《纳米材料导论》课程教学大纲

**一、课程基本信息Basic Information**

|  |  |  |  |
| --- | --- | --- | --- |
| **英文名称** | Introduction to Nanomaterials | **课程代码** | 09040016 |
| **课程性质** | Cross-major Elective Course | **授课对象** | Chemistry, Materials Science, Functional Materials, Chemical Engineering |
| **学 分** | 2.0 | **学 时** | 36 Hours |
| **主讲教师** | Zexin Zhang | **修订日期** | 2021.5 |
| **指定教材** | Dieter V. *Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition.* Germany: Wiley-VCH Verlag GmbH & Co. ISBN: 978-3-527-67186-1 | | |

**二、课程目标Objectives**

（一）**总体目标：**

This course covers the subject of nanomaterials and provides students with the basic concepts and advanced knowledge of nanomaterials, including the synthesis, characterization, applications, the scale-dependent properties of materials, and their link to functionality and applications. They will explore strategies for nanomaterials synthesis with a view on their advantages and limitations. They will be provided with an overview of the potential socio-economic and environmental impacts of nanomaterials as a disruptive technology.

（二）课程目标：

**1：**Through the study of the basic concepts of nanomaterials, students can understand the influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect. They will be proficient in the difference between nanoscale and microscale.

**2：**Through the study of the various synthesis strategies and characterization methods of nanomaterials, students will have a deep understanding of the advantages and disadvantages of different synthesis strategies and characterization methods as well as their application scope. They will master the scientific research thinking of using different synthesis strategies to obtain nanomaterials with different structures.

**3：**Through the study of the application examples of nanomaterials in various fields and their potential safety risks, students will deeply understand that nanomaterials have a wide range of application prospects, as well as their existing defects, and can fully realize that there is a long way to go for the development of nanotechnology.

（三）课程目标与毕业要求、课程内容的对应关系

**表1：课程目标与课程内容、毕业要求的对应关系表**

|  |  |  |  |
| --- | --- | --- | --- |
| **课程目标** | **课程子目标** | **对应课程内容** | **对应毕业要求** |
| 课程目标1 | 1.1 The history and development of nanomaterials | Chapter 1 General Concepts in Nanomaterials | Through the study of the "development and history of nanomaterials" in the first chapter, students can have the most basic knowledge and understanding of nanomaterials and nanoscale.  Through the study of the "nano-size effect" in Chapter 2, students can understand the impact of nano-scale size on the surface and interface, and can deeply think about the advantages and disadvantages of nanomaterials and the functions they can achieve, and further prospects for material design and Material application |
| 1.2 The basic concepts of nanoscale | Chapter 2 Characteristics of Nanomaterials Brought by Nano-Size Effect |
| 课程目标2 | 2.1 Overview of nanostructures and their Corresponding Functions | Chapter 3 Synthesis of Nanomaterials | Through the study of “overview of nanostructures” in Chapter 3, students can recognize the diversity of nanostructures;  Through the study of the synthesis strategy of nanomaterials in Chapter 3, students can understand the advantages and disadvantages of different synthesis methods, and can deeply understand the diversity of the process from selection of raw materials to screening of synthesis schemes. Students will form a certain scientific research thinking mode.  Through the study of “the characterization of nanomaterials” in Chapter 4, students can understand the characteristics of different characterization methods, and can recognize the differences between the characterization methods of nanomaterials and other materials. |
| 2.2 The fabrication strategies of nano-particles | Chapter 3 Synthesis of Nanomaterials |
| 2.3 Characterization of Nanomaterials | Chapter 4 Characterization of Nanomaterials |
| 课程目标3 | 3.1 The application of nanomaterials and its safety discussion | Chapter 5 Application of nanomaterials  Chapter 6 Discussion on the safety of nanomaterial  Chapter 7 Student presentations | Through the study of the application of nanomaterials in different fields in Chapter 5, students can understand the wide range of applications of nanomaterials, and can further think about the relationship between the structure, function and application of materials.  Through the study of the “Discussion on the safety of nanomaterials” in Chapter 6, students can recognize the limitations of nanomaterials and can look forward to its future improvement methods  Through the display section of Chapter 7, students can freely express their views on nanomaterials by choosing themes. A good atmosphere of communication can be formed between students and teachers and students themselves, and they can exercise communication skills and contract collaboration skills. |

