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Preamble

Upon successful completion of the distance study programme the graduates, which are primarily composed of engineers, natural scientists and medical doctors, have acquired skills that enable them to strongly improve products and processes in the organizations in which they operate. Thus the study programme makes a contribution to the high demand for skilled workers in the field of nanotechnology.

The five on-campus weekends contribute to the acquisition of practical skills. In this context, the students apply their acquired knowledge with the help of experienced tutors. This is usually done in the context of topic-specific lab work which is carried out at the Department of Physics at the University of Kaiserslautern, the Institute for Technical Chemistry of the University of Hannover and Forschungszentrum Jülich.

An important secondary objective of the distance study programme is learning of working in an international environment. The fact that the study programme has a high percentage of foreign students helps to acquire these skills in parallel to the studies.

The qualification objectives are described below on the basis of professional, methodological and social competences, as well as in terms of learning outcomes.

Professional competence is the ability to cope with job-specific tasks and situations independently and responsibly meeting the theoretical requirements. Methodological competence is the ability to apply certain working methods. Social competence is the ability to deal with fellow men unprejudiced, constructively and easily in the work environment. Interacting and cooperating with others, as well as management skills play a major role.

The overall qualification objective is: Graduates have the technical knowledge, skills and competences to understand issues in the broad field of nanotechnology and to cope independently and responsibly with tasks set by the theoretical requirements by applying the work methods they learned, and deal fairly, constructively and confidently with their fellow men.

The following competences are derived from the overall qualification objectives:

- **Professional competence:** The graduates have acquired an extensive factual knowledge about the principles, general approaches and models in the field of nanotechnology. Moreover, they have the ability to raise, formulate and formalize issues at all abstraction levels, and can solve these problems through critical thinking and a pronounced judgement in a scientific way.

- **Methodological competence:** The graduates have the ability to combine knowledge from different fields of nanotechnology and apply methods and techniques learned in this study programme. Furthermore, they can apply the acquired knowledge to new innovative methods from the field of nanotechnology in their field of activity, and they have the ability to learn and to develop new technologies.

- **Social competence:** The graduates have the ability to carry out activities in the field of nanotechnology independently to introduce new technologies in organizations, and they have the ability to work in an interdisciplinary and international team.
## Module: Fundamentals of Quantum Mechanics

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0001</td>
<td>Prof. Dr. Hans Christian Schneider</td>
<td>Prof. Dr. Hans Christian Schneider</td>
</tr>
</tbody>
</table>

### Workload

<table>
<thead>
<tr>
<th>Credit Points (CP):</th>
<th>Recommended Semester</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>First semester</td>
<td>6 weeks</td>
<td>winter term</td>
</tr>
</tbody>
</table>

#### 1. Parts of the module/courses:

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a) Textbook:</strong> written by apl. Prof. H.-J. Korsch 6 weeks</td>
<td>90h</td>
<td>5</td>
</tr>
<tr>
<td><strong>b) Exercises in textbook:</strong> written by apl. Prof. H.-J. Korsch 6 weeks</td>
<td>35h</td>
<td></td>
</tr>
</tbody>
</table>

#### 2. Impact on curriculum:
- compulsory module

#### 3. Content
- Classical and quantum physics
- The Schrödinger equation
- One-dimensional systems
- Two- and three-dimensional systems
- Some advanced topics (facultative)

#### 4. Intended Learning Outcomes and competencies: for a)-b)

On successfully completing the module students will be able to:
- understand the basic concepts of nonrelativistic quantum mechanics and its mathematical formulation,
- give examples when purely quantum mechanical effects without classical counterpart are important (as in the case of spin),
- solve standard problems of quantum mechanics such as the harmonic oscillator, angular momentum, the hydrogen atom and spin,
- apply the concepts of quantum mechanics in the analysis of physical problems,
- explain how quantum mechanical effects modify classical behavior.

#### 5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>Appendix A of the textbook has to be studied before the tutorial starts</td>
</tr>
</tbody>
</table>

#### 6. Requirements for receiving credit points (especially assessments, certificate of attendance):

- **a)** Successfully solving mail-in exercises (once per semester): not graded

#### 7. Determination of grade:
<table>
<thead>
<tr>
<th>Grade:</th>
<th>not graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance for</td>
<td>has no weight towards the final grade</td>
</tr>
<tr>
<td>final grade:</td>
<td></td>
</tr>
</tbody>
</table>

8. **Applicability of the module/suitability:**
   It is fundamental for all other courses that deal with materials and nanoscience: “Solid State Physics” (NT0003), “Quantum Information Processing” (NT0005), “Semiconductor Theory” (NT0006) and “Nanooptics” (NT0008).
   This module is also part of the distance studies certificate programme “Nanobiotechnology” (“Fundamentals of Quantum Mechanics” (NT0001)).

9. **Hints for preparation:**
   **Recommended literature:**
   
   **Available documents:**
   Textbook “Fundamentals of Quantum Mechanics” including self-control assignments for self-study

   **Online tutorial:**
   Discussion forum (online learning platform) available during the lecture time

10. **Registration procedure:** online registration

11. **Language:** English
## Module: Fundamentals of Molecular Biology, Genetics

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0002</td>
<td>Dr. Angelika Roth/Dr. Peter Reichmann</td>
<td>Dr. Angelika Roth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. Peter Reichmann</td>
</tr>
</tbody>
</table>

### Workload
- **Credit Points (CP):** 5
- **Recommended Semester:** First semester
- **Duration:** 6 weeks plus on-campus weekend
- **Regular cycle:** Winter term

### 1. Parts of the module/courses:

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP): 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Textbook:</td>
<td>written by Dr. A. Roth and Dr. P. Reichmann</td>
<td>90h</td>
</tr>
<tr>
<td>6 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Exercises in textbook:</td>
<td>written by Dr. A. Roth and Dr. P. Reichmann</td>
<td>34h</td>
</tr>
<tr>
<td>6 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) On-campus phase (Solid State Physics and Molecular Biology):</td>
<td>given by Dr. A. Roth and Dr. P. Reichmann</td>
<td>1h</td>
</tr>
<tr>
<td>tutorial</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2. Impact on curriculum:
- Compulsory module

### 3. Content
- Basics in chemistry
- DNA and RNA
- From amino acids to proteins
- The flow of genetic information
- Molecular biology of gene function
- Regulation of gene expression
- Alteration of genetic information
- Recombinant DNA technology
- Important techniques in molecular biology
- Genomics
- Biology in the computer age

### 4. Intended Learning Outcomes and competencies: for a)-c)

On successfully completing the module students will be able to:
- summarize the basics in biochemistry,
- understand the role of the essential chemical functional groups which are involved in
biochemical reactions of living cells,
- describe the structure and function of nucleic acids and proteins, the most important molecules in molecular biology,
- apply their knowledge from the biochemistry of their building blocks (amino acids, nucleotides),
- deduce structure and function of essential macromolecules like proteins, DNA and RNA
- explain central cellular processes,
- compare application and implementation of molecules in modern molecular biotechnology (e.g. detection, amplification, cloning, sequencing and sequence analysis with modern bioinformatics methods),
- analyze and evaluate experiments with are performed in modern molecular biology.

