scientific methods to solve research and/or innovation problems, integrating knowledge across different subfields.* |
| **PC3, PC4** | *The graduate understands the criteria for selecting, controlling and optimising chemical testing procedures according to investigation goals, sample type and quality requirements.* | *The graduate manages and optimises chemical testing procedures for complex investigations by setting parameters, quality criteria and interpretation steps to obtain valid results.* |
| **PC5, TC2** | *The graduate understands norms, roles and working practices specific to academic and professional research environments, including communication and collaboration standards.* | *The graduate interacts professionally in research and professional environments, gives and uses feedback, and argues scientific decisions within teams.* |
| **PC3, TC3** | *The graduate understands quality criteria and standards of scientific argumentation (coherence, validity, reproducibility, relevance) used to evaluate conclusions.* | *The graduate critically evaluates results and interpretations and communicates well-argued conclusions and recommendations in* |

[1] The professional and/or transversal skills targeted by the subject for which the course description is prepared will be copied from the curriculum of the degree programme. For each competency, the complete entry, including the competency code, will be copied with the exact wording that appears in the curriculum, without any changes. If no competency is copied from either of the two categories, the row corresponding to that category is deleted from the table.

[2] The learning outcomes relevant for the degree programme and targeted by the subject for which the course description is prepared will be listed. The entries, copied without any changes from the Curriculum by subject type (Core Subject/Specialisation Subject/Complementary Subject), are listed under the corresponding competency.

| | | |
|---|---|---|
| | | *academic/professional contexts, adapting the message to audiences and purpose.* |

**7. Subject-specific learning outcomes**

| **Knowledge and comprehension** |
|---|
| The student explains and compares the relationships between structure, composition, and properties in representative classes of functional materials, including perovskites, spinels, coordination polymers, MOFs, and 2D materials, arguing the role of crystal architecture in the emergence of specific material properties. |
| The student analyses the principles underlying the main strategies for synthesizing functional materials, including solid-state reactions, the sol-gel process, hydrothermal synthesis, microwave-assisted synthesis, and "twin" polymerization, correlating the chosen method with the structure and properties of the resulting material. |
| The student explains and critically evaluates the mechanisms involved in photocatalysis and nanocatalysis and argues the relevance of the studied functional materials for current applications in energy, the environment, and advanced materials. |
| **Specific academic skills** |
| The student applies and integrates concepts from solid-state chemistry, supramolecular chemistry, and materials science to critically analyse examples of functional materials and to justify the selection of appropriate synthetic strategies. |
| The student applies specific experimental methods for the preparation and processing of functional materials, including the synthesis of $Bi_2WO_6$ via solid-state reaction, sol-gel process, hydrothermal or microwave-assisted synthesis, as well as surface deposition techniques, and correctly interprets the resulting analytical data. |
| The student analyses, compares, and communicates, both orally and in writing, data and case studies regarding the properties, synthesis, and applications of functional materials, appropriately utilizing the specialized literature and presenting coherent scientific conclusions in academic contexts. |

**8. Contents**

| **8.1. Course** | **Teaching and learning methods** | **Remarks[3]** |
|---|---|---|
| 1. Introduction (including introduction of lecturers). Phase, phase diagram, solid state reaction *vs* reaction in solution | Presentation; Explanation | 1 hour |
| 2-6. Crystal chemistry I-V | Presentation; Explanation | 5 hours |
| 7. Perovskites – structures, polymorphism, ferroelectricity | Presentation; Explanation | 1 hour |
| 8. Hybrid perovskites – structures, perovskites for solar cells | Presentation; Explanation | 1 hour |
| 9. Spinel – structures, magnetism | Presentation; Explanation | 1 hour |
| 10. Polymorphism – polymorphs, phase transition | Presentation; Explanation | 1 hour |
| 11. Coordination polymers I – building blocks, including organometallic linkers and nodes | Presentation; Explanation | 1 hour |
| 12. Coordination polymers II – synthesis strategies | Presentation; Explanation | 1 hour |
| 13. MOFs – MOFs and related materials; applications | Presentation; Explanation | 1 hour |
| 14. 2D-materials I – graphenes (introduction, fundamental research) | Presentation; Explanation | 1 hour |
| 15. 2D-materials II – graphenes (production, characterization and applications of graphene and graphene-based materials, including environment aspects) | Presentation; Explanation | 1 hour |
| 16-19. Synthetic methods I-IV | Presentation; Explanation | 4 hours |
| 20-21. Sol-gel process I-II | Presentation; Explanation | 2 hours |
| 22. Twin polymerisation | Presentation; Explanation | 1 hour |
| 23-26. Photocatalysis I-IV | Presentation; Explanation | 4 hours |

[3] For example, organisational aspects, recommendations for students, specific aspects relating to the course/seminar, such as inviting experts in the field, etc.

| | | |
|---|---|---|
| 27. Nanocatalysis I – introduction; transition metal nanoparticles in catalysis (size, structure, surface composition) | Presentation; Explanation | 1 hour |
| 28. Nanocatalysis II – applications; case studies | Presentation; Explanation | 1 hour |


