《薄膜技术与纳米材料（英文）》课程教学大纲

一、课程基本信息

英文名称	Thin Films Technology and Nanostructure Materials	课程代码	PHYS3118
课程性质	Major Elective	授课对象	Physics
学　　分	2	学　　时	36
主讲教师	Rujun Tang(汤如俊)	修订日期	2021.9
指定教材	1. Rujun Tang, 《Introduction to Thin Film Materials and Technology》,Soochow University Press, ISBN: 978-7-5672-3579-3(2021). 2. Yaojun Zhang, 《Fundamentals of Nanomaterials》,Chemistry Industry Inc. publisher, ISBN: 9787122101297 (2011).		

二、课程目标

（一）总体目标：

The discipline of thin films technology and nanostructure materials is a new scientific field that has attracted much attentions in recent years. It involves the knowledge of condensed matter physics, chemistry, materials, electronics and other disciplines, and has a far-reaching impact on condensed matter physics and materials. This course is a professional improvement course related to condensed matter physics and material science. The task of the course is to enable students to understand and master the basic concepts of nano materials and thin film technologies, and the research progress of nano materials and thin film technologies. With the study of this course, we will cultivate students' comprehensive ability in interdisciplinary science, enable students to understand the latest achievements and development trend of nano materials and thin film technologies. It will also expand their scientific and technological vision, improve their scientific research quality and ability, and lay a foundation for knowledge innovation and technological innovation.

（二）课程目标：

Course objective 1：Understand the basic definitions of the length-scale; Understand the nanometer effects and physical properties of nanomaterials; Know some preparation techniques of nanomaterials, and know some characterization techniques of nanomaterials.

Course objective 2：Understand the basic knowledge of vacuum, the physical and chemical vapor deposition techniques, and some thin film growth mechanism. After finishing this course, the students are supposed to have some basic understanding on both the thin film/nano physics and technical applications of these knowledge in the modern thin film/nanotechnology industry.

（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

Course objective	**Course contents**	**Graduation requirements**
Course objective 1	**Chapter 1** A general introduction to nanomaterials **Chapter 2** Nanometer Effects of Nanomaterials **Chapter 3** Physical Properties of Nanomaterials **Chapter 4** Synthesis Techniques for Nanomaterials **Chapter 5** Characterization Techniques for Nanomaterials	Graduation requirement 2: master the basic knowledge, physical experiment methods and experimental skills related to mathematics and physics; have the ability to solve problems, explain or understand physical laws by using physical theories and methods. Graduation requirement 3: know the frontier development in physics, the physical methods in new technology; be familiar with the impact of new discoveries, theories and technologies in physics on society. Graduation requirement 5: master a foreign language (English); have the ability to read, write, and communicate in Applied English. Graduation requirements 7: have the ability of research, design, data processing and academic exchange. Graduation requirements 8: have the awareness of

		independent learning, lifelong learning and the ability to adapt to the society.
Course objective 2	**Chapter 6** Introduction to Thin Film Technologies **Chapter 7** Kinetic Theory of Gases and Vacuum Technology **Chapter 8** Thin films Deposition Techniques **Chapter 9** Thin Films Growth Theory **Chapter 10** Laboratory Tour	Graduation requirement 2: master the basic knowledge, physical experiment methods and experimental skills related to mathematics and physics; have the ability to solve problems, explain or understand physical laws by using physical theories and methods. Graduation requirement 3: know the frontier development in physics, the physical methods in new technology; be familiar with the impact of new discoveries, theories and technologies in physics on society. Graduation requirement 5: master a foreign language (English); have the ability to read, write, and communicate in Applied English. Graduation requirements 7: have the ability of research, design, data processing and academic exchange. Graduation requirements 8: have the awareness of independent learning, lifelong learning and the ability to adapt to the society.

三、教学内容

Chapter 1 A general introduction on nanomaterials

1. **Course objective**

This chapter includes the basic concept of nano scale, the concept of nano materials, the classification of nano materials, and the relationship between nano science and nano technology. Help students understand the frontier and development trends of physics, the physical ideas in new technologies. They are expected to be familiar with the impact of new discoveries, theories and technologies in nano science and nano technology.