5. Prerequisites for attending:

| Formal admission requirements | none |
| Contextual prerequisites      | none |

6. Requirements for receiving credit points (especially assessments, certificate of attendance):
   a) Written examination (90 minutes duration): graded
   b) Successful participation of on-campus tutorial: not graded

7. Determination of grade:

| Grade                           | determined from the written exam |
| Significance for final grade    | enters as grade weighted with its ECTS points: 5/61 |

8. Applicability of the module/suitability:

   The knowledge about nucleic acid and protein structure and function is a fundamental prerequisite for the on-campus phase “Screening Methods in Biology, Chip Technologies” (module “Analytical Techniques in Nanotechnology” (NT0007)).

   This module is also part of the distance studies certificate programme “Nanobiotechnology” ("Fundamentals of Molecular Biology, Genetics" (NT0002)).

9. Hints for preparation:

   **Recommended literature:**
   d) Madigan, M. T., Martinko, J. M., Bender, K.S., Buckley, D.H.; Brock: Biology of Microorganisms; Publisher: Benjamin Cummings (2014) 14th edition

   **Available documents:** Textbook "Fundamentals of Molecular Biology, Genetics" including self-control assignments for self-study written by Dr. P. Reichmann and Dr. A. Roth.

   **Online tutorial:** discussion forum (online learning platform) available during the lecture time

10. Registration procedure: online registration
11. Language: English
Module: Solid State Physics

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0003</td>
<td>Prof. Dr. Egbert Oesterschulze</td>
<td>Prof. Dr. Egbert Oesterschulze</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>125h (25h=1CP)</td>
<td>5</td>
<td>First semester</td>
<td>6 weeks plus on-campus weekend</td>
<td>winter term</td>
</tr>
</tbody>
</table>

1. Parts of the module/courses: (please choose/update the courses)
   Attendance time: Self study: (preparation + follow up) Credit Points (CP): 5
   a) Textbook: written by Dr. W. Kulisch 90h
   b) Exercises in textbook: written by Dr. W. Kulisch 34h
   c) On-campus phase (Solid State Physics and Molecular Physics): tutorial given by Prof. Dr. E. Oesterschulze 1h

2. Impact on curriculum: compulsory module

3. Content
   - Chemical bonding in solids
   - Structure of crystalline solids
   - Diffraction from periodic structures
   - Dynamics of atoms in a periodic crystal
   - Thermal properties of solids
   - Free electrons in a solid
   - Magnetism
   - Motion of electrons and transport phenomena
   - Dielectric properties of solids
   - Semiconductors
   - Superconductivity

4. Intended Learning Outcomes and competencies: for a)-c)
   On successfully completing the module students will be able to
   - classify/construct crystal structures and discuss experimental techniques to identify them,
   - appraise the phonon model for the description of mechanical/thermal properties,
   - conclude the band structure theory to distinguish the different types of electronic materials,
   - summarize the behavior of semiconducting materials and their impact on electronic devices,
   - discuss the behavior of magnetic materials with respect to their quantum mechanical origin,
- critically analyze the limits of the applied models and theories,
- summarize the quantum mechanical interpretation of the dynamics of solids,
- validate the introduced concepts solving exercises on one's own responsibility.

5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>Knowledge and comprehension of terms and contents of module “Fundamentals of Quantum mechanics” (NT0001)</td>
</tr>
</tbody>
</table>

6. Requirements for receiving credit points (especially assessments, certificate of attendance):

a) Written examination (90 minutes duration): graded
b) Participation of on-campus tutorial: not graded

7. Determination of grade:

<table>
<thead>
<tr>
<th>Grade:</th>
<th>determined from the written exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance for final grade:</td>
<td>enters as grade weighted with its ECTS points: 5/61</td>
</tr>
</tbody>
</table>

8. Applicability of the module/suitability:

The terms and models introduced in this module to describe large but periodic solid material are later extended and massively used: 1) to describe the physics in semiconducting nanomaterials (NT0006) and 2) the transport in various periodic or non-periodic nano-structured optical media (NT0008), 3) to assign the difference to the behavior of nanomaterials (NT0009, NT0010, NT0011), and 4) to describe transport/phenomena in electronic as well as magnetic nano-media (NT0012). In all other modules the basics of Solid State Physics play also a dominant role to describe the physics.

9. Hints for preparation:

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Available documents:</td>
<td>Textbook “Solid State Physics” including self-control assignments for self-study written by Dr. W. Kulisch</td>
</tr>
<tr>
<td>Online tutorial:</td>
<td>Discussion forum (online learning platform) available during the lecture time</td>
</tr>
</tbody>
</table>

10. Registration procedure: online registration

11. Language: English
# Module: Technology of Micro- and Nanoelectromechanical Systems

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0004</td>
<td>Dr. Sandra Wolff</td>
<td>Dr. Sandra Wolff</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>150h (25h=1CP)</td>
<td>6</td>
<td>Second semester</td>
<td>6 weeks plus on-campus weekend</td>
<td>summer term</td>
</tr>
</tbody>
</table>

1. Parts of the module/courses: *(please choose/update the courses)*

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

   a) Textbook: 6 weeks written by Dr. S Wolff 80h

   b) Exercises in textbook: 6 weeks written by Dr. S Wolff 20h

   c) On-campus phase (Lab in the cleanroom): tutorial, lab course given by Dr. S. Wolff, Dr. B. Lägel, Dr. T. Löber 7h 43h

2. Impact on curriculum:
   compulsory module

3. Content
   - Introduction to micro- and nano-electro-mechanical systems (MEMS and NEMS)
   - Lithography
   - Deposition of material
   - Structuring by removing material
   - Packaging
   - Cleanroom - basics

4. Intended Learning Outcomes and competencies: for a)-c)
   On successfully completing the module students will be able to
   - select the appropriate technology for a given or intended process,
   - create MEMS and NEMS devices,
   - sketch process flows for device manufacturing,
   - analyze and evaluate process flows and manufacturing technologies,
   - consider alternative technologies.