（大类基础课程、专业教学课程及开放选修课程按照本科教学手册中各专业拟定的毕业要求填写“对应毕业要求”栏。通识教育课程含通识选修课程、新生研讨课程及公共基础课程，面向专业为工科、师范、医学等有专业认证标准的专业，按照专业认证通用标准填写“对应毕业要求”栏；面向其他尚未有专业认证标准的专业，按照本科教学手册中各专业拟定的毕业要求填写“对应毕业要求”栏。）

**三、教学内容Contents**

（具体描述各章节教学目标、教学内容等。实验课程可按实验模块描述）

**第一章 1. General Concepts in Nanomaterials**

1.教学目标

(1) Understand the development and history of materials.

(2) Understand the history and development of nanomaterials.

(3) Understand the basic concepts related to nano size.

(4) Understand the functions, research hotspots and importance of nanomaterials.

2.教学重难点

Focus：Have a preliminary basic understanding of the characteristics and development of nanomaterials.

Difficulty: The difference between nanoscale and microscale.

3.教学内容

1.1 The history and development of materials

1.2 The history and development of nanomaterials

1.3 Concepts of nanoscale

1.4 Overview of nanomaterials

4.教学方法

(1) Lecture method: Concepts and basic theories are taught by lecture method. Such as the quantum mechanics laws, statistical mechanics laws and chemical kinetics active and the corresponding theories.

(2) Case teaching method: Analyze and discuss the hotpots of nanomaterial design research and the important process of scientific development

5.教学评价

Answer the following questions:

1. What is the difference between the nano-range and the micro-range?

2. List at least three examples of possible application of nanomaterials you contemplated and clarify it used what characteristics of nanomaterials

**第二章 2. Characteristics of Nanomaterials Brought by Nano-Size Effect**

1.教学目标

(1) Understand the influence of nanometer size on the magnetic behavior, chemical activity, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect, size effect.

(2) Understand the concept and importance of surfaces and interfaces

(3) Understand the importance of nanomaterial stability and how to achieve it

2.教学重难点

Focus and difficulties：

Grasp the concept of nano-size effect and realize its profound influence on the properties and functions of materials.

Understand the related concepts of surfaces and interfaces and their influence on the stability of materials.

3.教学内容

2.1 The characteristics of nanomaterials

2.2 Surfaces in nanomaterials

2.3 Interface

2.4 Nanoparticle stabilitym

4.教学方法

(1) Lecture method: Concepts and basic theories are taught by lecture method. Such as the nano-size effect, quantum effects, surface effect, interface, charge stabilization, electric double layer, crystal facet effect and nanoparticle stability and the corresponding theories.

(2) Case teaching method: Combined with actual cases, analyze the influence of surface interface on the stability of the material; discuss the influence of nano-size effect on its function and application.

5.教学评价

Answer the following questions:

1. Briefly describe the effect of nanometer size on the surface and interface of materials.

2. What advantages can size effect bring?

3. Why are the surfaces and interfaces important?

**第三章 3. Synthesis of Nanomaterials**

1.教学目标

(1) Understand the structure of nanomaterials and their preparation strategies;

(2) Understand the advantages and disadvantages of various preparation strategies of nanomaterials, and have preliminary research ideas for material design

2.教学重难点

Focus and difficulties：

Understand what methods can be used to make nanomaterials with specific structures;

Understand the advantages and disadvantages of various strategies

3.教学内容

3.1 Overview of nanostructures

3.2 Making nanostructures: top down

3.3 The beam technologies

3.4 Making nanostructures: bottom up

3.5 Mechanism basic of self-assembly strategie

3.6 Self-assembly for nanomaterials

4.教学方法

(1) Lecture method: Concepts and basic theories are taught by lecture method. Such as the top-down, bottom-up strategies and self-assembly strategies and the corresponding theories.