2. **Key and difficult points in Teaching**

Classification of nano materials，relationship between nano science and nano technology

3. **Teaching contents**

1）What is nanoscale?

This section introduces the concepts of size and nano. How small is “Small”? Is Nano new? What is a nanometer? What things are measured in nanometers? Is a red blood cell bigger or smaller than a bacterium? Step down in size to find out the answers and learn about different types of units that are used to measure very tiny things.

2）What is nanoscience and nanotechnology?

This section introduces the major areas of Nanoscience and Nanotechnology, and the difference between them. Nanomaterials will impact the vast branches of scientific research and technological development. Studies of fundamental nanoscience have gone ever deeper, and the attainment in new nanomaterials and understanding of their structure property relationship has promoted significant technological developments.

3）What is nanomaterial and the classifications of nanomaterials?

This section introduces the classification of nanomaterials. Materials can be produced that are nanoscale in one dimension (for example, very thin surface coatings), in two dimensions (for example, nanowires and nanotubes) or in all three dimensions (for example, nanoparticles).

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 2 Nanometer Effects of Nanomaterials

1. **Course objective**

This chapter includes how is material formed, what is small size effect and surface effect, what is quantum size effect, and what is tunnel effect. Help students master the basic knowledge and basic physical experimental methods related to nano size effect, and can use physical theory to explain or understand physical phenomenon in nanoscale.

2. **Key and difficult points in Teaching**

How is material formed， what is small size effect and surface effect

3. **Teaching contents**

1） How is material formed?

This section introduces the various types of chemical bonds, and discusses how the nature of the bonds gives an insight into some crystal structures. The concepts of grain and grain boundary will also be introduced.

2） What is Small Size Effect and surface effect?

This section introduces the small size effect and surface effect. When the size of the particles is equal to or smaller than the physical characteristic size such as the wavelength of the light, the Deborah wavelength and the coherence length of the superconductivity, the periodic boundary conditions of the crystal will be destroyed, and the atomic density near the surface layer of the amorphous nanoparticles decreases. This leads to changes in sound, light, electricity, magnetism, heat, mechanics, and other properties that exhibit new physical properties.

3） What is Quantum Size Effect?

This section introduces the Quantum Size Effect. Quantum size effects mean that when the particle size drops to a certain value, the energy levels near the Fermi level change from quasi continuous to discrete energy levels or the energy gap widens. When the energy level changes more than that of thermal energy, light energy and electromagnetic energy, the magnetic, optical, acoustic, thermal, electrical and superconducting properties of nanoparticles are significantly different from those of conventional materials.

4) What is Tunnel Effect?

This section introduces the phenomenon and definition of Tunnel Effect. Quantum tunneling or tunneling refers to the quantum mechanical phenomenon where a particle tunnels through a barrier that it classically could not surmount. It has important applications to modern devices such as the tunnel diode, quantum computing, and the scanning tunneling microscope.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 3 Physical Properties of Nanomaterials

1. **Course objective**

This chapter includes mechanical properties, thermal properties, magnetic properties, electric properties and optical properties of nanomaterials. Help students master the basic knowledge and basic physical experimental methods related to nano physics, and can use physical theory to explain or understand physical phenomenon in nanoscale.

2. **Key and difficult points in Teaching**

mechanical properties, thermal properties, magnetic properties, electric properties and optical properties of nanomaterials.

3. **Teaching contents**

1) Mechanical properties of Nanomaterials.

This section introduces the definitions of stress, strain and dislocation. The Hall-Petch Relationship and Inverse Hall-Petch Relationship will also be studied. The relationship between the stress and strain that a particular material displays is known as that particular material's stress–strain curve.

2) Thermal properties of Nanomaterials.

This section introduces the size dependent melting temperature, specific heat and thermal conductivity. When the size of the particles is small enough, the melting temperature, specific heat and thermal conductivity may be greatly changed.

3) Magnetic properties of Nanomaterials.

This section introduces the concepts of ferromagentism, magnetic domain and magnetic hysteresis loop; Phenomenons of super-paramagnetism, size dependent magnetic domain and hysteresis loop will also be studied.