5. Prerequisites for attending:
   Formal admission requirements: none
**Contextual prerequisites:**
a-b) none  
c) reading and understanding the textbook and completing the exercises

| 6. Requirements for receiving credit points (especially assessments, certificate of attendance):
|---|
a) Successfully solving mail-in exercises (once per semester): not graded
b) Successful participation of on-campus tutorial: not graded

<table>
<thead>
<tr>
<th>7. Determination of grade:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade:</td>
</tr>
<tr>
<td>Significance for final grade:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Applicability of the module/suitability:</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. Hints for preparation:</th>
</tr>
</thead>
</table>
| **Recommended literature:**
a) Waser, Rainer (Ed.): Nanoelectronics and Information Technology. Wiley-VCH, 2012,  
c) Franz, Gerhard: Low Pressure Plasmas and Microstructuring Technology. Springer, 2009,  
d) Bhushan, B. (Ed.): Handbook of Nanotechnology. Springer, 2nd ed., 2007,  
| **Available documents:** Textbook “Technology of Micro- and Nanoelectromechanical Systems” including self-control assignments for self-study written by Dr. S. Wolff |
| **Online tutorial:** Discussion forum (online learning platform) available during the lecture time |

| 10. Registration procedure: online registration |

| 11. Language: English |
### Elective Module: Quantum Information Processing

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0005</td>
<td>Prof. Dr. Artur Widera</td>
<td>Prof. Dr. Artur Widera</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>125h (25h=1CP)</td>
<td>5</td>
<td>Second semester</td>
<td>6 weeks</td>
<td>Summer term</td>
</tr>
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1. **Parts of the module/courses:**

   (please choose/update the courses)

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study:</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(preparation + follow up)</td>
<td>5</td>
</tr>
</tbody>
</table>

   a) **Textbook:**
   - 6 weeks
   - written by Prof. A. Widera
   - 90h

   b) **Exercises in textbook:**
   - 6 weeks
   - written by Prof. A. Widera
   - 35h

2. **Impact on curriculum:**

   elective module

3. **Content**

   - Single qubit operations
   - Quantum correlations and two-qubit operations
   - Experimental platforms for quantum information processing
   - Quantum cryptography
   - Quantum computation

4. **Intended Learning Outcomes and competencies: for a)-b)**

   On successfully completing the module students will be able to

   - differentiate the basics of quantum information processing both from a conceptual and an experimental point of view,
   - compare the theory of classical information science, the bit, and its quantum mechanical counterpart, the quantum bit,
   - apply the fundamental criteria for building a quantum computer and quantum computing networks to physical implementations of quantum information processing,
   - explain the manipulation of a single qubit and the concept of quantum entanglement as resource for quantum information processing,
   - apply prominent examples of quantum computation protocols to simple problems,
   - identify the fundamental differences of classical and quantum key distribution (QKD), and understand basic QKD protocols and their experimental implementation,
   - understand the concept of quantum error correction.

5. **Prerequisites for attending:**

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>None</th>
</tr>
</thead>
</table>
   | Contextual                     | a) none b) the study content of modules "Fundamentals of Quantum
<table>
<thead>
<tr>
<th>prerequisites:</th>
<th>Mechanics&quot; (NT0001) and &quot;Solid-state Physics&quot; (NT0003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Requirements for receiving credit points (especially assessments, certificate of attendance):</td>
<td></td>
</tr>
<tr>
<td>a) Successfully solving mail-in exercises (once per semester): not graded</td>
<td></td>
</tr>
<tr>
<td>7. Determination of grade:</td>
<td></td>
</tr>
<tr>
<td>Grade:</td>
<td>not graded</td>
</tr>
<tr>
<td>Significance for final grade:</td>
<td>has no weight towards the final grade</td>
</tr>
<tr>
<td>8. Applicability of the module/suitability:</td>
<td>-</td>
</tr>
<tr>
<td>9. Hints for preparation:</td>
<td></td>
</tr>
<tr>
<td>Available documents:</td>
<td>Textbook &quot;Quantum Information Processing&quot; including self-control assignments for self-study written by Prof. Dr. A. Widera</td>
</tr>
<tr>
<td>Online tutorial:</td>
<td>Discussion forum (online learning platform) available during the lecture time</td>
</tr>
<tr>
<td>10. Registration procedure: online registration</td>
<td></td>
</tr>
<tr>
<td>11. Language: English</td>
<td></td>
</tr>
</tbody>
</table>
## Module: Semiconductor Theory and Device Physics

<table>
<thead>
<tr>
<th>Code</th>
<th>Module Coordinator</th>
<th>Teaching Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0006</td>
<td>Prof. Dr. Hans Christian Schneider</td>
<td>Prof. Dr. Hans Christian Schneider</td>
</tr>
</tbody>
</table>

### Workload

- **Credit Points (CP):** 5
- **Recommended Semester:** Second semester
- **Duration:** 6 weeks plus on-campus weekend
- **Regular cycle:** Summer term

### 1. Parts of the module/courses:

- **a) Textbook:**
  - 6 weeks
  - Written by Prof. Dr. H. C. Schneider
  - 90h

- **b) Exercises in textbook:**
  - 6 weeks
  - Written by Prof. Dr. H. C. Schneider
  - 34h

- **c) On-campus phase (Lab in the cleanroom):**
  - Tutorial
  - Given by Prof. Dr. H. C. Schneider
  - 1h

### 2. Impact on curriculum:

- Compulsory module

### 3. Content

- Electromagnetic fields and many-level systems
- Crystal structures and the reciprocal lattice
- Electronic band structures in semiconductors: general methods
- Electronic states and transitions around the gap
- Phonons and elasticity theory
- Optical properties of semiconductors

### 4. Intended Learning Outcomes and competencies: for a)-c)

On successfully completing the module students will be able to

- apply the basics of a quantum mechanics to the electronic and optical properties of semiconductors,
- calculate the electronic structure of semiconductors and similar crystalline materials using a variety of complementary methods,
- distinguish general methods such as plane wave and pseudopotential theory,
- describe the standard model for optical transitions in semiconductors (kp-theory),
- understand the interaction between electrons, lattice and optical fields,
- analyze more complicated materials using the methods learned in this course.

### 5. Prerequisites for attending:
<table>
<thead>
<tr>
<th><strong>Formal admission requirements:</strong></th>
<th>none</th>
</tr>
</thead>
</table>
| **Contextual prerequisites:** | a) none  
b) The content of modules “Fundamentals of Quantum Mechanics” (NT0001) and “Solid-State Physics” (NT0003)  
c) Textbook should be studied before the tutorial |

6. **Requirements for receiving credit points** (especially assessments, certificate of attendance):  
   a) Written examination (120 minutes duration): graded  
b) Successful participation of on-campus tutorial: not graded

7. **Determination of grade:**  
   Grade: determined from the written exam  
   Significance for final grade: enters as grade weighted with its ECTS points: 5/61

8. **Applicability of the module/suitability:**  
   This module teaches some advanced techniques on semiconductor electronics and optics that are helpful for more specialized courses such as “Nanooptics” (NT0008) as well as “Transport in Nanostructures” (NT0012).