Bibliography

1. Course support notes (pdf) and videos – made available by course coordinator
2. A. R. West, *Solid State Chemistry and its Applications - Student Edition*, 2nd Ed., JohnWiley& Sons, Ltd, Chichester (UK), **2014**.
3. U. Schubert, N. Hüsing, *Synthesis of Inorganic Materials*, 4th Ed., Wiley-VCH, Weinheim (Germany), **2019**.
4. S. Kaskel (Ed), *The Chemistry of Metal–Organic Frameworks - Synthesis, Characterization and Applications* (2 vols.), Wiley-VCH, Weinheim (Germany), **2016**.
5. O. M. Yaghi, M. J. Kalmutzki, C. S. Diercks, *Introduction to Reticular Chemistry - Metal-Organic Frameworks and Covalent Organic Frameworks*, Wiley-VCH, Weinheim (Germany), **2019**.
6. S. R. Batten, S. M. Neville, D. R. Turner, *Coordination Polymers - Design, Analysis and Application*, RSC Publishing, Cambridge (UK), **2009**.
7. O. L. Ortiz, L. D. Ramirez (Eds), *Coordination Polymers and Metal Organic Frameworks - Properties, Types and Applications*, Nova Science Publishers, New York (USA), **2012**.
8. E. Hey-Hawkins, M. Hissler, *Smart Inorganic Polymers - Synthesis, Properties, and Emerging Applications in Materials and Life Sciences*,Wiley-VCH, Weinheim (Germany), **2019**.
9. A. C. Ferrari, *et al.*, *Science and Technology Roadmap for Graphene, Related Two-Dimensional Crystals, and Hybrid Systems (Review Article)*, *Nanoscale,* **2015**, *7*, 4598–4810.
10. P. Serp, K. Philippot (Eds), *Nanomaterials in Catalysis,* Wiley-VCH, Weinheim (Germany), **2012**.
11. Reviews and articles from recent scientific literature (ACS, Wiley, Elsevier, RCS, etc.).


| **8.2.1 Seminar** | **Teaching and learning methods** | **Remarks** |
|---|---|---|
| 1. Block seminar I - crystal chemistry; perovskites; hybrid perovskites; spinel; polymorphism (one topic of each) | Conversation; Learning by discovery; Problem solving | block of 4 hours – 5 seminar topics |
| 2. Block seminar II - coordination polymers (2 topics); MOFs (2 topics); 2D-materials – graphenes (3 topics) | Conversation; Learning by discovery; Problem solving | block of 4 hours – 7 seminar topics |
| 3. Block seminar III - synthetic methods (2 topics); sol-gel process (1 topic); twin polymerization (1 topic) | Conversation; Learning by discovery; Problem solving | block of 3 hours – 4 seminar topics |
| 4. Block seminar IV - photocatalysis (1 topic); nanocatalysis (3 topics) | Conversation; Learning by discovery; Problem solving | block of 3 hours – 4 seminar topics |


Bibliography

1. Course support notes (pdf) and recorded lectures – made available by course coordinators.
2. Reviews and scientific articles at choice, but no older than 2020 (from ACS, Wiley, Elsevier, RCS journals, etc.).


| **8.2.2 Laboratory** | **Teaching and learning methods** | **Remarks** |
|---|---|---|
| 1. Photocatalytic degradation of a dye solution | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 2. Synthesis of $Bi_2WO_6$: solid state reaction | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 3. Synthesis of $Bi_2WO_6$: Sol gel process | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 4. Synthesis of $Bi_2WO_6$: hydrothermal synthesis | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 5. Spray coating of $Bi_2WO_6$ via air brush technique | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 6. Synthesis of $Bi_2WO_6$: microwave assisted synthesis | Experiments; Learning by discovery; Interpretation of analytical data | 1 hour |
| 7. Discussion of practical work and analytical data | Experiments; Learning by discovery; Interpretation of analytical data | 8 hours |


Bibliography

1. Laboratory support notes (pdf) and videos – made available by course coordinators.
2. G. E. J. Poinern, *A Laboratory Course in Nanoscience and Nanotechnology*, Taylor and Francis Group, ISBN: 1482231034, **2014**.

**9. Evaluation**

| Type of activity | 9.1 Evaluation criteria[4] | 9.2 Evaluation methods[5] | 9.3 Percentage in the final grade |
|---|---|---|---|
| 9.4. Course | Correctness of answers –proper understanding and learning of notions and concepts discussed during lectures; correct use of learned concept within new contexts.<br>Correct solving of the problems as part of the examination subjects | Oral / written examination. Proven or intended fraud is punished according to the ECST rules of BBU | 50% |
| 9.5.1 Seminar | Quality of the presentation and discussion of the topic | On-line presentation | 25% |
| 9.5.2. Laboratory | Correct interpretation of analytical data and discussion | Laboratory report - delivered at the end of the practical course | 25 % |
| 9.6 Minimum standard for passing | | | |
| • Receiving a grade of 5 (five) on the final exam, the seminar presentation, and the lab report. | | | |

**10. SDG labels (Sustainable Development Goals)[6]**

| | | |
|---|---|---|
|  | ○ | Sustainable Development Generic Label |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |
| ○ | ○ | ○ | ◉ | ○ | ○ | ○ | ○ | ○ |
|  |  |  |  |  |  |  |  | No label applies |
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Date of entry:
17.04.2026

Signature of course coordinator
Acad. Prof. Dr. Cristian Silvestru

Lect. Dr. Eng. Lucian-Cristian Pop

Signature of seminar/laboratory coordinator
Lect. Dr. Eng. Lucian-Cristian Pop

Lector Dr. Ionuț-Tudor Moraru

Date of approval in the department:
24.04.2026

Signature of the head of department
Prof. Dr. Monica Ioana Toșa

[4] The evaluation criteria must directly reflect the learning outcomes targeted at the level of the degree programme respectively at the level of the subject. More specifically, the learning outcomes set out in the expected learning outcomes are assessed.
[5] Both final evaluation methods and ongoing evaluation strategies should be established.
[6] Select a single label which, according to the *Implementation of SDG labels in the academic process*, best matches the subject. If the subject addresses sustainable development in a generic manner (i.e. by presenting/introducing the general framework of sustainable development, etc.), then the Sustainable Development generic label may be applied. If none of the labels describe the subject, select the last option: *"No label applies."*