4) Electrical and optical properties of Nanomaterials.

This section introduces the concepts of energy band, band gap, the Size dependent conductivity (IV curve) and Coulomb blockade. The Concepts of surface plasma, light adsorption and emission will also be studied.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 4 Synthesis Techniques for Nanomaterials

1. **Course objective**

This chapter includes concept of top-down and bottom-up methods for preparation of nanoparticles. Help students master the basic knowledge and basic physical experimental methods related to nanomaterial synthesis.

2. **Key and difficult points in Teaching**

Top-down and bottom-up methods for preparation of nanoparticles

3. **Teaching contents**

1) Concept of top-down and bottom-up.

This section introduces the top-down and bottom-up methods to prepare the nanomaterials.

"Top-down" – building something by starting with a larger component and carving away material (like a sculpture). Such as photolithography and etching away material, as in building integrated circuits

"Bottom-up" – building something by assembling smaller components (like building a house). Such as self-assembly of atoms and molecules in chemical and biological systems.

2) Preparation methods of nanoparticles.

This section introduces some physical methods and chemical methods to prepare the nanomaterials, especially the Physical vapor deposition (PVD) and Chemical vapor deposition (CVD).

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 5 Characterization Techniques for Nanomaterials

1. **Course objective**

This chapter includes concept of mechanism of scanning electron microscope and mechanism of atomic force microscope. Help students master the basic knowledge and basic physical experimental methods related to nanomaterial synthesis.

2. **Key and difficult points in Teaching**

Mechanism of scanning electron microscope and mechanism of atomic force microscope

3. **Teaching contents**

1) Mechanism of scanning electron microscope.

This section introduces mechanism of scanning electron microscope. A scanning tunneling microscope (STM) is an instrument for imaging surfaces at the atomic level. STM is based on the concept of quantum tunneling. When a conducting tip is brought very near to the surface to be examined, a bias (voltage difference) applied between the two can allow electrons to tunnel through the vacuum between them. The resulting tunneling current is a function of tip position, applied voltage, and the local density of states (LDOS) of the sample. Information is acquired by monitoring the current as the tip's position scans across the surface, and is usually displayed in image form.

2) Mechanism of atomic force microscope.

This section introduces mechanism of atomic force microscope. Atomic-force microscopy (AFM) or scanning-force microscopy (SFM) is a type of scanning probe microscopy (SPM), with demonstrated resolution on the order of fractions of a nanometer, more than 1000 times better than the optical diffraction limit.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 6 Introduction to Thin Film Technologies

1. **Course objective**

This chapter includes concepts of what is thin film material, what is thin film science and technology and classifications of thin films. Help students master the basic knowledge and basic physical experimental methods related to thin film technologies.

2. **Key and difficult points in Teaching**

What is thin film material, what is thin film science and technology

3. **Teaching contents**

1) What is thin film material?

This section introduces the concept of thin film. Macroscopically, thin film is a layer of material between two planes, and its thickness is much smaller than that of the other two dimensions. From the microscopic point of view, thin film is made up of atoms or clusters of two-dimensional materials. But there are no strict boundaries regarding how "thin" a material can be considered as a thin film. In general, the research area of thin film physics and technology is between the nanometer scale to micron-meter scale. A film thicker than a micron is usually called a thick film.

2) What is thin film science and technology?

This section introduces the history of thin film science and technology. The explosive growth in the semiconductor industry has caused a rapid evolution of thin film materials that lend themselves to the fabrication of state-of-the-art semiconductor devices. In the last 25 years, tremendous advances have been made in the science and technology of thin films prepared by means of vapor phase deposition.

3) Classifications of thin films?

This section introduces the classifications of thin films.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 7 Kinetic Theory of Gases and Vacuum Technology

1. **Course objective**

This chapter includes concepts of vapor and gases, ideal-gas Law and mean free path, transport properties of thin film materials, gas evolution, gas throughput and mechanisms of vacuum pumps. Help students master the basic knowledge and basic physical experimental methods related to thin film technologies.

2. **Key and difficult points in Teaching**

Transport properties of thin film materials, and mechanisms of vacuum pumps.