9. **Hints for preparation:**  
   **Recommended literature:**  
   **Available documents:**  
   Textbook "Semiconductor Theory and Device Physics" including self-control assignments for self-study written by Prof. Dr. H. C. Schneider  
   **Online tutorial:** Discussion forum (online learning platform) available during the lecture time

10. **Registration procedure:** online registration

11. **Language:** English
# Module: Analytical Techniques in Nanotechnology

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0007</td>
<td>Prof. Dr. Christiane Ziegler</td>
<td>Prof. Dr. Christiane Ziegler, Dr. Christine Müller-Renno, Dr. Stefan Lach, Dr. Frank Stahl</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>300h (25h=1CP)</td>
<td>12</td>
<td>Third and Fourth semester</td>
<td>8 weeks plus two on-campus weekends</td>
<td>winter and summer term</td>
</tr>
</tbody>
</table>

## 1. Parts of the module/courses:
*(please choose/update the courses)*

### a) Textbooks
(Part 1 and Part 2):
8 weeks
written by Prof. Dr. C. Ziegler, Dr. C. Müller-Renno, Prof. Dr. R. Ulber and Dr. F. Stahl

### b) Exercises in textbooks:
8 weeks
written by Prof. Dr. C. Ziegler, Dr. C. Müller-Renno, Prof. Dr. R. Ulber and Dr. F. Stahl

### c) On-campus phase
(Characterization of Nanostructures, winter term):
Tutorial, lab course
given by Dr. B. Lägel, Dr. T. Löber, Dr. S. Wolff, Dr. C. Müller-Renno

### d) On-campus phase
(Microarray Technology, summer term):
Tutorial, lab course
given by Dr. F. Stahl, M. Pähler

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td>160h</td>
<td></td>
<td>12</td>
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<tr>
<td>40h</td>
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<td>6h</td>
<td>44h</td>
<td></td>
</tr>
<tr>
<td>13h</td>
<td>37h</td>
<td></td>
</tr>
</tbody>
</table>

## 2. Impact on curriculum:
compulsory module

## 3. Content
Content: Textbook "Characterization of Nanostructures" (Part 1)
- Prerequisites for resolution on the nanometer scale
- Overview on experimental aspects
- Microscopic techniques
- Spectroscopic and spectrometric techniques: chemical composition
- Spectroscopic techniques: electronic structure
- Spectroscopic techniques: vibrational and magnetic structure

Content Textbook “Screening Methods in Biology, Chip Technologies” (Part 2)

- Traditional screening of genes and gene expression
- High-throughput screening
- Chip technologies
- Gene expression analysis by RNA Seq
- Protein chip technologies
- Aptamer microarrays
- Cell and tissue microarrays
- Lab-on-a-chip

4. Intended Learning Outcomes and competencies:
   for a)-b)
   On successfully completing the module students will be able to
   - explain main characterization procedures of nanomaterials,
   - justify which characterization method is most suitable based on the prerequisites for resolution on the nanometer scale,
   - contrast the most powerful tools in the field of nanomicroscopies,
   - evaluate spectroscopic techniques which are used to get information about the chemical composition of nanomaterials,
   - compare spectroscopic techniques which provide information about the electronic structure of nanomaterials,
   - judge spectroscopic techniques which allow getting information about the vibrational and magnetic structure of nanomaterials,
   - understand the principles of traditional screening methods in biology,
   - explain the basic mechanisms in high-throughput screening systems,
   - compare different chip technologies such as DNA and protein chip technology,
   - perform their own chip experiment during the on-campus phase.

   for c)
   - decide which sample preparation for characterization of nanostructures is most suitable,
   - image the sample using by different analysis techniques,
   - interpret the information supplied by the different imaging techniques,
   - decide which imaging methods is appropriate for a specific sample of purpose.

   for d)
   - explain the molecular biology of gene expression, principles of traditional screening, methods in biology and basic mechanisms in highthroughput screening systems,
   - compare different microarray technologies such as DNA, Protein and Aptamer microarray technology,
   - to perform the data analysis of an microarray experiment,
   - use bioanalytical systems to describe complex reactions in biotechnological processes.
5. **Prerequisites for attending:**

| Formal admission requirements: | none |
| Contextual prerequisites: | a)-d) none |

6. **Requirements for receiving credit points (especially assessments, certificate of attendance):**

   a) Written examination (120 minutes duration): graded
   b) Successful participation of on-campus tutorials and lab courses: not graded

7. **Determination of grade:**

   Grade: determined from the written exam

   Significance for final grade: enters as grade weighted with its ECTS points: 8/61

8. **Applicability of the module/suitability:**

   This module is also part of the distance certificate programme "Nanobiotechnology" ("Analytical Techniques in Nanotechnology" (NT0007)).

9. **Hints for preparation:**

   **Recommended literature:**


<table>
<thead>
<tr>
<th>Available documents:</th>
<th>Textbooks &quot;Characterization of Nanostructures&quot; written by Prof. Dr. C. Ziegler, Dr. C. Müller-Renno and &quot;Screening Methods in Biology, Chip Technologies&quot; written by Prof. Dr. R. Ulber and Dr. F. Stahl. Both text books include self-control assignments for self-study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online tutorial:</td>
<td>Discussion forum (online learning platform) available during the lecture time</td>
</tr>
<tr>
<td>10. Registration procedure:</td>
<td>online registration</td>
</tr>
<tr>
<td>11. Language:</td>
<td>English</td>
</tr>
</tbody>
</table>
### Module: Nanooptics

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0008</td>
<td>Prof. Georg v. Freymann</td>
<td>Prof. Georg v. Freymann</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>150h (25h=1CP)</td>
<td>6</td>
<td>Third semester</td>
<td>6 weeks plus on-campus weekend</td>
<td>winter term</td>
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</table>

<table>
<thead>
<tr>
<th>1. Parts of the module/courses: (please choose/update the courses)</th>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Textbooks (Part 1 and Part 2):</td>
<td>108h</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>written by Prof. G v. Freymann and Prof. S. Maier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Exercises in textbooks:</td>
<td>41h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>written by Prof. G v. Freymann and Prof. S. Maier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) On-campus phase (Characterization of Nanostructures): tutorial</td>
<td>1h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>organized by Prof. G. v. Freymann</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 2. Impact on curriculum:                                         |                   |                                       |                     |
|                                                               | compulsion module |                                       |                     |

| 3. Content                                                      |                   |                                       |                     |
| Content of the textbook "Metamaterials and Photonic Crystals" (Part 1) |                   |                                       |                     |
| - Interaction of light with matter                              |                   |                                       |                     |
| - Photonic crystals                                             |                   |                                       |                     |
| - Photonic metamaterials                                        |                   |                                       |                     |
| Content of the textbook "Plasmonics" (Part 2)                   |                   |                                       |                     |
| - The optical properties of metals                              |                   |                                       |                     |
| - Surface plasmon polaritons                                    |                   |                                       |                     |
| - Localized surface plasmons                                    |                   |                                       |                     |
| - Selected applications of nanoplasmonics: nanoantennas          |                   |                                       |                     |

| 4. Intended Learning Outcomes and competencies:                 |                   |                                       |                     |
| On successfully completing the module students will be able to  |                   |                                       |                     |
| for a)                                                           |                   |                                       |                     |
| - understand, describe and determine the underlying light-matter-interaction in modern optical materials, |                   |                                       |                     |
- describe and develop optical properties of photonic crystals and metamaterials,
- evaluate state-of-the art literature,
- modify selected photonic applications to solve optical materials challenges,
- apply appropriate methods to solve problems related to optical material.