(2) Case teaching method: Analyze and discuss the characteristics and functions of nanomaterials with various structures, and list the nanomaterial products that have been industrialized and mass-produced.

5.教学评价

Answer the following questions:

1. Please characterize major top-down and bottom-up strategies.

2. List the raw materials that can make nano materials.

3. What is major fabrication strategies of nano-particles?

4. How to get nanomaterials with a narrow size distribution, such as quantum dots and nanowires?

**第四章 4.Characterization of Nanomaterials**

1.教学目标

(1) Understand the various methods and characteristics of nanomaterials

(2) Understand the synergistic relationship between material preparation and characterizations, which restrict each other but also promote the development of each other

2.教学重难点

Focus: The history, the working principle, sensitivity, imaging analysis and spectroscopy ofthescanning electron microscope, the transmission electron microscope, the atomic force microscope, the scanning tunneling microscope and the X-ray diffraction analysis;

Difficulties：Comparison of limitations and advantages of various characterization methods

3.教学内容

4.1 Scanning electron microscope and microstructure analysis

4.2 Transmission electron microscope and microstructure analysis

4.3 Atomic force microscope and microstructure analysi

4.4 Scanning tunneling microscope and microstructure analysis

4.5 Introduction of X-ray diffraction analysis

4.6 Other methods of analyzing materials

4.教学方法

(1) Lecture method: Concepts and basic theories are taught by lecture method. Such as the working principle, sensitivity, imaging analysis and spectroscopy ofthevarious microscopes.

(2) Discussion method: The class will discuss issues such as "the history of the development of microscope technology", "the advantages and disadvantages of microscopes and other characterization methods" and "the future development direction of characterization methods".

5.教学评价

Answer the following questions:

1. Compare the advantages and disadvantages of various microscopes and list the future development direction of optical instruments

2. Summarize the role and characterization mechanism of X-rays in the analysis of nanomaterials.

**第五章 5.Application of nanomaterials**

1.教学目标

(1) Understand the application of nanomaterials in electronics, biomedicine, aerospace materials and other fields;

(2) Understand the relationship between the structure, function and application of nanomaterials

2.教学重难点

Focus: Existing application fields and development directions of nanomaterials

Difficulties：The relationship between material structure, properties, functions and applications

3.教学内容

5.1 Application of nanomaterials in electronics

5.2 Application of Nanomaterials in Biomedicine

5.3 Application of Nanomaterials in Energy and Environmental Engineering

5.4 Application of nanomaterials in aerospace materials

5.5 Application of nanomaterials in other field

5.6 Future nanomaterials

4.教学方法

(1) Case teaching method: Combined with actual cases, list the application scenarios of nanomaterials in various fields.

(2) Discussion method: The class will discuss issues such as " in which areas will nanomaterials have application potential".

5.教学评价

Answer the following questions:

1. List the role and functioning of smart materials.

2. List the applications of nanomaterials in different dimensions and the properties of nanomaterials used in the applications.

3. What are the requirements for nanotechnology and materials in the future?

**第六章 6. Discussion on the safety of nanomaterials**

1.教学目标

Understand the existing safety problems of nanomaterials, think about solutions, and look forward to its future development

2.教学重难点

Focus: Safety issues of nanomaterials and causes of issues (raw materials, structure, size)

Difficulties：Think about ways to make nanomaterials safer and more widely used

3.教学内容

6.1  Security risks of nanostructures

6.2 Method for preventing the harmfulness of nanomaterials

4.教学方法

(1) Case teaching method: Combined with actual cases, list the current safety risks of nanomaterials in various application fields

(2) Discussion method: The class will discuss issues such as " the source of safety issues of nanomaterials and how to make them safer".

5.教学评价

Search for relevant literature and academic reports, list existing methods that may realize safer use of nanomaterials, and consider the feasibility of these methods.

**第七章 7. Student presentations**

1.教学目标

Fully stimulate students' enthusiasm for in-depth study of nanomaterials related knowledge, critical thinking and presentation.

