



COURSE DESCRIPTION CARD - SYLLABUS

Course name

BIOMIMETIC MATERIALS DESIGN STRATEGIES: FROM NATURE TO FUNCTIONAL SYSTEMS
[S5NC>BSPM]

Course

Proposed by Discipline

–

Year/Semester

2/4

Level of study

Doctoral School

Course offered in

English

Form of study

full-time

Requirements

elective

Number of hours

Lecture

8

Laboratory classes

0

Other

0

Tutorials

0

Projects/seminars

0

Number of credit points

2,00

Coordinators

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Lecturers

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Prerequisites

Fundamentals of general and inorganic chemistry (chemical bonding, crystal structure, fundamentals of coordination chemistry). Fundamentals of organic chemistry (functional groups, polymers, biopolymers). Fundamentals of materials science, including the structure–properties–applications relationship. General-level knowledge of biology/biochemistry (cell structure, biominerals, basic macromolecules: proteins, polysaccharides, lipids). Fundamentals of materials physics (mechanics, mechanical properties). Basic knowledge of materials characterization methods (SEM, XRD, FTIR/Raman spectroscopy). Interest in an interdisciplinary approach combining biology, chemistry, and materials engineering.

Course objective

The aim of the course is to familiarize students with biomimetic strategies for materials design, i.e. an approach based on drawing inspiration from structural, functional, and process solutions developed by nature through evolution and translating them into the design of modern functional materials. Presentation of key examples of biological materials and structures (e.g. biominerals, spider silk, butterfly photonic structures, self-cleaning surfaces, bone, and mollusk shells) as sources of design inspiration. Discussion of selected classes of biomimetic materials (hierarchical composites, self-healing materials, porous structures, and functional coatings), as well as methods for their fabrication and characterization. Raising students' awareness of sustainability and resource efficiency aspects arising from the biomimetic approach (e.g. synthesis under mild conditions, biodegradability, and reduced environmental footprint). Introduction to the concept of extreme biomimetics-the analysis of organisms living in extreme environments (extreme temperatures, high pressure, intense UV radiation, drought, high salinity, and anaerobic environments) as a source of design strategies for materials with enhanced functional resistance.

Course-related learning outcomes

Knowledge (W):

P8S_WG/SzD_W01: global achievements, covering theoretical foundations as well as general and selected specific issues that are relevant to scientific disciplines studied at the Doctoral School, to the extent that enables revision of existing paradigms.

P8S_WG/SzD_W03: scientific research methodology in disciplines represented at the Doctoral School.

Skills (U):

P8S_UW/SzD_U01: use knowledge from different branches of science to creatively identify, formulate and innovatively solve complex problems or to perform research tasks such as: (i) define the aim and subject of scientific research, form a research hypothesis, (ii) develop research methods, techniques and tools and use them creatively, (iii) draw conclusions on the basis of research results.

P8S_UW/SzD_U02: critically analyze and assess scientific research results, work of experts and other creative activities together with their contribution into knowledge development.

Social competences (K):

P8S_KK/SzD_K01: critically assess achievements within a given scientific discipline.

P8S_KK/SzD_K03: acknowledge the importance of knowledge in solving cognitive and practical problems

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Written examination (test/open-ended questions)

grading criteria: 3 – 50.1%–70.0%, 4 – 70.1%–90.0%, 5 – 90.1% and above)

Programme content

Introduction and Fundamentals of Biomimetics

Key Examples of Biological Materials

Extreme Biomimetics

Classes of Biomimetic Materials

Sustainability and Applications

Course topics

The classes have a seminar--based format and complement the lecture content through literature research, case study analysis, and the development of an original conceptual project for a biomimetic material. Firstly, students become familiar with tools and databases supporting biomimetic design (e.g. AskNature) and analyze classic case studies illustrating the transfer of a biological principle into an engineering solution. Subsequent classes focus on the critical analysis of scientific literature concerning selected biological systems, including biomineralization, hierarchical and fibrous materials, photonic structures, and functional surfaces, with an emphasis on linking experimental data (graphs, spectra, and microscopic images) to material properties. A separate module covers extremophiles and extreme biomimetics, in which

students analyze the adaptive mechanisms of organisms living under extreme conditions and discuss their potential for designing materials resistant to environmental stress.

The focus shifts to formulating a research problem (the “problem-driven” vs. “solution-driven” approach), selecting an organism or biological mechanism as a source of inspiration, reviewing the literature with regard to potential fabrication and characterization methods, and receiving expert guidance from the instructor. This part also addresses sustainability aspects related to the proposed material solutions.

Teaching methods

Lecture: an informative lecture supported by multimedia presentations, enriched with case studies, illustrative materials (microscopic images and diagrams of biological structures), and elements of problem-based lecturing that encourage students to draw their own conclusions based on the examples presented.

Case study: analysis of specific examples of transferring biological solutions to engineering applications, conducted in the form of group discussion.

Bibliography

Biomimetics for Designers: Applying Nature's Processes & Materials in the Real World - Veronika Kapsali

Biomimicry - Janine M. Benyus

M. Karuppusamy, S. Palanisamy, M. Gurusamy, et al. “Biomimetic and Bioinspired Materials: Design Strategies, Mechanical Properties, and Engineering Applications—A Review.” *Global Challenges* 10, no. 3 (2026): e70101. <https://doi.org/10.1002/gch2.70101>

M. Sarikaya, Biomimetics: Materials fabrication through biology, *Proc. Natl. Acad. Sci. U.S.A.* 96 (25) 14183-14185, <https://doi.org/10.1073/pnas.96.25.14183> (1999).

Rajesh R. Naik, Srikanth Singamaneni; Introduction: Bioinspired and Biomimetic Materials. *Chem. Rev.* 25 October 2017; 117 (20): 12581–12583. <https://doi.org/10.1021/acs.chemrev.7b00552>

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	8	0,50
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	42	1,50