for b)
- analyze a problem, compare and evaluate appropriate methods and choose the right method for the problem,
- propose novel design for optical materials based on plasmonics and metamaterials,
- evaluate and design the optical properties of photonic crystals and metamaterials,
- Recommend the proper solution for a sensing problem, i.e., if a dielectric or a plasmonic approach will work best for the problem at hand.

for c)
- discuss scientific problems in a team,
- reflect actual scientific developments and exchange ideas with the team.

5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>a)-b) none c) having read the corresponding textbooks</td>
</tr>
</tbody>
</table>

6. Requirements for receiving credit points (especially assessments, certificate of attendance):

   a) Written examination (90 minutes duration): graded
   b) Successful participation of on-campus tutorial: not graded

7. Determination of grade:

<table>
<thead>
<tr>
<th>Grade:</th>
<th>determined from the written exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance for final grade:</td>
<td>enters as grade weighted with its ECTS points: 6/61</td>
</tr>
</tbody>
</table>

8. Applicability of the module/suitability:

   This module extends the knowledge from the module “Solid State Physics” (NT0003) and applies the corresponding methods to modern optical materials.

9. Hints for preparation:

   **Recommended literature:**

   **Available documents:** Textbooks "Metamaterials and Photonic Crystals" and "Plasmonics" including self-control assignments for self-study written by Prof. G. v. Freymann and
<table>
<thead>
<tr>
<th></th>
<th>Prof. S. Maier, respectively</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Online tutorial</strong>:</td>
<td>Discussion forum (online learning platform) available during the lecture time</td>
</tr>
<tr>
<td><strong>10.</strong></td>
<td>Registration procedure: online registration</td>
</tr>
<tr>
<td><strong>11.</strong></td>
<td>Language: English</td>
</tr>
</tbody>
</table>
# Module: Nanomaterials 1

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0009</td>
<td>apl. Prof. Einar Kruis</td>
<td>apl. Prof. Einar Kruis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>175h (25h=1CP)</td>
<td>7</td>
<td>Fourth semester</td>
<td>8 weeks</td>
<td>summer term</td>
</tr>
</tbody>
</table>

1. **Parts of the module/courses:**

   *(please choose/update the courses)*

   **Attendance time:** Self study: (preparation + follow up)

   **Credit Points (CP):** 7

   - **a) Textbooks (Part 1 and Part 2):**
     - 8 weeks
     - written by apl. Prof. E. Kruis, Prof. R. Clasen
     - 126h

   - **b) Exercises in textbooks:**
     - 8 weeks
     - written by apl. Prof. E. Kruis, Prof. R. Clasen
     - 49h

2. **Impact on curriculum:**

   Compulsory module

3. **Content:**

   - Content of the textbook "Processing Ceramics and Composites and Their Applications" (Part 1)
     - Overview nanotechnology
     - Synthesis of nanosized powders
     - Characterization of nanopowders
     - Dispersing
     - Aerosols
     - Shaping
     - Drying
     - Modification
     - Sintering
     - Characterization

   - Content of the textbook „Physical Synthesis of Nanoparticles“ (Part 2)
     - Nanoparticle movement and interaction
     - Nucleation and growth
     - Gas-phase synthesis
     - Nanoparticle reactor design
     - Nanoparticle formation on substrates
     - Ball milling techniques

   - Content of the textbook „Chemical Synthesis of Nanoparticles“ (Part 2)
     - Basic mechanisms in liquid phase processes
     - Reduction processes and coprecipitation
     - Sol-gel nanoparticle synthesis
     - Synthesis in confined volumes
- Synthesis of nanoparticles by means of diblock copolymers
- Templated-based synthesis
- Gas-phase methods
- Size analysis methods

### Intended Learning Outcomes and competencies: for a)-b)
On successfully completing the module students will be able to
- analyze synthesis and fabrication methods for ceramics, composites and nanoparticle based on an understanding of the fundamental mechanisms involved,
- choose suitable synthesis methods for a given material and / or application,
- classify a given synthesis method in one of the categories given in the courses,
- select the required processing steps for a given ceramic or composite material,
- compare characterization or size analysis methods for material-related applications and select the most suitable method,
- develop kinetic equations to describe the particle size evolution and apply simple numerical methods for their solution,
- evaluate equation-based methods for describing fundamental mechanisms involved in nanoparticle movement, interaction, nucleation and growth which are relevant for reactor design.

### Prerequisites for attending:

| Formal admission requirements: | none |
| Contextual prerequisites:      | none |

### Requirements for receiving credit points (especially assessments, certificate of attendance):
a) Written examination (120 minutes duration): graded

### Determination of grade:

| Grade:                        | determined from the written exam |
| Significance for final grade: | enters as grade weighted with its ECTS points: 7/61 |

### Applicability of the module/suitability:
The module provides background knowledge useful for the module “Nanomaterials 2” (NT0010) and “Nanomaterials 3” (NT0011).
This module is also part of the distance studies certificate programme “Nanobiotechnology” (“Nanomaterials 1” (NT0009)).

### Hints for preparation:


Available documents: Textbooks "Processing Ceramics and Composites and Their Applications" written by Prof. S. Maier, "Physical Synthesis of Nanoparticles" written by apl. Prof. E. Kruis and "Chemical Synthesis of Nanoparticles". All textbooks include self-control assignments for self-study.