2.教学重难点

Stimulate students' enthusiasm for research;

Guide the direction of the class discussion, deepen the discussion, and cause thinking

3.教学内容

Students make and give presentations on any topics related to nanomaterials，other students（audience）and the lecture/professor comment and ask questions

4.教学方法

(1) Autonomous learning: based on the topics already taught in the classroom, choose interested ones to expand learning of related knowledge.

(2) Discussion method: In class, teachers and students discuss related issues around the topics that have been displayed.

5.教学评价

Select topics of interest for group report and presentation

**四、学时分配 Teaching Arrangements**

**表2：各章节的具体内容和学时分配表**

|  |  |  |
| --- | --- | --- |
| 章节 | 章节内容 | 学时分配 |
| 第一章 | General Concepts in Nanomaterials | 2 |
| 第二章 | Characteristics of Nanomaterials Brought by Nano-Size Effect | 4 |
| 第三章 | Synthesis of Nanomaterials | 8 |
| 第四章 | Characterization of Nanomaterials | 8 |
| 第五章 | Application of nanomaterials | 8 |
| 第六章 | Discussion on the safety of nanomaterials | 2 |
| 第七章 | Student presentations | 4 |

**五、教学进度Teaching Schedule**

**表3：教学进度表**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 周次 | 日期 | 章节名称 | 内容提要 | 授课时数 | 作业及要求 | 备注 |
| 1 | 根据校历待定 | Chapter 1 General Concepts in Nanomaterials | 1.1 The history and development of materials  1.2 The history and development of nanomaterials  1.3 Concepts of nanoscale  1.4 Overview of nanomaterials | 2 | Homework:  1. Complete the thought questions in this chapter  2. In the form of a timeline mind map, sort out the development of nanomaterials and make prospects.  Requirements:  1. Be able to master key concepts such as " quantum mechanics laws”, “statistical mechanics laws” and “chemical kinetics active ", etc.  2. Understand the difference between nanoscale and microscale, be able to explain it in them own language. |  |
| 2-3 | 根据校历待定 | Chapter 2 Characteristics of Nanomaterials Brought by Nano-Size Effect | 2.1 The characteristics of nanomaterials  2.2 Surfaces in nanomaterials  2.3 Interfaces  2.4 Nanoparticle stability | 4 | Homework:  1. Complete the thought questions in this chapter  2. Based on the knowledge learned in class and get access to relevant information, lists the methods to get nano products with good stability.  Requirements:  1. Be able to master key concepts such as "nano-size effect” and “interfaces ", etc.  2. Understand the importance of surface and interface for the stability of nanoparticles. |  |
| 4-7 | 根据校历待定 | Chapter 3 Synthesis of Nanomaterials | 3.1 Overview of nanostructures  3.2 Making nanostructures: top down  3.3 The beam technologies  3.4 Making nanostructures: bottom up  3.5 Mechanism basic of self-assembly strategies  3.6 Self-assembly for nanomaterials | 8 | Homework:  1. Complete the thought questions in this chapter  2. List the advantages and disadvantages of various synthetic strategies and the nanostructures that can be prepared using each of them  Requirements:  1. Mastering basic nanostructure classification and their functional features  2. Master the corresponding strategies for the synthesis of different nanostructures and understand the advantages and disadvantages of various strategies |  |
| 8-11 | 根据校历待定 | Chapter 4 Characterization of Nanomaterials | 4.1 Scanning electron microscope and microstructure analysis  4.2 Transmission electron microscope and microstructure analysis  4.3 Atomic force microscope and microstructure analysis  4.4 Scanning tunneling microscope and microstructure analysis  4.5 Introduction of X-ray diffraction analysis  4.6 Other methods of analyzing materials | 8 | Homework:  1. Complete the thought questions in this chapter  2. Write a report on material characterization methods, listing not less than three kinds of representations that are not mentioned in the class, and briefly describe their development history, principle of work and scope of application.  Requirements:  1. Master the application scenarios of various microscopy techniques.  2 Understand the relationship between analytical technology and material preparation strategies, which are mutually restrictive and mutually reinforcing. |  |
| 12-15 | 根据校历待定 | Chapter 5 Application of nanomaterials | 5.1 Application of nanomaterials in electronics  5.2 Application of Nanomaterials in Biomedicine  5.3 Application of Nanomaterials in Energy and Environmental Engineering  5.4 Application of nanomaterials in aerospace materials  5.5 Application of nanomaterials in other fields  5.6 Future nanomaterials | 8 | Homework:  1. Complete the thought questions in this chapter  2. Find and read relevant information, list possible future applications of nanomaterials, briefly outline the materials' structures and material characteristics that may be required to achieve the respective functions  Requirements:  1. Understanding that nanomaterials have vast applications  2. Being able to know the intrinsic connection between material structures, functions, and applications |  |
| 16 | 根据校历待定 | Chapter 6 Discussion on the safety of nanomaterials | 6.1 Security risks of nanostructures  6.2 Method for preventing the harmfulness of nanomaterials | 2 | Homework:  Complete the thought questions in this chapter  Requirements:  Recognizing the flipside of nanomaterials, and trying to think of ways to improve shortcomings from the perspective of material design. |  |
| 17-18 | 根据校历待定 | Chapter 7 Student presentation | Students make and give presentations on any topics related to nanomaterials | 4 | Homework:  Make and give presentations on any topics related to nanomaterials  Requirements:  1. The presentation is relevant and coherent  2. Being able to answer other students' questions about the content of the presentation smoothly |  |