3. **Teaching contents**

1) Vapor and Gases;

This section introduces the concepts of vapor and gases. Gases and vapors are naturally associated with thin film material and material processing systems. The equilibrium between thin film material and material vapor determines the temperatures achieved during processing.

2) Ideal-Gas Law and Mean Free Path;

The ideal gas law is the equation of state of a hypothetical ideal gas. It is a good approximation of the behavior of many gases under many conditions, although it has several limitations. In physics, the mean free path is the average distance traveled by a moving particle between successive impacts (collisions), which modify its direction or energy or other particle properties. Both ideal-gas law and mean free path are important for the thin film growth technology.

3)Transport properties of thin film materials.

This section introduces the transport properties of thin film materials between bulk target and substrate.

4) Gas Evolution and Throughput

This section introduces the gas evolution process, the gas evolution reaction and gas throughput process in the vacuum system. A gas evolution reaction is a chemical reaction in which one of the end products is a gas (such as oxygen or carbon dioxide) is produced.

5) Mechanisms of Vacuum Pumps

This section introduces mechanisms of various vacuum Pumps. The working mechanisms of rotary vane pump, diffusion pump and turbo-molecular pump will be studied respectively.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 8 Thin films Deposition Techniques

1. **Course objective**

This chapter includes concepts of mechanisms of thermal evaporation deposition, mechanisms of sputtering deposition, mechanisms of pulsed laser deposition and mechanisms of chemical vapor deposition. Help students master the basic knowledge and basic physical experimental methods related to thin film technologies.

2. **Key and difficult points in Teaching**

Mechanisms of sputtering deposition, mechanisms of pulsed laser deposition and mechanisms of chemical vapor deposition.

3. **Teaching contents**

1) Mechanisms of thermal evaporation deposition.

This section introduces the mechanism of thermal evaporation deposition. Evaporation is a common method of thin-film deposition. The source material is evaporated in a vacuum. The vacuum allows vapor particles to travel directly to the target object (substrate), where they condense back to a solid state. Evaporation is used in microfabrication, and to make macro-scale products such as metallized plastic film.

2) Mechanisms of sputtering deposition.

This section introduces the mechanism of sputtering deposition. Sputtering is a process whereby particles are ejected from a solid target material due to bombardment of the target by energetic particles, particularly, in the laboratory, gas ions. It only happens when the kinetic energy of the incoming particles is much higher than conventional thermal energies ($\gg$1 eV). This process can lead, during prolonged ion or plasma bombardment of a material, to significant erosion of materials, and can thus be harmful. On the other hand, it is commonly used for thin-film deposition, etching and analytical techniques. Sputtering is done either using DC Voltage (DC Sputtering) or using AC Voltage (RF Sputtering).

3) Mechanisms of pulsed laser deposition.

This section introduces the mechanism of pulsed laser deposition. Pulsed laser deposition (PLD) is a physical vapor deposition (PVD) technique where a high-power pulsed laser beam is focused inside a vacuum chamber to strike a target of the material that is to be deposited. This material is vaporized from the target (in a plasma plume) which deposits it as a thin film on a substrate (such as a silicon wafer facing the target). This process can occur in ultra-high vacuum or in the presence of a background gas, such as oxygen which is commonly used when depositing oxides to fully oxygenate the deposited films.

4) Mechanisms of Chemical Vapor Deposition (CVD).

This section introduces the mechanisms of chemical vapor deposition (CVD).

Chemical vapor deposition (CVD) is a chemical process used to produce high quality, high-performance, solid materials. The process is often used in the semiconductor industry to produce thin films. Metal organic compound vapor phase epitaxy (MOCVD) is a non-equilibrium growth technique that relies on gas source transport and thermal cracking reactions to achieve simultaneous synthesis and decomposition.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 9 Thin Films Growth Theory

1. **Course objective**

This chapter includes concepts of adsorption, nucleation and three important growth modes of thin film. Help students master the basic knowledge and basic physical experimental methods related to thin film technologies.

2. **Key and difficult points in Teaching**

Concepts of adsorption, nucleation and three important growth modes of thin film.

3. **Teaching contents**

1) Concepts of Adsorption.

This section introduces the concepts of adsorption and four key steps for thin film growth on a substrate.