Online tutorial: Discussion forum (online learning platform) available during the lecture time

10. Registration procedure: online registration

11. Language: English
## Elective Module: Nanomaterials 2

<table>
<thead>
<tr>
<th>Code:</th>
<th>NT0010</th>
<th>Module Coordinator:</th>
<th>Prof. Eisenbarth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Teaching Staff:</td>
<td>Prof. Eva Eisenbarth, Dr. Lach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>125h (25h=1CP)</td>
<td>5</td>
<td>Fourth semester</td>
<td>6 weeks</td>
<td>summer term</td>
</tr>
</tbody>
</table>

### 1. Parts of the module/courses:

*(please choose/update the courses)*

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study:</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(preparation + follow up)</td>
<td>5</td>
</tr>
</tbody>
</table>

- **a)** Textbooks (Part 1 and Part 2): 6 weeks
  - written by Prof. E. Eisenbarth, Prof. G. Duesberg, Prof. S. Roth
  - 90h

- **b)** Exercises in textbooks: 6 weeks
  - written by Prof. E. Eisenbarth, Prof. G. Duesberg, Prof. S. Roth
  - 35h

### 2. Impact on curriculum:

- elective module

### 3. Content

#### Content of the textbook “Nanotechnologically Modified Biomaterials” (Part 1)

- Biomaterials
- The interface biomaterial-biological system
- Nanotechnological aspects of biological systems
- Biomaterial properties control interactions with the biological system
- Nanotechnological tools improve biomaterials
- Nanosized materials for tissue engineering
- Nanotoxicology

#### Content of the textbook “Carbon Nanomaterials” (Part 2)

- Introduction
- Synthesis of carbon nanomaterials
- Purification, separation, and characterization of carbon nanomaterials
- Handling of carbon nanomaterials
- Physics of carbon nanomaterials
- Electrical measurements
- Applications
- Safety

### 4. Intended Learning Outcomes and competencies:

On successfully completing the module students will be able to for a)-b):

- explain the processes occurring between a synthetic biomaterial and a natural tissue in vivo,
- influence these processes by choosing appropriate surface and material properties and to
apply various methods to influence material and surface characteristics,
- differentiate between various methods to functionalize medically used materials to meet
  defined requirements for the application of a biomaterial,
- name, analyze and measure systematically pivotal nanotechnological properties of
  materials,
- evaluate toxic or harming properties of a biomaterial,
- understand crystal lattice structures and explain their influence on electronic properties,
- distinguish imaging and characterization techniques for carbon nanostructures, e.g. electron
  microscopy and diffraction as well as spectroscopy and scanning probe techniques,
- compare synthesis methods of carbon nanotubes and graphene,
- explain electrical properties of materials in general such as superconductivity,
  magnetoresistance, Hall Effect and Quantum Hall Effect.

5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>a)-b) none</td>
</tr>
</tbody>
</table>

6. Requirements for receiving credit points (especially assessments, certificate of attendance):

- a) Successfully solving mail-in exercises (once per semester): not graded

7. Determination of grade:

<table>
<thead>
<tr>
<th>Grade:</th>
<th>not graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance for final grade:</td>
<td>has no weight towards the final grade</td>
</tr>
</tbody>
</table>

8. Applicability of the module/suitability:

The contents of "Nanotechnologically Modified Biomaterials" and its mail-in exercises are also part of the distance studies certificate programme "Nanobiotechnology" ("Nanotechnologically Modified Biomaterials" (NT0010.1)).

9. Hints for preparation:


<table>
<thead>
<tr>
<th>Available documents:</th>
<th>Textbooks “Nanotechnologically Modified Biomaterials” written by Prof. E. Eisenbarth and “Carbon Nanomaterials” written by Prof. G. Duesberg and Prof. S. Roth. Both textbooks include self-control assignments for self-study.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online tutorial:</td>
<td>Discussion forum (online learning platform) available during the lecture time</td>
</tr>
<tr>
<td>10. Registration procedure:</td>
<td>online registration</td>
</tr>
<tr>
<td>11. Language:</td>
<td>English</td>
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</table>
## Module: Nanomaterials 3

<table>
<thead>
<tr>
<th>Code</th>
<th>Module Coordinator</th>
<th>Teaching Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0011</td>
<td>Prof. Herbert Urbassek</td>
<td>Prof. Herbert Urbassek, Dr. Asad Jamal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP)</th>
<th>Recommended Semester</th>
<th>Duration</th>
<th>Regular cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>125h (25h=1CP)</td>
<td>5</td>
<td>Fourth and Fifth semester</td>
<td>12 weeks (6 weeks per term)</td>
<td>summer and winter term</td>
</tr>
</tbody>
</table>

### 1. Parts of the module/courses:
*(please choose/update the courses)*

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Self study: (preparation + follow up)</th>
<th>Credit Points (CP): 5</th>
</tr>
</thead>
</table>

#### a) Textbooks
(Part 1 and Part 2):
12 weeks

- written by Prof. G. Reiter, Prof. H. Urbassek

| 90h               |                                        |                       |

#### b) Exercises in textbooks:
12 weeks

- written by Prof. G. Reiter, Prof. H. Urbassek

| 35h               |                                        |                       |

### 2. Impact on curriculum:

compulsory module

### 3. Content

**Content of the textbook “Self-assembly” (Part 1)**
- Introduction and definitions
- Building blocks and principles of self-assembly
- The concept of self-assembly through force balance
- Types of forces between molecules and particles
- Self-assembly at interfaces
- Self-assembly in solution
- Self-assembly of colloidal objects
- Self-assembly driven by external forces
- Implications of self-assembly for nanotechnology

**Content of the textbook “Computer Simulations and Modeling in Nanotechnology” (Part 2)**
- Interatomic interaction
- Molecular statics
- Molecular dynamics
- Computational chemistry
- Stochastic techniques
- Molecular orbitals and binding
- A primer on quantum chemistry

### 4. Intended Learning Outcomes and competencies:

On successfully completing the module students will be able to

for a)-b)

- summarize the basics of nanostructure formation using bottom-up approach,
- discuss how building units put themselves together without external intrusion,
- explain the increase in internal order of a system can lead to regular patterns on scales ranging from molecular to the macroscopic sizes,
- explain the atomistic modeling techniques available in nanotechnology and –science,
- understand the techniques of molecular dynamics simulation,
- compare the specific interatomic interactions in metals, semiconductors, ceramics and biomolecules,
- describe the connection between macroscopic thermodynamic properties and the atomistic dynamics,
- derive the properties of nanoparticles from the interactions,
- apply stochastic methods for modeling of materials,
- understand the basic principles of ab-initio electronic-structure calculations as applied to molecules and nanoparticles,
- apply their current knowledge of physics of self-assembly processes,
- distinguish between relevant and irrelevant information found in different sources of literature,
- judge the seriousness of the information source (make sure it is no “hoax” or information with commercial interest, e.g. from a company),
- summarize in their own words the information asked for, at the same time apply the rules of good scientific practice by clearly indicating your source of information.

5. Prerequisites for attending:

| Formal admission requirements: | none |
| Contextual prerequisites: | a)-b) none |

6. Requirements for receiving credit points (especially assessments, certificate of attendance):
   a) Successfully solving mail-in exercises (once per semester): not graded

7. Determination of grade:

| Grade: | not graded |
| Significance for final grade: | has no weight towards the final grade |

8. Applicability of the module/suitability:

   The study content of this module is important for the modules "Nanomaterials 2" (NT0010) and "Applications of Nanotechnology" (NT0013).