**六、教材及参考书目 References**

（电子学术资源、纸质学术资源等，按规范方式列举）

1．Dieter V. *Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition.* Germany: Wiley-VCH Verlag GmbH & Co., ISBN: 978-3-527-67186-1

2．Linsay, S. M. *Introduction to* *nanoscience*. 1st Edition. New York: Oxford University Press, ISBN 9780199544219

**七、教学方法 Teaching Methodology**

（讲授法、讨论法、案例教学法等，按规范方式列举，并进行简要说明）

Part of the teaching of this course adopts the flipped class model. Students are required to investigate and refer related documents before class and complete the corresponding teaching preview and problem thinking. Classroom teaching takes teacher-student discussion and student display as the main teaching activities.

1. Teaching method: Focus on the core concepts of the curriculum and explain it to students, such as "the nano-size effect", “quantum mechanics laws”, “statistical mechanics law”, “chemical kinetics active” and so on.

2. Discussion method: Organize students to discuss topics such as "the difference between the nano-range and the micro-range", " the advantages and disadvantages of microscopes and other characterization methods", and so on.

3. Case teaching method: In the teaching of the basic theory of nano-size effect, the field of application scenarios of nanomaterials and other topics, select the corresponding case and organize students to conduct active analysis and discussion around the case.

4. Experimental method: Through learning the basic operations of multimedia courseware production, learning to use basic audio and video processing and micro-class production software to form a basic educational technology practice ability

**八、考核方式及评定方法Exams and Evaluations**

**（一）课程考核与课程目标的对应关系**

**表4：课程考核与课程目标的对应关系表**

|  |  |  |
| --- | --- | --- |
| **课程目标** | **考核要点** | **考核方式** |
| 课程目标1 | 1. The basic concepts of nanomaterials  2. The influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect  3. The differences between nanoscale and microscale | Normal results: questioning, quizzes, assignments, presentations  Mid-term exam: essay or test paper  Final exam: test paper |
| 课程目标2 | 1. The various synthesis of nanomaterials.  2. The various characterization methods of nanomaterials | Normal results: questioning, quizzes, assignments, presentations  Mid-term exam: essay or test paper  Final exam: test paper |
| 课程目标3 | 1. The application of nanomaterials in various fields and their potential safety risks.  2.Great potential for development of nanomaterials and improved direction | Normal results: questioning, quizzes, assignments, presentations  Mid-term exam: essay or test paper  Final exam: test paper |

**（二）评定方法**

**1．评定方法**

This course is an examination class, and the assessment results are composed of: 30% of the process score + 20% of the mid-term exam + 50% of the final exam.

(1) Process grades are composed of quizzes, student presentations and assignments, etc.