Adsorption is the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface. This process creates a film of the adsorbate on the surface of the adsorbent. This process differs from absorption, in which a fluid (the absorbate) is dissolved by or permeates a liquid or solid (the absorbent), respectively. Adsorption is a surface-based process while absorption involves the whole volume of the material. The term sorption encompasses both processes, while desorption is the reverse of it. Adsorption is a surface phenomenon.

2) Concepts of Nucleation.

This section introduces the concepts of nucleation.

Nucleation is the first step in the formation of either a new thermodynamic phase or a new structure via self-assembly or self-organization in thin film. Nucleation is typically defined to be the process that determines how long an observer has to wait before the new phase or self-organized structure appears on a substrate. Nucleation is often found to be very sensitive to impurities in the system. Because of this, it is often important to distinguish between heterogeneous nucleation and homogeneous nucleation. Heterogeneous nucleation occurs at nucleation sites on surfaces in the system. Homogeneous nucleation occurs away from a surface.

3) Growth modes of thin film.

This section introduces three important growth modes of thin film.

Thin film growth modes: island mode, layered mode, island layer composite mode. The main influencing factor is temperature.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

Chapter 10 Laboratory Tour

1. **Course objective**

This chapter includes on-site observation of the mechanism of sputtering, pulsed laser deposition and CVD. Help students master the basic knowledge and basic thin film growth technologies in laboratory .

2. **Key and difficult points in Teaching**

On-site observation of the mechanism of sputtering, pulsed laser deposition

3. **Teaching contents**

On-site observation of the mechanism of sputtering, Pulsed laser deposition and CVD in the laboratories of Jiangsu Key Laboratory of Thin Films. This can help better understand what have studied in the previous courses.

4. **Teaching Methods**

Teachers teach, teachers and students discuss, and guide students' self-learning.

5. **Teaching Evaluation**

Corresponding exercises after class, supplementary exercises, thinking questions, etc;

四、学时分配

表 2：各章节的具体内容和学时分配表

Chapters	**Contents**	**Lecture Hours**
Chapter 1	A general introduction to nanomaterials	2
Chapter 2	Nanometer Effects of	4

	Nanomaterials	
Chapter 3	Physical Properties of Nanomaterials	8
Chapter 4	Synthesis Techniques for Nanomaterials	2
Chapter 5	Characterization Techniques for Nanomaterials	4
Chapter 6	Introduction to Thin Film Technologies	2
Chapter 7	Kinetic Theory of Gases and Vacuum Technology	4
Chapter 8	Thin films Deposition Techniques	4
Chapter 9	Thin Films Growth Theory	4
Chapter 10	Laboratory Tour	2

五、教学进度

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	/−	Chapter 1	The basic concept of nano scale, the concept of nano materials, the classification of nano materials, and the relationship between nano science and nano technology.	2	Questions in Chapter 1 lecture notes	

2	–	Chapter 2	How is material formed, what is small size effect and surface effect, what is quantum size effect, and what is tunnel effect.	4	Questions in Chapter 2 lecture notes	
3	–	Chapter 3	Mechanical properties, thermal properties, magnetic properties, electric properties and optical properties of nanomaterials.	8	Questions in Chapter 3 lecture notes	
4	–	Chapter 4	Concept of top-down and bottom-up methods for preparation of nanoparticles.	2	Questions in Chapter 4 lecture notes	
5	–	Chapter 5	Concept of mechanism of scanning electron microscope and mechanism of atomic force microscope.	2	Questions in Chapter 5 lecture notes	
6	–	Chapter 6	Concepts of what is thin film material, what is thin film science and technology and classifications of thin films.	2	Questions in Chapter 6 lecture notes	
7	–	Chapter 7	Concepts of vapor and gases, ideal-gas Law and mean free path, transport properties of thin film materials, gas evolution, gas throughput and mechanisms of vacuum pumps.	4	Questions in Chapter 7 lecture notes	
8	–	Chapter 8	Concepts of mechanisms of thermal evaporation deposition, mechanisms of sputtering deposition, mechanisms of pulsed laser deposition and mechanisms of chemical vapor deposition.	4	Questions in Chapter 8 lecture notes	