9. Hints for preparation:

Available documents: Textbooks “Self-assembly” and “Computer Simulations and Modeling in Nanotechnology” including self-control assignments for self-study written by Prof. G. Reiter and Prof. H. Urbassek.

Online tutorial: Discussion forum (online learning platform) available during the lecture time

10. Registration procedure: online registration

11. Language: English
## Module: Transport in Nanostructures

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0012</td>
<td>Prof. Dr. Thomas Heinzel</td>
<td>Prof. Dr. Thomas Heinzel, Dr. Philip Pirro</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Workload</th>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>175h (25h=1CP)</td>
<td>7</td>
<td>Fifth semester</td>
<td>6 weeks plus on-campus weekend</td>
<td>winter term</td>
</tr>
</tbody>
</table>

1. **Parts of the module/courses:**
   
   **(please choose/update the courses)**

   **Attendance time:** Self study: (preparation + follow up) **Credit Points (CP): 7**

   a) **Textbooks** (Part 1 and Part 2):
      6 weeks
      written by Prof. T. Heinzel, Prof. G. Reiss
      100h

   b) **Exercises in textbooks:**
      6 weeks
      written by Prof. T. Heinzel, Prof. G. Reiss
      25h

   c) **On-campus phase** (Nanoelectronics):
      Tutorial, lab course
      given by Dr. J. Moers, Dr. S. Wolff
      7h
      43h

2. **Impact on curriculum:**
   compulsory module

3. **Content**

   **Content of the textbook “Nanoelectronics” (Part 1)**
   - Introduction
   - Two-dimensional electron gases and semiclassical transport
   - Ballistic electronics
   - Electronic interference
   - Quantum dots

   **Content of the textbook “Nanomagnetism” (Part 2)**
   - Basics of magnetism
   - Techniques to measure magnetic properties
   - Domains and domains walls
   - Simulations of static and dynamic micro- and nanomagnetic phenomena
   - Magnetic nanoparticles
   - Magnetic nanowires
   - Two-dimensional magnetic nanostructures
   - Three-dimensional magnetic nanomaterials
### 4. Intended Learning Outcomes and competencies:

For a)-b)

On successfully completing the module students will be able to:
- apply the most important formalisms for treating electronic conductors beyond the Boltzmann model,
- analyze effects that emerge due to ballistic transport, electron coherence and Coulomb blockade,
- work with the quantization of the Hall effect,
- interpret a variety of applications of mesoscopic electronics,
- understand the basics of magnetism,
- explain light- and force-based techniques to study the magnetic properties of solids on a microscopic scale,
- compare magnetism at the macro-, micro- and nanoscopic scale and describe it phenomenologically by using the Landau-Lifshitz-Gilbert equation,
- describe the preparation, the magnetic properties and applications of zero-, one- and two-dimensional magnetic nanostructures,
- elaborate different aspects of magneto-resistance as transport phenomenon on polarized spin carriers,
- give an overview on magnetic nanomaterials where nanosized grains with varying properties from bulk-materials with tailorable properties.

c)
- select an appropriate clothes for entering a clean room, know how to behave inside a clean room and work in it,
- create a process flow to realize a nanoelectronic device,
- prepare a sample by using UV-photolithography, metal structuring techniques and dry etching techniques,
- characterize nanoelectronic devices,
- interpret measured data and draw conclusions.

### 5. Prerequisites for attending:

| Formal admission requirements: | none |
| Contextual prerequisites: | a)-b) none c) participation in the on-campus weekend “Lab in the cleanroom” |

### 6. Requirements for receiving credit points (especially assessments, certificate of attendance):

- a) Written examination (120 minutes duration): graded
- b) Successful participation of on-campus tutorial: not graded

### 7. Determination of grade:

| Grade: | determined from the written examination |
| Significance for final grade: | enters as grade weighted with its ECTS points: 5/61 |

### 8. Applicability of the module/suitability:

-
### Hints for preparation:

| Recommended literature: | “Nanoelectronics”:  
| Available documents: | Textbooks "Nanoelectronics" and "Nanomagnetism" including self-control assignments for self-study written by Prof. T. Heinzel and Prof. G. Reiss, respectively |
| Online tutorial: | Discussion forum (online learning platform) available during the lecture time |

### Registration procedure: online registration

### Language: English
# Elective Module: Applications of Nanotechnology

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0013</td>
<td>Dr. Sandra Wolff</td>
<td>Dr. Sandra Wolff</td>
</tr>
</tbody>
</table>

## Workload

<table>
<thead>
<tr>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Fifth semester</td>
<td>6 weeks</td>
<td>winter term</td>
</tr>
</tbody>
</table>

## 1. Parts of the module/courses:

*Please choose/update the courses*

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>5</td>
</tr>
</tbody>
</table>

### a) Textbooks

- **Part 1 and Part 2:**
  - 6 weeks
  - Written by Prof. Dr. C. Ziegler, Prof. P. Vogel, Prof. M.N.V. Ravi Majeti, Prof. U. Bakowsky, Prof. C.-M. Lehr
  - 90h

### b) Exercises in textbooks:

- **6 weeks**
  - Written by Prof. Dr. C. Ziegler, Prof. P. Vogel, Prof. M.N.V. Ravi Majeti, Prof. U. Bakowsky, Prof. C.-M. Lehr
  - 35h

## 2. Impact on curriculum:

**elective module**

## 3. Content

- **Content of the textbook “Molecular Nanosystems: Sensors” (Part 1)**
  - Sensors and Biosensors
  - Nanoelectromechanical Transducers
  - Biosensing Applications

- **Content of the textbook “Molecular Nanosystems: Molecular Motors” (Part 1)**
  - Importance of movement for living systems
  - Kinesin, dynein and myosin: motors for linear, intracellular transport
  - ATP synthase

- **Content of the textbook “Nanoparticles as Therapeutic Drug Carrier and Diagnostics” (Part 2)**
  - Features of polymeric nanoparticles
  - Preparation and characterization of nanoparticles
  - Recent developments in pharmaceutical nanoparticles technology
  - Therapeutic applications of nanoparticular carrier systems
  - Nanoparticles as diagnostics

## 4. Intended Learning Outcomes and competencies: for a)-b)

On successfully completing the module students will be able to

- explain the advantages and disadvantages of cantilever based biosensors,
- review the functionality of linear and rotary motors in living systems,
- report on the basic principles of the application of polymer nanoparticles in biomedical sciences,
- compare the different molecular motors and their potential application in nanotechnology
- envision potential nanotechnological applications,
- analyze the potential of nanoparticles for drug delivery and clinical diagnostics.
5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal admission</td>
<td></td>
</tr>
<tr>
<td>requirements:</td>
<td></td>
</tr>
<tr>
<td>Contextual</td>
<td></td>
</tr>
<tr>
<td>prerequisites:</td>
<td></td>
</tr>
</tbody>
</table>

6. Requirements for receiving credit points (especially assessments, certificate of attendance):

   a) Successfully solving mail-in exercises (once per semester): not graded

7. Determination of grade:

<table>
<thead>
<tr>
<th>Grade:</th>
<th>Not graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance for</td>
<td></td>
</tr>
<tr>
<td>final grade:</td>
<td>Has no weight towards the final grade</td>
</tr>
</tbody>
</table>

8. Applicability of the module/suitability:

   This module is also part of the distance studies certificate programme "Nanobiotechnology" ("Applications of Nanotechnology" (NT0013)).