(2) The mid-term and final exams are conducted in closed-book form. Examination paper assessment focuses on the curriculum objectives to examine students' professional basic knowledge, problem analysis, and problem-solving abilities.

**2．课程目标的考核占比与达成度分析**

**表5：课程目标的考核占比与达成度分析表**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **考核占比**  **课程目标** | **平时**  **（30%）** | **期中**  **（20%）** | **期末**  **（50%）** | **总评达成度** |
| 课程目标1 | 15% | 8% | 22% | {0.15 ｘ usual goal 1 result + 0.08 ｘ mid-term goal 1 result + 0.22 ｘ final goal 1 result}/45 |
| 课程目标2 | 10% | 9% | 18% | {0.1 ｘ usual goal 1 result + 0.09 ｘ mid-term goal 1 result + 0.18 ｘ final goal 1 result}/37 |
| 课程目标3 | 5% | 3% | 10% | {0.05 ｘ usual goal 1 result + 0.03 ｘ mid-term goal 1 result + 0.1 ｘ final goal 1 result}/18 |

**（三）评分标准**

| **课程**  **目标** | **评分标准** | | | |
| --- | --- | --- | --- | --- |
| **90-100** | **75-89** | **60-74** | **＜60** |
| **优** | **良** | **中** | **不合格** |
| **A** | **B** | **C** | **D** |
| **课程**  **目标1** | Through the study of the basic concepts of nanomaterials, students can deeply understand the influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect. They are proficient in the difference between nanoscale and microscale. | Through the study of the basic concepts of nanomaterials, students can good understand the influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect. They can good understand the difference between nanoscale and microscale. | Through the study of the basic concepts of nanomaterials, students can basic understand the influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect. They can basic understand the difference between nanoscale and microscale | Through the study of the basic concepts of nanomaterials, students can’t understand the influence of nanometer size on the magnetic behavior, chemical reactivity, mechanical properties, electrical properties, quantum effects, surface effect and size effect. They can’t understand the difference between nanoscale and microscale |
| **课程**  **目标2** | Through the study of the various synthesis strategies and characterization methods of nanomaterials, students have a deep understanding of the advantages and disadvantages of different synthesis strategies and characterization methods as well as their application scope. They master the scientific research thinking of using different synthesis strategies to obtain nanomaterials with different structures | Through the study of the various synthesis strategies and characterization methods of nanomaterials, students have a good understanding of the advantages and disadvantages of different synthesis strategies and characterization methods as well as their application scope. They have the scientific research thinking of using different synthesis strategies to obtain nanomaterials with different structures | Through the study of the various synthesis strategies and characterization methods of nanomaterials, students have a basic understanding of the advantages and disadvantages of different synthesis strategies and characterization methods as well as their application scope. They basically have the scientific research thinking of using different synthesis strategies to obtain nanomaterials with different structures | Through the study of the various synthesis strategies and characterization methods of nanomaterials, students don’t have an understanding of the advantages and disadvantages of different synthesis strategies and characterization methods as well as their application scope. They don’t have the scientific research thinking of using different synthesis strategies to obtain nanomaterials with different structures |
| **课程**  **目标3** | Through the study of the application examples of nanomaterials in various fields and their potential safety risks, students deeply understand that nanomaterials have a wide range of application prospects, as well as their existing defects, and can fully realize that there is a long way to go for the development of nanotechnology. | Through the study of the application examples of nanomaterials in various fields and their potential safety risks, students can good understand that nanomaterials have a wide range of application prospects, as well as their existing defects, and can realize that there is a long way to go for the development of nanotechnology. | Through the study of the application examples of nanomaterials in various fields and their potential safety risks, students can basic understand that nanomaterials have a wide range of application prospects, as well as their existing defects, and can basic realize that there is a long way to go for the development of nanotechnology. | Through the study of the application examples of nanomaterials in various fields and their potential safety risks, students can’t understand that nanomaterials have a wide range of application prospects, as well as their existing defects, and can’t realize that there is a long way to go for the development of nanotechnology. |