9	−	Chapter 9	Concepts of adsorption, nucleation and three important growth modes of thin film.	4	Questions in Chapter 9 lecture notes	
10	−	Chapter 10	On-site observation of the mechanism of sputtering, pulsed laser deposition and CVD.	2	None	

六、教材及参考书目

1) Rujun Tang, 《Introduction to Thin Film Materials and Technology》,Soochow University Press, ISBN: 978-7-5672-3579-3 (2021).
2) Yaojun Zhang, 《Fundamentals of Nanomaterials》,Chemistry Industry Inc. publisher, ISBN: 9787122101297 (2011).

七、教学方法

1. Consolidate the basic knowledges, pay attention to the cutting-edge content of science and technology to enrich the teaching content. Expand students' knowledge, and exercise students' scientific thinking ability and scientific research innovation ability.

2. Combination of blackboard writing and PPT, taking the advantages of traditional and modern teaching methods; Comprehensively adopt teaching methods and modes such as teaching and discussion.

3. Application of informatization means: informatization teaching environment makes the teaching form interactive.

八、考核方式及评定方法

（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

Course objective	**Key points of assessment**	**Assessment method**
Course objective 1	Relevant teaching contents	In-class learning performance + middle term test+ final exam

Course objective 2	Relevant teaching contents	In-class learning performance + middle term test+ final exam

（二）评定方法

1．Assessment method

In-class learning performance + middle term test+ final exam

In-class learning performance 10%，middle term test 20%, final exam 70%。

2．Analysis of assessment proportion and achievement degree of course objectives

表 5：课程目标的考核占比与达成度分析表

proportion / **objectives**	In-class performance	middle term test	final exam	achievement degree
Course objective 1	50%	100%	40%	objective 1 achievement ={0.1*In-class performance+0.2*middle term test +0.7* final exam}/Total score of objective 1 objective 2 achievement ={0.1*In-class performance +0.7* final exam}/Total score of objective 2 Final achievement ={0.5* objective 1 achievement+0.5* objective1 achievement}/Total score
Course objective 2	50%	0	60%	

（三）评分标准

课程目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
课程目标 1	Fully understood the classification of nano materials, nano size effect, physical properties of nano materials, preparation and testing of nano materials; Fully recognized the importance of nano materials in the field of modern scientific research; With scientific world outlook and methodology.	Good understanding on the classification of nano materials, nano size effect, physical properties of nano materials, preparation and testing of nano materials; Good understanding on the importance of nano materials in the field of modern scientific research; With scientific world outlook and methodology.	Basic understanding of nano classification, nano size effect, physical properties of nano materials, preparation and testing of nano materials; realized the importance of nano materials in the field of modern scientific research is basically recognized; With scientific world outlook and methodology.	Partially understood the classification of nano materials, nano size effect, physical properties of nano materials, preparation and testing of nano materials; Partially understood the importance of nano materials in the field of modern scientific research;	Do not understand the classification of nano materials, nano size effect, physical properties of nano materials, preparation and testing of nano materials; The importance of nano materials in the field of modern scientific research is not recognized;
课程目标 2	Fully understood the concept of thin film technology, knowledge of vacuum technology, common vacuum technology and principle of thin film growth; Fully realized the importance of thin film technology in the field of modern scientific research; With scientific world outlook and methodology.	Good understanding of the concept of thin film technology, knowledge of vacuum technology, common vacuum technology and principle of thin film growth; Fully realized the importance of thin film technology in the field of modern scientific research; With scientific world outlook and methodology.	Basic understanding on the concept of thin film technology, knowledge of vacuum technology, common vacuum technology and principle of thin film growth; Basic realized the importance of thin film technology in the field of modern scientific research; With scientific world outlook and methodology.	Partially understood the concept of thin film technology, the knowledge of vacuum technology, the common vacuum technology of thin film growth and the principle of thin film growth; Partially understood the importance of thin film technology in the field of modern scientific research;	Do not understand the concept of thin film technology, knowledge of vacuum technology, common vacuum technology and principle of thin film growth; The importance of thin film technology in the field of modern scientific research is not recognized;