9. Hints for preparation:

   Recommended literature:


| Available documents: | Textbooks "Molecular Nanosystems: Sensors" written by Prof. C. Ziegler, "Molecular Nanosystems: Molecular Motors" written by Prof. P. Vogel, "Nanoparticles as Therapeutic Drug Carrier and Diagnostics" written by Prof. M.N.V. Ravi Majeti, Prof. U. Bakowsky, Prof. C.-M. Lehr. All textbooks include self-control assignments for self-study. |
| Online tutorial: | Discussion forum (online learning platform) available during the lecture time |
| 10. Registration procedure: | online registration |
| 11. Language: | English |
# Module: Nanotechnology in its Societal Context

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT0014</td>
<td>Jan Büssers</td>
<td>Jan Büssers</td>
</tr>
</tbody>
</table>

## Workload

<table>
<thead>
<tr>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Fifth semester</td>
<td>4 weeks</td>
<td>winter term</td>
</tr>
</tbody>
</table>

## 1. Parts of the module/courses:

(please choose/update the courses)

<table>
<thead>
<tr>
<th>Attendance time:</th>
<th>Credit Points (CP):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study: (preparation + follow up)</td>
<td>2</td>
</tr>
</tbody>
</table>

#### a) Textbook:
- 4 weeks written by Prof. A. Nordmann
- 36h

#### b) Exercises in textbook:
- 4 weeks written by Prof. A. Nordmann
- 14h

## 2. Impact on curriculum:

compulsory module

## 3. Content

- Approaching nanotechnoscience
- The incredible tininess of nano
- The nanomachinery of life
- From dead matter to smart materials
- Nanomagic
- Enhancement debates
- Green nano
- Responsible development
- Collective experiments

## 4. Intended Learning Outcomes and competencies: for a)-b)

On successfully completing the module students will be able to

- elaborate arguments and summarize the central issues provided in a text,
- evaluate chances and risks of nanotechnology,
- participate in public debates about topics related to nanotechnology,
- explain the importance of responsible development and regulatory supervision.

## 5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>a)-b) none</td>
</tr>
</tbody>
</table>

## 6. Requirements for receiving credit points (especially assessments, certificate of attendance):

a) Successfully solving mail-in exercises (once per semester): not graded

## 7. Determination of grade:

Grade: not graded
<table>
<thead>
<tr>
<th><strong>Significance for final grade:</strong></th>
<th>has no weight towards the final grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. <strong>Applicability of the module/suitability:</strong></td>
<td>-</td>
</tr>
</tbody>
</table>
| 9. **Hints for preparation:** | **Recommended literature:**
| **Available documents:** | Textbook "Nanotechnology in its Societal Context" including self-control assignments for self-study written by Prof. A. Nordmann |
| **Online tutorial:** | Discussion forum (online learning platform) available during the lecture time |
| 10. **Registration procedure:** | online registration |
| 11. **Language:** | English |
## Module: Master’s Thesis

<table>
<thead>
<tr>
<th>Code:</th>
<th>Module Coordinator:</th>
<th>Teaching Staff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTh</td>
<td>Prof. Egbert Oesterschulze</td>
<td>Any university teacher</td>
</tr>
</tbody>
</table>

### Workload

<table>
<thead>
<tr>
<th>Credit Points (CP):</th>
<th>Recommended Semester:</th>
<th>Duration:</th>
<th>Regular cycle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Sixth semester</td>
<td>6 months</td>
<td></td>
</tr>
</tbody>
</table>

### 1. Parts of the module/courses:

(please choose/update the courses)

- **a) Master’s Thesis**
  - **Attendance time:** 500h
  - **Self study:** (preparation + follow up)
  - **Credit Points (CP):** 20

### 2. Impact on curriculum:

compulsory module

### 3. Content

Dependent on the chosen topic.

### 4. Intended Learning Outcomes and competencies: for a)

On successfully completing the module students will be able to
- develop a holistic view to critically, independently and creatively identify, formulate and deal with complex issues,
- plan and use adequate methods to conduct qualified tasks in given frameworks and to evaluate this work,
- create, analyse and evaluate different scientific as well as technical solutions,
- contribute to research and development work,
- identify the issues that must be addressed within the framework of the specific thesis in order to take into consideration all relevant dimensions of sustainable development.

### 5. Prerequisites for attending:

<table>
<thead>
<tr>
<th>Formal admission requirements:</th>
<th>a) Proof of successful completion of the graded and ungraded work performed in the first two semesters.</th>
<th>b) Proof of two passing exam grades from all of the achievements in the third to fifth semesters, as well as participation in two on-campus sessions in these seminars.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextual prerequisites:</td>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

### 6. Requirements for receiving credit points (especially assessments, certificate of attendance):

- a) Successfully completing Master’s Thesis: graded

### 7. Determination of grade:

- **Grade:** determined from the Master’s Thesis
- **Significance for final grade:** enters as grade weighted with its ECTS points: 20/61
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Applicability of the module/suitability:</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
<tr>
<td>9.</td>
<td>Hints for preparation:</td>
</tr>
<tr>
<td><strong>Recommended literature:</strong></td>
<td>Educational books, specialized books, technical books, appropriate scientific and technical journals, any further literature suggested by the advisor, depending on the chosen topic.</td>
</tr>
<tr>
<td><strong>Available documents:</strong></td>
<td>The textbooks the student has access to her / his textbooks of the study programme, to the university's library and e-library</td>
</tr>
<tr>
<td><strong>Online tutorial:</strong></td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Registration procedure:</td>
</tr>
<tr>
<td></td>
<td>In the first step a suggested thesis's topic is submitted by the student to obtain the acceptance from the examination board. In the second step the student officially registers for the accepted thesis's topic.</td>
</tr>
<tr>
<td>11.</td>
<td>Language: English</td>
</tr>
</tbody>
</table>